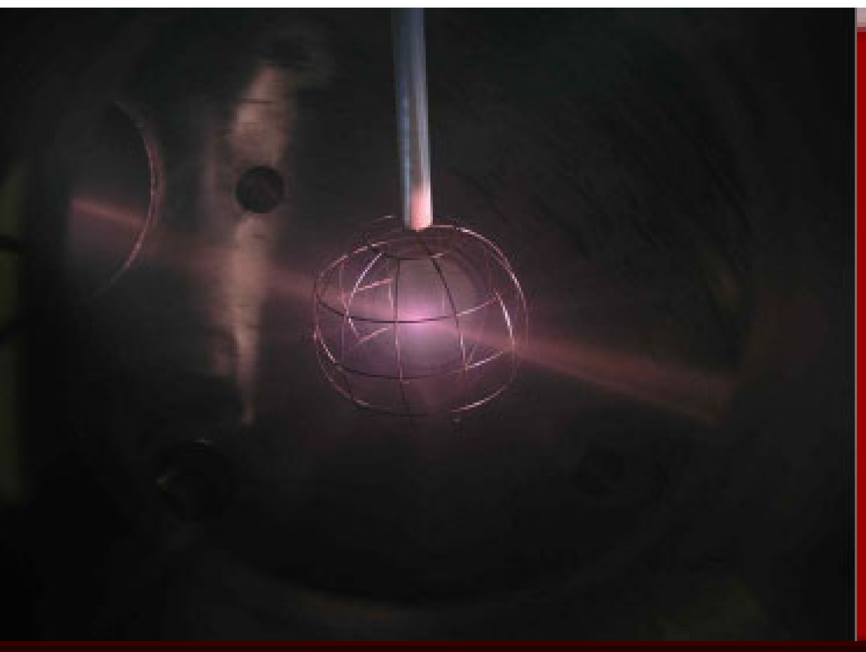

Ion Extraction from a Helicon Plasma Source for an Inertial Electrostatic Confinement Fusion Device

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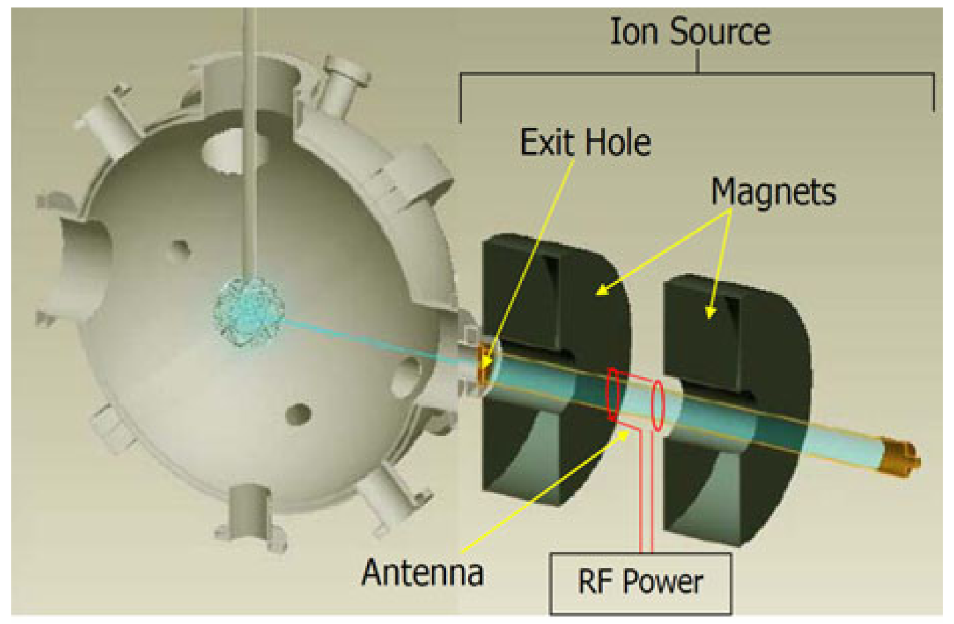
Summary

