Helicon Ion Source and Core Physics Research for the UW IEC Device

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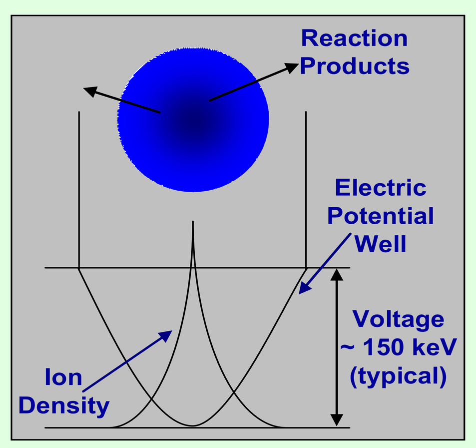
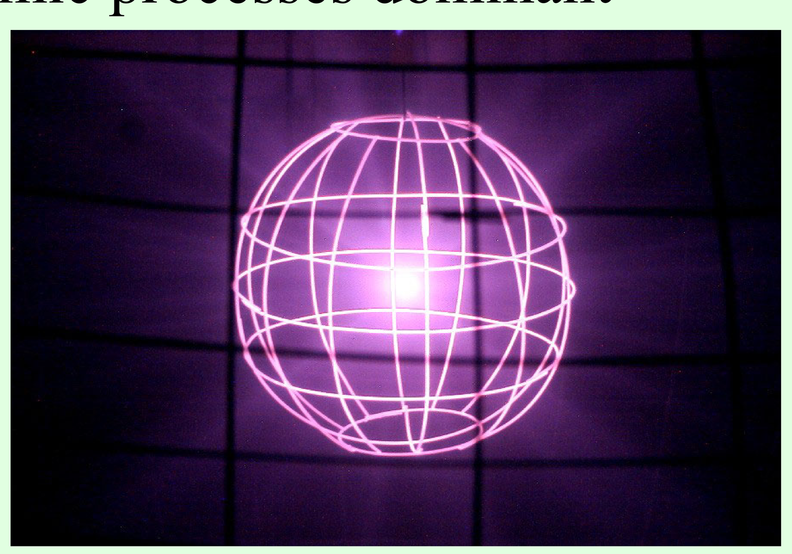
IEC Theory

•Inertial-Electrostatic Confinement (IEC) Devices operate by ionizing fusion fuels and accelerating ions into a spherical potential well which is created by concentric spherical electrodes

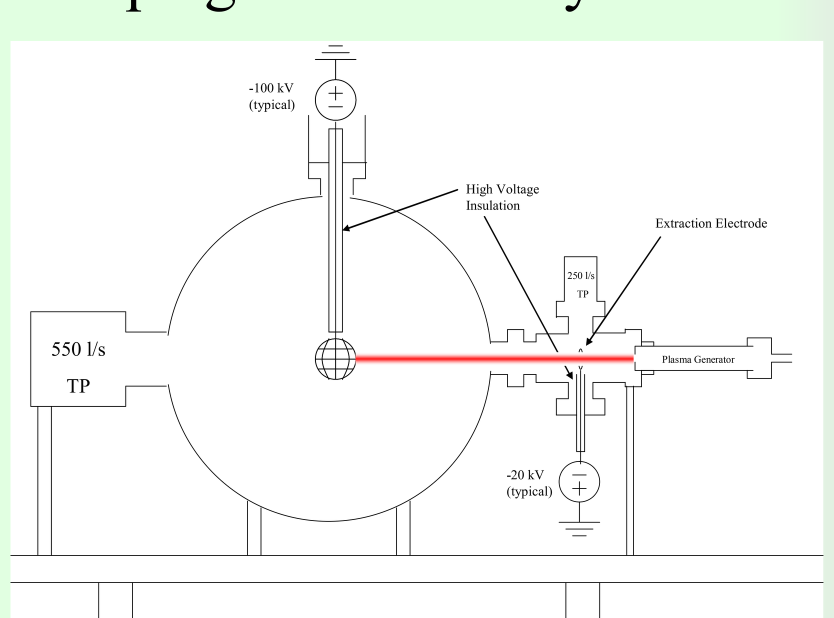


•Present gridded IEC devices operate at relatively high pressures, making losses to atomic processes dominant



