



**Institute of Advanced Energy  
Kyoto University**

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**ANNUAL REPORT**

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**2011**

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京都大学エネルギー理工学研究所

# **ANNUAL REPORT**

## **2011**

**Institute of Advanced Energy  
Kyoto University**

Gokasho, Uji, Kyoto  
Japan



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## FOREWORD



The year of 2011 passed away leaving many disastrous memories: the huge earthquake and tsunami, the following nuclear power plant accident, landslides brought by heavy rains, the economic crisis starting in Europe and then spreading around the world, political instability in Islamic countries, and others. In this busy year, we launched “Joint Usage/Research Program on Zero-Emission Energy”, which is the program authorized by the MEXT. Many researchers participated in the program. In relation to this, we started “Zero-Emission Energy Network” on the occasion of an international symposium held in September 2011. We continue forward with the program. Meanwhile, 2011 was the second year of the second 6-years operation planning period (FY2010-FY2015). In this second period, the competency of the research institute is strictly tested since the government urges national universities to accelerate their full-scale reform action. From this point of view, we have to further strengthen our capabilities of research and education on the basis of the accomplishment of our academic activities, and to exhibit our prospective future.

We are working hard toward further progress in research and education, and conducting a lot of collaborative researches in the advanced energy science and technology fields; we especially lay stress on “Advanced Plasma and Quantum Energy” and “Photon and Energy Nano-Science”. The Global COE program “Energy Science in the Global Warming Era” (2008–2012) is going well. We are also acting as a core institution of international energy researches, especially in the Asian region. In September 2011, we organized the 2nd International Symposium of Advanced Energy Science at the Uji campus. The four-year retrofitting project against earthquake for our main building was completed last year. In addition, we are carrying on the repair & remodeling of the other research buildings according to our own renovation plan. Now our research environments have been greatly improved.

The worldwide concern regarding energy supplies and global warming drives our efforts, and energy issues become urgent priorities especially after the Fukushima accident. We shall renew our efforts in the new period, through research and education on advanced energy science and technology, to cope with these critical issues and contribute to the benefit of future generations.

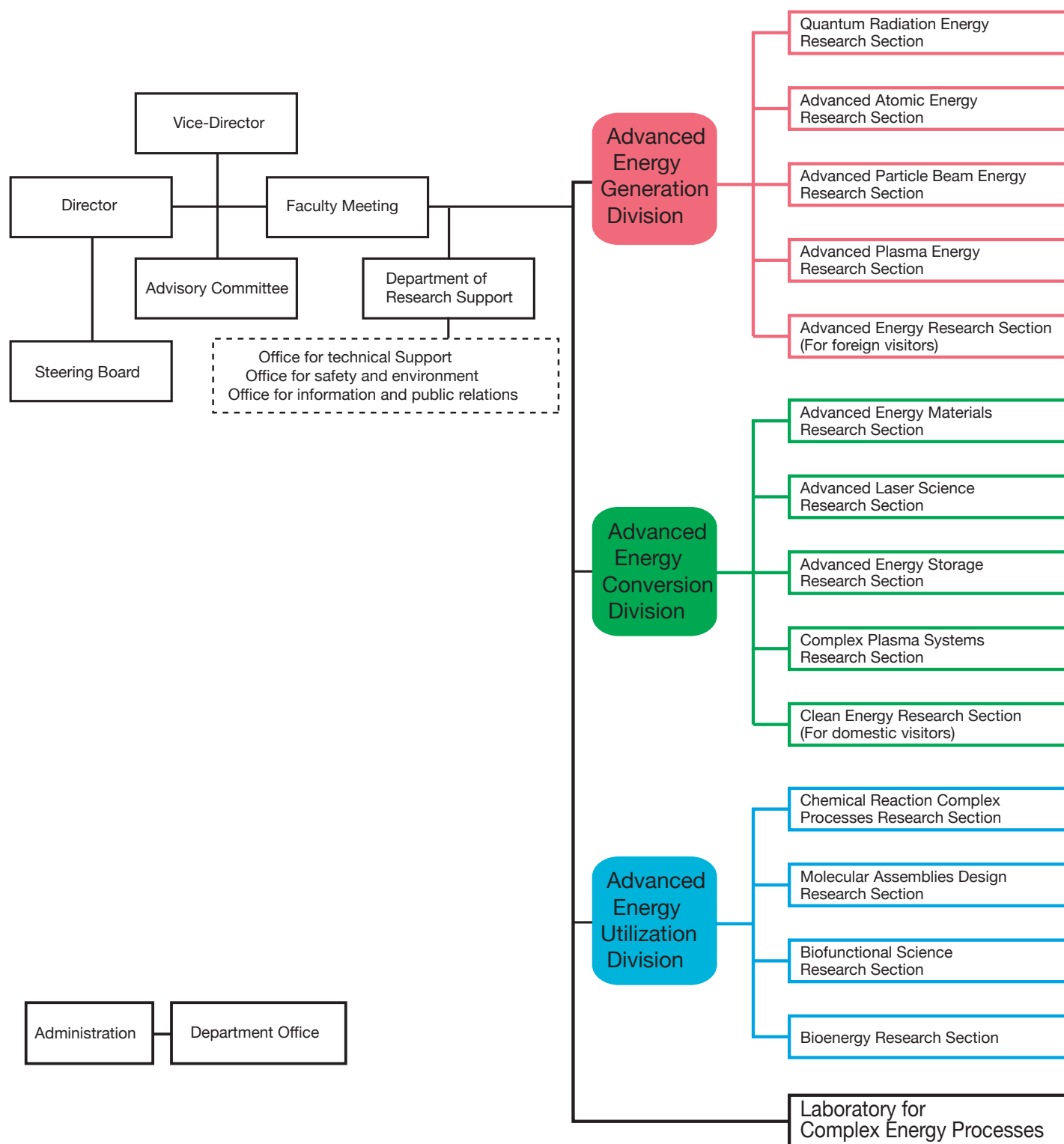
It is our great pleasure to issue this Annual Report. We hope that it provides you with good understanding of the activities of the Institute of Advanced Energy, Kyoto University.

A handwritten signature in black ink, appearing to read 'Y. Ogata'.

March 2012

Yukio H. OGATA  
Director  
Institute of Advanced Energy  
Kyoto University

## 2. ORGANIZATION CHART



### **3. RESEARCH ACTIVITIES**





## **3-1. RESEARCH ACTIVITIES IN EACH SECTION**

## Quantum Radiation Energy Research Section

H. Ohgaki, Professor  
 T. Kii, Associate Professor  
 H. Zen, Assistant Professor  
 (T. Sonobe, GCOE Assistant Professor)  
 (T. Hori, Specially Appointed Professor)

## 1. Introduction

Coherent-radiation energy with wide wavelength tunability, high power and high efficiency is quite promising in the 21st century that is sometimes called the "era of light".

The research in this section aims at developing the technology to generate new quantum-radiation energy and apply the radiation in various fields; atomic energy including plasma heating, energy transportation in the universe, material science, material synthesis, electronic device, medical and biological science, etc.

Free-electron laser (FEL) is one of the powerful candidates for the new quantum radiation, and it is sometimes called the light source of next generation.

## 2. Free-electron Laser

FEL is regarded as a light source of the next generation because of its wide wavelength tunability where the conventional lasers cannot reach, potential high efficiency, and high power. However, the system is usually much larger and the cost is higher than conventional lasers. We are going to overcome these difficulties by exploiting an RF (radio-frequency) gun, an energy recovering system, an undulator, etc.

### 2.1 KU-FEL

The target wavelength of KU-FEL is MIR (Mid infra-red) regime, from 5 to 20  $\mu\text{m}$ . The tunable IR laser will be used for basic researches on energy materials and systems, such as high-efficiency solar cells, energy conversion in bio materials. Figure 1 shows a schematic drawing of the KU-FEL system. The KU-FEL consists of a 4.5-cell thermionic RF gun, a 3-m travelling wave accelerator tube, a beam transport system, and a 1.6-m undulator and an optical resonator.

In this year, the 1.6-m undulator was replaced with 1.8-m one to have higher laser gain. At the same time, the optical resonator mirrors have also been replaced with new ones for smaller optical loss and higher gain. After those modifications, FEL lasing and power saturation at 7.5  $\mu\text{m}$  has already been achieved. Preliminary

experimental and numerical studies predict that the tunable range will be from 5 to 16  $\mu\text{m}$  with present configuration, at least.

Another topic of KU-FEL development is introduction of photo-cathode RF gun, which enables us to generate higher peak power and wider tunable range MIR-FEL. Development of an UV-laser system for illuminating photo-cathode has been started under collaboration with Dr. R. Kuroda, Researcher of AIST.

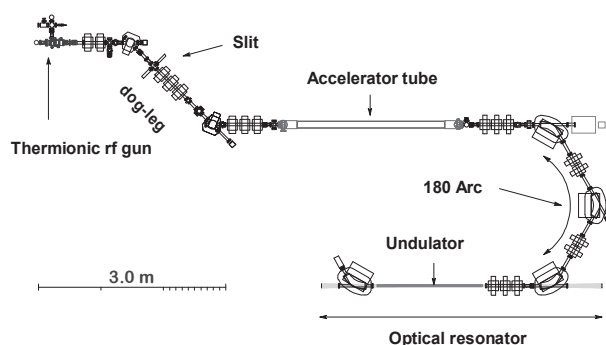


Fig. 1 Schematic drawing of the KU-FEL

### 2.2 MIR-FEL Application in the Energy Science

It is well known that an infrared region light has a good resonance with molecular vibration and lattice vibration in some liquid or solid compound. In particular, wide-gap semiconducting materials such as SiC, ZnO, and TiO<sub>2</sub> show unique electrical and optical properties through coupling of phonon with electronic structures, resulting in photochemical phenomena with microwave irradiation. Therefore, it is considered that the irradiation of MIR-FEL on such semiconducting materials possibly excites the phonon selectively, and then gives rise to the changes in electronic structures. For the verification of selective phonon excitation and for the observation of electronic structure change induced by MIR-FEL irradiation, the low temperature Raman scattering and photoluminescence (PL) measurement system with MIR-FEL irradiation has been developed (Fig. 2). This study aims at development of new evaluation tech-

nique of electron-phonon interaction in such wide-gap semiconducting materials by MIR-FEL.

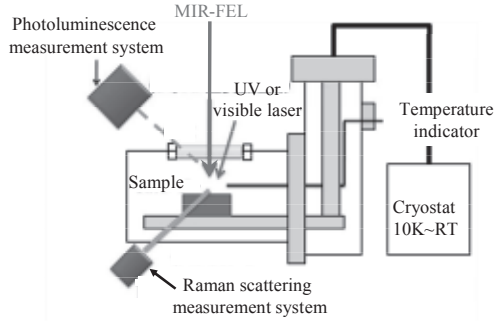


Fig. 2 Conceptual drawing of PL and Raman scattering measurement system combined with MIR-FEL.

### 3. Bulk HTSC Staggered Array Undulator

An undulator or a wiggler with strong magnetic field will play an important role in future synchrotron light sources and free electron lasers. We proposed the bulk high critical temperature superconductor staggered array undulator (Bulk HTSC SAU) in order to generate a strong periodic field. The Bulk HTSC SAU consists of stacked bulk high-Tc superconductors (HTSs) and a solenoid magnet which is used to magnetize the bulk HTSs as shown in fig.3.

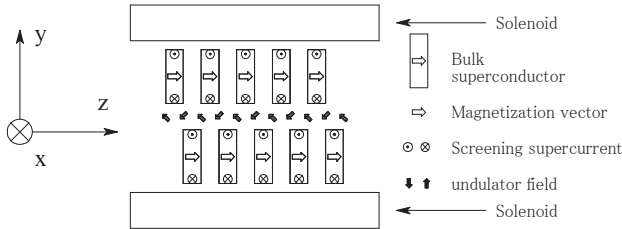


Fig. 3 Conceptual drawing of the bulk HTSC SAU and generation principle of the periodic undulator field using an induced current.

We measured the magnetic performance of the bulk HTS at the temperature range of 4.0 to 77 K. The current density at 30 K was about 3.5 kA/mm<sup>2</sup> which was about 10 times higher than that at 77 K. It is numerically expected that the undulator peak field  $B_0$  reaches to 1.08 T for the undulator period length  $\lambda_u$  of 9.9 mm and the undulator gap length of 4 mm. The expected field strength is better than that of the Halbach structure using permanent magnets.

### 4. Non-destructive Isotope Detection using NRF

A Nuclear Resonance Fluorescence (NRF) measurement is a powerful tool for investigation not only of the nuclear physics, but also of isotope detection for the homeland security such as a nondestructive measurement of containers at airports or harbors, detection or identification of special nuclear materials (SNM). The required performances of the detector used in the NRF facility are high energy resolution, high full energy efficiency, and high counting rate. LaBr<sub>3</sub>(Ce) scintillator is a strong candidate to meet these requirements because of its superior energy resolution and high counting rates. Typically, LaBr<sub>3</sub>(Ce) can resolve spectral lines spaced twice closer than NaI. Furthermore, the peaks would contain a continuum contribution approximately half of peaks in NaI. On the other hand, LaBr<sub>3</sub>(Ce) contains some traces of radioactive materials which causes the detector to be self-radioactive specially near the range of 2 MeV which is very important because there are many levels of SNM around 2 MeV. The performance of LaBr<sub>3</sub>(Ce) is tested using High Intensity gamma-ray source (HIγS) at Duke University FEL facility. The resonant energy was 2.13 MeV scattered from <sup>11</sup>B. The NRF peak is shown in Fig. 4. The energy resolution is approximately 1.7% and the net count of NRF peaks has exceeded the detection limit.

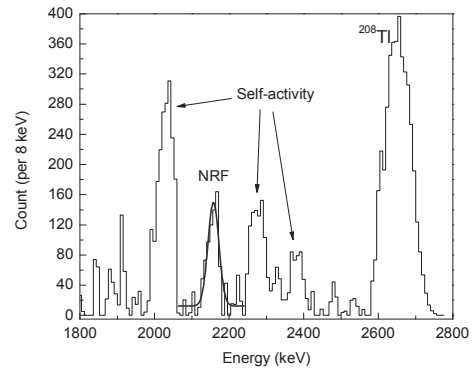


Fig. 4 Measured nuclear resonance fluorescence peak by using 3.5'' φx4'' LaBr<sub>3</sub>(Ce) scintillator.

### Acknowledgment

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## Financial Support

### 1. Grant-in-Aid for Scientific Research

大垣英明, 基盤研究(B), 逆コンプトン $\gamma$ 線を用いた原子核共鳴蛍光散乱同位体イメージングに関する基礎的研究

紀井俊輝, 基盤研究(B), バルク超伝導体を用いた新型短周期アンジュレータ

全炳俊, 若手研究(B), パルス圧縮を用いた大強度短パルス放射光発生に関する研究

### 2. Others

大垣英明, 文部科学省, 「安全・安心な社会のための犯罪・テロ対策技術等を実用化するプログラム」ガンマ線による核物質非破壊検知システム

大垣英明, 文部科学省, 政府開発援助ユネスコ活動費補助金・アジア地域の持続可能な発展のためのエネルギー科学教育の推進 (ベトナム)

大垣英明, 文部科学省, グローバル COE・地球温暖化時代のエネルギー科学拠点

大垣英明, 高エネルギー加速器研究機構, 大学等連携支援事業・赤外自由電子レーザー発生のための光高周波電子源励起用マルチバンチ短パルスレーザー開発

大垣英明, 共同研究 ((株) 大林組), 環境中の放射性核種除去研究

紀井俊輝, 共同研究 ((財) 若狭湾エネルギー研究センター), 粒子線照射による新型バルク超伝導体アンジュレータの性能向上に関する基礎的研究

## Publications

M. Bakr, R. Kinjo, Y.W. Choi, M. Omer, K. Yoshida, S. Ueda, M. Takasaki, K. Ishida, N. Kimura, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Back Bombardment for Dispenser and Lanthanum Hexaboride Cathodes, J. Phys. Rev. STAB, 14, 060708-1-060708-9, 2011

M. Bakr, R. Kinjo, Y.W. Choi, M. Omer, K. Yoshida, S. Ueda, M. Takasaki, K. Ishida, N. Kimura, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Comparison of Heating Property of LaB6 and CeB6 by Back Bombardment Effect in Thermionic RF gun, Journal of the Korean Physical Society, 59, 5, 3273-3279, 2011

N. Yamamoto, M. Shimada, M. Adachi, H. Zen, T. Tanikawa, Y. Taira, S. Kimura, M. Hosaka, Y. Takashi,

T. Takahashi, M. Katoh, Ultra-short coherent terahertz radiation from ultra-short dips in electron bunches circulating in a storage ring, Nuclear Instruments and Methods in Physics Research A, 637, S112-S115, 2011

Y. Taira, M. Adachi, H. Zen, T. Tanikawa, N. Yamamoto, M. Hosaka, Y. Takashima, K. Soda, M. Katoh, Generation of energy-tunable and ultra-short-pulse gamma rays via inverse Compton scattering in an electron storage ring, Nuclear Instruments and Methods in Physics Research A, 652, 696-700, 2011

Y. Taira, M. Adachi, H. Zen, T. Tanikawa, M. Hosaka, Y. Takashima, N. Yamamoto, K. Soda, M. Katoh, Feasibility study of ultra-short gamma ray pulse generation by laser Compton scattering in an electron storage ring, Nuclear Instruments and Methods in Physics Research A, 637, S116-S119, 2011

K. Yoshida, T. Sonobe, M. Bakr, T. Sakka, T. Sagawa, E. Nakata, T. Morii, T. Kii, K. Masuda, H. Ohgaki, Material Analysis Laboratory in KU-FEL, Kyoto University, Energy Procedia, 9, 483-490, 2011

K. Yoshida, T. Sonobe, M.A. Bakr, Y.W. Choi, R. Kinjo, M. Omer, M. Takasaki, S. Ueda, N. Kimura, K. Ishida, K. Masuda, T. Kii, H. Ohgaki, Application of MIR-FEL Irradiation to Selectively Excite Phonons in Wide-gap Semiconductors, Journal of the Korean Physical Society, 59, 5, 3235-3238, 2011

F. Yamane, H. Ohgaki, K. Asano, Social Factors Affecting Economic Welfare of the Residents around Nuclear Power Plants in Japan, Energy Procedia, 9, 619-629, 2011

F. Yamane, H. Ohgaki, K. Asano, Nuclear Power-Related facilities and Neighboring Land Price: A Case Study on mutshu-Ogawara Region, Japan, Risk Analysis, 31, 12, 1969-1994, 2011

H. Toyokawa, T. Hayakawa, T. Shizuma, R. Hajima, K. Masuda, H. Ohgaki, Nondestructive inspection of explosive materials using linearly polarized two-colored photon beam, Nucl. Instrum. and Methods in Phys. Res. -sect A, 652, 1, 21-24, 2011

H. Toyokawa, H. Ohgaki, T. Hayakawa, T. Kii, T. Shizuma, R. Hajima, N. Kikuzawa, K. Masuda, F. Kitatani, H. Harada, Two-Dimensional Isotope Imaging of Radiation Shielded Materials Using Nuclear Resonance Fluorescence, Japanese Journal of Applied Physics, 50, 100209, 2011

M. Bakr, R. Kinjo, Y.W. Choi, M. Omer, K. Yoshida, S.

Ueda, M. Takasaki, K. Ishida, N. Kimura, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Back Bombardment for Dispenser and Lanthanum Hexaboride Cathodes, Phys. Rev. ST-AB, 14, 060708-1, 060708-9, 2011

K. Yoshida, T. Sonobe, M.A. Bakr, Y.W. Choi, R. Kinjo, M. Omer, M. Takasaki, S. Ueda, N. Kimura, K. Ishida, K. Masuda, T. Kii, H. Ohgaki, Application of MIR-FEL Irradiation to Selectively Excite Phonons in Wide-gap Semiconductors, Journal of the Korean Physical Society, 59, 5, 3235-3238, 2011

M. Bakr, R. Kinjo, Y.W. Choi, M. Omer, K. Yoshida, S. Ueda, M. Takasaki, K. Ishida, N. Kimura, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, Comparison of Heating Property of LaB6 and CeB6 by Back Bombardment Effect in Thermionic RF gun, Journal of the Korean Physical Society, 59, 5, 3273-3279, 2011

H. Ohgaki, T. Kii, K. Masuda, M. Omer, T. Misawa, C.H. Pyeon, R. Hajima, T. Hayakawa, T. Shizuma, M. Kando, I. Daido, H. Toyokawa, Proposal of a Non-Destructive Detection System for Hidden Nuclear Materials Based on a Neutron / Gamma-ray Hybrid System, Journal of the Korean Physical Society, 59, 5, 3155-3159, 2011

T. Shizuma, T. Hayakawa, R. Hajima, N. Kikuzawa, H. Ohgaki, H. Toyokawa, Nondestructive identification of isotopes using nuclear resonance fluorescence, REVIEW OF SCIENTIFIC INSTRUMENTS, 83, 15103, 2012

紀井俊輝, 金城良太, 放射光発生用挿入光源へのバ  
ルク超伝導体の応用, 低温工学, 46, 3, 118-124,  
2011

T. Kii, R. Kinjo, M.A. Bakr, T. Sonobe, K. Higashimura, K. Masuda, H. Ohgaki, K. Yoshida, H. Zen, Conceptual Design of a Novel Insertion Device using Bulk Superconducting Magnet, Physica C: Superconductivity, 471, 21-22, 897-900, 2011

J. Cravioto, M. Bakr, S. Aoyagi, S. Park, N.A. Utama, Community acceptance of nuclear power generation in Japan and relevant influencing factors, 2011 IEEE First Conference on Clean Energy and Technology CET, 248-252, 2011

T. Kii, T. Hori, K. Masuda, H. Ohgaki, M. Omer, H. Toyokawa, R. Hajima, T. Hayakawa, T. Shizuma, M. Kando, T. Misawa, C. Pyeon, Design Study of a Nuclear Material Detection System Based on a Quasi Monochromatic Gamma Ray Generator and a Nuclear Resonance Fluorescence Gamma Ray Detection System, Proce. of IPAC2011, 3666-3668, 2011

R. Hajima, T. Shizuma, T. Hayakawa, I. Daito, Y. Hayashi, M. Kando, H. Kotaki, N. Kikuzawa, T. Hori, H. Ohgaki, Compact Gamma-ray Source for Non-destructive Detection of Nuclear Material in Cargo, Proce. of IPAC2011, 3663-3665, 2011

T. Tanikawa, M. Adachi, M. Katoh, J. Yamazaki, H. Zen, Y. Taira, M. Hosaka, N. Yamamoto, SATURATION EFFECT ON VUV COHERENT HARMONIC GENERATION AT UVSOR-II, Proce. of IPAC2011, 3098-3100, 2011

Y. Taira, N. Yamamoto, M. Hosaka, K. Soda, M. Adachi, H. Zen, T. Tanikawa, M. Katoh, DEVELOPMENT OF PULSE WIDTH MEASUREMENT TECHNIQUES IN A PICOSECOND RANGE OF ULTRA-SHORT GAMMA RAY PULSES, Proce. of IPAC2011, 1473-1475, 2011

M. Omer, M.A. Bakr, R. Kinjo, Y.W. Choi, K. Yoshida, N. Kimura, K. Ishida, T. Komai, M. Shibata, K. Shimahashi, H. Imon, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, R. Hajima, T. Hayakawa, T. Shizuma, H. Toyokawa, Assessment of LaBr3 (Ce) Scintillators System for Measuring Nuclear Resonance Fluorescence Excitations near 2 MeV, 2011 IEEE Nuclear Science Symposium Conference Record, NP5.S-98, 1627-1630, 2012

N. Kimura, T. Kii, R. Kinjo, M.A. Bakr, Y.W. Choi, M. Omer, K. Yoshida, K. Ishida, T. Komai, M. Shibata, K. Shimahashi, H. Imon, T. Sonobe, H. Zen, K. Masuda, H. Ohgaki, Calculation and Experiment for Improvement of Termination Field of Bulk HTSC Staggered Array Undulator, Proc. of 8th Annual Meeting of PASJ, TUPS078, 2011

K. Ishida, M.A. Bakr, Y.W. Choi, R. Kinjo, M. Omer, K. Yoshida, N. Kimura, T. Komai, M. Shibata, K. Shimahashi, H. Imon, H. Zen, T. Sonobe, K. Masuda, T. Kii, H. Ohgaki, Evaluation of Lasing Range with a 1.8 m Undulator in KU-FEL, Proc. of 8th Annual Meeting of PASJ, TUPS069, 2011

T. Hori, R. Kinjo, H. Kotaki, M. Kando, H. Ohgaki, T. Kii, M. Omer, I. Daito, R. Hajima, T. Hayakawa, Racetrack Microtron for Nuclear Material Detection System, Proc. of 8th Annual Meeting of PASJ, OPS140, 2011

T. Kii, M.A. Bakr, R. Kinjo, Y.W. Choi, M. Omer, K. Yoshida, N. Kimura, K. Ishida, T. Komai, M. Shibata, K. Shimahashi, H. Imon, H. Zen, T. Sonobe, K. Masuda, H. Ohgaki, Present Status of Kyoto University MIR-FEL Facility, Proc. of 8th Annual Meeting of PASJ,



TUPS015, 2011

R. Kinjo, K. Nagahara, T. Kii, N. Kimura, M.A. Bakr, Y.W. Choi, M. Omer, K. Yoshida, K. Ishida, T. Komai, M. Shibata, K. Shimahashi, H. Zen, H. Imon, T. Sonobe, K. Masuda, K. Nagasaki, H. Ohgaki, Simulation of Electron Trajectory in Bulk HTSC Staggered Array Undulator, Proc. of 8th Annual Meeting of PASJ, TUPS077, 2011

Y. Gotoh, Y. Hida, H. Zen, M. Katoh, N. Yamamoto, M. Hosaka, Y. Takashima, Pulsed Quadrupole Injection for a Small Scale Synchrotron Radiation Facility, Proc. of 8th Annual Meeting of PASJ, MOPS049, 2011

H. Zen, K. Hayashi, J. Yamazaki, M. Adachi, M. Katoh, Stabilization of Injector and Injection Kickers in UVSOR-II, Proc. of 8th Annual Meeting of PASJ, MOPS084, 2011

M. Adachi, H. Zen, J. Yamazaki, K. Hayashi, M. Katoh, Status OF UVSOR-II, Proc. of 8th Annual Meeting of PASJ, TUPS007, 2011

H. Zen, M. Hosaka, N. Yamamoto, M. Adachi, M. Katoh, Investigation on Chirped Pulse Generation and Compression for CHG-FEL, Proc. of 8th Annual Meeting of PASJ, TUPS048, 2011

H. Zen, Y. Kikuchi, M. Hosaka, N. Yamamoto, K. Hayashi, T. Kondo, J. Yamazaki, M. Adachi, Y. Takashima, M. Katoh, Compensation of Nonlinear Effect in Apple-II Undulator by Multi-wire Method in UVSOR-II, Proc. of 8th Annual Meeting of PASJ, TUPS049, 2011

N. Wasa, Y. Uematsu, Y. Takashima, T. Tanikawa, M. Adachi, H. Zen, M. Katoh, M. Hosaka, N. Yamamoto, Coherent Harmonic Generation Using Relativistic Electron Beam and Higher Harmonics of a Laser, Proc. of 8th Annual Meeting of PASJ, TUPS065, 2011

Y. Taira, M. Adachi, H. Zen, N. Yamamoto, M. Hosaka, K. Soda, M. Katoh, Development of Pulse width Measurement Techniques of Ultra-short Gamma ray Pulses, Proc. of 8th Annual Meeting of PASJ, TUPS071, 2011

大垣英明, 早川岳人, 核共鳴蛍光散乱による隠匿された物質の非破壊同位体分析, 応用物理, 80 巻, 11, 955-959, 2011

大垣英明, 早川岳人, 大東出, レーザー逆コンプトン散乱ガンマ線を用いた核共鳴蛍光による同位体の非破壊分析, レーザー研究, 40, 3, 188-193, 2012

## Presentations

F. Yamane, H. Ohgaki, K. Asano, Social Factors Affecting Economic Welfare of the Residents around Nuclear Power Plants in Japan, 9th EMSES 2011, Wiang Inn Hotel, Chiang Rai, 2011.5.26

H. Ohgaki, T. Kii, K. Masuda, M.A. Bakr, R. Kinjo, Y.W. Choi, A.M. Omer, K. Yoshida, S. Ueda, M. Takasaki, K. Ishida, N. Kimura, T. Sonobe, Research Activities on Laser and Accelerator based Photon Beams in Kyoto University, 9th EMSES 2011, Wiang Inn Hotel, Chiang Rai, 2011.5.27

K. Yoshida, T. Sonobe, K. Ishida, N. Kimura, S. Ueda, M. Takasaki, Material Analysis Laboratory in KU-FEL, Kyoto University, 9th EMSES 2011, Wiang Inn Hotel, Chiang Rai, 2011.5.27

Y. Gotoh, Y. Hida, H. Zen, M. Katoh, N. Yamamoto, M. Hosaka, Y. Takashima, Pulsed Quadrupole Injection for a Small Scale Synchrotron Radiation Facility, 8th Annual Meeting of PASJ, つくば国際会議場, 2011.8.1-3

H. Zen, K. Hayashi, J. Yamazaki, M. Adachi, M. Katoh, Stabilization of Injector and Injection Kickers in UVSOR-II, 8th Annual Meeting of PASJ, つくば国際会議場, 2011.8.1-3

M. Adachi, H. Zen, J. Yamazaki, K. Hayashi, M. Katoh, Status OF UVSOR-II, 8th Annual Meeting of PASJ, つくば国際会議場, 2011.8.1-3

H. Zen, M. Hosaka, N. Yamamoto, M. Adachi, M. Katoh, Investigation on Chirped Pulse Generation and Compression for CHG-FEL, 8th Annual Meeting of PASJ, つくば国際会議場, 2011.8.1-3

H. Zen, Y. Kikuchi, M. Hosaka, N. Yamamoto, K. Hayashi, T. Kondo, J. Yamazaki, M. Adachi, Y. Takashima, M. Katoh, Compensation of Nonlinear Effect in Apple-II Undulator by Multi-wire Method in UVSOR-II, 8th Annual Meeting of PASJ, つくば国際会議場, 2011.8.1-3

N. Wasa, Y. Uematsu, Y. Takashima, T. Tanikawa, M. Adachi, H. Zen, M. Katoh, M. Hosaka, N. Yamamoto, Coherent Harmonic Generation Using Relativistic Electron Beam and Higher Harmonics of a Laser, 8th Annual Meeting of PASJ, つくば国際会議場, 2011.8.1-3

Y. Taira, M. Adachi, H. Zen, N. Yamamoto, M. Hosaka, K. Soda, M. Katoh, Development of Pulse width Measurement Techniques of Ultra-short Gamma ray Pulses, 8th Annual Meeting of PASJ, つくば国際会議

場, 2011.8.1-3

N. Kimura, T. Kii, R. Kinjo, M.A. Bakr, Y.W. Choi, M. Omer, K. Yoshida, K. Ishida, T. Komai, M. Shibata, K. Shimahashi, H. Imon, T. Sonobe, H. Zen, K. Masuda, H. Ohgaki, Calculation and Experiment for Improvement of Termination Field of Bulk HTSC Staggered Array Undulator, 8th Annual Meeting of PASJ, つくば国際会議場, 2011.8.1-3

K. Ishida, M.A. Bakr, Y.W. Choi, R. Kinjo, M. Omer, K. Yoshida, N. Kimura, T. Komai, M. Shibata, K. Shimahashi, H. Imon, H. Zen, T. Sonobe, K. Masuda, T. Kii, H. Ohgaki, Evaluation of Lasing Range with a 1.8 m Undulator in KU-FEL, 8th Annual Meeting of PASJ, つくば国際会議場, 2011.8.1-3

T. Kii, M. Omer, T. Hori, K. Masuda, H. Ohgaki, H. Toyokawa, R. Hajima, T. Hayakawa, T. Shizuma, M. Kando, T. Misawa, C. Pyeon, DESIGN STUDY OF A NUCLEAR MATERIAL DETECTION SYSTEM BASED ON A QUASI MONOCHROMATIC GAMMA RAY GENERATOR AND A NUCLEAR RESONANCE FLUORESCENCE GAMMA RAY DETECTION SYSTEM, 8th Annual Meeting of PASJ, つくば国際会議場, 2011.8.1-3

T. Tanikawa, M. Adachi, M. Katoh, J. Yamazaki, H. Zen, M. Hosaka, Y. Taira, N. Yamamoto, Saturation Effect on VUV Coherent Harmonic Generation at UVSOR-II, FEL2011, Shanghai, China, 2011.8.22-26

H. Zen, K. Hayashi, S.I. Kimura, E. Nakamura, T. Tanikawa, J. Yamazaki, M. Adachi, M. Katoh, M. Hosaka, Y. Takashima, N. Yamamoto, T. Takahashi, Present Status and Future Prospects of Project on Utilizing Coherent Light Sources for User Experiments at UVSOR-II, FEL2011, Shanghai, China, 2011.8.22-26

C. Szwaj, S. Bielawski, T. Tanikawa, M. Adachi, M. Katoh, H. Zen, M. Hosaka, N. Yamamoto, Injection of a Free Electron Laser Oscillator with an External Laser, FEL2011, Shanghai, China, 2011.8.22-26

M. Hosaka, Y. Taira, Y. Takashima, N. Yamamoto, M. Adachi, M. Katoh, T. Tanikawa, H. Zen, S. Bielawski, C. Szwaj, C. Evain, Intense Coherent THz Synchrotron Radiation Induced by a Storage Ring FEL Seeded with a Femtosecond Laser, FEL2011, Shanghai, China, 2011.8.22-26

H. Zen, M. Adachi, M. Katoh, S. Bielawski, C. Szwaj, M. Hosaka, Technical Developments for Injecting External Laser to a Storage Ring FEL in CW and Q-switched Operation, FEL2011, Shanghai, China, 2011.8.22-26

H. Zen, T. Tanikawa, M. Adachi, M. Katoh, M. Hosaka, N. Yamamoto, Chirped Pulse Generation by CHG-FEL, FEL2011, Shanghai, China, 2011.8.22-26

N. Kimura, T. Kii, R. Kinjo, M.A. Bakr, Y.W. Choi, M. Omer, K. Yoshida, K. Ishida, T. Komai, M. Shibata, K. Shimahashi, H. Imon, T. Sonobe, H. Zen, K. Masuda, H. Ohgaki, IMPROVEMENT OF TERMINATION FIELD OF BULK HTSC STAGGERED ARRAY UNDULATOR, FEL2011, Shanghai, China, 2011.8.22-26

K. Ishida, M.A. Bakr, Y.W. Choi, R. Kinjo, M. Omer, K. Yoshida, N. Kimura, T. Komai, M. Shibata, K. Shimahashi, H. Imon, H. Zen, T. Sonobe, K. Masuda, T. Kii, H. Ohgaki, Evaluation of Lasing Range with a 1.8 m Undulator in KU-FEL, FEL2011, Shanghai, China, 2011.8.22-26

H. Ohgaki, Accelerator Based Photon Beams, Generation and Applications at Kyoto University, The 2011 IQEC/CLEO Pacific Rim Conference, Sydney Convention and Exhibition Centre, 2011.8.31

T. Tanikawa, M. Adachi, M. Katoh, J. Yamazaki, H. Zen, Y. Taira, M. Hosaka, N. Yamamoto, SATURATION EFFECT ON VUV COHERENT HARMONIC GENERATION AT UVSOR-II, The second International Particle Accelerator Conference (IPAC-11), San Sebastian, Spain, 2011.9.4-9

Y. Taira, N. Yamamoto, M. Hosaka, K. Soda, M. Adachi, H. Zen, T. Tanikawa, M. Katoh, DEVELOPMENT OF PULSE WIDTH MEASUREMENT TECHNIQUES IN A PICOSECOND RANGE OF ULTRA-SHORT GAMMA RAY PULSES, The second International Particle Accelerator Conference (IPAC-11), San Sebastian, Spain, 2011.9.4-9

T. Kii, T. Hori, K. Masuda, H. Ohgaki, M. Omer, R. Hajima, T. Hayakawa, M. Kando, T. Shizuma, T. Misawa, C.H. Pyeon, H. Toyokawa, Design Study of a Nuclear Material Detection System Based on a Quasi Monochromatic Gamma Ray Generator and a Nuclear Resonance Fluorescence Gamma Ray Detection System, The second International Particle Accelerator Conference (IPAC-12), San Sebastian, Spain, 2011.9.4-9

R. Hajima, T. Shizuma, T. Hayakawa, N. Kikuzawa, I. Daito, M. Kando, H. Kotaki, Y. Hayashi, T. Hori, T. Kii, H. Ohgaki, COMPACT GAMMA-RAY SOURCE FOR NON-DESTRUCTIVE DETECTION OF NUCLEAR MATERIAL IN CARGO, The second International Particle Accelerator Conference (IPAC-11), San Sebastian, Spain, 2011.9.4-9



M. Hosaka, Y. Taira, N. Yamamoto, M. Adachi, M. Katoh, T. Tanikawa, H. Zen, S. Bielawski, C. Szwaj, C. Evain, Coherent THz Synchrotron Radiation Induced by an FEL Oscillation in an Electron Storage Ring, The second International Particle Accelerator Conference (IPAC-11), San Sebastian, Spain, 2011.9.4-9

M. Adachi, K. Hayashi, J. Yamazaki, M. Katoh, H. Zen, Status and Upgrade Program of UVSOR Accelerators, The second International Particle Accelerator Conference (IPAC-11), San Sebastian, Spain, 2011.9.4-9

M. Adachi, K. Hayashi, J. Yamazaki, M. Hosaka, N. Yamamoto, M. Katoh, H. Zen, New Light Source Development Site at UVSOR, The second International Particle Accelerator Conference (IPAC-11), San Sebastian, Spain, 2011.9.4-9

S. Bielawski, C. Szwaj, T. Tanikawa, M. Adachi, M. Katoh, S.I. Kimura, H. Zen, C. Evain, M. Hosaka, Y. Takashima, N. Yamamoto, M. Le Parquier, A. Mochihashi, M. Shimada, T. Takahashi, CSR Induced by Modulated Laser Pulses: Detailed Study of the Saturation Effect, The second International Particle Accelerator Conference (IPAC-11), San Sebastian, Spain, 2011.9.4-9

T. Kii, R. Kinjo, N. Kimura, M. Shibata, M.A. Bakr, Y.W. Choi, M. Omer, K. Yoshida, K. Ishida, T. Komai, K. Shimahashi, T. Sonobe, H. Zen, K. Masuda, H. Ohgaki, Low-temperature operation of a Bulk HTSC Staggered Array Undulator, 22nd International Conference on Magnet Technology, Marseille, France, 2011.9.12-16

金城良太, 紀井俊輝, 木村尚樹, Mahmoud Bakr, Yong Woon Choi, Mohamed Omer, 吉田恭平, 石田啓一, 駒井琢也, 柴田茉莉江, 島橋亨兵, 園部太郎, 増田開, 長崎百伸, 大垣英明, 高温超伝導バルク磁石を用いたスタガードアレイアンジュレータへの強磁性体の導入による磁場増強, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

早川岳人, 菊澤信宏, 静間俊行, 羽島良一, 瀬谷道夫, 大垣英明, 核共鳴蛍光散乱測定法と核データ, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

静間俊行, 早川岳人, 菊澤信宏, 大垣英明, 豊川弘之, 小松原哲郎, レーザーコンプトンガンマ線を用いた鉄領域核の核共鳴蛍光散乱実験, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

山根史博, 大垣英明, 浅野耕太, 原子力発電所周辺

の住民経済厚生とその規定要因; サイト間比較分析, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

大垣英明, 紀井俊輝, 増田開, 三澤毅, 卞哲浩, Omer Mohamed, 早川岳人, 堀利匡, 羽島良一, 静間俊行, 菊澤信宏, 神門正城, 大東出, 豊川弘之, 藤本真也, 中性子/ $\gamma$ 線複合型核検知システム開発の現状 II; (1) 全体システムの設計の現状, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

増田開, 大垣英明, 梶原泰樹, 山垣悠, 三澤毅, 卞哲浩, 中性子/ $\gamma$ 線複合型核検知システム開発の現状 II; (2) 放電型 D-D 核融合中性子源の開発, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

三澤毅, 高橋佳之, 八木貴宏, 卞哲浩, 増田開, 大垣英明, 中性子/ $\gamma$ 線複合型核検知システム開発の現状 II; (3) 加速器中性子源と HEU を用いた基礎実験, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

M. Omer, M. Bakr, R. Kinjo, Y.W. Choi, K. Yoshida, N. Kimura, K. Ishida, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, R. Hajima, T. Hayakawa, T. Shizuma, H. Toyokawa, Nuclear Resonance Fluorescence Excitations Measured by LaBr<sub>3</sub> (Ce) Scintillators, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

H. Ohgaki, Non-destructive Inspection of hidden SNM by using Laser-Compton Backscattering Gamma-ray induced NRF, KAERI WCI International Advisory Meeting, KOREA ATOMIC ENERGY RESEARCH INSTITUTE, DAEJON, KOREA, 2011.9.23

M. Omer, M.A. Bakr, R. Kinjo, Y.W. Choi, K. Yoshida, N. Kimura, K. Ishida, T. Komai, M. Shibata, K. Shimahashi, H. Imon, T. Sonobe, T. Kii, K. Masuda, H. Ohgaki, R. Hajima, T. Hayakawa, T. Shizuma, H. Toyokawa, Assessment of LaBr<sub>3</sub>(Ce) Scintillators System for Measuring Nuclear Resonance Fluorescence Excitations near 2 MeV, 2011 IEEE Nuclear Science Symposium, Assessment of LaBr<sub>3</sub>(Ce) Scintillators System for Measuring Nuclear Resonance Fluorescence Excitations near 2 Me, 2011 IEEE Nuclear Science Symposium, Valencia, Spain, 2011.10.23-29

全炳俊, KU-FEL の現状と展望(2011), 第 18 回 FEL と High Power Radiation 研究会, 自然科学研究機構岡崎コンファレンスセンター, 2011.12.5-6

石田啓一, 1.8m アンジュレータ導入後の KU-FEL の特性予測, 第 18 回 FEL と High Power Radiation

研究会, 自然科学研究機構岡崎コンファレンスセンター, 2011.12.5-6

全炳俊, 熱陰極高周波電子銃における Back-bombardment 現象とその対策, ビーム物理研究会若手の会, 仙台市青葉区作並, 2011.12.9-10

紀井俊輝, 大垣英明, 全炳俊, 堀利匡, 園部太郎, M.A. Bakr, C.Y. Choi, 吉田恭平, M. Omer, N. Hani, 石田啓一, 木村尚樹, 駒井琢也, 柴田茉莉江, 島橋享平, 増田開, 金城良太, T. Konstantin, 井門秀和, 京都大学エネルギー理工学研究所における量子放射エネルギー研究, ビーム物理研究会若手の会, 仙台市青葉区作並, 2011.12.9-10

阿達正浩, 田中誠一, 山崎潤一郎, 林憲志, 木村真一, 保坂将人, 山本尚人, 高嶋圭史, 平義隆, 全炳俊, 高橋俊晴, 谷川貴紀, 加藤政博, UVSOR-II におけるコヒーレント光源開発の現状, 第 25 回日本放射光学会年会放射光科学合同シンポジウム, 鳥栖市民文化会館・中央公民館, 2012.1.6-9

全炳俊, 石田啓一, 木村尚樹, M. Omer, 崔 龍雲, 金城良太, 吉田恭平, M.A. Bakr, 園部太郎, 紀井俊輝, 増田開, 大垣英明, 京都大学小型中赤外自由電子レーザの現状と将来計画, 第 25 回日本放射光学会年会放射光科学合同シンポジウム, 鳥栖市民文化会館・中央公民館, 2012.1.6-9

山崎潤一郎, 阿達正浩, 林憲志, 田中誠一, 加藤政博, 全炳俊, UVSOR-II 加速器の現状, 第 25 回日本放射光学会年会放射光科学合同シンポジウム, 鳥栖市民文化会館・中央公民館, 2012.1.6-9

平義隆, 豊川弘之, 阿達正浩, 全炳俊, 山本尚人, 保坂将人, 曾田一雄, 加藤政博, 超短パルスガンマ線のパルス幅測定手法の開発と陽電子消滅寿命測定への応用, 第 25 回日本放射光学会年会放射光科学合同シンポジウム, 鳥栖市民文化会館・中央公民館, 2012.1.6-9

全炳俊, 阿達正浩, 保坂正人, 山本尚人, 加藤政博, Chirped Pulse Generation を用いた CHG-FEL による大強度・短パルス放射光発生, 第 25 回日本放射光学会年会放射光科学合同シンポジウム, 鳥栖市民文化会館・中央公民館, 2012.1.6-9

植松遥平, 保坂将人, 高嶋圭史, 山本尚人, 和佐直毅, 阿達正浩, 山崎潤一郎, 林憲志, 全炳俊, 加藤政博, UVSOR 新オプティカルクライストロンのためのバンチャー電磁石の設計, 第 25 回日本放射光学会年会放射光科学合同シンポジウム, 鳥栖市民文化会館・中央公民館, 2012.1.6-9

肥田洋平, 後藤義明, 全炳俊, 阿達正浩, 山本尚人, 保坂将人, 高嶋圭史, 加藤政博, UVSOR における、

パルス六極電磁石を用いた入射システムの研究, 第 25 回日本放射光学会年会放射光科学合同シンポジウム, 鳥栖市民文化会館・中央公民館, 2012.1.6-9

M. Bakr, Y.W. Choi, R. Kinjo, M. Omer, K. Yoshida, H. Negm, N. Kimura, K. Ishida, T. Komai, M. Shibata, K. Shimahashi, H. Zen, T. Sonobe, K. Masuda, T. Kii, H. Ohgaki, The Status and Future Development in KUFEL, The 3rd Asian Core Workshop on Advanced Quantum-Beam Sources and Applications, KAERI INTEC, Daejeon, Korea, 2012.2.23-24

R. Kinjo, T. Kii, M. Shibata, M.A. Bakr, Y.W. Choi, M. Omer, K. Yoshida, H. Negm, N. Kimura, K. Ishida, T. Komai, K. Shimahashi, H. Imon, H. Zen, T. Sonobe, K. Masuda, K. Nagasaki, H. Ohgaki, Development Status of Bulk High Tc Superconductor Staggered Array Undulator, The 3rd Asian Core Workshop on Advanced Quantum-Beam Sources and Applications, KAERI INTEC, Daejeon, Korea, 2012.2.23-24

Y.W. Choi, M.A. Bakr, R. Kinjo, M. Omer, K. Yoshida, H. Negm, N. Kimura, K. Ishida, T. Komai, M. Shibata, K. Shimahashi, T. Sonobe, H. Zen, K. Masuda, T. Kii, H. Ohgaki, Development of BPM Readout System for Electron Beam Stabilization in KU-FEL, The 3rd Asian Core Workshop on Advanced Quantum-Beam Sources and Applications, KAERI INTEC, Daejeon, Korea, 2012.2.23-24

島橋享兵, 石田啓一, 金城良太, 崔龍雲, Mohamed Omer, 吉田恭平, Negm Hani, 木村尚樹, 駒井琢也, 柴田茉莉江, 園部太郎, 全炳俊, 増田開, 紀井敏輝, 大垣英明, KU-FEL への 1.8m アンジュレータ導入後の特性予測と発振実験の比較, 日本原子力学会「2012 年春の年会」, 福井大学文京キャンパス, 2012.3.19-21

柴田茉莉江, 木村尚樹, 金城良太, 紀井俊輝, 駒井琢也, 島橋享兵, 石田啓一, Negm Hani, 吉田恭平, Mohamed Omer, 崔龍雲, 園部太郎, 全炳俊, 増田開, 大垣英明, 高温超伝導バルク磁石を用いたスタガードアレイアンジュレータのビーム方向磁場補正, 日本原子力学会「2012 年春の年会」, 福井大学文京キャンパス, 2012.3.19-21

Y.W. Choi, R. Kinjo, M. Omer, K. Yoshida, N. Hani, K. Ishida, N. Kimura, K. Shimahashi, M. Shibata, T. Komai, T. Sonobe, H. Zen, K. Masuda, T. Kii, H. Ohgaki, BPM signal processing for KU-FEL linac(1), 日本原子力学会「2012 年春の年会」, 福井大学文京キャンパス, 2012.3.19-21

M.D Omer, R. Kinjo, Y.W. Choi, K. Yoshida, H. Negm, M. Bakr, H. Zen, T. Hori, T. Kii, K. Masuda, H. Ohgaki, R. Hajima, T. Hayakawa, T. Shizuma, H. Toyoy-

kawa, Potential of LaBr<sub>3</sub> (Ce) for Measuring Nuclear Resonance Fluorescence Excitations of Nuclear Materials near 2 MeV, 日本原子力学会「2012 年春の年会」, 福井大学文京キャンパス, 2012.3.19-21

大垣英明, 紀井俊輝, 増田開, 三澤毅, 卞哲浩, 梶原泰樹, 堀利匡, Omer Mohamed, 藤本真也, 羽島良一, 早川岳人, 静間俊行, 神門正城, 大東出, 豊川弘之, 中性子/ $\gamma$ 線複合型核検知システム開発の現状 III, 日本原子力学会「2012 年春の年会」, 福井大学文京キャンパス, 2012.3.19-21

山根史博, 大垣英明, 浅野耕太, 福島第一原発事故前後における原発立地地域の資産価値変動, 日本原子力学会「2012 年春の年会」, 福井大学文京キャンパス, 2012.3.19-21

紀井俊輝, 金城良太, 木村尚樹, 柴田茉莉江, Y.W. Choi, M. Omer, N. Hani, 吉田恭平, 石田啓一, 駒井琢也, 島橋享兵, 井門秀和, M.A. BAKR, 堀利匡, 園部太郎, 全炳俊, 増田開, 大垣英明, バルク超伝導体を用いた短周期・強磁場アンジュレータの開発, 物理学会第 67 回年次大会, 関西学院大学西宮上ヶ原キャンパス, 2012.3.24-27

Y. Qin, X. Wang, 全炳俊, 中嶋隆, 紀井俊輝, 大垣英明, Autocorrelation measurement of KUFEL, 物理学会第 67 回年次大会, 関西学院大学西宮上ヶ原キャンパス, 2012.3.24-27

大東出, 神門正城, 小瀧秀行, 林由紀雄, 早川岳人, 静間俊行, 羽島良一, 大垣英明, 核物質非破壊検知用レーザーコンプトン $\gamma$ 線源の開発, 物理学会第 67 回年次大会, 関西学院大学西宮上ヶ原キャンパス, 2012.3.24-27

## Advanced Atomic Energy Research Section

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### 1. Introduction

The major objective of the study in this section is to pursue advanced energy systems for the sustainable development under global environmental constraints. The studies described below are featured by not only the innovative technology of energy generation, conversion and utilization systems. The attractiveness of the total energy system considered by the socio-economic analysis of future society and markets in the global scale and the scope covering 21<sup>st</sup> century and beyond is reflected. Typically, we propose a Zero-emission energy scenario based on fusion energy for biomass-based recycling system.

The major studies performed in our laboratory this fiscal year were as follows:

- (1) Design of small and realistic biomass-fusion hybrid energy system
- (2) Development of advanced fusion blanket and divertor with liquid LiPb and SiC composite for high temperature heat
- (3) Conversion of waste biomass by endo-thermic reaction to generate hydrogen and liquid fuel
- (4) Design and analysis of DC microgrid system for zero-emission electricity system
- (5) Development of compact neutron beam using newly developed cylindrical discharge device.
- (6) Analysis of radioactive impact of nuclides from fusion plants.
- (7) Materials R&D for the above-mentioned issues

The joining of Prof. Ryuta Kasada to this research activity from December has added above (7) and further added the material aspects to all of other areas. This report introduces the recent results of some of these subjects.

### 2. Vacuum sieve tray for tritium extraction from liquid Pb-17Li

We propose the vacuum sieve tray shown in the fig.1 as a tritium extraction process for liquid blanket. Formation of droplet of liquid Li-17Pb released from a nozzle into vacuum was studied for the evaluation of the feasibility. Size of droplets formed from the nozzles was estimated by theoretical and experimental methods. For the theoretical estimation, the

non-dimensional comparison of the physical bulk property of liquid Pb-17Li with water (H<sub>2</sub>O) at ambient temperature was applied. It was found to be reasonable to apply the Plateau-Rayleigh-Instability theory for the droplet size formula of the fluid Pb-17Li for the nozzle diameter 0.4 mm–1.0 mm, temperature 400 °C–500 °C, at initial velocity of 3 m/s. The experimental results of the droplet size showed

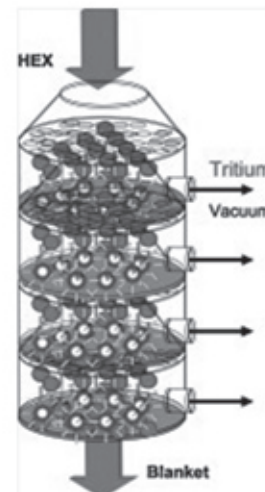


Fig. 1 Schematic image of vacuum-sieve-tray.

good agreement with the theory. This device was used for the parametric study of extraction of deuterium during their free fall in vacuum. The scaling of the device suggests the feasibility of the process.

### 3. Development of Cylindrical Discharge type Fusion Device for neutron beam source

Neutron beam can be used for various applications in the fields such as nondestructive inspection of metal, medical applications and radiography. We developed cylindrical discharge type fusion device that can provide 2.45MeV high energy and isotropic neutrons by D-D fusion reactions on the surface of the cylindrical electrode. Single direction beam is obtained by adequate design of the reflector, moderator and shield absorber surrounding it. Energy spectrum is also changed to meet the requirements for various applications. The evaluation of beam op-



tics such as neutron flux distribution, energy spectrum and convergent was conducted with MCNP5 code to reveal the effect of reflector (tungsten and iron) and moderator's material (graphite, polyethylene and heavy water) and shape. As a result, effects of combinations of reflectors on neutron flux and beam velocity angular, as well as energy were obtained and compared as shown in the Fig.2 for example. Combined W and Fe reflector generates more than 90% of fast neutron over 1MeV in the fast/total ratio, and focuses more than three times of flux compared with isotropic radiation. Combined PE and D<sub>2</sub>O reflector generates more than 30% thermal neutron, that required more moderator on the beam line to increase its thermal fraction while avoiding a degradation of the beam quality.

This result showed that generation of single direction beam with desirable neutron energy is possible with this cylindrical discharge fusion neutron source. Quantity of generated neutron is the issue

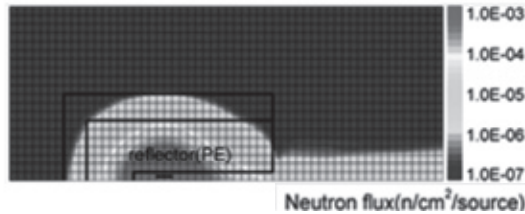


Fig. 2 Neutronics calculation to achieve a suitable configuration of reflector materials for D-D neutron beam source.

and geometry of electrodes and improvement of operating condition are being improved experimentally.

#### 4. Conversion of waste biomass by endo-thermic reaction to generate hydrogen and liquid fuel

We propose the utilization of fusion heat to produce synthetic fuels from waste biomass as an alternative of electricity generation. As the part of the feasibility study, by-product of the gasification to H<sub>2</sub>-CO mixture from the endothermic reaction between biomass and water vapor was studied in this year. The preliminary result showed that some forms of carbons such as char and tar exist with nickel catalyst in parts of the experimental devices. In order to separate such ash from catalysts, new experimental device with a circulation system is under constructing, as the modification of the device shown in the figure 3.

#### 5. Study of a phase separation in Fe-Cr alloys for structural materials of nuclear energy power plants

The equilibrium phase diagram of Fe-Cr system at low temperature is not experimentally determined and confused because of the low atomic mobility. This problem has been a long-standing subject of research and is now attracting interest because the

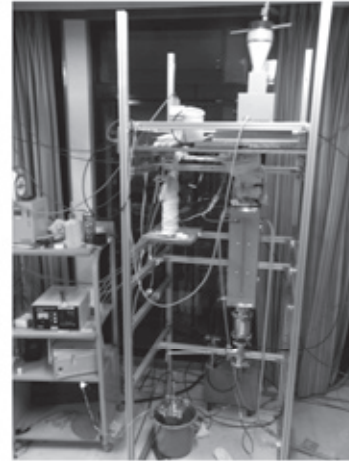


Fig. 3 Biomass gasification system.

Fe-Cr alloys are candidates for advanced fission and fusion reactor structural materials. A conventional and engineering way to observe the phase separation is a hardness test. However, there are evidences for the occurrence of the phase separation without any observable hardness changes after the similar aging conditions. This means the early stages of phase separation is not sensitive for their hardness change. Therefore experimental studies of phase separation in the Fe-Cr system has been carried out using various modern techniques; neutron small angle scattering, field ion microscopy, atom probe field ion microscopy, X-ray small angle diffraction, transmission electron microscopy, Mössbauer spectroscopy, and magnetization measurement. However, the very early stages of the phase separation may be neglected during these experiments because the wave length of the phase separation in Fe-Cr is found to be at the nanometer scale. In this study, we examine the positron annihilation spectroscopy to detect the atomic scale phase separation in Fe-Cr system. Effect of ion-irradiation on the Fe-Cr alloys are also investigated. As shown in Fig. 4, positron annihilation spectroscopy reveals the early stage of the phase separation of Fe-70Cr alloy after the ion irradiation at 475 °C up to 5 dpa.

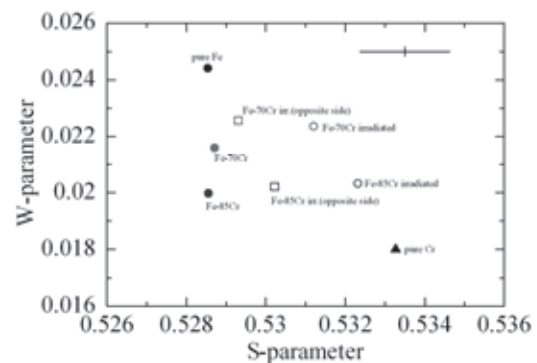


Fig. 4 Effect of ion-irradiation on the S- and W-parameter obtained from positron annihilation spectroscopy.

## Collaboration Works

核融合科学研究所, ヘリカル型核融合炉システムのトリチウム安全性, 小西哲之

## Financial Support

小西哲之, 受託研究 ((独) 日本学術振興会), 平成 23 年度アジア研究教育拠点事業

笠田竜太, 受託研究 (文部科学省), 原子力機器用鉄クロム系材料の相分離現象に関する基礎的研究

笠田竜太, 共同研究 ((独) 日本原子力研究開発機構), 低放射化フェライト鋼の照射下挙動評価に関する研究

笠田竜太, 共同研究 ((株) 原子力安全システム研究所), 原子炉容器鋼の照射脆化におよぼす応力の影響

笠田竜太, 奨学寄附金 (核融合エネルギーフォーラム), 核融合エネルギー研究に対する助成

## Publications

K. Ibane, Y. Yamamoto, S. Konishi, High temperature plasma facing components designs for biomass hybrid reactor: GNOME, Proc. Of the 24th Symposium of Fusion Engineering, 2011

K. Noborio, Y. Yamamoto, C. Park, Y. Takeuchi, S. Konishi, High Temperature Operation of LiPb Loop, Fusion Science and Technology, 60, 1, 298-302, 2011

K. Noborio, S. Konishi, T. Maegawa, Y. Yamamoto, Numerical Calculation of Reactions on Electrode Surfaces and in a Volume of a Discharge Type Fusion Neutron Source, Proc. 2011 IEEE/NPSS 24th Symposium on Fusion Engineering, CD-ROM, 2011

Y. Yamamoto, M. Ichinose, F. Okino, K. Noborio, S. Konishi, Design of Tritium Collecting System from LiPb and LiPb Dropping Experiment, Fusion Science and Technology, 60, 2, 558-562, 2011

T. Shibata, K. Noborio, Y. Yamamoto, S. Konishi, Analysis of Tritium Behavior in the Atmosphere near the Water Surface, Fusion Science and Technology, 60, 1, 384-388, 2011

T. Maegawa, K. Noborio, S. Konishi, Y. Yamamoto, Generation of Neutron Beam with the Cylindrical Discharge Type Fusion Device, Proc. 2011 IEEE/NPSS 24th Symposium on Fusion Engineering,

CD-ROM, 2011

T. Shibata, K. Noborio, Y. Yamamoto, S. Konishi, Tritium Concentration in the Environment and Ge-nomic DNA, Fusion Science and Technology, 60, 3, 1200-1203, 2011

C. Park, K. Noborio, R. Kasada, Y. Yamamoto, S. Konishi, Compatibility of SiCf/SiC composite exposed to liquid Pb-Li flow, Journal of Nuclear Materials, 417, 1^3, 1218-1220, 2011

F.Okino, K. Noborio, Y. Yamamoto, S. Konishi, Vacuum sieve tray for tritium extraction from liquid Pb-17Li, Journal of Fusion Engineering and Design, 2011

Y. Yamamoto, N. Ichinose, F. Okino, K. Noborio, S. Konishi, Design of tritium collecting system from LiPb and LiPb dropping experiment, Fusion Science and Technology, 60, 2, 558-562, 2011

S.H. Kim, H.K. Yoon, K. Noborio, S. Konishi, , Development of Composite Material with Directional Property for High Thermal Conductivity for Divertor, Zero-Carbon Energy Kyoto 2011 (Springer), 2011

C. Park, K. Noborio, R. Kasada, Y. Yamamoto, S. Konishi, Compatibility of SiCf/SiC Composite Exposed to Liquid LiPb Flow, Journal of Nuclear Materials, 417, 1218-1220, 2011

## Presentations

K. Ibane, Y. Yamamoto, S. Konishi, Designed features of the biomass-fusion hybrid reactor: GNOME, 4th IAEA Technical Meeting on First Generation of Fusion Power Plants -Design and Technology, Vienna, Austria, 2011.6.8-9

K. Ibane, Y. Yamamoto, S. Konishi, High temperature plasma facing components designs for biomass hybrid reactor: GNOME, 24th Symposium on Fusion Engineering (SOFE2011), Chicago, USA, 2011.6.26-30

S. Kwon, D. Lee, S. Noh, S. Konishi, Study of ZnO thin film deposition and dependence to substrate temperature by ALD system, Kyoto University Global COE Program, Energy Science in the Age of Global Warming (Toward a CO2 Zero-emission Energy System), Suwon, Korea, 2011.8.18-19

M. Bunno, P. Hilscher, A. Aprilia, T. Ryosuke, H. Kojima, S.R. Kwon, P. Ruankham, T. Fujii, Z. Ilham, Y.J. Lee, Y. Sato, R. Kodama, K. Yamauchi, Towards New Lifestyle without Nuclear and Fossil-Based En-

ergy, Kyoto University Global COE Program, Energy Science in the Age of Global Warming (Toward a CO2 Zero-emission Energy System), Suwon, Korea, 2011.8.18-19

S.H. Kim, H.K. Yoon, K. Noborio, S. Konishi, Development of composite material with directional property for high thermal conductivity for divertor, The 3rd International Symposium: Kyoto University Global COE Program, Suwon, Korea, 2011.8.18-19

G. Mishra, J.B. Lagrange, L.F. Jiao, S. Park, M. Omer, T. Koyanagi, S. Kim, K. Miyagi, D. Shiba, M. Yamasaki, Y. Yamashita, Q. Zhang, The Potential Analysis of PV Power in GOBI Desert to Meet Electricity Demand in Japan, The 3rd International Symposium: Kyoto University Global COE Program, Suwon, Korea, 2011.8.18-19

T. Kajiwar, R. Abdullah, K. Nishioka, Y. Masaoka, R. Iwaoka, T. Mukawa, S. Aoyagi, N. Um, D.H. Kim, S. Joonwichien, Y.T. Tsai, T. Sonobe, Study on the Acceptable Value of CO2 Reduction as a Global Target Towards Low Carbon Society, The 3rd International Symposium: Kyoto University Global COE Program, Suwon, Korea, 2011.8.18-19

K. Ibano, Y. Yamamoto, S. Konishi, Neutronics and coolants studies for the operational window analysis of the biomass-fusion hybrid reactor, The 3rd International Symposium: Kyoto University Global COE Program “Energy Science in the Age of Global Warming –Toward CO2 Zero-emission–”, Swong, Korea, 2011.8.19

T. Shibata, K. Noborio, Y. Yamamoto, S. Konishi, Assessment of tritium migration path from foods to DNA, 10th International Symposium on Fusion Nuclear Technology, Portland, Oregon, USA, 2011.9.11-16

D.H. Kim, K. Ibano, K. Noborio, Y. Yamamoto, S. Konishi, Design and Analysis of High Temperature Divertor Component for Biomass Hybrid Fusion Reactor: GNOME, The International Symposium on Fusion Nuclear Technology, Portland, Oregon, USA, 2011.9.11-16

C. Park, K. Noborio, Y. Yamamoto, S. Konishi, Compatibility of SiC exposed to liquid Pb–Li flow for development of SiC–LiPb Blanket and Divertor component, International Symposium on Fusion Nuclear Technology (ISFNT-10), Portland, Oregon, USA, 2011.9.11-16

伊庭野健造, 勝間聖二, 登尾一幸, 竹内右人, 小西哲之, バイオマスハイブリッド核融合プラントの設計(1) トカマク設計, 日本原子力学会 2011

年秋の大会, 福岡, 2011.9.19-22

登尾一幸, 柴田敏宏, 山本靖, 小西哲之, IV 炉周辺材料とトリチウムとの相互作用とその処理 (6) トリチウムの公衆影響に至る経路分析に基づくプラント設計の評価, 日本原子力学会 2011 年秋の大会, 北九州国際会議場, 2011.9.19-22

K. Noborio, Y. Yamamoto, S. Konishi, Development of High Temperature LiPb–SiC Blanket, Japan-Korea ITER Tritium/Blanket Joint Workshop, Rokkasho, Aomori, 2011.11.9-10

K. Ibano, Y. Yamamoto, S. Konishi, Study of sputtering and redeposition behavior of wall materials by high energy particle loads tests, PLASMA2011, Kanazawa, Japan, 2011.11.22-25

登尾一幸, 柴田敏宏, 小西哲之, トリチウムの公衆影響に至る経路分析に基づくプラント設計評価, 核融合科学研究所・研究会「ヘリカル動力炉システムのトリチウム安全性」, 核融合科学研究所, 2011.12.7

登尾一幸, 柴田敏宏, 小西哲之, トリチウムの環境への経路分析に基づくプラント設計の評価, 科研特定領域「核融合トリチウム」若手交流研究会, 九州大学, 2011.12.9-10

H. Gwon, K. Ibano, K. Noborio, R. Kasada, K. Nam, S. Konishi, Evaluation of Fracture Behavior and Thermal Efficiency on Divertor for Fusion Reactor, Asian-Core University Program on Advanced Energy Science, Beijing, China, 2012.1.15-18

S.H. Kim, H.K. Yoon, S. Konishi, Development of Divertor Material with Directional Thermal Conductivity, Asian-Core University Program on Advanced Energy Science, Beijing, China, 2012.1.15-18

松井直也, Neutronics Calculation on the beam optics from Cylindrical Discharge type Fusion Device, Asian-Core, Tsinghua University, 2012.1.15-18

D. Matsui, S. Kokaji, K. Noborio, Y. Takeuchi, R. Kasada, S. Konishi, Continuous gasification OF BIOMass with high temperature HEAT, Asian-core, Beijing, China, 2012.1.15-18

中井靖記, Feasibility study of the treatment of cancer using cylindrical discharge type fusion neutron beam source for BNCT, AsianCORE winter seminar, 北京科技大学, 2012.1.16

H.S. Gwon, K. Ibano, K. Noborio, R. Kasada, K.W. Nam, S. Konishi, Evaluation of Fracture Behavior and Thermal Efficiency on Divertor for Fusion Reactor, Asian-Core University Program on Advanced

Energy Science, Beijing, China, 2012.1.16-17

S. Kwon, K. Ibano, T. Maegawa, K. Noborio, R. Kasada, S. Konishi, Neutronics analysis of SiC-LiPb high temperature blanket for tritium self-sufficiency, Asian-Core University Program on Advanced Energy Science, Beijing, China, 2012.1.16-17

S. Katsuma, R. Kasada, S. Konishi, Simulation of Micro-Grid Cost to Respond Local Electrical Demand, Asian CORE Winter School Technical Program, Beijing China, 2012.1.16-18

K. Wada, K. Ibano, K. Noborio, Y. Takeuchi, R. Kasada, S. Konishi, Distribute heat load in Nuclear Fusion Divertor with heat pipe. , A-CORE, Beijing, 2012.1.16-18

中井靖記, Feasibility study of the treatment of cancer using cylindrical discharge type fusion neutron beam source for BNCT, GCOE 年次報告会, 京都大学宇治キャンパスきはだホール, 2012.1.30

中井靖記, Applicability of Electric Vehicle Usage with Less Nuclear Power Plants in Japan ~Is EV OK or not?~, GCOE 年次報告会, 京都大学宇治キャンパスきはだホール, 2012.1.30

M. Erywijaya, L. Jiao, L. Hongrong, H.S Gwon, Y. Yamamoto, M. Tetsuya, N.I. Un, S. Koda, J.Y Lim, A comparison analysis of electricity expansion planning through centralized and decentralized system: a lesson from China and Indonesia, Kyoto University Global COE Program, Energy Science in the Age of Global Warming, Kyoto, Japan, 2012.1.30

T. Fujii, A. Ali, H. Sun, R. Abdullah, R. Kodama, K. Kawamoto, D.H. K, Y.W. C, K. Miyagi, D. Shiba, T. Sonobe, The impact of our daily foods on the Global Warming, Kyoto University Global COE Program, Energy Science in the Age of Global Warming (Toward a CO2 Zero-emission Energy System), Kyoto, Japan, 2012.1.30

Q. Yu, H. Takai, K. Yoshida, T. Kajiwara, H. Seto, P.S. Hong, M.L. Cristina, M. Yamasaki, R.H. Fanohasina, S. Kim, K. Yamauchi, Proposal of New Lifestyle to Implement the Traffic Mitigation Strategy for Solutions of CO2 Reduction in Kyoto City, Kyoto University Global COE Program, Energy Science in the Age of Global Warming (Toward a CO2 Zero-emission Energy System), Kyoto, Japan, 2012.1.30

Y. Nakai, S. Kwon, K. Fukasawa, M.A. Mansor, H. Kojima, I. Seo, K. Nishioka, H.H. Negm, F. Goembira, T. Koyanagi, K. Yamauchi, Applicability of Electric Vehicle Usage with Less Nuclear Power

Plants in Japan, Kyoto University Global COE Program, Energy Science in the Age of Global Warming (Toward a CO2 Zero-emission Energy System), Kyoto, Japan, 2012.1.30

登尾一幸, 核融合プラント内・環境中トリチウム移行経路分析とプラント設計, 第 15 回若手科学者によるプラズマ研究会, 原子力機構那珂研, 2012.3.14-16

登尾一幸, 小西哲之, トリチウムの環境挙動と生体影響の知見に基づく漏洩制御, 科研費特定領域「核融合トリチウム」領域番号 476 研究成果/計画報告会, 名古屋市, 2012.3.16-17

前川隆洋, 登尾一幸, 山本靖, 小西哲之, 放電管核融合装置による中性子ビームの光学とエネルギー Spektrum における複合反射材の影響, 日本原子力学会 2012 年春の年回, 福井大学, 2012.3.19-21

伊庭野健造, 和田浩太郎, 山本靖, 小西哲之, 高熱水素粒子負荷試験によるタングステン材料の損耗評価, 日本原子力学会 2012 年春の年回, 福井大学, 2012.3.19-21

興野文人, 登尾一幸, 山本靖, 小西哲之, リチウム鉛液滴中の落下中振動による溶解水素輸送, 日本原子力学会 2012 春例会, 福井大学, 2012.3.19-21



## Advanced Particle Beam Energy Research Section

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K. Masuda, Associate Professor

**1. Introduction**

Advanced and innovative control methods for the collective behavior of charged particles are being developed in this research section to bring about enormous contributions to the human beings. Studies of nonlinear interactions between charged particles and electromagnetic fields are particularly emphasized. Main research subjects are now focused on the following; improvement and understanding of confinement and transport in fusion plasmas, development of heating and current drive systems using high power millimeter waves, plasma diagnostics using millimeter waves and Langmuir probes, development and application of compact and portable neutron/proton sources driven by fusion plasmas and production/diagnostics of highly brilliant relativistic electron beams for advanced light sources such as free electron lasers.