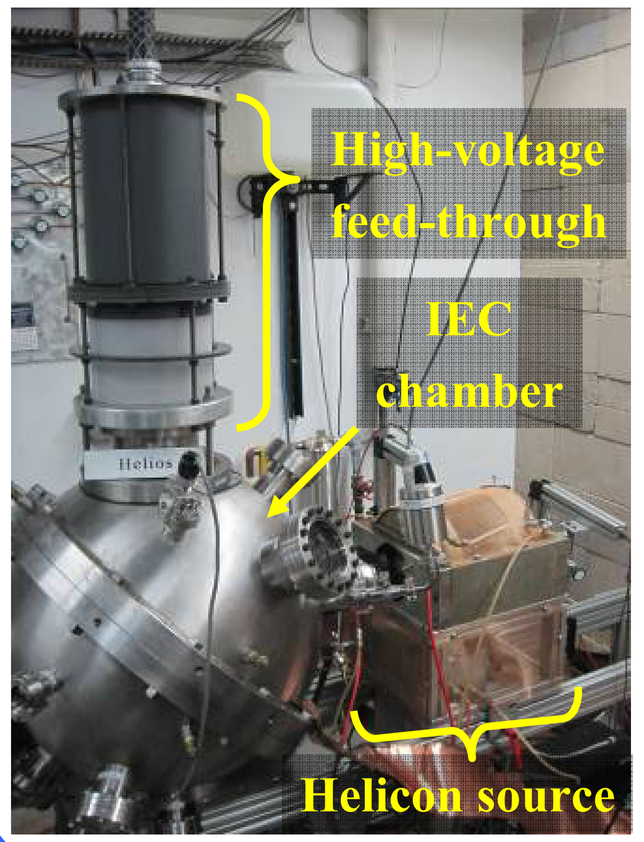
- The plasma parameters of a helicon ion source coupled to an inertial electrostatic confinement fusion device suggest that the extractable ion current should be higher than previously measured by a witness plate method.
- A Faraday cup has been constructed to have a more reliable method for ion current measurement.
- Double probe measurements may only be valid below an ion-mass-dependent threshold magnetic field strength.
- The ion source is likely operating in an inductively-coupled mode rather than a helicon wave mode, which would yield higher achievable plasma densities and extractable ion current.

Inertial Electrostatic Confinement

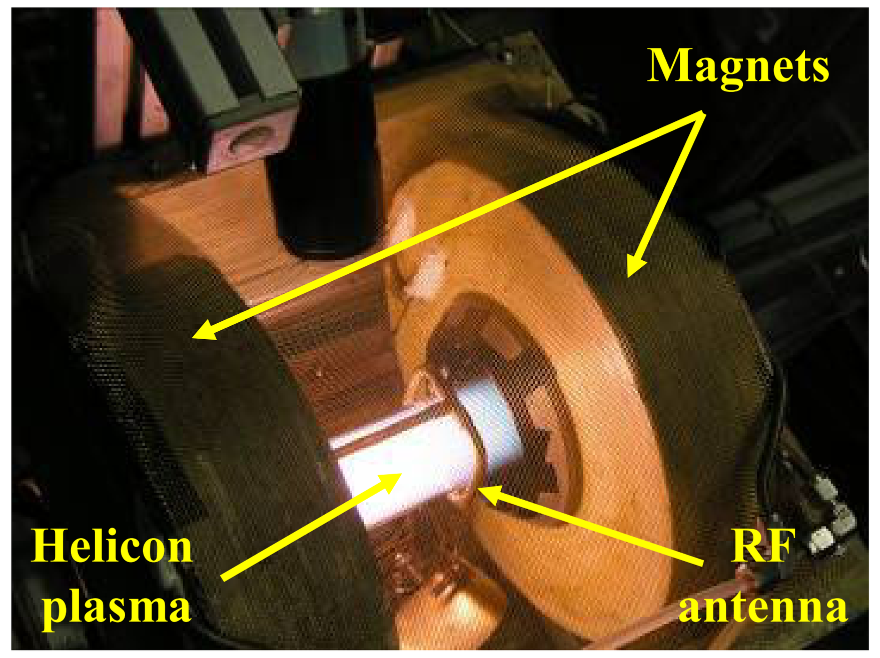
- IEC devices are well suited for studying advanced fuel fusion reactions requiring high ion energies. Instead of heating a bulk Maxwellian plasma, ions are directly accelerated to fusion-relevant energies.
- An electrostatic well between two concentric electrodes or semi-transparent grids confines ions radially. Atomic and molecular interactions with background neutral gas greatly affect the ion energy spectrum.