IEC Device Operating at ~7mT

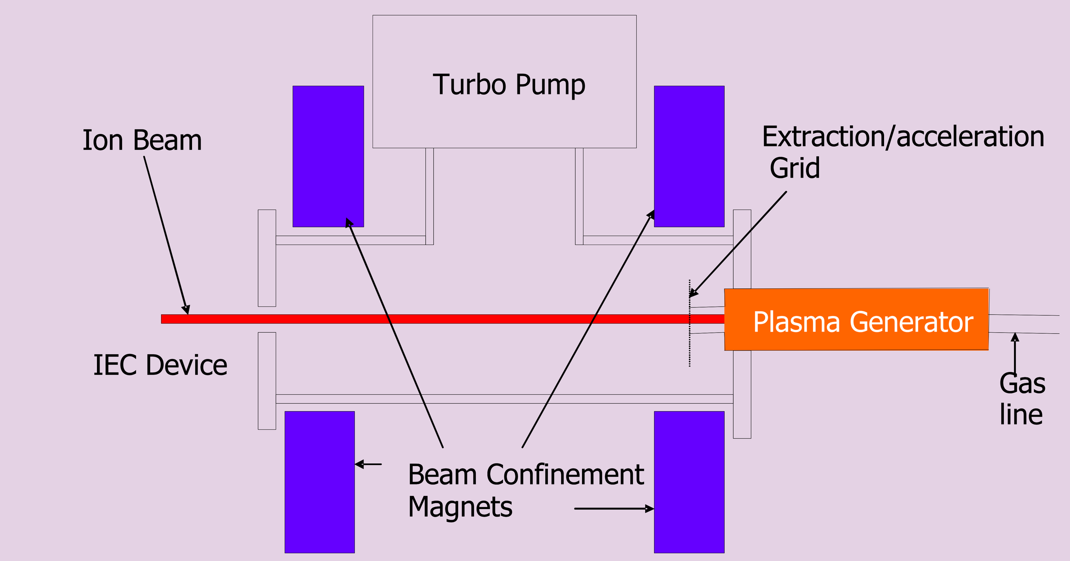
•Reducing neutral pressure will reduce losses, such as charge exchange and ion-neutral collisions. A computational and experimental campaign is underway to explore this.



