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Inertial Electrostatic/Magnetic Confinement Hybrid Device

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Abstract

- **A new type of fusion reaction device – one that includes aspects of both: Inertial Electrostatic Confinement and Magnetic Confinement – is proposed. This device would operate on pulsed power and utilize electron-gun based fuel ionization. A magnetic field would confine the ionized fuel to the outer perimeter of the cylindrical reaction chamber ensuring maximum kinetic energies of the colliding particles. Ion-path focusing grids would be employed to further increase the collision probabilities. All of these would ensure maximum efficiency of the device, which could have a considerable effect on rare isotope manufacturing and other IEC areas.**

Approach

- **Several theoretical calculations predicting the device's performance, power supply circuitry models and simulations, and ion-pathway focusing grid simulations have been performed and presented. The end results indicate MAGICA's superior performance over standard IEC devices.**

Device Operation

- **Cylindrical geometry**
- **Pulsed power**
- **Fuel electron ionization**
- **Brief magnetic plasma confinement**
- **Inertial Electrostatic Confinement of nuclear fusion fuel**
- **Neutron production and detection.**

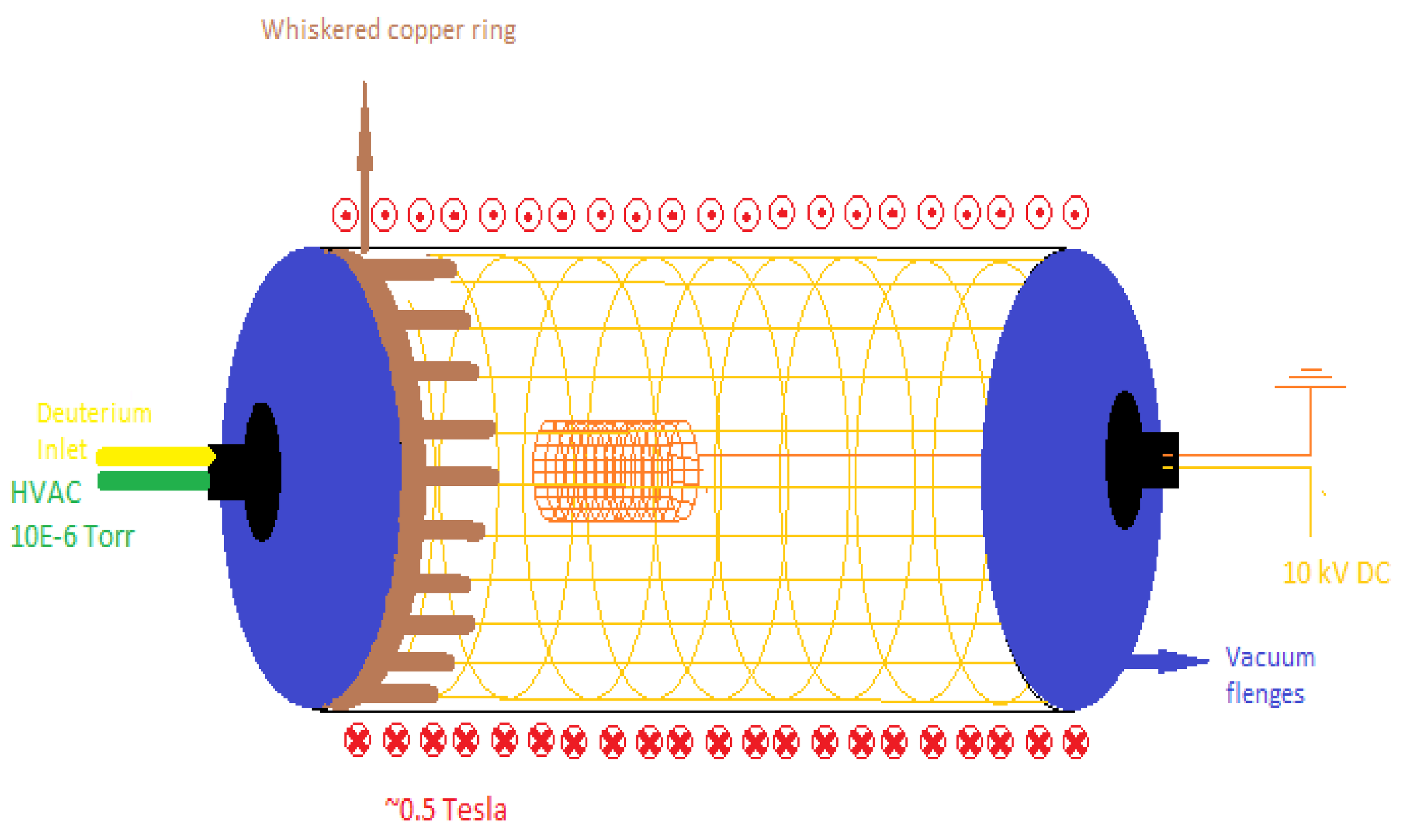

Fig. 1: Cross-sectional view of the proposed reactor vacuum chamber

Power Circuitry

- **Approximately 17.5 kV (pulsed) needed for electrodes**
- **100 A pulse through electron whiskers**
- **3 kV transformer Connected to 7-stage Cockroft-Walton Generator**
- **24 Rayleigh Pulse Forming Network connection**
- **System resulting in: ~18 kV steady voltage for 10 ms, with rise-time of 0.3 ms**

