Planar Geometry IEC Fusion Device
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Introduction
In the classic gridded inertial electrostatic confinement (IEC) fusion reactor, ion bombardment of the grid leads to heating, thermionic electron emission, and significant power loss; and the heating can ultimately melt the grid. Gridless IEC devices have sought to overcome these limitations. At IEC2011, Klein reported a gridless device called the “Multiple Ambipolar Beam Line Experiment” (MARBLE) in which ions are circulated as a linear beam in an electrostatic analog of an optical resonator (Figure 1).

The MARBLE design was inspired by the linear electrostatic ion trap developed by Zajfman, et al. (Figure 2) and the simpler “anharmonic ion trap” (Figure 3). The number of ions stored in any electrostatic trap is limited by the space charge at the points of lowest velocity, i.e. the turning points of the circulating ion beam, and the number stored ions limits the fusion rate. The MARBLE device employed multiple overlapping traps in the same physical space to enable the trapping of more ions.

The spherical gridded fusor, in theory, can trap recirculating ion beams throughout the full solid angle space of the sphere maximizing the area of the turning region. Thus, overlapping traps in the same physical space to enable the trapping of more ions. The spherical fusor design was simplified here to a planar geometry for gridless and gridless devices.

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Description of the Planar Geometry IEC Fusion Device
Linear electrostatic ion traps all possess cylindrical symmetry about the ion beam axis. If one imagines taking the cross section of a linear trap and rotating it about a central axis perpendicular to the ion motion, the result is a planar beam device with a series of concentric rings above and below the ion beams as shown in Figure 4. If all of the ring electrodes are grounded and a negative potential is placed on the center pins, the device is a planar analog of the trap shown in Figure 3 (Case 1). Operating the device with a gradient of positive potentials on alternate rings, with the intervening rings and center electrodes grounded, yields a planar analog of the MARBLE device (Case 2).

In the work reported here, both Case 1 and Case 2 were simulated using the electrode configuration shown in cross section in Figure 5.

Simulation Studies
Simulations were carried out using SIMION 8.1 software to predict the trajectories of deuterium ions in a planar ion trap device. Case 1 and Case 2 were modeled under vacuum conditions. If the ions are generated in the model with even a small amount of energy (0.1 eV) in the tangential direction, they will quickly spread out all around the trap as shown in Figure 6, suggesting that the planar trap will allow trapping of ions with trajectories throughout the full circular angle space.

Effects of Background Gas Collisions
A fusion device requires the presence of fuel, so vacuum simulations do not give a true picture of ion behavior. The system was therefore modeled in the presence of background gas using a hard sphere elastic collision model to examine the effect of collisional scattering upon the ion trapping. Figure 9 shows the scattering in a Case 1 device at pressures of deuterium gas from 1 Pa. (where trapping is comparable to vacuum). This suggests that the planar trap may not be useful at pressures normally used in devices with ion formation from simple Paschen discharge, and that other means of ion generation will be required. The commercial residual gas analyzer based upon the single potential linear trap (Figure 3) generates ions within the trap using an electron beam injected from a filament outside the trap. The same method could be used in a planar trap fusion device to enable operation at lower pressures.

Conclusions
These studies suggest that a planar geometry device could function as proposed and offer improved performance over previous geometries. However, the scattering simulations suggest that the device may require operation at lower pressure than normally used in gridded spherical devices. A prototype device is under construction.

References