**2. Measurement of electron density fluctuations using microwave reflectometer in Heliotron J**

It is necessary to understand the mechanism of anomalous transport to improve plasma confinement. It is considered that anomalous transport comes from fluctuations of magnetic field, electric field, plasma density and temperature out of various instability of plasma. Therefore, we have newly installed a microwave reflectometer to Heliotron J and measured electron density fluctuations. The goal of this research is to study the characteristics of plasma confinement by means of investigating MHD instabilities of energetic particles and long-range correlation of fluctuations by combining the reflectometer with other measurement methods.

The injection frequency of microwave ranges from 24.75 to 42 GHz, corresponding to the O-mode cut-off density from  $0.8$  to  $2.2 \times 10^{19} \text{ m}^{-3}$ . It is generated by a voltage controlled oscillator and an x3 frequency multiplier. After the injection waves are up-converted with a signal of 100 MHz generated by a local oscillator, they are injected into the Heliotron J plasma through a pyramidal horn. The receiving pyramidal horn is installed next to the incident horn. The horns are oriented perpendicular to the magnetic field, viewing the magnetic axis. The received microwaves are down-converted to the frequency of 100 MHz with fluctuations, delivering to an I/Q detector. We can estimate the complex phase difference between the received waves and the reference

waves through the I and Q signals. The sampling frequency of a data acquisition system is 1 MHz.

Density fluctuation measurement has started in Heliotron J ECRH and NBI plasmas using this reflectometer system. Figure 1 shows the coherence between a phase signal of the reflectometer and a signal of a magnetic probe in a neutral beam injection experiment at  $B = 1.25 \text{ T}$ , and the target density is  $n_e = 0.8 \times 10^{19} \text{ m}^{-3}$ . The measurement results show that the reflectometer signal has a high correlation with the magnetic probe, which may be a Global Alfvén Eigenmode.

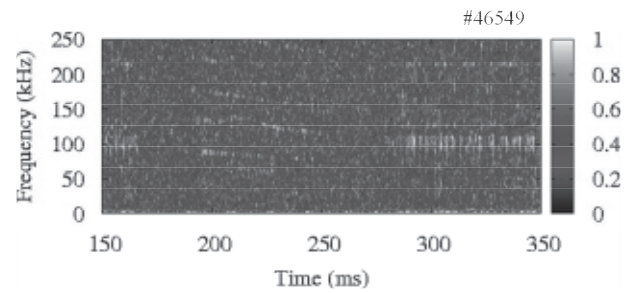


Fig. 1. Coherence between phase signal of reflectometer and signal of magnetic probe

**3. Modeling of Preionization for Plasma Production in Superconducting tokamaks**

In superconducting tokamaks such as ITER and JT-60SA, the toroidal electric field applied for ionization may be too low to start up plasmas reliably. To solve this problem, preionization using Electron Cyclotron Resonance Heating (ECRH) has been proposed. Successful ECRH preionization has been experimentally demonstrated in tokamaks such as normal conducting tokamaks, JT-60U and DIII-D and a superconducting tokamak, KSTAR. Since the electric field may be limited to  $0.5 \text{ Vm}^{-1}$  in the JT-60SA, which is now under construction in JAEA, we need to find out effective plasma production schemes. The ECRH preionization effects are theoretically investigated by a zero-dimensional (0-D) model to examine conditions for reliable startup in JT-60SA and to understand the physical process. For more quantitative analysis, we are developing a one-dimensional (1-D) model, which includes radial transport of energy and particles.

The 1-D model mainly consists of five equations; the electron and ion energy density transport equations, the electron and hydrogen atom density transport equa-

tions and the toroidal current equation. Figure 2 shows an example of temporal behavior of electron temperature profile on a JT-60SA configuration. The absorbed ECRH power,  $P_{\text{ECRH}}$ , is assumed to be 150 kW. The calculation results show that there is a threshold in the ECRH power, and the absorbed power of about 100 kW may be required for reliable startup. The required ECRH power is lower than that estimated by zero-dimensional model. This is because that inclusion of radial dependence makes the power density higher at the central region where the ECRH power is deposited.

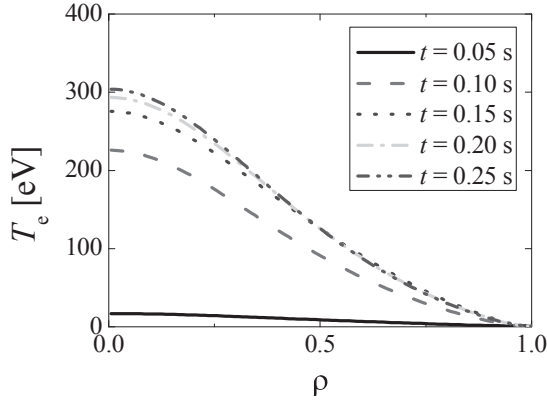


Fig. 2. Temporal behavior of electron temperature profile on a JT-60SA configuration.

#### 4. Fusion rate dependence on applied voltage in a high-voltage glow-discharge-driven IEC device

An inertial electrostatic confinement (IEC) fusion device basically consists of a spherical anode at ground potential and a transparent gridded cathode at a negative high potential. Ions are accelerated toward the center as they gain energy relevant to D-D, D-T and D-3He fusion reactions from the applied electric fields. An important advantage of IEC over accelerator-driven neutron generators employing solid targets comes from the use of “gas target”. This enables high-power operation of IEC devices to produce copious amount of D-D neutrons in a compact system.

Some of near-term and urgent applications, e.g. active interrogation of special nuclear materials (SNM), require enhancement in the neutron production rate (NPR) of an order of magnitude. One of the most promising ways to meet this urgent requirement is to apply a higher bias voltage to the central cathode grid, because the D-D fusion cross-section increases rapidly as the ion energy increases.

In this study, NPR dependence on the applied bias voltage was studied (see Fig. 3) in a newly developed glow-discharge-driven IEC device, which employs multistage high-voltage (HV) feedthrough technique to achieve 200 kV in a compact system. As the result, NPR is found to increase by a factor of  $\sim 3$  as the applied voltage,  $V$ , increases up to 160 kV from the maximum

limit of  $\sim 80$  kV by a conventional single-stage HV feedthrough. At around 160 kV, NPR is found to be dependent on  $V$  to the power of  $1.5 \pm 0.4$ . This means that an additional  $\sim 50\%$  NPR enhancement is expected by an increase of  $V$  up to 200 kV after HV conditioning underway. We also plan to increase the operating deuterium gas pressure, i.e. the target density, by a factor of 2-3, in order to reach the NPR requirement of  $10^8$  n/sec for the active SNM interrogation system.

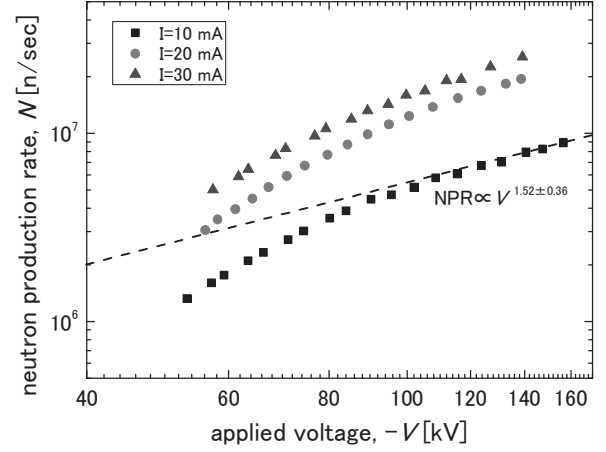


Fig. 3. Neutron production rates as functions of applied voltage for discharge currents of 10, 20 and 30 mA.

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## Collaboration Works

Univ. Wisconsin (米国), Univ. Wisconsin (米国), ORNL (米国), Max Planck Institute (ドイツ), Stuttgart Univ. (ドイツ), Provence Univ. (フランス), CIEMAT (スペイン), ANU (オーストラリア), Kharkov Institute (ウクライナ), SWIP (中華人民共和国), 先進ヘリカルにおける改善閉じ込めの研究, 佐野史道, 水内亨, 長崎百伸, 岡田浩之, 小林進二, 山本聡, D. Anderson (Univ. Wisconsin, USA), J.H. Harris (Oak Ridge National Laboratory, USA), F. Wagner, M. Hirsch, V. Erckmann, H. Laqua, N.B. Marushchenko (Max Plank Institute, Germany), M. Ramisch (Stuttgart Univ., Germany), J. Sanchez, E. Ascasibar, C. Hidalgo, T. Estrada, A. Cappa, A. Alonso (CIEMAT, Spain), B. Blackwell, D. Pretty, H. Punzmann (Australian National Univ., Australia), V. Chechkin, V. Pankratov (Kharkov Institute, Ukraine), X.R. Duan, Q.W. Yang, L.W. Yan, W.W. Xiao (Southwest Institute of Physics, China)

Stuttgart University (ドイツ), CIEMAT (スペイン), ヘリカル磁場配位における乱流揺動研究, 長崎百伸, 大島慎介, 佐野史道, 水内亨, 花谷清, 岡田浩之, 南貴司, 小林進二, 山本聡

IPP, Greifswald (ドイツ), 電子サイクロトロン電流駆動の理論解析, 長崎百伸

西南物理研究所 (中華人民共和国), IPP, Greifswald (ドイツ), 反射計を用いた電子密度分布・揺動解析, 長崎百伸

Director of the Nuclear Physics Department, Head of the Applied Physics Laboratory, Univ. Wisconsin (米国), Univ. Wisconsin (米国), ORNL (米国), Max Planck Institute (ドイツ), Stuttgart Univ. (ドイツ), Provence Univ. (フランス), CIEMAT (スペイン), ANU (オーストラリア), Kharkov Institute (ウクライナ), SWIP (中華人民共和国), 「先進ヘリカルにおける改善閉じ込めの研究」, 佐野史道, 水内亨, 長崎百伸, 岡田浩之, 小林進二, 山本聡, D. Anderson (Univ. Wisconsin, USA), J.H. Harris (Oak Ridge National Laboratory, USA), F. Wagner, M. Hirsch, V. Erckmann, H. Laqua, N.B. Marushchenko (Max Plank Institute, Germany), M. Ramisch (Stuttgart Univ., Germany), J. Sanchez, E. Ascasibar, C. Hidalgo, T. Estrada, A. Cappa, A. Alonso (CIEMAT, Spain), B. Blackwell, D. Pretty, H. Punzmann (Australian National Univ., Australia), V. Chechkin, V. Pankratov (Kharkov Institute, Ukraine), X.R. Duan, Q.W. Yang, L.W. Yan, W.W. Xiao (Southwest Institute of Physics, China), V.G. Khlopov Radium Institute (ロシア), Low-background Spectroscopic Position-Sensitive Neutron Detector for Detection of Nu-

clear Materials in Cargo Containers, 増田開

核融合科学研究所, 先進ヘリカルによるプラズマ構造形成・不安定制御と閉じ込め磁場最適化の研究, 佐野史道, 水内亨, 長崎百伸, 花谷清, 岡田浩之, 南貴司, 小林進二, 山本聡

核融合科学研究所, 高速カメラによる Heliotron J 周辺プラズマの研究, 水内亨, 佐野史道, 岡田浩之, 小林進二, 山本聡, 長崎百伸, 南貴司

核融合科学研究所, Heliotron J 装置における電極バイアスによる径方向電場制御, 佐野史道, 水内亨, 岡田浩之, 長崎百伸, 小林進二, 山本聡

核融合科学研究所, 極低磁場での電子バーンシュタイン波加熱のヘリオトロンJプラズマ閉じ込めへの影響, 長崎百伸, 山本聡, 佐野史道, 水内亨, 岡田浩之, 南貴司, 小林進二

核融合科学研究所, ヘリオトロン J, CHS, LHD 装置における重水素プラズマの粒子輸送の研究, 南貴司, 佐野史道, 水内亨, 長崎百伸, 小林進二, 岡田浩之, 山本聡

核融合科学研究所, ヘリオトロン J での反転磁気シシア配位プラズマ生成とアルヴェン固有モード特性, 山本聡, 長崎百伸, 小林進二, 佐野史道, 水内亨, 岡田浩之, 南貴司

核融合科学研究所, 方向性プローブを用いた揺動による粒子異常輸送の研究, 佐野史道, 水内亨, 長崎百伸, 岡田浩之, 花谷清, 南貴司, 小林進二, 山本聡

核融合科学研究所, ヘリオトロン J プラズマにおける放射損失の空間構造とその動態に関する研究, 長崎百伸, 山本聡, 佐野史道, 水内亨, 岡田浩之

核融合科学研究所, 低磁気シシアヘリオトロン配位における磁気島に対するプラズマ応答の研究, 佐野史道, 岡田浩之, 水内亨, 南貴司, 小林進二, 長崎百伸, 山本聡

核融合科学研究所, ヘリオトロン J における密度分布の動的挙動と能動的制御に関する研究, 長崎百伸, 佐野史道, 水内亨, 岡田浩之, 小林進二

核融合科学研究所, Heliotron-J における閉じ込め改善モードへの遷移に対するポロイダルイオン粘性の役割の検証, 佐野史道, 水内亨, 岡田浩之, 山本聡, 小林進二, 長崎百伸, 南貴司

核融合科学研究所, ヘリオトロン J 装置における ICRF 加熱を用いた高速イオン閉じ込めの磁場最適化研究, 岡田浩之, 佐野史道, 花谷清, 水内亨, 南

貴司, 小林進二, 長崎百伸, 山本聡

核融合科学研究所, トリムコイルを用いたヘリオトロンの磁場配位最適化, 佐野史道, 水内亨, 長崎百伸, 花谷清, 岡田浩之, 南貴司, 小林進二, 山本聡

核融合科学研究所, 低磁気シアプラズマにおける高速イオンと高速イオン励起 MHD 不安定性の相互作用に関する研究, 山本聡, 小林進二, 岡田浩之, 南貴司, 佐野史道, 水内亨, 長崎百伸

核融合科学研究所, ヘリカル系における電子サイクロトロン電流駆動による回転変換制御, 長崎百伸, 佐野史道, 増田開, 水内亨, 花谷清, 岡田浩之, 南貴司, 小林進二, 山本聡

核融合科学研究所, 2.45GHz マイクロ波入射アシストによる NBI プラズマ生成, 長崎百伸, 小林進二, 増田開, 佐野史道, 水内亨, 岡田浩之, 南貴司, 山本聡

日本原子力研究開発機構共同研究, 予備電離を用いたプラズマ生成のモデル化と応用, 長崎百伸,

日本原子力研究開発機構共同研究, 高性能炉心プラズマの強電子加熱特性に関する研究, 長崎百伸

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長崎百伸, 基盤研究(C), 非誘導電流駆動を用いた回転変換制御

増田開, 若手研究(A), 慣性静電閉じ込めプラズマ中の球状集束ビーム衝突核融合反応機構の解明

金城良太, 特別研究員奨励費, 高温超伝導バルク磁石を用いたアンジュレータ

## Publications

K. Mukai, K. Nagasaki, T. Mizuuchi, V. Zhuravlev, S. Ohshima, T. Fukuda, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, Y. Nakamura, K. Hanatani, S. Konoshima, M. Takeuchi, K. Mizuno, H.Y. Lee, F. Sano, Electron Density Profile Behavior during SMBI Measured with AM Reflectometer in Heliotron J Plasma, Plasma and Fusion Research, 6, 1402111-1402111, 2011

Y. Yoshimura, S. Kubo, T. Shimoizuma, H. Igami, H. Takahashi, M. Nishiura, S. Sakakibara, K. Tanaka, K. Narihara, T. Mutoh, H. Yamada, K. Nagasaki, N.B. Marushchenko, Y. Turkin, Dependence of EC-Driven

Current on the EC-Wave Beam Direction in LHD, Plasma and Fusion Research, 6, 2402073-2402073, 2011

H. Okada, K. Nomura, H. Watada, S. Kobayashi, H.Y. Lee, T. Mizuuchi, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, M. Takeuchi, S. Konoshima, T. Mutoh, K. Mukai, K. Yamamoto, M. Suwa, H. Yashiro, H. Yoshino, Y. Nakamura, K. Hanatani, F. Sano, Numerical Analysis of ICRF Minority Heating in Heliotron J, Plasma and Fusion Research, 6, 2402063-2402063, 2011

K. Nagasaki, S. Yamamoto, H. Yoshino, K. Sakamoto, N.B. Marushchenko, Y. Turkin, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Konoshima, M. Takeuchi, Y. Nakamura, S. Ohshima, K. Mukai, H.Y. Lee, K. Mizuno, Y. Yoshimura, G. Motojima, A. Cappa, B.D. Blackwell, F. Sano, Influence of trapped electrons on ECCD in Heliotron J, Nucl. Fusion, 51, 103035-103035, 2011

A. Isayama, Overview of JT-60U results towards the resolution of key physics and engineering issues in ITER and JT-60SA, Nucl. Fusion, 51, 94010-94010, 2011

K. Masuda, Y. Yamagaki, T. Kajiwara, J. Kipritidis, Numerical Study of Ion Recirculation in an Improved Spherical Inertial Electrostatic Confinement Fusion Scheme by Use of a Multistage High-Voltage Feedthrough, Fusion Science and Technology, 60, 2, 625-629, 2011

増田開, 量子放射光源のための高輝度大電流電子銃, 日本学術振興会 真空ナノエレクトロニクス第 158 委員会第 88 回研究会資料, 1, 20, 2011

N. Nishino, T. Mizuuchi, M. Takeuchi, K. Mukai, Y. Takabatake, K. Nagasaki, S. Kobayashi, H. Okada, S. Ohshima, S. Yamamoto, T. Minami, K. Hanatani, S. Konoshima, Y. Nakamura, F. Sano, Peripheral plasma measurement during SMBI in Heliotron J using fast cameras, Journal of Nuclear Materials, 415, Issue 1, Supplement, S447-S450, 2011

T. Mizuuchi, S. Kobayashi, M. Takeuchi, K. Mukai, N. Nishino, Y. Nakashima, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, S. Ohshima, S. Kishi, H. Lee, K. Minami, Y. Takabatake, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Comparison between supersonic molecular-beam injection and conventional gas-puffing for plasma performance in Heliotron J, Journal of Nuclear Materials, 415, Issue 1, Supplement, S443-S446, 2011



H. Toyokawa, T. Hayakawa, T. Shizuma, R. Hajima, K. Masuda, H. Ohgaki, Nondestructive inspection of explosive materials using linearly polarized two-colored photon beam, Nuclear Instruments and Methods in Physics Research, A652, 1, 21-24, 2011

H. Toyokawa, H. Ohgaki, T. Hayakawa, T. Kii, T. Shizuma, R. Hajima, N. Kikuzawa, K. Masuda, F. Kitatani, H. Harada, Two-Dimensional Isotope Imaging of Radiation Shielded Materials Using Nuclear Resonance Fluorescence, Japanese Journal of Applied Physics, 50, 100209-1-100209-3, 2011

前川孝, 井手俊介, 梶原健, 長崎百伸, 諫山明彦, 羽田和慶, 将来の大型超伝導トカマク装置に向けたプラズマ着火・立ち上げ研究の現状, プラズマ核融合学会誌 J. Plasma Fusion Res., 87, 10, 671-681, 2011

長崎百伸, 坂本慶司, 出射浩, 出原敏孝, 山田英明, 第 8 回高パワーマイクロ波とテラヘルツ波に関する国際研究集会 (8th International Workshop Strong Microwaves and Terahertz Waves: Sources and Applications, プラズマ核融合学会誌, 87, 10, 734-735, 2011

梶原泰樹, 増田開, 山垣悠, Lepoultier Sabine, 長崎百伸, 環状イオン源駆動型慣性静電閉じ込め核融合装置における陽子計測を用いた核融合反応空間分布計測, 日本原子力学会 2011 年秋の大会, G17, 2011

金城良太, 紀井俊輝, 木村尚樹, Mahmoud Bakr, Yong Woon Choi, Mohamed Omer, 吉田恭平, 石田啓一, 駒井琢也, 柴田茉莉江, 島橋亨兵, 園部太郎, 増田開, 長崎百伸, 大垣英明, 高温超伝導バルク磁石を用いたスタガードアレイアンジュレータへの強磁性体の導入による磁場増強, 日本原子力学会 2011 年秋の大会, I05, 2011

大垣英明, 紀井俊輝, 増田開, 三澤毅, 卞哲浩, Omer Mohamed, 早川岳人, 堀利匡, 羽島良一, 静間俊行, 菊澤信宏, 神門正城, 大東出, 豊川弘之, 藤本真也, 中性子 $\gamma$ 線複合型核検知システム開発の現状 II ; (1) 全体システムの設計の現状, 日本原子力学会 2011 年秋の大会, O09, 2011

増田開, 大垣英明, 梶原泰樹, 山垣悠, 三澤毅, 卞哲浩, 中性子 $\gamma$ 線複合型核検知システム開発の現状 II ; (2) 放電型 D-D 核融合中性子源の開発, 日本原子力学会 2011 年秋の大会, O10, 2011

三澤毅, 高橋佳之, 八木貴宏, 卞哲浩, 増田開, 大垣英明, 中性子 $\gamma$ 線複合型核検知システム開発の現状 II ; (3) 加速器中性子源と HEU を用いた基礎実験, 日本原子力学会 2011 年秋の大会, O11, 2011

K. Yoshida, T. Sonobe, M. Bakr, T. Sakka, T. Sagawa, E. Nakata, T. Morii, T. Kii, K. Masuda, H. Ohgaki, Material Analysis Laboratory in KU-FEL, Kyoto University, Energy Procedia, 9, 483-490, 2011

R. Kinjo, T. Kii, N. Kimura, M.A. Bakr, Y.W. Choi, M. Omer, K. Yoshida, K. Ishida, H. Imon, T. Komai, M. Shibata, K. Shimahashi, H. Zen, T. Sonobe, K. Masuda, K. Nagasaki, H. Ohgaki, Enhancement of Undulator Field in Bulk HTSC Staggered Array Undulator with Hybrid Configuration, 33rd International Free Electron Laser Conference 2011, WEPB19, 2011

N. Kimura, M.A. Bakr, Y.W. Choi, H. Imon, K. Ishida, T. Kii, R. Kinjo, T. Komai, K. Masuda, H. Ohgaki, M. Omer, M. Shibata, K. Shimahashi, T. Sonobe, K. Yoshida, Improvement of Termination Field of Bulk HTSC Staggered Array Undulator, 33rd International Free Electron Laser Conference 2011, MOPC02, 2011

K. Yoshida, M.A. Bakr, Y.W. Choi, H. Imon, K. Ishida, T. Kii, N. Kimura, R. Kinjo, T. Komai, K. Masuda, H. Ohgaki, M. Omer, M. Shibata, K. Shimahashi, T. Sonobe, Development of the Material Analysis Facility in KU-FEL, 33rd International Free Electron Laser Conference 2011, TUPA02, 2011

K. Ishida, M.A. Bakr, Y.W. Choi, H. Imon, T. Kii, N. Kimura, R. Kinjo, T. Komai, K. Masuda, H. Ohgaki, M. Omer, M. Shibata, K. Shimahashi, T. Sonobe, K. Yoshida, Envaluation of Lasing Range wit a 1.8m Undulator in KU-FEL, 33rd International Free Electron Laser Conference 2011, WEPB17, 2011

M.A. Bakr, Y.W. Choi, H. Imon, K. Ishida, T. Kii, N. Kimura, R. Kinjo, T. Komai, K. Masuda, H. Ohgaki, M. Omer, M. Shibata, K. Shimahashi, T. Sonobe, K. Yoshida, M. Kawai, Assessment of Thermionic Emission Properties and Back Bombardment Effects for LaB6 and CeB6, 33rd International Free Electron Laser Conference 2011, THPA34, 2011

T. Kajiwar, K. Masuda, Y. Kamiya, Y. Yamagaki, G. Hashimoto, K. Nagasaki, Enhancement of Ion Current in a Magnetron Ion Source for an Inertial Electrostatic Confinement Fusion Device, Plasma Conference 2011, 22P159-P, 2011

Y. Yamagaki, K. Masuda, T. Kajiwar, G. Hashimoto, Y. Kamiya, K. Nagasaki, Improvement of Neutron Production Rate at Inertial Electrostatic Confinement Fusion by Use of a Multi-Stage Feedthrough, Plasma Conference 2011, 23P163-P, 2011

K. Masuda, T. Kajiwar, Y. Yamagaki, G. Kamiya, Y.

Kamiya, Overview of IEC Research at Kyoto University, 13th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, WE-03, 2011

T. Kajiwar, Y. Kamiya, K. Masuda, Y. Yamagaki, G. Hashimoto, K. Nagasaki, Study on Upgrades of the Magnetron Ion Source for High Current Operation of the Low Pressure Driven IEC Device, 13th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, TH-04, 2011

Y. Yamagaki, K. Masuda, T. Kajiwar, G. Hashimoto, Y. Kamiya, K. Nagasaki, Experimental Results from an IEC Device Employing a 5-stage High Voltage Feed-through, 13th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, TH-05, 2011

橋本元輝, 増田開, 梶原泰樹, 長崎百伸, 大西正視, 吉田拓真, 放電型 D-D 核融合装置を用いた X 線中性子同時ラジオグラフィの研究, 日本原子力学会 2012 年春の年会 予稿集, P18, 2011

梶原泰樹, 山垣悠, 増田開, 橋本元輝, 神谷葉子, 長崎百伸, 慣性静電閉じ込め核融合装置における高電圧領域の電圧依存性, 日本原子力学会 2012 年春の年会 予稿集, A43, 2011

大垣英明, 紀井俊輝, 増田開, 三澤毅, 卞哲浩, 梶原泰樹, 堀利匡, Omer Mohamed, 藤本真也, 羽島良一, 早川岳人, 静間俊行, 神門正城, 大東出, 豊川弘之, 中性子 $\gamma$ 線複合型核検知システム開発の現状Ⅲ, 日本原子力学会 2012 年春の年会 予稿集, J42, 2011

島橋享兵, 石田啓一, 金城良太, 崔龍雲, Mohamed Omer, 吉田恭平, Negm Hani, 木村尚樹, 駒井琢也, 柴田茉莉江, 園部太郎, 全炳俊, 増田開, 紀井俊輝, 大垣英明, KU-FEL への 1.8m アンジュレータ導入後の特性予測と発振実験の比較, 日本原子力学会 2012 年春の年会 予稿集, P22, 2011

柴田茉莉江, 木村尚樹, 金城良太, 紀井俊輝, 駒井琢也, 島橋享兵, 石田啓一, Negm Hani, 吉田恭平, Mohamed Omer, 崔龍雲, 園部太郎, 全炳俊, 増田開, 大垣英明, 高温超伝導バルク磁石を用いたスタガードアレイアンジュレータのビーム方向磁場補正, 日本原子力学会 2012 年春の年会 予稿集, P23, 2011

M. Omer, R. Kinjo, Y.W. Choi, K. Yoshida, H. Negm, M. Bakr, H. Zen, T. Hori, T. Kii, K. Masuda, H. Ohgaki, R. Hajima, T. Hayakawa, T. Shizuma, H. Toyokawa, Potential of LaBr<sub>3</sub> (Ce) for Measuring Nuclear Resonance Fluorescence Excitations of Nuclear Materials near 2MeV, 日本原子力学会 2012 年春の年会 予稿集, O18, 2011

Y.W. Choi, R. Kinjo, M. Omer, K. Yoshida, N. Hani, K. Ishida, N. Kimura, K. Shimahashi, M. Shibata, T. Komai, T. Sonobe, H. Zen, K. Masuda, T. Kii, H. Ohgaki, BPM signal processing for KU-FEL linac (1), 日本原子力学会 2012 年春の年会 予稿集, P33, 2011

## Presentations

長崎百伸, 鈴木康浩, 榊原悟, MHD 平衡と安定性, 平成 22 年度核融合科学研究所成果報告会、第 1 部 大型ヘリカル装置計画プロジェクト, 核融合科学研究所, 2011.4.11-13

T. Kajiwar, K. Masuda, J. Kipritidis, K. Nagasaki, Measurement of Spatial Distribution of Fusion Reactions in an Inertial Electrostatic Confinement Fusion Device Driven by a Ring-Shaped Magnetron Ion Source, 38th International Conference on Plasma Science, Chicago, IL, USA, 2011.6.26-30

K. Nagasaki, N. B. Marushchenko, S. Yamamoto, K. Sakamoto, Y. Turkin, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Konoshima, M. Takeuchi, Y. Nakamura, S. Ohshima, K. Mukai, H.Y. Lee, K. Mizuno, S. Murakami, Y. Moriya, Y. Yoshimura, G. Motojima, Á. Cappa, F. Sano, Physics study of ECCD in Heliotron J, 8th International Workshop on "Strong Microwaves and Terahertz Waves: Sources and Applications", Nizhny Novgorod, Russia, 2011.7.9-16

増田開, 量子放射光源のための高輝度大電流電子銃, 日本学術振興会 真空ナノエレクトロニクス第 158 委員会 第 88 回研究会, 京都大学宇治キャンパス, 2011.8.22

K. Nagasaki, Development of Advanced Helical Fusion System, 2nd International Symposium of Advanced Energy Science, Zero-emission energy –present and future, Obaku Plaza, Kyoto University, 2011.9.27-28

梶原泰樹, 増田開, 山垣悠, Lepoultier Sabine, 長崎百伸, 環状イオン源駆動型慣性静電閉じ込め核融合装置における陽子計測を用いた核融合反応空間分布計測, 日本原子力学会 2011 年秋の大会, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

金城良太, 紀井俊輝, 木村尚樹, Mahmoud Bakr, Yong Woon Choi, Mohamed Omer, 吉田恭平, 石田啓一, 駒井琢也, 柴田茉莉江, 島橋享兵, 園部太郎, 増田開, 長崎百伸, 大垣英明, 高温超伝導バルク磁石を用いたスタガードアレイアンジュレータへの強磁性体の導入による磁場増強, 日本原子力学会 2011 年秋の大会, 北九州国際会議場・西日本総合

展示場, 2011.9.19-22

大垣英明, 紀井俊輝, 増田開, 三澤毅, 卞哲浩, Omer Mohamed, 早川岳人, 堀利匡, 羽島良一, 静間俊行, 菊澤信宏, 神門正城, 大東出, 豊川弘之, 藤本真也, 中性子/ $\gamma$ 線複合型核検知システム開発の現状 II ; (1) 全体システムの設計の現状, 日本原子力学会 2011 年秋の大会, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

増田開, 大垣英明, 梶原泰樹, 山垣悠, 三澤毅, 卞哲浩, 中性子/ $\gamma$ 線複合型核検知システム開発の現状 II ; (2) 放電型 D-D 核融合中性子源の開発, 日本原子力学会 2011 年秋の大会, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

三澤毅, 高橋佳之, 八木貴宏, 卞哲浩, 増田開, 大垣英明, 中性子/ $\gamma$ 線複合型核検知システム開発の現状 II ; (3) 加速器中性子源と HEU を用いた基礎実験, 日本原子力学会 2011 年秋の大会, 北九州国際会議場・西日本総合展示場, 2011.9.19-22

K. Nagasaki, E. Ascasibar, Recent Plasma Startup Experiments in TJ-II and Heliotron J, 7th Integrated Operation Scenario Topical Group Meeting, Kyoto University, Kyoto, 2011.10.18-21

長崎百伸, 鈴木隆博, E. Joffrin, 運転領域開発 改訂点・今後の課題, 平成 23 年度核融合エネルギーフォーラム・プラズマ物理サブクラスター合同会合, 日本原子力研究開発機構那珂研究所, 2011.11.9-10

香川輔, 小林進二, 門信一郎, 大石鉄太郎, 永榮蓉子, 大島慎介, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 中村祐司, 花谷清, H.Y. Lee, 南貴之, 向井清史, L. Zang, 荒井翔平, 八代浩彰, 和多田泰士, 和田善信, 水野浩志, 木島滋, 佐野史道, ヘリオトロン J におけるビーム放射分光計測システム開発, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

南貴司, 荒井翔平, 釧持尚輝, 八代浩彰, 高橋千尋, 小林進二, 水内亨, 岡田浩之, 長崎百伸, 中村祐司, 花谷清, 山本聡, 木島滋, 大島慎介, 佐野史道, Heliotron J プラズマの分布時間発展計測のための Nd : YAG トムソン散乱計測装置開発の現状 (1), Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

荒井翔平, 南貴司, 水内亨, 釧持尚輝, 高橋千尋, 長崎百伸, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 香川輔, 水野浩志, 南貴之, 和多田泰士, 和田善信, 木島滋, 佐野史道, Heliotron J プラズマの分布時間発展計測のための Nd : YAG トムソン散乱計測装置開発の現状 (2), Plasma Conference 2011, 石川県立

音楽堂, 2011.11.22-25

八代浩彰, 南貴司, 荒井翔平, 釧持尚輝, 水内亨, 高橋千尋, 長崎百伸, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 香川輔, 水野浩志, 南貴之, 和多田泰士, 和田善信, 木島滋, 佐野史道, Heliotron J プラズマの分布時間発展計測のための Nd : YAG トムソン散乱計測装置開発の現状 (3), Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

梶原泰樹, 増田開, 神谷葉子, 山垣悠, 橋本元輝, 長崎百伸, 慣性静電閉じ込め核融合駆動用マグネトロンの放電イオン源の大電流化, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

岡田浩之, 和多田泰士, 和田善信, 小林進二, 李庸, 水内亨, 長崎百伸, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, 臧臨閣, 八代浩彰, 南貴之, 香川輔, 荒井翔平, 水野浩志, 佐野史道, ヘリオトロン J における ICRF 加熱の共鳴位置による加熱特性の変化, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

H.Y. Lee, 小林進二, 南貴之, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 中村祐司, 花谷清, 大島慎介, 原田伴誉, 香川輔, 向井清史, L. Zang, 荒井翔平, 八代浩彰, 和多田泰士, 和田善信, 木島滋, 佐野史道, ヘリオトロン J におけるトロイダル回転速度分布計測ならびに外部運動量入力計算, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

南貴之, 小林進二, H.Y. Lee, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 中村祐司, 花谷清, 大島慎介, 原田伴誉, 香川輔, 向井清史, L. Zang, 荒井翔平, 八代浩彰, 和多田泰士, 和田善信, 木島滋, 佐野史道, ヘリオトロン J における荷電交換再結合分光による不純物イオン温度分布計測, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

水野浩志, 長崎百伸, 向井清史, 福田武司, 大島慎介, 水内亨, 南貴司, 岡田浩之, 増田開, 小林進二, 山本聡, 中村祐司, 花谷清, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 木島滋, 佐野史道, ヘリオトロン J におけるマイクロ波反射計を用いた電子密度揺動計測, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

向井清史, 長崎百伸, 水内亨, V. Zhuravlev, 田中謙治, 南貴司, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 水野浩志, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 木島滋, 佐野史道, ヘリオトロン J にお



ける ECH プラズマでの密度変調実験, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

和田善信, 岡田浩之, 長崎百伸, 山本聡, 水内亨, 南貴司, 小林進二, 中村祐司, 花谷清, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 和多田泰士, 荒井翔平, 香川輔, 水野浩志, 南貴之, 八代浩彰, 木島滋, 佐野史道, ヘリオトロン J における軟 X 線波高分析による高速電子エネルギー分布のピッチ角依存性, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

大島慎介, 橋本紘平, 山本聡, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 小林進二, 花谷清, 木島滋, 竹内正樹, 佐野史道, ヘリオトロン J 装置における静電プローブによる周辺プラズマ揺動計測とその構造の解明, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

和多田泰士, 岡田浩之, 小林進二, H.Y. Lee, 水内亨, 長崎百伸, 花谷清, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, L. Zang, 荒井翔平, 香川輔, 南貴之, 和田善信, 水野浩志, 佐野史道, ヘリオトロン J における ICRF 加熱での高速イオンのピッチ角及び空間位置依存性, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

西野信博, 水内亨, 笠嶋慶純, L. Zang, 竹内正樹, 大島慎介, 向井清史, 李庸, 長崎百伸, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 花谷清, 中村祐司, 佐野史道, ヘリオトロン J での高速カメラと静電プローブによるフィラメント状周辺プラズマ揺動の研究(II), Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

長崎百伸, N. Marushchenko, 山本聡, 水内亨, 南貴司, 岡田浩之, 増田開, 小林進二, 中村祐司, 花谷清, 木島滋, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 水野浩志, 荒井翔平, 香川輔, 南貴之, 和多田泰士, 和田善信, 吉村泰夫, 村上定義, 佐野史道, ヘリオトロン J における ECCD を用いた回転変換制御, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

小林進二, 長崎百伸, 坂本欣三, 山本聡, 水内亨, 岡田浩之, 南貴司, 花谷清, 中村祐司, 木島滋, 大島慎介, 向井清史, LEE Hyunyong, ZANG Linge, 東使潔, 佐野史道, ヘリオトロン J におけるマイクロ波入射アシストによる NBI プラズマ着火, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

山垣悠, 増田開, 梶原泰樹, 橋本元輝, 神谷葉子, 長崎百伸, 多段電圧導入端子を用いた慣性静電閉じ込め核融合装置の中性子発生率の向上に関する研究, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

吉田拓真, 梶原泰樹, 高岡和摩, 鎌倉慶太, 大澤穂高, 増田開, 大西正視, トリチウムを用いた放電型プラズマ中性子源の基礎実験, Plasma Conference 2011, 石川県立音楽堂, 2011.11.22-25

T. Estrada, K. Nagasaki, E. Blanco, G. Perez, V. Tribaldos, Microwave Reflectometry Diagnostics: Present day systems and challenges for future devices, 21st International Toki Conference, Ceratopia, Toki-City, Gifu, Japan, 2011.11.28-12.1

K. Hada, K. Nagasaki, K. Masuda, R. Kinjo, S. Ide, A. Isayama, Plasma startup using ECRH preionization in JT-60SA, Korea-Japan Workshop on "Physics and Technology of Heating and Current Drive", Institute of Advanced Energy, Kyoto University, 2011.12.6-8

K. Masuda, T. Kajiwara, Y. Yamagaki, G. Kamiya, Y. Kamiya, Overview of IEC Research at Kyoto University, 13th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, The Menzies Hotel, Sydney, Australia, 2011.12.7-8

T. Kajiwara, Y. Kamiya, K. Masuda, Y. Yamagaki, G. Hashimoto, K. Nagasaki, Study on Upgrades of the Magnetron Ion Source for High Current Operation of the Low Pressure Driven IEC Device, 13th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, The Menzies Hotel, Sydney, Australia, 2011.12.7-8

Y. Yamagaki, K. Masuda, T. Kajiwara, G. Hashimoto, Y. Kamiya, K. Nagasaki, Experimental Results from an IEC Device Employing a 5-stage High Voltage Feed-through, 13th US-Japan Workshop on Inertial Electrostatic Confinement Fusion, The Menzies Hotel, Sydney, Australia, 2011.12.7-8

K. Nagasaki, Confinement and Transport in Helical Fusion Plasmas, Asian CORE International Symposium on Advanced Energy Systems and Materials, University of Science and Technology Beijing, 2012.1.16-17

K. Nagasaki, S. Kobayashi, S. Yamamoto, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, Y. Nakamura, S. Konoshima, S. Ohshima, K. Mukai, H.Y. Lee, L. Zang, K. Toshi, K. Sakamoto, K. Toi, T. Estrada, F. Sano, Startup of NBI Plasmas Assisted by 2.45 GHz Microwaves in Heliotron J, 18th Int. Stellarator/Heliotron Workshop & 10th Asia Pacific Plasma Theory Conference, Australian National University & Murramarang Beachfront Nature Resort, 2012.1.29-2.3

橋本元輝, 増田開, 梶原泰樹, 長崎百伸, 大西正視, 吉田拓真, 放電型 D-D 核融合装置を用いた X 線中性子同時ラジオグラフィの研究, 日本原子力学会



2012 年春の年会, 福井大学, 2012.3.19-21

梶原泰樹, 山垣悠, 増田開, 橋本元輝, 神谷葉子, 長崎百伸, 慣性静電閉じ込め核融合装置における高電圧領域の電圧依存性, 日本原子力学会 2012 年春の年会, 福井大学, 2012.3.19-21

大垣英明, 紀井俊輝, 増田開, 三澤毅, 卞哲浩, 梶原泰樹, 堀利匡, Omer Mohamed, 藤本真也, 羽島良一, 早川岳人, 静間俊行, 神門正城, 大東出, 豊川弘之, 中性子/ $\gamma$ 線複合型核検知システム開発の現状Ⅲ, 日本原子力学会 2012 年春の年会, 福井大学, 2012.3.19-21

島橋享兵, 石田啓一, 金城良太, 崔龍雲, Mohamed Omer, 吉田恭平, Negm Hani, 木村尚樹, 駒井琢也, 柴田茉莉江, 園部太郎, 全炳俊, 増田開, 紀井俊輝, 大垣英明, KU-FEL への 1.8m アンジュレータ導入後の特性予測と発振実験の比較, 日本原子力学会 2012 年春の年会, 福井大学, 2012.3.19-21

柴田茉莉江, 木村尚樹, 金城良太, 紀井俊輝, 駒井琢也, 島橋享兵, 石田啓一, Negm Hani, 吉田恭平, Mohamed Omer, 崔龍雲, 園部太郎, 全炳俊, 増田開, 大垣英明, 高温超伝導バルク磁石を用いたスタガードアレイアンジュレータのビーム方向磁場補正, 日本原子力学会 2012 年春の年会, 福井大学, 2012.3.19-21

M. Omer, R. Kinjo, Y.W. Choi, K. Yoshida, H. Negm, M. Bakr, H. Zen, T. Hori, T. Kii, K. Masuda, H. Ohgaki, R. Hajima, T. Hayakawa, T. Shizuma, H. Toyokawa, Potential of LaBr<sub>3</sub> (Ce) for Measuring Nuclear Resonance Fluorescence Excitations of Nuclear Materials near 2MeV, 日本原子力学会 2012 年春の年会, 福井大学, 2012.3.19-21

Y.W. Choi, R. Kinjo, M. Omer, K. Yoshida, N. Hani, K. Ishida, N. Kimura, K. Shimahashi, M. Shibata, T. Komai, T. Sonobe, H. Zen, K. Masuda, T. Kii, H. Ohgaki, BPM signal processing for KU-FEL linac (1), 日本原子力学会 2012 年春の年会, 福井大学, 2012.3.19-21

長崎百伸, 小林進二, 山本聡, 水内亨, 岡田浩之, 南貴司, 花谷清, 増田開, 中村祐司, 木島滋, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 水野浩志, 南貴之, 和多田泰士, 和田善信, 東使潔, 坂本欣三, T. Estrada, 東井和夫, 佐野史道, Heliotron J における 2.45GHz マイクロ波アシストによる NBI プラズマ生成, 日本物理学会第 67 回年次大会, 関西学院大学西宮上ヶ原キャンパス, 2012.3.24-27

羽田和慶, 長崎百伸, 増田開, 金城良太, 井手俊介, 諫山明彦, JT-60SA における予備電離を用いたプラズマ着火に関する輸送解析, 日本物理学会第 67 回

年次大会, 関西学院大学西宮上ヶ原キャンパス, 2012.3.24-27

## Advanced Plasma Energy Research Section

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### 1. Introduction

The current subjects of this research section are to study the properties of high temperature plasmas in order to control and improve the plasma energy confinement from the physical viewpoint of nuclear fusion research. The experimental and theoretical investigations for the optimization of the helical-axis heliotron configuration are in progress under the collaboration with other groups of the institute and also groups of other universities/institutes under the auspices of the Collaboration Program of the Lab. Complex Energy Processes, IAE, the Collaborative Research Program of NIFS (National Institute for Fusion Science), etc.

In this report, some remarkable results obtained in the Heliotron J experimental study in FY2010 are reported focusing on (1) the fueling control study and (2) the development of beam emission spectroscopy for density fluctuation measurement.

### 2. Study of Fueling Control for Confinement Experiments

Fueling control by SMBI is a powerful knob to control plasma density and its radial profile. Effectiveness of SMBI fueling has been studied based on the profile data. Figures 1 (a) and (c) show time traces of the line-averaged density  $\bar{n}_e$  and the stored energy  $W_p$  with gas-fueling and heating sequences for NBI sustained plasmas. Figures 1(b) and (d) show radial profiles of ion temperature  $T_i$  from CXRS, electron temperature  $T_e$  and density  $n_e$  from TVTS. Plasmas are initiated by using a short pulse of ECH and then sustained only by two-staged NBI heating ( $H_0$ ,  $E_{\text{beam}}=25\text{-}27\text{keV}$ ,  $P_{\text{inj}}\sim 0.6\text{MW}$  per a beam-line), where the initially NBI (NBI#1) sustains the plasma and then the second NBI (NBI#2) is superimposed. Just before the start of NBI#2,  $n_e$  is increased by using SMBI or GP to study a target plasma scenario for NBI. In the discharge shown in Figs. 1(a) & (b), a single pulse of SMBI from an outboard horizontal port is injected at  $t\sim 216$  ms, which is indicated in a large spike of  $H_{\alpha}^{\text{SMBI}}$  ( $H_{\alpha}$  signal at the SMBI port). In the discharge in Figs. 1 (c) & (d), a short pulse ( $\sim 10\text{ms}$ ) of high intensity GP (HIGP) from four inboard ports is used instead of SMBI, where other discharge conditions are almost the same. The maximum  $W_p$  in the SMBI (Fig. 1(a))

and the HIGP (Fig. 1(c)) cases are  $\sim 4\text{kJ}$  and  $\sim 3.4\text{kJ}$ , respectively, where  $n_e$  ( $\sim 3\times 10^{19}\text{m}^{-3}$ ) is almost the same for both cases. As shown in Figs. 1(b) & (d),  $T_e$  and  $T_i$  in the SMBI case are higher than those in the HIGP case at the  $W_p$ -peak timing ( $\sim 235\text{ms}$  and  $\sim 237\text{ms}$ , respectively). More clear difference is observed in the  $n_e$ -profile. A peaked  $n_e$ -profile is observed after SMBI ( $\sim 235\text{ms}$ ), while it is very flat ( $\sim 237\text{ms}$ ) for the case of HIGP. This is qualitatively consistent with the edge  $n_e$ -profile reconstructed from an AM microwave reflectometer data. The reflectometer data also indicates the dynamics of edge  $n_e$ -profile during the  $W_p$ -increasing phase after SMBI or HIGP. After density increase just after the

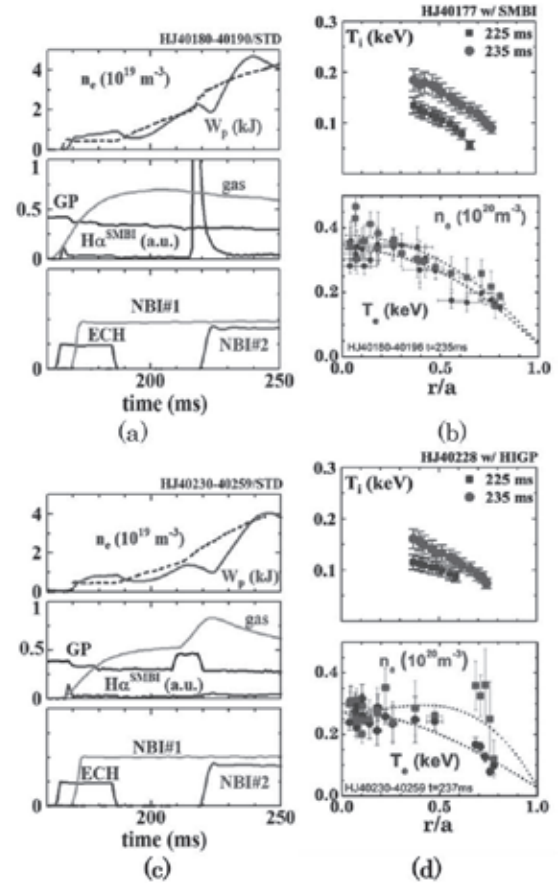


Fig. 1. Examples of time traces of NBI sustained plasma with SMBI (a) and HIGP (c). Radial profiles of ion temperature, electron temperature and density for each case are plotted in the right column, (b) and (d), respectively.

short pulse fueling, temporal reduction of the edge  $n_e$  is observed, suggesting the core density peaking, and then the edge  $n_e$  and its radial gradient increases for both the cases. Such behavior is not observed after the second NBI when SMBI nor HIGP is not used. On the other hand, the amount of gas to obtain the same increment of  $n_e$  is about 30-40% higher in GP (HIGP) compared to SMBI, perhaps due to the beam-like motion of SMBI neutrals with a high flux-density in a small area ( $\sim 10 \text{ cm}^2$ ) at the last closed flux surface. The expected difference in the neutral density outside the plasma after SMBI or HIGP might contribute to make the observed different  $n_e$ -profile at  $\sim 20\text{ms}$  after the fueling.

SMBI can also affect plasma fluctuations: Using a beam emission spectroscopy (BES) system, a reduction in the density fluctuation by energetic-ion-driven MHD activity was observed after SMBI. Recent experiments point out the importance of SMBI fueling for plasma density control to obtain better plasma performance and/or to study particle transport.

### 3. Density Fluctuation and Its Radial Structure Measurements by Beam Emission Spectroscopy

It is an important subject to measure the density fluctuation and its radial structure induced by MHD instabilities or turbulence in high temperature plasmas. In this section, we present the development of the density fluctuation and its radial structure measurement with a BES system in Heliotron J.

To achieve a good spatial resolution using heating NBI as diagnostic beam, the BES sightlines were

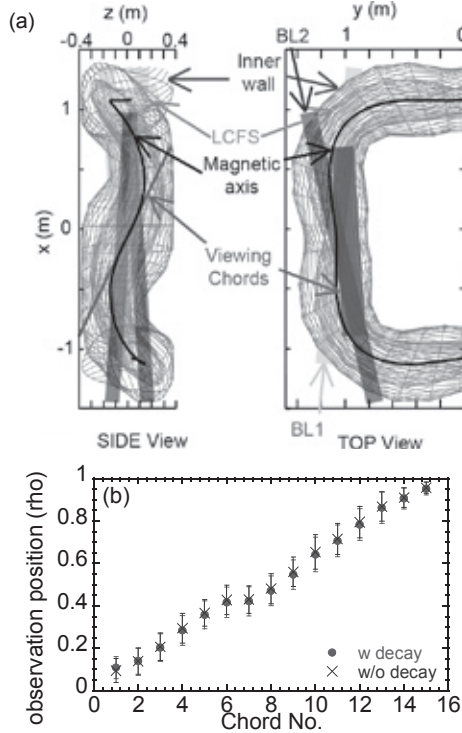


Fig. 2. (a) BES sightlines and (b) measurement position and spatial resolution for each chord.

designed to align the flux surface in the beam-plasma intersection region. The numerical calculation was performed to estimate the optimized sightlines: The collision locations between beam atoms and plasmas were deduced by the beam trajectory analysis including the beam attenuation effect. The excited-state beam atoms can travel about  $\sim \text{cm}$  due to the characteristic decay time  $\tau_j = 1/A_j \cdot 1/(1 + n_p D_j/A_j)$ . Therefore the beam emission positions are estimated with taking the decay length of the excited beam atoms. Based on the optimization study, we have installed the new diagnostic port and the objective optical systems (see Fig. 2(a)). As shown in Fig. 2 (b), the BES system has 16 sightlines which observe the beam emission at the position from  $\rho=0.07$  to  $0.94$  with spatial resolution  $\Delta\rho$  around  $\pm 0.07$ , where  $\rho$  is the normalized minor radius.

Figures 3(a) and 3(b) show the coherence between the BES intensity and the Mirnov signal at  $\rho=0.36$  and  $0.95$ . Some coherent modes caused by energetic-ion-driven MHD activities were observed in the frequency range of 25-100kHz. Figure 3(c) shows  $I_{BE}/\langle I_{BE} \rangle$ , being proportional to the density fluctuation, as a function of the normalized minor radius. The radial structure of the density fluctuations differ from each other: The mode with a frequency of  $\sim 90\text{kHz}$  (case A) spreads widely in the whole plasma region. In the case of the mode with  $\sim 65\text{kHz}$  (case B) the fluctuation is observed in the region  $\rho < 0.6$ . The mode with  $\sim 27\text{kHz}$  (case C), on the contrary, is localized at the peripheral region ( $\rho > 0.7$ ). The developed BES system enables us to measure the radial structure of the density fluctuation in the whole plasma region.

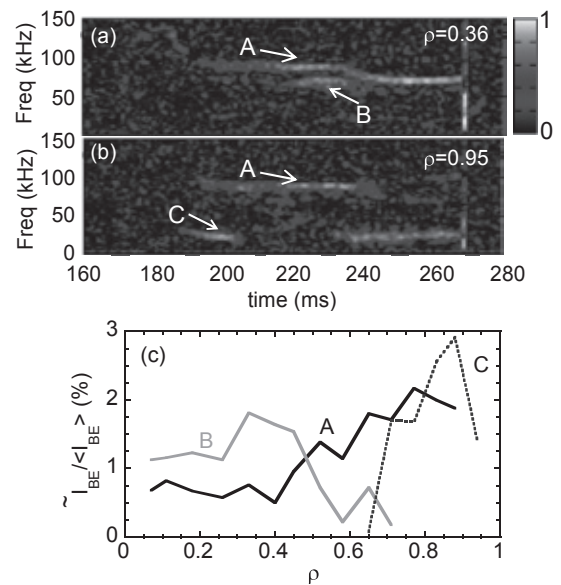


Fig. 3. (a) and (b) Coherence between BES intensities and Mirnov signal and (c) radial profile of the density fluctuation  $I_{BE}/\langle I_{BE} \rangle$ .

## Collaboration Works

Univ. Wisconsin (米国), Univ. Wisconsin (米国), ORNL (米国), Max Planck Institute (ドイツ), Stuttgart Univ.(ドイツ), Provence Univ. (フランス), CIEMAT (スペイン), ANU (オーストラリア), Kharkov Institute (ウクライナ), SWIP (中華人民共和国), 先進ヘリカルにおける改善閉じ込めの研究, 佐野史道, 水内亨, 長崎百伸, 岡田浩之, 小林進二, 山本聡, D. Anderson (Univ. Wisconsin, USA), J.H. Harris (Oak Ridge National Laboratory, USA), F. Wagner, M. Hirsch, V. Erckmann, H. Laqua, N.B. Marushchenko (Max Plank Institute, Germany), M. Ramisch (Stuttgart Univ., Germany), J. Sanchez, E. Ascasibar, C. Hidalgo, T. Estrada, A. Cappa, A. Alonso (CIEMAT, Spain), B. Blackwell, D. Pretty, H. Punzmann (Australian National Univ., Australia), V. Chechkin, V. Pankratov (Kharkov Institute, Ukraine), X.R. Duan, Q.W. Yang, L.W. Yan, W.W. Xiao (Southwest Institute of Physics, China)

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## Publications

T. Mizuuchi, K. Nagasaki, H. Okada, S. Kobayashi, S. Yamamoto, T. Minami, S. Ohshima, M. Takeuchi, K. Mukai, H. Lee, L.G. Zang, K. Nomura, M. Suwa, K. Yamamoto, H. Yashiro, H. Yoshino, S. Arai, T. Kagawa, T. Minami, K. Mizuno, Y. Wada, H. Watada, N. Nishino, Y. Nakashima, K. Hanatani, Y. Nakamura, S. Konoshima, F. Sano, Recent Progress in Plasma Control Studies on the Improvement of Plasma Performance in Heliotron, PLASMA SCIENCE & TECHNOLOGY, 13, 1, 21-25, 2011

S. Kobayashi, K. Nagasaki, S. Yamamoto, K. Sakamoto, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, Y. Nakamura, S. Konoshima, S. Ohshima, M. Takeuchi, K. Mukai, H.Y. Lee, S. Kishi, K. Minami, Y. Takabatake, H. Yoshino, F. Sano, Plasma

startup using neutral beam injection assisted by 2.45 GHz microwaves in Heliotron J, Nuclear Fusion, 51, 6, 62002, 2011

T. Mizuuchi, S. Kobayashi, M. Takeuchi, K. Mukai, N. Nishino, Y. Nakashima, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, S. Ohshima, S. Kishi, H. Lee, K. Minami, Y. Takabatake, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Comparison between supersonic molecular-beam injection and conventional gas-puffing for plasma performance in Heliotron J, Journal of Nuclear Materials, 415, S443-S446, 2011

N. Nishino, T. Mizuuchi, M. Takeuchi, K. Mukai, Y. Takabatake, K. Nagasaki, S. Kobayashi, H. Okada, S. Ohshima, S. Yamamoto, T. Minami, K. Hanatani, S. Konoshima, Y. Nakamura, F. Sano, Peripheral plasma measurement during SMBI in Heliotron J using fast cameras, Journal of Nuclear Materials, 415, Issue 1, S447- S450, 2011

H. Okada, K. Nomura, H. Watada, S. Kobayashi, H. Lee, T. Mizuuchi, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, M. Takeuchi, S. Konoshima, T. Mutoh, K. Mukai, K. Yamamoto, M. Suwa, H. Yashiro, H. Yoshino, Y. Nakamura, K. Hanatani, F. Sano, Numerical Analysis of ICRF Minority Heating in Heliotron J, Plasma and Fusion Research, 6, Special Issue 1, 2402063, 2011

K. Mukai, K. Nagasaki, T. Mizuuchi, V. Zhuravlev, S. Ohshima, T. Fukuda, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, Y. Nakamura, K. Hanatani, S. Konoshima, M. Takeuchi, K. Mizuno, H. Lee, F. Sano, Electron Density Profile Behavior during SMBI Measured with AM Reflectometer in Heliotron J Plasma, Plasma and Fusion Research, 6, Regular Issue, 1402111, 2011

K. Nagasaki, S. Yamamoto, H. Yoshino, K. Sakamoto, N. B. Marushchenko, Y. Turkin, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Konoshima, M. Takeuchi, Y. Nakamura, S. Ohshima, K. Mukai, H.Y. Lee, K. Mizuno, Y. Yoshimura, G. Motojima, Á. Cappa, B.D. Blackwell, F. Sano, Influence of trapped electrons on ECCD in Heliotron J, Nuclear Fusion, 51, 10, 103035 1- 103035 8, 2011

M. Yoshikawa, F. Yaguchi, Y. Miyata, M. Morimoto, Y. Shima, I. Yamada, K. Kawahata, H. Funaba, R. Yasuhara, T. Minami, K. Narihara, Y. Nakashima, M. Ichimura, T. Imai, Measuring Electron Temperature in the Tandem Mirror GAMMA 10 Plasma Using a Yttrium-Aluminium-Garnet Thomson Scattering System, Plasma and Fusion Research, 6, p. 1202095-1-3., 2011

H. Lee, S. Kobayashi, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, Y. Nakamura, K. Hanatani, S. Konoshima, S. Ohshima, K. Mukai, T. Kagawa, F. Sano, Measurement of Ion Temperature and Toroidal Rotation Velocity Using Charge Exchange Recombination Spectroscopy in Heliotron J, Plasma and Fusion Research, 7, Regular Issue, 1402019 1-1402019 6, 2012

S. Ohshima, K. Hashimoto, M. Takeuchi, S. Yamamoto, S. Kobayashi, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, H. Matsuura, F. Sano, Edge Fluctuation Measurement using Multiple Langmuir Probes in Heliotron J, APTWG2011 1st Asia Pacific Transport Working Group (APTWG) International Conference, C-P16, 2011

K. Mukai, K. Nagasaki, T. Mizuuchi, V. Zhuravlev, S. Kobayashi, K. Tanaka, T. Minami, H. Okada, S. Yamamoto, Y. Nakamura, K. Hanatani, S. Konoshima, S. Ohshima, K. Mizuno, H.Y. Lee, L. Zang, S. Arai, T. Kagawa, T. Minami, H. Yashiro, Y. Wada, H. Watada, F. Sano, Density modulation experiment in Heliotron J, APTWG2011 1st Asia Pacific Transport Working Group (APTWG) International Conference, B-P6, 2011

H.Y. Lee, S. Kobayashi, T.Y. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, Y. Nakamura, K. Hanatani, S. Konoshima, S. Ohshima, K. Mukai, T. Kagawa, F. Sano, Measurement of ion temperature and toroidal rotation velocity in Heliotron J, APTWG2011 1st Asia Pacific Transport Working Group (APTWG) International Conference, A-P4, 2011

S. Ohshima, M. Takeuchi, S. Yamamoto, S. Kobayashi, K. nagasaki, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, H. Matsuura, F. Sano, Edge turbulenc Study in Neutral Beam Heated Plasma of Hliotron J, 38th EPS Conference on Plasma Physics, P4-134, 2011

S. Yamamoto, M. Suwa, S. Kobayashi, S. Ohshima, D. Spong, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, Y. Nakamura, S. Konoshima, K. Nagaoka, F. Sano, Studies of MHD instabilities destabilized by energetic ions in Heliotron J plasmas, 12th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems, P2-18, 2011

T. Minami, Present Status of the Nd:YAG Thomson Scattering System Development for Time Evolution Measurement of Plasma profile on Heliotron J, 8th General Scientific Assembly of the Asia Plasma and

Fusion Association(APFA 2011), A3a-8, 2011

L. Zang, M. Takeuchi, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H.Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Observation of Edge Plasma Fluctuations with Fast Camera in Heliotron J, 8th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA 2011), P1p1-4, 2011

R. Ikeda, K. Toi, K. Nagasaki, S. Ohshima, M. Takeuchi, S. Yamamoto, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, F. Sano, H. Igami, Y. Yoshimura, Production of Over-dense Plasmas by 2.45 GHz Electron Bernstein Waves and Measurement of Power Deposition on Heliotron J, 8th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA 2011), P1p1-5, 2011

T. Mizuuchi, S. Kobayashi, K. Mukai, S. Ohshima, S. Yamamoto, T. Minami, K. Nagasaki, H. Okada, K. Mizuno, H.Y. Lee, L. Zang, H. Yashiro, S. Arai, T. Kagawa, T. Minami, Y. Wada, H. Watada, K. Kasajima, N. Nishino, Y. Nakashima, K. Hanatani, Y. Nakamura, S. Konoshima, F. Sano, Effect of Gas Fueling Control on Plasma Performance in Heliotron J, 21th International Toki Conference (ITC-21), P1-46, 2011

S. Ohshima, K. Hashimoto, S. Yamamoto, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, K. Hanatani, S. Konoshima, K. Mukai, H.Y. Lee, M. Takeuchi, F. Sano, Study of Edge Fluctuation Characteristics using Multiple Langmuir Probes in Heliotron J, 21th International Toki Conference (ITC-21), P1-49, 2011

S. Yamamoto, S. Kobayashi, S. Ohshima, M. Suwa, K. Yasuda, K. Nagasaki, Y. Nakamura, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, B. Blackwell, D. Pretty, F. Sano, Studies of MHD stability in Heliotron J Plasmas, 21th International Toki Conference (ITC-21), O-2, 2011

K. Hosoi, Y. Nakashima, S. Kobayshi, N. Nishino, T. Mizuuchi, T. Ishii, K. Ichimura, H. Takeda, T. Imai, Modeling of SMBI experiments based on Monte-Carlo simulation in GAMMA 10, 21th International Toki Conference (ITC-21), P2-82, 2011

F. Sano, T. Mizuuchi, K. Nagasaki, H. Okada, K. Hanatani, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshim, S. Ohshima, Y. Nakamura, K. Mukai, H.Y. Lee, L. Zang, S. Arai, T. Kagawa, T. Minami, K. Mizuno, Y. Wada, H. Watada, H. Yashiro, N. Kenmochi, Y. Nagae, M. Sha, S. Murakami, K. Kasajima, N. Nishino, Y. Nakashima, T. Mutoh, M.