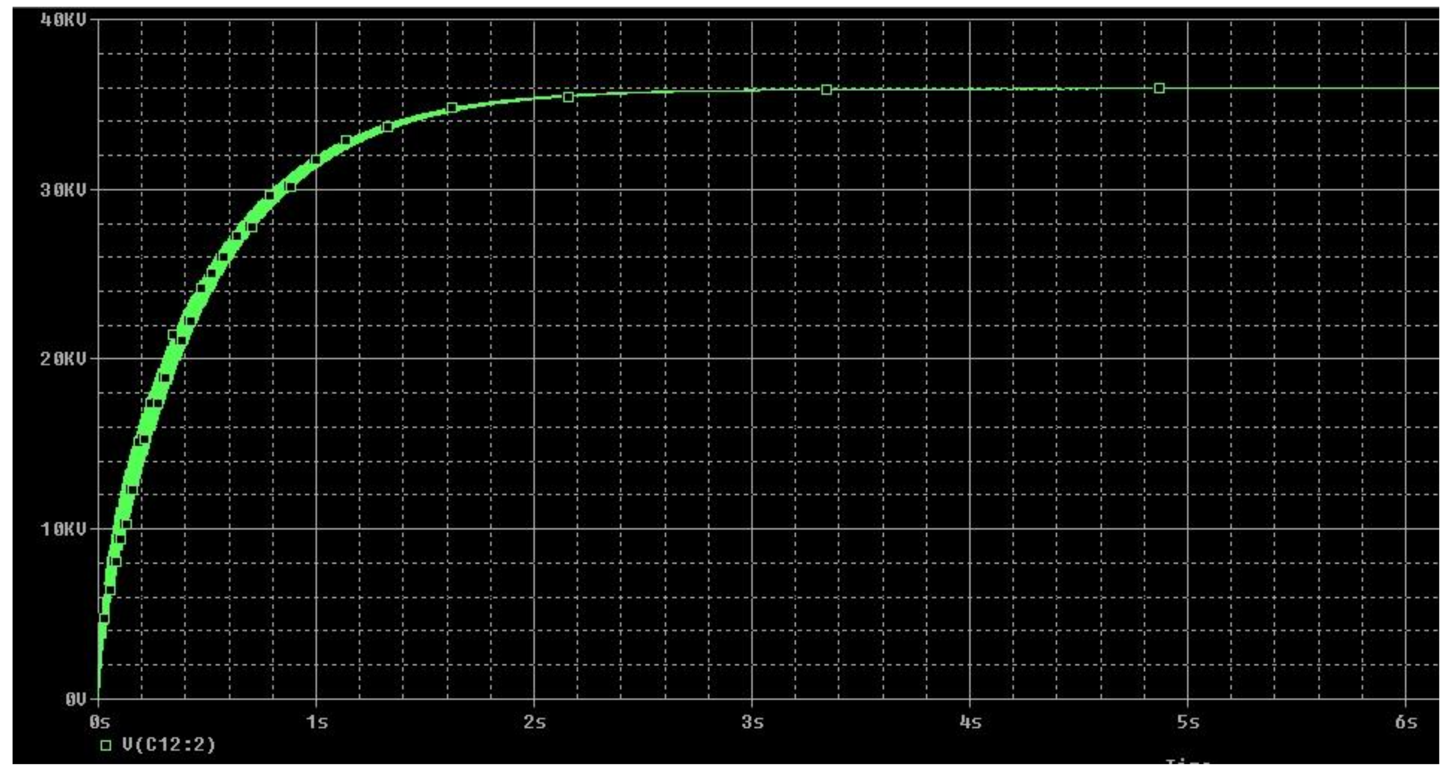

Fig. 2: PSPICE simulation of 7-stage CWG voltage raise. 35 kV levels reached at approximately 2 seconds