HELIOS Experimental Setup

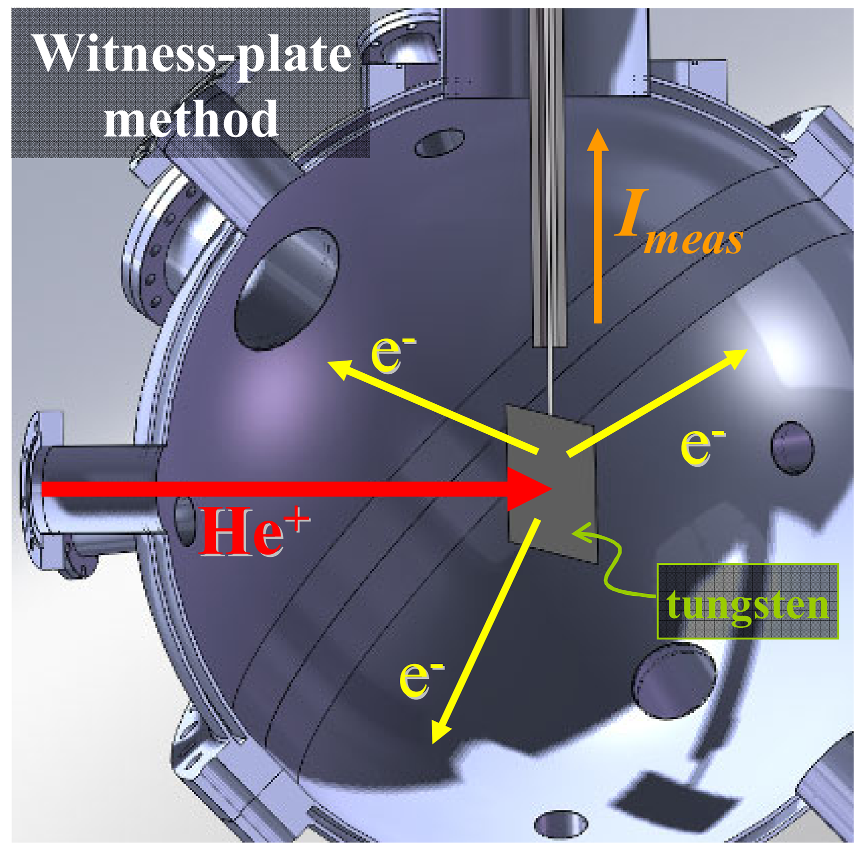


- HELIOS is an IEC device with an external helicon ion source, allowing for a lower background pressure to mitigate the ion energy spectrum softening by charge-exchange reactions with neutrals.
- ^{3}He-^{3}He fusion reactions in an IEC system were first demonstrated in HELIOS, at ~10^3 reactions/s at V_{cath} = -134 kV and I_{ion} = 7 mA [1]. Higher rates are essential for diagnostic investigations of IEC physics with helium-3 fuel.



- A campaign is underway to enhance the ion current extracted from the helicon ion source, as well as the high-voltage capabilities.