Yokoyama, K. Toi, K. Tanaka, Recent progress in Heliotron J experiment, 18th International Stellarator/Heliotron Workshop, S1.4Ex, 2012

H Okada, H. Watada, Y. Wada, S. Kobayashi, H.Y. Lee, T. Mizuuchi, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, T. Mutoh, S. Konoshima, K. Mukai, L. Zhan, H. Yashiro, T. Minami, T. Kagawa, S. Arai, K. Mizuno, F. Sano, Characteristics of ICRF Minority Heating for the Bumpiness and the Resonance Position in the Magnetic Field of Heliotron J, 18th International Stellarator/Heliotron Workshop, P3.14, 2012

S. Kobayashi, S. Yamamoto, S. Kado, T. Kagawa, Y. Nagae, S. Ohshima, T. Oishi, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H.Y. Lee, T. Minami, Y. Nakamura, S. Konoshima, K. Toshi, F. Sano, Density Fluctuation and Its Radial Structure Measurements by Beam Emission Spectroscopy in Heliotron J, 18th International Stellarator/Heliotron Workshop, P1.2, 2012

T. Mizuuchi, S. Kobayashi, K. Mukai, S. Ohshima, S. Yamamoto, T. Minami, K. Nagasaki, H. Okada, H.Y. Lee, L. Zang, S. Arai, T. Kagawa, T.Y. Minami, K. Mizuno, H. Watada, Y. Wada, H. Yashiro, K. Hashimoto, N. Kenmochi, Y. Nagae, Y. Nakamura, M. Sha, K. Kasajima, N. Nishino, Y. Nakashima, K. Hanatani, Y. Nakamura, S. Konoshima, F. Sano, Gas Fuelling Effect on Plasma Performance in Heliotron J, 18th International Stellarator/Heliotron Workshop, P3.5, 2012

H. Lee, S. Kobayashi, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, M. Yokoyama, S. Ohshima, K. Mukai, T. Harada, L. Zang, S. Arai, T. Kagawa, K. Mizuno, Y. Wada, H. Watada, H. Yashiro, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Charge exchange recombination spectroscopy for ion transport in Heliotron J, 18th International Stellarator/Heliotron Workshop, P3.7, 2012

L. Zang, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of filament features of edge plasma fluctuations in Heliotron J, 18th International Stellarator/Heliotron Workshop, S9.3Div, 2012

K. Nagasaki, S. Kobayashi, S. Yamamoto, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, Y. Nakamura, S. Konoshima, S. Ohshima, K. Mukai, H.Y. Lee, L. Zang, K. Toshi, K. Sakamoto, K. Toi, F. Sano, Startup of NBI Plasmas Assisted by 2.45 GHz Microwaves in Heliotron J, 18th International

Stellarator/Heliotron Workshop, S15.4F1, 2012

N. Nishino, L. Zang, M. Takeuchi, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H.Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of filament features in edge plasma turbulence using a combination of fast video cameras and a hybrid probe system in Heliotron J, 18th International Stellarator/Heliotron Workshop, P3.11, 2012

S. Ohshima, K. Hashimoto, S. Yamamoto, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, K. Hanatani, S. Konoshima, K. Mukai, H.Y. Lee, M. Takeuchi, F. Sano, Edge Fluctuation Study using Multiple Langmuir Probes in Heliotron J, 18th International Stellarator/Heliotron Workshop, P3.13, 2012

山本聡, 小林進二, 大島慎介, 諏訪勝重, 安田圭佑, E. Ascasíbar, R. Jiménez-Gómez, 永岡賢一, D. Spong, B. Blackwell, D. Pretty, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 中村祐司, 花谷清, 木島滋, 向井清史, 李炫庸, 佐野史道, 低磁気シアヘリカルプラズマにおける高速イオン励起 MHD 不安定性研究, Plasma conference 2011 (PLASMA 2011) プラズマ・核融合学会第 28 回年会/応用物理学会第 29 回プラズマプロセッシング研究会/日本物理学会(領域 2)2011 年秋季大会, 23D13, 2011

T. Kagawa, S. Kobayashi, S. Kado, T. Oishi, Y. Nagae, S. Ohshima, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, H. Lee, T. Minami, K. Mukai, L. Zang, S. Arai, H. Watada, Y. Wada, K. Mizuno, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Development of beam emission spectroscopy system in Heliotron, PLASMA 2011, 22P098-P, 2011

T. Minami, S. Arai, N. Kenmochi, H. Yashiro, C. Takahashi, S. Kobayashi, T. Mizuuchi, S. Ohshima, S. Yamamoto, H. Okada, K. Nagasaki, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状(1), PLASMA 2011, 22P109-P, 2011

荒井翔平, 南貴司, 剣持尚輝, 八代浩彰, 高橋千尋, 小林進二, 水内亨, 大島慎介, 山本聡, 岡田浩之, 長崎百伸, 向井清史, 李炫庸, 臧臨閣, 香川輔, 水野浩二, 南貴之, 和多田泰士, 和田善信, 中村祐司, 花谷清, 木島滋, 佐野史道, Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状(2), PLASMA 2011, 22P110-P, 2011

八代浩彰, 南貴司, 荒井翔平, 鋤持尚輝, 水内亨, 高橋千尋, 長崎百伸, 佐野史道, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 香川輔, 水野浩志, 南貴之, 和多田泰士, 和田善信, 木島滋, 笠嶋慶純, 原田伴蒼, 久田祥史, Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状 (3), PLASMA 2011, 22P114-P, 2011

岡田浩之, 和多田泰士, 和田善信, 小林進二, 李炫庸, 水内亨, 長崎百伸, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, 臧臨閣, 八代浩彰, 南貴之, 香川輔, 荒井翔平, 水野浩志, 佐野史道, ヘリオトロン J における ICRF 加熱の共鳴位置による加熱特性の変化, PLASMA 2011, 23P026-P, 2011

李炫庸, 小林進二, 南貴之, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 大島慎介, 原田伴蒼, 香川輔, 向井清史, Zang Linge, 木島滋, 佐野史道, ヘリオトロン J におけるトロイダル回転速度分布計測ならびに外部運動量入力計算, PLASMA 2011, 23P027-P, 2011

南貴之, 小林進二, H.Y. Lee, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 大島慎介, 原田伴蒼, 香川輔, 向井清史, L. Zang, 荒井翔平, 八代浩彰, 和多田泰士, 和田善信, 村上定義, 中村祐司, 花谷清, 木島滋, 佐野史道, ヘリオトロン J における荷電交換再結合分光による不純物イオン温度分布計測, PLASMA 2011, 23P028-P, 2011

水野浩志, 長崎百伸, 向井清史, 中村雄一, 福田武司, T. Estrada, 大島慎介, 水内亨, 南貴司, 岡田浩之, 増田開, 小林進二, 山本聡, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 中村祐司, 花谷清, 木島滋, 佐野史道, ヘリオトロン J におけるマイクロ波反射計を用いた電子密度揺動計測, PLASMA 2011, 23P029-P, 2011

向井清史, 長崎百伸, 水内亨, V. Zhuravlev, 田中謙治, 南貴司, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 水野浩志, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 木島滋, 佐野史道, ヘリオトロン J における ECH プラズマでの密度変動実験, PLASMA 2011, 23P030-P, 2011

和田善信, 岡田浩之, 長崎百伸, 山本聡, 水内亨, 南貴司, 小林進二, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 和多田泰士, 荒井翔平, 香川輔, 水野浩志, 南貴之, 八代浩彰, 中村祐司, 花谷清, 木島滋, 佐野史道, ヘリオトロン J における軟 X 線波高分析による高速電子エネルギー

一分布のピッチ角依存性, PLASMA 2011, 23P032-P, 2011

大島慎介, 橋本紘平, 山本聡, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 小林進二, 花谷清, 木島滋, 竹内正樹, 佐野史道, ヘリオトロン J 装置における静電プローブによる周辺プラズマ揺動計測とその構造の解明, PLASMA 2011, 23P033-P, 2011

和多田泰士, 岡田浩之, 小林進二, H.Y. Lee, 水内亨, 長崎百伸, 花谷清, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, L. Zang, 荒井翔平, 香川輔, 南貴之, 和田善信, 水野浩志, 佐野史道, ヘリオトロン J における ICRF 加熱での高速イオンのピッチ角及び空間位置依存性, PLASMA 2011, 23P035-P, 2011

西野信博, 臧臨閣, 竹内正樹, 水内亨, 大島慎介, 笠嶋慶純, 沙夢雨, 向井清史, 李炫庸, 長崎百伸, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 花谷清, 中村祐司, 佐野史道, ヘリオトロン J での高速カメラと静電プローブによるフィラメント状周辺プラズマ揺動の研究(II), PLASMA 2011, 23P036-P, 2011

長崎百伸, N. Marushchenko, 山本聡, 坂本欣三, Y. Turkin, 水内亨, 岡田浩之, 南貴司, 花谷清, 増田開, 小林進二, 木島滋, 大島慎介, 中村祐司, 向井清史, 李炫庸, 水野浩志, L. Zang, 荒井翔平, 香川輔, 南貴之, 水野浩志, 和田善信, 和多田泰士, T. Estrada, 村上定義, 吉村泰夫, 本島巖, 佐野史道, ヘリオトロン J における ECCD を用いた回転変換制御, PLASMA 2011, 23P037-P, 2011

L. Zang, M. Takeuchi, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H.Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of Filament Features of Edge Plasma Fluctuations using fast video cameras with a combination of Langmuir probe measurements in Heliotron J (I), PLASMA 2011, 23P038-P, 2011

小林進二, 長崎百伸, 坂本欣三, 山本聡, 水内亨, 岡田浩之, 南貴司, 花谷清, 中村祐司, 木島滋, 大島慎介, 向井清史, Lee Hyunyong, Zang Linge, 東使潔, 佐野史道, ヘリオトロン J における非共鳴マイクロ波入射アシストによる NBI プラズマ着火, PLASMA 2011, 23P094-P, 2011  
細井克洋, 中嶋洋輔, 小林進二, 西野信博, 水内亨, 石井貴, 市村和也, 武田寿人, 上田英明, 木暮諭, 高橋樹仁, 保高暁, 今井剛, GAMMA 10SMBI 実験における中性粒子輸送解析, PLASMA 2011, 23P059-P, 2011

北出崇二, 吉川正志, 中嶋洋輔, 水内亨, 小林



進二, 細井克洋, 今井剛, 多波長同時計測分光器を用いた GAMMA10 セントラル部の放射スペクトル測定, PLASMA 2011, 22P101-P, 2011

## Presentations

S. Ohshima, K. Hashimoto, M. Takeuchi, S. Yamamoto, S. Kobayashi, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, H. Matsuura, F. Sano, Edge Fluctuation Measurement using Multiple Langmuir Probes in Heliotron J, APTWG20111, 1st Asia Pacific Transport Working Group (APTWG) International Conference, Gifu, 2011.6.14-17

K. Mukai, K. Nagasaki, T. Mizuuchi, V. Zhuravlev, S. Kobayashi, K. Tanaka, T. Minami, H. Okada, S. Yamamoto, Y. Nakamura, K. Hanatani, S. Konoshima, S. Ohshima, K. Mizuno, H.Y. Lee, L. Zang, S. Arai, T. Kagawa, T. Minami, H. Yashiro, Y. Wada, H. Watada, F. Sano, Density modulation experiment in Heliotron J, APTWG20111, 1st Asia Pacific Transport Working Group (APTWG) International Conference, Gifu, 2011.6.14-17

H.Y. Lee, S. Kobayashi, T.Y. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, Y. Nakamura, K. Hanatani, S. Konoshima, S. Ohshima, K. Mukai, T. Kagawa, F. Sano, Measurement of ion temperature and toroidal rotation velocity in Heliotron J, APTWG20111, 1st Asia Pacific Transport Working Group (APTWG) International Conference, Gifu, 2011.6.14-17

S. Ohshima, M. Takeuchi, S. Yamamoto, S. Kobayashi, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, H. Matsuura, F. Sano, Edge turbulence Study in Neutral Beam Heated Plasma of Heliotron J, 38th EPS Conference on Plasma Physics, Strasborug, 2011.6.27-7.1

小林進二, ヘリオトロロン J および GAMMA10 における粒子補給の最適化実験, 筑波大学プラズマ研究センター シンポジウム, 筑波大学, 2011.7.20-22

S. Yamamoto, M. Suwa, S. Kobayashi, S. Ohshima, D. Spong, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, Y. Nakamura, S. Konoshima, K. Nagaoka, F. Sano, Studies of MHD instabilities destabilized by energetic ions in Heliotron J plasmas, 12th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems, Austin Texas, USA, 2011.9.7-11

T. Ito, M. Osakabe, K. Ida, M. Yoshinuma, M. Kobayashi, M. Goto, R. Seki, S. Murakami, M. Isobe,

S. Kobayashi), K. Toi, the LHD experiment group, Fast ion charge exchange spectroscopy for high energy ions produced by N-NB, 12th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems, Austin Texas, USA, 2011.9.7-11

T. Minami, Present Status of the Nd:YAG Thomson Scattering System Development for Time Evolution Measurement of Plasma profile on Heliotron J, 8th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA 2011), Guilin, China, 2011.11.1-4

L. Zang, M. Takeuchi, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H.Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Observation of Edge Plasma Fluctuations with Fast Camera in Heliotron J, 8th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA 2011), Guilin, China, 2011.11.1-4

R. Ikeda, K. Toi, K. Nagasaki, S. Ohshima, M. Takeuchi, S. Yamamoto, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, F. Sano, H. Igami, Y. Yoshimura, Production of Over-dense Plasmas by 2.45 GHz Electron Bernstein Waves and Measurement of Power Deposition on Heliotron J, 8th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA 2011), Guilin, China, 2011.11.1-4

山本聡, 小林進二, 大島慎介, 諏訪勝重, 安田圭佑, E. Ascasíbar, R. Jiménez-Gómez, 永岡賢一, D. Spong, B. Blackwell, D. Pretty, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 中村祐司, 花谷清, 木島滋, 向井清史, 李炫庸, 佐野史道, 低磁気シアヘリカルプラズマにおける高速イオン励起 MHD 不安定性研究, プラズマ・核融合学会第 28 回年会/応用物理学会第 29 回プラズマプロセス研究/日本物理学会(領域 2)2011 年秋季大会, 石川県立音楽堂, 2011.11.22-25

T. Kagawa, S. Kobayashi, S. Kado, T. Oishi, Y. Nagae, S. Ohshima, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, H. Lee, T. Minami, K. Mukai, L. Zang, S. Arai, H. Watada, Y. Wada, K. Mizuno, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Development of beam emission spectroscopy system in Heliotron (J ヘリオトロロン J におけるビーム放射分光計測システム開発), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

T. Minami, S. Arai, N. Kenmochi, H. Yashiro, C. Takahashi, S. Kobayashi, T. Mizuuchi, S. Ohshima, S.

Yamamoto, H. Okada, K. Nagasaki, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Present status of the Nd:YAG Thomson scattering system development for time evolution measurement of plasma profile on Heliotron J (1), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

S. Arai, T. Minami, N. Kenmochi, H. Yashiro, C. Takahashi, S. Kobayashi, T. Mizuuchi, S. Ohshima, S. Yamamoto, H. Okada, K. Nagasaki, K. Mukai, H. Lee, L. Zang, T. Kagawa, K. Mizuno, T. Minami, H. Watada, Y. Wada, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状(2), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

H. Yashiro, T. Minami, S. Arai, N. Kenmochi, T. Mizuuchi, C. Takahashi, K. Nagasaki, F. Sano, H. Okada, S. Kobayashi, S. Yamamoto, Y. Nakamura, K. Hanatani, S. Ohshima, K. Mukai, H.Y. Lee, L. ZANG, T. Kagawa, K. Mizuno, T. Minami, H. Watada, Y. Wada, S. Konoshima, K. Kasajima, T. Harda, A. Hisada, Present status of the Nd:YAG Thomson scattering system development for time evolution measurement of plasma profile on Heliotron J (3), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

岡田浩之, 和多田泰士, 和田善信, 小林進二, 李炫庸, 水内亨, 長崎百伸, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, 臧臨閣, 八代浩彰, 南貴之, 香川輔, 荒井翔平, 水野浩志, 佐野史道, ヘリオトロン J における ICRF 加熱の共鳴位置による加熱特性の変化, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

李炫庸, 小林進二, 南貴之, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 大島慎介, 原田伴誉, 香川輔, 向井清史, Zang Linge, 木島滋, 佐野史道, ヘリオトロン J におけるトロイダル回転速度分布計測ならびに外部運動量入力計算, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

南貴之, 小林進二, H.Y. Lee, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 大島慎介, 原田伴誉, 香川輔, 向井清史, L. Zang, 荒井翔平, 八代浩彰, 和多田泰士, 和田善信, 村上定義, 中村祐司, 花谷清, 木島滋, 佐野史道, ヘリオトロン J における荷電交換再結合分光による不純物イオン温度分布計測, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

水野浩志, 長崎百伸, 向井清史, 中村雄一, 福田武司, T. Estrada, 大島慎介, 水内亨, 南貴司, 岡田浩之, 増田開, 小林進二, 山本聡, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 中村祐司, 花谷清, 木

島滋, 佐野史道, ヘリオトロン J におけるマイクロ波反射計を用いた電子密度揺動計測, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

向井清史, 長崎百伸, 水内亨, V. Zhuravlev, 田中謙治, 南貴司, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 水野浩志, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 木島滋, 佐野史道, ヘリオトロン J における ECH プラズマでの密度変動実験, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

和田善信, 岡田浩之, 長崎百伸, 山本聡, 水内亨, 南貴司, 小林進二, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 和多田泰士, 荒井翔平, 香川輔, 水野浩志, 南貴之, 八代浩彰, 中村祐司, 花谷清, 木島滋, 佐野史道, ヘリオトロン J における軟 X 線波高分析による高速電子エネルギー分布のピッチ角依存性, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

大島慎介, 橋本紘平, 山本聡, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 小林進二, 花谷清, 木島滋, 竹内正樹, 佐野史道, ヘリオトロン J 装置における静電プローブによる周辺プラズマ揺動計測とその構造の解明, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

和多田泰士, 岡田浩之, 小林進二, H.Y. Lee, 水内亨, 長崎百伸, 花谷清, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, L. Zang, 荒井翔平, 香川輔, 南貴之, 和田善信, 水野浩志, 佐野史道, ヘリオトロン J における ICRF 加熱での高速イオンのピッチ角及び空間位置依存性, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

N. Nishino, L. Zang, M. Takeuchi, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H. Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of filament features of edge plasma fluctuations using fast video cameras with a combination of Langmuir probe measurements in Heliotron J (II), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

長崎百伸, N. Marushchenko, 山本聡, 坂本欣三, Y. Turkin, 水内亨, 岡田浩之, 南貴司, 花谷清, 増田開, 小林進二, 木島滋, 大島慎介, 中村祐司, 向井清史, 李炫庸, 水野浩志, L. Zang, 荒井翔平, 香川輔, 南貴之, 水野浩志, 和田善信, 和多田泰士, T. Estrada, 村上定義, 吉村泰夫, 本島巖, 佐野史道, ヘリオトロン J における ECCD を用いた回転変換制御, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

L. Zang, M. Takeuchi, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H.Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of Filament Features of Edge Plasma Fluctuations using fast video cameras with a combination of Langmuir probe measurements in Heliotron J (I), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

小林進二, 長崎百伸, 坂本欣三, 山本聡, 水内亨, 岡田浩之, 南貴司, 花谷清, 中村祐司, 木島滋, 大島慎介, 向井清史, Lee Hyunyong, Zang Linge, 東使潔, 佐野史道, ヘリオトロン J における非共鳴マイクロ波入射アシストによる NBI プラズマ着火, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

細井克洋, 中嶋洋, 小林進二, 西野信博, 水内亨, 石井貴, 市村和也, 武田寿人, 上田英明, 木暮諭, 高橋樹仁, 保高暁, 今井剛, GAMMA 10SMBI 実験における中性粒子輸送解析, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

北出崇二, 吉川正志, 中嶋洋輔, 水内亨, 小林進二, 細井克洋, 今井剛, 多波長同時計測分光器を用いた GAMMA10 センtral部の放射スペクトル測定, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

T. Mizuuchi, S. Kobayashi, K. Mukai, S. Ohshima, S. Yamamoto, T. Minami, K. Nagasaki, H. Okada, K. Mizuno, H.Y. Lee, L. Zang, H. Yashiro, S. Arai, T. Kagawa, T. Minami, Y. Wada, H. Watada, K. Kasajima, N. Nishino, Y. Nakashima, K. Hanatani, Y. Nakamura, S. Konoshima, F. Sano, Effect of Gas Fueling Control on Plasma Performance in Heliotron J, 21th International Toki Conference (ITC-21), Gifu, Japan, 2011.11.28-12.1

S. Ohshima, K. Hashimoto, S. Yamamoto, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, K. Hanatani, S. Konoshima, K. Mukai, H.Y. Lee, M. Takeuchi, F. Sano, Study of Edge Fluctuation Characteristics using Multiple Langmuir Probes in Heliotron J, 21th International Toki Conference (ITC-21), Gifu, Japan, 2011.11.28-12.1

S. Yamamoto, S. Kobayashi, S. Ohshima, M. Suwa, K. Yasuda, K. Nagasaki, Y. Nakamura, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, B. Blackwell, D. Pretty, F. Sano, Studies of MHD stability in Heliotron J Plasmas, 21th International Toki Conference (ITC-21), Gifu, Japan, 2011.11.28-12.1

南貴司, 分布時間発展計測のための Heliotron J Nd:YAG トムソン散乱計測装置開発, NIFS 共同

研究 合同研究会, 核融合科学研究所, 2012.1.5-6

李炫庸, ヘリオトロン J における荷電交換再結合分光を用いたイオン温度及び回転速度分布計測, NIFS 共同研究 合同研究会, 核融合科学研究所, 2012.1.5-6

臧臨閣, Fast imaging study of filament structures of edge plasma fluctuations in Heliotron J, NIFS 共同研究 合同研究会, 核融合科学研究所, 2012.1.5-6

小林進二, ヘリオトロン J におけるビーム放射分光法を用いた密度揺動計測, NIFS 共同研究 合同研究会, 核融合科学研究所, 2012.1.5-6

F. Sano, T. Mizuuchi, K. Nagasaki, H. Okada, K. Hanatani, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, S. Ohshima, Y. Nakamura, K. Mukai, H.Y. Lee, L. Zang, S. Arai, T. Kagawa, T. Minami, K. Mizuno, Y. Wada, H. Watada, H. Yashiro, N. Kenmochi, Y. Nagae, M. Sha, S. Murakami, K. Kasajima, N. Nishino, Y. Nakashima, T. Mutoh, M. Yokoyama, K. Toi, K. Tanaka, Recent progress in Heliotron J experiment, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

H Okada, H. Watada, Y. Wada, S. Kobayashi, H.Y. Lee, T. Mizuuchi, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, T. Mutoh, S. Konoshima, K. Mukai, L. Zhan, H. Yashiro, T. Minami, T. Kagawa, S. Arai, K. Mizuno, F. Sano, Characteristics of ICRF Minority Heating for the Bumpiness and the Resonance Position in the Magnetic Field of Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

S. Kobayashi, S. Yamamoto, S. Kado, T. Kagawa, Y. Nagae, S. Ohshima, T. Oishi, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H.Y. Lee, T. Minami, Y. Nakamura, S. Konoshima, K. Toshi, F. Sano, Density Fluctuation and Its Radial Structure Measurements by Beam Emission Spectroscopy in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

T. Mizuuchi, S. Kobayashi, K. Mukai, S. Ohshima, S. Yamamoto, T. Minami, K. Nagasaki, H. Okada, H.Y. Lee, L. Zang, S. Arai, T. Kagawa, T.Y. Minami, K. Mizuno, H. Watada, Y. Wada, H. Yashiro, K. Hashimoto, N. Kenmochi, Y. Nagae, Y. Nakamura, M. Sha, K. Kasajima, N. Nishino, Y. Nakashima, K. Hanatani, Y. Nakamura, S. Konoshima, F. Sano, Gas Fuelling Effect on Plasma Performance in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

H. Lee, S. Kobayashi, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, M. Yokoyama, S. Ohshima, K. Mukai, T. Harada, L. Zang, S. Arai, T. Kagawa, K. Mizuno, Y. Wada, H. Watada, H. Yashiro, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Charge exchange recombination spectroscopy for ion transport in Heliotron J , 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

L. Zang, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of filament features of edge plasma fluctuations in Heliotron J , 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

K. Nagasaki, S. Kobayashi, S. Yamamoto, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, Y. Nakamura, S. Konoshima, S. Ohshima, K. Mukai, H.Y. Lee, L. Zang, K. Toshi, K. Sakamoto, K. Toi, F. Sano, Startup of NBI Plasmas Assisted by 2.45 GHz Microwaves in Heliotron J , 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

N. Nishino, L. Zang, M. Takeuchi, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H.Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of filament features in edge plasma turbulence using a combination of fast video cameras and a hybrid probe system in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

S. Ohshima, K. Hashimoto, S. Yamamoto, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, K. Hanatani, S. Konoshima, K. Mukai, H.Y. Lee, M. Takeuchi, F. Sano, Edge Fluctuation Study using Multiple Langmuir Probes in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

T. Ito, M. Osakabe, K. Ida, M. Yoshinuma, M. Kobayashi, M. Goto, S. Murakami, M. Isobe, R. Seki, S. Kobayashi, K. Toi, the LHD experimental group, Development and application of active charge exchange spectroscopy for study of fast ion distribution and transport on LHD, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3



## Advanced Energy Research Section

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## 1. Introduction

A blob or filament is a plasma coherent structure aligned magnetic field, which is considerably denser than the surrounding background plasma and highly localized in the directions perpendicular to the equilibrium magnetic field. In experiments and simulations, these intermittent filaments are often formed near the boundary between open and closed field lines, and seem to arise in theory from the saturation process for the dominant edge instabilities and turbulence. Blobs become charge-polarized under the action of an external force which causes unequal drifts on ions and electrons; the resulting polarization-induced  $E \times B$  drift moves the blobs radially outwards across the scrape-off-layer (SOL). Since confined plasmas generally are subject to radial or outwards expansion forces, blob transport is a general phenomenon occurring in nearly all plasmas. This paper is intended to provide a brief introduction for blob or filament study in the HL-2A tokamak.

## 2. Experimental setup

Plasma filament experiments were performed in ohmically heated deuterium discharges on the HL-2A tokamak with major radius  $R = 1.65$  m and minor radius  $a = 0.4$  m. Typical experimental parameters were plasma current  $I_p = 168$  kA, toroidal magnetic field  $B_t = 1.9$  T, line-averaged density  $n_e = 1.9 \times 10^{19} \text{ m}^{-3}$ . The Greenwald density limit was  $n_G = 3.3 \times 10^{19} \text{ m}^{-3}$ . The statistical characteristics of blob turbulence across the separatrix had been studied with Langmuir 5-tips array in HL-2A edge plasma [Cheng 2010, PPCF52, 055003]. Recently, two novel Langmuir probe arrays are combined to investigate three dimensional characteristics of plasma filaments, as shown in figure 1. One is a poloidal 10-tip array (labeled as ‘Array A’) locating below the midplane. The distance between the first

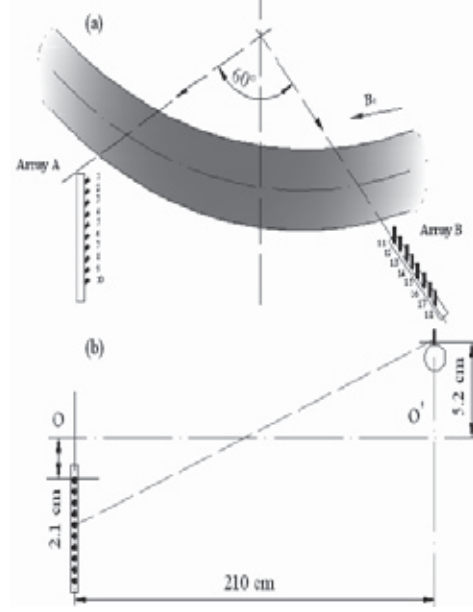


Figure 1. The combination of poloidal and radial probe arrays with toroidally spaced by 60 degree. Adjacent separation of two tips in array A and array B is 4 mm.

probe and midplane is  $d_1 = 2.1$  cm, the separation between the first tip and the  $i^{\text{th}}$  tip in array A is defined as  $\Delta d_0(i) = (i-1)\Delta d$  ( $1 \leq i \leq 10$ ), where  $\Delta d = 4$  mm is the adjacent probe separation. The maximum radial distance between a tip and the same magnetic flux is smaller than 4.0 mm, which is comparable with the exposed probe length. Another is a radial 8-tip array (labeled as ‘Array B’), which is positioned at  $d_2 = 5.2$  cm above the mid-plane. The toroidal separation between probe arrays is 210 cm, which is large enough for toroidally spatial resolution. This probe array arrangement provides enough flexibility to study filament dynamics and propagation characteristics, especially, the parallel coherence along a field line.

For suitable  $B_t$  and  $I_p$ , a field line passing one tip of the array B may intersect the  $i^{\text{th}}$  tip in the array A at the vertical position  $z_0 = (i-1) \Delta d + d_1$ , which is defined as the distance between the mid-plane and the intersection. The  $z_0$  needs satisfy this condition:  $((z_0 + d_2)/L_\phi) = 2 \times 10^{-7} I_p / (a + \Delta r) B_t$ , where  $L_\phi$  denotes the toroidal separation between array A and array B,  $\Delta r$  is radial distance between a tip in array A and the magnetic separatrix. Positive  $\Delta r$  means outside the separatrix. The peak of maximum correlation is close to an ideal field line.

### 3. Filament propagation in SOL

Based on the significant parallel correlation aligned magnetic field, spatial structures in poloidal-radial plane (2D) have been clearly observed using the novel combination of a poloidal and a radial probe array. Cross-conditional average is used to extract spatial structures from ambient turbulence based on a given amplitude threshold. There are two independent filaments appearing in 2D plane outside the separatrix. The first filament (marked by a circle) moves into the observation region with poloidal and radial sizes less than 10 mm, see figure 2 (a), and then its amplitude gradually grows, as shown in figure 2(b) and figure 2(c). Meantime, the second filament appears (denoted by a cross), see figure 2(d), which has a separation of 25 mm from the first one, implying that the second filament is independent of the first filament. Thus, these structures probably form inside the separatrix and then propagate across the separatrix into the SOL. Figure 2(e) illustrates that the second filament gradually moves into our measurement region, and the distance between them becomes smaller, indicating that the isolation filament has different propagation velocity. As shown in figure 2(f), the first filament almost disappears, which suggests that the filament lifetime is about 20-30  $\mu\text{s}$ . From figure 2(f) to figure 2(h), the poloidal movement of the second filament is apparent, but its radial movement is ambiguous, which implies the faster poloidal movement than the radial one. The radial and poloidal velocities of filaments are estimated to be about 0.5-0.8 km/s and 1.1-2.0 km/s, respectively, using  $V = \Delta x / \Delta t$ , where  $\Delta x$  is the movement distance in 2D plane during the interval  $\Delta t$ . The filament radial velocity is about 2 % of ion sound speed. In addition, the most obvious feature is filaments inclination in the 2D plane.

### 4. Summary

Significant parallel correlation and three-dimensional characteristics of plasma filaments in the SOL plasma of HL-2A tokamak are studied using a novel combination of a poloidal Langmuir 10-probe and a radial 8-probe array toroidally

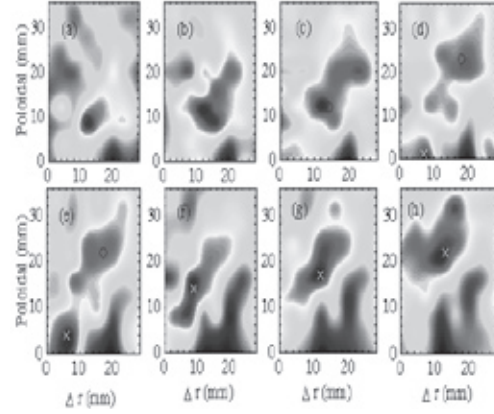


Figure 2. The 2D images of conditional average of floating potentials measured with poloidal 10-probe and radial 8-probe arrays at 8 different delay times.

The adjacent interval is 5  $\mu\text{s}$ .

separated by 210 cm. Based on significant parallel coherence, the propagation processes of two independent filaments in poloidal-radial plane are clearly observed. This result implies that filaments form inside the separatrix. The filament lifetime is about 20-30  $\mu\text{s}$ . Typical radial and poloidal velocities are about 0.5-0.8 km/s and 1.1-2.0 km/s, respectively.



## Advanced Energy Research Section

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### 1. Summary

In this report the author presents a selection of results achieved during her research activity on microwave reflectometry in fusion plasmas.

### 2. Introduction

Microwave reflectometry, a radar technique used for diagnosing fusion plasmas, has experienced significant advances in the last two decades becoming a very attractive diagnostic presently used in almost all fusion devices. This technique allows measuring electron density profiles, plasma instabilities, turbulence and radial electric fields with excellent spatial and temporal resolution. The author has been working on microwave reflectometry during the last twenty years in different fusion devices and this report is intended to address a selection of the results achieved during her research activity with emphasis on the results obtained in the last years.

### 3. Microwave Reflectometry

Microwave reflectometry systems can be grouped in two categories, conventional and Doppler reflectometry, depending on which of the physical processes undergone in the plasma by the probing microwave beam is dominating the recorded signals. Conventional reflectometry is used to measure electron density profile, plasma instabilities and density turbulence by probing the plasma perpendicularly to the density cut-off surfaces and detecting the signal after reflection at the cut-off layer. Doppler reflectometry measures the density turbulence and its perpendicular rotation velocity at different turbulence scales, making use of a finite tilt angle between the probing beam and the cut-off layer normal to measure the Bragg back-scattered process that takes place at the cut-off layer.

### 4. Density profile measurements

One of the techniques developed during the 1990's to measure the density profile minimizing the detrimental effect of the density turbulence on the profile measurement quality is the Amplitude Modulation (AM) reflectometry. This technique is being successfully applied in both TJ-II [1] and Heliotron J [2] helical devices. The evolution of the density profile during density perturbation experiments or during spontaneous confinement

transitions has been measured in TJ-II using this technique. The density profile reconstruction from the reflectometry data relies on inversion algorithm. Recently, an integrated data analysis technique has been implemented in TJ-II [3]. Based on Bayesian analysis, this technique combines the information delivered by several diagnostics (reflectometry, interferometry, Thomson scattering and He-beam diagnostics) and instead of analysing all measurements separately and combining the results, a single model profile is used to fit all data simultaneously. By this process, the ambiguity in the profile initialization, inherent to the reflectometry profile reconstruction, is circumvented.

### 5. Density fluctuation measurements

Conventional reflectometry is applied to turbulence measurements although in some cases, the reflecting layer for microwave frequencies shows a complex corrugated structure leading to strong interference in the reflected beam that hinders the density fluctuation information and makes difficult to extract quantitative information. For specific scenarios, in particular for coherent plasma perturbations, e.g. MHD modes or high frequency Alfvén eigenmodes, a quantitative description of the density fluctuations is possible. In conventional reflectometry the plasma is probed perpendicularly. However, a small misalignment often exists due to errors in the antenna arrangement and/or due to changes in the plasma column shape or position. In these cases, plasma fluctuations propagating poloidally are the source of the asymmetric complex amplitude spectra that produces the so-called phase run-away. From the asymmetry in the spectra it is not possible to obtain accurate values of the rotation velocity but it can be useful to monitor changes in the velocity or to determine the spatial localization of the velocity shear layer [4]. Moreover, the asymmetry in the spectra is found to be modulated by coherent structures rotating in the plasma. Rather than a modulation in the plasma turbulence, the experimental observations point to a geometrical effect, i.e. a modulation in the angle between the plasma cut-off layer surface and the probing beam due to distortion in the cut-off layer shape. As a consequence the identification of coherent modes is possible even in conditions in which the detection of the modes in the complex amplitude spectra is hindered by the broadband turbulence.

Doppler reflectometry is being used at TJ-II since 2009 [5]. This technique allows the measurement of density fluctuations,  $\tilde{n}_e$ , and radial electric field,  $E_r$ , simultaneously and with very good spatial and temporal resolution. In addition, by measuring at two radial positions, the radial electric field shear,  $E_r$ -shear, can be obtained. These quantities play a key role in the edge barrier formation at the Low to High (L-H) confinement transition. In TJ-II, spontaneous L-H transitions are observed in pure NBI heated plasmas under Li coated wall conditions. L-H transitions show a pronounced reduction in  $\tilde{n}_e$  in the edge plasma region where the  $E_r$ -shear develops. However, high temporal resolution measurements show that the reduction in  $\tilde{n}_e$  precedes the increase in the mean  $E_r$ -shear. Furthermore, simultaneous with the reduction in turbulence, an increase in the  $E_r$ -shear low frequency oscillations is measured [6]. These observations indicate that mean ExB sheared flow is not the unique element to explain the reduction of turbulence at the transition, oscillating sheared flows have to be also considered. These results are consistent with models predicting L-H transition triggered by zonal flows. Further experimental evidence supporting the central role of zonal flows has been observed close to the L-H transition threshold conditions. In these cases, pronounced oscillations in both,  $E_r$ -shear and density fluctuation level are measured at the plasma edge. This oscillatory behaviour shows a characteristic predator-prey relationship between turbulence and flows, with the flow –the predator– following the turbulence –the prey– with a phase delay of  $90^\circ$  in a limit-cycle way [7]. The turbulence-flow oscillation pattern repetition frequency decreases as the plasma density increases, and the  $E_r$  oscillation amplitude decreases while that of the turbulence level increases. These observations can be explained based on the collisional damping of flows, which eventually sets the turbulence level. The coupling found between turbulence and flows follows that found in the predator-prey theory model [8]. In this model the turbulence driven zonal flow triggers the transition by regulating the turbulence until the mean flow is high enough to suppress turbulence effectively. Due to the self-regulation between turbulence and flows, the transition is marked by an oscillatory behaviour with a predator-prey relationship between turbulence and zonal flows. Recently, this intermediate oscillatory transient stage has also been observed in other devices but only the temporal dynamics of the turbulence-flow interaction has been reported and no information is given on its spatial evolution. However, the spatial evolution should also be taken into account as a necessary step to go towards the L-H transition model. In TJ-II this fundamental issue has been addressed for the first time from the experimental point of view [9]. Both, radial outward and inward propagation velocities of the turbulence-flow front are found (see fig. 1). The

results indicate that the edge shear flow linked to the L-H transition can behave either as a slowing-down, damping mechanism of outward propagating turbulent-flow oscillating structures, or as a source of inward propagating turbulence-flow events.

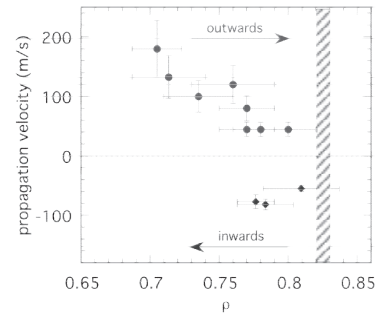


Fig. 1: Radial propagation velocity of the turbulence-flow front vs. plasma radius. The  $E_r$ -shear location is indicated as a striped area.

Finally, H-L back-transition experiments at TJ-II have revealed signatures of spatial spreading of plasma turbulence [10]. These experiments show a gradual decrease in  $E_r$  and  $E_r$ -shear as the plasma approaches the back-transition and a fast drop in the  $E_r$ -shear right at the back-transition. The turbulence level shows a distinct behavior at both sides of the  $E_r$ -shear position, suggesting the following scenario: Radial spreading of the turbulence, braked during the H-mode by the high  $E_r$ -shear, becomes noticeable as  $E_r$ -shear declines and produces a gradual increase in the turbulence level at the internal radial positions, reaching the  $E_r$ -shear location right before the H-L back-transition. The consequence is a gradual retreat of the transport barrier quantified as the width of the turbulence reduction region. These experimental results resemble simulation studies where the key quantity to the control of turbulence spreading was found to be the  $E_r$ -shearing rate and point to the possible role of radial spreading of turbulence in determining the width of transport barriers.

- [1] T. Estrada, J. Sánchez, B. van Milligen *et al.*, Plasma Phys. Control. Fusion **43**, 1535 (2001)
- [2] K. Mukai, K. Nagasaki, V. Zhuravlev *et al.*, Contrib. Plasma Phys. **50**, 646 (2010)
- [3] B. Ph. van Milligen, T. Estrada, E. Ascasíbar *et al.*, Rev. Sci. Instrum. **82**, 073503 (2011)
- [4] T. Estrada, E. Blanco, L. Cupido *et al.*, Nuclear Fusion **46**, S792 (2006)
- [5] T. Happel, T. Estrada, E. Blanco *et al.*, Rev. Sci. Instrum. **80**, 073502 (2009)
- [6] T. Estrada, T. Happel, L. Eliseev *et al.*, Plasma Phys. Control. Fusion **51** (2009) 124015
- [7] T. Estrada, T. Happel, C. Hidalgo *et al.*, Europhysics Letters **92**, 35001 (2010)
- [8] E.-J. Kim and P.H. Diamond. Phys. Plasmas **10**, 1698 (2003)
- [9] T. Estrada, C. Hidalgo, T. Happel and P.H. Diamond. Phys. Rev. Lett. **107**, 245004 (2011)
- [10] T. Estrada, C. Hidalgo and T. Happel. Nuclear Fusion **51**, 032001 (2011)

## Advanced Energy Research Section

João Tomé, Foreign Visiting Associate Professor  
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University of Aveiro, Aveiro, Portugal)

### Abstract

I join the Institute of Advanced Energy, Kyoto University, between January 5<sup>th</sup> and April 3<sup>rd</sup>, as Visiting Associate Professor in the group of Professor Takashi Morii. During my stay I started a joint project on Porphyrins on DNA Origami, to develop novel artificial photosynthetic system. Besides this research project, my activities also included frequent interaction with the coworkers, students and staff in Prof. Morii's Lab, attending also the biweekly group seminars and progress meetings with all of them. During my stay I also give a lecture at the Institute of Advanced Energy and an invited talk at University of Hyogo. In addition I had the opportunity to attend many of the seminars hosted by the Institute during this period.

### 1. Joint research project

I was invited by Prof. Morii to join the Institute of Advanced Energy and his group for a period of three months. Before coming we discussed a possible joint project that could be interesting for both groups. As synthetic chemist, mostly on porphyrin and related compounds and Prof. Morii expert in DNA origami, the idea was design and develop new porphyrin- and [C<sub>60</sub>]fullerene-oligoDNA conjugates to be used on DNA origami nanotechnology. This DNA technique can allow the construction of nanostructure models with multi-photon components in a controlled intercomponent distance, orientation, and defined donor-acceptor ratios, with potential application in photoinduced energy- and electron-transfer processes. So, during my stay in Prof. Morii's lab, I started synthesizing oligo DNA-porphyrin conjugates that could be used, by Dr. Eiji Nakata, to build the novel DNA origami decorated with porphyrins. In the beginning, the first coupling strategies selected did not give the desired porphyrin-oligoDNA derivatives, leading us to develop different porphyrin derivatives and consequently different coupling reactions. These new strategies already allowed the synthesis of three new porphyrin-oligoDNA conjugates, which were characterized by UV-Vis spectroscopy and mass spectrometry. Is now time to play with the DNA

origami to get novel functional nanomaterials and devices. Advanced imaging methods, such as AFM will be used to characterize the obtained origami nanostructures. Photoinduced energy- and electron-transfer between the components will be study by steady-state and time-resolved emission and transient absorption studies.

### 2. Biweekly progress meetings and research seminars

I attended all the biweekly progress meetings and research seminars of Prof. Morii's group. These highly informal group meetings allow me to follow the progress of all works developed by the students or postdocs on their research activities, and also their plans for the coming period. Here, I must thank a lot all of them for the tremendous efforts to present their results and handouts in English. During these meetings I also presented the results of my project and discussed the next experimental details.

The research seminars involved the presentation of a select paper by one of the students, which could be important for his research project. He should introduce the theme and explain the described work. Also here the presentation and handouts were very well prepared in English, which allow all the foreigners to participate actively in the discussion.

### 3. Seminars

During my stay in Kyoto, I had the chance to participate in two seminars. One of them was here at the Institute of Advanced Energy, and the other at University of Hyogo. The one here, at March 9<sup>th</sup>, entitled Institute of Advanced Energy Biofunctional Science Seminar and hosted by Professor Morii, I gave the lecture "Porphyrins and Phthalocyanines for Photomedicine and Organic Solar Cells", presenting a survey of my research on porphyrins (Pors), phthalocyanines (Pcs) and [C<sub>60</sub>]fullerene (C<sub>60</sub>), highlighting the synthetic strategies to obtain some of these molecules and functional materials, showing at the same time some of the obtained results in different applications.

These three family of molecules possess unique photo-physical and –chemical properties which make them valuable compounds in different scientific fields, namely in medicine, catalysis, solar energy converters, etc. The possibility of combine Pors and Pcs with light to mimic the photosynthetic process, explains the high attention devoted by the scientific community to such compounds. However, the design and the efficient synthesis of such photoexcitable compounds, with the best properties for distinct applications, is still a great challenge for many chemists. The possibility to decorate the periphery of their cores, with different motifs, opens the possibility to fine-tune the properties for several distinct applications. For example, Por-C<sub>60</sub> and Por-Pc dyads and Por-Pc~C<sub>60</sub> supramolecular systems can be used in electronic and energy transfer processes; while Pors and Pcs decorated with multi-glyco or -pyridinium groups can be water soluble photosensitizers for cancer photodynamic therapy (PDT) and microorganisms photodynamic Inactivation (PDI), respectively.

At University of Hyogo at Himeji, on March 13<sup>th</sup>, I gave the talk “Porphyrins and Analogues as Photosensitizers” in University of Hyogo Energy Symposium. In this talk I have the opportunity to introduce the Photodynamic Therapy theme and show many of the porphyrinic photosensitizer

derivatives that my group has been prepared and some of their biological results in PDT and PDI.

#### 4. Coming collaborations

It is planning to continue the project by exchanging materials, but also interchange graduate students of the Morii's and Tomé's groups. So, next summer is already arranged a three months stay of one of my PhD students here at the Morii's group to continue this stimulating project. These international research stages allow not only reinforce the collaboration, but also give to the students international experiencing. There is a significant pedagogical value in sending students to collaborating labs for at least two or three months to learn different science, approaches, methods, and culture. For that there is already in progress a bilateral agreement between the Institute of Advanced Energy and the University of Aveiro, for interchanging of graduate students between both Institutions.

We believe that these works will allow us, in a joint effort, extend our studies to the development of new promising photoinduced Por-oligoDNA nanosystems to be used in energy- and electron-transfer devices.

## Advanced Energy Materials Research Section

K. Matsuda, Professor  
 T. Hinoki, Associate Professor  
 K. Jimbo, Assistant Professor

## 1. Introduction

We are investigating the scientific principle and applications of new materials including nano-materials for advanced energy science. In Advanced Energy Material Research section, the physical properties of nano-carbon materials (carbon nanotube, and graphene) by advanced optical spectroscopy and compositional ceramics (SiC) materials by multi-scale experiments for the material properties (MUSTER) are studied. Followings are main research achievements in the year of 2011.

## 2. Analysis of the Photovoltaic Properties of Single-Walled Carbon Nanotube/Silicon Heterojunction Solar Cells

Carbon nanotubes have attracted a great deal of interest for photovoltaic applications due to their excellent physical and electronic properties, including a band gap that is widely tunable by controlling the tube diameter and high carrier mobility along their one-dimensional axis. Recently, the heterostructures of carbon nanotubes and Si have been extensively studied to realize highly efficient photovoltaic cells.

Here, we studied the photovoltaic properties of carbon nanotubes/*n*-Si heterojunction solar cells. Figure 1 shows the typical current density-voltage curve of carbon nanotubes/*n*-Si heterojunction solar cell under dark and light illumination conditions. This device shows the photovoltaic conversion efficiency of 2.4 %. The photovoltaic conversion effi-

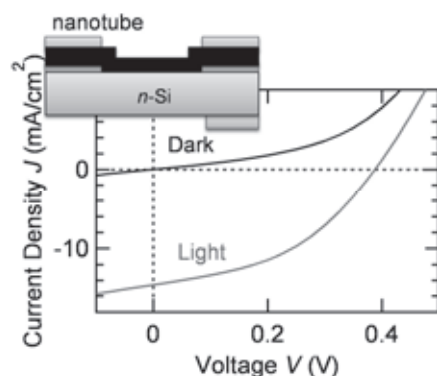


Fig. 1 Current-voltage curve of carbon nanotube solar cells (conversion efficiency of 2.4%)

ciency strongly depends on the thickness of the carbon nanotube network and shows a maximum value at the optimized thickness. We observed incident photon to charge carrier efficiency spectra and found that most of the photocarriers that contribute to the photovoltaic process are generated in the *n*-Si layer. Moreover, detailed analysis of current-voltage curves based on the equivalent circuit model showed that shunt loss and forward-bias current are the dominant factors influencing power loss in the cell. Our findings suggest that the realization of high-density semiconducting SWNT networks at the interface of Si is important for further improvement of the conversion efficiency of SWNT/*n*-Si heterojunction solar cells.

## 3. Dispersion-Process Effects on the Photoluminescence Quantum Yields of Single-Walled Carbon Nanotubes

Carbon nanotubes are applicable to novel optoelectronic devices. A wide range of tunable emission wavelengths, determined by the tube diameter in the near-infrared region, is useful for light-emitting devices, such as light-emitting diodes and single photon sources, as well as also for fluorescence bio-labels. These devices are based on the luminescence arising from exciton recombination processes. However, reported photoluminescence (PL) quantum yields (QYs) of carbon nanotubes are typically in the range of a few %. The physical mechanisms behind these limitations, as well as possible procedures that could be used to enhance the PL QYs, have been extensively investigated.

Here, we studied dispersion-process effects on the PL QYs of carbon nanotubes dispersed using aromatic polymers. It was found that PL QYs of carbon nanotubes dispersed using aromatic polymers are nearly independent of the growth method used to synthesize carbon nanotubes, indicating that PL QYs are mainly determined by post-growth dispersion processes. Moreover, we found that relatively high PL QYs can be obtained when only a moderate bath-type sonicator is used for dispersion, and the PL QYs are strongly decreased with increasing sonication time when a vigorous tip-type sonicator is used. The number density of exciton (bound elec-



tron-hole pair) quenching sites introduced during sonication was very low ( $<2 \mu\text{m}^{-1}$ ). The nanotube length almost determined the PL QYs of carbon nanotubes dispersed using aromatic polymers, as confirmed by experimental results and exciton diffusion model calculations.

#### 4. Development of Pseudo Ductile Porous Silicon Carbide Ceramics

Porous silicon carbide (SiC) ceramics are very attractive engineering ceramics in particular for high temperature use and nuclear application due to high temperature strength, oxygen resistance, chemical stability, low activation, radiation resistance and so on. However the application of porous SiC ceramics is limited due to brittle feature. Novel porous SiC composites were developed at Kyoto University. The objective of this work is to develop pseudo ductile porous SiC ceramics by SiC fiber reinforcement.

The composites consisted with just SiC fiber and crystalline porous SiC matrix without fiber/matrix interphase like carbon (C) as shown in Fig. 2. The SiC matrix was formed with C powder by liquid phase sintering or reaction sintering method. The porous SiC matrix was formed following decarburization process. The composites showed pseud-ductile behavior and complicated fracture behavior due to frictional stress at debonded fiber/matrix interface. Three point flexural strength was approximately 300 MPa in case of the material with 30 % porosity.

Silicon carbide composites require fiber/matrix interface layer like C for pseud-ductile fracture behavior. The control of thickness and quality for the interface layer is very difficult, although it is the key to determine mechanical properties of the composites. The novel composites showed pseud-ductile behavior without the interface layer. It is easy to fabricate uniform material and reduce the material cost significantly. The C interface layer is the weakest link in some cases in particular for oxygen environment at high temperature. The novel material just consists with SiC and applicable for various severe environment.

Compared to current porous silicon carbide ceramics, strength is more than three times with pseud-ductile feature by fiber reinforcement. High temperature use is expected above metal applied temperature condition. The novel material has

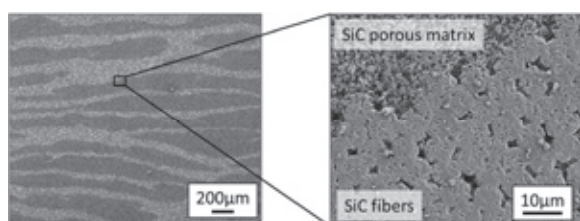


Fig. 2. SEM images of the novel silicon carbide composites with porous matrix

pseud-ductile behavior and reliability and applicable for structural material. It is different from brittle ceramics. The novel material doesn't require fiber/matrix interphase like carbon. It decrease material cost significantly. Productivity is also excellent compared to current silicon carbide composites. The material just consists with silicon carbide. Excellent resistance to high temperature oxygen and chemical corrosion is expected.

#### 5. Simulation of Neutron Damage on Nuclear Ceramics by Ion Irradiation

Due to the absence of fusion reactors at present, fusion materials research relies upon simulation experiments. A Multiple Beams–Material Interaction Research Facility (DuET), composed of two accelerators for heavy ions and  $\text{He}^+$ , respectively, has been a useful tool to study the synergistic effects of lattice displacements and  $(n, \alpha)$  reaction on material properties. Existing fission reactors have been used for the simulation study as well, but cope with many problems such as no helium generation, cost, and uncertainty of the temperature. The highly controllable and accurate irradiation conditions of DuET would help to achieve comprehensive experiments with the significant advantage in time ( $\sim 1/1k$ ) and cost ( $\sim 1/100$ ). Our research group have focused on the irradiation effects of ceramic materials, mainly SiC and graphite, and demonstrated that the exceptionally high irradiation tolerances of the SiC/SiC composites such as the retaining of the initial strength after irradiation in a wide temperature range of 280-1400°C and the lack of measurable void swelling below 1200°C.

#### 6. Transverse Laser Cooling of Magnesium Ion Beam by Synchro-Betatron Resonance at S-LSR

As collaboration research with Advanced Research Center for Beam Science, Institute for Chemical Research, K. Jimbo engages in a laser cooling experiment of magnesium ion beam at Small Laser-equipped Storage Ring (S-LSR). Synchrotron oscillation in the longitudinal direction and betatron oscillation in the horizontal direction was intentionally coupled in the deceleration phase of RF cavity located at the finite dispersive section. The horizontal beam size was measured for various synchrotron tunes as shown in Figure. When the synchrotron tune was 0.068, which were close to the resonant point of the fractional betatron tune 0.07, the initial beam size 0.8mm was decreased to 0.55mm. Cooling caused beam size reductions illustrated transferring the longitudinal cooling force to transverse direction by the synchro-betatron resonance; 2-D coupling was confirmed.