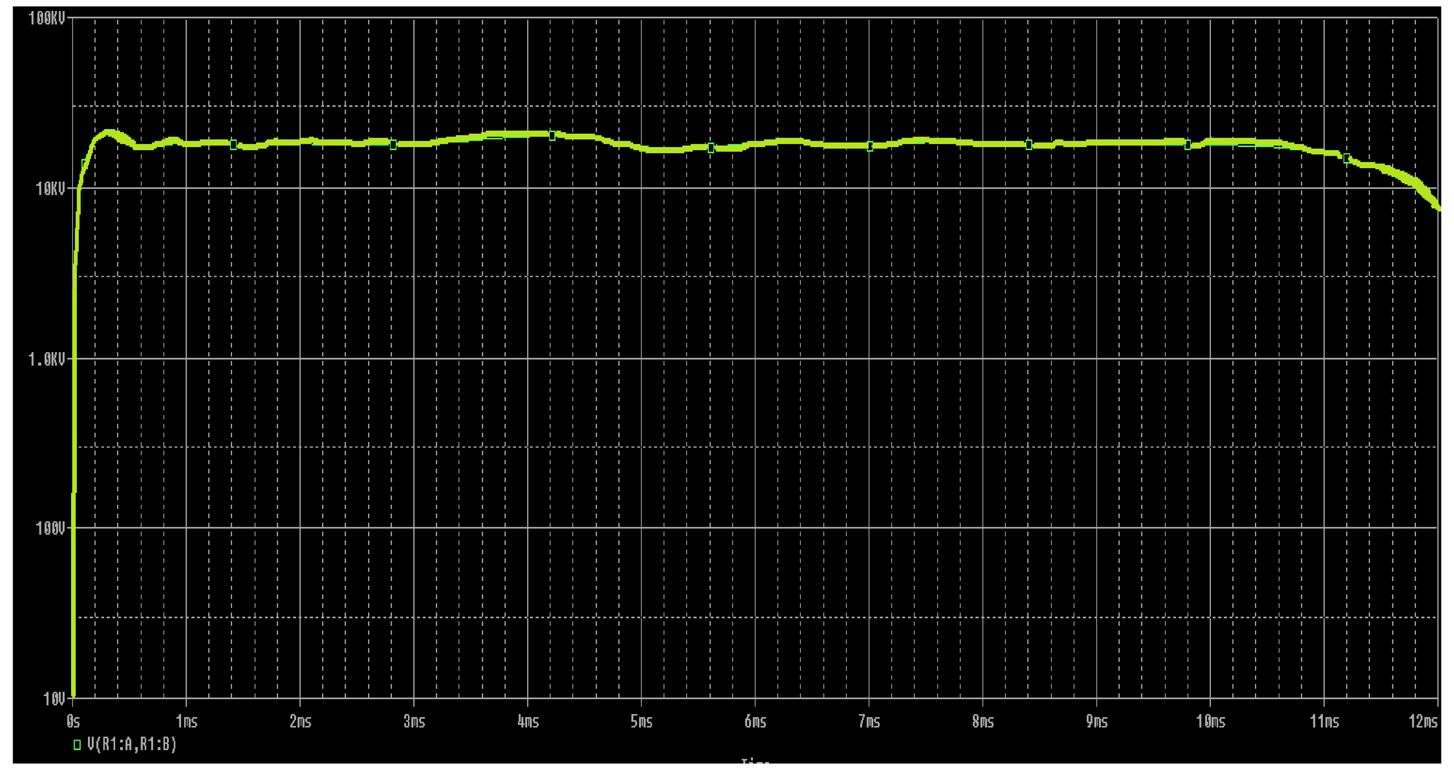

Fig. 3: PSPICE simulation of 24-stage RPFN output pulse. Reasonably flat, 17.5 kV, 100 A pulse lasting ~10 ms. Pulse raise time ~10 micro seconds

Neutronics

- **Neutronic output was calculated using the below equation**
- **Considerations were made for D-D and D-T fusion cross-sections, ionization likelihood, and interaction probabilities**
- **Total neutrons produced per 10 ms shot (predicted): 1.05E4**

$$N_{fusions} = \frac{\sigma_{fusion}(1 - Prob_{Coll}) \dfrac{\sigma_{ionization}\left(\frac{P}{k_B T}\right) * Volume * \left(\frac{t * I}{q_{electron}}\right)}{A_{ionization}}}{A_{fusion}}$$

Where:

- σ_{fusion} **= Deuterium-Deuterium fusion cross-section**
- $Prob_{Coll}$ **= Area-based probability of ion collision**
- $\sigma_{ionization}$ **= Ionization cross-section**
- **P = Pressure within the chamber**
- k_B**=Boltzmann constant**
- T**= Temperature within the chamber**
- **t=Pulse time length**
- $q_{electron}$**=Electron charge**
- $A_{ionization}$**=Total ionization area**
- $Afusion$ **= Total fusion area**

Total Power Consumption

- **Calculated power requirements per device shot:**
  - **50 Electron Whiskers: 50*70V*100A*10ms=0.9722 W*hr, drawing at 0.35 MW per shot**
  - **Electrodes: 17,500V*20 mA*10ms= 9E-4 W*hr, drawing at 0.35kW per shot**