Spherical IEC schematic

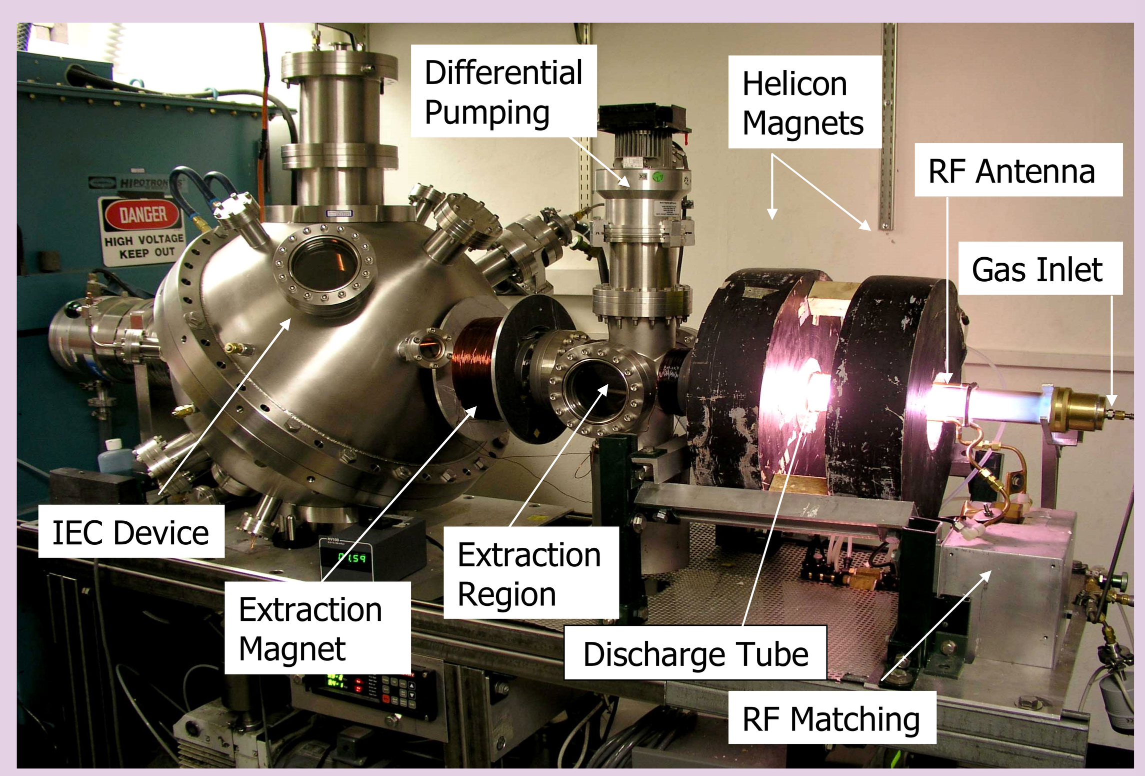
Ion Source

• A helicon ion source is used to achieve high current and low pressure

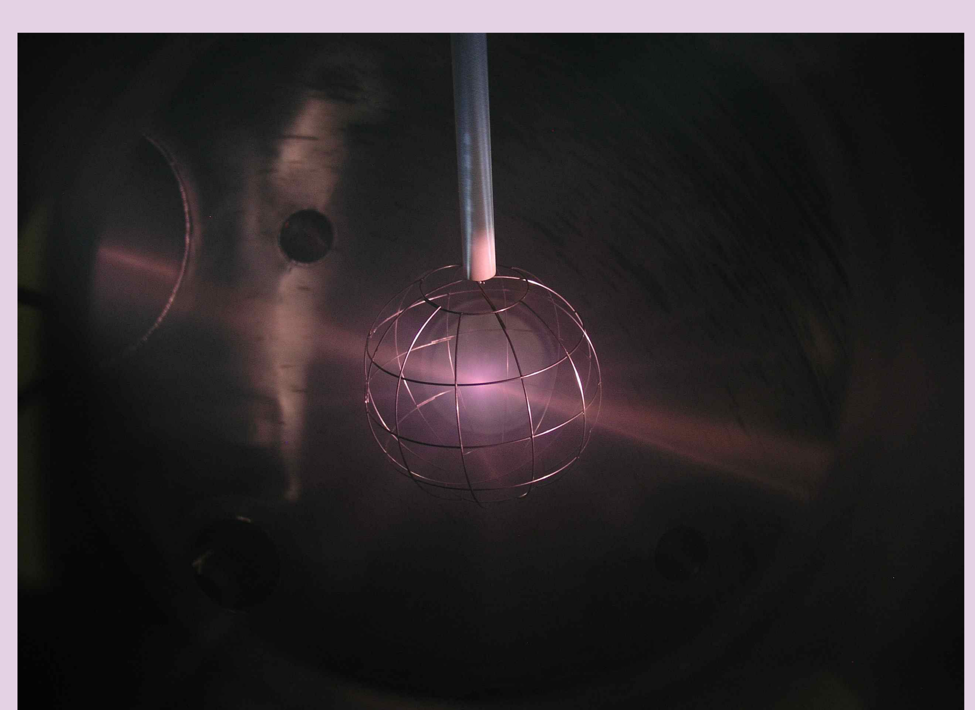


Ion source/extraction system schematic

• The source is mated to an IEC and high voltage is used to inject the ions



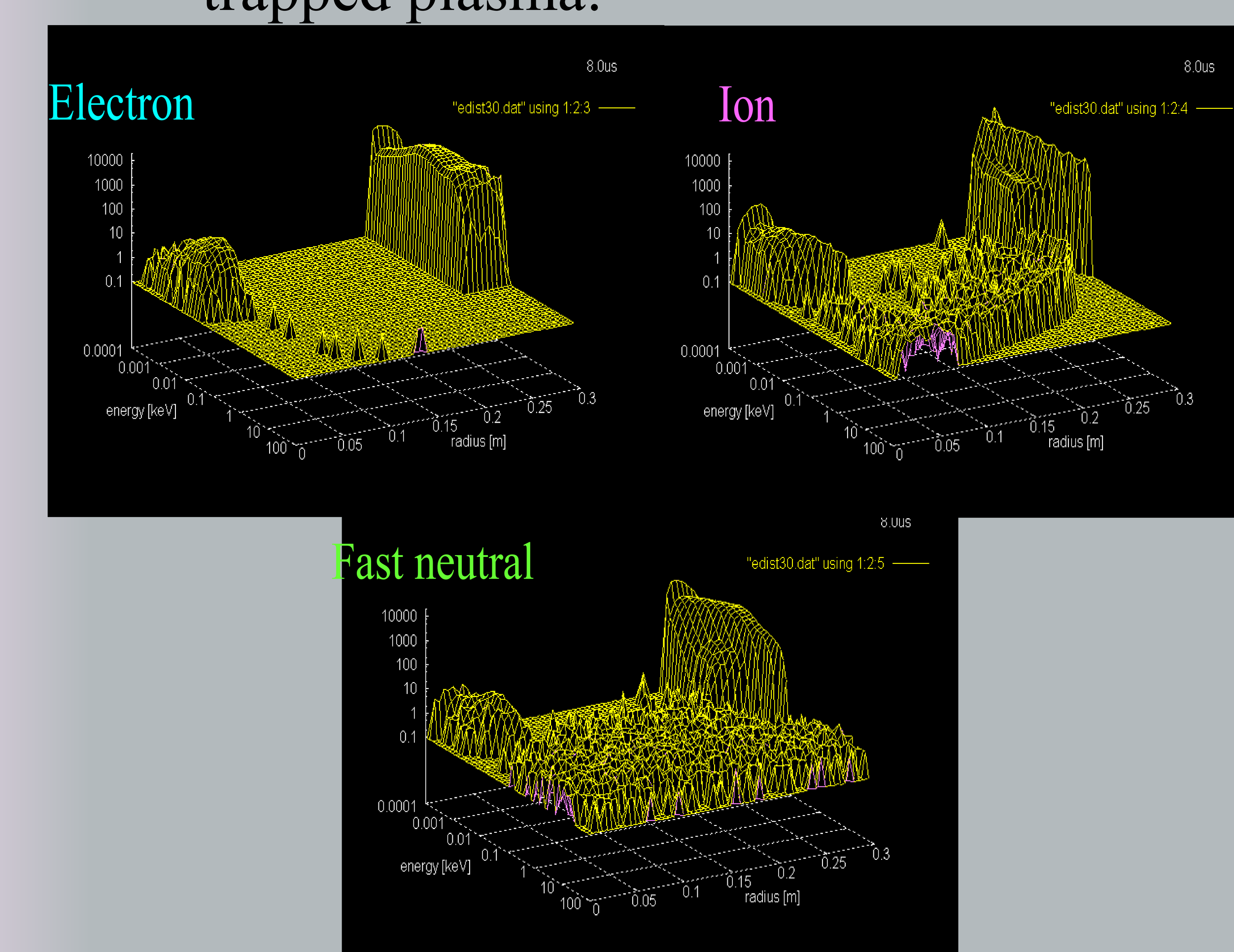
Ion source mated to IEC



He Beam Discharging into IEC

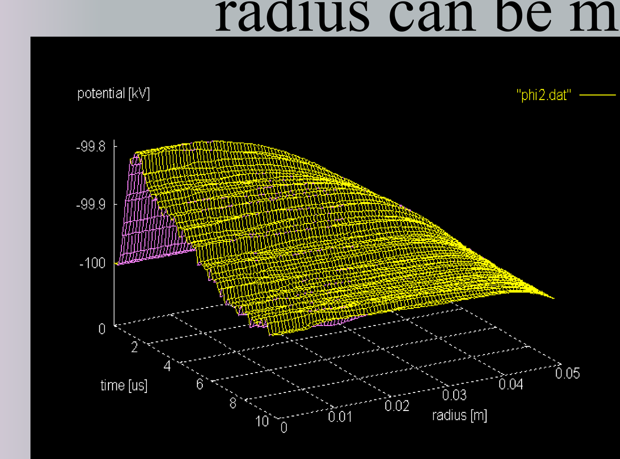
PDS-1

- 1-D MC-PIC code written by UC-Berkeley, adapted by R. Nebel at LANL and K. Tomiyasu at UW-Madison for IEC
- Models atomic, nuclear and some surface interactions
- Code predicts low-temperature trapped plasma:

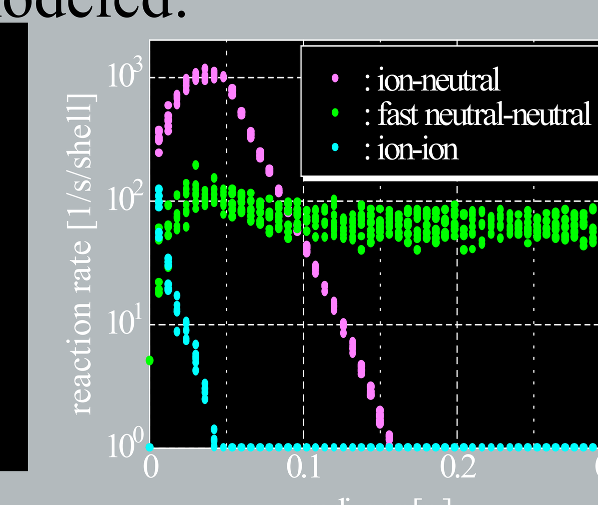


Sample output from PDS-1

- Potential structure and fusion rate vs. radius can be modeled:



Potential inside IEC cathode



Fusion rate vs. R

- Code has been run at 2 mtorr pressure and will be adapted for simulation near 50 μtorr

Ion Flow Analysis

• Inward attenuation on a partial pass (similar outward equation), grid attenuation not shown:

$$f_{in}(r, s) = \exp\left[-\int_r^s n_g \, \sigma_{cx}(s, q) \, d q\right]$$

• Infinite number of passes gives the total current, J(r,s), at r from ions born at s [total current J(s)]:

$$J(r, s) = J(s)\left[\frac{f_{in}(r,s)}{1-f_{in}^2(0,s)} + \frac{f_{out}(0,s)\, f_{out}(r,s)}{1-f_{out}^2(0,s)}\right]$$

where $J(s) = \int_s^{r_a} S(s, q)\, 4\pi q^2 \, d q$

• Ion source, S(r,s) using flux conservation:

$$S(r, s) = \frac{n_g\,[\sigma_{cx}(r,s)+\sigma_{iz}(r,s)]\,J(r,s)}{4\pi r^2} + \frac{J_a\, \delta(s-r_a)}{4\pi r_a^2}$$

• Resulting equation is a Volterra equation of the 2nd kind, which will be solved numerically.

Summary

- Experimental theoretical, and computational campaigns are underway to investigate IEC core physics
- Helicon ion source constructed to achieve core convergence experimentally
- PDS-1 has shown trapped plasma population in core at 2 mT
- Ion flow analysis allows lifetime tracking of ions