## Collaboration Works

Oak Ridge National Laboratory (米国), TAITAN (Tritium, Irradiation and Thermo fluid for America and Nippon) Task2-2 接合・被覆システムの健全性, 檜木達也

Oak Ridge National Laboratory (米国), TAITAN (Tritium, Irradiation and Thermo fluid for America and Nippon) Task2-3 動的変形挙動, 檜木達也

Politecnico di Torino (イタリア), Oak Ridge National Laboratory (米国), セラミックス材料の接合強度評価技術開発, 檜木達也

Politecnico di Torino (イタリア), Mechanical and sealant joining of SiC/SiC composites for high temperature applications, 檜木達也

核融合科学研究所, 液体ブランケット二重冷却システム用炭化珪素材料の開発, 檜木達也

日立造船 (株), CNT 太陽電池の開発, 松田一成

((独) 日本原子力研究開発機構, 微小試験片を用いた寿命特性評価試験技術に関する研究, 檜木達也

((独) 日本原子力研究開発機構, SiC/SiC 複合材料の照射下強度予測のための SiC 照射データベース整備, 檜木達也

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松田一成, 特定領域研究, カーボンナノチューブの光機能性発現に向けた光学応答制御

松田一成, 基盤研究(B), ナノカーボン物質における量子制御とナノカーボン・フォトニクスの開拓

毛利真一郎, 若手研究(B), 局在光電場中の単一カーボンナノチューブ電子状態の解明とその制御

### 2. Others

檜木達也, 受託研究 ((独) 科学技術振興機構), 反応焼結法による SiC 繊維強化多孔質 SiC セラミックスの開発

檜木達也, 受託研究 (原子燃料工業 (株)), セラミックス材料の原子炉燃料利用に関する技術動向調査

宮内雄平, 受託研究 ((独) 科学技術振興機構), 量子ナノ構造近接相互作用により創発する先端光機能

松田一成, 共同研究 (日立造船 (株)), カーボンナノチューブ太陽電池の開発

檜木達也, 共同研究 ((独) 日本原子力研究開発機構), 微小試験片を用いた寿命特性評価試験技術に関する研究

檜木達也, 共同研究 ((独) 日本原子力研究開発機構), SiC/SiC 複合材料の照射下強度予測のための SiC 照射データベース整備

松田一成, 奨学寄附金 ((公) 旭硝子財団), 共鳴レーザートラッピング技術の開発とカーボンナノチューブへの応用

松田一成, 奨学寄附金 ((公) 山田科学振興財団), ナノカーボン物質におけるスピン・量子制御の開拓

檜木達也, 奨学寄附金 ((公) 日本セラミックス協会), アジア各国のセラミックス関係団体主催の学術会議に出席するための渡航費用

## Publications

F.M.M. Rahman, F. Wang, K. Matsuda, T. Kimura, N. Komatsu, Diameter-based separation of single-walled carbon nanotubes through selective extraction with dipyrrene nanotweezers, Chemical Science, 2, 862-867, 2011

F. Wang, K. Matsuda, F.M.M. Rahman, T. Kimura, N. Komatsu, Improved selectivity in discriminating handedness and diameter of sin-

- gle-walled carbon nanotubes with N-Substituted 3,6-Carbazolyene-Bridged Chiral Diporphyrin nanotweezers, *Nanoscale*, 3, 4117-4124, 2011
- M. Okano, R. Matsunaga, K. Matsuda, S. Masubuchi, T. Machida, Y. Kanemitsu, Raman study on the interlayer interactions and the band structure of bilayer graphene synthesized by alcohol chemical vapor deposition, *Applied Physics Letters*, 99, 15, 151916-1-151916-3, 2011
- Y. Harada, T. Kita, K. Matsuda, Y. Kanemitsu, .H. Mariette, Near-field photoluminescence spectroscopy of CdTe/Cd<sub>0.75</sub>Mn<sub>0.25</sub>Te tilted superlattices, *Physica Status Solidi C*, 9, 2, 262-265, 2012
- K. Matsuda, Exciton dephasing in a single carbon nanotube studied by photoluminescence spectroscopy, *Electronic Properties of Carbon Nanotubes*, Chapter 16, 353-368, 2011
- 松田一成, 炭素物質の示す光学的性質, 「炭素学」化学同人社, 201-222, 2011
- Y. Lee, Y. Park, T. Hinoki, Thermal Conductivity of SiCf /SiC Composites at Elevated Temperature, *Zero-Carbon Energy Kyoto 2010 Green Energy and Technology*, Part III, , (ii), 306-310, 2011
- K. Toyoshima, T. Hino, T. Hinoki, Development of the Crack Detection Technique for NITE SiC/SiC Composite Applied to Fusion Blanket , "Zero-Carbon Energy Kyoto 2010 Green Energy and Technology ", Part III, , (ii), 311-316, 2011
- Y. Ueki, T. Kunugi, K. Nagai, M. Hirabayashi, K. Ara, Y. Yonemoto, T. Hinoki, Experimental Investigation on Contact Angles of Molten Lead-Lithium on Silicon Carbide Surface, "Zero-Carbon Energy Kyoto 2010 Green Energy and Technology", Part III, (ii), 271-277, 2011
- Y.J. Lee, Y.H. Park, T. Hinoki, Influence of Grain Size on Thermal Conductivity of SiC Ceramics , *Symposium 10 Create an alert RSS this journal 2011 IOP Conf. Ser.: Materials Science Engineering*. doi:10.1088/1757-899X/18/16/162014, Vol.18, 2011
- K. Abe, S. Nogami, A. Hasegawa, T. Nozawa, T. Hinoki, Study on stress relaxation behavior of silicon carbide by BSR method, *Journal of Nuclear Materials Proceedings of ICFRM-14*, Volume 417, Issues 1-3, 1, 356-58, 2011
- M. Ferraris, M. Salvo, V. Casalegno, S. Han, Y. Katoh, H.C. Jung, T. Hinoki, A. Kohyama, Joining of SiC-based materials for nuclear energy applications, *Journal of Nuclear Materials Proceedings of ICFRM-14*, Volume 417, Issues 1-3, 1, 379-82, 2011
- H. Katsui, A. Hasegawa, Y. Katoh, Y. Hatano, T. Tanaka, S. Nogami, T. Hinoki, T. Shikama, Study on Compatibility between Silicon Carbide and Solid Breeding Materials under Neutron Irradiation, *Fusion Science and Technology; Journal*, 60, 1, 288-91, 2011
- H.C. Jung, T. Hinoki, Y. Katoh, A. Kohyama, Development of a shear strength test method for NI-TE-SiC joining material, *Journal of Nuclear Materials Proceedings of ICFRM-14*, Volume 417, Issues 1-3, 1, 383-86, 2011
- K. Toyoshima, T. Hino, Y. Hirohata, Y. Yamauchi, T. Hinoki, Crack propagation analysis of SiCf/SiC composites by gas permeability measurement , *Journal of the European Ceramic Society*, 31, 6, 1141-144, 2011
- Z. Zhong, T. Hinoki, A. Kohyama, Microstructure and mechanical strength of diffusion bonded joints between silicon carbide and F82H steel, *Journal of Nuclear Materials Proceedings of ICFRM-14* , Volume 417, Issues 1-3, 1, 395-99, 2011
- Y. Katoh, K. Ozawa, T. Hinoki, Y. Choi, L.L. Snead, A. Hasegawa, Mechanical properties of advanced SiC fiber composites irradiated at very high temperatures, *Journal of Nuclear Materials Proceedings of ICFRM-14* , Volume 417, Issues 1-3, 1 , 416-20, 2011
- M.S. Suh, K. Shimoda, T. Hinoki, Fabrication of SiC/SiC composites by means of in situ crystallization of SiC fibers, *Journal of Nuclear Materials Proceedings of ICFRM-14*, Volume 417, Issues 1-3, 1, 359-362, 2011
- Y. Ueki, K. Nagai, T. Kunugi, M. Hirabayashi, K. Ara, Y. Yonemoto, T. Hinoki, Contact angle measurement of molten lead-lithium on silicon carbide surfaces, *Fusion Engineering and Design Proceedings of the 26th Symposium of Fusion Technology (SOFT-26)*, 86, 9-11, 2297-2300, 2011
- T. Muroga, D.K. Sze, K. Okuno, T. Terai, A. Kimura, R.J. Kurtz, A. Sagara, A. Nygren, Y. Ueda, R.P. Doerner, J.P. Sharpe, T. Kunugi, N.B. Morley, Y. Hatano, M.A. Sokolov, T. Yamamoto, A. Hasegawa, Y. Katoh, Y. Ohno, K. Tokunaga, S. Konishi, S. Fukuda, S. Calderoni, Midterm Summary of Japan-US Fusion Cooperation Program TITAN, *FUSION SCIENCE AND TECHNOLOGY*, 60, 1, 321-328, 2011
- K.W. Nama, J.W. Kim, T. Hinoki, A. Kohyama, J. Murai, T. Murakami, Application of ultrasonic in-

spection to characterization of advanced SiC/SiC composites, Journal of Nuclear Materials Proceedings of ICFRM-14, Volume 417, Issues 1-3, 1, 353-355, 2011

T. Koyanagi, S. Kondo, T. Hinoki, The influence of sintering additives on the irradiation resistance of NITE SiC, Journal of Nuclear Materials Proceedings of ICFRM-14, Volume 417, Issues 1-3, 1, 435-439, 2011

T. Nishitani, T. Yamanishi, H. Tanigawa, T. Nozawa, M. Nakamichi, T. Hoshino, A. Kohyama, A. Kimura, T. Hinoki, T. Shikama, Japanese contribution to the DEMO-R&D program under the Broader Approach activities, Fusion Engineering and Design, 86, 12, 2924-2927, 2011

S. Kondo, Y. Katoh, L.L. Snead, Concentric ring on ring test for unirradiated and irradiated miniature SiC specimens, Journal of Nuclear Materials Proceedings of ICFRM-14, Volume 417, Issues 1-3, 1, 406-410, 2011

## Presentations

K. Jimbo, T. Hiromasa, M. Nakao, A. Noda, H. Souda, H. Tongu, INVESTIGATION OF SYNCHRO, BE-TATRON COUPLINGS AT S-LSR, IPAC11, New York, 2011.3.28-4.1

R. Matsunaga, K. Matsuda, Y. Kanemitsu, Optical spectroscopy of dark excitons and trions in carbon nanotubes, 4th Workshop of Nanotube Optics and Nanospectroscopy, (Wonton'11), University of Bordeaux, Bordeaux, France, 2011.5.29-6.1

檜木達也, Present Status of Irradiation and PIE Irradiation effects, TITAN workshop, 京都大学宇治おうばくプラザ, 2011.5.30-6.2

檜木達也, Scientific progress on Joining and Coating on Task 2 ; Joining SiC, TITAN workshop, 京都大学宇治おうばくプラザ, 2011.5.30-6.2

檜木達也, Tungsten and PFM ; W coating on SiC, TITAN workshop, 京都大学宇治おうばくプラザ, 2011.5.30-6.2

松田一成, ナノカーボン物質におけるナノ光科学とその応用, 北海道大学大学院工学研究院応用物理学部門講演会, 北海道大学札幌キャンパス, 2011.6.10

檜木達也, SiC/SiC 複合材料の物理特性, 核融合エネルギーフォーラム炉工学クラスタープランケット・サブクラスター平成 23 年度第 1 回会合

(合同開催), 核融合科学研究所岐阜県土岐市, 2011.6.24

松田一成, ナノカーボン・フォトニクスに向けて: ナノカーボン物質のナノ光科学, 先端領域若手研究リーダー育成拠点, 山梨大学サイエンスカフェ, 2011.7.6

松田一成, ナノカーボン物質の電子物性と光電変換機能, 第 7 回有機太陽電池シンポジウム, 京都, 2011.7.15-16

毛利真一郎, 宮内雄平, 松田一成, 単層カーボンナノチューブの発光量子効率におけるポストプロセスの影響, 第 41 回フラーレン・ナノチューブ・グラフェン学会, 東京都八王子市・首都大学東京南大沢キャンパス, 2011.9.5-7

檜木達也, 李泳柱, 足立幸志, 神田航希, 野口幸嗣, 低摩耗多孔質炭化珪素素材の開発, 公益社団法人日本セラミックス協会第 24 回秋季シンポジウム, 北海道大学 札幌キャンパス, 2011.9.7-9

下田一哉, Christain Colin, 檜木達也, 炭化ケイ素系繊維の高温その場測定法による耐熱性評価, 公益社団法人日本セラミックス協会第 24 回秋季シンポジウム, 北海道大学 札幌キャンパス, 2011.9.7-9

近藤創介, 檜木達也, 小柳孝彰, 高純度 SiC の照射クリープひずみの照射温度、線量、応力依存, 日本原子力学会 2011 年秋の大会, 北九州国際会議場他, 2011.9.19-22

樋口徹, 坂本寛, 中司雅文, 笠田竜太, 長谷川晃子, 近藤創介, 大野直子, 橋富興宣, 松井秀樹, 木村晃彦, 牟田浩明, 木村裕明, ジルコニウム水素化物の超微小硬さに及ぼすイオン照射効果, 日本原子力学会 2011 年秋の大会, 北九州国際会議場他, 2011.9.19-22

檜木達也, 下田一哉, 李泳柱, Lance L. Snead, Kurt Terrani, 加藤雄大, 軽水炉向け被覆粒子燃料炭化珪素マトリックスの開発, 日本原子力学会 2011 年秋の大会, 北九州国際会議場他, 2011.9.19-22

金本美慧, 小柳孝彰, 近藤創介, 檜木達也, SiC/SiC 複合材料の照射後界面特性変化に及ぼす照射温度効果, 日本原子力学会 2011 年秋の大会, 北九州国際会議場他, 2011.9.19-22

小柳孝彰, 近藤創介, 檜木達也, Si イオンと He イオンを同時照射した液相焼結 SiC 粒界上のバブル生成挙動, 日本原子力学会 2011 年秋の大会, 北九州国際会議場他, 2011.9.19-22

毛利真一郎, 宮内雄平, 松田一成, ホールドー

プした単層カーボンナノチューブ吸収スペクトルのブロードニング, 2011 年日本物理学会秋季大会, 富山大学五福キャンパス, 2011.9.21-24

K. Matsuda, Nano-carbon photonics: fundamental physics and application of carbon nanotube, JSPS Japan-Germany Nano-photonics seminar, Kyoto University, Kyoto City, Japan, 2011.9.26-27

T. Hinoki, Current Status of Nuclear Grade Silicon Carbide Composites, 15th International Conference on Fusion Reactor Materials(ICFRM15), Charleston, SC, 2011.10.16-22

S. Kondo, Microstructural Evolution In Irradiated Silicon Carbide, 15th International Conference on Fusion Reactor Materials(ICFRM15), Charleston, SC, 2011.10.16-22

T. Koyanagi, Irradiated Strength of SiC/SiC Composites Estimated using the Differential Swelling between Fiber, Matrix and Interphase, 15th International Conference on Fusion Reactor Materials(ICFRM15), Charleston, SC, 2011.10.16-22

Y. Lee, Thermal Conductivity of Neutron Irradiated SiC/SiC Composites at Elevated Temperature, 15th International Conference on Fusion Reactor Materials(ICFRM15), Charleston, SC, 2011.10.16-22

K. Shimoda, In-Situ Physical, Mechanical and Electrical Behaviors of Ion-Irradiated Tyranno-SA SiC Fibers at Elevated Temperatures, 15th International Conference on Fusion Reactor Materials(ICFRM15), Charleston, SC, 2011.10.16-22

M. Kanamoto, Irradiation Effects on The Interfacial Properties of SiC/SiC Composites, 15th International Conference on Fusion Reactor Materials(ICFRM15), Charleston, SC, 2011.10.16-22

S. Kondo, The Effect of Applied Stress on the Dimensional Stability of Silicon Carbide under Ion Irradiation, 15th International Conference on Fusion Reactor Materials(ICFRM15), Charleston, SC, 2011.10.16-22

K. Matsuda, Novel excitonic properties of carbon nanotubes toward nano-carbon optics, 17th Micro-optics Conference (MOC'11), Sendai International Center, Sendai, Japan, 2011.10.30-31

T. Hinoki, Pseudo Ductile Porous Silicon Carbide Ceramics, 3rd International Symposium on Advanced Ceramics and Technology for Sustainable Energy Applications (ACTSEA-2011), Howard Beach Resort Kenting Hinchun Town, Pingtung, Taiwan, R.O.C, 2011.10.30-11.2

T. Hinoki, NUCLEAR GRADE SILICON CARBIDE COMPOSITES, 台湾国立精華大学共同研究招待講演 2011.11.3, 台湾国立精華大学, 2011.11.3

K. Matsuda, Study of excitonic properties in carbon nanotubes toward nano-carbon photonics, JSPS The 2nd Japan-France Nano-photonics seminar, Toba Hotel International, Toba, Japan, 2011.11.6-9

大野直子, 長谷川晃子, 笠田竜太, 近藤創介, 橋富興宣, 松井秀樹, 木村晃彦, 樋口徹, 坂本寛, 中司雅文, Zr 水素化物のイオン照射硬化, 社団法人日本金属学会 2011 年秋期講演 (第 149 回), 沖縄コンベンションセンターおよびカルチャーリゾートフェストーネ沖縄県宜野湾市, 2011.11.7-9

橋富興宣, 近藤創介, 岩田憲幸, 笠田竜太, 檜木達也, 木村晃彦, 二重イオンビーム照射施設 (DuET) を用いた核融合炉材料の照射影響評価, 社団法人日本金属学会 2011 年秋期講演 (第 149 回), 沖縄コンベンションセンターおよびカルチャーリゾートフェストーネ沖縄県宜野湾市, 2011.11.7-9

大村高正, 岩田憲幸, 近藤創介, 笠田竜太, 檜木達也, 木村晃彦, マルチスケール材料評価基盤施設 (MUSTER) を用いたエネルギー材料研究, 社団法人日本金属学会 2011 年秋期講演 (第 149 回), 沖縄コンベンションセンターおよびカルチャーリゾートフェストーネ沖縄県宜野湾市, 2011.11.7-9

T. Hinoki, K. Shimoda, Y.H. Park, Pseudo Ductile Porous Silicon Carbide Ceramics, トリノ工科大学共同研究招待講演, トリノ工科大学, 2011.11.12

S. Kondo, Y. Katoh, L.L. Snead and T. Hinoki, MICROSTRUCTURAL EVOLUTION IN THE IRRADIATED FUSION CERAMICS, International Symposium on Role of Electron Microscopy in Industry ~Toward Genuine Collaboration Between Academia and Industry~ (産業界における電子顕微鏡の役割 ~真の産学協同に向けて~), 名古屋大学 Noyori Conference Hall, 2012.1.19-20

K. Shimoda, T. Hinoki, K.A. Terrani, L.L. Snead, Y. Katoh, Processing of inert SiC matrix with TRISO coated fuel by liquid phase sintering, 36th International Conference and Expo on Advanced Ceramics and Composites (ICACC'12), Hilton Daytona Beach Resort and Ocean Center Daytona Beach Florida, USA, 2012.1.22-27

T. Hinoki, K. Shimoda, Y. Park, Novel Silicon Carbide Composites without Interface Layer, 36th International Conference and Expo on Advanced Ce-



ramics and Composites (ICACC'12), Hilton Daytona Beach Resort and Ocean Center Daytona Beach Florida, USA, 2012.1.22-27

Y. Katoh, M. Ferraris, T. Hinoki, C.H. Henager, Joining Silicon Carbide for Nuclear and Fusion Energy Applications, 36th International Conference and Expo on Advanced Ceramics and Composites (ICACC'12), Hilton Daytona Beach Resort and Ocean Center Daytona Beach Florida, USA, 2012.1.22-27

豊島和沖, SiC 接合材料のねじり試験によるせん断強度評価, 2011 年度 GCOE 年次報告会, 京都大学黄檗プラザ, 2012.1.30

小柳孝彰, SiC/SiC 複合材料中の粒子線照射後残留応力, 平成 23 年度グローバル COE (地球温暖化時代のエネルギー科学拠点) 年次報告会, 京都大学宇治キャンパスおうばくプラザ, 2012.1.30

Y. Nakai, S.R. Kwon, K. Fukasawa, M.R.A. Mansor, H. Kojima, I.S. Seo, K. Nishioka, H. Negm, F. Goembira, T. Koyanagi, K. Yamauchi, Applicability of Electric Vehicle Usage with Less Nuclear Power Plants in Japan ~ Is EV OK or not?, 平成 23 年度グローバル COE (地球温暖化時代のエネルギー科学拠点) 年次報告会, 京都大学宇治キャンパスおうばくプラザ, 2012.1.30

檜木達也, 高温ガス炉の炉心材料開発状況, 「高温ガス炉プラント研究会」第 6 回定期講演会～世界のエネルギーと環境と安全に貢献～, 京都大学百周年時計台記念館国際交流ホール I, 2012.1.31

T. Hinoki, Current Status of Nuclear Grade Silicon Carbide Composites”, Germany/Japan Seminar on Energy, Obaku Plaza Institute of Advanced Energy, Kyoto University, 2012.2.2-3

K. Matsuda, Nano-material Science and its Application for Advanced Energy, Germany/Japan Seminar on Energy, Obaku Plaza Institute of Advanced Energy, Kyoto University, 2012.2.2-3

T. Hinoki, Material Performance -Evaluation and Irradiation, Workshop on “Summary of TITAN Achievements and Examination of the New Direction” (Post-TITAN Planning Workshop), Hilton Gaithersburg North, 2012.2.7-10

豊島和沖, HFIR 照射 SiC 接合・被覆材のねじり試験によるせん断強度評価溶解, H23.TAITAN 日米報告会, 東京ガーデンパレス, 2012.3.1-2

小柳孝彰, SiC の HFIR 中性子照射下クリープ挙動, H23.TAITAN 日米報告会, 東京ガーデンパレス, 2012.3.1-2

J.S. Park, K. Matsuda, S. Mouri, Y. Miyauchi, N. Nakashima, Observation of positive- and negative-charged excitons in the electrochemical-doped single-walled carbon nanotubes, 第 42 回フラーレン・ナノチューブ・グラフェン学会, 東京大学武田ホール, 2012.3.6-8

S. Konabe, K. Matsuda, S. Okada, Suppression of exciton-electron scattering in doped single-walled carbon nanotubes, 第 42 回フラーレン・ナノチューブ・グラフェン学会, 東京大学武田ホール, 2012.3.6-8

毛利真一郎, 宮内雄平, 松田一成, PFO 分散単層カーボンナノチューブの発光量子効率の決定要因, 2012 年春季応用物理学関係連合講演会, 早稲田大学早稲田キャンパス, 2012.3.15-18

小澤大知, 平岡和志, 宮内雄平, 毛利真一郎, 松田一成, 単層カーボンナノチューブ-シリコンヘテロ接合太陽電池の光電変換機構の解明, 2012 年春季応用物理学関係連合講演会, 早稲田大学早稲田キャンパス, 2012.3.15-18

檜木達也, 下田一哉, 朴二玄, 李泳柱, 豊島和沖, 大西一彰, 川原太一, 小西規文, 野中宏行, 西村博司, 佐藤彰洋, 繊維強化ポーラス SiC 複合材料の開発, 日本セラミックス協会, 京都大学 (吉田キャンパス), 2012.3.19-21

大西一彰, 川原太一, 小西規文, 野中宏行, 西村博司, 佐藤彰洋, 檜木達也, 下田一哉, 繊維強化ポーラス SiC 複合材料の実用化技術開発, 日本セラミックス協会, 京都大学 (吉田キャンパス), 2012.3.19-21

李泳柱, 檜木達也, 下田一哉, 朴二玄, 田中照也, 繊維強化 SiC ポーラス複合材料の物理特性, 日本セラミックス協会, 京都大学 (吉田キャンパス), 2012.3.19-21

豊島和沖, 朴二玄, 下田一哉, 檜木達也, SiC 繊維強化ポーラス SiC 複合材料の破壊挙動, 日本セラミックス協会, 京都大学 (吉田キャンパス), 2012.3.19-21

小柳孝彰, 下田一哉, 檜木達也, SiC ナノ粉末表面不純物の化学分析及び構造解析, 日本セラミックス協会, 京都大学 (吉田キャンパス), 2012.3.19-21

近藤創介, 檜木達也, 小柳孝彰, SiC の照射クリープに及ぼすヘリウム効果, 原子力学会 2012 年春の年会, 福井大学文京キャンパス, 2012.3.19-21

T. Hinoki, K. Shimoda, Porous Silicon Carbide Composites for LWR Cladding, 1st Asian Nuclear



Fuel Conference (ANFC), Osaka University, Japan,  
2012.3.22-23

松田一成, 毛利真一郎, 宮内雄平, 朴珍成, 中嶋直敏, 電気化学的手法による単層カーボンナノチューブにおける正、負トリオンの観測, 2012 年第 67 回日本物理学会年次大会, 兵庫県西宮市、関西学院大学西宮上ヶ原キャンパス, 2012.3.24-27

毛利真一郎, 宮内雄平, 松田一成, カーボンナノチューブの発光量子効率と励起子ダイナミクス, 2012 年第 67 回日本物理学会年次大会, 関西学院大学西宮上ヶ原キャンパス, 2012.3.24-27

岩村宗千代, 宮内雄平, 毛利真一郎, 松田一成, 酸素ドーブ単層カーボンナノチューブの光学特性, 2012 年第 67 回日本物理学会年次大会, 関西学院大学西宮上ヶ原キャンパス, 2012.3.24-27

神保光一, S-LSR における二つの温度成分を持ったイオンビームの共鳴点付近のシンクロトロン振動, 2012 年第 67 回日本物理学会年次大会, 関西学院大学西宮上ヶ原キャンパス, 2012.3.24-27

## Advanced Laser Science Research Section

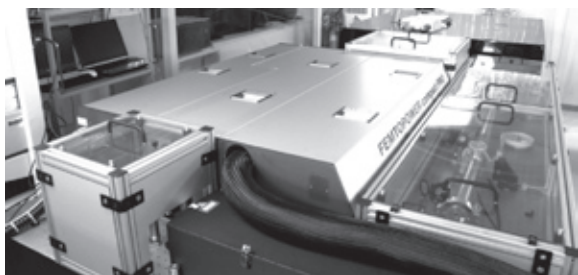
K. Miyazaki, Professor  
 T. Nakajima, Associate Professor  
 K. Hata, Assistant Professor  
 G. Miyaji, Assistant Professor

Research interest is focused on the development of advanced lasers and their applications to pioneering new fields of photon energy technology. The laser development is aiming at the development of high-intensity, few-cycle femtosecond (fs) laser pulses with stabilized carrier envelope phase (CEP) and the generation of coherent attosecond (as) EUV radiation. The advanced coherent light sources are used for the study of ultrafast strong-field interactions with atoms, molecules and solid surfaces. The goal is to demonstrate potential abilities of coherent radiation sources in new regimes of science and technology and contribute to the progress.

## 2. High-intensity, ultrashort-pulse lasers

Three Ti:sapphire laser chirped-pulse amplification (CPA) systems are working in our Section, which emit high-intensity fs pulses at the center wavelength of 800 nm. The first one produces a peak power of 1 TW (40 mJ in 40 fs). This system has been used for the study of ultrafast strong-field interactions with atoms and molecules. The second CPA laser system was designed for the study of materials control and processing, which can produce 10 mJ in 100 fs pulses with a well-defined intensity distribution of the output beam.

The third is an advanced Ti:sapphire laser CPA system for attosecond science, which produces an average output power of 1.6 W in CEP-locked 25 fs pulses at a repetition rate of 1 kHz. The 25-fs pulses can be compressed to a few cycles ( $\sim 5$  fs dura-



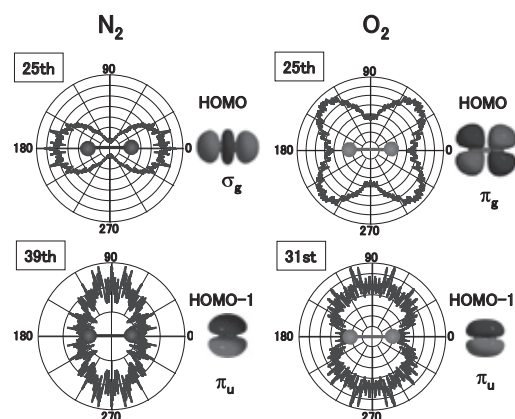
**Fig. 1.** CEP-stabilized Ti:sapphire CPA laser system that produces intense 5 fs pulses.

tion) by a pulse compressor consisting of a gas-filled hollow fiber and chirped mirrors for dispersion compensation. Figure 1 shows the overview of the laser system. The intense few-cycle laser pulses are used for the high-order harmonic generation in a gaseous medium to produce attosecond EUV pulses.

## 3. High-order harmonic generation from different orbitals in aligned molecules

We have developed a novel technique to detect the ultrafast revival structure of non-adiabatically aligned molecules, using high-order harmonic generation (HHG) with intense fs laser pulses in the pump-probe measurement. This technique has been used extensively as the most effective tool for studying structures and ultrafast dynamics of gaseous molecules under field-free conditions.

The angle-dependent harmonic yield around the molecular axis is the key to deduce the ultrafast nonlinear response of a single molecule. The HHG is mostly dominated with the electron density distribution in the highest occupied molecular orbitals (HOMO). However, it has often been observed that the HHG is affected by low-lying molecular orbitals, especially in the generation of very high order harmonics beyond the cutoff region. We have studied the effect of different molecular orbitals on the HHG.



**Fig. 2.** Angle-dependent harmonic signal of different orders for  $N_2$  and  $O_2$  molecules.

In the pump and probe measurement, the 40-fs laser pulses were focused into a pulsed supersonic molecular beam. The harmonic radiation emitted at different orders was simultaneously detected with an extreme ultraviolet CCD camera mounted on a flat-field spectrograph.

The harmonic signal was measured as a function of the time delay between the pump and probe pulses. The time-dependent amplitude of harmonic signals was found to reverse at high harmonic orders. The signal reversal started at the  $q$ th order around the cutoff region, and the higher order signals decreased rapidly with the reversed amplitude. The lowest  $q$ th order with the reversed amplitude increases with an increase in the probe laser intensity.

To see the origin of the signal reversal, the HHG was observed at the time for the top alignment by changing the angle  $\alpha$  between the polarization directions of the pump and probe pulses. Figure 2 shows examples of the angle-dependent harmonic signal observed at the top alignment for  $N_2$  and  $O_2$ . The results have demonstrated that the HHG above the cutoff regions are strongly dominated with the lower molecular orbitals such as HOMO-1 for  $N_2$  and  $O_2$ , and HOMO-1 and HOMO-2 for  $CO_2$ .

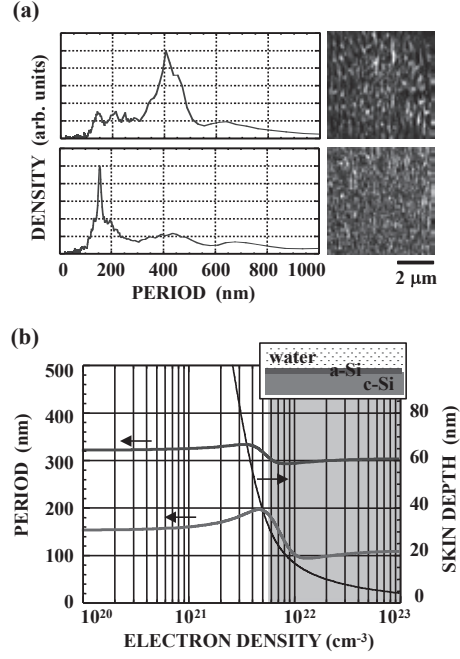
#### 4. Nanostructuring in fs laser ablation

The formation of periodic nanostructures observed with fs laser pulses suggests a new field of nanoscale, ultrafast light-matter interactions and its potential routes to laser nano-processing beyond the diffraction limit. For complete understanding of the ultrafast interaction mechanism, we have made a series of experimental studies for different materials with the 100-fs laser. The laser beam was focused at a moderate fluence on the target.

The periodic nanostructure could be formed on a variety of material surfaces with superimposed multiple shots of fs laser pulses at low fluence. We have shown for DLC film that *near-field* enhanced with fs laser pulses plays the essential role in initiating the nanoscale ablation on the target surface, and the origin of nano-periodicity observed can be attributed to the excitation of *surface plasmon polaritons* (SPPs) in the surface layer where the dielectric properties are rapidly changed due to the generation of high-density free electrons to work like a metal.

We have recently observed for Si in water that the surface nanostructures were formed with two periods at  $\sim 150$  nm and  $\sim 400$  nm, and these two kinds of nanostructures have represented characteristic behaviors depending on the fluence and shot number of laser pulses. The morphological change has suggested that the fine nanostructure is efficiently produced in succession to the coarse structure.

The experimental results were analyzed with a model target that consists of the uppermost amorphous Si (a-Si) layer and the lower crystalline Si



**Fig. 3.** (a) SEM image of the ablated Si surface and its Fourier spectrum observed with 400 (upper) and 2000 shots (lower) at  $60 \text{ mJ/cm}^2$ , and (b) structural periods and skin depth calculated as a function of  $N_e$  for the water/a-Si (upper) and a-Si/c-Si (lower) interfaces. The model surface is shown in the inset.

(c-Si) substrate. The model calculation has demonstrated that the picture based on the excitation of SPPs illustrates well the ultrafast dynamic process of nanostructuring on Si and the other semiconductor materials. Figure 3 shows (a) examples of a couple of the SEM image and its Fourier spectrum, and (b) the structure period calculated as a function of the electron density  $N_e$  in the a-Si layer, where SPPs can be excited in the shaded region of  $N_e \leq 5.5 \times 10^{21} \text{ cm}^{-3}$ . The calculated periods are  $\sim 300$  nm and  $100 - 200$  nm for the two interfaces, being consistent with the observation.

Based on the results obtained, we succeeded in fabricating nano-gratings with the grooves much smaller than the laser wavelength on GaN and DLC. The periodicity of grooves can be controlled with the laser parameters such as fluence and pulse numbers.

#### 5. Theoretical study of laser-matter interactions

We have studied the pulse propagation in the negative index metamaterial, and found that the choice of the chirp and the central wavelength of the incident pulse significantly alters the propagation velocity of the pulse.

#### 6. Critical heat fluxes of subcooled water flow

Based on the experimental results, we have derived the predictable transient critical heat flux correlations against inlet and outlet subcoolings in a short SUS304-tube with various twisted-tape inserts.

## Collaboration Works

Johns Hopkins University (米国), フェムト秒レーザーによる表面ナノ構造生成過程のモデル構築, 宮崎健創

University of Brawijaya (インドネシア), 超短パルス高強度レーザーによる分子配向と高次高調波発生, 宮崎健創

宇宙科学研究所 (ルーマニア), 高強度超短パルスレーザーによって誘起される非摂動相互作用の理論研究, 中嶋隆

天津工業大学 (中華人民共和国), フェムト秒フィラメントの空間伝搬特性, 中嶋隆

中国計量学院 (中華人民共和国), アト秒パルスのキャラクターゼーション, 中嶋隆

核融合科学研究所, 短い垂直円管内水の過渡乱流熱伝達, 畑幸一

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### 1. Grant-in-Aid for Scientific Research

宮崎健創, 新学術領域研究, 超高速光パルス誘起ナノ界面プラズマによる周期構造形成

宮崎健創, 基盤研究(B), 超短パルスレーザー励起ナノ構造生成のアト秒ダイナミクスとその応用

中嶋隆, 基盤研究(A), 超短レーザーパルス列照射による高効率・高汎用核スピン偏極

畑幸一, 基盤研究(C), 強制対流サブクール沸騰限界熱流束発生機構の研究

### 2. Others

宮地悟代, 奨学寄附金 ((財) 稲盛財団), 位相を安定化した高強度フェムト秒レーザーによるナノ加工に関する研究

## Publications

G. Miyaji, K. Zhang, J. Fujita, K. Miyazaki, Nanostructuring of Silicon surface with femtosecond-laser-induced near field, Proceedings of the 12th International Symposium on Laser Precision Micro-fabrication(LPM2011), WeP20/1-WeP20/4, 2011

宮崎健創, 宮地悟代, 吉井一倫, アト秒レーザーパルスによる極限光計測基盤の開拓, 京都大学学際融合教育推進センター, 生存科学研究ユニット平成 23 年度研究成果報告会, 141-142, 2012

K. Yoshii, G. Miyaji, K. Miyazaki, Angle-Dependent High-Order Harmonic Generation from a Single N<sub>2</sub> and O<sub>2</sub> Molecule, CLEO Europe-EQEC 2011, Conference Digest, CG.P.6 THU, 2011

G. Miyaji, K. Zhang, J. Fujita, K. Miyazaki, Nanostructuring of Silicon Surface with Near-Field Enhanced in Femtosecond Laser Ablation, CLEO Europe-EQEC 2011, Conference Digest, CM.P.6 TUE, 2011

T. Nakajima, Recursion-relation analysis for optical pumping to polarize nuclei by a sequence of short laser pulses, J. Opt. Soc. Am. B, 28, 2123-2128, 2011

J. Chen, R. Itakura, T. Nakajima, Reconstruction of attosecond pulses using a two-color pumping, J. Opt. Soc. Am. B, 28, 2195-2199, 2011

V. Fedorov, T. Nakajima, Controlling the propagation velocity of a femtosecond laser pulse with negative index metamaterials, Phys. Rev. Lett., 107, 143903, 2011

X. Ren, T. Nakajima, Ionization suppression of heteronuclear diatomic molecules probed by intense laser, Phys. Rev. A, 85, 23403, 2011

K. Hata, S. Masuzaki, Twisted-Tape-Induced Swirl Flow Heat Transfer and Pressure Drop in a Short Circular Tube under Velocities Controlled, Nuclear Engineering and Design, 241, 4434-4444, 2011

K. Hata, N. Kai, Y. Shirai, S. Masuzaki, Transient Turbulent Heat Transfer for Heating of Water in a Short Vertical Tube, Proceedings of 19th International Conference on Nuclear Engineering, ICONE19-43190, 1-10, 2011

K. Hata, N. Kai, Y. Shirai, S. Masuzaki, A. Hamura, Computational Study of Turbulent Heat Transfer for Heating of Water in a Short Vertical Tube, Proceedings of 19th International Conference on Nuclear Engineering, ICONE19-43301, 1-11, 2011

K. Hata, N. Kai, Y. Shirai, S. Masuzaki, Heat Transfer and Critical Heat Flux of Subcooled Water Flow Boiling in a Short Horizontal Tube, Proceedings of 14th International Topical Meeting on Nuclear Reactor Thermal Hydraulics, NURETH14-098, 1-23, 2011

K. Hata, N. Kai, Y. Shirai, S. Masuzaki, A. Hamura, Computational Study of Turbulent Heat Transfer For Heating of Water in a Short Vertical Tube Under Velocities Controlled, Proceedings of 14th International

Topical Meeting on Nuclear Reactor Thermal Hydraulics, NURETH14-173, 1-22, 2011

K. Hata, N. Kai, Y. Shirai, S. Masuzaki, Transient Turbulent Heat Transfer for Heating of Water in a Short Vertical Tube, Journal of Power and Energy Systems, 5, 3, 414-428, 2011

## Presentations

G. Miyaji, K. Zhang, J. Fujita, K. Miyazaki, Nanostructuring of Silicon Surface with Near-Field Enhanced in Femtosecond Laser Ablation, 2011 Conf. on Lasers&Electro-Optics Europe and 12th European Quantum Electronics Conf., Int. Cong. Center Munich, Munich, 2011.5.24

K. Yoshii, G. Miyaji, K. Miyazaki, Angle-Dependent High-Order harmonic Generation from a Single N<sub>2</sub> and O<sub>2</sub> Molecule, 2011 Conf. on Lasers&Electro-Optics Europe and 12th European Quantum Electronics Conf., Int. Cong. Center Munich, Munich, 2011.5.26

甲斐尚人, 畑幸一, 白井康之, 増崎貴, 羽邑光道, 短い垂直円管内水の乱流熱伝達の数値解析, 第48回日本伝熱シンポジウム講演論文集, 岡山コンベンションセンター ママカリフォーラム, 2011.6.1-3

畑幸一, 増崎貴, 短いスワール管内水の強制対流サブクール沸騰限界熱流束(テーパーツイスト比の影響), 第48回日本伝熱シンポジウム講演論文集, 岡山コンベンションセンター ママカリフォーラム, 2011.6.1-3

G. Miyaji, K. Zhang, J. Fujita, K. Miyazaki, Nanostructuring of silicon surface with femtosecond laser induced near-field, The 12th Int. Symp. On Laser Precision Microfabrication(2011), Takamatsu, 2011.6.8

K. Miyazaki, K. Yoshii, G. Miyaji, Retrieving angle-dependent high-order harmonic generation for a single molecule, 20th Int. national Laser Physics Workshop, Hotel Terme Sarajevo, 2011.6.14

T. Nakajima, Ionic coherence induced by single-photon ionization, 20th International Laser Physics Workshop (LPHYS'11), Hotel Hollywood(Bosnia-Herzegovina), 2011.7.11-15

Y. Qin, T. Nakajima, T. Kii, H. Ohgaki, Use of Fringe-Resolved Autocorrelation for the Diagnosis of the Beam Quality of FEL, 第8回日本加速器学会年会, つくば国際会議場, 2011.8.1-3

宮崎健創, 超短パルスレーザーによるナノアブレーションと周期構造形成, 平成23年度多元技術融合光プロセス研究会第2回研究交流会, 産総研臨海副都心センター、東京, 2011.8.23

石井尚樹, 吉井一倫, 小藺正典, 宮地悟代, 宮崎健創, CO<sub>2</sub>からの高次高調波発生における複数分子軌道の効果, 2011年秋季応用物理学学会学術講演会, 山形大学、山形市, 2011.8.30

宮地悟代, 藤田隼也, 吉藤貴一, 宮崎健創, フェムト秒レーザーアブレーション中に増強される近接場による半導体表面のナノ構造, 2011年秋季応用物理学学会学術講演会, 山形大学、山形市, 2011.8.31

甲斐尚人, 畑幸一, 白井康之, 増崎貴, 短い垂直円管内水の過渡乱流熱伝達, 日本原子力学会2011年「秋の大会」予稿集, 北九州国際会議場, 2011.9.19-22

畑幸一, 甲斐尚人, 白井康之, 増崎貴, 羽邑光道, 短い垂直円管内水の乱流熱伝達の数値解析(その2. 粘性底層に及ぼす流速の影響), 日本原子力学会2011年「秋の大会」予稿集, 北九州国際会議場, 2011.9.19-22

K. Miyazaki, Periodically enhanced near-field for nanostructuring of solid surfaces with femtosecond laser pulses, 4th JST-DFG German-Japanese Nanophotonics Joint Research Project Meeting, Kyoto Univ., Uji, 2011.9.26

安丸尚樹, 宮崎健創, 千徳英介, 木内淳介, フェムト秒レーザーによりナノ構造が形成されたDLCおよびGCの摩擦特性, 日本機械学会第3回マイクロ・ナノ工学シンポジウム講演, 東京, 2011.9.26-27

宮崎健創, 原子分子・固体表面における超高速コヒーレント励起とその応用, 宮崎大学光科学プロジェクト第19回光科学セミナー, 宮崎大学、宮崎市, 2011.10.19

宮地悟代, フェムト秒レーザー誘起近接場による固体表面へのナノ構造形成, 理研エクストリームフォトリクスセミナー, 理化学研究所、和光市, 2011.10.28

T. Nakajima, Ionic coherence induced by ultrafast electron ejection, 42th Winter Colloquium on the Physics of Quantum Electronics (PQE2012), Snowbird(USA), 2012.1.2-6

宮崎健創, 宮地悟代, 吉井一倫, アト秒レーザーパルスによる極限光計測基盤の開拓, 京都大学学際融合教育推進センター、生存科学研究ユニット平成23年度研究成果報告会, 京都大学、宇治,



2012.2.28

中嶋隆, Li Deng, ブロードバンドナノ秒パルスによるミュオニウムのスピン偏極と高効率 VUV 光発生のための新スキームの検討, 第 58 回応用物理学関係連合講演会, 早稲田大学, 2012.3.15-18

中嶋隆, V. Fedorov, チャープによるメタマテリアル媒質中のパルス伝搬速度制御, 第 58 回応用物理学関係連合講演会, 早稲田大学, 2012.3.15-18

吉藤貴一, 宮地悟代, 宮崎健創, フェムト秒レーザーによるシリコン表面でのナノ構造生成の超高速ダイナミクス, 第 59 回応用物理学関係連合講演会, 早稲田大学, 2012.3.16

石井尚樹, 吉井一倫, 宮地悟代, 宮崎健創, 配向分子からの高次高調波発生における複数分子軌道の寄与, 第 59 回応用物理学関係連合講演会, 早稲田大学, 2012.3.16

畑幸一, 甲斐尚人, 白井康之, 増崎貴, 羽邑光道, 短い垂直円管内水の乱流熱伝達の数値解析 (その 3. 温度境界層に及ぼす管径の影響), 日本原子力学会 2012 年「春の年会」予稿集, 福井大学 文京キャンパス, 2012.3.19-21

甲斐尚人, 畑幸一, 白井康之, 増崎貴, 短い水平円管内水の強制対流サブクール沸騰熱伝達と限界熱流束, 日本原子力学会 2012 年「春の年会」予稿集, 福井大学 文京キャンパス, 2012.3.19-21

中嶋隆, ブロードバンドナノ秒パルスを用いたミュオニウムの再偏極, 日本物理学会第 67 回年次大会, 関西学院大学, 2012.3.24-27

Y. Qin, T. Nakajima, H. Zen, T. Kii, and H. Ohgaki, Autocorrelation measurement of KUFEL, 日本物理学会第 67 回年次大会, 関西学院大学, 2012.3.24-27

## Advanced Energy Storage Research Section

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K. Morishita, Associate Professor  
R. Kasada, Assistant Professor

## 1. Introduction

Efficient energy conversion and storage are great concerns for sound human life in the near future. This section takes up a mission of materials R & D for advanced nuclear energy conversion and storage, such as development of fusion blanket structural materials and fuel claddings of advanced nuclear systems. Current main researches are as follows:

(1) Development of structural materials for fusion systems: Materials R&D is essential for realization of fusion energy. Among the issues for materials R&D for fusion application, we have been focusing on the development of radiation tolerant structural materials, which include reduced activation ferritic (RAF) steels and oxide dispersion strengthened (ODS) steels for fusion blanket. R&D of high Cr ODS steels has been performed as a national program to develop an innovative material with radiation tolerance, corrosion-resistance and high-temperature strength for advanced nuclear fission and fusion systems.

(2) Tungsten diverter R&D: Evaluation of feasibility of tungsten (W) diverter has been performed along with joining technology development of W/ODS steel joints by means of transient liquid phase bonding method. The application of ODS steels as structural components of W-diverter has been considered to be effective to reduce the temperature gradient between plasma facing material and coolant constituents.

(3) Multiscale modeling: Tungsten (W) is proposed as one of the candidates for the first wall protection in fusion power plants. In irradiated tungsten at temperatures where vacancies can move, voids (vacancy clusters) are experimentally observed by transmission electron microscopy (TEM). Voids induce swelling, which leads to the dimensional changes of the material.

(4) Radiation damage mechanism of fission nuclear structural materials: For the sake of the highly efficient and safe operation of nuclear fission reactors, the mechanisms of irradiation embrittlement and stress corrosion cracking have been investigated. Small specimen test technique for evaluation of structural integrity has been developed towards extension of operation period of light water reactors.

## 2. Development of structural materials for fusion systems

The objective of this research is to develop joining and welding technologies for innovative nuclear fusion materials to realize high thermal efficient operation of advanced fusion blanket systems. In this work, friction stir welding (FSW) and solid state diffusion bonding (SSDB) method was applied to the ODS steel (16Cr-4Al-2W-0.35Y<sub>2</sub>O<sub>3</sub>), and the mechanism of high performance properties of the ODS steels has been investigated by means of high-resolution TEM microstructure observation.

Structure determination and chemical analysis of nano-scaled oxide particles in an ODS steel, which demonstrates much higher performance than ordinary ferritic steel, were carried out by means of high resolution TEM examinations. It was shown that the higher strength of the ODS steels was due to good coherency of fine oxide particles of Y<sub>2</sub>TiO<sub>5</sub> and Y<sub>2</sub>Ti<sub>2</sub>O<sub>7</sub> with the matrix of the ODS steel.

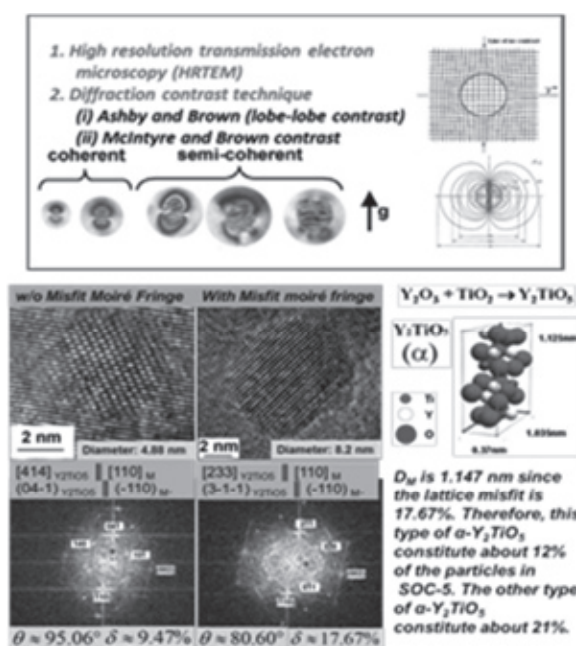


Fig. 1 Oxide particles in an ODS steel (Fe-15Cr-4Al-2W-0.1Ti-0.35Y<sub>2</sub>O<sub>3</sub>) and evaluation of coherency between the particles and matrix.

FSW was performed for an ODS steel with high Cr concentration at a rotating speed of 800 rpm with a line-scanning speed of 50 mm/min. The FSW treatment resulted in a growth of the grains, and consequently, a remarkable reduction of the strength at RT. However, the reduction of strength at elevated temperatures was so small that the FSW is adequate for the application of ODS steels to practical blanket fabrication.

SSDB was carried out at 1200°C at 25MPa for 1 hr with and without insert material. Since the melting temperature of the insert material was lower than 1200°C, the insert material is melted and the method is often called as transient liquid phase bonding (TLPB). Tensile strength of both the SSDB and TLPB was not degraded by the bonding treatment. The elongation of TLPB was reduced to about a half of the material. However, the elongation of SSDB was not reduced at all, indicating the SSDB joining method is very suitable for ODS steels.

### 3. Damage rate dependence of defect cluster nucleation in tungsten during irradiation

Component materials of nuclear fusion reactors suffer from the bombardment of high energy particles. In irradiated materials, a variety of point defects such as interstitials, vacancies, helium and hydrogen gas atoms are produced by atomic displacements and nuclear transformation.

Tungsten (W) is proposed as one of the candidates for the first wall protection in fusion power plants. In irradiated tungsten at temperatures where vacancies can move, voids (vacancy clusters) are experimentally observed by transmission electron microscopy (TEM). Voids induce swelling, which leads to the dimensional changes of the material.

In the present study, kinetic Monte-Carlo (KMC) simulations were performed to evaluate void nucleation process in W during irradiation, in order to understand void formation mechanism. The growth or shrinkage of a void is determined by a balance between the influx and outflux of point defects into and from the void, respectively. The influx of point defects into a void is given by  $4\pi RD_k C_k$  in the unit of  $s^{-1}$ , where  $C_k$  is the concentration of type  $k$  point defect in the matrix which depends on irradiation condition.  $C_k$  is usually obtained by solving the following simultaneous rate equations applied to the system:

$$\frac{dC_I}{dt} = P - \frac{4\pi r_0}{\Omega} (D_I + D_V) C_I C_V - K_{SI} D_I C_I$$

$$\frac{dC_V}{dt} = P - \frac{4\pi r_0}{\Omega} (D_I + D_V) C_I C_V - K_{SV} D_V C_V$$

On the other hand, the outflux of point defects from a void is provided by the binding energy of point defects to a void, which was previously obtained by classical MD and ab-initio calculations.

The nucleation rate of voids depends on temperature and the sink concentration of a system. It is found that the nucleation rate is a decreasing function of temperature, and it is also a decreasing function of sink strength. A more interesting point here is the dependence of nucleation rates on damage rate described by dpa/s, as shown in Fig. 2. When the sink strength is relatively low, the nucleation rate is in proportion to the damage rate, while when the sink concentration is high, the nucleation rate is in proportion to the square of damage rate. All of these findings have not been obtained by the conventional nucleation theory that assumes the steady-state condition for embryo growths.

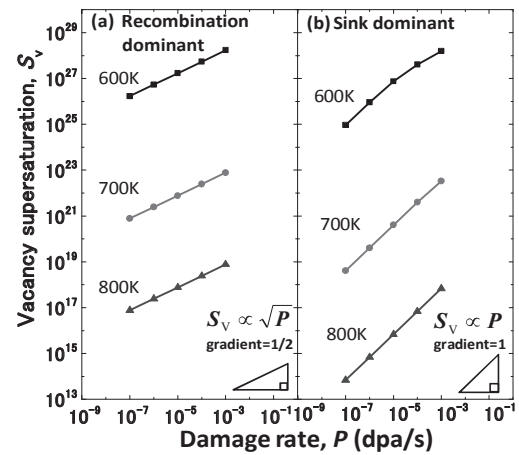


Fig. 2 Damage rate dependence of void nucleation rates as a function of sink strength

### 4. Nanoindentation test method R&D

The irradiation hardening behavior of reduced-activation ferritic steels was investigated by means of nanoindentation test technique utilizing DuET facility. The ion-irradiation experiments were conducted at 290 °C with 6.4 MeV  $Fe^{3+}$  ions up to 3 dpa at a 600 nm depth from the irradiated surface. Furthermore, these experiments were conducted with and without simultaneous energy-degraded 1 MeV  $He^+$  ions up to 300 appm. The materials used were F82H, F82H+1Ni, and F82H+2Ni to investigate the effect of Ni addition on the irradiation hardening behavior.

The measured nanoindentation hardness was converted to the bulk-equivalent hardness based on a combination of the Nix-Gao model to explain the indentation size effect and the composite hardness model to explain the softer substrate effect of the non-irradiated region beyond the irradiated depth range. It is clearly shown that the Ni addition enhances the irradiation hardening of F82H. The effect of simultaneously-implanted helium on the irradiation hardening is negligible in the investigated irradiation conditions.

## Collaboration Works

韓国原子力研究所（大韓民国），Effects of neutron irradiation on ODS ferritic steels（先進鉄鋼材料の照射効果研究），木村晃彦

Illinois大学（米国），ODS steels R&D for next generation nuclear systems，木村晃彦

Russian Research Center, Kurchatov Institute (Russia), Irradiation effects on high Cr ODS steels，木村晃彦

UCSB (USA), Advanced ferritic steels R&D，木村晃彦

韓国先進科学技術大学（大韓民国），Corrosion behavior of advanced ferritic steels，木村晃彦

PSI（スイス），In-situ creep behavior of ODS steels under ion irradiations，木村晃彦

Pacific Northwest 国立研究所（米国），Resistance to neutron irradiation in ODS ferritic steels，木村晃彦

KAIST（大韓民国），Corrosion Properties of Nuclear Materials，木村晃彦

中国科学技術院近代物理研究所（中華人民共和国），Helium Implantation Experiment on Advanced ferritic steels，木村晃彦

Nuclear Materials Research Division ,KAERI,（大韓民国），Evaluation of radiation tolerance of ODS steels under neutron irradiation，木村晃彦

CEA/DEN/SACLAY/DMN/SRMP（フランス），Hydrogen and Helium Implantation Experiment on Nano-scaled Oxide Dispersion Strengthened Steels，木村晃彦

Mechanical Properties and Mechanics Group ORNL（米国），Evaluation of radiation tolerance of ODS steels under neutron irradiation，木村晃彦

Nuclear Materials Research Division ,KAERI（大韓民国），Evaluation of radiation tolerance of ODS steels under neutron irradiation，木村晃彦

CEA/DEN/SACLAY/DMN/SRMP（フランス），Hydrogen and Helium Implantation Experiment on Nano-scaled Oxide Dispersion Strengthened Steels，木村晃彦

Mechanical Properties and Mechanics Group ORNL（米国），Evaluation of radiation tolerance of ODS steels under neutron irradiation，木村晃彦

核融合科学研究所，核融合ブランケット接合・被覆材料の中性子照射影響評価，木村晃彦

核融合科学研究所，低放射化構造材料のW被覆プロセス技術開発研究，木村晃彦

東北大学金属材料研究所・共同利用，核融合炉用鉄鋼材料の接合被覆界面における照射・環境影響評価，木村晃彦，笠田竜太

東北大学金属材料研究所・共同利用，軽水炉寿命延長時における圧力容器の照射脆化支配因子の検討，木村晃彦，笠田竜太

東北大学金属材料研究所・共同利用，先進原子力システム用ナノ酸化物粒子分散強化鋼における照射効果，木村晃彦，笠田竜太

九州大学応用力学研究所・共同研究，タングステン被覆低放射化材料の接合界面における微細組織-力学特性相関，木村晃彦，笠田竜太

九州大学応用力学研究所・共同研究，タングステン被覆低放射化材料の高熱負荷特性，笠田竜太，木村晃彦

京都大学原子炉実験所・共同研究，陽電子消滅法を用いた Fe/Cr 相分離検出に関する研究，木村晃彦，笠田竜太

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### 1. Grant-in-Aid for Scientific Research

森下和功，基盤研究(C)，照射下材料内の非平衡欠陥集合体核生成の機構論的解明と体系化

藪内聖皓，特別研究員奨励費，高経年化原子炉圧力容器鋼の照射脆化に及ぼす Mn 影響の解明

### 2. Others

木村晃彦，文部科学省，先端研究施設共用促進事業

森下和功，受託研究（(株)三菱総合研究所），平成 23 年度高経年化技術評価高度化事業（経年プラントの安全評価の体系化に関する調査研究）

木村晃彦, 共同研究 ((独) 日本原子力研究開発機構), 破壊靱性に関する微小試験片の試験技術開発 (1)

木村晃彦, 共同研究 ((独) 日本原子力研究開発機構), 低放射化フェライト鋼の照射下挙動評価に関する研究

木村晃彦, 共同研究 ((株) 原子力安全システム研究所), 原子炉容器鋼の照射脆化におよぼす応力の影響

木村晃彦, 奨学寄附金 (日本核燃料開発 (株)), 原子力エネルギー材料に関する研究助成

## Publications

L. Hsiung, M. Fluss, S. Tumey, J. Kuntz, B. El-Dasher, M. Wall, B. Choi, A. Kimura, F. Willaime, Y. Serruys, HRTEM study of oxide nanoparticles in K3-ODS ferritic steel developed for radiation tolerance, *Journal of Nuclear Materials*, 409, 72-79, 2011

K. Yabuuchi, M. Saito, R. Kasada, A. Kimura, Neutron irradiation hardening and microstructure changes in Fe-Mn binary alloys, *Journal of Nuclear Materials*, 414, 498-502, 2011

P. Dou, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Effects of extrusion temperature on the nano-mesoscopic structure and mechanical properties of an Al-alloyed high-Cr ODS ferritic steel, *Journal of Nuclear Materials*, 417, 166-170, 2011

J. Isselin, R. Kasada, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Evaluation of fracture behavior of recrystallized and aged high-Cr ODS ferritic steels, *Journal of Nuclear Materials*, 417, 185-188, 2011

N.Y. Iwata, T. Liu, P. Dou, R. Kasada, A. Kimura, T. Okuda, M. Inoue, F. Abe, S. Ukai, S. Ohnuki, T. Fujisawa, Effects of MA environment on the mechanical and microstructural properties of ODS ferritic steels, *Journal of Nuclear Materials*, 417, 162-165, 2011

R. Kasada, S.G. Lee, J. Isselin, J.H. Lee, T. Omura, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Anisotropy in tensile and ductile-brittle transition behavior of ODS ferritic steels, *Journal of Nuclear Materials*, 417, 180-184, 2011

B.J. Kim, R. Kasada, A. Kimura, H. Tanigawa,

Effects of cold work and phosphorous on the ductile to brittle transition behavior of F82H steels, *Journal of Nuclear Materials*, 417, 135-139, 2011

B.J. Kim, R. Kasada, A. Kimura, H. Tanigawa, Effects of specimen size on fracture toughness of phosphorous added F82H steels, *Fusion Engineering and Design*, 86, 2403-2408, 2011

A. Kimura, R. Kasada, N. Iwata, H. Kishimoto, C.H. Zhang, J. Isselin, P. Dou, J.H. Lee, N. Muthukumar, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, T.F. Abe, Development of Al added high-Cr ODS steels for fuel cladding of next generation nuclear systems, *Journal of Nuclear Materials*, 417, 176-179, 2011

L.H. Lee, R. Kasada, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Influence of alloy composition and temperature on corrosion behavior of ODS ferritic steels, *Journal of Nuclear Materials*, 417, 1225-1228, 2011

T. Nagasaka, T. Muroga, H. Watanabe, R. Kasada, N. Iwata, A. Kimura, Mechanical properties of V-4Cr-4Ti alloy after first-wall coating with tungsten, *Journal of Nuclear Materials*, 417, 306-309, 2011

N. Muthukumar, J.H. Lee, A. Kimura, SCC behavior of austenitic and martensitic steels in supercritical pressurized water, *Journal of Nuclear Materials*, 417, 1221-1224, 2011

T. Nishitani, H. Tanigawa, T. Nozawa, S. Jitsukawa, M. Nakamichi, T. Hoshino, T. Yamanishi, N. Baluc, A. Möslang, R. Lindou, S. Tosti, E.R. Hodgson, S. Clement Lorenzo, A. Kohyama, A. Kimura, T. Shikama, K. Hayashi, M. Araki, Recent progress in blanket materials development in the Broader Approach activities, *Journal of Nuclear Materials*, 417, 1331-1335, 2011

S.H. Noh, R. Kasada, A. Kimura, S.H.C. Park, S. Hirano, Microstructure and mechanical properties of friction stir processed ODS ferritic steels, *Journal of Nuclear Materials*, 417, 245-248, 2011

M. Nono, T. Nakajima, M. Iwama, R. Kasada, A. Kimura, SCC behavior of SUS316L in the high temperature pressurized water environment, *Journal of Nuclear Materials*, 417, 878-882, 2011

N. Oono, S.H. Noh, N. Iwata, T. Nagasaka, R. Kasada, A. Kimura, Microstructures of brazed and solid-state diffusion bonded joints of tungsten with oxide dispersion strengthened steel, *Journal of Nuclear Materials*, 417, 253-256, 2011



- E. Wakai, S. Nogami, R. Kasada, A. Kimura, H. Kurishita, M. Saito, Y. Ito, F. Takada, K. Nakamura, J. Molla, P. Garin, Small specimen test technology and methodology of IFMIF/EVEDA and the further subjects, *Journal of Nuclear Materials*, 417, 1325-1330, 2011
- K. Yabuuchi, H. Yano, R. Kasada, H. Kishimoto, A. Kimura, Dose dependence of irradiation hardening of binary ferritic alloys irradiated with Fe<sup>3+</sup> ions, *Journal of Nuclear Materials*, 417, 988, 991, 2011
- C.H. Zhang, A. Kimura, R. Kasada, J. Jang, H. Kishimoto, Y.T. Yang, Characterization of the oxide particles in Al-added high-Cr ODS ferritic steels, *Journal of Nuclear Materials*, 417, 221-224, 2011
- J. Isselin, R. Kasada, A. Kimura, Work Hardening, Sensitization, and Potential Effects on the Susceptibility to Crack Initiation of 316L Stainless Steel in BWR Environment, *Journal of Nuclear Science and Technology*, 48, 12, 1462-1470, 2011
- A. Kimura, R. Kasada, S.H. Noh, S. Ukai, S. Ohnuki, N. Hashimoto, T. Shibayama, H. Kurishita, A. Hasegawa, S. Nogami, M. Satoh, Y. Ueda, K. Okuno, Y. Ohya, Y. Hatano, H. Watanabe, N. Yoshida, T. Tokunaga, T. Nagasaka, N. Ashikawa, M. Tokitani, T. Muroga, A. Sagara, W-coating on Low Activation Structural Materials, *Annual Report of National Institute for Fusion Science (April 2010-March 2011)*, 221, 2011
- A. Kimura, R. Kasada, S.H. Noh, H. Kurishita, M. Yamazaki, M. Narui, S. Ukai, S. Ohnuki, N. Hashimoto, T. Shibayama, A. Hasegawa, S. Nogami, M. Satoh, Y. Ueda, K. Okuno, Y. Ohya, Y. Hatano, H. Watanabe, N. Yoshida, T. Tokunaga, T. Nagasaka, N. Ashikawa, M. Tokitani, T. Muroga, A. Sagara, Irradiation Effects on Joining/Coating of Low Activation Structural Materials, *Annual Report of National Institute for Fusion Science (April 2010-March 2011)*, 549, 2011
- K. Okuno, T. Terai, T. Kunugi, Y. Hatano, A. Kimura, A. Hasegawa, A. Sagara, T. Muroga T., Integration of Tritium, Irradiation and Thermofluid Research, *Annual Report of National Institute for Fusion Science (April 2010-March 2011)*, 305, 2011
- T. Shikama, H. Kurishita, M. Yamazaki, M. Hatakeyama, M. Narui, M. Watanabe, S. Nagata, M. Chou, A. Hasegawa, Y. Hatano, H. Atsumi, A. Kimura, I. Takagi, K. Sato, S. Ohnuki, H. Watanabe, Y. Ueda, T. Terai, T. Oda, Y. Oya, B. Tsuchiya, T. Nishitani, T. Muroga, Advanced Evaluation of Radiation Effects on Fusion Materials, *Annual Report of National Institute for Fusion Science (April 2010-March 2011)*, 548, 2011
- B. El-Dasher, J. Farmer, J. Ferreira, M.S. Caro, A. Rubenchik, A. Kimura, Corrosion of oxide dispersion strengthened iron-chromium steels and tantalum in fluoride salt coolant: An in situ compatibility study for fusion and fusion-fission hybrid reactor concepts, *Journal of Nuclear Materials*, 419, 15-23, 2011
- N. Oono, R. Kasada, T. Higuchi, K. Sakamoto, M. Nakatsuka, A. Hasegawa, S. Kondo, H. Matsui, A. Kimura, Irradiation hardening and microstructure evolution of ion-irradiated Zr-hydride, *Journal of Nuclear Materials*, 419, 366-370, 2011
- B.J. Kim, R. Kasada, A. Kimura, H. Tanigawa, Evaluation of grain boundary embrittlement of phosphorus added F82H steel by SSTT, *Journal of Nuclear Materials*, 421, 153-159, 2012
- 木村晃彦, 材料が支える原子力システム--信頼性の向上のために--, *日本原子力学会誌*, 53, 11, 56-60, 2011
- Y. Watanabe, K. Morishita, A. Kohyama, Composition Dependence of Formation Energy of Self-interstitial Atom Clusters in  $\beta$ -SiC: Molecular dynamics and molecular statics calculations, *Journal of Nuclear Materials*, 417, 1119-1122, 2011
- D. Kato, H. Iwakiri, K. Morishita, Formation of vacancy clusters in tungsten crystals under hydrogen-rich condition, *Journal of Nuclear Materials* (accepted), 2011
- Y. Watanabe, K. Morishita, Y. Yamamoto, Nucleation and growth of self-interstitial atom clusters in  $\beta$ -SiC during irradiation: Kinetic Monte-Carlo modeling, *Nuclear Instruments and Methods in Physics Research, B*, 269, 1698-1701, 2011

## Presentations

- A. Kimura, A brief review of Super ODS steels R&D and proposal of irradiation experiments, IAEA Research Coordination Meeting (RC-1186.1) on Benchmarking of Structural Materials Pre-selected for Advanced Nuclear Reactors, IAEA-HQ, Vienna, Austria, 2011.5.3
- H.I. Je, A. Kimura, The Strain Rate Effect on High-Temperature Tensile Properties of High-Cr Oxide Dispersion Strengthened Steels, 3rd G-COE International Symposium (Specially Jointed with BK21 Program at Ajou University) – “ZERO CARBON ENERGY 2011” –, Ajou University, Suwon, Korea, 2011.8.18-19

H. Noto, Grain refinement of 9Cr-ODS ferritic steels by Transient Liquid Phase (TLP) bonding for Fusion Reactor, 3rd G-COE International Symposium (Specially Jointed with BK21 Program at Ajou University) – “ZERO CARBON ENERGY 2011” –, Ajou University, Suwon, Korea, 2011.8.18-19

Y. Yamamoto, K. Morishita, Y. Izumi, Y. Watanabe, Monte-Carlo simulation of void nucleation in nuclear materials during irradiation, The 3rd International Symposium: Kyoto University Global COE Program of Energy Science, Ajou University, Korea, GCOE, Kyoto University, 2011.8.18-19

木村晃彦, 原子力材料講義, 福島高専インターンシップ事業: 原子力材料講義, 京都大学おうばくプラザ, 2011.8.23-26

森下和功, 材料照射損傷挙動のマルチスケールモデリングと照射相関則の構築, 第6回原子力科学技術に関する連携重点研究討論会および成果報告会, 茨城県ひたちなか市ホテルクリスタルパレス, 2011.8.25

渡辺淑之, 森下和功, 核融合炉材料研究分野における BA-CSC の利用について, 核融合エネルギーフォーラム モデリング・シミュレーションサブクラスター平成23年度第1回会合, 日本原子力研究開発機構東京事務所, 2011.8.29

笠田竜太, 佐藤紘一, 原子力機器用鉄クロム系材料の相分離現象に関する基礎的研究, 日本原子力学会 2011 年秋の大会, 北九州国際会議場, 2011.9.19-22

樋口徹, 坂本寛, 中司雅文, 笠田竜太, 長谷川晃子, 近藤創介, 大野直子, 橋富興宣, 松井秀樹, 木村晃彦, 牟田浩明, 木村裕明, ジルコニウム水素化物の超微小硬さに及ぼすイオン照射効果, 日本原子力学会 2011 年秋の大会, 北九州国際会議場, 2011.9.19-22

徳永知倫, 光原昌寿, 中島英治, 渡辺英雄, 吉田直亮, 長坂琢也, 時谷政行, 増崎貴, 笠田竜太, 高畠剛, 黒木信義, 江里幸一郎, 鈴木哲, 秋場真人, VPS-W 被覆低放射化フェライト・マルテンサイト鋼の開発, 日本原子力学会 2011 年秋の大会, 北九州国際会議場, 2011.9.19-22

渡辺淑之, 森下和功, 山本泰功, 徐ギュウ, 義家敏正, 核融合炉内材料の点欠陥挙動の数値解析, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場, 2011.9.19-22

森下和功, 山本泰功, 泉裕太, 渡辺淑之, 照射材料中の欠陥集合体の核生成シミュレーション, 日本原子力学会「2011 年秋の大会」, 北九州国際

会議場, 2011.9.19-22

山本泰功, 岩切宏友, 泉裕太, 森下和功, 渡辺淑之, 金田保則, 加藤太治, ジルコニウム中の欠陥エネルギー論, 日本原子力学会「2011 年秋の大会」, 北九州国際会議場, 2011.9.19-22

K. Yabuuchi, R. Kasada, A. Kimura, Effects of Mn on the microstructural evolution of bcc Fe irradiated by neutrons and Fe<sup>3+</sup> ions, Workshop on Ion Implantation as a Neutron Irradiation Analogue, Oxford University, Oxford, UK, 2011.9.26-28

A. Kimura, Materials Science and Technology Development for Nuclear Energy, 2nd International Symposium of Advanced Energy Science - Zero emission energy -present and future-, Ohbaku Plaza, Kyoto University, 2011.9.27-28

M. Ando, H. Sakasegawa, H. Tanigawa, R. Kasada, Effect of Micro-Segregation on Irradiation Hardening in Ion-Irradiated RAFM Steel, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Mariotto, Charleston, SC, USA, 2011.10.16-22

P. Dou, A. Kimura, R. Kasada, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Phase and Metal/Oxide Interface Structure of Nanoparticles in High-Cr Oxide Dispersion Strengthened Ferritic Steels with Different Titanium Contents, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Mariotto, Charleston, SC, USA, 2011.10.16-22

M.J. Fluss, L. Hsiung, S. Tumey, Y. Serruys, F. Willaime, A. Kimura, Dual (He + Fe) and Triple (H + He + Fe) Ion-Beam Implantation of ODS Steels, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Mariotto, Charleston, SC, USA, 2011.10.16-22

Y. Himei, S. H. Noh, R. Kasada, A. Kimura, K. Yabuuchi, T. Nagasaka, S. Nogami, Interfacial Shear Strength of W-Coated ODS Steel and Ion Irradiation Effects of Tungsten, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Mariotto, Charleston, SC, USA, 2011.10.16-22

Q. Huang, N. Baluc, Y. Dai, S. Jitsukawa, A. Kimura, R.J. Kurtz, R. Lindau, T. Muroga, G.R. Odette, B. Raj, R.E. Stoller, L. Tan, H. Tanigawa, A.-A.F. Tavassoli, F. Wan, Y. Wu, Recent Progress of R&D Activities on Reduced Activation Ferritic/Martensitic Steels, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Mariotto, Charleston, SC, USA, 2011.10.16-22

N.Y. Iwata, R. Kasada, A. Kimura, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Effects of Milling Parameters on the Microstructure and Charpy Impact Properties of MA/ODS Ferritic Steels, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

H.I. Je, R. Kasada, A. Kimura, The Effect of Strain Rate on the High Temperature Tensile Properties of ODS Ferritic Steels, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