  - **Magnetic field: 12 V * 12.63A*10 ms=4E-5W*hr, drawing at 151 W**
  - **<u>Total:</u> 0.9 W*hr drawing at 0.35 MW per shot;**
  - **~ 11,600 neutrons/W*hr**

Conclusion and Future Work

- **A new type of fusion reactor has been presented. Initial calculations pertinent to the device's operation have been performed and provided in this presentation. This submission is part one of an ongoing research project at the University of Florida. Future work will include GEANT simulations of the device, as well as large-scale runs of the focusing grid simulations to determine optimal geometries. Part two will focus on implementation of the above theory via the design and construction of the said device. Finally, part three will discuss the results obtained (primarily the neutron flux) and focus on means of improving those results.**

Focusing Grids

- **Adding mid-voltage electrodes between the main cathode and anode relaxes magnetic field lines**
- **Ionic stochastic behavior decrease**
- **Decrease in ionic travel focus area increases interaction probability**
- **Schwatz-Christoffel Matchematica Simulation has**

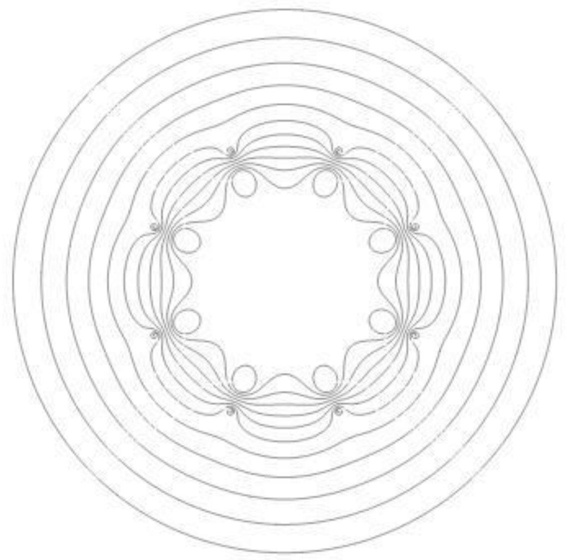

Fig. 4: Magnetic field lines simulated within a standard, cylindrical IEC chamber

