Recent Progress at PNL and SHINE
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PNL Introduction

- Development stage company founded in 2005
  - Currently 20 employees in Madison, WI

- PNL neutron generator has demonstrated $3 \times 10^{11}$ n/s DD operation
  - Higher neutron yield addresses unmet market need
  - Core technology protected by 3 pending/2 provisional patents

- PNL is working to transition from an R&D company to a manufacturing company
  - Effort will be largely funded by DoD and DoE grants to develop a commercial version of the neutron generator
Facility and Testing Infrastructure

- PNL and SHINE moved to new facility in May 2012
- ~8000 ft² of industrial space and 6000 ft² of office space
High Energy Neutrons are Generated by Shooting an Ion Beam into a Gas Target

1) Power supply brings dome voltage to 300 kV
2) Ion source creates dense plasma
3) Accelerator extracts 50 mA from source
4) Electrostatic quadrupole focuses beam
5) Differential pump system keeps gas out of accelerator
6) Gas target is struck by beam, generating fusion neutrons
PNL Intense Neutron Source

- Eight years in development
- Demonstrated $3 \times 10^{11} \text{n/s D-D}$
  - High current ion source and accelerator
- Gas target $\rightarrow$ lifetime of years
- PNL source allows many neutron applications to become practical
Technology Progress

- **High Voltage Power Supply:** Fully operational, but derated in voltage

- **Ion Source:** Tested to 20% above 50mA spec; 122-hour (>99.9% uptime) operation with extraction

- **Accelerator:** Tested to 275kV

- **Focus Element:** Electro Static Quadrupole (ESQ) demonstrated to 38 mA; Solenoid demonstrated to 50 mA;

- **Differential Pumping:** Fully operational

- **Gas Target:** Demonstrated at 40 mA

- **Neutrons:** Neutron rates of $3 \times 10^{11}$ n/s achieved
Neutron Uses

- Interrogation of materials
  - Radiography and tomography (nondestructive evaluation)
  - Detection of explosives (IED’s) and nuclear material
  - Diffraction and scattering for materials characterization

- Transmutation of materials
  - Medical isotope production
  - Silicon doping for semiconductor production
  - Nuclear waste remediation

- Demand for compact, high-yield neutron generators existed for decades
  - Reactors inaccessible/expensive/non-mobile
  - Commercial neutron tubes too weak to be practical
Defective munitions kill soldiers

DoD has bought thousands of X-ray systems
- $100k’s to several $M each
- Not entirely effective

Defects in propellant cause catastrophic failures
- Nearly invisible to X-rays
- Highly visible to neutrons

Stated Army Goal: image every shell with neutron radiography
Radiography - Aerospace Market

- Aerospace NDT market = $300M/year
- Neutrons only solution for key components:
  - Turbine blades
  - Composite wing structures
  - Batteries/Fuel Cells
- Access to neutrons limited to only a few reactor/national lab sites
  - Must compete for beam time
  - Expensive: >$100k/week
  - Cannot solve real-time problems
- PNL collaboration underway with Air Force and Rolls-Royce

Catastrophic Defect (invisible to x-rays)

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Explosives Detection

- IED defeat is a leading priority for the DoD
- PNL technology can be applied to long-range detection
- Standoff IED detection contract to begin in mid-2014
  - Miniaturize neutron generator for mobile applications
Nuclear Material Detection

- Nuclear smuggling: largest-magnitude threat to US Homeland

- Department of Homeland Security spent $billions on passive “portal monitors”
  - Cannot detect shielded Special Nuclear Material
  - Neutrons can overcome this problem

- Leading world expert Tsahi Gozani joined PNL from Rapiscan Labs
SHINE Introduction

- Development stage company founded in 2010.
  - Currently 30 employees in Madison, WI
- SHINE was established to commercialize a safer,
  - cleaner, and more economical technology for producing medical isotopes.
- The SHINE system employs an accelerator-driven LEU solution subcritical assembly.
- A license application has been submitted to the US Nuclear Regulatory Commission.
- Janesville, WI has been chosen as the site of the new SHINE facility, which will supply half of U.S. demand for Mo-99.
**99Mo Allows Internal Imaging**

**Example Images**

*Top left:* SPECT brain image showing onset of bipolar disorder

*Top right:* 3D reconstruction of cardiac stress test

*Bottom left:* 2D stress test images taken with advanced cameras
Conventional Production of $^{99}$Mo

- 2/3 of world’s supply from 2 research reactors
  - Canada & the Netherlands
  - No production in U.S., though U.S. is biggest consumer

- Many issues
  - Reactors are 50 years old & unreliable
  - Use highly enriched uranium (HEU) → security threat
  - High level of waste

- Reactor problems have led to severe $^{99}$Mo shortages
  - Negative impact on public health
  - Significant price increase (3x)

- Both reactors to be shut-down this decade
SHINE ⁹⁹Mo Production

- High-intensity accelerator to induce fission
  - Less complex
  - Much less technical risk

- Low-enriched uranium (LEU) target
  - Avoids the security concern of HEU
  - Preferred reimbursement

- Uranium dissolved in an aqueous solution
  - Target reusable, generates far less waste
PNL founded to develop an intense source of neutrons for many near-term applications

SHINE founded to use PNL generators to produce Mo-99 for medical imaging

Good progress has been made by both companies, but more work needs to be done
Questions?

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