R. Kasada, Y. Takayama, Y. Sakamoto, Y. Himeji, K. Nakagawa, K. Yabuuchi, A. Kimura, Application of Nano-Indentation Technique to Investigate Irradiation Hardening of Ion-Irradiated Fusion Reactor Materials, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

B.J. Kim, R. Kasada, A. Kimura, E. Wakai, H. Tanigawa, Application of the Master Curve Method to the Evaluation of Fracture Toughness of F82H Steels, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

A. Kimura, R. Kasada, N. Iwata, J. Isselin, P. Dou, J.H. Lee, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, Dispersion Morphology Control for High Performance Oxide Dispersion Strengthened Ferritic Steels, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

A. Kimura, S. Noh, Y. Himeji, R. Kasada, K. Tokunaga, T. Tokunaga, H. Watanabe, N. Yoshida, T. Nagasaka, M. Tokitani, T. Muroga, S. Nogami, Y. Ueda, M. Sato, Y. Hatano, Y. Oya, System Integration Study of W-Armored Structure Components, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

Zinkle, A. Kimura, International ODS development program and advanced blanket designs, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

S.H. Noh, R. Kasada, A. Kimura, T. Nagasaka, M.A. Sokolov, Effects of Neutron Irradiation on Hardness of Vacuum Plasma Sprayed W-Coated ODS Ferritic

Steels, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

S.H. Noh, R. Kasada, A. Kimura, M.A. Sokolov, Hardness Distribution of Friction Stir Processed ODS Ferritic Steel after Neutron Irradiation, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

H. Noto, R. Kasada, A. Kimura, S. Ukai, Grain refinement of transient liquid phase bonding zone using ODS steel insert foil, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

N. Oono, R. Kasada, T. Higuchi, K. Sakamoto, M. Nakatsuka, A. Hasegawa, S. Kondo, N.Y. Iwata, H. Matsui, A. Kimura, Irradiation hardening and microstructure evolution of Ion-irradiated Zr-hydrides, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

Y. Oya, M. Shimada, T. Tokunaga, H. Watanabe, N. Yoshida, Y. Hatano, R. Kasada, T. Nagasaka, A. Kimura, K. Okuno, Behavior of Deuterium Retention and Surface Morphology for VPS-W/F82H, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

R. Pippan, St. Wurster, H. Li, N. Baluc, C. Garcia-Rosales, H. Kurishita, A. Kimura, A. Hasegawa, R.J. Kurtz, T. Crosby, M. Rieth, J.H. You, Recent Progress in R&D on Tungsten Alloys for Divertor Structural and Plasma Facing Components, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

M. Satou, T. Oniyangi, K. Abe, T. Nagasaka, R. Kasada, A. Kimura, Measurement of Bonding Strength between Tungsten Coating and Reduced Activation Ferritic Steel, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

Y. Takayama, Y. Sakamoto, R. Kasada, K. Yabuuchi, A. Kimura, M. Ando, D. Hamaguchi, H. Tanigawa, Nanoindentation hardness and its extrapolation to Vickers hardness of F82H steels after single- and dual-ion beam irradiation, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA,

2011.10.16-22

T. Tokunaga, H. Watanabe, T. Nagasaka, R. Kasada, N. Yoshida, M. Tokitani, M. Mitsuhashi, H. Nakashima, T. Takabatake, N. Kuroki, S. Masuzaki, K. Ezato, S. Suzuki, M. Akiba, Development of High-Grade VPS-Tungsten Coatings on F82H Reduced Activation Steel, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

H. Watanabe, T. Tokunaga, N. Yoshida, Y. Nagasaka, T. Muroga, R. Kasada, A. Kimura, The Microstructure of W Sprayed Low Activation V-4Cr-4Ti Alloys after Heat Load, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

K. Yabuuchi, R. Kasada, A. Kimura, The Effect of Mn Content on Microstructural Evolution in bcc Fe under Ion-Irradiation, 15th International Conference on Fusion Reactor Materials (ICFRM-15), Hotel Charleston Marriott, Charleston, SC, USA, 2011.10.16-22

Y. Yamamoto, K. Morishita, Y. Watanabe, Damage Rate Dependence of Defect Cluster Nucleation in Tungsten during Irradiation, 15th. International Conference on Fusion Reactor Materials (ICFRM-15), Charleston, USA, 2011.10.16-22

Y. Watanabe, K. Morishita, Y. Yamamoto, KMC Simulations of Defect Cluster Formation in  $\beta$ -SiC during Irradiation, 15th. International Conference on Fusion Reactor Materials (ICFRM-15), Charleston, USA, 2011.10.16-22

森下和功, 山本泰功, 泉裕太, 渡辺淑之, 高経年化対策に必要な材料照射相関則の構築, 日本保全学会第8回学術講演会, 学士会館, 2011.10.21

H.I Je, R. Kasada, A. Kimura, Strain Rate Effects on High-Temperature Tensile Properties of Several Types of Steels, 日本金属学会 2011 年秋期(第 149 回)講演大会, 沖縄コンベンションセンター, 2011.11.7-9

H. Noto, R. Kasada, A. Kimura, S. Ukai, ODS インサート材を用いた TLP 接合部微細化技術開発, 日本金属学会 2011 年秋期(第 149 回)講演大会, 沖縄コンベンションセンター, 2011.11.7-9

姫井善正, Noh Sanghoon, 笠田竜太, 木村晃彦, 藪内聖皓, 長坂琢也, 野上修平, W-ODS 鋼接合材の界面せん断応力と W のイオン照射効果, 日本金属学会 2011 年秋期(第 149 回)講演大会, 沖

縄コンベンションセンター, 2011.11.7-9

藪内聖皓, 笠田竜太, 木村晃彦, イオン照射した Fe-Mn 合金における転位ループの照射後焼鈍回復挙動, 日本金属学会 2011 年秋期(第 149 回)講演大会, 沖縄コンベンションセンター, 2011.11.7-9

坂本雄太, 笠田竜太, 木村晃彦, Fe-Cr 二元合金の時効硬化・照射硬化評価のためのナノインデンテーション硬さ-マイクロビッカース硬さと関連に関する研究, 日本金属学会 2011 年秋期(第 149 回)講演大会, 沖縄コンベンションセンター, 2011.11.7-9

A. Kimura, N. Hashimoto, S.H. Noh, K. Yabuuchi, H. Noto, R. Kasada, S. Nogami, H. Kurishita, T. Nagasaka, T. Yamamoto, M. Sokolov, Development and Integrity Assessment of Joints and Coatings of Advanced First-wall Structural Materials, The 2011 International Symposium on Advanced Engineering, Pukyong National University, Busan, Korea, 2011.11.10

木村晃彦, 橋本直幸, 長坂琢也, Task 2-2 : H23 年度活動状況報告および H24 年度提案, 2011 年度第 1 回日米協力 TITAN 計画国内研究者会議, 核融合科学研究所, 2011.11.18

木村晃彦, 栗下裕明, 長谷川晃, 上田良夫, 江里幸一郎, 増崎貴, PFM-W の材料科学-現状、課題、そして展望 22D15, プラズマ・核融合学会第 28 回年会, 石川県立音楽堂, 2011.11.22-25

A. Kimura, R. Kasada, N. Iwata, J. Isselin, P. Dou, J.H. Lee, T. Okuda, M. Inoue, S. Ukai, S. Ohnuki, T. Fujisawa, F. Abe, The Mechanism of Dispersion Strengthening in Super ODS Steel, 6th International Conference on Creep, Fatigue and Creep-Fatigue Interaction (CF-6), Radisson Blu Resort Temple Bay, Mamallapuram, Tamil Nadu, India, 2012.11.22-25

森下和功, 渡辺淑之, 濱口大, 谷川博康, 核融合材料設計に向けたマルチスケールモデリング, PLASMA 2011 (Plasma Conference), 金沢市, 石川県立音楽堂, 2011.11.22-25

木村晃彦, エネルギー事情と今後のエネルギー開発--福島県と共に考える--, 福島高専地域フォーラム<震災復興事業>市民への公開第 4 回福島高専・京大エネルギー理工学研究所との連携講演会原子力災害からの復興に向けて, グランパークホテルエクセルいわき, 2011.11.26

泉裕太, 山本泰功, 渡辺淑之, 森下和功, Zr 合金の酸化膜成長速度, 軽水炉燃料に関する研究会, 京都大学エネルギー理工学研究所, 京都府宇治市, 2011.11.30-12.1



山本泰功, 岩切宏友, 泉裕太, 渡辺淑之, 森下和功, 金田保則, 加藤太治, Zr 酸化膜の成長速度～ZrO<sub>2</sub> 中の欠陥エネルギー評価～, 軽水炉燃料に関する研究会, 京都大学エネルギー理工学研究所, 京都府宇治市, 2011.11.30-12.1

森下和功, 山本泰功, 阿部弘亨, 谷口良則, 土内義浩, 杉山智之, 天谷政樹, 宮野廣, 運用中の炉心・燃料の安全基準, 軽水炉燃料に関する研究会, 京都大学エネルギー理工学研究所, 京都府宇治市, 2011.11.30-12.1

能登裕之, 木村晃彦, 栗下裕明, W/ODS 鋼接合開発, LHD 計画共同研究第 3 回研究会兼 BA 研究会, 京都大学エネルギー理工学研究所, 2011.12.8

山本泰功, 泉裕太, 岩切宏友, 森下和功, 渡辺淑之, ジルコニウム酸化膜中の欠陥エネルギー論, 京都大学原子炉実験所ワークショップ「材料照射効果と応用」, 京都大学原子炉実験所, 2011.12.16

渡辺淑之, 森下和功, 濱口大, 谷川博康, 照射下材料ミクロ構造変化のモデル化, 京都大学原子炉実験所ワークショップ「材料照射効果と応用」, 京都大学原子炉実験所, 2011.12.16

森下和功, 宮野廣, 安全評価体系化 (使用済み燃料プール), 平成 23 年度高経年化対策強化基盤整備事業 第 2 回システム安全研究会, 東京大学工学部, 2011.12.21

木村晃彦, タングステン・ダイバータ研究開発, タングステン材料に関する合同研究報告会, 核融合科学研究所 LHD 計画共同研究中間報告会, 「核融合炉の中性子照射環境に対応した高熱流束機器用タングステン材料の開発と製造」, 原子力機構 BA 共同研究「タングステンプラズマ対向材料の評価と原型炉における課題の抽出, プラズマ・核融合学会, 「タングステン材料科学」専門委員会, 核融合科学研究所, 2011.12.22

森下和功, 宮野廣, 安全評価体系化 (軽水炉燃料の運用), 平成 23 年度高経年化対策強化基盤整備事業 第 1 回燃料検討会, 三菱総合研究所, 2011.12.27

A. Kimura, Fukushima Related Issue -- Hydrogen production at severe accident--, OECD/NEA Nuclear Science Committee Working Party on Scientific Issues of the Fuel Cycle (WPFC), Sixth Meeting of the Expert Group on Innovative Structure Materials, OECD/NEA, Paris, 2012.1.9

森下和功, 宮野廣, 燃料検討会での検討内容について, 平成 23 年度高経年化対策強化基盤整備事業 第 2 回燃料検討会, 三菱総合研究所, 2012.1.10

木村晃彦, 田中信夫, 斗内政吉, 築山光一, 庄子哲雄, 種村眞幸, 先端研究施設共用促進事業概要と六大学連携の趣旨について, 文部科学省先端研究施設共用促進事業先端研究施設共用促進事業連携シンポジウム～復興と新生のための科学技術支援と産学官連携促進～, 名古屋大学野依学術記念交流館, 2012.1.18

木村晃彦, 笠田竜太, 能登裕之, 姫井善正, Noh Sanghoon, 上田良夫, 長坂琢也, 時谷政行, 芦川直子, 相良明男, 室賀健夫, 渡辺英雄, 徳永和俊, 吉田直亮, 徳永知倫, 波多野雄治, 大矢恭久, 野上修平, 佐藤学, 鶴飼重治, 低放射化構造材料の W 被覆プロセス技術開発研究, 平成 23 年度 LHD 計画共同研究成果報告会, 核融合科学研究所, 2012.1.19

森下和功, 宮野廣, 安全評価体系化 (燃料運用基準と使用済み燃料プール), 平成 23 年度高経年化対策強化基盤整備事業 第 3 回燃料検討会, 三菱総合研究所, 2012.1.23

森下和功, 宮野廣, 安全評価体系化 (燃料プール), 平成 23 年度高経年化対策強化基盤整備事業 第 3 回システム安全研究会, 三菱総合研究所, 2012.1.23

森下和功, 宮野廣, 安全評価体系化 (燃料), 平成 23 年度高経年化対策強化基盤整備事業中間報告会, 三菱総合研究所, 2012.1.27

A. Kimura, N. Hashimoto, T. Nagasaka, T. Yamamoto, M. Sokolov, Task 2-2 Review: FuY 2011 accomplishments and annual program for work for FuY 2012, 6th Steering Committee Meeting of TITAN Program, Hilton Washington DC North/Gaithersburg, 2012.2.7-10

森下和功, 宮野廣, 安全評価体系化 (燃料), 平成 23 年度高経年化対策強化基盤整備事業システム安全研究会, 東京大学工学部, 2012.2.20

森下和功, 宮野廣, 安全評価体系化 (燃料), 平成 23 年度高経年化対策強化基盤整備事業 第 4 回燃料検討会, 三菱総合研究所, 2012.2.23

森下和功, 宮野廣, 安全評価体系化 (燃料), 平成 23 年度高経年化技術評価高度化事業成果報告会, 三菱総合研究所, 2012.2.27

岩田憲幸, 泉博之, 木村晃彦, ナノ酸化物粒子分散強化鉄鋼材料の生体内医療用材料としての適用性の検討, 京都大学学際融合教育研究推進センター生存基盤科学研究ユニット研究成果報告会, 京都大学おうばくプラザ, 2012.2.28-29

登尾一幸, 森下和功, 柴田敏宏, 小西哲之, 自然



環境中の物質移行モデルの高度化, 京都大学学際融合教育研究推進センター生存基盤科学研究ユニット研究成果報告会, 京都大学宇治おうばくプラザきはだホール, 2012.2.28-29

佐藤学, 鬼柳任, 長坂琢也, 笠田竜太, 木村晃彦, 低放射化フェライト鋼上に作製したタングステン皮膜の接合強度評価, 日本原子力学会 2012 年春の年会, 福井大学文京キャンパス, 2012.3.19-21

B.J. Kim, E. Wakai, R. Kasada, A. Kimura, Validation and evaluation of master Curve method to application for fusion structure materials in fracture toughness, 日本原子力学会 2012 年春の年会, 福井大学文京キャンパス, 2012.3.19-21

堀田智宏, 徳永和俊, 荒木邦明, 藤原正, 宮本好雄, 長谷川真, 中村一男, 江里幸一郎, 鈴木哲, 榎枝幹男, 秋場真人, 長坂琢也, 笠田竜太, 木村晃彦, 減圧プラズマ溶射タングステン被覆低放射化フェライト・マルテンサイト鋼の高熱負荷特性, 日本原子力学会 2012 年春の年会, 福井大学文京キャンパス, 2012.3.19-21

山本泰功, 岩切宏友, 森下和功, 渡辺淑之, 金田保則, 加藤太治, ジルコニウム酸化膜成長速度の応力依存性, 日本原子力学会「2012 春の年会」, 福井大学, 2012.3.19-21

Y. Watanabe, K. Morishita, A. Kohyama, Modeling and simulation of defects in SiC during irradiation, Korea-Japan Symposium 2012 on Advanced Energy System and Materials, Donggeui University, Busan, Korea, 京都大学エネルギー理工学研究所, 2012.3.26-27

H.I. Je, A. Kimura, Deformation and Fracture Behavior of ODS Ferritic Steels in Supercritical Pressurized Water, 日本金属学会 2012 年春期(第 150 回)大会, 横浜国立大学常盤台キャンパス, 2012.3.28-30

能登裕之, 木村晃彦, 栗下裕明, 松尾悟, 先進 W-1.1%TiC と低放射化 ODS フェライト鋼の固相拡散接合, 日本金属学会 2012 年春期(第 150 回)大会, 横浜国立大学常盤台キャンパス, 2012.3.28-30

A. Kimura, KIT-IAM/KU-IAE collaborative research activity--Energy Materials Science--, 2nd Japanese-German Presidents' Conference German-Japanese HeKKSAGOn Universities Consortium, 京都大学, 2012.3.29-30

## Complex Plasma Systems Research Section

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**1. Introduction**

This research section seeks to investigate the confinement optimization of “hot” plasma in the helical-axis heliotron line. For the experimental and theoretical investigation of this theme, the plasma device of Heliotron J has been operated at the Laboratory for Complex Energy Processes since FY2000. Recent results of Heliotron J plasma confinement in FY2011 are summarized as follows:

(1) Effects of neoclassical drift optimization on the global bulk plasma confinement are the key issues of Heliotron J experiments based on the bumpiness-toroidicity diagram of the collisionless particle flux by the Shaing & Hokin model. The low  $\epsilon_t$  and high  $\epsilon_b$  configuration has realized a high performance plasma of  $\langle\beta_{dia}\rangle \sim 0.8\%$  (5 kJ) at  $B=1.32$  T under the reheat-mode like conditions by using short and strong gas-puffing. (2) On the other hand, supersonic molecular beam injection (SMBI) as another method of gas fuelling could expand the operation region of Heliotron J, providing unique plasma evolution including an induced H-mode. The dynamic  $T_e$  variation in the core region is remarkable due to its beneficial effects of core fueling. In addition, moderate fueling by multiple SMBI allowed a stepwise growth of internal energy ( $W_p$ ) in ECH+NBI operation. Above a certain threshold density ( $n_e \sim 1.75 \times 10^{19} \text{ m}^{-3}$ ), this operation also resulted in H-mode plasma (simultaneous increases in density  $n_e$  and plasma energy  $W_p$  together with a reducing divertor probe array signals as well as a reducing  $H_\alpha$  signal within  $\sim 15$  ms. (3) Fast camera measurement systems have revealed that SMBI causes the reversal of the poloidal rotation of the filament structure of the edge plasma fluctuation. (4) AM reflectometer system has been developed to measure the temporal variation of plasma density profile. By using this system, the gas-puff modulation analysis for 0.3-MW ECH particle transport (pump-out) has been carried out and the obtained results revealed that the spatially constant particle diffusion coefficient  $D_{core} \approx 2.3 \text{ m}^2/\text{s}$  and the particle convection velocity  $V_{core} \approx 2.3 \text{ m/s}$  (outward) in the core region for  $n_e = 0.9 \times 10^{19} \text{ m}^{-3}$ , and that both  $D_{core}$  and  $V_{core}$  increase rapidly with a decrease in  $n_e$ . Here it is assumed that  $D(r) = D_{core}$  and  $V(r) = (r/a)V_{core}$  where  $D_{core}$  and  $V_{core}$  are constant in  $r/a < 0.6$ . (5) The

parallel (nearly, toroidal) velocity  $v_\phi$  of the fully stripped carbon species for co- (or ctr-) NBI plasmas was measured, simultaneously with  $T_i(\rho)$  in the almost whole radius, by the newly installed CXRS. The measured value of  $v_\phi$  showed a rather peaked radial profile with a peaked deposited beam torque. Furthermore, the edge rotation indicates non-zero positive value for both co- and ctr- injections, suggesting some contributions from radial electric field, diamagnetic, or turbulence. As for the configuration effects of toroidal rotation, the lower toroidal rotation was observed for the larger toroidal mirror ratio configuration (high-bumpy configuration) than that of the standard configuration (medium-bumpy configuration) or reversed toroidal mirror configuration. (6) A simple force balance between the beam torque and the neoclassical parallel viscous damping could not provide a reasonable explanation of the observed central toroidal rotation reduction by more than a factor of 10, as compared with neoclassical prediction, which depends on the toroidal mirror ratio. Parallel particle momentum given by NBI may be interpreted to be transported out of the plasma by the strong perpendicular momentum diffusive process and others. (7) A new approach to plasma startup using NBI assisted by 2.45 GHz microwaves was developed for high- $\beta$  experiments. (8) Characterization of energetic-ion-driven MHD instabilities (GAEs or EPMs) has progressed using magnetic probes, soft X-ray diagnostics, hybrid directional Langmuir probes, beam emission spectroscopy (BES), etc. and relevant simulations. For low-density NBI (co+ctr)-only plasmas, BES measurements showed that there exist at least three kinds of density fluctuations ( $\sim 90$  kHz,  $\sim 70$  kHz,  $\sim 20$  kHz) whose radial distributions are substantially different (A: broad, B: core, C: edge). (9) Electron cyclotron current drive (ECCD) experiments revealed that the EC driven current can be controlled by  $N_{||}$ , depending on the magnetic configuration. Comparative studies of experimental ECCD and TRAVIS-code predictions clarified the important role of trapped particles on ECCD.

**2. Energetic-ion-driven MHD Instabilities in Helical Plasmas with Low Magnetic Shear**

Most concepts of advanced helical plasma have a low magnetic shear in combination with a magnetic well for good stability against pressure-driven MHD instability and low toroidal field period  $N_p$  for both good particle confinement and MHD stability. The existence and stability of energetic-ion-driven MHD instabilities such as Alfvén eigenmodes (AEs), which would affect the transport of energetic ions including alpha particles in a fusion reactor, are characterized by the magnetic configuration. In order to clarify the energetic-ion-driven MHD instabilities in advanced helical plasmas, we have experimentally and numerically investigated the energetic-ion-driven MHD instabilities in Heliotron J and TJ-II (CIEMAT, Spain) under the international research collaboration. Both have three-dimensional magnetic configuration, low magnetic shear and  $N_p = 4$  to obtain good MHD stability. In addition, both share similar parameters such as plasma major radius, and energy and power of tangential NBI. The iota, which is the main difference between both devices and key parameter to characterize the shear Alfvén spectra, can be varied in the range 0.45~0.65 and 0.9~2.0 in the Heliotron J and TJ-II, respectively. The MHD instabilities destabilized by the energetic ions are observed in NBI-heated plasmas of Heliotron J and TJ-II. The frequency of observed modes is in the range of Alfvén frequency and inversely proportional to the square root of density. In order to identify the observed mode, we have compared the experimental results and numerical simulations by STELLGAP and AE3D code where we took into account three-dimensional magnetic configuration which leads to the both poloidal and toroidal mode coupling of each shear Alfvén wave. In the case of Heliotron J, we only found the global AE (GAE), whose frequency is lying just below the shear Alfvén continuum of  $m=2/n=1$  as shown in Figs.1 (a) and (b). Figures 1 (a) and (b) show the radial profile of the displacement of discrete eigenfunction, which is mainly composed by the  $m=2/n=1$  component and corresponds to the GAE, and shear Alfvén continua of each Fourier component belonging to the same mode family  $N_f=1$ . Black broken line in Fig. 1(b) indicates the frequency of discrete eigenfunction shown in Fig. 1 (a). The frequency, mode number and radial structure of calculated GAE agree with the experimental results obtained from Mirnov coils and soft X-ray measurement. The observed modes are identified as GAE in the Heliotron J. It is presumed that the effect of toroidal mode coupling for GAE is fairly weak although  $N_p$  is small. HAE frequency is predicted above 500 kHz in the Heliotron J. On the other hand, in the case of TJ-II, we only found helicity-induced AEs (HAEs) with frequency similar to the experimental results in simulations. It seems that the observed mode in the TJ-II is HAE although there are uncertainty in both toroidal

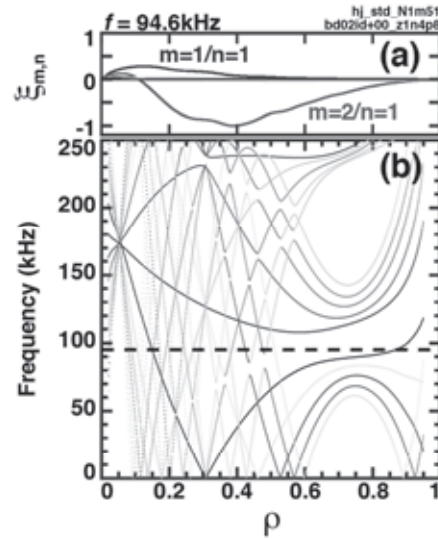


Fig.1. (a) Displacement profile of eigenfunction with  $f=95.6$  kHz and (b) Calculated shear Alfvén continua for mode family  $N_f=1$  of Heliotron J.

and poloidal mode number. To make more clear the effect of iota on AEs, we have performed iota scan experiments in both devices where the iota is scanned in the range of 0.47~0.63 in Heliotron J and 1.53~1.85 in TJ-II. Figures 2 (a) and (b) respectively show the GAE frequency as a function of iota in Heliotron J, obtained from numerical simulations and experiments, respectively. Experimental results show two trends that the GAE frequencies labeled A, and B and C in Fig. 2(b) respectively decrease and increase with an increase of iota. This is the same tendency found in the numerical simulations. The difference of the frequency dependence on iota can be explained by the difference of poloidal mode number of GAE, as shown in Fig. 2(b). In addition to the iota scan experiment shot by shot, we have performed dynamic iota scan experiments with constant density in time in TJ-II. We can actually follow the frequency change of observed modes in dynamic iota scan experiment. The observed frequency decreases as iota increases. This frequency dependence on iota can be explained by not GAE but HAE. From these results, the most unstable AE is GAE and HAE in configurations with low (iota~0.5) and high (iota~1.5) iota, respectively.

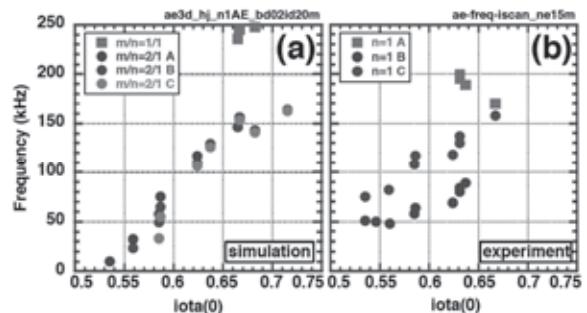


Fig. 2. Frequency of GAE obtained from (a) simulation and (b) experiment in Heliotron J.

## Collaboration Works

Univ. Wisconsin (米国), Univ. Wisconsin (米国), ORNL (米国), Max Planck Institute (ドイツ), Stuttgart Univ.(ドイツ), Provence Univ. (フランス), CIEMAT (スペイン), ANU (オーストラリア), Kharkov Institute (ウクライナ), SWIP (中華人民共和国), 先進ヘリカルにおける改善閉じ込めの研究, 佐野史道, 水内亨, 長崎百伸, 岡田浩之, 小林進二, 山本聡, D. Anderson (Univ. Wisconsin, USA), J.H. Harris (Oak Ridge National Laboratory, USA), F. Wagner, M. Hirsch, V. Erckmann, H. Laqua, N.B. Marushchenko (Max Plank Institute, Germany), M. Ramisch (Stuttgart Univ., Germany), J. Sanchez, E. Ascasibar, C. Hidalgo, T. Estrada, A. Cappa, A. Alonso (CIEMAT, Spain), B. Blackwell, D. Pretty, H. Punzmann (Australian National Univ., Australia), V. Chechkin, V. Pankratov (Kharkov Institute, Ukraine), X.R. Duan, Q.W. Yang, L.W. Yan, W.W. Xiao (Southwest Institute of Physics, China)

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核融合科学研究所, 先進ヘリカルによるプラズマ構造形成・不安定制御と閉じ込め磁場最適化の研究, 佐野史道, 水内亨, 長崎百伸, 花谷清, 岡田浩之, 南貴司, 小林進二, 山本聡

核融合科学研究所, 高速カメラによる Heliotron J 周辺プラズマの研究, 水内亨, 佐野史道, 岡田浩之, 小林進二, 山本聡, 長崎百伸, 南貴司

核融合科学研究所, Heliotron J 装置における電極バイアスによる径方向電場制御, 佐野史道, 水内亨, 岡田浩之, 長崎百伸, 小林進二, 山本聡

核融合科学研究所, ヘリオトロン J における高効率燃料供給に向けたペレット入射の検討, 水内亨, 岡田浩之, 佐野史道

核融合科学研究所, 極低磁場での電子バーンシュタイン波加熱のヘリオトロン J プラズマ閉じ込めへの影響, 長崎百伸, 山本聡, 佐野史道, 水内亨, 岡田浩之, 南貴司, 小林進二

核融合科学研究所, ヘリオトロン J, CHS, LHD 装置における重水素プラズマの粒子輸送の研究, 南貴司, 佐野史道, 水内亨, 長崎百伸, 小林進二, 岡田浩之, 山本聡

核融合科学研究所, 弱磁場ヘリオトロン非中性プラズマ実験のまとめと閉じ込め時間測定のための誘導電荷法の検討, 佐野史道, 水内亨, 岡

田浩之, 小林進二, 山本聡

核融合科学研究所, ヘリオトロン J での反転磁気シア配位プラズマ生成とアルヴェン固有モード特性, 山本聡, 長崎百伸, 小林進二, 佐野史道, 水内亨, 岡田浩之, 南貴司

核融合科学研究所, 方向性プローブを用いた揺動による粒子異常輸送の研究, 佐野史道, 水内亨, 長崎百伸, 岡田浩之, 花谷清, 南貴司, 小林進二, 山本聡

核融合科学研究所, ヘリオトロン J プラズマにおける放射損失の空間構造とその動態に関する研究, 長崎百伸, 山本聡, 佐野史道, 水内亨, 岡田浩之

核融合科学研究所, 低磁気シアヘリオトロン配位における磁気島に対するプラズマ応答の研究, 佐野史道, 岡田浩之, 水内亨, 南貴司, 小林進二, 長崎百伸, 山本聡

核融合科学研究所, 閉じ込め磁場最適化研究に向けた非軸対称系新古典輸送理論の体系化と実験的検証, 岡田浩之, 小林進二, 山本聡, 花谷清, 南貴司

核融合科学研究所, ヘリオトロン J における密度分布の動的挙動と能動的制御に関する研究, 長崎百伸, 佐野史道, 水内亨, 岡田浩之, 小林進二

核融合科学研究所, Heliotron-J における閉じ込め改善モードへの遷移に対するポロイダルイオン粘性の役割の検証, 佐野史道, 水内亨, 岡田浩之, 山本聡, 小林進二, 長崎百伸, 南貴司

核融合科学研究所, ヘリオトロン J 装置における ICRF 加熱を用いた高速イオン閉じ込めの磁場最適化研究, 岡田浩之, 佐野史道, 花谷清, 水内亨, 南貴司, 小林進二, 長崎百伸, 山本聡

核融合科学研究所, トリムコイルを用いたヘリオトロン J の磁場配位最適化, 佐野史道, 水内亨, 長崎百伸, 花谷清, 岡田浩之, 南貴司, 小林進二, 山本聡

核融合科学研究所, 低磁気シアプラズマにおける高速イオンと高速イオン励起 MHD 不安定性の相互作用に関する研究, 山本聡, 小林進二, 岡田浩之, 南貴司, 佐野史道, 水内亨, 長崎百伸

核融合科学研究所, ヘリカル系における電子サイクロトロン電流駆動による回転変換制御, 長崎百伸, 佐野史道, 増田開, 水内亨, 花谷清, 岡田浩之, 南貴司, 小林進二, 山本聡



核融合科学研究所, ヘリカル系プラズマにおけるトロイダル電流の MHD と閉じ込めへの影響, 小林進二, 山本聡

核融合科学研究所, データマイニング法を用いた LHD プラズマの MHD 安定性解析, 山本聡

核融合科学研究所, LHD プラズマにおけるヘリシティ誘起アルヴェン固有モードの特性解明, 山本聡

核融合科学研究所, 高速イオン荷電交換分光計測におけるバルクイオン起源のハロー中性粒子の影響, 小林進二, 山本聡

核融合科学研究所, 高エネルギー粒子閉じ込めの物理機構解明と高性能化, 山本聡, 小林進二

核融合科学研究所, 2.45GHz マイクロ波入射アシストによる NBI プラズマ生成, 長崎百伸, 小林進二, 増田開, 佐野史道, 水内亨, 岡田浩之, 南貴司, 山本聡

## Financial Support

佐野史道, 共同研究 (核融合科学研究所), 双方向型共同研究「先進ヘリカルによるプラズマ構造形成・不安定制御と閉じ込め磁場最適化の研究」ほか

## Publications

T. Mizuuchi, K. Nagasaki, H. Okada, S. Kobayashi, S. Yamamoto, T. Minami, S. Ohshima, M. Takeuchi, K. Mukai, H. Lee, L.G. Zang, K. Nomura, M. Suwa, K. Yamamoto, H. Yashiro, H. Yoshino, S. Arai, T. Kagawa, T. Minami, K. Mizuno, Y. Wada, H. Watada, N. Nishino, Y. Nakashima, K. Hanatani, Y. Nakamura, S. Konoshima, F. Sano, Recent Progress in Plasma Control Studies on the Improvement of Plasma Performance in Heliotron, PLASMA SCIENCE & TECHNOLOGY, 13, 1, 21-25, 2011

S. Kobayashi, K. Nagasaki, S. Yamamoto, K. Sakamoto, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, Y. Nakamura, S. Konoshima, S. Ohshima, M. Takeuchi, K. Mukai, H. Y. Lee, S. Kishi, K. Minami, Y. Takabatake, H. Yoshino, F. Sano, Plasma startup using neutral beam injection assisted by 2.45 GHz microwaves in Heliotron J, Nuclear Fusion, 51, 6, 62002, 2011

T. Mizuuchi, S. Kobayashi, M. Takeuchi, K. Mukai, N. Nishino, Y. Nakashima, S. Yamamoto, H. Okada, K. Nagasaki, T. Minami, S. Ohshima, S. Kishi, H. Lee, K. Minami, Y. Takabatake, Y. Nakamura, K. Hanatani,

S. Konoshima, F. Sano, Comparison between supersonic molecular-beam injection and conventional gas-puffing for plasma performance in Heliotron J, Journal of Nuclear Materials, 415, S443-S446, 2011

N. Nishino, T. Mizuuchi, M. Takeuchi, K. Mukai, Y. Takabatake, K. Nagasaki, S. Kobayashi, H. Okada, S. Ohshima, S. Yamamoto, T. Minami, K. Hanatani, S. Konoshima, Y. Nakamura, F. Sano, Peripheral plasma measurement during SMBI in Heliotron J using fast cameras, Journal of Nuclear Materials, 415, S447-S450, 2011

H. Okada, K. Nomura, H. Watada, S. Kobayashi, H. Lee, T. Mizuuchi, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, M. Takeuchi, S. Konoshima, T. Mutoh, K. Mukai, K. Yamamoto, M. Suwa, H. Yashiro, H. Yoshino, Y. Nakamura, K. Hanatani, F. Sano, Numerical Analysis of ICRF Minority Heating in Heliotron J, Plasma and Fusion Research, 6, S1, 2402063, 2011

Y. Suzuki, S. Sakakibara, K. Watanabe, Y. Narushima, S. Ohdachi, S. Yamamoto, H. Okada, LHD experiment group, Study of Magnetic Island Using a 3D MHD Equilibrium Calculation Code, Plasma and Fusion Research, 6, S1, 2402134, 2011

A.V. Melnikov, L.G. Eliseev, M.A. Ochando, K. Nagaoaka, E. Ascasibar, A. Cappa, F. Castejon, T. Estrada, C. Hidalgo, S.E. Lysenko, J.L.de Pablos, M.A. Pedrosa, S. Yamamoto, S. Ohshima, HIBP group and TJ-II team, A Quasi-Coherent Electrostatic Mode in ECRH Plasmas on TJ-II, Plasma and Fusion Research, 6, S1, 2402030, 2011

K. Mukai, K. Nagasaki, T. Mizuuchi, V. Zhuravlev, S. Ohshima, T. Fukuda, T. Minami, H. Okada, S. Kobayashi, S. Yamamoto, Y. Nakamura, K. Hanatani, S. Konoshima, M. Takeuchi, K. Mizuno, H. LEE, F. Sano, Electron Density Profile Behavior during SMBI Measured with AM Reflectometer in Heliotron J Plasma, Plasma and Fusion Research, 6, R1, 1402111, 2011

K. Nagasaki, S. Yamamoto, H. Yoshino, K. Sakamoto, N.B. Marushchenko, Y. Turkin, T. Mizuuchi, H. Okada, K. Hanatani, T. Minami, K. Masuda, S. Kobayashi, S. Konoshima, M. Takeuchi, Y. Nakamura, S. Ohshima, K. Mukai, H.Y. Lee, K. Mizuno, Y. Yoshimura, G. Motojima, A. Cappa, B.D. Blackwell, F. Sano, Influence of trapped electrons on ECCD in Heliotron J, Nuclear Fusion, 51, 10, 103035\_1-103035\_8, 2011

H. Lee, S. Kobayashi, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, Y. Nakamura, K. Hanatani,



S. Konoshima, S. Ohshima, K. Mukai, T. Kagawa, F. Sano, Measurement of Ion Temperature and Toroidal Rotation Velocity Using Charge Exchange Recombination Spectroscopy in Heliotron J, Plasma and Fusion Research, 7, 1402019, 2012

## Presentations

山本聡, LHD 高エネルギー粒子の物理グループ  
成果報告, LHD 成果報告会, 核融合科学研究所,  
2011.4.11-12

S. Ohshima, K. Hashimoto, M. Takeuchi, S. Yamamoto, S. Kobayashi, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, H. Matsuura, F. Sano, Edge Fluctuation Measurement using Multiple Langmuir Probes in Heliotron J, APTWG2011 1st Asia Pacific Transport Working Group (APTWG) International Conference, NIFS, 2011.6.14-17

K. Mukai, K. Nagasaki, T. Mizuuchi, V. Zhuravlev, S. Kobayashi, K. Tanaka, T. Minami, H. Okada, S. Yamamoto, Y. Nakamura, K. Hanatani, S. Konoshima, S. Ohshima, K. Mizuno, H.Y. Lee, L. Zang, S. Arai, T. Kagawa, T. Minami, H. Yashiro, Y. Wada, H. Watada, F. Sano, Density modulation experiment in Heliotron J, APTWG2011 1st Asia Pacific Transport Working Group (APTWG) International Conference, NIFS, 2011.6.14-17

H.Y. Lee, S. Kobayashi, T.Y. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, Y. Nakamura, K. Hanatani, S. Konoshima, S. Ohshima, K. Mukai, T. Kagawa, F. Sano, Measurement of ion temperature and toroidal rotation velocity in Heliotron J, APTWG2011 1st Asia Pacific Transport Working Group (APTWG) International Conference, NIFS, 2011.6.14-17

S. Ohshima, M. Takeuchi, S. Yamamoto, S. Kobayashi, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, H. Matsuura, F. Sano, Edge turbulence Study in Neutral Beam Heated Plasma of Heliotron J, 38th EPS Conference on Plasma Physics, Strasborug, France, 2011.6.27-7.1

S. Yamamoto, M. Suwa, S. Kobayashi, S. Ohshima, D. Spong, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, Y. Nakamura, S. Konoshima, K. Nagaoka, F. Sano, Studies of MHD instabilities destabilized by energetic ions in Heliotron J plasmas, 12th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems, Austin Texas, USA, 2011.9.7-11

山本聡, 小林進二, 大島慎介, 諏訪勝重, 安田圭

佑, E. Ascasíbar, R. Jiménez-Gómez, 永岡賢一, D. Spong, B. Blackwell, D. Pretty, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 中村祐司, 花谷清, 木島滋, 向井清史, 李炫庸, 佐野史道, 低磁気シアヘリカルプラズマにおける高速イオン励起 MHD 不安定性研究, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

香川輔, 小林進二, 門信一郎, 大石鉄太郎, 永榮蓉子, 大島慎介, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 中村祐司, 花谷清, H.Y. Lee, 南貴之, 向井清史, L. Zang, 荒井翔平, 八代浩彰, 和多田泰士, 和田善信, 水野浩志, 木島滋, 佐野史道, ヘリオトロン J におけるビーム放射分光計測システム開発, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

南貴司, 荒井翔平, 釦持尚輝, 八代浩彰, 高橋千尋, 小林進二, 水内亨, 岡田浩之, 長崎百伸, 中村祐司, 花谷清, 山本聡, 木島滋, 大島慎介, 佐野史道, Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状(1), PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

荒井翔平, 南貴司, 釦持尚輝, 八代浩彰, 高橋千尋, 小林進二, 水内亨, 大島慎介, 山本聡, 岡田浩之, 長崎百伸, 向井清史, 李炫庸, 臧臨閣, 香川輔, 水野浩二, 南貴之, 和多田泰士, 和田善信, 中村祐司, 花谷清, 木島滋, 佐野史道, Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状(2), PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

八代浩彰, 南貴司, 荒井翔平, 釦持尚輝, 水内亨, 高橋千尋, 長崎百伸, 佐野史道, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 香川輔, 水野浩志, 南貴之, 和多田泰士, 和田善信, 木島滋, 笠嶋慶純, 原田伴譽, 久田祥史, Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状 (3), PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

岡田浩之, 和多田泰士, 和田善信, 小林進二, 李炫庸, 水内亨, 長崎百伸, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, 臧臨閣, 八代浩彰, 南貴之, 香川輔, 荒井翔平, 水野浩志, 佐野史道, ヘリオトロン J における ICRF 加熱の共鳴位置による加熱特性の変化, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

李炫庸, 小林進二, 南貴之, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 大島慎介, 原田伴譽, 香川輔, 向井清史, Zang Linge, 木島滋, 佐野史道, ヘリオトロン J におけるトロイダル回転速度分布計測ならびに外部運動量入力計算, PLASMA 2011, 石川県立音楽

堂, 2011.10.22-25

南貴之, 小林進二, H.Y. Lee, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 大島慎介, 原田伴譽, 香川輔, 向井清史, L. Zang, 荒井翔平, 八代浩彰, 和多田泰士, 和田善信, 村上定義, 中村祐司, 花谷清, 木島滋, 佐野史道, ヘリオトロン J における荷電交換再結合分光による不純物イオン温度分布計測, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

水野浩志, 長崎百伸, 向井清史, 中村雄一, 福田武司, T. Estrada, 大島慎介, 水内亨, 南貴司, 岡田浩之, 増田開, 小林進二, 山本聡, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 中村祐司, 花谷清, 木島滋, 佐野史道, ヘリオトロン J におけるマイクロ波反射計を用いた電子密度揺動計測, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

向井清史, 長崎百伸, 水内亨, V. Zhuravlev, 田中謙治, 南貴司, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 水野浩志, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 木島滋, 佐野史道, ヘリオトロン J における ECH プラズマでの密度変調実験, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

和田善信, 岡田浩之, 長崎百伸, 山本聡, 水内亨, 南貴司, 小林進二, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 和多田泰士, 荒井翔平, 香川輔, 水野浩志, 南貴之, 八代浩彰, 中村祐司, 花谷清, 木島滋, 佐野史道, ヘリオトロン J における軟 X 線波高分析による高速電子エネルギー分布のピッチ角依存性, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

大島慎介, 橋本紘平, 山本聡, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 小林進二, 花谷清, 木島滋, 竹内正樹, 佐野史道, ヘリオトロン J 装置における静電プローブによる周辺プラズマ揺動計測とその構造の解明, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

和多田泰士, 岡田浩之, 小林進二, H.Y. Lee, 水内亨, 長崎百伸, 花谷清, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, L. Zang, 荒井翔平, 香川輔, 南貴之, 和田善信, 水野浩志, 佐野史道, ヘリオトロン J における ICRF 加熱での高速イオンのピッチ角及び空間位置依存性, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

西野信博, 臧臨閣, 竹内正樹, 水内亨, 大島慎介, 笠嶋慶純, 沙夢雨, 向井清史, 李炫庸, 長崎百伸, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 花谷清, 中村祐司, 佐野史道, ヘリオトロン J での高速カメラと静電プローブによるフィラメ

ント状周辺プラズマ揺動の研究(II), PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

長崎百伸, N. Marushchenko, 山本聡, 坂本欣三, Y. Turkin, 水内亨, 岡田浩之, 南貴司, 花谷清, 増田開, 小林進二, 木島滋, 大島慎介, 中村祐司, 向井清史, 李炫庸, 水野浩志, L. Zang, 荒井翔平, 香川輔, 南貴之, 水野浩志, 和田善信, 和多田泰士, T. Estrada, 村上定義, 吉村泰夫, 本島巖, 佐野史道, ヘリオトロン J における ECCD を用いた回転変換制御, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

臧臨閣, 竹内正樹, 西野信博, 水内亨, 大島慎介, 笠嶋慶純, 沙夢雨, 向井清史, 李炫庸, 長崎百伸, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 花谷清, 中村祐司, 佐野史道, Study of Filament Features of Edge Plasma Fluctuations using fast video cameras with a combination of Langmuir probe measurements in Heliotron J (I), PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

小林進二, 長崎百伸, 坂本欣三, 山本聡, 水内亨, 岡田浩之, 南貴司, 花谷清, 中村祐司, 木島滋, 大島慎介, 向井清史, Lee Hyunyoung, Zang Linge, 東使潔, 佐野史道, ヘリオトロン J における非共鳴マイクロ波入射アシストによる NBI プラズマ着火, PLASMA 2011, 石川県立音楽堂, 2011.10.22-25

T. Minami, S. Arai, N. Kenmochi, H. Yashiro, C. Takahashi, S. Kobayashi, T. Mizuuchi, S. Ohshima, S. Yamamoto, H. Okada, K. Nagasaki, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Present Status of the Nd:YAG Thomson Scattering System Development for Time Evolution Measurement of Plasma profile on Heliotron J, 8th General Scientific Assembly of the Asia Plasma and Fusion Association(APFA 2011), Cuilin, China, 2011.11.1-4

L.Zang, M. Takeuchi, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H.Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, Observation of Edge Plasma Fluctuations with Fast Camera in Heliotron J, 8th General Scientific Assembly of the Asia Plasma and Fusion Association(APFA 2011), Cuilin, China, 2011.11.1-4

T. Mizuuchi, S. Kobayashi, K. Mukai, S. Ohshima, S. Yamamoto, T. Minami, K. Nagasaki, H. Okada, K. Mizuno, H.Y. Lee, L. Zang, H. Yashiro, S. Arai, T. Kagawa, T. Minami, Y. Wada, H. Watada, K. Kasajima, N. Nishino, Y. Nakashima, K. Hanatani, Y. Nakamura, S. Konoshima, F. Sano, Effect of Gas Fueling Control on Plasma Performance in Heliotron J, 21th International Toki Conference (ITC-21), Toki Gifu, 2011.11.28-12.1

S. Ohshima, K. Hashimoto, S. Yamamoto, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, K. Hanatani, S. Konoshima, K. Mukai, H.Y. Lee, M. Takeuchi, F. Sano, Study of Edge Fluctuation Characteristics using Multiple Langmuir Probes in Heliotron J, 21th International Toki Conference (ITC-21), Toki Gifu, 2011.11.28-12.1

S. Yamamoto, S. Kobayashi, S. Ohshima, M. Suwa, K. Yasuda, K. Nagasaki, Y. Nakamura, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, B. Blackwell, D. Pretty, F. Sano, Studies of MHD stability in Heliotron J Plasmas, 21th International Toki Conference (ITC-21), Toki Gifu, 2011.11.28-12.1

山本聡, 低磁気シアヘリカル装置における高速イオン励起 MHD 不安定性の研究, NIFS 共同研究合同研究会, 核融合科学研究所, 2012.1.5-6

F. Sano, T. Mizuuchi, K. Nagasaki, H. Okada, K. Hanatani, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, S. Ohshima, Y. Nakamura, K. Mukai, H.Y. Lee, L. Zang, S. Arai, T. Kagawa, T. Minami, K. Mizuno, Y. Wada, H. Watada, H. Yashiro, N. Kenmochi, Y. Nagae, M. Sha, S. Murakami, K. Kasajima, N. Nishino, Y. Nakashima, T. Mutoh, M. Yokoyama, K. Toi, K. Tanaka, Recent progress in Heliotron J experiment, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

H. Okada, H. Watada, Y. Wada, S. Kobayashi, H.Y. Lee, T. Mizuuchi, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, T. Mutoh, S. Konoshima, K. Mukai, L. Zhan, H. Yashiro, T. Minami, T. Kagawa, S. Arai, K. Mizuno, F. Sano, Characteristics of ICRF Minority Heating for the Bumpiness and the Resonance Position in the Magnetic Field of Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

S. Kobayashi, S. Yamamoto, S. Kado, T. Kagawa, Y. Nagae, S. Ohshima, T. Oishi, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H.Y. Lee, T. Minami, Y. Nakamura, S. Konoshima, K. Toshi, F. Sano, Density Fluctuation and Its Radial Structure Measurements by Beam Emission Spectroscopy in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

T. Mizuuchi, S. Kobayashi, K. Mukai, S. Ohshima, S. Yamamoto, T. Minami, K. Nagasaki, H. Okada, H. Y. Lee, L. Zang, S. Arai, T. Kagawa, T.Y. Minami, K. Mizuno, H. Watada, Y. Wada, H. Yashiro, K. Hashimoto, N. Kenmochi, Y. Nagae, Y. Nakamura, M. Sha, K. Kasajima, N. Nishino, Y. Nakashima, K. Hanatani,

Y. Nakamura, S. Konoshima, F. Sano, Gas Fuelling Effect on Plasma Performance in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

H. Lee, S. Kobayashi, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, M. Yokoyama, S. Ohshima, K. Mukai, T. Harada, L. Zang, S. Arai, T. Kagawa, K. Mizuno, Y. Wada, H. Watada, H. Yashiro, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Charge exchange recombination spectroscopy for ion transport in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

L. Zang, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of filament features of edge plasma fluctuations in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

K. Nagasaki, S. Kobayashi, S. Yamamoto, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, Y. Nakamura, S. Konoshima, S. Ohshima, K. Mukai, H.Y. Lee, L. Zang, K. Toshi, K. Sakamoto, K. Toi, F. Sano, Startup of NBI Plasmas Assisted by 2.45 GHz Microwaves in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

N. Nishino, L. Zang, M. Takeuchi, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H. Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of filament features in edge plasma turbulence using a combination of fast video cameras and a hybrid probe system in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

S. Ohshima, K. Hashimoto, S. Yamamoto, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, K. Hanatani, S. Konoshima, K. Mukai, H. Y. Lee, M. Takeuchi, F. Sano, Edge Fluctuation Study using Multiple Langmuir Probes in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3



## Clean Energy Conversion Research Section

Sadao Masamune, Visiting Professor  
(Kyoto Institute of Technology)

### 1. Introduction

The RFP is a compact, high-beta magnetic confinement concept, where beta is the ratio of plasma pressure to magnetic pressure. The great advantage of the RFP is that it requires weak external toroidal magnetic field. Recent RFP research has revealed two scenarios for confinement improvement. One is the plasma current profile control to suppress the core resonant dynamo modes [1]. The other is the Quasi-Single Helicity (QSH) scenario which allows only a single dominant mode to grow. In this QSH scenario, magnetic surfaces recover inside the magnetic island associated with the dominant mode. As an extreme case, the Single Helical Axis (SHAx) state has emerged as a new self-organized helical RFP state [2].

### 2. QSH state in RELAX experiment

An equilibrium analysis has shown that the aspect ratio  $A (= R/a)$  is an important parameter for optimization of the RFP configuration because the safety factor ( $q$ ) profile is closely connected to  $A$  in the self-organized state. Furthermore, some theories show that the pressure-driven bootstrap current increases as  $A$  is lowered to less than 2. RELAX is a RFP machine ( $R = 0.5$  m/ $a = 0.25$  m:  $A = R/a = 2$ ) to explore the plasma characteristics in low- $A$  regime. The RFP configuration is often discussed in  $(\Theta, F)$  space, where the pinch parameter  $\Theta$  is the ratio of edge poloidal field  $B_p(a)$  to the average toroidal field  $\langle B_t \rangle$ , and the field reversal parameter  $F$  is the ratio of the edge toroidal field  $B_t(a)$  to  $\langle B_t \rangle$ . Experimentally achieved wide discharge regions in  $(\Theta, F)$  space in RELAX are discussed in ref [3]. In shallow reversal plasmas, the discharge tends to transit to the QSH state [4], or helical Ohmic equilibrium state which is essentially the same as the SHAx

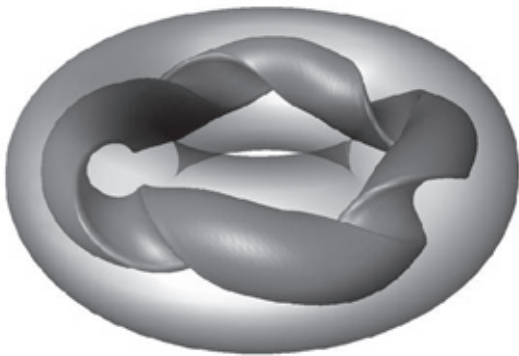


Fig.1 A schematic drawing of QSH in RELAX.

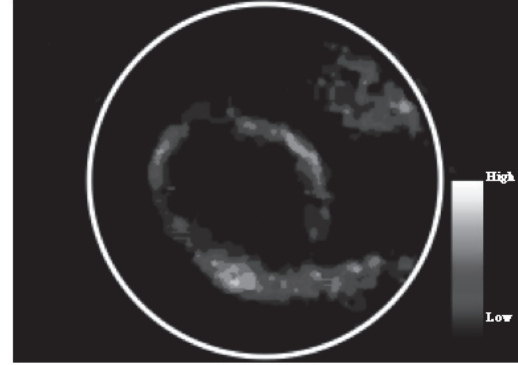


Fig.2: An example of SXR helical structure enhanced by applying subtraction technique to the experimental tangential images taken by a high-speed camera ( $10^5$  fps).

state. Experimental internal field profiles of  $B_r$ ,  $B_p$ , and  $B_t$  showed good agreement with the theoretical helical Ohmic equilibrium state [5].

A schematic drawing of the QSH state in RELAX is given in Fig.1, where the helical pitch is determined by the  $m=1/n=4$  tearing mode which has the innermost resonant surface.

### 3. Direct observation of helical filament in soft-X ray tangential image in RELAX

Recent progress in high-speed soft-X ray (SXR) imaging diagnostic has made it possible to observe time evolution of the tangential SXR image. We take SXR images at a rate of  $10^5$  frames per second with a high-speed camera. When subtraction technique is applied to the images with 10  $\mu$ s time interval, we can identify a simple helical structure as shown in Fig.2. By subtraction, the background SXR radiation which corresponds to an axisymmetric equilibrium component is removed, and the remaining structure originating from time evolving asymmetric component is enhanced. The color code in Fig.1 shows that a helically deformed core with higher SXR emissivity is rotating. The radial location of the filament agrees with the location of the  $q = 1/4$  resonant surface, and the poloidal location of the helical filament corresponds to the O-point of the magnetic island associated with the dominant  $m = 1/n = 4$  mode. The rotation speed of the helical structure is  $\sim 1.6 \times 10^4$  rad/s, almost the same as that of the  $m = 1/n = 4$  mode. These results are consistent with the SXR emissivity profile measurement which

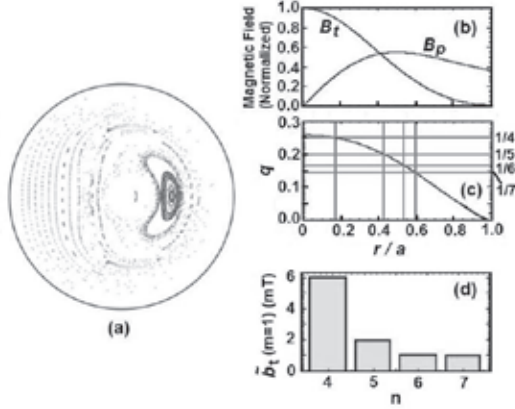


Fig.3: (a) Poincare plot of the field lines using ORBIT code. (b) equilibrium field. (c)  $q$  profile with major resonances. (d) edge magnetic fluctuation spectrum.

suggested improved confinement in the helically deformed core [4].

#### 4. Magnetic topology of QSH in RELAX

Figure 3 shows a Poincaré plot of the magnetic field lines in a poloidal cross section during the QSH phase in RELAX. It is the result of ORBIT code, in which the radial eigenfunctions of the resonant modes were obtained by solving the Newcomb equations. Experimental magnetic fluctuation spectra at the edge were used as the boundary conditions. We can identify the helically deformed nested flux surfaces in the core region. One of the characteristics in RELAX is that helical RFP state is realized with lower current (and lower current density) than in other RFPs. The magnetic Reynolds number  $S$  is also lower. The easier access to the helical state may result from the  $q$  profile in low- $A$  RFP where wider space without major resonance allows the island to grow without interacting neighboring mode.

#### 5. High-current operation in RELAX

The MHD behavior of RELAX plasmas has been studied in detail in the current region from 40 kA to 80 kA in ref [3], where two possible improved confinement regions were suggested: QSH-dominated shallow-reversal region and deep-reversal region with low magnetic fluctuation level. In both regions, further improvement of confinement can be expected with higher  $S$  because quality of the QSH is improved more at higher  $S$ , and magnetic fluctuation level decreases with increasing  $S$  in the RFP. In order to improve plasma performance we have started optimization of high current operation. An example of the optimized 100 kA discharge is shown in Fig. 4. The discharge resistance decreases with increasing the plasma current, which has shown the possibilities of improved performance of low- $A$

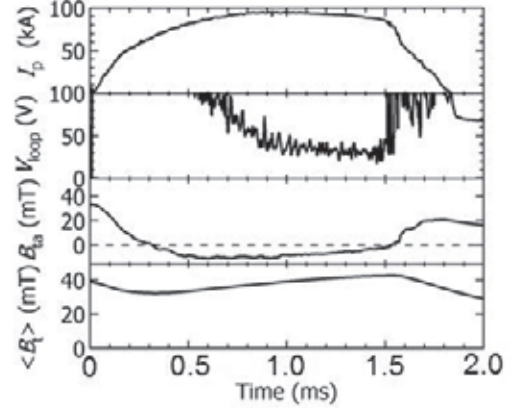


Fig.4: Optimized 100 kA discharge waveform.

RFP plasma.

#### 6. Summary

We have made a direct observation of the soft-X ray (SXR) helical structure in the quasi-single helicity (QSH) phase in a low-aspect-ratio (low- $A$ ) reversed field pinch (RFP) machine RELAX. The field line trace has shown a large helical deformation in the core with closed flux surfaces, being consistent with the present and previous SXR imaging diagnostics. The helical core with higher temperature and/or density are easily formed in RELAX which may be attributable to the characteristic  $q$  profile in low- $A$  RFP configuration. Discharge optimization at high current ( $\sim 100$  kA) has shown possibilities of improved performance of low- $A$  RFP plasma.

#### References

- [1] M.D. Wyman et al., Phys. Plasmas **15**, 010701 (2008).
- [2] R. Lorenzini et al., Nature Phys. **5**, 570 (2009).
- [3] R. Ikezoe et al., Plasma Phys. Control. Fusion **53**, 025003 (2011).
- [4] T. Onchi et al., J. Phys. Soc. Jpn. **80**, 114501 (2011).
- [5] K.Oki et al., Plasma Fusion Res. Vol.7 (2012) in press.



## Clean Energy Conversion Research Section

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### 1. Introduction

Achieving better time-resolution of a measurement allows us to observe matter's faster dynamics. Generally, molecular structural change occurs with a few-tens femtoseconds (1 femtosecond, fs, =  $10^{-15}$  s) while electron motion in an atom or a molecule can occur attoseconds (1 attosecond, as, =  $10^{-18}$  s) time scale. Once attosecond time-resolution can be achieved, one can measure electron dynamics in a molecule without disturbance from the molecular structural change.

There are major two approaches for attosecond measurements: one is to use high harmonic emission as a pump or a probe pulse while the other is to use a so-called re-colliding electron pulse [1-2]. High harmonics and re-colliding electron pulses are generated by irradiation of intense infrared, femtosecond laser pulses to gaseous atoms or molecules. For attosecond measurements, stabilization of the carrier-envelope phase (CEP) of the laser pulses are essential. We have developed intense laser and measurement systems for measuring attosecond phenomena in atoms and molecules.

### 2. CEP stabilized laser and measurement systems

Our chirp pulse amplified, Ti:Sapphire laser system generates 35 fs, CEP stabilized, 2 mJ pulses. The center wavelength is 780 nm and the repetition rate is 1 KHz. The 35 fs laser pulses can be compressed to  $< 5$  fs by a conventional pulse compression technique which uses a hollow-core fiber and chirped mirrors. The carrier-envelope phase of the oscillator laser pulse is measured by a f-to-2f optical interferometer and stabilized by adjusting position of one of the end mirrors in the oscillator.



**Fig. 1.** Overview of the laser system and the attosecond measurement systems.

The CEP stabilized pulse is amplified by a single stage, multi-path amplifier. We measured the CEP stability of the amplified pulse by a single-shot, f-to-2f spectrometer and confirmed that the stability is sufficient for attosecond measurements.

We made experimental apparatuses for generating high harmonics and measuring the spectrum. We used a pulsed jet to inject gas to generate high harmonics. The high harmonic emission are dispersed by a flat-field grating and measured by a two-dimensional microchannel plate. We also made a single-channel time-of-flight mass spectrometer and a velocity map imaging photoelectron momentum spectrometer. These spectrometers are used to observe photoions or photoelectrons generated by irradiation of attosecond high harmonic generation to a sample molecule.

### 3. Measuring attosecond electron wavepacket motion [3]

One of the major aims of attosecond science is to measure electron dynamics in a molecule with attosecond time-resolution. In terms of atoms, Sansone *et al* has measured electron wavepacket motion in Kr atom using transient absorption spectroscopy [4]. The electron motion is induced by coherent optical coupling between the spin-orbit states. However, it is difficult to apply this approach to electron motion in a molecule because a molecule has more complicated energy levels than atom's.

We developed a new approach to observe dynamical changes in an electron wavefunction or electron wave packet motion in a polyatomic molecule[3]. We combined different color laser pulses spatially and temporally and measured high harmonic spectrum generated from a sample molecule as a function of the delay between the two pulses. From the two-dimensional high harmonic generation spectrum, we obtained information of dynamical change of the electron wavepacket in the molecule in the range from 800 as to 1400 as after the motion is started.

### References

- [1] H. Niikura *et al.*, **Nature** **417**, 917 (2002).
- [2] H. Niikura *et al.*, **Nature** **421**, 826 (2003).
- [3] H. Niikura *et al.*, **Phys. Rev. Lett.** **107**, 093004 (2011).
- [4] G. Sansone *et al.*, **Nature** **465**, 763 (2010).

## Chemical Reaction Complex Processes Research Section

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T. Sakka, Associate Professor  
K. Fukami, Assistant Professor

### 1. Introduction

Surfaces and surface layers on solid materials play an important role in many photo-energy conversion processes. In this research section we investigate the formation of various surface structures and study surface and interfacial phenomena. We utilize electrochemical methods and laser spectroscopic techniques to perform research in this subject.

In this academic year we have investigated the effect of alcohols upon macroporous Si formation, new design of Si rugate filter for gas sensing, control of platinum electrodeposition in microporous Si, particle monolayer structure at oil-water interface under electrostatic potential, and the mechanism of non-gated double pulse underwater laser-induced breakdown spectroscopy.

### 2. Effects of alcohols and organic solvents in the electrolyte on macroporous Si formation

Anodization of silicon in HF solution produces a porous Si. The size and shape of the pores are dependent on anodization conditions including solution composition. Historically, many researchers have added alcohol in the HF solution. It is considered that the alcohol reduces the surface tension and the reduction is effective to avoid the Si surface to be covered by H<sub>2</sub> bubbles and to facilitate the infiltration of electrolyte into the narrow pores. The effects of alcohol upon the pore formation have attracted little attention. However, macropore formation in p-type Si usually requires the presence of organic solvent such as acetonitrile and DMSO (dimethylsulphoxide). In some cases, alcohol is also contained in the solution.

The reactivity of alcohol with Si was investigated in the course of the macropore formation. The presence of methanol results in dissolution of the porous layer leading to collapse of pore walls and also recession of the top surface of the porous layer. Increase of carbon number, i.e. methanol to butanol, causes the structural stabilization. Further addition of another organic solvent such as diethyl ether and acetonitrile reduces the instability. Increase of HF concentration also enhances the stability. These results obviously show the reactivity of alcohol with Si. The type of alcohol has an effect on the pore formation. Not only current density or HF concen-

tration but also the type of alcohol affects the pore structure.

### 3. Structural design of Si rugate filters for gas sensing

Electrochemical anodization of a silicon wafer in HF solution results in the formation of a porous layer. Many structural properties of the layer, such as porosity, can be tuned by controlling the anodization parameters. This enables facile production of periodic structures as a function of layer depth. Rugate filters utilize a structure in which porosity is sinusoidally modulated. Due to the nanometer-size scale of the pores the material can be optically considered as an effective medium, where the refractive index is dependent on the porosity. With proper control over the structural periodicity and refractive index variation, structures that exhibit photonic bandgaps can be produced.

p-type silicon was anodized in HF solution using a computer controlled current source. Different types of structural modifications to a rugate filter such as stacking and superposition of filters, and refractive index matching layers were surveyed for the effectiveness on gas sensing. Vaporized ethanol was employed as the gas.

High sensitivity can be obtained with a stacked filter, whereas the superposition filter structure allows the preparation of a thinner filter layer, which promotes faster recovery from vapor exposure. The use of a refractive matching layer minimizes interference fringes produced by stacked structures. Based on the results both the stacked and the superimposed filter structure show promise in gas sensing applications.

### 4. Control of platinum electrodeposition in microporous silicon

We have found that platinum electrodeposition in microporous silicon is strongly enhanced by using a chemically-modified hydrophobic microporous silicon. In this year, for understanding this behavior, we have developed a theoretical model of the hydration properties of platinum ions and the pore wall, which is a statistical-mechanical theory and calculates the concentration of platinum ions in the immediate vicinity of the pore wall. The theoretical results have revealed that the hy-

drophobic wall induces a great enrichment of platinum ions, but the hydrophilic wall results in a decrease of the concentration. In addition, this model has also suggested that the electrodeposition within the porous layer is enhanced if the diameter of platinum ion is large. Thus we changed the ions from  $[\text{PtCl}_4]^{2-}$  to  $[\text{PtBr}_4]^{2-}$ . As a result, we have observed that the number of platinum particles increased to a great extent as predicted by the theoretical approach.