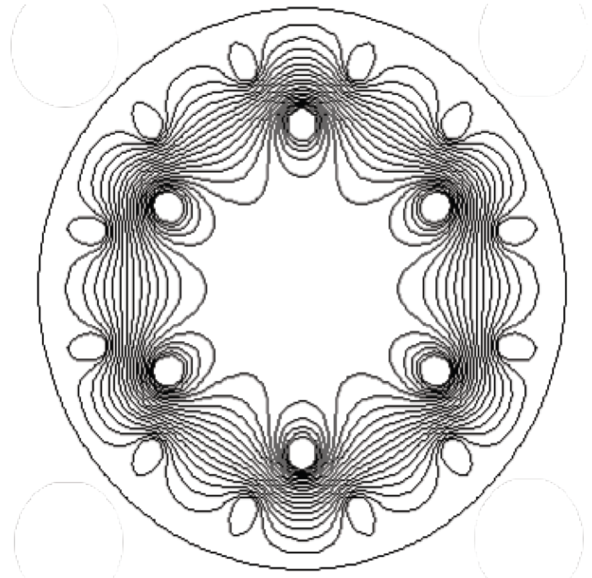

Fig. 5: Magnetic field lines simulated within a cylindrical IEC chamber with added FGs

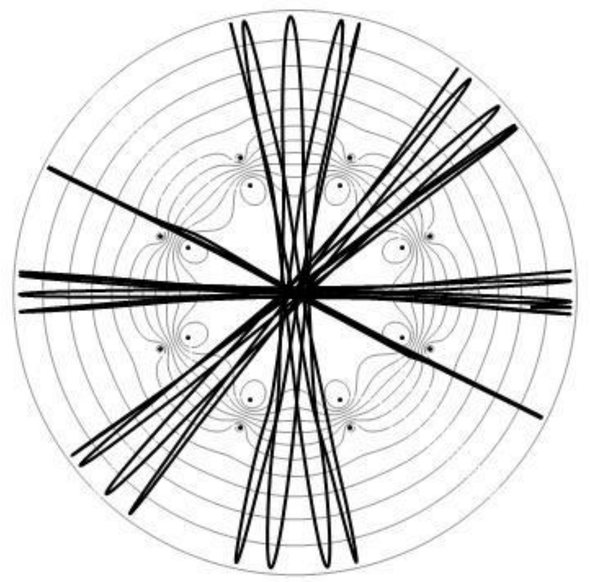

Fig. 6: Ionic path simulation within a standard, cylindrical IEC chamber

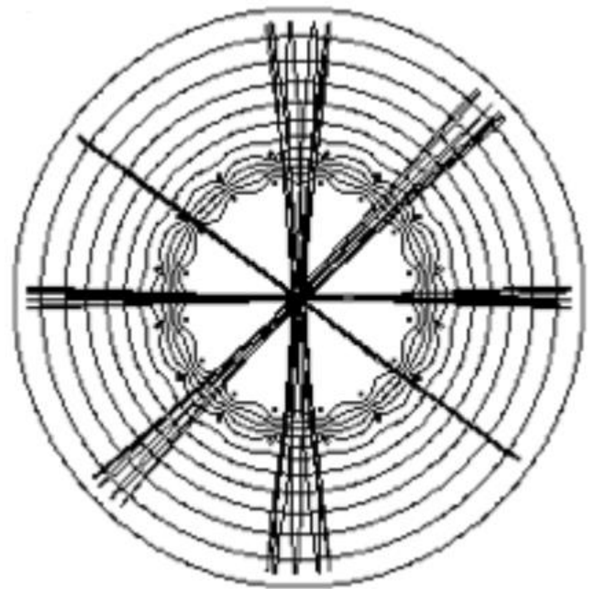

Fig. 7: Ionic path simulation within a cylindrical IEC chamber with added FGs

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