Thus we think that the difference in the electrodeposition behavior with hydrophobic and hydrophilic microporous silicon can be explained by the hydration property. By considering the hydration property, the electrodeposition reaction in the porous layer can be controlled in a variety of manners.

### 5. Control of particle monolayer structure at oil-water interface by electrostatic potential

Self-assembly of particles at oil-water interface can be used as an initial step for various two-dimensional structure formation. Such two dimensional ordering of the colloidal particles is sensitive to the interparticle interaction. The interaction is basically inherent in properties of the particles and liquids. However, if the particles are charged, the interaction can be controlled by applied external electric potential.

Spherical plain polystyrene particles dispersed at n-decane/0.1 M NaCl aqueous solution interface were studied. The diameter of the particles was 3.2  $\mu\text{m}$ . We put two electrodes made of Pt wire with 5  $\mu\text{m}$  in diameter from the decane phase to the very vicinity of the interface. The distance between the electrode tips was 370  $\mu\text{m}$ . The behavior of polystyrene particles was monitored with a microscope equipped with a CCD detector.

Fig. 5-1 shows the optical microscope image of the interface obtained with applying 20 V between the two electrodes. The plain polystyrene particles were attracted by the positive electrode, meaning that the particles are negatively charged. Surface charge density can be estimated by analyzing the particle distribution near the electrode. The analysis is based on the calculation of the electric force applied to charged particles.

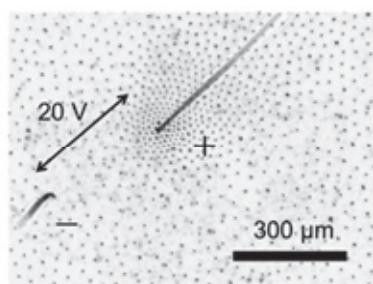


Fig. 5-1 Optical microscope image of polystyrene particles at n-decane/0.1 M NaCl aq interface with applying potential between the two electrodes inserted from the n-decane phase.

### 6. Mechanism of non-gated double pulse underwater laser-induced breakdown spectroscopy

In the last academic year we have clarified that multipulse irradiation results in the ablation plasma which gives clear well-defined atomic emission spectral lines in water even without time-gated detection of the optical emission. In this year we found that such non-gated detection is possible also for the double pulse irradiation, if we optimize the pulse interval and the pulse energy. The optimized pulse interval ranges from 15  $\mu\text{s}$  to 50  $\mu\text{s}$ , and the optimized energies of the first and second pulses, respectively, are 0.4 mJ and 1 mJ. The mechanism behind such observation was investigated.

The shadowgraph measurements show that the cavitation bubble generated by the first pulse becomes maximum after 15  $\mu\text{s}$  to 50  $\mu\text{s}$  from the first pulse, which corresponds to the optimized timing of the second pulse. We also obtained a shadowgraph image of the cavitation bubble with simultaneous imaging of the plasma (Fig. 6-1). The gate width is 500 ns covering the timing of the second pulse, and hence the plasma image includes the emission immediately after the irradiation. The plasma sits well inside the cavitation bubble, and not contacting the boundary of the bubble. Furthermore, the measurement of the spectra with the second pulse irradiating the spot spatially shifted from the first pulse results in the extinction of the emission, even though the second pulse irradiation is inside the bubble.

In consequence, narrow and clear atomic emission lines owe to the synergetic effects of the first and later pulses, i.e., the first pulse creates a bubble and heat the irradiation spot without the formation of plasma and the later pulse produces a rather low-density plasma in the bubble by mildly ablate the spot which have been energized by the first pulse.

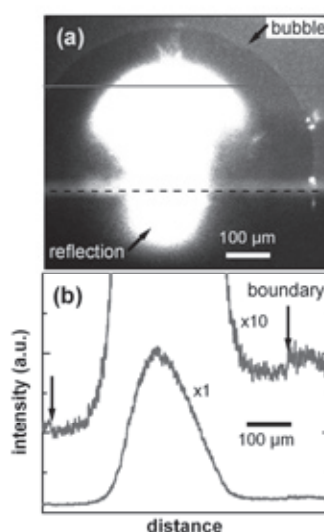


Fig. 6-1 Shadowgraph image of the bubble with simultaneous imaging of the plasma caused by the second pulse. The image is shown in (a), and the intensity profile along the solid line in (a) is shown in (b). Broken line in (a) indicates the surface of the target.

## Financial Support

### 1. Grant-in-Aid for Scientific Research

尾形幸生, 基盤研究(B), 電気化学ツールによるシリコンのナノ・マイクロ構造微細加工

作花哲夫, 基盤研究(C), 液中その場材料表面元素分析のためのレーザープラズマの最適化

深見一弘, 若手研究(B), 電気化学反応における成長界面のモデル化に基づく新奇デンドライト抑制法

### 2. Others

作花哲夫, 受託研究 (日本原子力研究開発機構), ロングパルスレーザーによる溶存元素発光特性の解明

尾形幸生, 奨学寄附金 ((株) コミュニケーション・テクノロジー), 新エネルギーのための研究教育学術活動助成

尾形幸生, 奨学寄附金 (積水化学工業 (株)), 新エネルギーのための研究教育学術活動助成

尾形幸生, 奨学寄附金 ((社) 環境技術普及機構), 新エネルギーのための研究教育学術活動助成

尾形幸生, 奨学寄附金 (尾池工業 (株)), 新エネルギーのための研究教育学術活動助成

## Publications

鈴木祥一郎, 尾形幸生, Ar イオン打ち込み処理による高誘電率ポリイミドフィルム表面の SEM 観察, 表面技術, 62, 5, 267-272, 2011

K. Fukami, M.L. Chourou, R. Miyagawa, A. Munoz-Noval, T. Sakka, M. Manso-Silvan, R.J. Martin-Palma, Y.H. Ogata, Gold nanostructures for surface-enhanced Raman spectroscopy, prepared by electrodeposition in porous silicon, Materials, 4, 4, 791-800, 2011

R. Miyagawa, K. Fukami, T. Sakka, Y.H. Ogata, Surface-enhanced Raman scattering from gold deposited mesoporous silicon, Phys. Status Solidi A, 208, 6, 1471-1474, 2011

K. Fukami, M.L. Chourou, T. Sakka, Y.H. Ogata, Numerical simulation of copper filling within mesoporous silicon by electrodeposition, Phys. Status Solidi A, 208, 6, 1407-1411, 2011

M.L. Chourou, K. Fukami, T. Sakka, Y.H. Ogata, Gold

electrodeposition into porous silicon: Comparison between meso- and macroporous silicon, Phys. Status Solidi C, 8, 6, 1783-1786, 2011

T. Jalkanen, J. Salonen, V. Torres-Costa, K. Fukami, T. Sakka, and Y.H. Ogata, Structural considerations on multistopband mesoporous silicon rugate filters prepared for gas sensing purposes, Opt. Express, 19, 14, 13291-13305, 2011

## Presentations

K. Fukami, R. Koda, T. Urata, D. Shiojima, T. Sakka, Y.H. Ogata, Electrodeposition of platinum within porous silicon: the effect of displacement deposition, 9th Eco-Energy and Materials Science and Engineering Symposium, Wiang Inn, Chiang Rai, Thailand, 2011.5.27

T. Sakka, Application of multipulse microchip laser to insitu under-water laser induced breakdown spectroscopy, 9th Eco-Energy and Materials Science and Engineering Symposium, Wiang Inn, Chiang Rai, Thailand, 2011.5.27

田村文香, 作花哲夫, 深見一弘, 尾形幸生, 水中レーザープラズマ発光分光におけるゲート動作なしでの明瞭な原子発光線観測, 第 72 回応用物理学会学術講演会, 山形大学, 2011.8.31

作花哲夫, 鈴木友矩, 小川昌秀, 深見一弘, 尾形幸生, 貴金属水溶液中でのチタンのレーザーアブレーション, 第 72 回応用物理学会学術講演会, 山形大学, 2011.9.1

小澤大知, Gisle Øye, 作花哲夫, 深見一弘, 尾形幸生, 鉛直油水界面における単粒子層の粒子間相互作用, 第 63 回コロイドおよび界面化学討論会, 京都大学, 2011.9.8

幸田吏央, 浦田智子, 深見一弘, 作花哲夫, 尾形幸生, 化学修飾された多孔質シリコンへの金属めっきに孔径が及ぼす影響, 電気化学会第 79 回大会, 朱鷺メッセ, 新潟市, 2011.9.10

T. Jalkanen, J. Salonen, K. Fukami, T. Sakka, Y.H. Ogata, 多孔質シリコンに基づくマイクロキャビティ作製およびバイオセンシングへの応用, 電気化学会第 79 回大会, 朱鷺メッセ, 新潟市, 2011.9.9

T. Urata, N. Takeda, K. Fukami, T. Sakka, Y.H. Ogata, Effect of solvent polarity on stable macropore growth in p-type silicon, The 62nd Annual Meeting of the International Society of Electrochemistry, TOKI MESSE, Niigata, 2011.9.12



R. Koda, T. Urata, K. Fukami, T. Sakka, Y.H. Ogata, Electrodeposition of platinum into chemically-modified microporous silicon substrates, The 62nd Annual Meeting of the International Society of Electrochemistry, TOKI MESSE, Niigata, 2011.9.12

T. Jalkanen, J. Salonen, K. Fukami, T. Sakka, Y.H. Ogata, Preparation of multistopband mesoporous silicon rugate filters for gas sensing purposes, The 62nd Annual Meeting of the International Society of Electrochemistry, TOKI MESSE, Niigata, 2011.9.15

小澤大知, Gisle Oye, 作花哲夫, 深見一弘, 尾形幸生, Interaction between particles at a vertical oil-water interface, International Symposium on Renewable Energy & Materials Tailoring 2011, 京都大学, 2011.9.18

土屋聖人, 山内 健, 坪川紀夫, 深見一弘, 作花哲夫, 尾形幸生, 表面微細構造を制御したシリコンを鋳型に用いたスマートゲルの作製と物性評価, 第 61 回ネットワークポリマー講演討論会, 関西大学 100 周年記念会館, 2011.10.13

T. Sakka, T. Suzuki, M. Ogawa, K. Fukami, Y.H. Ogata, Laser ablation in a solution containing noble metal ions: formation of semiconductor-metal nanocomposites, 11th International Conference on Laser Ablation, Playa del Carmen, Mexico, 2011.11.14

A. Tamura, T. Sakka, K. Fukami, Y.H. Ogata, Continuum-free emission spectrum measurement without time-gating for underwater laser-induced breakdown spectroscopy, 11th International Conference on Laser Ablation, Playa del Carmen, Mexico, 2011.11.14

土屋聖人, 小澤大知, Gisle Oye, 作花哲夫, 深見一弘, 尾形幸生, 油水界面に吸着した微粒子による構造形成と粒子間相互作用, 第 13 回関西表面技術フォーラム, キャンパスプラザ京都, 2011.11.29

松本歩, 田村文香, 作花哲夫, 深見一弘, 尾形幸生, 液相レーザーアブレーションプラズマの発光分光による多元素分析の検討, 第 13 回関西表面技術フォーラム, キャンパスプラザ京都, 2011.11.29

山本光洋, 深見一弘, 作花哲夫, 尾形幸生, 多孔質シリコン孔形成過程の動的シミュレーション, 平成 23 年度第 3 回関西電気化学研究会, 関西大学, 2011.12.10

田村文香, 作花哲夫, 深見一弘, 尾形幸生, 水中での低出力ダブルパルスレーザーアブレーションにより生成する気泡の挙動, 第 59 回応用物理学関係連合講演会, 早稲田大学, 2012.3.16

松本歩, 田村文香, 作花哲夫, 深見一弘, 尾形幸生, 液相レーザーアブレーションプラズマの発光スペクトルの検出位置依存性, 第 59 回応用物理学関係連合講演会, 早稲田大学, 2012.3.16

土屋聖人, 小澤大知, Gisle Oye, 作花哲夫, 深見一弘, 尾形幸生, 異なる 2 種類のコロイド粒子による油水界面における二次元構造の形成, 日本化学会第 92 春季年会, 慶応義塾大学, 2012.3.27

T. Jalkanen, E. Makila, K. Fukami, T. Sakka, J. Salonen, Y.H. Ogata, Thermally promoted addition of undecylenic acid on thermally hydrocarbonized porous silicon optical reflectors, 8th International Conference on Porous Semiconductors-Science and Technology (PSST-2012), Malaga, Spain, 2012.3.26

A. Munoz-Noval, V. Torres, R. J. Martin-Palma, M.A. Garcia-Tunon, K. Fukami, Y.H. Ogata, P. Herrero, M. Manso-Silvan, Characterization of hybrid cobalt-porous silicon systems: protective effect of the matrix in the metal oxidation, 8th International Conference on Porous Semiconductors-Science and Technology (PSST-2012), Malaga, Spain, 2012.3.26

R. Koda, K. Fukami, T. Sakka, Y.H. Ogata, Electrodeposition of noble metals into chemically modified microporous silicon substrates, 8th International Conference on Porous Semiconductors-Science and Technology (PSST-2012), Malaga, Spain, 2012.3.26

T. Urata, K. Fukami, T. Sakka, Y.H. Ogata, Pore formation in p-type silicon in solutions containing different types of alcohol, 8th International Conference on Porous Semiconductors-Science and Technology (PSST-2012), Malaga, Spain, 2012.3.28



## Molecular Assemblies Design Research Section

H. Sakaguchi, Professor

T. Sagawa, Associate Professor

### 1. Introduction

Nanometer-scale technology and science are so important to produce the unprecedented materials for energy. Our group studies the basics of assembling small molecules into the advanced materials and devices in energy sector with high efficiency. Followings are main research achievements in Molecular Assemblies Design Research section in the year of 2011.

### 2. High hole mobility of molecular wires by electrochemical epitaxial polymerization

Key to realize the high performance of organic devices using conjugated polymers is how to fabricate a highly organized structure on surface at a single molecular scale. Here we have demonstrated a unique single-molecular processing-technique using electrochemistry, called 'electrochemical epitaxial polymerization' (ECEP). This technique is based on a step-by-step electropolymerization of monomer along the lattice of iodine-covered Au(111) surface to form the single conjugated-polymer wires by applying voltage-pulses into monomer-electrolyte solution.

Epitaxially polymerized conjugated polymers can be successfully deposited layer by layer on I-Au(111) up to 10 nm thickness. We have recently demonstrated polymerized wires on I-Au(111) could be transferred to insulator substrates such as surface-oxidized Si, glass and various insulating polymers.

Electric double layer capacitor (EDLC) FET devices using epitaxially polymerized molecular wires showed highest hole mobility of  $1 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$  that have never been reported so far in conjugated polymers. Other types of FET using different gate dielectrics were compared with these results.

### 3. Benzotrithiophene polymer network prepared by electrochemical polymerization with a combination of thermal conversion

Polythiophenes are known to have well established 1D  $\pi$ -conjugated system. We previously reported electrochemical epitaxial polymerization, which is the molecular-scale polymerization of monomers along the atom-lattice of substrate, to

produce highly ordered polythiophene wires with a length of 100 nm on iodine modified Au(111). 2D materials are desired to be fabricated on electrode using this electrochemical technique. Thiophene-based molecule, which possesses  $C_3$  symmetry such as benzo[b]trithiophene (BTT) is a candidate as a precursor to form the well developed 2D  $\pi$ -conjugated thiophene network by the polymerization reaction. There is only a report with regard to the electropolymerization of BTT using cyclic voltammogram on Pt disc or ITO electrode, showing instability of electropolymerized BTT from the results of oxidation potential varied with repeated scan. However, the detail features of these compounds are unknown.

In this context, two-step method to produce 2D conjugated polymer network on substrate, electropolymerization of BTT to form oligomers with combination of thermal conversion into 2D polymers has been investigated. Advantage of electropolymerization is to form BTT oligomers absorbed onto electrode surface. Formed BTT oligomers have a higher sublimation temperature than that of monomer because the monomer sublimates at temperature of 200 degrees with an atmospheric pressure of nitrogen. Therefore, thermal treatment around 500 degrees in order to develop the further conjugation by a cyclodehydrogenation reaction can be applied to BTT oligomers as second step. In conclusion, we proposed the method combined electropolymerization and thermal treatment applied for  $C_3$  symmetric BTT molecule to produce the conjugated-polymer network. Thermally treated electropolymerized BTT film at 500 degrees shows  $10^7$  times higher conductivity than before. It retains thiophene structure in spite of heating by Raman spectra. Absorption spectra of heat treated electropolymerized BTT film suggests extended  $\pi$ -conjugation. These results indicate the production of 2D network polymer consisted from  $C_3$  symmetric BTT.

### 4. Improvement of efficiencies of organic solar cells: Development of materials and novel design of device structure

Polymer solar cell is one of the promising new

type photovoltaic conversion devices with the advantages of lightweight, large-area, flexibility and low cost roll-to-roll production by using the convenient well-developed solution-based thin film deposition technology. For the sake of highly efficient photocurrent conversion efficiencies of organic thin film solar cells in terms of reduction of carbon dioxide emissions, we intended to (1) improve the evaluation of carrier transportation for the devices, (2) reform the surface of nanostructured electrodes, and (3) develop novel coating methods for thin-film making in FY2011.

(1) Improvement of the evaluation of carrier transportation for the devices: Poly(3-hexylthiophene) (P3HT) as a conventional donor material and (6,6)-phenyl C61 butyric acid methyl ester (PC61BM) as an acceptor have been prepared and applied for organic photovoltaics (OPVs). Carrier mobility for glass/acceptor have been P3HT-PC61BM /TiO<sub>x</sub>/Al has been measured by CELIV (Carrier Extraction by Linearly Increasing Voltage) technique. Further improvement and modification of the evaluation technique based on the CELIV method was performed and lifetime of the carrier has been able to be obtained by CESC (Carrier Extraction at Short Circuit) method [Jpn. J. Appl. Phys., 2011, 50, 01BC13].

(2) Reforming of the surface of nanostructured electrodes: Several lengths of ZnO nanorod arrays were prepared by changing the duration of hydrothermal growth. Various types of small molecular organic dyes were adsorbed onto the surface of the ZnO nanorod arrays and applied them for polymer (P3HT) hybrid OPVs as an electron-transporting layer. The use of indoline dye D205, which has dipole

moments directing away from the ZnO surface, was found to suppress the reverse saturation dark current density and charge recombination, and to consequently lead to higher open-circuit voltage and improved power conversion efficiency (PCE) from 0.22% to 0.71%. Suaraine derivative was synthesized and was found to improve device performance by extending the light-harvesting range to the near infrared region, leading to increased short-circuit current density and the highest PCE of 1.02% [J. Phys. Chem. C, 2011, 115 (48), 23809-23816].

(3) Development of novel coating methods for thin-film making: Additional spray coating method has been newly developed as alternative of conventional spin coating method for preparation of thin-films. Surface roughness and pinholes were remarkably reduced by the combination of the additional spray coating and post annealing. This thin-film making process achieved power conversion efficiency of over 3% for glass-ITO/PEDOT:PSS/P3HT-PC61BM /TiO<sub>x</sub>/Al [Organic Electronics, 2011, 12 (12), 2165-2173].

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## Financial Support

### 1. Grant-in-Aid for Scientific Research

坂口浩司, 新学術領域研究, 電気化学プログラム  
ム自己組織化の学理と応用

佐川尚, 基盤研究(C), 高度に結晶化した有機  
無機ナノ構造体の構築と太陽光発電用透明導  
電膜への展開

佐川尚, 特別研究員奨励費, 導電性ポリマーナ  
ノファイバーを用いた有機太陽電池の作製と  
評価

### 2. Others

吉川暹, 受託研究 ((独) 新エネルギー・産業  
技術総合開発機構), 太陽エネルギー技術研究  
開発 太陽光発電システム次世代高性能技術の  
開発 有機薄膜太陽電池モジュール創製に関す  
る研究開発

吉川暹, 受託研究 ((株) 昭和), 平成 22 年度  
戦略的基盤技術高度化支援事業 金属チタンを  
基板とする色素増感太陽電池の開発

吉川暹, 受託研究 ((独) 科学技術振興機構),  
高分子ハイブリッドセルの開発

吉川暹, 奨学寄附金 (積水化学工業 (株)), 新  
エネルギーのための研究教育学術活動助成

## Publications

P. Charoensirithavorn, T. Sagawa, S. Hayase, S.  
Yoshikawa, One-Dimensional Nanostructure Ar-  
rays for Dye-Sensitized Solar Cell Patcharee Char-  
oensirithavorn, ASME Journal of Solar Energy  
Engineering - special issue Solar Energy Research  
in Asia, 133, 011101-1-011101-6, 2011

H. Tsukigase, Y. Suzuki, M.H. Berger, T. Sagawa, S.  
Yoshikawa, Synthesis of SnS Nanoparticles by  
SILAR Method for Quantum Dot-Sensitized Solar  
Cells, Journal of Nanoscience and Nanotechnology,  
11, 3, 1914-1922, 2011

Y.T. Tsai, K. Goto, O. Yoshikawa, S. Mori, T. Sa-  
gawa, S. Yoshikawa, Charge Transporting Proper-  
ties and Output Characteristics in Polythio-  
phene:Fullerene Derivative Solar Cells, Japanese  
Journal of Applied Physics, 50, 01BC13-1-01BC13-4, 2011

S. Pavasupree, N. Laosiripojana, S. Chuangchote, T.

Sagawa, Fabrication and Utilizations of Titania  
Nanofibers from Natural Leucoxene Mineral for  
Photovoltaic Applications, Japanese Journal of  
Applied Physics, 50, 01BJ16-1-01BJ16-4, 2011

R. Tange, K. Inai, T. Sagawa, S. Yoshikawa,  
Application of Self-Assembling Photosynthetic  
Dye for Organic Photovoltaics, Journal of Materi-  
als Research, 26, 2, 306-310, 2011

H. Tsukigase, Y. Suzuki, M.H. Berger, T. Sagawa, S.  
Yoshikawa, Wet Chemical Synthesis and  
Self-Assembly of SnS<sub>2</sub> Nanoparticles on TiO<sub>2</sub> for  
Quantum Dot-Sensitized Solar Cells, Journal of  
Nanoscience and Nanotechnology, 11, 4, 3215-3221, 2011

H. Nomoto, S. Chuangchote, T. Sagawa, H.  
Sakaguchi, S. Yoshikawa, M. Takafuji, H. Ihara,  
Highly Oriented Donor-Acceptor Molecules within  
Electrospun Nanofibers, Molecular Crystals and  
Liquid Crystals, 539, 40-44, 2011

H. Jintoku, S. Shimoda, M. Takafuji, T. Sagawa, H.  
Ihara, Tuning of Molecular Orientation of Por-  
phyrin Assembly According to Monitoring the  
Chiroptical Signals, Molecular Crystals and Liquid  
Crystals, 539, 63-67, 2011

佐川尚, 酸化チタン担持高分子による光誘起電  
子移動プロセスの効率化, 高分子論文集特集号  
「高分子と触媒」, 68, 5, 307-314, 2011

P. Ruankham, T. Sagawa, H. Sakaguchi, S. Yoshi-  
kawa, Vertically aligned ZnO nanorods doped with  
Li for polymer solar cell: Defect related photovol-  
taic properties, Journal of Materials Chemistry, 21,  
26, 9710-9715, 2011

M. Murata, Y. Morinaka, Y. Murata, O. Yoshikawa,  
T. Sagawa, S. Yoshikawa, Modification of  
σ-Framework of [60]Fullerene for  
Bulk-Heterojunction Solar Cells, Chemical  
Communications, 47, 26, 7335-7337, 2011

K. Miyamoto, H. Jintoku, T. Sawada, M. Takafuji,  
T. Sagawa, H. Ihara, Informative Secondary Chi-  
roptics in Binary Molecular Organogel Systems for  
Donor-Acceptor Energy Transfer, Tetrahedron  
Letters, 52, 31, 4030-4035, 2011

T. Umeyama, M. Odoi, O. Yoshikawa, T. Sagawa,  
S. Yoshikawa, D. Evgenia, N. Tezuka, Y. Matano,  
K. Stranius, N.V. Tkachencko, H. Lemmetyinen, H.  
Imahori, Synthesis and Photovoltaic Properties of  
Thiophene-Imide-Fused Thiophene Alternating  
Copolymers with Different Alkyl Side Chains,  
Journal of Materials Chemistry, 21, 33,

12454-12461, 2011

S. Chuangchote, T. Sagawa, S. Yoshikawa, Electrospun TiO<sub>2</sub> Nanowires for Hybrid Photovoltaic Cells, *Journal of Materials Research*, 26, 17, 2316-2321, 2011

S. Chuangchote, T. Sagawa, S. Yoshikawa, Indium Tin Oxide Nanofibers and Their Applications for Dye-Sensitized Solar Cells, *ECS Transactions*, 41, 6, 223-229, 2011

J.H. Lee, T. Sagawa, S. Yoshikawa, Morphological and Topographical Characterizations in Spray Coated Organic Solar Cells Using an Additional Solvent Spray Deposition, *Organic Electronics*, 12, 12, 2165-2173, 2011

H. Jintoku, T. Sagawa, M. Takafuji, H. Ihara, Non-covalent One-to-one Donor-acceptor Assembled Systems Based on Porphyrin Molecular Gels for Unusually High Efficiencies in Electron Transfers, *Chemistry A European Journal*, 17, 41, 11628-11636, 2011

L. Macaraig, T. Sagawa, S. Yoshikawa, Self-Assembly Monolayer Molecules for the Improvement of the Anodic Interface in Bulk Heterojunction Solar Cells, *Energy Procedia*, 9, 283-291, 2011

K. Yoshida, T. Sonobe, M. Bakr, T. Sakka, T. Sagawa, E. Nakata, T. Morii, T. Kii, K. Masuda, H. Ohgaki, Materials Analysis Laboratory in KU-FEL, Kyoto University, *Energy Procedia*, 9, 483-490, 2011

S. Chuangchote, T. Sagawa, S. Yoshikawa, Design of Metal Wires-based Organic Photovoltaic Cells, *Energy Procedia*, 9, 553-558, 2011

P. Ruankham, L. Macaraig, T. Sagawa, H. Nakazumi, S. Yoshikawa, Surface Modification of ZnO Nanorods with Small Organic Molecular Dyes for Polymer-Inorganic Hybrid Solar Cells, *The Journal of Physical Chemistry C*, 115, 48, 23809-23816, 2011

佐川尚, 有機太陽電池の材料開発とデバイス設計, *ケミカルエンジニアリング*, 56, 3, 38-42, 2011

佐川尚, 高分子型有機太陽電池の耐久性向上・長寿命化に向けた取り組み (第3章 第3節 第2項), 有機デバイスおよび材料の耐久性向上および長寿命化に向けた最新技術資料集, 情報機構, 147-157, 2011

佐川尚, ナノ構造酸化物を用いた有機薄膜太陽電池の高効率化, *表面技術*, 63, 2, 86-89, 2012

T. Nakae, R. Ohnishi, Y. Kitahata, T. Soukawa, H. Sato, S. Mori, T. Okujima, H. Uno, H. Sakaguchi, Effective Synthesis of Diiodinated Picene and Dibenzo[a,h]anthracene by AuCl-Catalyzed Double Cyclization, *Tetrahedron Letters*, 53, 13, 1617-1619, 2012

T. Nakae, S. Mizobuchi, M. Yano, T. Ukai, H. Sato, T. Shinmei, T. Inoue, T. Irfune, H. Sakaguchi, Benzo[b]trithiophene Polymer Network Prepared by Electrochemical Polymerization with a Combination of Thermal Conversion, *Chemistry Letters*, 41, 2, 140-141, 2012

## Presentations

S. Chuangchote, T. Sagawa, S. Yoshikawa, Electrospun TiO<sub>2</sub> Nanofibers for Organic-inorganic Hybrid Photovoltaic Cells, 2011 Materials Research Society Spring Meeting, San Francisco, U.S.A., 2011.4.25-29

J.h. Lee, T. Sagawa, H. Sakaguchi, S. Yoshikawa, Efficiency Enhancement by An Additional Solvent Deposition in Spray Coated OSCs, 2011 Materials Research Society Spring Meeting, San Francisco, U.S.A., 2011.4.25-29

T. Sagawa, N. Fujisawa, S. Yoshikawa, Control of Nanomorphology and Charge Transportation of Polymer Solar Cell by Thermal Annealing and Liquid Additive, 2011 Materials Research Society Spring Meeting, San Francisco, U.S.A., 2011.4.25-29

坂口浩司, 超極細分子細線で電荷を運ぶ—エネルギーナノ工学—, 第16回エネルギー理工学研究所公開講演会, 京都大学宇治キャンパス 宇治おうばくプラザ きはだホール, 2011.5.14

李在衡, 佐川尚, 坂口浩司, 吉川暹, 種々のポリチオフェン/フラーレン薄膜の作成とセル特性評価, 第60回高分子学会年次大会, 大阪国際会議場, 2011.5.25-27

中西洋平, 川野佑子, 大野工司, 辻井敬亘, 佐藤貴哉, 佐川尚, 吉川暹, ポリマーブラシ付と複合微粒子積層膜を用いた色素増感太陽電池の開発, 第60回高分子学会年次大会, 大阪国際会議場, 2011.5.25-27

J.H. Lee, T. Sagawa, H. Sakaguchi, S. Yoshikawa, Efficiency Enhancement by an Additional Solvent Deposition in Spray Coated Polythiophene/Fullerene



Bulk Heterojunction Solar Cells, 9th Eco-Energy and Materials Science and Engineering Symposium (EMSES 2011), Chiang Rai, Thailand, 2011.5.25-28

P. Ruankham, T. Sagawa, H. Sakaguchi, S. Yoshikawa, Dye-modification of Zinc Oxide Nanorods for Hybrid Solar Cells Based on Poly(3-hexylthiophene), 9th Eco-Energy and Materials Science and Engineering Symposium (EMSES 2011), Chiang Rai, Thailand, 2011.5.25-28

L. Macaraig, T. Sagawa, H. Sakaguchi, S. Yoshikawa, Self-assembly Monolayer Molecules for the Improvement of the Anodic Interface in Bulk Heterojunction Solar Cells, 9th Eco-Energy and Materials Science and Engineering Symposium (EMSES 2011), Chiang Rai, Thailand, 2011.5.25-28

S. Chuangchote, T. Sagawa, S. Yoshikawa, Design of Metal Wires for Organic Photovoltaic Cells, 9th Eco-Energy and Materials Science and Engineering Symposium (EMSES 2011), Chiang Rai, Thailand, 2011.5.25-28

坂口浩司, 超極細分子細線でデバイスを作る, 第1回京都大学宇治キャンパス産学交流会, 京都大学宇治キャンパスおうばくプラザ, 2011.6.30

針崎良太, 城崎智洋, 堀川真希, 永岡昭二, 佐川尚, 高藤誠, 伊原博隆, 光電変換アクセプターユニットとしての高分散性フラーレン誘導体の開発, 第48回化学関連支部合同大会, 北九州国際会議場, 2011.7.9

佐川尚, 李在衡, ピパットルアンカム, 吉川暹, バルクヘテロ接合の界面設計とデバイス特性評価, CREST 有機太陽電池シンポジウム, 京都大学宇治構内きはだホール, 2011.7.15-16

Y. Morinaka, M. Murata, Y. Murata, O. Yoshikawa, T. Sagawa, S. Yoshikawa, Modification of the  $\sigma$ -Framework of [60]Fullerene for Bulk-heterojunction Solar Cells, 14th International Symposium on Novel Aromatic Compounds (ISNA-14), Eugene, Oregon, U.S.A., 2011.7.24-29

J.h. Lee, T. Sagawa, S. Yoshikawa, Photovoltaic efficiency enhancement by an additional solvent deposition in spray coated polythiopen/fullerene bulk heterojunction solar cells, 3rd GCOE International Symposium, Suwon, Korea, 2011.8.18-19

P. Ruankham, T. Sagawa, S. Yoshikawa, Surface Modification of ZnO Nanorods with Organic Dye Molecules for Polymer/Inorganic Hybrid Solar

Cells, 3rd GCOE International Symposium, Suwon, Korea, 2011.8.18-19

L. Macaraig, S. Chuangchote, T. Sagawa, S. Yoshikawa, Strontium Titanate Nanofibers Fabrication for Hydrogen Production through Water Splitting, 3rd GCOE International Symposium, Suwon, Korea, 2011.8.18-19

坂口浩司, ナノ炭素材料のビルドアップ表面合成, 分子ナノシステムの創発化学第3回全体会議, 亀の井ホテル (大分県別府市), 2011.8.20

登政博, 村田理尚, 森中裕太, 若宮淳志, 佐川尚, 吉川暹, 村田靖次郎, リチウムアセチリドを用いた1,2-ジヒドロフラーレン誘導体の合成と有機太陽電池特性, 第22回基礎有機化学討論会, 筑波大学 大学会館, 2011.9.21-23

坂口浩司, 電気化学エピタキシャル重合—分子細線の組織化と機能—, 第60回高分子討論会, 岡山大学津島キャンパス, 2011.9.28-30

S. Chuangchote, Takashi Sagawa, Susumu Yoshikawa, Indium Tin Oxide Nanofibers and Their Applications for Dye-Sensitized Solar Cells, 220th ECS Meeting and Electrochemical Energy Summit, Boston, U.S.A., 2011.10.9-14

佐川尚, 有機薄膜太陽電池の材料、デバイスの開発と高効率化技術, 情報機構セミナー, タワーホール船堀 (東京), 2011.10.21

S. Chuangchote, T. Sonobe, T. Sagawa, S. Yoshikawa, Electrospun  $\text{TiO}_2$  Nanofibers Composed of Bundle of Aligned Nanofibrils: Fabrication, Structural and Photoelectronic Properties, Taiwan Association for Coatings and Thin Films Technology (TACT 2011) International Thin Films Conference, Kenting, Taiwan., 2011.11.20-23

J.h. Lee, T. Sagawa, S. Yoshikawa, Optimization of Bulk Heterojunction for Highly Efficient Spray Coated Polymer Solar Cells, Taiwan Association for Coatings and Thin Films Technology (TACT 2011) International Thin Films Conference, Kenting, Taiwan., 2011.11.20-23

北畑吉晴, 大竜二, 中江隆博, 森重樹, 奥島鉄雄, 宇野英満, 坂口浩司, 塩化金(I)触媒を用いた分子内多点環化反応による縮環芳香族分子の合成, 2011 ハロゲン利用ミニシンポジウム, 宇都宮大学陽東キャンパス, 2011.11.25

石岩大敦, 矢野真葵, 中江博隆, 森重樹, 奥島鉄雄, 宇野英満, 坂口浩司, 部分グラフェンの化学合成を指向したハロゲン化オリゴフェニレン分子の合成, 2011 ハロゲン利用ミニシンポ

ジウム, 宇都宮大学陽東キャンパス, 2011.11.25

菊池貴志, 溝渕真吾, 中江隆博, 森重樹, 奥島鉄雄, 宇野英満, 坂口浩司, 1,6,7,12-テトラブロモペリレンビスイミド類の合成と熱挙動, 2011 ハロゲン利用ミニシンポジウム, 宇都宮大学陽東キャンパス, 2011.11.25

S. Chuangchote, T. Sagawa, S. Yoshikawa, Nanofibers for Solar Cells, 4th Thailand-Japan International Academic Conference (TJIA 2011), Tokyo, Japan, 2011.11.26

S. Chuangchote, T. Sagawa, H. Sakaguchi, S. Yoshikawa, High Hole-Mobility Poly (3-hexylthiophene) Nanofibers Fabricated by Electrospinning for Nanostructured Solar Cells, 2011 Materials Research Society (MRS) Fall Meeting, Boston, U.S.A., 2011.11.28-12.2

P. Ruankham, L. Macaraig, T. Sagawa, H. Nakazumi, S. Yoshikawa, Small Organic Molecular Dyes Modification onto ZnO Nanorods Surface for Polymer-Inorganic Hybrid Solar Cells, 2011 Materials Research Society (MRS) Fall Meeting, Boston, U.S.A., 2011.11.28-12.2

L. Macaraig, S. Chuangchote, T. Sagawa, S. Yoshikawa, Fabrication of SrTiO<sub>3</sub> Nanofibers for Hydrogen Production, 2011 Materials Research Society (MRS) Fall Meeting, Boston, U.S.A., 2011.11.28-12.2

T. Sagawa, Future Power of Plastic Solar Cells for Zero-CO<sub>2</sub> Emission Society, EcoDesign, Kyoto, 2011.11.30-12.2

J.H. Lee, T. Sagawa, S. Yoshikawa, Thickness dependence of photovoltaic performance of additionally spray coated solar cells, 2011 Annual Meeting of GCOE, Kihada Hall, Uji, Kyoto, Japan, 2012.1.30

P. Ruankham, J.H. Lee, L. Macaraig, Y.T. Tsai, S. Chuangchote, T. Sagawa, Materials Design and Evaluation of Device Structures for Photovoltaic Systems: Polymer based Organic Photovoltaic Cells and Metaloxide based Photocatalysts for Hydrogen Generation, Ajou-KIT-Kyoto University Joint International Symposium, Kihada Hall, Uji, Kyoto, Japan, 2012.2.1

中江隆博, 坂口浩司, 縮環芳香族分子の高効率合成とナノ炭素材料への展開, 分子ナノシステムの創発化学第3回公開シンポジウム, 大阪科学技術センター, 2012.2.3-4

矢野真葵, 溝渕真吾, 中江隆博, 佐藤久子, 鶴

飼拓也, 坂口浩司, 電解重合と熱変換を用いたベンゾ [b] トリチオフェンポリマーネットワークの作成, 分子ナノシステムの創発化学第3回公開シンポジウム, 大阪科学技術センター, 2012.2.3-4

佐川尚, 有機薄膜太陽電池の高効率化と長寿命化を目指した材料開発とデバイス設計, 「 $\pi$  共役系有機エレクトロニクス材料の開発・応用に関する研究会」・「有機電子デバイスの最適化を目指した学際的フォーラム」, 名古屋大学, 2012.2.22

佐川尚, 有機太陽電池の材料設計と素子構造評価の基本的な考え方, 第2回 PHOENICS 国際シンポジウム, 熊本大学, 2012.3.5

S. Mizobuchi, T. Kikuchi, T. Nakae, H. Sato, S. Mori, T. Okujima, H. Uno, H. Sakaguchi, Synthesis of functionalized graphene nanoribbon by thermal polymerization of perylene bisimides derivative, 第42回フラーレン・ナノチューブ・グラフェン総合シンポジウム, 東京大学武田先端知ビル武田ホール, 2012.3.6-8

北畑吉晴, 大西竜二, 宗川達也, 中江隆博, 佐藤久子, 森重樹, 奥島鉄雄, 宇野英満, 坂口浩司, 塩化金(I)触媒を用いた分子内多点環化による縮合物の合成, 新学術領域研究「高次 $\pi$ 空間の創発と機能開発」第7回公開シンポジウム, メルパルク松山, 2012.3.13-14

矢野真葵, 溝渕真吾, 鶴飼拓也, 中江隆博, 佐藤久子, 坂口浩司, 電気化学重合-熱変換の二段階法によるベンゾ [b] トリチオフェンネットワークポリマーの作成, 新学術領域研究「高次 $\pi$ 空間の創発と機能開発」第7回公開シンポジウム, メルパルク松山, 2012.3.13-14

ルンカム ピパット, 佐川尚, 吉川暹, ポリ (3-ヘキシルチオフェン) /酸化亜鉛ハイブリッド太陽電池のキャリア移動特性, 2012 年春季第59回応用物理学関係連合講演会, 早稲田大学, 2012.3.15-18

矢野真葵, 溝渕真吾, 鶴飼拓也, 中江隆博, 佐藤久子, 坂口浩司, 電解重合と熱変換を用いたベンゾ [b] トリチオフェンポリマーネットワークの作成, 日本化学会第92春季年会(2012), 慶應義塾大学日吉キャンパス・矢上キャンパス, 2012.3.25-28

大西竜二, 北畑吉晴, 中江隆博, 佐藤久子, 森重樹, 奥島鉄雄, 宇野英満, 坂口浩司, 塩化金触媒を用いた分子内四点環化反応によるハロゲン化縮環化合物の高効率合成及び誘導体の物性, 日本化学会第92春季年会(2012), 慶應義塾大学日吉キャンパス・矢上キャンパス,

2012.3.25-28

北畑吉晴, 大西竜二, 中江隆博, 佐藤久子, 森重樹, 奥島鉄雄, 宇野英満, 坂口浩司, 塩化金(I)触媒を用いた多点環化反応による縮環芳香族の高収率合成, 日本化学会第 92 春季年会(2012), 慶應義塾大学日吉キャンパス・矢上キャンパス, 2012.3.25-28

山元朋毅, 松原祥平, 鵜飼拓也, 野本博之, 坂口浩司, ナフタレン系グラフェンナノリボンの電気化学的表面合成, 日本化学会第 92 春季年会(2012), 慶應義塾大学日吉キャンパス・矢上キャンパス, 2012.3.25-28

登政博, 村田理尚, 若宮淳志, 佐川尚, 吉川暹, 村田靖次郎, ダンベル型フラーレン誘導体の合成と光電変換特性, 日本化学会第 92 春季年会(2012), 慶應義塾大学日吉キャンパス・矢上キャンパス, 2012.3.25-28

野本博之, 山元朋毅, 松原祥平, 鵜飼拓也, 坂口浩司, グラフェンナノリボンの電気化学的形成, 電気化学会第 79 回大会, アクトシティ浜松, 2012.3.29-31

## Biofunctional Science Research Section

T. Morii, Professor  
E. Nakata, Lecturer

### 1. Introduction

The work in our research group takes synthetic, organic chemical, biochemical and biophysical approaches to understand the biological molecular recognition and chemical reactions. Rational design and functional evaluation of semi-synthetic miniature proteins, synthetic peptides and RNA/peptide assemblies enable precise recognition and fluorescence detection of biologically important molecules and in water, the solvent of life. Followings are main research achievements in fiscal year 2011.

### 2. Zinc-Finger Proteins for Site-Specific Protein Positioning on DNA-Origami based molecular switchboard

Structural DNA nanotechnology, which includes DNA origami, enables the rapid production of self-assembled nanostructures. One of the key features of this technology is that fully addressable nanoarchitectures of various shapes and geometries are easily designed and constructed. By taking advantage of their addressable nature, DNA nanostructures have been used as scaffolds for the site-directed assembly of functional entities, such as small molecules and nanoparticles. As well as these functional entities, proteins are a particularly interesting class of molecules to assemble because of their huge functional variability. We developed that different locations within DNA-origami structures are site-specifically and orthogonally targeted by using sequence-specific DNA-binding proteins as an adaptor, and demonstrate that adaptor-fused functional proteins are assembled at specific locations within DNA-origami structures. As

the first trial, we choose the zinc-finger proteins (ZFPs), because it is one of the best-characterized classes of DNA-binding proteins and the artificial ZFPs can bind to a wide variety of DNA sequences. Two types of well-characterized ZFPs, each with an affinity for a unique sequence of ten base pairs in the low nanomolar range, were chosen as the orthogonal adaptors for specific locations in the DNA-origami structures. A rectangular DNA-origami structure that has five addressable cavities was designed. Each addressable cavity was designed to hold up to four ZFP-adaptor binding sites. The folding of an M13mp18 single-stranded DNA through the use of 159 staple strands was prepared. The mixture of DNA-origami and ZFP adaptor fused chimeric protein was adsorbed onto mica and analyzed by AFM at the single-molecule level. The AFM images indicated the selective and orthogonal binding of ZFP adaptors to their expected locations. Through these experiments, we have demonstrated that ZFPs are convenient and selective adaptors for targeting specific location within DNA-origami structures. The diversity of target DNA sequences and the semi-programmable design of ZFPs offers orthogonal adaptors, thereby enabling the placement of multiple engineered proteins at different locations onto DNA-origami structures. Nature uses multiple proteins and/or enzymes in close proximity to efficiently carry out chemical reactions and signal transductions. Such assemblies of multiple proteins may be realized in vitro by using DNA-origami structures that have defined binding sites and various kinds of ZFP adaptor-fused proteins.

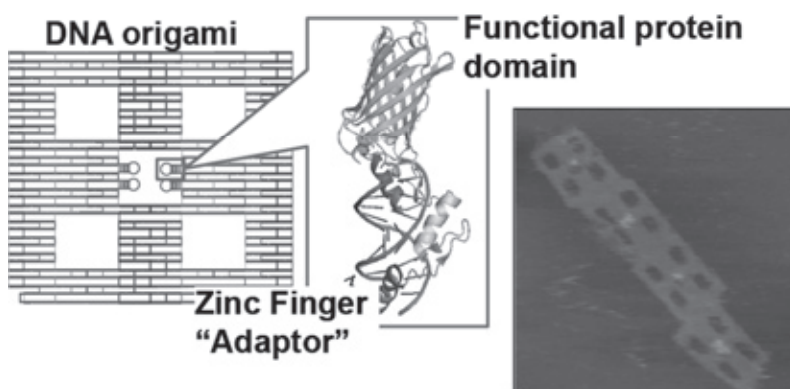


Figure 1. Conjugation of DNA origami and ZFP adaptor fused functional domain as the molecular switchboard.



### 3. The sophistication of ribonucleopeptide module for fluorescent sensor

We have reported a strategy that enables isolation of fluorescent ribonucleopeptide (RNP) sensors with a variety of binding and signal-transducing characteristics, i.e., a high signal-to-noise ratio, various wavelengths and concentration ranges for the ligand detection. The strategy would provide ideal fluorescent RNP sensors for sensing biologically importance. We have sophisticated the methodology from different perspectives.

#### 3-1. Construction of dopamine sensors by using fluorescent ribonucleopeptide complexes

A facile strategy of stepwise molding of a RNP complex affords fluorescent RNP sensors with selective dopamine recognition. In vitro selection of a RNA-derived RNP library, a complex of the Rev peptide and its binding site Rev Responsive Element (RRE) RNA appended with random nucleotides in variable lengths, afforded RNP receptors specific for dopamine. The modular structure of the RNP receptor enables conversion of dopamine-binding RNP receptors to fluorescent dopamine sensors. Application of conditional selection schemes, such as the variation of salt concentrations and application of a counter-selection step by using a competitor ligand resulted in isolation of RNP receptors with defined dopamine-binding characteristics. The results indicate that the selection condition controls the ligand-binding mechanism of RNP receptors.

#### 3-2. Facile conversion of RNA aptamers to modular fluorescent sensors

A GTP aptamer was converted to a modular fluorescent GTP sensor by conjugation of RRE RNA and successive complex formation with a

fluorophore-modified Rev peptide. Structural changes associated with substrate binding in the RNA aptamer were successfully transduced into changes in fluorescence intensity because of the modular structure of ribonucleopeptides. A simple modular strategy involving conjugation of a fluorophore-modified ribonucleopeptide to the stem region of an RNA aptamer deduced from secondary structural information helps produce fluorescent sensors, which allow tuning of excitation and detection wavelengths through the replacement of the fluorophore at the N-terminal of the Rev peptide.

#### 3-3. A ribonucleopeptide module for effective conversion of an RNA aptamer to a fluorescent sensor

We demonstrated a short RNA motif that induces an efficient communication between the structural changes associated with the ligand-binding event of RNA aptamer and an optical response of a fluorescent RNP module. An optimized short RNA motif was used as a communication module for the rational design of modular RNP sensors. A modular combination of a GTP-binding RNA aptamer, the short RNA motif and the fluorophore-labeled RNP module afforded a fluorescent GTP sensor that retain the ligand-binding affinity of the parent aptamer.

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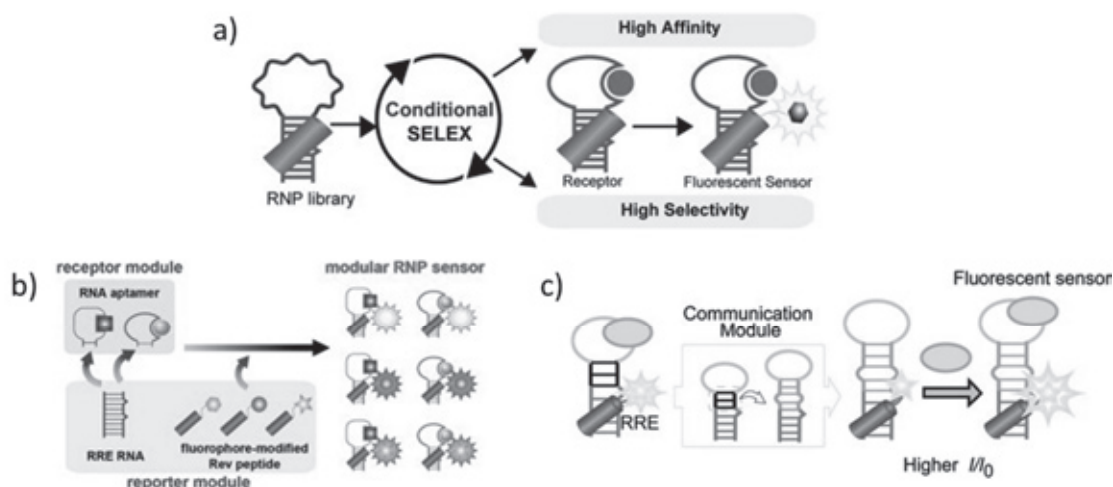


Figure 2 The sophistication of RNP module for fluorescent sensor a) Construction of dopamine sensors. b) Facile conversion of RNA aptamers to modular fluorescent sensors. c) A ribonucleopeptide module for effective conversion of an RNA aptamer to a fluorescent sensor.

## Collaboration Works

ウェイン州立大学(米国), 機能性 RNA 素子の開発, 森井孝

国立シンガポール大学 (シンガポール), イノシトール誘導体の生理活性評価, 森井孝

Ghent University (ベルギー), クロスリンク反応性を内在する機能性生体高分子によるケミカルバイオロジーの開拓, 森井孝

## Financial Support

### 1. Grant-in-Aid for Scientific Research

森井孝, 新学術領域研究, 単一細胞内セカンドメッセンジャー代謝動態のリアルタイム計測

森井孝, 基盤研究(A), モジュール設計による機能性 RNA-タンパク質複合体創製原理の確立

森井孝, 挑戦的萌芽研究, タウタンパク質によるアミロイド繊維形成を支配するアミノ酸リン酸化コードの探求

中田栄司, 若手研究(B), 癌特有の微小環境に応答する蛍光性小分子プローブの開発

松本桂彦, 特別研究員奨励費, 画期的なフォトクロミック核酸塩基の開発

### 2. Others

森井孝, 受託研究 ((独) 科学技術振興機構), 高機能 RNP ナノデバイスの開発

森井孝, 受託研究 ((独) 日本学術振興会), 二国間事業共同研究 (ベルギー) 「クロスリンク反応性を内在する機能性生体高分子によるケミカルバイオロジーの開拓」

## Publications

S. Nakano, E. Nakata, T. Morii, Facile conversion of RNA aptamers to modular fluorescent sensors with tunable detection wavelengths, *Bioorg. Med. Chem. Lett.*, 21, 3, 4503-4506, 2011

F.F. Liew, T. Hasegawa, M. Fukuda, E. Nakata, T. Morii, Construction of dopamine sensors by using fluorescent ribonucleopeptide complexes, *Bioorg. Med. Chem.*, 19, 15, 4473-4481, 2011

F.F. Liew, H. Hayashi, S. Nakano, E. Nakata, T. Morii, A ribonucleopeptide module for effective conversion of

an RNA aptamer to a fluorescent sensor, *Bioorg. Med. Chem.*, 19, 19, 5771-5775, 2011

K. Anraku, T. Inoue, K. Sugimoto, K. Kudo, Y. Okamoto, T. Morii, Y. Mori, M. Otsuka, Design and synthesis of biotinylated inositol 1,3,4,5-tetrakisphosphate targeting Grp1 pleckstrin homology domain, *Bioorg. Med. Chem.*, 19, 22, 6833-6841, 2011

E. Nakata, F.F. Liew, C. Uwatoko, S. Kiyonaka, Y. Mori, Y. Katsuda, M. Endo, H. Sugiyama, T. Morii, Zinc finger proteins for site-specific protein positioning on DNA origami, *Angew Chem. Int. Ed.*, 51, 10, 2421-2424, 2012

M. Inoue, T. Konno, K. Tainaka, E. Nakata, H. Yoshida, T. Morii, Positional effects of phosphorylation on the stability and the morphology of tau-related amyloid fibrils, *Biochemistry*, 51, 10, 1396-1406, 2012

Y. Uto, S. Yamamoto, R. Takeuchi, Y. Nakagawa, K. Hirota, H. Terada, S. Onizuka, E. Nakata, H. Hori, Effect of the Gc-derived Macrophage-activating Factor Precursor (preGcMAF) on Phagocytic Activation of Mouse Peritoneal Macrophages, *Anticancer Research*, 31, 2489-2492, 2011

E. Nakata, M. Koizumi, Y. Yamashita, K. Onaka, Y. Sakurai, N. Kondo, K. Ono, Y. Uto, H. Hori, Design, Synthesis and Destructive Dynamic Effects of BODIPY-containing and Curcuminoid Boron Tracedrugs for Neutron Dynamic Therapy, *Anticancer Research*, 31, 2477-2482, 2011

E. Nakata, Y. Nazumi, Y. Yukimachi, Y. Uto, H. Maezawa, T. Hashimoto, Y. Okamoto, H. Hori, Synthesis and photophysical properties of new SNARF derivatives as dual emission pH sensors, *Bioorg. Med. Chem. Lett.*, 21, 6, 1663-1666, 2011

E. Nakata, F.F. Liew, S. Nakano, T. Morii, Recent progress in the construction methodology of fluorescent biosensors based on biomolecules, *Biosensors for Health, Environment and Biosecurity*, 2011

中田栄司, 森井孝, 宇都義浩, 堀均, がんの特異的な検出を目指した蛍光イメージング法の最近の展開, *放射線生物研究*, 46, 2, 145-157, 2011

森井孝, 第 6 章 機能性 RNA-タンパク質複合体, 核酸化学のニュートレンド DNA/RNA の新たな可能性を拓く

## Presentations

T. Morii, Modular Functionalization of Ribonucleopeptide Assemblies, School of Physical & Mathematical Sciences, Nanyang Technological University, Singapore, 2011.4.13

森井孝, 生物がエネルギーを利用するためのしかけを考える, 京都大学エネルギー理工学研究所公開講演会「ゼロエミッションエネルギーって何だろう?」, きはだホール, 2011.5.14

森井孝, 単一細胞内セカンドメッセンジャー代謝動態のリアルタイム計測, 新学術領域研究「過渡的複合体」班会議, リゾナーレ小湊, 2011.5.17-19

T. Morii, A Modular Strategy for Tailoring Functional Ribonucleopeptides, Bioorganic Chemistry Gordon Research Conference, USA, 2011.6.13

田村友樹, 仲野瞬, 中田栄司, 森井孝, RNP を用いたモジュール型蛍光センサーの作製, 生体関連化学部会若手の会第 23 回サマースクール, 広島(宮島), 2011.7.22-23

西口泰裕, 中田栄司, 森井孝, DNA ナノ構造体への機能性分子修飾による新規機能性材料の開発, 生体関連化学部会若手の会第 23 回サマースクール, 広島(宮島), 2011.7.22-23

松本桂彦, 中田栄司, 森井孝, 高い DNA/RNA 配列認識能を有する PNA 蛍光センサー, 生体関連化学部会若手の会第 23 回サマースクール, 広島(宮島), 2011.7.22-23

松本桂彦・中田栄司, 森井孝, 高い配列認識能をもつ PNA 蛍光センサーによる RNA 検出, 生体関連化学部会第 26 回若手フォーラム, 筑波大学, 2011.9.11

松本桂彦, 中田栄司, 森井孝, 準安定二重鎖を用いた RNA 配列認識 PNA 蛍光センサー, 第 5 回バイオ関連化学シンポジウム, つくば国際会議場「エポカルつくば」, 2011.9.12-14

中田栄司, 上床知佐奈, 劉芳芳, 清中茂樹, 森泰生, 勝田陽介, 遠藤政幸, 杉山弘, 森井孝, DNA origami 上への機能性タンパク質固定化技術の開発, 第 5 回バイオ関連化学シンポジウム, つくば国際会議場「エポカルつくば」, 2011.9.12-14

T. Morii, A Modular Strategy for Assembling Receptors and Sensors from Ribonucleopeptides, 2nd Asian 3 Round Table on Nucleic Acids, China, 2011.10.15

K. Matsumoto, T. Morii, Toward of a photoinduced oxidase by using the electric charge transportation through DNA, FIBER International Symposium FIBER

Forum 2011, Hyogo, 2011.11.6-8

K. Matsumoto, E. Nakata, I. Saito, T. Morii, Sequence selective RNA detection by metastable PNA/RNA fluorescence probe, The 38th International Symposium on Nucleic Acid Chemistry, Hokkaido, 2011.11.9-11

T. Tamura, S. Nakano, E. Nakata, T. Morii, Facile conversion of RNA aptamers to modular fluorescent sensors, The 38th International Symposium on Nucleic Acid Chemistry, Hokkaido, 2011.11.9-11

E. Nakata, C. Uwatoko, F.F. Liew, S. Kiyonaka, Y. Mori, Y. Katsuta, M. Endo, H. Sugiyama, T. Morii, Development of the immobilization technology of functional proteins on DNA origami, The 38th International Symposium on Nucleic Acid Chemistry, Hokkaido, 2011.11.9-11

森井孝, 細胞内シグナル伝達分子を可視化するケミカルバイオロジー・ツール, 熊本大学大学院薬学研究科, 熊本大学大学院薬学研究科, 2011.11.25

T.A. Ngo, E. Nakata, F.F. Liew, Y. Nishiguchi, T. Morii, Development of the attachment technology of functional proteins on DNA origami, 11th iCeMS International Symposium, Kyoto, 2011.12.6

中田栄司, 松本桂彦, 森井孝, RNA 高精度検出用蛍光プローブ, グローバル COE「地球温暖化時代のエネルギー科学拠点」産学連携シンポジウム, 京都テルサテルサホール, 2011.12.15

中田栄司, 森井孝, 細胞内 pH 計測用自己集合型蛍光プローブ, グローバル COE「地球温暖化時代のエネルギー科学拠点」産学連携シンポジウム, 京都テルサテルサホール, 2011.12.15

中田栄司, RNA 高精度検出用蛍光プローブ, 大学シーズ説明発表会, 京都リサーチパーク, 2012.1.23

森井孝, 細胞内シグナル分子を可視化する, アゴラ・サノフィ, 京都大学時計台記念館, 2012.1.25

森井孝, Assembling functional protein-nucleic acids complexes, 第 2 回分子ナノテクノロジーセンターシンポジウム, 兵庫県立大学書写キャンパス書写記念会館記念ホール, 2012.3.13

中田栄司, バイオイメーシングを指向した蛍光プローブの新しい設計法の開発, 第 2 回分子ナノテクノロジーセンターシンポジウム, 兵庫県立大学書写キャンパス書写記念会館記念ホール, 2012.3.13

F.F. Liew, A Modular Strategy for the Construction and Modification of Fluorescent Ribonucleopeptide Sensor,

第 2 回分子ナノテクノロジーセンターシンポジウム, 兵庫県立大学書写キャンパス書写記念会館記念ホール, 2012.3.13

N.A. Tien, Development of the adaptor for locating protein on DNA nanostructure, 第 2 回分子ナノテクノロジーセンターシンポジウム, 兵庫県立大学書写キャンパス書写記念会館記念ホール, 2012.3.13

T. Morii, Assembling functional protein-nucleic acids complexes, Dongguk University, Dongguk University, 2012.3.16

中田栄司, 吉田裕生, 井上雅文, 今野卓, 森井孝, タウタンパク質由来の凝集性ペプチドによるアミロイド線維形成能の評価, 日本化学会第 92 春季年会, 慶応大学日吉キャンパス・矢上キャンパス, 2012.3.25-28

松本桂彦, 中田栄司, 森井孝, 準安定複合体を利用した RNA 検出蛍光プローブの開発, 日本化学会第 92 春季年会, 慶応大学日吉キャンパス・矢上キャンパス, 2012.3.25-28

西口泰裕, LIEW Fong Fong, 中田栄司, 森井孝, Zinc Finger protein を介した DNA origami 上への機能性タンパク質の配置, 日本化学会第 92 春季年会, 慶応大学日吉キャンパス・矢上キャンパス, 2012.3.25-28

田村友樹, 仲野瞬, 中田栄司, 森井孝, RNA アプタマーを用いた機能性リボヌクレオペプチドの段階的構築, 日本化学会第 92 春季年会, 慶応大学日吉キャンパス・矢上キャンパス, 2012.3.25-28



## Bioenergy Research Section

M. Katahira, Professor  
 T. Kodaki, Associate Professor  
 T. Nagata, Assistant Professor

### 1. Introduction

We explore the way how biomolecules such as proteins (involving enzymes) and functional nucleic acids (DNA and RNA) work at atomic resolution based on structural biology with NMR. We determine both static and dynamical structures with the aid of our own development of the new methodology and elucidate the underlying mechanism of functions of these biomolecules. Structural biological approach is also applied to analyze components of wood biomass at atomic resolution. The analysis is useful to develop the way to extract energy and valuable materials that can be used as starting materials of various products from the wood biomass. Thus, we pursue to contribute to the paradigm shift from oil refinery to biorefinery.

Followings are main research achievements in the year of 2011.

### 2. Development of the method to analyze components of wood biomass by solution NMR –Analysis of all components of whole wood in an intact state at atomic resolution–

We have developed a new way of sample preparation of wood biomass for the analysis by a solution NMR method. This new preparation brings much sharper NMR signals and much better signal to noise ratio. As a result, it is possible to analyze all components of whole wood biomass in an intact state (no artificial chemical modification) at atomic resolution (Figure 1). We have also developed the method to accurately quantify the components of wood biomass with NMR. We have applied the developed method to monitor the bio-degradation of wood biomass by fungi. Selective degradation of either cellulose or lignin depending on a kind of fungi used was successfully detected. Thus, our NMR method has a wide range of application to identify various components of wood biomass and to monitor their conversion.

### 3. Construction of a kinetic model to explain the location-dependent deamination frequency of DNA by anti-HIV protein, APOBEC3G

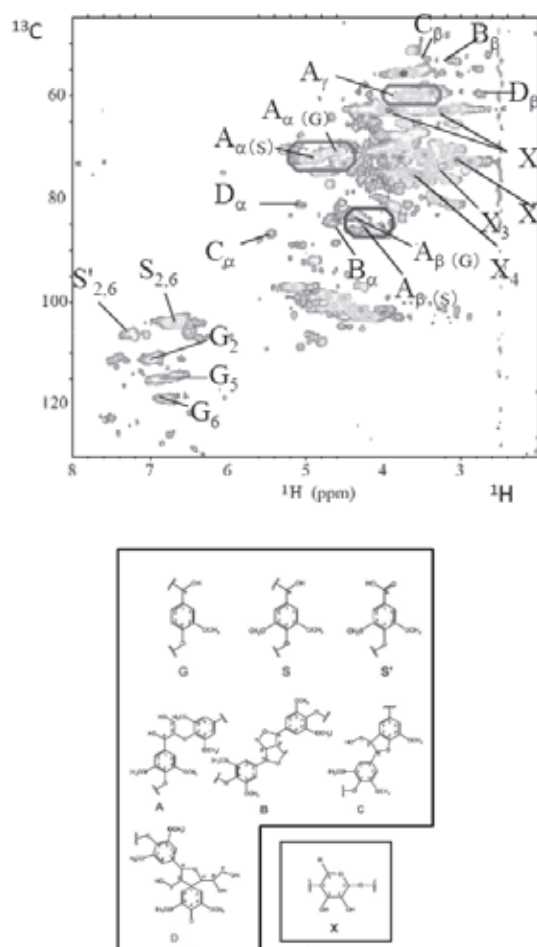


Figure 1  $^1\text{H}$ - $^{13}\text{C}$  HSQC spectrum of wood biomass. Identification of cellulose and lignin substructures is illustrated.

We developed the way to monitor deamination of a cytidine by anti-HIV protein, APOBEC3G (A3G), in real-time using NMR signals. Then, we have found that a cytidine located closer to the 5' end of single-stranded DNA (ssDNA) is deaminated more frequently than that located less close to the 5' end. Here, we have constructed a kinetic model that can successfully explain the location-dependent deamination. In this model, A3G slides on ssDNA to either 5' or 3' direction with the equal speed, but a catalytic rate of the deamination is

larger when A3G approaches to a substrate cytidine in 3' to 5' directionality than that in 5' to 3' directionality (Figure 2). This difference in the catalytic rate is rationalized from the inspection of the three-dimensional structure of A3G. In this model, the cytidine located closer to the 5' end has more chance to meet A3G approaching in the 3' to 5' directionality, which would result in higher frequency of the deamination for that cytidine. Thus, the experimental result can be successfully explained by this kinetic model. This behavior of A3G is supposed to be utilized to effectively deaminate and destroy the minus strand DNA of HIV.

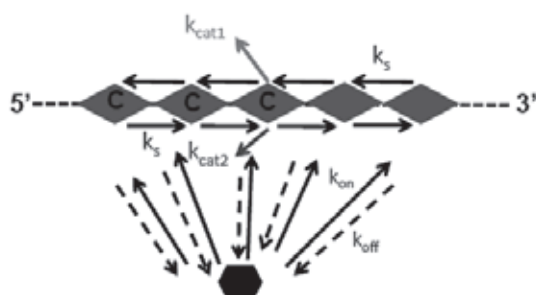


Figure 2 The kinetic model constructed to explain the location-dependent deamination frequency along DNA by anti-HIV protein, A3G.

#### 4. Elucidation of the way how RNA aptamer traps prion protein

We have identified how RNA aptamer binds to and traps a full-length prion protein that causes prion diseases such as mad cow disease. RNA aptamer forms a dimeric architecture and each monomer simultaneously binds to the two sites located in the N-terminal flexible region of the prion protein, respectively (Figure 3). Electrostatic and stacking interactions contribute to the binding at each site.

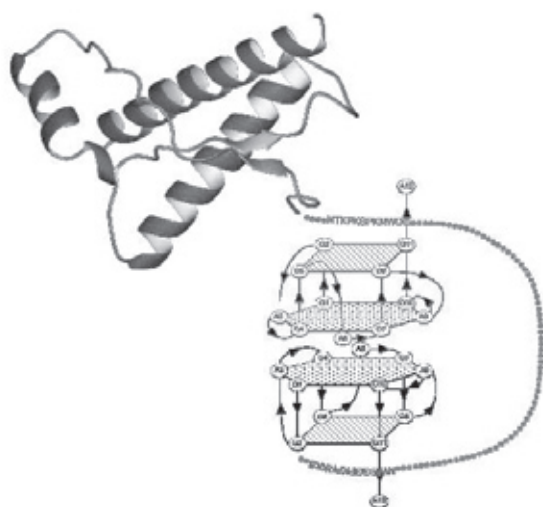


Figure 3 The way how dimeric RNA aptamer traps full-length prion protein.

The tight binding (trapping) inhibits the conversion of prion protein into an abnormal form related to diseases, which would result in repression of prion diseases. Cell-based assay to confirm this idea is in progress.

#### 5. Development of intelligent enzymes that switch their activity in response to $K^+$

The structure of r(GGAGGAGGAGGA) (R12) changes from a single-stranded form to a compact quadruplex one in response to  $K^+$ . In a hammerhead ribozyme, two portions of the catalytic core are linked with the stem and are located closely to exert the activity. Here, this stem was replaced by R12 (or R11 that lacks the terminal A residue) with some linker residues (Figure 4). One of the newly constructed ribozymes exhibited enhanced activity in response to  $K^+$ . It is suggested that the quadruplex formation restored the active catalytic core. Other ribozymes exhibited repressed activity in response to  $K^+$ . It is suggested that the quadruplex prevents the formation of the active core. Thus, we have succeeded in developing intelligent ribozymes that switch their activity either positively or negatively in response to  $K^+$ . This switching capability may have therapeutic applications because the intra- and extracellular  $K^+$  concentrations are very different.

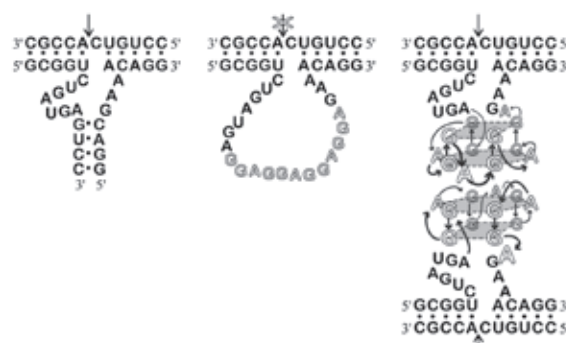


Figure 4 Architecture of intelligent ribozymes that switch their activity in response to  $K^+$ .

#### 6. Development of Highly Efficient Bioethanol Production Yeast Using Protein Engineering

In this fiscal year, the more efficient xylose fermentation and the decrease of xylitol excretion was observed by introducing the strictly NADPH dependent XR with the strictly  $NADP^+$  dependent XDH. These effects are probably due to the full recycling of coenzymes between the mutated XR and XDH.

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### 1. Grant-in-Aid for Scientific Research

片平正人, 新学術領域研究, DNA 上の極性を有したスライディングとカップルした塩基変換酵素反応の解析

片平正人, 基盤研究(B), A1 蛋白質-テロメアーテロメレース 3 者複合体の構造解析とテロメレース阻害法の開発

片平正人, 挑戦的萌芽研究, 核酸で構成された人工イオンチャネルの創製

小瀧努, 基盤研究(C), 酵素および生物機能高度化によるバイオエタノール高効率生産酵母の開発

永田崇, 基盤研究(C), TAM 受容体チロシンキナーゼのリガンド認識機構の解明と創薬に向けた分子基盤

古川亜矢子, 特別研究員奨励費, 抗 HIV 薬の創製を指向した関連蛋白質の酵素反応の実時間モニタリングと構造解析

西村裕志, 特別研究員奨励費, 超高分解能分子モニタリングで捉える選択的リグニン分解機構のダイナミクスと包括解析

真嶋司, 特別研究員奨励費, プリオン蛋白質とそれを捕捉する RNA アプタマーの複合体の構造及び相互作用研究

### 2. Others

片平正人, 受託研究 ((独) 産業技術総合研究所), ラベル不要の高機能性バイオセンサシステムの開発

片平正人, 受託研究 ((独) 科学技術振興機構), NMR による植物包括精密構造分析法の開発

小瀧努, 受託研究 ((独) 産業技術総合研究所), 五炭糖発酵酵母および酵母生産菌の分子機能改変の研究

片平正人, 奨学寄附金 (住友電工グループ), パラダイムシフトを見据えた構造生物学に立脚したバイオマスの有効活用方法研究の推進

片平正人, 奨学寄附金 ((財) 岩谷直治記念財団), 「溶液 NMR 法による木質バイオマスの水熱分解過程の丸ごと実時間モニタリングと活用基盤の確立

## Publications

K. Kondo, M. Takeda, W. Ejima, Y. Kawasaki, T. Umez, M. Yamada, J. Koizumi, T. Mashima, M. Katahira, Study of a novel glycoconjugate, thiopeptidoglycan, and a novel polysaccharide lyase, thiopeptidoglycan lyase, *Internat. J. Biol. Macromol.*, 48, 256-262, 2011

S. Nakano, T. Mashima, A. Matsugami, M. Inoue, M. Katahira, T. Morii, Structural aspects for the recognition of ATP by ribonucleopeptide receptors, *J. Am. Chem. Soc.*, 133, 4567-4579, 2011

R. Sugiyama, H. Nishitsuji, A. Furukawa, M. Katahira, Y. Habu, H. Takeuchi, A. Ryo, H. Takaku, Heat shock protein 70 inhibits HIV-1 Vif-mediated ubiquitination and degradation of APOBEC3G, *J. Biol. Chem.*, 286, 10051-10057, 2011

S.M.R. Khattab, S. Watanabe, M. Saimura, T. Kodaki, A Novel Strictly NADPH-Dependent *Pichia stipitis* Xylose Reductase Constructed by Site-directed Mutagenesis., *Biochem. Biophys. Res. Commun.*, 404, 634-637, 2011

H. Okamura, M. Nishikiori, H. Xiang, M. Ishikawa, E. Katoh, Interconversion of two GDP-bound conformations and their selection in an Arf-family small G protein, *Structure*, 13, 988-998, 2011

M. Nishikiori, M. Mori, K. Dohi, H. Okamura, E. Katoh, S. Naito, T. Meshi, M. Ishikawa, A host small GTP-binding ARL8 plays crucial roles in tobamovirus RNA replication, *PLoS Pathog.*, 8, e1002409, 2011

H. Nishimura, Y. Setogawa, T. Watanabe, Y. Honda, T. Watanabe, Epoxy ceriporic acid produced by selective lignin-degrading fungus *Ceriporiopsis subvermispora*, *Chem. Phys. Lipids.*, 164, 707-712, 2011

S.M.R. Khattab, S. Watanabe, M. Saimura, M.M. Afifi, A.N.A. Zohri, U.M. Abdul-Raouf, T. Kodaki, Construction of a Novel Strictly NADPH-Dependent *Pichia Stipitis* Xylose Reductase by Site-Directed Mutagenesis for Effective Bioethanol Production., *Green Energy and Technology "Zero-Carbon Energy Kyoto 2010*, 117-122, 2011

片平正人, 論文にみる最重要概念と革新実験データ, CSJ トレビュー 酸化学のニュートレンド, 6, 36-40, 2011

T. Ohyama, T. Nagata, K. Tsuda, N. Kobayashi, T. Imai, H. Okano, T. Yamazaki, M. Katahira, Structure of Musashi1 in a complex with target RNA: The role of aromatic stacking interactions, *Nucleic Acids Res.*, 40, 3268-3281, 2012

T. Nagata, Y. Sakurai, Y. Hara, T. Mashima, M. Katahira, Intelligent ribozyme that switches its activity in response to K<sup>+</sup> through quadruplex formation, FEBS J., 279, 1456-1463, 2012

S. Yamashita, T. Nagata, M. Kawazoe, C. Takemoto, T. Kigawa, P. Güntert, T. Terada, M. Shirouzu, M. Wakiyama, M. Muto, S. Yokoyama, Structure of the first and second double-stranded RNA-binding domains of human TAR RNA-binding protein, Protein Sci., 20, 118-130, 2012

T. Nagata, K. Tsuda, N. Kobayashi, M. Shirouzu, T. Kigawa, P. Güntert, S. Yokoyama, Y. Muto, Solution structures of the double-stranded RNA-binding domains from RNA helicase A, Proteins, 80, 1707-1723, 2012

T. Nagata, K. Tsuda, N. Kobayashi, P. Güntert, S. Yokoyama, Y. Muto, J2, 1H, 13C, and 15N resonance assignments of the dsRBDs of mouse RNA helicase A, Biomolecular NMR Assignments, 6, 155-158, 2012

M. Takeda, K. Kondo, M. Yamamada, M. Sumikawa, J. Koizumi, T. Mashima, M. Katahira, Presence of alternating glucosaminoglycan in the sheath of Thiothrix nivea, Internat. J. Biol. Macromol., 50, 236-244, 2012

H. Nishimura, K. Murayama, T. Watanabe, Y. Honda, T. Watanabe, Diverse rare lipid-related metabolites including w-7 and w-9 alkenylitaconic acids (ceriporic acids) secreted by a selective white rot fungus, Ceriporiopsis subvermispora, Chem. Phys. Lipids., 165, 97-104, 2012

## Presentations

片平正人, 疾患関連タンパク質とアプタマーに関する構造・機能相関の研究, 新学術領域班会議, 小淵沢, 2011.5.17-19

古川亜矢子, 松永智子, 岩岡諒, 永田崇, 小林直宏, 高折晃史, 森下了, 梁明秀, 片平正人, XMRV プロテアーゼの NMR による構造解析, 第 11 回日本蛋白質科学会年会, 吹田, 2011.6.7-9

T. Mashima, H. Fujiwara, T. Koshida, M. Saimura, M. Imamura, T. Yokoyama, F. Nishikawa, S. Nisikawa, M. Katahira, Structural basis of the high affinity of the RNA aptamer against prion protein, RNA2011 SIXTEEN ANNUAL MEETING OF THE RNA SOCIETY, 京都, 2011.6.14-18

片平正人, ゲル化したバイオマス試薬の溶液 NMR スペクトル及びプリオンタンパク質と RNA アプタマーの複合体の構造決定, 第 12 回若手 NMR 研究

会, 守山, 2011.6.23-25

片平正人, ラベル不要の高機能性バイオセンサシステムの開発, JST サイトビジット専攻会議, つくば, 2011.7.13-14

松永智子, 澤崎達也, 小島良績, 森下了, 佐藤裕徳, 大出裕高, 古川亜矢子, 片平正人, 杉浦互, 梁明秀, コムギ無細胞タンパク質合成系を用いた Xenotropic murine leukemia virus-related virus (XMRV) プロテアーゼの解析, 日本プロテオーム学会 2011 年大会, 新潟, 2011.7.28-29

Kodaki T., Highly Efficient Bioethanol Production Yeast from Sugars in Lignocellulosic Biomass using Protein Engineering, The 3rd International Symposium: Kyoto University Global COE Program, Ajou, Korea, 2011.8.17-20

R. Iwaoka, A. Furukawa, H. Okamura, M. Katahira, Elucidation of functions on APOBEC3DE and APOBEC3F Based on Structure-Oriented Analysis, 3rd G-COE International Symposium (Specially Jointed with BK21 Program at Ajou University) “ZERO CARBON ENERGY 2011”, Ajou University, Suwon, Korea, 2011.8.18-19

N. Kobayashi, A. Furukawa, S. Kitazawa, T. Nagata, R. Kitahara, M. Katahira, T. Fujiwara, MagRO-Assign: a tool for automated sequence specific assignment of chemical shifts for NMR signals of protein backbone, EUROMAR2011, Frankfurt, Germany, 2011.8.21-25

片平正人, アプタマーとプリオンタンパク質の複合体の構造解析及びインテリジェントリボザイムの創薬, 第 7 会分子複合医薬研究会, 池田, 2011.8.31

S. Matsunaga, Y. Kojima, R. Morishita, T. Sawasaki, A. Furukawa, M. Katahira, A. Takaori, W. Sugiura, A. Ryo, An in vitro cleavage assay system for XMRV protease by wheat-germ cell free protein production, IUMS2011, 札幌, 2011.9.6-10

西村裕志, 小澤佑, 岡村英保, 佐々木碧, 片平正人, 渡辺隆司, 木質バイオマスの定量・微細構造解析のための HSQC/HMBC NMR 法の開発, 第 56 回リグニン討論会, 鶴岡, 2011.9.15-16

安藤大將, 西村裕志, 片平正人, 高野俊幸, 中坪文明, 矢野浩之, リグニンの  $\beta$ -O-4 結合新規選択的開裂法 ( $\gamma$ -TTSA 法) の検証 (2) -DHP への適用-, 第 56 回リグニン討論会, 鶴岡, 2011.9.15-16

M. Katahira, A. Furukawa, T. Nagata, H. Takaku, R. Morishita, A. Takaori, A. Ryo, リアルタイムモニタリングによって示された APBEC3G による DNA 上の



極性を有したスライディングとカップルしたシトシン脱アミノ基反応, 日本生物物理学会第 49 回年会, 姫路, 2011.9.16-18

H. Okamura, T. Matsunaga, A. Furukawa, Y. Sato, R. Iwaoka, T. Nagata, N. Kobayashi, A. Takaori, R. Morishita, A. Ryo, M. Katahira, NMR による XMRV プロテアーゼとその阻害剤との複合体の構造生物学的研究, 日本生物物理学会第 49 回年会, 姫路, 2011.9.16-18

T. Mashima, H. Fujiwara, M. Endo, M. Saimura, M. Imamura, T. Yokoyama, F. Nishikawa, S. Nishikawa, M. Katahira, RNA アプタマーがプリオンタンパク質を捕捉するメカニズム, 日本生物物理学会第 49 回年会, 姫路, 2011.9.16-18

三亀啓吾, 大橋康典, 片平律子, 小澤佑, 片平正人, 渡邊崇人, 本田与一, 菅原智, 小池謙造, 渡辺隆司, リグニン誘導体を用いた天然型有機系紫外線吸収剤, 第 56 回リグニン討論会, 鶴岡, 2011.9.16-18

片平正人, 抗 HIV タンパク質の酵素活性のリアルタイムモニタリング及び抗プリオンタンパク質アプタマーの捕捉機構, 立命館大学講演会, 草津, 2011.10.18

T. Nagata, Y. Sakurai, Y. Hara, T. Mashima, M. Katahira, r(GGA)4 chimeric ribozyme switches its activity in response to  $K^+$  via quadruplex formation, The 38th International Symposium on Nucleic Acid Chemistry, 札幌, 2011.11.9-11

H. Nishimura, A. Furukawa, H. Okamura, Y. Kozawa, R. Morishita, A. Ryo, K. Sugase, T. Watanabe, M. Katahira, Base-deamination rate dependent on the direction of sliding of an enzyme along DNA as revealed by numerical analysis of NMR data, and wood biomass studied by solution NMR, The International Symposium on Nuclear Magnetic Resonance 2011, 横浜, 2011.11.15-18

A. Furukawa, K. Sugase, R. Morishita, T. Nagata, A. Ryo, A. Takaori, M. Katahira, Real-time monitoring of the cytidine deamination along single-stranded DNA by an anti-HIV factor, APOBEC3G, The International Symposium on Nuclear Magnetic Resonance 2011, 横浜, 2011.11.15-18

片平正人, プリオンタンパク質に対する RNA アプタマーの構造と相互作用様式, 第 2 回神経科学と構造生物学の融合プログラム, 岡崎, 2011.11.21-22

T. Ohyama, T. Nagata, K. Tsuda, N. Kobayashi, T. Imai, H. Okano, T. Yamazaki, M. Katahira, Structural basis for the sequence-specific RNA-recognition mechanism

of Musashi 1, 第 34 回日本分子生物学会年会, 横浜, 2011.12.13-16

A. Furukawa, K. Sugase, R. Morishita, T. Nagata, A. Ryo, A. Takaori, M. Katahira, Real-time monitoring the cytidine deamination along single-stranded DNA by an anti-HIV factor, APOBEC3G, 第 34 回日本分子生物学会年会, 横浜, 2011.12.13-16

藤原弘道, 真嶋司, 西川富美子, 才村正幸, 遠藤美紗, 今村守一, 横山隆, 西川諭, 片平正人, プリオンタンパク質の N 末ドメインと RNA アプタマーの相互作用の解析, 第 34 回日本分子生物学会年会, 横浜, 2011.12.13-16

永田崇, 酵素活性の実時間追跡と構造解析による抗 HIV 治療薬の開発型研究, 第 7 回先端医科学研究センタープロジェクト報告会, 横浜, 2012.1.10

Y. Imamura, H. Nishimura, Y. Matsushita, M. Katahira, K. Fukushima, N. Terashima, Structural analysis of lignin by a specific  $^{13}C$ -enrichment technique combined with 2D NMR of whole wall of ginkgo tracheid, The 12th International Symposium on Biomimetic Materials Processing, 名古屋, 2012.1.24-27

西村裕志, 小澤佑, 永田崇, 小瀧努, 渡辺隆司, 片平正人, 大型装置の連携利用による有用バイオマス生分解の実時間モニタリングとメカニズムの解明, 生存科学基盤研究ユニット成果報告会, 京都, 2012.2.28-29

片平正人, 渡辺隆司, 小瀧努, 吉岡康一, 西村裕志, 超高感度溶液 NMR 法による木質バイオマスの丸ごと、高分解能、リアルタイム計測法の開発と応用, 生存圏ミッションシンポジウム, 京都, 2012.3.1

西村裕志, 小澤佑, 岡村英保, 渡辺隆司, 片平正人, 溶液 NMR 法による木材細胞壁成分の精密評価と生分解モニタリング, 第 62 回日本木材学会大会, 札幌, 2012.3.15-17

三亀啓吾, 大橋康典, 西村裕志, 片平律子, 小澤佑, 片平正人, 渡邊崇人, 本田与一, 菅原智, 小池謙造, 渡辺隆司, リグニン誘導体を用いた天然型紫外線吸収剤の開発, 第 62 回日本木材学会大会, 札幌, 2012.3.15-17

安藤大將, 西村裕志, 片平正人, 高野俊幸, 中坪文明, 矢野浩之, リグニン  $\beta$ -O-4 結合新規選択的開裂法の検討(3) -MWL への適用-, 第 62 回日本木材学会大会, 札幌, 2012.3.15-17

A. Furukawa, T. Mashima, K. Sugase, H. Fujiwara, T. Nagata, R. Morishita, A. Ryo, F. Nishikawa, S. Nishikawa, Y. Kamatari, K. Kuwata, M. Katahira,

Sliding-direction-dependent activity of anti-HIV enzyme, and structural basis of anti-prion activity of RNA aptamer, Korea-Japan Bilateral NMR Symposium, 札幌, 2012.3.16

H. Nishimura, Y. Kozawa, H. Okamura, T. Watanabe, M. Katahira, Towards evaluation of wood cell wall structures and those biodegradation using solution NMR, Korea-Japan Bilateral NMR Symposium, 札幌, 2012.3.16

T. Mashima, H. Fujiwara, F. Nishikawa, M. Saimura, Y. Kamatari, K. Kuwata, M. Imamura, T. Yokoyama, S. Nishikawa, M. Katahira, Recognition of prion protein by the RNA aptamer, Korea-Japan Bilateral NMR Symposium, 札幌, 2012.3.16

小澤佑, 西村裕志, 片平正人, 渡辺隆司, 木材腐朽菌による木質バイオマス分解過程のNMR法を用いた解析, 日本農芸化学会, 京都, 2012.3.22-26

西村裕志, 岡村英保, 小澤佑, 渡辺隆司, 片平正人, 溶液NMR法による木質バイオマスの定量と精密構造解析, 日本農芸化学会, 京都, 2012.3.22-26

# Laboratory for Complex Energy Processes Section

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## Introduction

### A. Theoretical Biophysics

A variety of self-assembling and ordering processes in biological systems, which occur at molecular levels, are sustaining life. Biopolymers, a great diversity of molecular and ionic species, or water is simply *material* when each of them is separately present. However, the complicated correlations among these material constituents can lead to *life*. We are elucidating those correlations, uncovering the mechanism of the biological self-assembly, and clarifying the roles of water by developing special theories based on statistical mechanics and morphometric thermodynamics. The achievements will provide important bases of nanobiotechnology. The current subjects are investigations on the hydrophobic and hydrophilic hydrations, anomalous behavior of confined liquids, folding/unfolding mechanisms of proteins, receptor-ligand binding, prediction of the native structure of a protein, and mechanism of the functioning of ATP-driven proteins.

### B. Plasma Physics

The major subjects are to study fast-ion confinement in plasma confinement devices and to investigate interactions between fast-ions and materials, such as a first wall and a vacuum vessel. The fast-ion confinement is a critical issue for the fusion reactor since the alpha particles produced in the D-T reaction should be utilized to heat plasma efficiently. The interactions between fast-ions and materials cause the impurity problem for the plasma energy confinement and the damage for the vessel or the first wall materials occurs.

Fast-ion profile and velocity distribution are investigated using ion cyclotron range of frequency (ICRF) minority heating in Heliotron J with special emphasis on the effect of the toroidal ripple of magnetic field strength ('bumpiness'). Optimization of the ICRF heating is important for the three-dimensional magnetic configuration. We also investigate the effect of the position of the ion cyclotron resonance layer on the fast ion formation and confinement.

#### (A-1) Potential of mean force between a large solute and a biomolecular complex: A model analysis on protein flux through chaperonin system [1]

Insertion of a large solute into an even larger vessel comprising biopolymers followed by release of the same solute from it is one of the important

functions sustaining life. As a typical example, an unfolded protein is inserted into a chaperonin from bulk aqueous solution, a cochaperonin acting as a lid is attached to the chaperonin rim and the protein folds into its native structure within the closed cavity, the cochaperonin is detached after the folding is finished, and the folded protein is released back to the bulk solution. On the basis of the experimental observations manifesting that the basic aspects of the protein flux through the chaperonin system is independent of the chaperonin, cochaperonin, and protein species, we adopt a simple model system with which we can cover the whole cycle of the protein flux. We calculate the spatial distribution of the solvent-mediated potential of mean force (PMF) between a spherical solute and a cylindrical vessel or vessel/lid complex. The calculation is performed using the three-dimensional integral equation theory, and the PMF is decomposed into energetic and entropic components. We argue that an unfolded protein with a larger excluded volume (EV) and weak hydrophobicity is entropically inserted into the chaperonin cavity and constrained within a small space almost in its center. The switch from insertion to release is achieved by decreasing the EV and turning the protein surface hydrophilic in the folding process. For this release, in which the energetic component is requisite, the feature that the chaperonin inner surface in the absence of the cochaperonin is not hydrophilic plays essential roles. On the other hand, the inner surface of the chaperonin/cochaperonin complex is hydrophilic, and the protein is energetically repelled from it: The protein remains constrained within the small space mentioned above without contacting the inner surface for correct folding. The structural and inner-surface properties of the chaperonin or complex are controlled by the ATP binding to the chaperonin, hydrolysis of ATP into ADP and Pi, and dissociation of ADP and Pi. The function of the chaperonin system is exhibited by synchronizing the chemical cycle of ATP hydrolysis with hydration properties of a protein in the water confined on the scale of a nanometer which are substantially different from those in the bulk water.

#### (A-2) Crucial importance of water-entropy effect for predicting hot spots in protein-protein complexes [2]

"Hot spots" are residues accounting for the majority of the protein-protein binding free energy (BFE) despite that they comprise only a small fraction of the protein-protein interface. A hot spot

can be found experimentally by measuring the BFE change upon mutating it to alanine: The mutation gives rise to a significantly large increase in the BFE. Theoretical prediction of hot spots is an enthusiastic subject in biophysics and bioinformatics. For the development of a reliable prediction method, it is essential to understand the physical origin of hot spots. To this end, we calculate the water-entropy gains upon the binding both for a wild-type complex and for its mutant complex using a hybrid method of the angle-dependent integral equation theory applied to a molecular model for water and the morphometric approach. We note that this type of calculation has never been employed in the previously reported methods. The BFE change due to alanine mutation is evaluated only from the change in the water-entropy gain with no parameters fitted to the experimental data. It is shown that the overall performance of predicting hot spots in our method is higher than that in Robetta, a standard free-energy-based method using fitting parameters, when the most widely used criterion for defining an actual hot spot is adopted. This result strongly suggests that the water-entropy effect we calculate is the key factor governing basic physics of hot spots.

#### **(B-1) Study of bumpiness and heating position effect on fast ions using ICRF minority heating in Heliotron J**

The fast ion confinement and ion heating efficiency is studied using ICRF minority heating. The better confinement in the high bumpiness and the localization of fast ions in the high-field side heating in the medium bumpiness are found in the experiment and simulation.

Fast ion velocity distribution is investigated using fast protons generated by ICRF minority heating in Heliotron J, a low-shear helical-axis heliotron ( $R_0 = 1.2$  m,  $a = 0.1$ – $0.2$  m,  $B_0 \leq 1.5$  T). The fast ions are measured by a charge-exchange neutral particle energy analyzer (CX-NPA) installed at the opposite position in the toroidal angle to the ICRF antennas. By changing resonance layer position, the CX flux was measured, and then fast-ion energy spectrum and ion heating efficiency were investigated. The experimental condition is as follows: the magnetic field strength is 1.25 T, the line-averaged electron density is  $0.4 \times 10^{19} \text{ m}^{-3}$  and the ICRF power of 0.25–0.30 MW is injected into a target plasma produced by a 70-GHz ECH. The ion and electron temperatures at the center of the ECH plasma are about 0.2 and 0.8 keV, respectively. The minority ratio is about 10%. Frequency of ICRF is 19 MHz or 23.2 MHz.

The wide range observation (about 25% in the poloidal cross section of a plasma) of fast ions is performed by changing the line of sight of the CX-NPA in two directions for three bumpinesses. The bumpinesses ( $B_{04}/B_{00}$ , where  $B_{04}$  is the bumpy component and  $B_{00}$  is the averaged magnetic field

strength) are chosen to be 0.15 (high) and 0.06 (medium) at the normalized radius of 0.67 in this study. For the quantitative comparison of the fast ion tail, the effective temperature of fast minority ions is evaluated from the energy spectrum in the range of 1 keV to 7 keV. In this energy range, protons can follow a banana orbit although the collision effect is not negligible. The better performance of the high bumpiness is confirmed in this vertical angle scan of the CX-NPA at horizontal angles from  $-2^\circ$  to  $12^\circ$ . The tail temperature is largest in the high bumpiness case and the difference of the energy spectra in the vertical scan within 0.4 in the normalized minor radius is very small for the on-axis heating condition for all configurations. In addition to that, the scan experiment is performed for the difference position of the minority proton resonance layer in the medium bumpiness. The large change in the vertical scan is found for the inner-side heating in the medium bumpiness at  $\varphi = 0^\circ$  and  $4^\circ$ , whereas there is little change at  $6^\circ$ . Here,  $\varphi$  is horizontal angle of the CX-NPA. In the upper part of the plasma, more fast ions are observed. There is no such profile change in the on-axis condition for three bumpinesses.

The area of the CX-NPA measurement is limited due to the observation port size. For the comprehension of the fast ion confinement and bulk heating, however, the fast ion information in all area of the plasma volume is required. For this purpose, a Monte-Carlo simulation has been developed [3]. Using this code, the toroidal angle distributions of fast minority ions for one toroidal period ( $90^\circ$ ) are calculated for the cases of the experiment. The horizontal angle of  $0^\circ$  is near the corner section and the angle of  $6^\circ$  is toward the straight section for the top view of Heliotron J plasma. From the result, it is found that the fast ions in the high bumpiness are largest at every angle. It is also found that the number of fast ions is larger in the corner section for the high-field side heating case than in the on-axis case and the fast ions in the on-axis heating cases are almost uniformly distributed in toroidal direction. The volume averaged number of fast ions is larger in the high-field side heating case. It is possible that this causes the higher bulk heating efficiency. The increase of the fast ions in the experiment is found near  $\varphi = 0^\circ$  where the generation of more fast ions is observed in the calculation.

#### **References**

- [1] K. Amano, H. Oshima, and M. Kinoshita, *J. Chem. Phys.* **135**, 185101 (2011).
- [2] H. Oshima, S. Yasuda, T. Yoshidome, M. Ikeguchi, and M. Kinoshita, *Phys. Chem. Chem. Phys.* **13**, 16236 (2011).
- [3] Okada, H., et al., *Plasma Fusion Res.* **6** (2011) 2402063.



## Collaboration Works

Univ. Wisconsin (米国), Univ. Wisconsin (米国), ORNL (米国), Max Planck Institute (ドイツ), Stuttgart Univ.(ドイツ), Provence Univ. (フランス), CIEMAT (スペイン), ANU (オーストラリア), Kharkov Institute (ウクライナ), SWIP (中華人民共和国), 先進ヘリカルにおける改善閉じ込めの研究, 佐野史道, 水内亨, 長崎百伸, 岡田浩之, 小林進二, 山本聡, D. Anderson (Univ. Wisconsin, USA), J.H. Harris (Oak Ridge National Laboratory, USA), F. Wagner, M. Hirsch, V. Erckmann, H. Laqua, N.B. Marushchenko (Max Plank Institute, Germany), M. Ramisch (Stuttgart Univ., Germany), J. Sanchez, E. Ascasibar, C. Hidalgo, T. Estrada, A. Cappa, A. Alonso (CIEMAT, Spain), B. Blackwell, D. Pretty, H. Punzmann (Australian National Univ., Australia), V. Chechkin, V. Pankratov (Kharkov Institute, Ukraine), X.R. Duan, Q.W. Yang, L.W. Yan, W.W. Xiao (Southwest Institute of Physics, China)

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核融合科学研究所, ヘリオトロン J におけるマルチチャンネル Ha/Da 線放射分布計測を用いた粒子補給の最適化, 小林進二, 水内亨, 岡田浩之

核融合科学研究所, ヘリオトロン J におけるビーム放射分光法による密度揺動の空間分布計測, 小

林進二, 水内亨, 岡田浩之

核融合科学研究所, トリムコイルを用いたヘリオトロン J の磁場配位最適化, 佐野史道, 水内亨, 長崎百伸, 花谷清, 岡田浩之, 南貴司, 小林進二, 山本聡

核融合科学研究所, 低磁気シアプラズマにおける高速イオンと高速イオン励起 MHD 不安定性の相互作用に関する研究, 山本聡, 小林進二, 岡田浩之, 南貴司, 佐野史道, 水内亨, 長崎百伸

核融合科学研究所, ヘリカル系における電子サイクロトロン電流駆動による回転変換制御, 長崎百伸, 佐野史道, 増田開, 水内亨, 花谷清, 岡田浩之, 南貴司, 小林進二, 山本聡

核融合科学研究所, 2.45GHz マイクロ波入射アシストによる NBI プラズマ生成, 長崎百伸, 小林進二, 増田開, 佐野史道, 水内亨, 岡田浩之, 南貴司, 山本聡

## Financial Support

### Grant-in-Aid for Scientific Research

木下正弘, 新学術領域研究, ATP 駆動蛋白質の機能発現における水の役割: 統計力学理論解析

木下正弘, 基盤研究(B), 液体論を基盤とした蛋白質立体構造予測法の構築

岡田浩之, 基盤研究(C), 高速イオン閉じ込めに対する磁場のトロイダルリップル成分の寄与に関する研究

天野健一, 特別研究員奨励費, 生体系における水の並進エントロピーの重要性: 統計力学理論解析

## Publications

S. Yasuda, T. Yoshidome, Y. Harano, R. Roth, H. Oshima, K. Oda, Y. Sugita, M. Ikeguchi, M. Kinoshita, Free-Energy Function for Discriminating the Native Fold of a Protein from Misfolded Decoys, *Proteins – Structure Function and Bioinformatics*, 79, 2161-2171, 2011

R. Kodama, R. Roth, Y. Harano, M. Kinoshita, Morphometric Approach to Thermodynamic Quantities of Solvation of Complex Molecules: Extension to Multicomponent Solvent, *Journal of Chemical Physics*, 135, 045103-1-045103-8, 2011

H. Oshima, S. Yasuda, T. Yoshidome, M. Ikeguchi, M. Kinoshita, Crucial Importance of Water-Entropy

Effect for Predicting Hot Spots in Protein-Protein Complexes, *Physical Chemistry Chemical Physics*, 13, 16236-16246, 2011

Y. Karino, R. Akiyama, M. Kinoshita, A Simple Theory for Entropic Interaction Induced between Large Spheres in a Binary Mixture of Small and Medium Spheres, *Journal of the Physical Society of Japan*, 80, 114802-1-114802-8, 2011

K. Amano, H. Oshima, M. Kinoshita, Potential of Mean Force between a Large Solute and a Biomolecular Complex: A Model Analysis on Protein Flux through Chaperonin System, *Journal of Chemical Physics*, 135, 185101-1-185101-14, 2011

S. Chiba, Y. Harano, R. Roth, M. Kinoshita, M. Sakurai, Evaluation of Protein-Ligand Binding Free Energy Focused on its Entropic Components, *Journal of Computational Chemistry*, 33, 550-560, 2012

T. Yoshidome, Importance of Water Entropy in Rotation Mechanism of F<sub>1</sub>-ATPase, *BIOPHYSICS*, 7, 113-122, 2011

吉留崇, F<sub>1</sub>-ATPase の回転のメカニズムにおける水のエントロピーの重要性, *生物物理*, 51, 230-231, 2011

吉留崇, モーター蛋白質 F<sub>1</sub>-ATPase の回転のメカニズム: 水のエントロピーの重要性, *分子シミュレーション研究会会誌「アンサンブル」*, 13, 50-56, 2011

木下正弘, 「疎水性」の本当の物理起源: その温度依存性を通しての考察, *低温生物工学会誌*, 58, 19-25, 2012

T. Kagawa, S. Kobayashi, S. Kado, T. Oishi, Y. Nagae, S. Ohshima, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, H. Lee, T. Minami, K. Mukai, L. Zang, S. Arai, H. Watada, Y. Wada, K. Mizuno, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Development of beam emission spectroscopy system in Heliotron (Jヘリオトロン J におけるビーム放射分光計測システム開発), *PLASMA* 2011, 22P098-P, 2011

南貴司, 荒井翔平, 釧持尚輝, 八代浩彰, 高橋千尋, 小林進二, 水内亨, 岡田浩之, 長崎百伸, 中村祐司, 花谷清, 山本聡, 木島滋, 大島慎介, 佐野史道, Present status of the Nd:YAG Thomson scattering system development for time evolution measurement of plasma profile on Heliotron J (1)(Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状 (1)), *PLASMA* 2011, 22P109-P, 2011

荒井翔平, 南貴司, 釵持尚輝, 八代浩彰, 高橋千尋, 小林進二, 水内亨, 大島慎介, 山本聡, 岡田浩之, 長崎百伸, 向井清史, 李炫庸, 臧臨閣, 香川輔, 水野浩二, 南貴之, 和多田泰士, 和田善信, 中村祐司, 花谷清, 木島滋, 佐野史道, Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状(2), PLASMA 2011, 22P110-P, 2011

八代浩彰, 南貴司, 荒井翔平, 釵持尚輝, 水内亨, 高橋千尋, 長崎百伸, 佐野史道, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 向井清史, H.Y.Lee, L.Zang, 香川輔, 水野浩志, 南貴之, 和多田泰士, 和田善信, 木島滋, 笠嶋慶純, 原田伴誉, 久田祥史, Present status of the Nd:YAG Thomson scattering system development for time evolution measurement of plasma profile on Heliotron J (3)(Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状 (3)), PLASMA 2011, 22P114-P, 2011

岡田浩之, 和多田泰士, 和田善信, 小林進二, 李炫庸, 水内亨, 長崎百伸, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, 臧臨閣, 八代浩彰, 南貴之, 香川輔, 荒井翔平, 水野浩志, 佐野史道, Dependence of the ICRF Heating Efficiency on the Resonance Position in Heliotron J(ヘリオトロン J における ICRF 加熱の共鳴位置による加熱特性の変化), PLASMA 2011, 23P026-P, 2011

李炫庸, 小林進二, 南貴之, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 大島慎介, 原田伴誉, 香川輔, 向井清史, Zang Linge, 木島滋, 佐野史道, Measurement of toroidal rotation velocity profile and calculation of external momentum input by NBI in Heliotron J(ヘリオトロン J におけるトロイダル回転速度分布計測ならびに外部運動量入力計算), PLASMA 2011, 23P027-P, 2011

南 貴之, 小林進二, H.Y. Lee, 門信一郎, 水内 亨, 長崎百伸, 岡田浩之, 南 貴司, 山本 聡, 大島慎介, 原田伴誉, 香川 輔, 向井清史, L. Zang, 荒井翔平, 八代浩彰, 和多田泰士, 和田善信, 村上定義, 中村祐司, 花谷 清, 木島 滋, 佐野史道, ヘリオトロン J における荷電交換再結合分光による不純物イオン温度分布計測, PLASMA 2011, 23P028-P, 2011

水野浩志, 長崎百伸, 向井清史, 中村雄一, 福田武司, T. Estrada, 大島慎介, 水内亨, 南貴司, 岡田浩之, 増田開, 小林進二, 山本聡, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 中村祐司, 花谷清, 木島滋, 佐野史道, Measurement of Electron Density Fluctuations using Microwave Reflectometer in Heliotron J (ヘリオトロン J におけるマイクロ波反射計を用いた電子密度揺動計測), PLASMA

2011, 23P029-P, 2011

向井清史, 長崎百伸, 水内亨, V. Zhuravlev, 田中謙治, 南貴司, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 水野浩志, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 木島滋, 佐野史道, Density modulation experiment in Heliotron-J ECH plasma (ヘリオトロン J における ECH プラズマでの密度変調実験), PLASMA 2011, 23P030-P, 2011

和田善信, 岡田浩之, 長崎百伸, 山本聡, 水内亨, 南貴司, 小林進二, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 和多田泰士, 荒井翔平, 香川輔, 水野浩志, 南貴之, 八代浩彰, 中村祐司, 花谷清, 木島滋, 佐野史道, Pitch Angle Dependence of Fast Electrons Energy Spectra Measured with a Soft X-Ray Pulse height Analyzer in Heliotron J ヘリオトロン J における軟 X 線波高分析による高速電子エネルギー分布のピッチ角依存性, PLASMA 2011, 23P032-P, 2011

大島慎介, 橋本紘平, 山本聡, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 小林進二, 花谷清, 木島滋, 竹内正樹, 佐野史道, Edge plasma fluctuation measured with multiple Langmuir probes in Heliotron J (ヘリオトロン J 装置における静電プローブによる周辺プラズマ揺動計測とその構造の解明), PLASMA 2011, 23P033-P, 2011

和多田泰士, 岡田浩之, 小林進二, H.Y. Lee, 水内亨, 長崎百伸, 花谷清, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, L. Zang, 荒井翔平, 香川輔, 南貴之, 和田善信, 水野浩志, 佐野史道, Dependence of Fast Ions Generated by ICRF Minority Heating on Pitch Angle and Spatial Position in Heliotron J (ヘリオトロン J における ICRF 加熱での高速イオンのピッチ角及び空間位置依存性), PLASMA 2011, 23P035-P, 2011

西野信博, 臧 臨閣, 竹内正樹, 水内亨, 大島慎介, 笠嶋慶純, 沙夢雨, 向井清史, 李炫庸, 長崎百伸, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 花谷清, 中村祐司, 佐野史道, Study of filament features of edge plasma fluctuations using fast video cameras with a combination of Langmuir probe measurements in Heliotron J (II) ヘリオトロン J での高速カメラと静電プローブによるフィラメント状周辺プラズマ揺動の研究(II)", PLASMA 2011, 23P036-P, 2011

長崎百伸, N. Marushchenko, 山本聡, 坂本欣三, Y. Turkin, 水内亨, 岡田浩之, 南貴司, 花谷清, 増田開, 小林進二, 木島滋, 大島慎介, 中村祐司, 向井清史, 李炫庸, 水野浩志, L. Zang, 荒井翔平, 香川輔, 南貴之, 水野浩志, 和田善信, 和多田泰士, T.Estrada, 村上定義, 吉村泰夫, 本島巖, 佐野史道, Control of Rotational Transform by



ECCD in Heliotron J (ヘリオトロン J における ECCD を用いた回転変換制御), PLASMA 2011, 23P037-P, 2011

"臧 臨閣, 竹内正樹, 西野信博, 水内亨, 大島慎介, 笠嶋慶純, 沙 夢雨, 向井清史, 李炫庸, 長崎百伸, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 花谷清, 中村祐司, 佐野史道", Study of Filament Features of Edge Plasma Fluctuations using fast video cameras with a combination of Langmuir probe measurements in Heliotron J (I), PLASMA 2011, 23P038-P, 2011

小林進二, 長崎百伸, 坂本欣三, 山本聡, 水内亨, 岡田浩之, 南貴司, 花谷清, 中村祐司, 木島滋, 大島慎介, 向井清史, Lee Hyunyoung, Zang Linge, 東使潔, 佐野史道, NBI Plasma Startup using Non-resonant Microwave Injection in Heliotron J (ヘリオトロン J における非共鳴マイクロ波入射アシストによる NBI プラズマ着火), PLASMA 2011, 23P094-P, 2011

## Presentations

天野健一, 尾嶋拓, 木下正弘, 溶媒中におけるポリマーの立体構造特性を解析するための効率的な方法, 日本生物物理学会, 第 3 回中国四国支部学会, 広島大学, 2011.5.14

天野健一, 木下正弘, 筒状容器における大球溶質の挿入と放出:単純化モデルを用いたシャペロニン GroEL に関する理論解析, 日本生物物理学会, 第 3 回中国四国支部学会, 広島大学, 2011.5.14

吉留崇, 蛋白質圧力変性の物理機構, 第 11 回日本蛋白質科学会年会 ワークショップ「蛋白質の構造変化と水と一圧力効果の理論と実験の協奏に向けて」, ホテル阪急エキスポパーク, 2011.6.9

T. Yoshidome, Y. Ito, M. Ikeguchi, M. Kinoshita, Importance of Water Entropy in Rotation Mechanism of  $F_1$ -ATPase, 5th Mini-Symposium on Liquids, Okayama University, 2011.6.25

S. Ohshima, M. Takeuchi, S. Yamamoto, S. Kobayashi, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, H. Matsuura, F.Sano, Edge turbulence Study in Neutral Beam Heated Plasma of Heliotron J, 38th EPS Conference on Plasma Physics, Strasborug, 2011.6.27-7.1

木下正弘, 「疎水性」の本当の物理起源: その温度依存性を通しての考察, 第 56 回低温生物工学会大会セミナー, いわて県民情報交流センター, 2011.7.7

木下正弘, ATP-駆動蛋白質の機能発現における水と ATP の役割, 新学術領域研究「水を主役とした ATP エネルギー変換」前期研究成果報告会, 大阪ガーデンパレス, 2011.8.9

吉留崇, 伊藤祐子, 池口満徳, 木下正弘, Rotation Mechanism of  $F_1$ -ATPase: Crucial Importance of Water-Entropy Effect, 新学術領域研究「水を主役とした ATP エネルギー変換」前期研究成果報告会, 大阪ガーデンパレス, 2011.8.9

S. Yasuda, T. Yoshidome, Y. Harano, R. Roth, H. Oshima, Y. Sugita, M. Ikeguchi, M. Kinoshita, Free-Energy Function for Discriminating the Native Fold of a Protein from Misfolded Decoys, The Third International Symposium of Kyoto University GCOE of Energy Science, Ajou University, Korea, 2011.8.19

M. Kinoshita, Roles of Water and ATP in Functioning of ATP-Driven Proteins, The 7th Congress of the International Society for Theoretical Chemical Physics (ISTCP-VII), Waseda University, 2011.9.2-8

T. Yoshidome, Y. Ito, M. Ikeguchi, M. Kinoshita, On the Physical Mechanism of Rotation of  $F_1$ -ATPase: Crucial Importance of the Water Entropy Effect, 8th Liquid Matter Conference, Universität Wien, Austria, 2011.9.9

H. Oshima, S. Yasuda, T. Yoshidome, M. Ikeguchi, M. Kinoshita, Theoretical Analysis for Hot Spots in Protein-Protein Complexes: Critical Importance of Water Entropy, 8th Liquid Matter Conference, Universität Wien, Austria, 2011.9.9

S. Yasuda, T. Yoshidome, H. Oshima, R. Kodama, Y. Harano, M. Kinoshita, Effects of Side-Chain Packing on the Formation of Secondary Structures in Protein Folding, 8th Liquid Matter Conference, Universität Wien, Austria, 2011.9.9

吉留崇, 池口満徳, 木下正弘, A Theoretical Analysis on Water-Entropy Change in Yeast  $F_1$ -ATPase during 16 Degrees Rotation of Gamma Subunit, 第 49 回日本生物物理学会年会, 兵庫県立大学, 2011.9.16

尾嶋拓, 安田賢司, 吉留崇, 池口満徳, 木下正弘, Crucial Importance of Water-Entropy Effect for Predicting Hot Spots in Protein-Protein Complexes, 第 49 回日本生物物理学会年会, 兵庫県立大学, 2011.9.16

木下正弘, ATP 駆動蛋白質の機能発現における水と ATP の共同効果, 日本生物物理学会第 49 回年会シンポジウム「水と ATP がつくる非対称性」, 兵庫県立大学, 2011.9.16-18



木下正弘, 分子認識などの生命現象における水の並進エントロピーの重要性, 日本学術振興会回折構造生物第 169 委員会第 36 回研究会, ゆうぽうと, 東京都品川区, 2011.10.4

T. Minami, S. Arai, N. Kenmochi, H. Yashiro, C. Takahashi, S. Kobayashi, T. Mizuuchi, S. Ohshima, S. Yamamoto, H. Okada, K. Nagasaki, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Present Status of the Nd:YAG Thomson Scattering System Development for Time Evolution Measurement of Plasma profile on Heliotron J, 8th General Scientific Assembly of the Asia Plasma and Fusion Association(APFA 2011), Guilin, China, 2011.11.1-4

L. Zang, M. Takeuchi, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H.Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Observation of Edge Plasma Fluctuations with Fast Camera in Heliotron J, 8th General Scientific Assembly of the Asia Plasma and Fusion Association (APFA 2011), Guilin, China, 2011.11.1-4

三嶋浩和, 安田哲司, 吉留崇, 池口満徳, 木下正弘, 実験で得られた蛋白質天然構造モデルのキャラクタリゼーション, 第 34 回溶液化学シンポジウム, 名古屋大学 ES 総合館 ES ホール, 2011.11.15-17

山本聡, 小林進二, 大島慎介, 諏訪勝重, 安田圭佑, E. Ascasibar, R. Jiménez-Gómez, 永岡賢一, D.Spong, B.Blackwell, D.Pretty, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 中村祐司, 花谷清, 木島滋, 向井清史, 李炫庸, 佐野史道, Studies of energetic-ion-driven MHD instabilities in low magnetic shear helical plasmas, (低磁気シアヘリカルプラズマにおける高速イオン励起 MHD 不安定性研究), Plasma conference 2011 (PLASMA 2011) プラズマ・核融合学会第 28 回年会/応用物理学会第 29 回プラズマプロセッシング研究会/日本物理学会(領域 2)2011 年秋季大会, 石川県立音楽堂, 2011.11.22-25

T. Kagawa, S. Kobayashi, S. Kado, T. Oishi, Y. Nagae, S. Ohshima, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, H. Lee, T. Minami, K. Mukai, L. Zang, S. Arai, H. Watada, Y. Wada, K. Mizuno, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Development of beam emission spectroscopy system in Heliotron (J ヘリオトロン J におけるビーム放射分光計測システム開発), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

T. Minami, S. Arai, N. Kenmochi, H. Yashiro, C.

Takahashi, S. Kobayashi, T. Mizuuchi, S. Ohshima, S. Yamamoto, H. Okada, K. Nagasaki, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Present status of the Nd:YAG Thomson scattering system development for time evolution measurement of plasma profile on Heliotron J (1)(Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状(1)), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

S. Arai, T. Minami, N. Kenmochi, H. Yashiro, C. Takahashi, S. Kobayashi, T. Mizuuchi, S. Ohshima, S. Yamamoto, H. Okada, K. Nagasaki, K. Mukai, H. Lee, L. Zang, T. Kagawa, K. Mizuno, T. Minami, H. Watada, Y. Wada, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状(2), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

H. Yashiro, T. Minami, S. Arai, N. Kenmochi, T. Mizuuchi, C. Takahashi, K. Nagasaki, F. Sano, H. Okada, S. Kobayashi, S. Yamamoto, Y. Nakamura, K. Hanatani, S. Ohshima, K. Mukai, H. Lee, L. Zang, T. Kagawa, K. Mizuno, T. Minami, H. Watada, Y. Wada, S. Konoshima, K. Kasajima, T. Harda, A. Hisada, Present status of the Nd:YAG Thomson scattering system development for time evolution measurement of plasma profile on Heliotron J (3) (Heliotron J プラズマの分布時間発展計測のための Nd:YAG トムソン散乱計測装置開発の現状 (3)), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

H. Okada, H. Watada, Y. Wada, S. Kobayashi, H. Lee, T. Mizuuchi, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, T. Mutoh, S. Konoshima, K. Mukai, L. Zhan, H. Yashiro, T. Minami, T. Kagawa, S. Arai, K. Mizuno, F. Sano, Dependence of the ICRF Heating Efficiency on the Resonance Position in Heliotron J (ヘリオトロン J における ICRF 加熱の共鳴位置による加熱特性の変化), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

李炫庸, 小林進二, 南貴之, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 村上定義, 大島慎介, 原田伴誉, 香川輔, 向井清史, Zang Linge, 木島滋, 佐野史道, Measurement of toroidal rotation velocity profile and calculation of external momentum input by NBI in Heliotron J (ヘリオトロン J におけるトロイダル回転速度分布計測ならびに外部運動量入力計算), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

南貴之, 小林進二, H.Y. Lee, 門信一郎, 水内亨, 長崎百伸, 岡田浩之, 南貴司, 山本聡, 大島慎介, 原田伴誉, 香川輔, 向井清史, L. Zang, 荒井翔平, 八代浩彰, 和多田泰士, 和田善信, 村上定義, 中村祐司, 花谷清, 木島滋, 佐野史道, ヘリオト

ロン J における荷電交換再結合分光による不純物イオン温度分布計測, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

水野浩志, 長崎百伸, 向井清史, 中村雄一, 福田武司, T. Estrada, 大島慎介, 水内亨, 南貴司, 岡田浩之, 増田開, 小林進二, 山本聡, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 中村祐司, 花谷清, 木島滋, 佐野史道, Measurement of Electron Density Fluctuations using Microwave Reflectometer in Heliotron J (ヘリオトロン J におけるマイクロ波反射計を用いた電子密度揺動計測), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

向井清史, 長崎百伸, 水内亨, V. Zhuravlev, 田中謙治, 南貴司, 岡田浩之, 小林進二, 山本聡, 中村祐司, 花谷清, 大島慎介, 水野浩志, H.Y. Lee, L. Zang, 荒井翔平, 香川輔, 南貴之, 八代浩彰, 和多田泰士, 和田善信, 木島滋, 佐野史道, Density modulation experiment in Heliotron-J ECH plasma (ヘリオトロン J における ECH プラズマでの密度変調実験), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

和田善信, 岡田浩之, 長崎百伸, 山本聡, 水内亨, 南貴司, 小林進二, 大島慎介, 向井清史, H.Y. Lee, L. Zang, 和多田泰士, 荒井翔平, 香川輔, 水野浩志, 南貴之, 八代浩彰, 中村祐司, 花谷清, 木島滋, 佐野史道, Pitch Angle Dependence of Fast Electrons Energy Spectra Measured with a Soft X-Ray Pulse height Analyzer in Heliotron J ヘリオトロン J における軟 X 線波高分析による高速電子エネルギー分布のピッチ角依存性, PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

大島慎介, 橋本紘平, 山本聡, 長崎百伸, 水内亨, 岡田浩之, 南貴司, 小林進二, 花谷清, 木島滋, 竹内正樹, 佐野史道, Edge plasma fluctuation measured with multiple Langmuir probes in Heliotron J (ヘリオトロン J 装置における静電プローブによる周辺プラズマ揺動計測とその構造の解明), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

和多田泰士, 岡田浩之, 小林進二, H.Y. Lee, 水内亨, 長崎百伸, 花谷清, 南貴司, 山本聡, 大島慎介, 武藤敬, 木島滋, 向井清史, L. Zang, 荒井翔平, 香川輔, 南貴之, 和田善信, 水野浩志, 佐野史道, Dependence of Fast Ions Generated by ICRF Minority Heating on Pitch Angle and Spatial Position in Heliotron J (ヘリオトロン J における ICRF 加熱での高速イオンのピッチ角及び空間位置依存性), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

西野信博, 臧 臨閣, 竹内正樹, 水内亨, 大島慎介, 笠嶋慶純, 沙夢雨, 向井清史, 李炫庸, 長崎

百伸, 岡田浩之, 南貴司, 小林進二, 山本聡, 木島滋, 花谷清, 中村祐司, 佐野史道, Study of filament features of edge plasma fluctuations using fast video cameras with a combination of Langmuir probe measurements in Heliotron J (II) ヘリオトロン J での高速カメラと静電プローブによるフィラメント状周辺プラズマ揺動の研究(II), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

長崎百伸, N. Marushchenko, 山本聡, 坂本欣三, Y. Turkin, 水内亨, 岡田浩之, 南貴司, 花谷清, 増田開, 小林進二, 木島滋, 大島慎介, 中村祐司, 向井清史, 李炫庸, 水野浩志, L. Zang, 荒井翔平, 香川輔, 南貴之, 水野浩志, 和田善信, 和多田泰士, T. Estrada, 村上定義, 吉村泰夫, 本島巖, 佐野史道, Control of Rotational Transform by ECCD in Heliotron J (ヘリオトロン J における ECCD を用いた回転変換制御), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

L. Zang, M. Takeuchi, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H. Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of Filament Features of Edge Plasma Fluctuations using fast video cameras with a combination of Langmuir probe measurements in Heliotron J (I), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

小林進二, 長崎百伸, 坂本欣三, 山本聡, 水内亨, 岡田浩之, 南貴司, 花谷清, 中村祐司, 木島滋, 大島慎介, 向井清史, Lee Hyunyoung, Zang Linge, 東使潔, 佐野史道, NBI Plasma Startup using Non-resonant Microwave Injection in Heliotron J (ヘリオトロン J における非共鳴マイクロ波入射アシストによる NBI プラズマ着火), PLASMA 2011, 石川県立音楽堂, 2011.11.22-25

T. Mizuuchi, S. Kobayashi, K. Mukai, S. Ohshima, S. Yamamoto, T. Minami, K. Nagasaki, H. Okada, K. Mizuno, H.Y. Lee, L. Zang, H. Yashiro, S. Arai, T. Kagawa, T. Minami, H. Watada, Y. Wada, K. Kasajima, N. Nishino, Y. Nakashima, K. Hanatani, Y. Nakamura, S. Konoshima, F. Sano, Effect of Gas Fueling Control on Plasma Performance in Heliotron J, 21th International Toki Conference (ITC-21), Gifu, Japan, 2011.11.28-12.1

S. Ohshima, K. Hashimoto, S. Yamamoto, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, K. Hanatani, S. Konoshima, K. Mukai, H.Y. Lee, M. Takeuchi and F. Sano, Study of Edge Fluctuation Characteristics using Multiple Langmuir Probes in Heliotron J, 21th International Toki Conference (ITC-21), Gifu, Japan, 2011.11.28-12.1

S. Yamamoto, S. Kobayashi, S. Ohshima, M. Suwa,

K. Yasuda, K. Nagasaki, Y. Nakamura, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, S. Konoshima, B. Blackwell, D. Pretty, K. Mukai, Y.H. Lee, T. Estrada, F. Sano, Studies of MHD stability in Heliotron J Plasmas, 21th International Toki Conference (ITC-21), Gifu, Japan, 2011.11.28-12.1

木下正弘, 生命現象発現における水分子並進移動の役割, 新世代研究所第6回合同研究会, 明治大学紫紺館, 2011.11.29

天野健一, シャペロニンの機能発現における水の役割: 統計力学理論解析, 物性理論セミナー, 九州大学大学院理学研究院物理部門, 2011.12.2

F. Sano, T. Mizuuchi, K. Nagasaki, H. Okada, K. Hanatani, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, S. Ohshima, Y. Nakamura, K. Mukai, H.Y. Lee, L. Zang, S. Arai, T. Kagawa, T. Minami, K. Mizuno, Y. Wada, H. Watada, H. Yashiro, N. Kenmochi, Y. Nagae, M. Sha, S. Murakami, K. Kasajima, N. Nishino, Y. Nakashima, T. Mutoh, M. Yokoyama, K. Toi, K. Tanaka, Recent progress in Heliotron J experiment, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

H. Okada, H. Watada, Y. Wada, S. Kobayashi, H.Y. Lee, T. Mizuuchi, K. Nagasaki, T. Minami, S. Yamamoto, S. Ohshima, T. Mutoh, S. Konoshima, K. Mukai, L. Zhan, H. Yashiro, T. Minami, T. Kagawa, S. Arai, K. Mizuno, F. Sano, Characteristics of ICRF Minority Heating for the Bumpiness and the Resonance Position in the Magnetic Field of Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

S. Kobayashi, S. Yamamoto, S. Kado, T. Kagawa, Y. Nagae, S. Ohshima, T. Oishi, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Murakami, H.Y. Lee, T. Minami, Y. Nakamura, S. Konoshima, K. Toshi, F. Sano, Density Fluctuation and Its Radial Structure Measurements by Beam Emission Spectroscopy in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

T. Mizuuchi, S. Kobayashi, K. Mukai, S. Ohshima, S. Yamamoto, T. Minami, K. Nagasaki, H. Okada, H. Y. Lee, L. Zang, S. Arai, T. Kagawa, T. Y. Minami, K. Mizuno, H. Watada, Y. Wada, H. Yashiro, K. Hashimoto, N. Kenmochi, Y. Nagae, Y. Nakamura, M. Sha, K. Kasajima, N. Nishino, Y. Nakashima, K. Hanatani, Y. Nakamura, S. Konoshima, F. Sano, Gas Fuelling Effect on Plasma Performance in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

H. Lee, S. Kobayashi, T. Minami, S. Kado, T. Mizuuchi, K. Nagasaki, H. Okada, T. Minami, S. Yamamoto, S. Murakami, M. Yokoyama, S. Ohshima, K. Mukai, T. Harada, L. Zang, S. Arai, T. Kagawa, K. Mizuno, Y. Wada, H. Watada, H. Yashiro, Y. Nakamura, K. Hanatani, S. Konoshima, F. Sano, Charge exchange recombination spectroscopy for ion transport in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

L. Zang, N. Nishino, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of filament features of edge plasma fluctuations in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

K. Nagasaki, S. Kobayashi, S. Yamamoto, T. Mizuuchi, H. Okada, T. Minami, K. Hanatani, Y. Nakamura, S. Konoshima, S. Ohshima, K. Mukai, H. Y. Lee, L. Zang, K. Toshi, K. Sakamoto, K. Toi, F. Sano, Startup of NBI Plasmas Assisted by 2.45 GHz Microwaves in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

N. Nishino, L. Zang, M. Takeuchi, T. Mizuuchi, S. Ohshima, K. Kasajima, M. Sha, K. Mukai, H. Y. Lee, K. Nagasaki, H. Okada, T. Minami, S. Kobayashi, S. Yamamoto, S. Konoshima, K. Hanatani, Y. Nakamura, F. Sano, Study of filament features in edge plasma turbulence using a combination of fast video cameras and a hybrid probe system in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

S. Ohshima, K. Hashimoto, S. Yamamoto, K. Nagasaki, T. Mizuuchi, H. Okada, T. Minami, S. Kobayashi, K. Hanatani, S. Konoshima, K. Mukai, H. Y. Lee, M. Takeuchi, F. Sano, Edge Fluctuation Study using Multiple Langmuir Probes in Heliotron J, 18th International Stellarator/Heliotron Workshop, Canberra, Australia, 2012.1.29-2.3

S. Yasuda, H. Oshima, T. Yoshidome, M. Ikeguchi, M. Kinoshita, Prediction of Hot Spots in Protein-Protein Complexes Focused on Water Entropy, 京都大学グローバルCOEプログラム「地球温暖化時代のエネルギー科学拠点」平成23年度年次報告会, きはだホール, 京都大学宇治キャンパス, 2012.1.30

T. Yoshidome, Y. Ito, N. Matubayasi, M. Ikeguchi, M. Kinoshita, A Novel Rotation Mechanism of F1-ATPase Based on the Water-Entropy Effect,

Biophysical Society 56th Annual Meeting, San Diego  
Convention Center, USA, 2012.2.27

天野健一, 尾嶋拓, 木下正弘, シャペロニンの蛋白質折り畳み援助機能に関する基礎解析, 次世代ナノ統合シミュレーションソフトウェアの研究開発第6回公開シンポジウム, ニチイ学館, 神戸ポートアイランドセンター, 2012.3.6

吉留崇, 伊藤祐子, 松林伸幸, 池口満徳, 木下正弘, -サブユニットの16度回転前後におけるイースト F1-ATPase の構造特性: 水のエン트로ピー効果に焦点をあてた理論解析, 新学術領域研究「水を主役とした ATP エネルギー変換」第4回領域全体会議, 岩沼屋, 仙台, 2012.3.7-9

天野健一, 尾嶋拓, 木下正弘, シャペロニンの蛋白質折り畳み援助機能に関する基礎解析, 新学術領域研究「水を主役とした ATP エネルギー変換」第4回領域全体会議, 岩沼屋, 仙台, 2012.3.7-9

尾嶋拓, 安田賢司, 吉留崇, 池口満徳, 木下正弘, 白質複合体におけるホットスポットの理論的予測, 新学術領域研究「水を主役とした ATP エネルギー変換」第4回領域全体会議, 岩沼屋, 仙台, 2012.3.7-9

木下正弘, 埋もれた界面の理論的研究: 固体表面近傍における液体の構造について, 2012年(平成24年)春季第59回応用物理学関係連合講演会, シンポジウム「中性子・X線のコラボレーションによる薄膜・多層膜の埋もれた界面の解析の新しい展開」, 早稲田大学早稲田キャンパス, 2012.3.15-18

原諒平, 天野健一, 木下正弘, 吉森明, 粒子が狭い空間に入るときの溶媒の効果, 日本物理学会第67回年次大会, 関西学院大学, 2012.3.24-27

長崎百伸, 吉野隼生, N. Marushchenko, 山本聡, 小林進二, 水内亨, 花谷清, 岡田浩之, 南貴司, 坂本欣三, 木島滋, 大島慎介, 竹内正樹, 向井清史, 李庸, 諏訪勝重, 野村航大, 山本健土, 吉村泰夫, 佐野史道, ヘリオトロンJにおける電子サイクロトロン電流駆動時のECE挙動, 日本物理学会・第66回年次大会, 新潟大学五十嵐キャンパス, 2011.3.25-28



## **3-2. JOINT USAGE/RESEARCH PROGRAM**



## Joint Usage/Research Program “Zero-Emission Energy Research”

It is an urgent task to get solutions against the energy and environmental problem for the sustainable development of human beings. The new energy system should be an environmentally friendly or ecological one. Here, we should consider not only the energy sources but also the efficiency in the phase of energy usage. The former should have good quality and enough quantity. The latter should be useful to realize three Rs in the energy system;

- Reduce of energy consumption, environmental pollutant such as greenhouse gas, waste-heat, hazardous waste, etc.
- Reuse of waste heat/energy, etc.
- Recycle of fuel, etc.

In order to realize them, only the extension of present technology is not enough. Interdisciplinary study with innovative ideas is necessary to realize an energy system for next generation.

We propose a new ambitious concept of Zero-Emission Energy. IAE Zero-Emission Energy Research aims at the realization of environmentally friendly energy system for sustainable society with minimum emission of environmental pollutants and with maximum utilization of energy and resources. In FY 2011, we launched “Joint Usage/Research Program on Zero-Emission Energy”, which is the program authorized by the MEXT. Here, we aim (1) to promote interdisciplinary collaboration researches for Zero-Emission Energy Science & Technology, (2) to promote education & practical training for young researchers and (3) to explore new horizon of Advanced Energy System for sustainable development. IAE provides many unique & attractive facilities for the Joint Usage/Research in advanced plasma and quantum energy field (DuET (Dual-Beam Facility for Energy Science and Technology), MUSTER (Multi-scale testing and research facility), Advanced Plasma Energy Experiment Devices, Advanced Energy Conversion Experiment, etc.) and also in photonics and energy nano-science research field (ultra-high-resolution NMRs, Functional Analytical Systems for the Generation of Catalytic Materials, Research Facilities for Energy Nanoscience, KU-FEL (Free Electron Laser), CEP-stabilized high-intensity ultra-short pulse laser, etc.).

Many researchers have participated in this program. Joint Usage/Research collaborations of total 72 subjects on Zero-Emission Energy were performed in FY2011 with more than 420

participants including graduate/undergraduate students from all-Japan Universities and Institutions. The results of these collaborations are reported in “IAE Joint Usage/Research Program on Zero-Emission Energy 2011.” If you have interest to this collection, please contact to ZE Research Office ([kyodo-office@iae.kyoto-u.ac.jp](mailto:kyodo-office@iae.kyoto-u.ac.jp)). In addition to the Joint Usage/Research collaborations, we organized “2nd International Symposium of Advanced Energy Science ~ Zero-emission Energy — Present and Future —” on September 27-28, 2011 at Uji Campus, Kyoto University. About 160 scientists and students including four foreign and four domestic invited speakers were participated in the symposium. This kind of international symposium will be held routinely every year. Since international activities toward Zero-Emission Energy Research are indispensable for the realization of sustainable society, we also started “Zero-Emission Energy Network” on the occasion of the symposium to share the knowledge of Advanced Energy and Zero-Emission Energy with researchers in energy science and technology field.

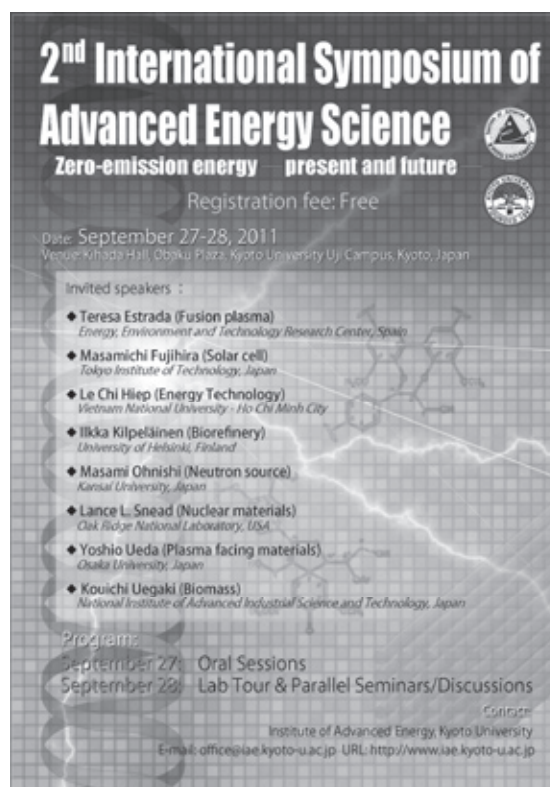


Fig. 1 Poster of International Symposium

## **Lists of ZE Joint Usage/Research Subjects in FY2011**

(Subject, Principal Researcher, IAE Key Person)

Photo-Energy Conversion System Using DNA As Charge Transporting Materials,  
K. Yamana (University of Hyogo), T. Morii

Tungsten material behavior under complex irradiation environment,  
Y. Ueda (Osaka University), A. Kimura

Development of environment-friendly low energy-loss carbon surfaces nanostructured with femtosecond laser pulses,  
N. Yasumaru (Fukui National College of Technology), K. Miyazaki

Development of an efficient molecular ion measurement system using intense ultra-short laser pulses,  
H. Niikura (Waseda University), K. Miyazaki

Evaluation of Nano-particle Dispersion Strengthening Mechanism in Tungsten Alloy,  
A. Hasegawa (Tohoku University), A. Kimura

Synthesis of Nano Bubble Dispersion Strengthened (N-BDS) Alloy and Study of Its Radiation Effect,  
S. Ukai (Hokkaido University), A. Kimura

High-Fluence Irradiation Behavior of Reduced Activation Fusion Reactor Materials,  
H. Tanigawa (Japan Atomic Energy Agency), T. Hinoki

Structural analysis of lignin by ultra-high sensitivity NMR for biorefinery,  
T. Watanabe (RISH, Kyoto University),  
M. Katahira

He effects on mechanical properties of ion-irradiated RAFM steel,  
H. Abe (Tohoku University), A. Kimura

Studies on Helical Structure in Current-Carrying Toroidal Plasmas and Their Impact on Helical Plasma Research,  
S. Masamune (Kyoto Institute of Technology),  
T. Mizuuchi

Technology development of joining between nanostructured, toughened W-TiC and ODSS alloys for blanket structures,  
H. Kurishita (Tohoku University), A. Kimura

Investigation of laser fabrication process for

high-performance spherical light scatterers and their application for solar cells,  
Y. Ishikawa (Kagawa University), T. Sakka

Development of multi-pulse laser for energy enhancement of KU-FEL,  
R. Kuroda (National Institute of Advanced Industrial Science and Technology), H. Ohgaki

Enzymatic conversion of carbon dioxide to methanol using biopolymer gel matrix,  
N. Tanaka (Kyoto Institute of Technology),  
T. Morii

Construction of a high particle and high temperature loading experiment system using the ion beam test stand, and test fusion reactor diverter system,  
Y. Yamamoto (Kansai University), T. Konishi

Study on Gas Fueling and Pumping Systems for D-T Burning in Discharge Fusion Neutron Source,  
M. Ohnishi (Kansai University), K. Masuda

Synthesis of photocatalytic film and processing of biological tissue using infrared free electron laser,  
Y. Hayakawa (Nihon University), H. Ohgaki

Research on enzymatic hydrolysis of plant biomass,  
S. Sawayama, (Graduate School of Agriculture, Kyoto University), T. Kodaki

Structural determination of self-organizing glycoconjugates of bacterial origin aiming to heighten the added value of biomass,  
M. Takeda (Yokohama National University), M. Katahira

Studies on DNA Nanowire Transistor,  
K. Yamana (University of Hyogo), T. Morii

Highly efficient photochemical reactions induced by optimal laser pulses,  
Y. Ohtsuki (Tohoku University), T. Nakajima

Development of tools for observing mechanical and chemical energy produced from thermal fluctuations by deaminase,  
T. Nagata (Yokohama City University), M. Katahira

Fabrication of functional organic thin-films and evaluation of their PL and PV properties,  
H. Ihara (Kumamoto University), T. Sagawa

Development of small molecular organic thin-film solar cells,  
M. Hiramoto (Institute for Molecular Science),  
T. Sagawa

- High power harmonic beam line to characterize useful materials for zero-emission,  
T. Sekikawa (Hokkaido University), T. Nakajima
- Zero-emission energy system-challenge design and development of low-carbon boron tracemolecules,  
H. Hori (University of Tokushima), E. Nakata
- A fluorescent peptide probe for imaging of energy metabolism in cells,  
S. Sato (iCeMS, Kyoto University), T. Morii
- Collisional transport in toroidal geometry,  
M. Kikuchi (Japan Atomic Energy Agency),  
K. Nagasaki
- Unraveling the electronic properties of carbon nanotubes using microscopic spectroscopy,  
Y. Miyata, (Nagoya University), K. Matsuda
- Fundamental study and applications of electrical properties of graphene nanostructures using optical spectroscopy,  
J. Haruyama (Aoyama Gakuin University),  
K. Matsuda
- Build-Up Strategy of ultra-thin carbon wire for Energy Conservation Devices,  
T. Nakae (Ehime University), H. Sakaguchi
- Mechanism of Porous Semiconductors by Electrochemical Reactions: The Role of Solvent on Pore Formation,  
E. Tsuji (Hokkaido University), K. Fukami
- A study of interaction between mobile dislocation and irradiation defects in vanadium alloys,  
K. Fukumoto (University of Fukui), A. Kimura
- Flow analysis from a nozzle for SMBI,  
N. Nishino (Hiroshima University), T. Mizuuchi
- Generation of high-intensity fs vacuum ultraviolet pulses by using harmonic radiation,  
M. Kaku (University of Miyazaki), K. Miyazaki
- Phase relaxation mechanism of excitons in doped carbon nanotubes,  
S. Konabe (University of Tsukuba), K. Matsuda
- First-principle simulation studies on radiation defects and hydrogen behaviors in advanced blanket materials,  
D. Kato (National Institute for Fusion Science),  
K. Morishita
- Correlation measurement of electron cyclotron emission signals at two toroidal positions in torus plasmas,  
Y. Yoshimura (National Institute for Fusion Science), K. Nagasaki
- Study on the efficient hydrogenation reaction of fragment ions produced by laser ablation of molecular solids,  
T. Kobayashi (RIKEN), T. Nakajima
- Study of micro turbulence in plasma for a zero mission energy source,  
K. Tanaka (National Institute for Fusion Science),  
T. Minami
- Development of visualization method of three dimensional high temperature plasmas,  
S. Ohdachi (National Institute for Fusion Science),  
S. Yamamoto
- Development of Electrochemically Polymerized Polythiophene Film toward High-Performance Organic Thin-Film Solar Cells,  
T. Akiyama (University of Shiga Prefecture), H. Sakaguchi
- Development of iron-base composite materials with high thermal conductivity,  
N. Hashimoto (Hokkaido University), A. Kimura
- Heavy irradiation experiment of stainless steels under fusion condition,  
S. Ohnuki (Hokkaido University), A. Kimura
- Boundary plasma diagnostics and rf heating for a helical-axis heliotron device,  
K. Uehara (Japan Aerospace Exploration Agency),  
T. Mizuuchi
- Interaction between defects and deuterium in tungsten,  
K. Sato (Kyoto University Research Reactor Institute), A. Kimura
- Evaluation of Fatigue Crack Initiation Behavior in Plasma Facing Material for Fusion Reactor,  
S. Nogami (Tohoku University), A. Kimura
- Synergistic effects of displacement damage and transmutant helium on the microstructure of fusion reactor structural materials and joints,  
T. Yamamoto (University of California Santa Barbara), A. Kimura
- Radiation induced hardening of pressure vessels steels due to ion irradiation,  
H. Watanabe (Kyushu University), A. Kimura



Microstructure evolution of ion-irradiated oxide/nitride ceramics ~ Role of electronic excitation and selective displacement damage ~, K. Yasuda (Kyushu University), A. Kimura

Development of processes for aliphatic aldehydes and aromatic ketones by means of mid-IR pulse LASER irradiation, K. Fugami (Gunma University), T. Sakka

Assembly of micro-actuator and analysis of its motion mode by laser beam, T. Yamauchi (Niigata University), K. Fukami

Research for the evaluation method of small specimen test technology for fracture toughness, E. Wakai (Japan Atomic Energy Agency), A. Kimura

Evaluation on Corrosion Properties of Friction Stir Welded RAF steels, D. Hamaguchi (Japan Atomic Energy Agency), A. Kimura

Evaluation on Fusion Relevant-Irradiation Properties of ODS steels for the DEMO blanket, H. Sakasegawa (Japan Atomic Energy Agency), A. Kimura

Modeling of radiation dependence of microstructural evolution in Fe, Q. Xu (Kyoto University Research Reactor Institute), K. Morishita

Theoretical study on atomistic modeling for interactions between hydrogen/oxygen atoms and additive elements in zirconium alloys, Y. Kaneta (University of Tokyo), K. Morishita

Nano-Structural Analysis of Pyrolytic Carbon Interphase in Advanced SiC/SiC Composites After Heavy Ion Bombardment at High Temperature with and without Helium Effects, K. Ozawa (Japan Atomic Energy Agency), T. Hinoki

Development of single-electron irradiation technique for microscopic track structure study, Y. Uozumi (Kyushu University), H. Ohgaki

Development of Radiation Detection Method Emitted from IEC Device, T. Misawa (Kyoto University Research Reactor Institute), K. Masuda

Improvement of low temperature ductility of high chromium low activation vanadium alloys, T. Nagasaka (National Institute for Fusion Science),

A. Kimura

Experimental study of plasma energy transport caused from turbulence fluctuation, S. Ohshima (Kyoto University Pioneering Research Unit for Next Generation), S. Yamamoto

Study of the effect of crystallographic orientation on the thermal and electric conductivities in SiC, T. Suzuki (National Institute for Materials Science), T. Hinoki

Phase measurement of Vacuum-Ultraviolet pulse and control of electronic states, R. Itakura (Japan Atomic Energy Agency), T. Nakajima

Property change on plasma facing materials for fusion reactor by high energy ion irradiation, K. Tokunaga (Kyushu University), A. Kimura

Study on characterization of SiC/SiC composite materials by beam induced luminescence measurement, T. Tanaka (National Institute for Fusion Science), T. Hinoki

Microstructural Evolution of Low Activation Ferrite Steels by Ion Irradiation, H. Kinoshita (Fukushima National College of Technology), A. Kimura

Two-dimensional imaging of fluctuations by fast cameras using a sheet-shaped supersonic molecular beam, M. Takeuchi (Japan Atomic Energy Agency), T. Mizuuchi

Safety assessment of nuclear power plants and future energy education, H. Iwakiri (University of the Ryukyus), K. Morishita

Irradiation hardening of FSWed Alloy, T. Shibayama (Hokkaido University), T. Hinoki

Study of neutral transport in high-temperature plasmas, Y. Nakashima (University of Tsukuba), S. Kobayashi

Design of functional protein nano-fiber and its application to the cell culture plate, N. Tanaka (Kyoto Institute of Technology), T. Morii



### **3-3. COLLABORATION WORKS IN THE LABORATORY FOR COMPLEX ENERGY PROCESSES**

# Collaboration Works in The Laboratory for Complex Energy Processes

## 1. Introduction

The laboratory was established in 1996 simultaneously with the institute as an attached facility for research on advanced processes of energy production, conversion and application. On the other hand, resource and energy problems as well as global warming problems become very serious in recent years. We must concentrate all our knowledge and wisdom to find solutions to these problems. From such a viewpoint, the laboratory has been recognized again since FY2006 so that the research targets of the laboratory should be focused on two specific fields, (i) "advanced studies of science and technology on plasma energy and quantum energy" and (ii) "innovative studies of nano-bio functional materials for power generation". Therefore, two sections (A2 and A3 mentioned below) are founded. Section of promotion for international collaborative research arranges and promotes international and domestic research collaborations.

In order to perform the research objectives of the Institute of Advanced Energy, it is essentially necessary to organize the cooperative research program with much close connection between related research fields in the institute. The laboratory takes charge of organizing and promoting the cooperative research project as a center of research activity in the Institute. The research staffs in the institute participate in specific projects to carry out their subjects. The scientists of other faculties in Kyoto University can also participate the cooperative project to enhance the progress of research and educational activities. The laboratory also manages various functions such as symposium and seminar for related topics on energy field. The cooperative research activities will be published in a publication edited in the laboratory at the end of the year.

### A1 Section of Promotion for International Collaborative Research

This section promotes international collaborative research on advanced energy to lead the field of energy science and technology as an international pioneer. Collaborative researches between the institute and domestic/international organizations are supported towards realization of advanced energy system as practical applications with contributions to human society. This section also promotes personal exchange, cooperative research activities and multi-lateral collaborative research with industries. Establishment of infrastructure and human resource development are supported for execution of collaborative R&D activities on advanced energy.

### A2 Section of Promotion for Advanced Plasma

and Quantum Energy

This section promotes studies on advanced plasmas and quantum energy for realizing future energy systems, integrating plasma energy science and advanced energy material research. In particular, based on the results obtained in our related group, we aim at extending the research fields and contributing to human society by utilizing the existing key devices such as Heliotron J, DuET and MUSTER which have been developed in IAE.

### A3 Section of Promotion for Photon and Energy Nano-Science Research

This section promotes studies on photon and energy nano-science for realizing next generation renewable energy system. In particular, functional nano- and bio-materials to utilize solar energy and bio-energy are studied by unifying laser science, nano-technology, and bio-technology. We aim at extending our research field by utilizing the existing devices such as System for Creation and Functional Analysis of Catalytic Materials, SEMs, SPM, Solar Simulator, TW fs laser, MIR-FEL, and so on.

### B Cooperative use of facilities and equipments

Facilities and equipment of the laboratory are provided to researches cooperated for the scientists in the university.

2. The cooperative research project consists of (a) a specific program for "Promotion of a priority project" and (b) a standard program.

A specific program was not planned in this year.

Summary of the standard cooperative research subjects carried out in the year of 2009.

A public collection of cooperative research application was carried out, in this year, for a program which consists of three groups of "Kiban", "Syorei" and "Kikaku-chosa" cooperative research. The "Kiban" cooperative research means a program to promote leading research themes of the institute projects. The "Syorei" cooperative research means a program to promote general research themes with respect to the institute projects. The "Kikaku-chosa" cooperative research means a program to promote the cooperative research through a seminar or symposium.

As a result, the research themes of 32 were applied and applications of 32 were accepted after the approval by a steering committee of the laboratory. The number of research subjects is listed in Table 1 according to the project categories.



**Table 1 Number of the accepted research subjects according to the standard project theme**

The whole sum 32

		category A			B	total
		A1	A2	A3		
Kibann	inside	1 *	2 *	2 *	0	5*/(4Excluding field-overlapped applications)
*1	outside	0	0	0	0	0
Syorei	inside	3	11	9	0	23
*2	outside	2	0	0	0	2
Kikaku	inside	1	1	0	0	2
-chosa	outside	0	0	0	0	0
*3						

**“inside” or “outside” : Numbers applied by the inside or outside of the Institute**

The individual research subjects are as follows, \*1, \*2 and \*3 mean the “Kiban”, “Syorei” and “Kikaku-chosa” cooperative research theme, respectively,

The individual research subjects are as follows.

**A1,**

**“International Collaborative Research on Advanced Energy Materials Science and Technology”**

- (1) M.J. Fluss, L.L. Hsiung
- (2) M.A. Pouchon
- (3) J. Kwon
- (4) T. Yamamoto, Y. Wu, G.R. Odette
- (5) C. Zhang
- (6) A. Möeslang
- (7) E. Meslin
- (8) A. Kimura, K. Yabuuchi, R. Kasada, T. Hinoki, S. Kondo
- (1) Laurence Livermore National Laboratory, Livermore, California 94550 USA
- (2) Paul Scherrer Institute, CH-5232 Villigen PSL, Switzerland
- (3) Korea Atomic Energy Research Institute, Daejeon Korea
- (4) Dept. of Mechanical Engineering, University of California Santa Barbara
- (5) Institute of Modern Physics, Chinese Academy of Science Landu, China
- (6) Karlsruhe Institute of Technology, Karlsruhe, Germany
- (7) CEA/DEN/SACLAY/DMN/SRMP91191GIF-SUR -YVETTE CEDEX, France
- (8) Institute of Advanced Energy, Kyoto University

**A2,**

**“Development of Advanced Plasma and Quantum Energy Studies”**

- (1) K. Nagasaki, K. Masuda, S. Ohshima
- (2) Institute of Advanced Energy, Kyoto University

**A2, A3**

**“Basic Studies on Photon and Energy Nano-Science Research”**

- (1) H. Ohgaki, Section of Promotion for Photon and

**Energy Nano-Science research**

- (1) Institute of Advanced Energy, Kyoto University

**“The mechanism of trapping of protein by RNA aptamer and its application to the integration of proteins”**

- (1) M. Katahira, T. Morii, T. Kotaki, E. Nakata, E. Okamura,
- (2) A. Furukawa
- (1) Institute of Advanced Energy, Kyoto University
- (2) Japan Society for the Promotion of Science

**A1**

**“Workshop on the Workshop on the research and development of nuclear fuels ”**

- (1) K. Morishita
- (2) S. Ohnuki
- (3) Y. Watanabe
- (4) S. Ishino
- (5) Y. Kaneda
- (6) D. Kato
- (7) Y. Yamamoto, Y. Izumi
- (8) X. Qui, T. Yoshiie
- (9) H. Iwakiri
- (1) Institute of Advanced Energy, Kyoto University
- (2) Graduate School of Engineering, Hokkaido University
- (3) Japan Atomic Energy Agency
- (4) University of Tokyo
- (5) School of Engineering, The University of Tokyo
- (6) National Institute for Fusion Science
- (7) Graduate School of Engineering, Kyushu University
- (8) Kyoto University Research Reactor Institute
- (9) Faculty of Education, University of the Ryukyus

**“Modeling of the oxidation of unclear fuel clad and hydrogen production”**

- (1) K. Morishita
- (2) Y. Yamamoto, Y. Izumi
- (3) Y. Kaneta
- (4) S. Ishino
- (5) Y. Watanabe
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Energy Science, Kyoto University*
- (3) *School of Engineering, The University of Tokyo*
- (4) *University of Tokyo*
- (5) *Japan Atomic Energy Agency*

**“Prototype of SMBI System for Edge Plasma Diagnostics”**

- (1) T. Mizuuchi, S. Kobayashi
- (2) N. Nishino
- (3) Y. Nakashima
- (4) M. Takeuchi
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Engineering, Hiroshima University*
- (3) *Plasma Research Center, University of Tsukuba*
- (4) *Japan Atomic Energy Agency*

**“Numerical Simulation of DC/Pulsed Magnetron Discharge”**

- (1) K. Masuda
- (2) M. Bilek, J. Kipritidis
- (3) T. Kajiwara, Y. Yamazaki
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *The School of Physics, the University of Sydney*
- (3) *Graduate School of Energy Science, Kyoto University*

**“Misorientation Dependence of Energies of Small Angle Boundaries in Si”**

- (1) K. Ishihara
- (2) A. Ohtsuki
- (1) *Graduate School of Energy Science, Kyoto University*
- (2) *Institute of Advanced Energy, Kyoto University*

**“Energy Transmission via Amplitude and Frequency Modulations on a Carrying wave at GHz band in Gas and Solid Plasma”**

- (1) M. Sato
- (2) T. Mizuuchi
- (3) T. Mitani, K. Kashimura
- (1) *National Institute for Fusion Science*
- (2) *Institute of Advanced Energy, Kyoto University*
- (3) *Research Institute for Sustainable Humanosphere, Kyoto University*

A2

**“Control of Rotational Transform by Using Electron Cyclotron Current”**

- (1) K. Nagasaki, K. Sakamoto, F. Sano, T. Mizuuchi, K. Hanatani, T. Minami, H. Okada, K. Masuda, S. Kobayashi, S. Yamamoto, S. Konoshima,

- (2) S. Ohshima
- (3) Y. Nakamura
- (4) Y. Yoshimura, G. Motojima
- (5) N. Marushchenko
- (6) A. Cappa, T. Estrada
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Kyoto University Pioneering Research Unit for Next Generation, Kyoto University*
- (3) *Graduate School of Energy Science, Kyoto University*
- (4) *National Institute for Fusion Science*
- (5) *Max Plank Institute, Germany*
- (6) *CIEMAT, Spain*

**“Control of TF/Helical Combined Ripple by the Placement of Ferritic Steel Plates”**

- (1) A. Kimura, K. Nagasaki, K. Yabuuchi, O. Hashitomi, T. Ohmura
- (1) *Institute of Advanced Energy, Kyoto University*

**“Observation of Stereoscopic Image for Plasma Turbulence”**

- (1) T. Mizuuchi
- (2) Z. Linge, S. Mengyu
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Energy Science, Kyoto University*

**“The Mechanism of Mu Effects based on the Annihilation Behavior of Frankel Pairs Among Cascade Damage Structures”**

- (1) A. Kimura, K. Yabuuchi, O. Hashitomi, T. Ohmura, R. Kasada
- (1) *Institute of Advanced Energy, Kyoto University*

**“Assessment of Corrosion Resistance of AL-added ODS Steels in Pb-Liquid Metal Alloy”**

- (1) A. Kimura, K. Yabuuchi, O. Hashitomi, T. Ohmura,
- (2) S. Takaya, M. Inoue
- (3) G. Müller, A. Heinzl
- (4) T. Okuda
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Japan Atomic Energy Agency*
- (3) *Kalsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, Germany*
- (4) *Kobelco Research Institute. Inc.*

**“Spatial Structure of Cavities in First-Wall Materials for Fusion Reactor”**

- (1) R. Kasada, A. Kimura
- (2) Y. Himei, K. Yabuuchi, H. Noto,
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Energy Science, Kyoto University*

**“Computational Study of Turbulent Heat Transfer for Heating Water in a Short Vertical Tube (Part 1 Effect of Viscous Sub-layer on Flow Velocity)”**

- (1) K. Hata

- (2) N. Kai, Y. Shirai
- (3) T. Masuzaki
- (4) M. Hamura
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Energy Science, Kyoto University*
- (3) *National Institute for Fusion Science*
- (4) *Concentration Heat and Momentum Ltd*

**“Porous Silicon carbide for Super-low Fraction”**

- (1) T. Hinoki, Y. Lee
- (2) K. Adachi, K. Kanda, Y. Noguchi
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Faculty of Engineering, Tohoku University*

**“Development of High Resolution Plasma Profile Measuring System for Advanced Plasma Energy”**

- (1) T. Minami, S. Kobayashi, T. Mizuuchi, K. Nagasaki, H. Okada, S. Yamamoto, K. Hanatani, S. Konoshima, F. Sano
- (2) S. Ohshima
- (3) M. Takeuchi
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Kyoto University Pioneering Research Unit for Next Generation, Kyoto University*
- (3) *Japan Atomic Energy Agency*

**“Enlargement of operational region of high temperature plasmas using plasma initiation method by neutral beam injection”**

- (1) S. Kobayashi, T. Minami, T. Mizuuchi, K. Nagasaki, H. Okada, S. Yamamoto, K. Hanatani, S. Konoshima, F. Sano K. Tohshi, K. Sakamoto
- (2) Y. Nakamura, H.Y. Lee, K. Mukai, T. Kagawa T. Minami
- (3) Y. Suzuki, K. Nagaoka, Y. Takeiri, S. Okamura
- (4) T. Ohishi
- (5) Y. Nakashima
- (6) S. Murakami
- (7) S. Kado,
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Energy Science, Kyoto University*
- (3) *National Institute for Fusion Science*
- (4) *Faculty of Engineering, Nagoya University*
- (5) *Plasma Research Center, University of Tsukuba*
- (6) *Graduate School of Engineering, Kyoto University*
- (7) *School of Engineering, The University of Tokyo*

**“Study of Mechanism of Ion Cyclotron Range of Frequency Heating of Plasma in a Non-Axisymmetric Magnetic Field”**

- (1) H. Okada, S. Kobayashi, S. Yamamoto, T. Minami, T. Mizuuchi, K. Nagasaki, F. Sano, K. Hanatani
- (2) Y. Nakashima
- (3) T. Mutoh
- (4) Y. Nakashima

- (5) N. Nishino
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Energy Science, Kyoto University*
- (3) *National Institute for Fusion Science*
- (4) *Plasma Research Center, University of Tsukuba*
- (5) *Graduate School of Engineering, Hiroshima University*

**“Studies of energetic ion loss caused by MHD instabilities using Faraday type lost ion probe in Heliotron J plasmas”**

- (1) S. Yamamoto, H. Okada, F. Sano, T. Minami, K. Hanatani, T. Mizuuchi, S. Kobayashi, S. Konoshima, Y. Nakamura
- (2) M. Isobe, K. Nagaoka, C. Wei
- (3) S. Ohshima
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Energy Science, Kyoto University*
- (3) *National Institute for Fusion Science*
- (4) *Kyoto University Pioneering Research Unit for Next Generation, Kyoto University*

A3

**“Development of the enzyme that switches its activity either OFF—>ON or ON—>OFF in response to K<sup>+</sup> concentration”**

- (1) M. Katahira, T. Morii, E. Nakata, M. Saimura
- (2) A. Furukawa
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Japan Society for the Promotion of Science*

**“Developing the diagnosis technique for the KUFEL pulses”**

- (1) T. Nakajima, Y. Qin, T. Kii, T. Sakka, H. Ohgaki
- (2) T. Sekigawa
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Engineering, Hokkaido University*

**“Observation of ultrafast dynamics on solid surfaces in femtosecond laser ablation”**

- (1) G. Miyaji, K. Miyazaki
- (2) A.E. Kaplan
- (3) J. Reif
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Johns Hopkins University*
- (3) *Brandenburgische Technische Univ.*

**“Structural analysis of XMRV protease in complex with an inhibitor”**

- (1) H. Okamura, M. Saimura, E. Nakata, T. Morii, M. Katahira
- (2) A. Furukawa
- (1) *Institute of Advanced Energy, Kyoto University*
- (3) *Japan Society for the Promotion of Science*

**“Development of a highly efficient bioethanol**

**production yeast by protein and genetic engineering”**

- (1) T. Kodaki, M. Katahira
- (2) S. Sawayama
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Graduate School of Agriculture, Kyoto University*

**“Metal electrodeposition in nanoporous electrodes by controlling the hydration properties”**

- (1) K. Fukami, M. Kinoshita, T. Sakka, Y. Ogata
- (2) Y. Suzuki,
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Uyemura Co.Ltd*

**“Feasibility Study on Controlling Superconductivity of REBCO by electron irradiation”**

- (1) T. Kii, H. Ohgaki, K. Masuda, H. Zen  
T. Sonobe,
- (1) *Institute of Advanced Energy, Kyoto University*

**“Formation of particle layers at liquid-liquid interfaces and the interparticle interactions”**

- (1) T. Sakka, D. Ozawa, K. Tuchiya, T. Nakajima,  
K. Fukami, Y. Ogata
- (2) G. Oye
- (3) Y. Suzuki
- (1) *Institute of Advanced Energy, Kyoto University*
- (2) *Uyemura & Co.,Ltd.*

**“Development of Non-Destructive Electron Bunch Length Monitor for KU-FEL”**

- (1) H. Zen, Yong-Woon. Choi, H. Ohgaki.  
K. Masuda. T. Kii
- (1) *Institute of Advanced Energy, Kyoto University*



# SYMPOSIUM IN THE LABORATORY

## Symposium

The Symposium has been arranged in order to introduce the research activities in sections and to enhance the mutual cooperation among different fields. In 2009, three regular meetings and the annual meeting for the cooperative research results were held with following theme.

### 1. The regular meeting

#### (1) **The First Meeting, July 29, 2011**

R. Kasada, “Perspectives of advanced energy science and technology after FUKUSHIMA 2011”, *Institute of Advanced Energy, Kyoto University*

#### (2) **The Second Meeting, January 14, 2011**

Senior Research Scientist Neculai Plugaru “Materials Modeling From First Principles Electronic Structure”, National Institute of Materials Physics

### 2. The Annual Meeting for the Cooperative Research Results, April 6, 2012

#### (1) T. Nakajima “Basic Studies on Photon and Energy Nano-Science Research”, *Institute of Advanced Energy, Kyoto University*

#### (2) T. Sakka. K. Miyazaki, “**Formation of particle layers at liquid-liquid interfaces and the interparticle interactions**”, *Institute of Advanced Energy, Kyoto University*

#### (3) K. Nagasaki, “**Development of Advanced Plasma and Quantum Energy Studies**” , *Institute of Advanced Energy, Kyoto University*

#### (4) T. Minami “**Development of High Resolution Plasma Profile Measuring System for Advanced Plasma Energy**”, *Institute of Advanced Energy, Kyoto University*

#### (5) K. Masuda “**Numerical Simulation of DC/Pulsed Magnetron Discharge**”, *Institute of Advanced Energy, Kyoto University*

## University

#### (6) A. Kimura, “International Collaborative Research on Advanced Energy Materials Science and Technology”, *Institute of Advanced Energy, Kyoto University*

#### (7) T. Hinoki, “**Porous Silicon carbide for Super-low Fraction**”, *Institute of Advanced Energy, Kyoto University*

#### (8) M. Katahira, “**The mechanism of trapping of protein by RNA aptamer and its application to the integration of proteins**”, *Institute of Advanced Energy, Kyoto University*

Interaction between dislocation and precipitate in a BBC metal using the in-situ TEM observation method



## **3-4. PROJECTS WITH OTHER UNIVERSITIES AND ORGANIZATIONS**

## Asian CORE (Center Of Research and Education) program, 2008-2012

The Asian CORE (Center Of Research and Education) program for the “Advanced Energy Science” between Japan, Korea and China was granted by the JSPS (Japan Society for the Promotion of Science) of 5 year collaboration was completed its fourth year. In this program, Japan and core institutes in Asian nations are expected to establish the network of research and education by the extensive collaboration of mutually equal contribution, in the advanced and important fields of energy science. The Institute of Advanced Energy is assigned as a hub institute in Japan to represent universities and research institutes, with Prof. Yukio Ogata as the representative and Prof. Satoshi Konishi as the Program Coordinator. Counterparts are Prof. Hangyu Joo in Seoul National University in Korea and Prof. Kan Wang in Tsinghua University in China.

Advanced energy science and technology are of common interests in these countries where industrial application of energy is extensive. This program supports the exchanges of scientists and students in the field of advanced energy research, for collaboration, workshops and other research activities. This program is operated by equal contribution basis, and it requires “matching fund” from counterpart countries, and Korea and China have different types of funding to send and accept approximately same level of exchanges. Because the sources in Korea and China are not from the similar programs in these countries, steering Committee Meetings are not held in this fiscal year and operation are controlled by electronic communications.

Subtasks on five technical areas were agreed for

the collaboration as follows.

Task 1 Advanced Nuclear Energy Systems: liquid metal technology, high temperature nuclear energy conversion, neutronics, and fusion technology.

Task 2 Fusion Plasma Science: plasma physics, simulation and theory, heating and current drive, diagnostics and plasma wall interaction.

Task 3 Bioenergy: Synthesis of biofuel from biomass materials and energy production systems.

Task 4 Advanced Energy Materials: nuclear materials for high temperature use, ODS and ceramics, irradiation, and microscopy.

Task 5 Application of Quantum Radiation: electron beam, accelerator technology, free electron laser, tera hertz wave and its application.

In the fiscal year 2011, we have conducted the exchanges in these areas as summarized in the fig.1. Because of the large number of carry overs from the March 2011 due to the disaster in Japan, and following cancellation of visits from Korea and China, major changes on the planned exchanges were needed. Significant number of the exchanges were postponed from 2010 plan to this fiscal year under the approval by JSPS. Despite of the difficulties, the outstanding exchanges were completed and furthermore activities than previously planned were finally conducted by the efforts of the three parties.

In this year the Winter school was held in Beijing in January 2012 with the contributions from R-1, R-2, and R-4. Figure 2 shows the group photo of the participants at this seminar. In the next fiscal year, this program will be completed.

	J→K	K→J	J→C	C→J
SCM	0/0	0/0	0/0	0/0
Task-1	16/68	0/0	0/0	5/15
Task-2	0/0	4/22	3/29	3/45
Task-3	4/8	0/0	2/8	0/0
Task-4	35/137	0/0	3/17	1/9
Task-5	10/40	0/0	2/15	0/0
Seminar	0/0	0/0	24/93	0/0
subtotal	65/253	4/22	34/162	9/69
Total	112/506			

Fig.1 Conducted exchanges in 2011 under the Asian CORE program.(man/man-day)



Fig.2 Asian CORE seminar held in Beijing in Jan., 2012.

## **Global COE Program “Energy Science in the Age of Global Warming – Toward CO2 Zero-emission Energy System–”**

Securing energy and conservation of the environment are the most important issues for the sustainable development of human beings. Until now, people have relied heavily on fossil fuels for their energy requirements and have released large amounts of Greenhouse gases such as carbon dioxide (abbreviated to CO<sub>2</sub> below). CO<sub>2</sub> has been regarded as the main factor in climate change in recent years. It is becoming a pressing issue in the world how to control over the CO<sub>2</sub> release. The energy problem cannot be simply labeled as a technological one, as it is also deeply involved with social and economic elements. It is necessary to establish the “Low carbon energy science” in the interdisciplinary field adding the social science and the human science to the natural science.

From FY2008, four departments of Kyoto University, Graduate School of Energy Science, Institute of Advanced Energy, Department of Nuclear Engineering, Research Reactor Institute have joined together, and also with the participation from Institute of Economic Research have been engaging in "Energy Science in the Age of Global Warming - Toward a CO<sub>2</sub> Zero-emission Energy System" for a Global COE Program of the Ministry of Education, Culture, Sports, Science and Technology under the full faculty support taking advantage of characteristics of the university. This program aims to establish an international education and research platform to foster educators, researchers, and policy makers who can develop technologies and propose policies for establishing a scenario toward a CO<sub>2</sub> zero-emission society no longer dependent on fossil fuels, by the year 2100.

In the course of implementing the Global COE, we placed the GCOE Unit for Energy Science Education at the center, and we proceed from the Scenario Planning Group, the Advanced Research Cluster to the Evaluation, forming mutual associations as we progress. The Scenario Planning Group sets out a CO<sub>2</sub> zero emission technology roadmap and establishes a CO<sub>2</sub> zero emission scenario. They will also conduct analysis from the society values and human behavior aspect. The Advanced Research Cluster, as an education platform based on research, promotes the socio-economic study of energy, study of new technologies for solar energy and biomass energy, and research for advanced nuclear energy by following the road map established by the Scenario Planning Group. Evaluation is conducted by exchanging ideas among advisors inside and outside of the university and from abroad, to gather feedback on the

scenario, education, and research.

For education, which is the central activity of the Global COE, we establish “the GCOE Unit for Energy Science Education” and select students from the doctoral course, and foster these human resources. The students plan and conduct interdisciplinary group research containing both the social and the human science and the natural science toward CO<sub>2</sub> zero emission at the initiative of the students themselves. The students will acquire the faculty to survey the whole “energy system” through participation in scenario planning and interaction with researchers from other fields, and apply it to their own research. This approach is expected to become a major feature of human resources cultivation. We will strive to foster young researchers not only who will be able to employ their skills and knowledge with a wide international perspective as well as expertise in their field of study in order to respond to the needs of the society in terms of the variety of energy and environmental problems, but who will also lead people to a 21st century full of vitality and creativity, working towards harmony between the environment and mankind.

In FY2011, we carried on full-scale operations at the education programs of the students, and also promoted the study at both the Scenario Planning Group and the Advanced Research Cluster earnestly. In order to report the developments and to discuss the future activities widely, we held the 3<sup>rd</sup> International Symposium of the Global COE titled “Zero-Carbon Energy 2011” in August, 2011 in cooperation with Ajou University, Korea, and the annual symposium of the Global COE on January, 2012. We also made a strong effort to the international exchange promotion activities such as co-hosting SEE (Sustainable Energy and Environment) forums held in Malaysia on September, 2011 as well as in Thailand on February, 2012, 3<sup>rd</sup> Nuclear Energy Seminar in Thailand in March, 2012 and other related seminars and symposiums, as well as a AUN-KU International Energy Seminar.



## Bidirectional Collaborative Research Program

Since 2004, the Heliotron J group at Kyoto University has joined the bidirectional collaborative research program of National Institute for Fusion Science (NIFS). The purpose of this program is to extend the activities of nuclear fusion research at universities in Japan after the Committee of the Science Subdivision under the Council for Science and Technology has decided to set up its master plan for Japanese fusion research and development by promoting collaborative research activities. This plan was summarized in the report “Policy for executing Japanese nuclear fusion research”, where it was pointed out that continuous scientific research activities for comprehensive understanding of toroidal plasma physics are needed under the parameters which can be extrapolated to the fusion reactor.

The main objective of the research is to improve the confinement and stability performance for advanced helical magnetic configurations such as the helical-axis heliotron, Heliotron J. Six topics for the collaboration research for this FY are selected; (1) confinement improvement by controlling magnetic configuration and related plasma self-organization, (2) instability suppression by controlling magnetic configuration, (3) ECH/EBW heating physics, (4) toroidal current control, (5) fueling control and exhaust control of heat and particles, and (6) fluctuation measurement by BES and so on. The results of several subjects are described below.

**Dependence of fast ion confinement on the magnetic field configuration using ion cyclotron range of frequency (ICRF) heating [1]:** Fast-ion confinement is one of most important topics for helical devices since the alpha particle heating efficiency in a fusion reactor depends on the loss cone structure for fast ions in velocity space. The toroidal ripple (bumpiness) of the magnetic field strength is one of key parameters for enhancing confinement in the Heliotron J configuration. The wide range observation (about 25% in the poloidal cross section of plasma) of fast ions is performed by changing the line of sight of the CX-NPA in two directions for three bumpinesses. For the quantitative comparison of the fast ion tail, the effective temperature of fast minority ions is evaluated from the energy spectrum in the range of 1 keV to 7 keV. In this energy range and density ( $0.4 \times 10^{19} \text{ m}^{-3}$ ), protons can follow a banana orbit although the collision effect is not negligible. The better performance of the high bumpiness is

confirmed in this vertical angle scan of the CX-NPA at the horizontal angles from  $-2^\circ$  to  $12^\circ$ .

**Evaluation of particle diffusion by the density modulation experiment [2]:** Using AM reflectometer functioned for X-mode, the ECH plasma density profile is measured. It is flat or hollowed profile. The injected wave frequency is from 33 GHz to 56 GHz with the scan frequency in the profile measurement of 1 kHz. The particle diffusion coefficient defined by the equation below is evaluated using density modulation technique.

$$\frac{\partial n_e}{\partial t} = -\nabla \cdot \Gamma + S \quad \Gamma = -D \nabla n_e + n_e V$$

Here,  $\Gamma$ ,  $S$ ,  $D$ ,  $V$  are particle flux, particle source, diffusion coefficient and convection velocity, respectively. The coefficient for the ECH plasmas with the line averaged density of  $(0.6 \text{ or } 0.9) \times 10^{19} \text{ m}^{-3}$  is (5.2 or 2.3)  $\text{m}^2/\text{s}$  at the normalized minor radius within 0.6. Convection velocity is 59 or 2.3 m/s for each case.

**Fluctuation measurement using beam emission spectroscopy (BES):** A BES system has been developed for the density fluctuation measurement. The spatial resolution in normalized minor radius is 0.06 and detectable area is from 0.07 to 0.94 using 16 fiber channels. The detector is APD with interference filter. The DC signal is larger in the plasma core than that in the edge region. S/N has been improved by 20 times compared with the prototype system tested in FY2010. From this improvement, the density fluctuation profiled has been detected.

### References

- [1] H. Okada, et al., “Numerical Analysis of ICRF Minority Heating in Heliotron J”, Plasma Fusion Res. **6** (2011) 2402063.
- [2] K. Mukai, et al., “Electron Density Profile Behavior during SMBI Measured with AM Reflectometer in Heliotron J Plasma”, Plasma Fusion Res, **6** (2011), 1402111.
- [3] T. Mizuuchi, et al., “Comparison between supersonic molecular-beam injection and conventional gas-puffing for plasma performance in Heliotron J”, J. Nucl. Mater. **415** (2011) 5443.
- [4] K. Nagasaki, et al., “Influence of trapped electrons on ECCD in Heliotron J”, Nucl. Fusion **51** (2011) 103035.

# Application of DuET and MUSTER for Industrial Research and Engineering (ADMIRE Project)

## 1. Introduction

The Application of DuET and MUSTER for Industrial Research and Engineering (ADMIRE) Project at the Institute of Advanced Energy (IAE), Kyoto University is one of the MEXT-supported programs "Open Advanced Facilities to Industry" to provide private companies with utilization of experimental facilities and expertise of IAE, Kyoto University. Scientists and engineers of private industries are welcomed to use advanced facilities, such as the DuET and the MUSTER in the IAE. Technical guidance to operate experimental equipments as well as consulting on the experimental results is also offered to the users. Experimental equipment in the MUSTER Facilities, such as high-performance TEM, SEM, FIB, EPMA, Auger, and the DuET Facility i.e. dual beam ion accelerator system are included in the list covered by the ADMIRE Project free of charge up to 2 years in the "Trial use mode".

## 2. Project details

The ADMIRE Project was launched in 2006 funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of JAPAN. The DuET and MUSTER are two of the representing facilities in the IAE, Kyoto University dedicated for the research of energy science and technology, with the special emphasis on fusion and fission reactor materials R&Ds. The ADMIRE Project aims to provide the wide range of the public with the research resources of IAE. Thus, research topics to be accepted by the ADMIRE Project are NOT restricted to fission or fusion reactor materials, nor energy science and technology. We welcome many proposals from a variety of fields all over the world.

The ADMIRE Project has four modes of facility use: a) Trial use mode, b) Charged use mode-X (exclusive use of data), c) Charged use mode-N (non-exclusive use of data), and d) Collaborative use.

### a) Trial use mode

In this mode, users are allowed to utilize the ADMIRE facilities free of charge for a fixed term, i.e. six months for the MUSTER facilities or twelve months for the DuET facilities. The term may be repeated once if requested and approved. This enables a MUSTER user to use the facility up to one year, and a DuET user up to two years, if approved by the Subject Selecting Committee. The only obligation of the user is to submit a relatively simple report at the end of the term. If the user requests to postpone the immediate dissemination of the outcome, in order to secure its IPR, a moratorium up to two years may be given.

### b) Charged use mode-X (exclusive use of data)

This mode is programmed for those users who have strong interests on the intellectual property rights to be obtained through the ADMIRE utilization. There is no obligation to submit reports, etc. to the ADMIRE. The subject title and the name of the user may be kept undisclosed if the user so requests.

### c) Charged use mode-N (non-exclusive use of data)

This mode is similar to the mode-X but is different only in that submission of a report is obligatory. The charge rate for facility use is lower compared to the mode-X.

### d) Collaborative use

This mode is similar to the standard collaborative research conducted jointly by private companies and university staff under a contract to which both parties agreed. This is not just utilization of the facility but full collaboration on specific subjects.

## 3. Benefits for companies

- Rapid progress of products development by use of high performance equipments.
- Reduction of expenditure for equipments.
- Rapid exploration of new idea.
- Use of very expensive equipments.

Access to excellent facilities and research resources at IAE.



Figure 1: Dual-Beam Facility for Energy Science and Technology



## **3-5. STUDENT AWARDS**

**Poster presentation award for GCOE group research “Applicability of Electric Vehicle Usage with Less Nuclear Power Plants in Japan ~ Is EV OK or not? ~” in the 3rd International Symposium Kyoto University Global COE Program.**

**Advanced Atomic Energy Research Section  
Yasunori Nakai (as 1<sup>st</sup> author) (D3),  
Saerom Kwon (as 2<sup>nd</sup> author) (D1)**

Low-CO<sub>2</sub>-emission technologies, such as nuclear power plant and electric vehicle (EV) have been widely known as a way to cope with the global warming issue. Nuclear energy, which had contributed to about 30% of total electricity production in Japan before the Fukushima incident, had been expected to play an important role in the achievement of a low carbon society. Though a majority of the population is now against nuclear energy due to the Fukushima nuclear power plant incident in March 2011, it should be properly acknowledged that CO<sub>2</sub> emission from electricity generation would increase without the nuclear power plants. On the other hand, electricity consumption in Japan will likely to escalate when EV market is expanded as planned. Presently, EV is one of the environmentally-friendly technologies that is most popular, though the electricity for EVs might not be as “clean” as before. There are numerous dilemmas to consider in order balancing the risks and the benefits of advanced technologies. The risks, from the light to the serious one will arise as higher cost, instability of energy supply, usage of rare metals, and unexpected accidents are encountered. Big wind turbine, for example, may destroy the diversity of ecosystem around its feet.

Another example is crop production for biofuels that might demolish rainforests and/or sacrifice foods crops for local inhabitants. Even old technologies for the mining of fossil fuels have often put their workers to death. Our choice of energy sources must not be taken without the awareness of hidden risks, must not be made with close-mindedness, and must not be formed by temporal mood partly created by mass media. In making this critical judgment, objective and quantitative analyses are required for scientists and engineers to support the decision. In this research, CO<sub>2</sub> emission from the use of EVs was re-estimated in the cases when the contribution of nuclear power plants to the total electricity supply in Japan decreases by various degrees down to zero. It is revealed that when all electricity in Japan produced by natural gas (somewhat optimistic case), CO<sub>2</sub> emission by EV could be comparable to that of the latest gasoline vehicles. It should also be noted that the production process of EV with rare metals might be more complicated and emit more CO<sub>2</sub> than that of gasoline vehicle.

**Excellent presentation award for “Neutronics calculation on the beam optics from cylindrical discharge type fusion device” in the International Symposium on Advanced Energy Systems and Materials, sponsored by Asian-Core University Program on Advanced Energy Science**

**Advanced Atomic Energy Research Section  
Naoya Matsui (M1)**

Neutron beam can be used for various applications in the field of engineering and biology such as nondestructive inspection of metal, medical applications and radiography.

We developed cylindrical discharge type fusion device that can provide 14MeV high energy and isotropic neutrons by D-T fusion reactions on the surface of the cylindrical electrode. Single direction beam is obtained by surrounding reflector, moderator and shield absorber. Energy spectrum is also changed to meet the requirements for various application.

This study has a purpose to evaluate beam optics such as beam neutron flux distribution, energy spectrum. MCNP5 was used for neutronics calculation. To reveal the effect of reflector (tungsten) and moderator's material (polyethylene and heavy water) and shape are important.

As a result, Reflector can yield high intensity beam. W generates more than 90% of fast neutron over 1MeV in the fast/total ratio. Moderators have an effect on to produce thermal neutron beam cleanly. D<sub>2</sub>O generates more than 15% of thermal neutron under 0.1eV in the thermal/total ratio.

This study showed that generation of single direction beam with desirable neutron energy is possible by using reflector and moderator with cylindrical discharge fusion neutron source.



**Student Presentation Award in 13<sup>th</sup>  
US-Japan Workshop on Inertial Electro-  
static Confinement Fusion.**

**Advanced Particle Beam Energy Research Section  
Yu Yamagaki (M2)**

The 13th US-Japan Workshop on Inertial Electrostatic Confinement (IEC) Fusion was held in Sydney, Australia on December 7 and 8, 2011. Since the 1st US-Japan IEC exchange held at Los Alamos National Laboratory, United States in 1998, annual workshops have been held in US and Japan. The 13th workshop was held for the first time outside US and Japan. More than 30 including 14 students participated from US, Australia and Japan. In this workshop, Yu Yamagaki, M2 student of Advanced Particle Beam Energy Research Section, presented his work on experimental results from a newly developed IEC fusion device employing a 5-stage high-voltage (HV) feedthrough, and received the student presentation award.

An IEC fusion device consists of a spherical anode at ground potential, and a spherical transparent cathode at the center with a large negative bias of  $\sim 100$  kV. Deuterium ions are accelerated toward the center as they gain energy from the applied electric fields. The use of a highly transparent cathode minimizes ion loss to the cathode grid and allows recirculation of energetic ions. Spherical focusing of ions is thus expected to result in a high ion density inside the gridded cathode. He found numerically, however, that the envisaged recirculation of ions in an IEC devices employing a conventional single-stage HV feedthrough is not very significant (only 2-3 oscillatory motions on average before reaching the HV feedthrough rod), because the HV feedthrough for the central cathode induces asymmetry of the potential inside the anode. Furthermore, for a higher voltage operation of IEC aiming at an improved fusion rate, the bore size of the HV feedthrough port needs to be larger in order to avoid arcing. This geometry modification would make the field symmetry worse.

He designed and constructed an IEC device employing the 5-stage HV feedthrough, in order to apply a high bias voltage and to improve the spherical symmetry of the electric field distribution. Numerical simulations show that the averaged recirculation number of deuterium ions is improved by a factor of  $\sim 3$ . He then conducted HV conditioning and successfully achieved a high bias voltage of  $-180$  kV, which is much higher than the maximum limit of  $-80$  kV by use of the original single-stage feedthrough. This revealed the fusion rate dependence on the applied voltage. It is found that the fusion rate is in proportion to the applied voltage to the power of  $2.4 \pm 0.3$  in the range of  $-80$  kV to  $-130$  kV.

**Encouragement award of Atomic Energy  
Society of Japan in 2011**

**Advanced Energy Storage Research Section  
Kiyohiro Yabuuchi (D3)**

The Atomic Energy Society of Japan (AESJ) energetically pursues human welfare and sustainable development while conserving global and local environments through the atomic energy research, development, utilization, and education, under the principle of information disclosure with maintaining a harmonious relationship with society and securing nuclear safety.

This award was offered for the comprehensive study on irradiation hardening behavior and microstructural evolution in Fe-Mn alloys. We have studied on the irradiation hardening behavior and microstructure evolution in Fe-based binary alloys. We found a significant irradiation hardening of Fe-Mn binary alloys. Microstructure observation by transmission electron microscope (TEM) revealed that the significant irradiation hardening was due to formation of dislocation loops in high density. Moreover, in-situ TEM observation revealed one of the mechanisms of the formation of high density dislocation loops in irradiated Fe-Mn alloys; 1D motion of dislocation loops in Fe-Mn alloys was suppressed. This study contributed to understanding the mechanism of irradiation embrittlement of RPV steels.

**Excellent student award of Kansai branch of Atomic Energy Society of Japan in 2011**

**Advanced Energy Storage Research Section  
Kiyohiro Yabuuchi (D3)**

The Atomic Energy Society of Japan (AESJ) energetically pursues human welfare and sustainable development while conserving global and local environments through the atomic energy research, development, utilization, and education, under the principle of information disclosure with maintaining a harmonious relationship with society and securing nuclear safety.

In the previous study, we found and reported a significant irradiation hardening of Fe-Mn alloys irradiated with neutron. In Fe-Mn alloys irradiated with  $\text{Fe}^{3+}$  ion, a similar remarkable irradiation hardening was also observed. Moreover, irradiation hardening behavior was investigated at various irradiation conditions, such as, dose, Mn-content and irradiation temperature. Microstructure observation by transmission electron microscope (TEM) revealed that the significant irradiation hardening was due to dislocation loops in high density

**“Poster Award” of the Japan Institute of Metals in 2011(Fall meeting)**

**Advanced Energy Storage Research Section  
Kiyohiro Yabuuchi (D3)**

The Japan Institute of Metals, JIM, was founded as a non-profit public organization on February 14, 1937 with the primary objective of promotion and development of science and technology of metals and materials. JIM holds 3-day Annual Meetings twice a year, in spring and in fall, with presentations of over 2500 papers in total annually.

In the 2011 fall meeting, he presented a poster on the annealing behavior of dislocation loops in Fe-Mn alloys irradiated with  $\text{Fe}^{3+}$  ion. In the previous studies, we reported a significant irradiation hardening of Fe-Mn alloys. However, the mechanisms had not been cleared. In this study, it was revealed that the suppression of 1D motion of dislocation loops by solid solution Mn atoms suppressed the motion of small interstitials loops and provided nucleation sites for dislocation loops which caused the significant irradiation hardening.

## Poster presentation award in the International Symposium on Renewable Energy and Materials Tailoring

Chemical Reaction Complex Processes Research Section  
Daichi Kozawa (M2)

The International Symposium on Renewable Energy and Materials Tailoring (REMT) was held in Yoshida Campus, Kyoto University. The topics of the symposium are materials tailoring and its application to renewable energy processes. The symposium is international and participants are from various countries including USA, UK, France, Germany, Norway, Korea, etc. More than 90 papers are presented in the symposium.

In the REMT symposium, I gave a poster presentation entitled "Interaction between particles at a vertical oil-water interface". In this presentation, I proposed a newly developed method to estimate the interparticle interaction potential between the particles trapped at an oil-water interface. The method is based on the application of gravitational field in the in-plane direction to the particles transferred to a vertical oil-water interface. The particles in the lower part of the vertical interface are rather dense compared with the upper part due to the compression by the gravitational effect. The method provides a convenient method to measure the interparticle interactions between the particles at oil-water interfaces.

Due to the development of the new method to measure the interparticle interactions, I was awarded a poster presentation award in the symposium. Since the particle ordering is generally governed by the interparticle interactions, our research is important not only from the point of view of the basic research, but also for the design of the structures formed by particle monolayers at an oil-water interface.

## Poster presentation award in TACT 2011 International Thin Films Conference.

Coatings for sustainable energy  
Molecular Assemblies Design Research Section  
Jae-hyeong Lee (D1)

TACT2011 aims to provide an open forum to discuss the current state of scientific and technological achievements in the coatings and thin films of industrial importance. This conference is an event of knowledge exchange and interactive platform for researchers and engineers from industry, research laboratories and academic institutes. More than 500 attendees are expected. The scope includes a variety of coatings and thin films technologies for sustainable energy, nano devices and optoelectronic applications. Invited speeches, oral reports and posters will be arranged in a three-day long program at Howard Beach Resort Kenting in Pingtung, Taiwan.

In a spray coating process, characteristic performance of organic solar cells (OSCs) has been limited by some drawbacks such as isolated droplets, non-uniform surface and pinholes. We demonstrated a simple process to overcome these inherent factors. We obtained more efficient OSCs with improved interconnection among droplets and reduced amount of pinholes by additionally spraying o-dichlorobenzene (DCB) solvent after the conventional spray coating of the poly(3-hexyl thiophene):[6,6]-phenyl-C61-butyric acid methyl ester (P3HT:PCBM) active layer solution. Moreover, the additionally sprayed solvent caused changes in the matrix of the active layer such that the thermal annealing effect is maximized. As a consequence, an improvement of the power conversion efficiency to 3.06% was achieved, which is more than twice of that of a conventionally sprayed device.

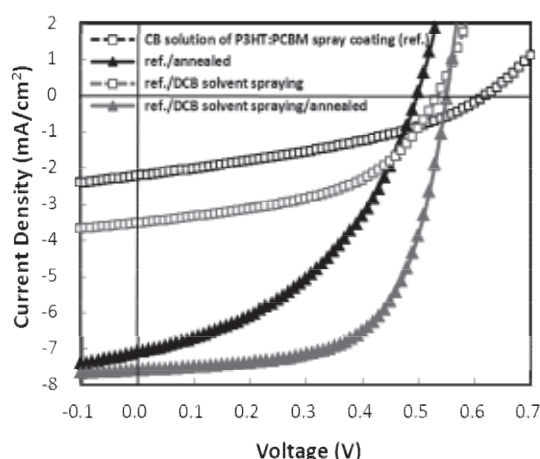


Fig. J-V curve of OSCs of glass-ITO/ PE-DOT:PSS/P3HT-PCBM/solvent spray coating with or without annealing/TiO<sub>x</sub>/Al (100 mW/cm<sup>2</sup>, AM 1.5G) fabricated by the spray coating.

## Poster presentation award in 2011 Annual Meeting of GCOE.

Molecular Assemblies Design Research Section  
Jae-hyeong Lee (D1)

The Global COE will provide new approach for the education and research on energy science as an international COE of Energy Science under the Age of Global Warming. The objective is to perform the research toward the realization of zero CO<sub>2</sub> emission system in a scientific/technological as well as policy-making manner through the coherent research and development of renewable energy, and the timely assessment of research progress based on what is actually needed from the public. Annual meetings have been held every year mainly at Obaku plaza in Uji campus.

My presentation referred to optimization of cells resulted from improved interconnection among droplets and reduction of pin-holes by additionally spraying pure o-dichlorobenzene solvent. The optimal thickness of the active layer, which achieved maximal efficiency, was found to be around 220 nm with highly efficient light harvesting and charge transfer due to the minimization of internal pinholes. Particularly, the short circuit current and fill factor does not decrease severely with the increment of the thickness of the active layer (even 737 nm thick), though the spin coated device drops gradually with increasing the thickness.

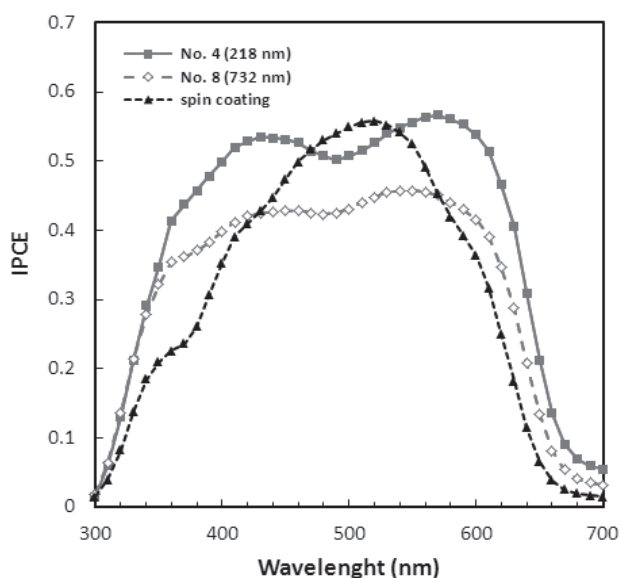


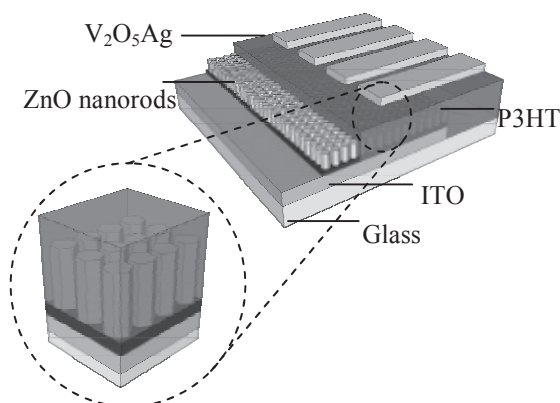
Fig. IPCE of OSCs of glass-ITO/PEDOT:PSS/P3HT-PCBM/solvent spray coating /LiF/Al (100 mW/cm<sup>2</sup>, AM 1.5G).

## Best presentation award in the 3th international symposium Kyoto University Global COE program (specially jointed with BK21 Program, Ajou University).

Molecular Assemblies Design Research Section  
Pipat Ruankham (D1)

The 3th international symposium of Kyoto University Global Center of Excellence (GCOE) was held and jointed with BK21 program of Ajou University, Korea. The aim is to bring together researchers and students of GCOE program involved in zero-carbon energy research.

In the symposium, I presented a poster of my work on the surface modification of ZnO nanorods with organic dye molecules for hybrid polymer-inorganic solar cells. In the beginning part, the morphology of ZnO nanorods, device preparation and properties of dye molecules were discussed. Then, the improvement of photovoltaic performance through surface modification with dye molecules was presented.

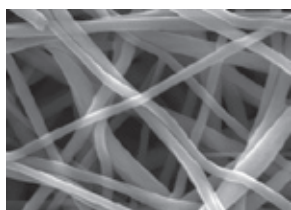


**Presentation award in Ajou-KIT-Kyoto University joint international symposium “Energy Science in the Age of Global Warming”.**

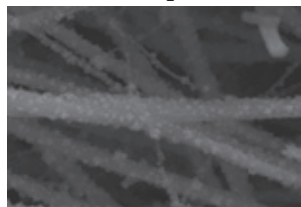
**Molecular Assemblies Design Research Section  
Pipat Ruankham (D1)**

The international symposium was organized by Kyoto University Global COE program jointed with Ajou University, Korea, and Karlsruher Institut für Technology (KIT), German. The aim is to discuss on the topic of energy science in the age of global warming.

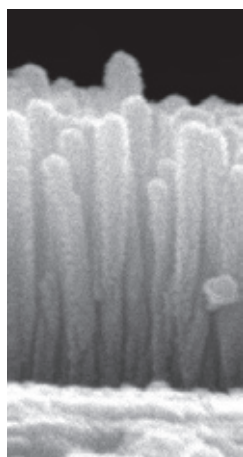
On behalf of my group researchers, I presented the works doing in my laboratory, concerning materials design and device structures for photovoltaic system and hydrogen production. I started with the introduction of one dimensional metal oxide nanostructures applying for dye sensitized solar cells, hybrid solar cells and hydrogen production. Also, the large-scale preparation of organic solar cell was presented. The unique functionality of each material was shown and discussed.



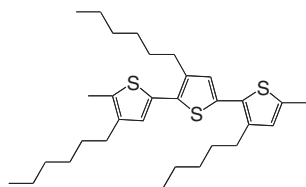
TiO<sub>2</sub> nanofibers



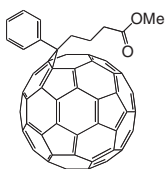
SrTiO<sub>3</sub> nanofibers



ZnO nanorods



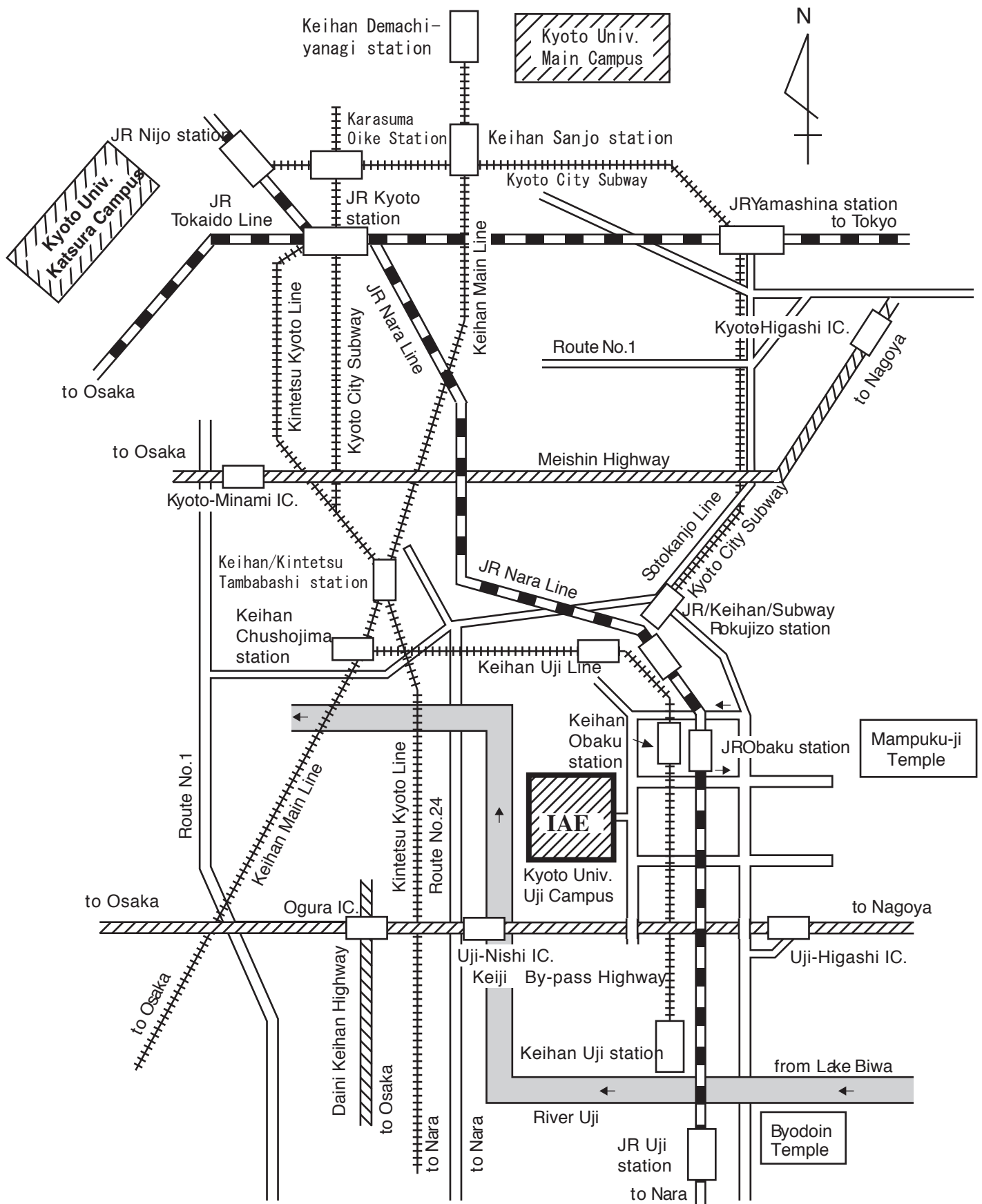
Poly(3-hexylthiophene)



Fullerene derivative  
(PCBM)



## 4. HOW TO GET TO IAE





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