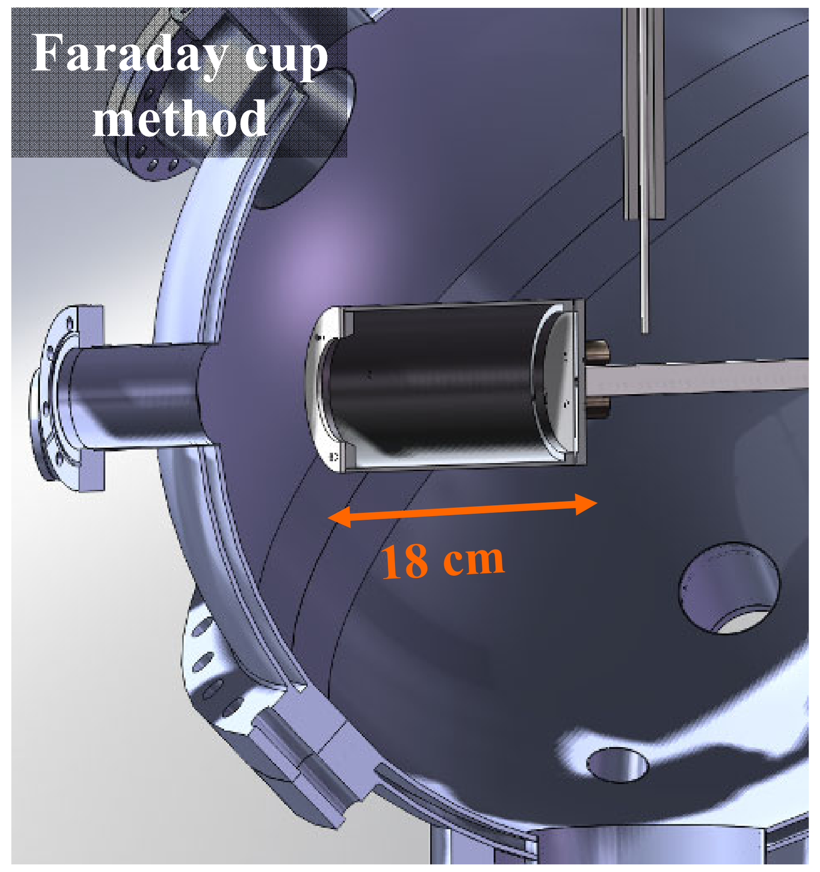
Ion Beam Current Measurement



- Total cathode current is mostly secondary electrons.
- Ion current, more relevant to fusion rates, is calculated from total measured current by assuming a secondary emission coefficient of a flat witness plate.

$$I_{He+} = \frac{I_{meas}}{1+\gamma}$$

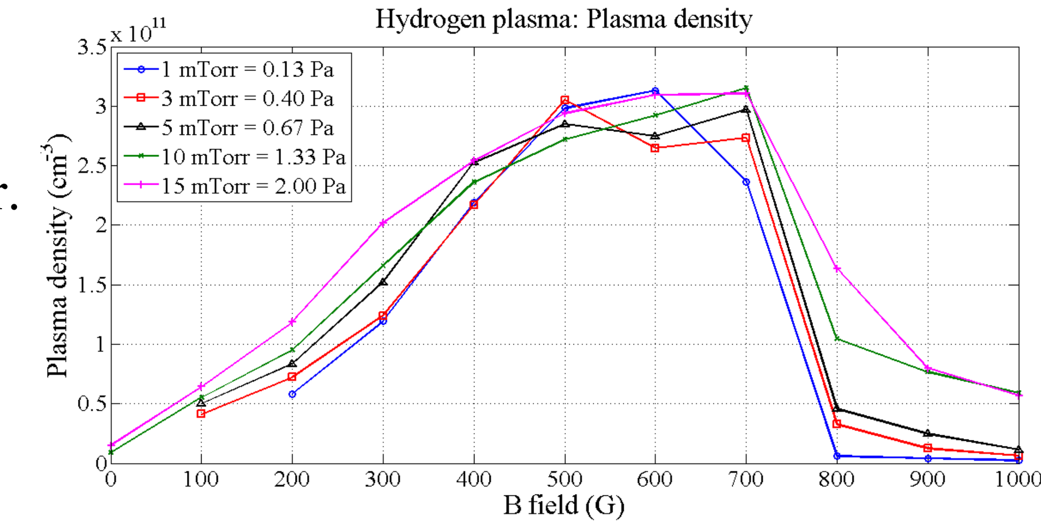
- The applicability of $\gamma(E)$ for this measurement can be problematic.

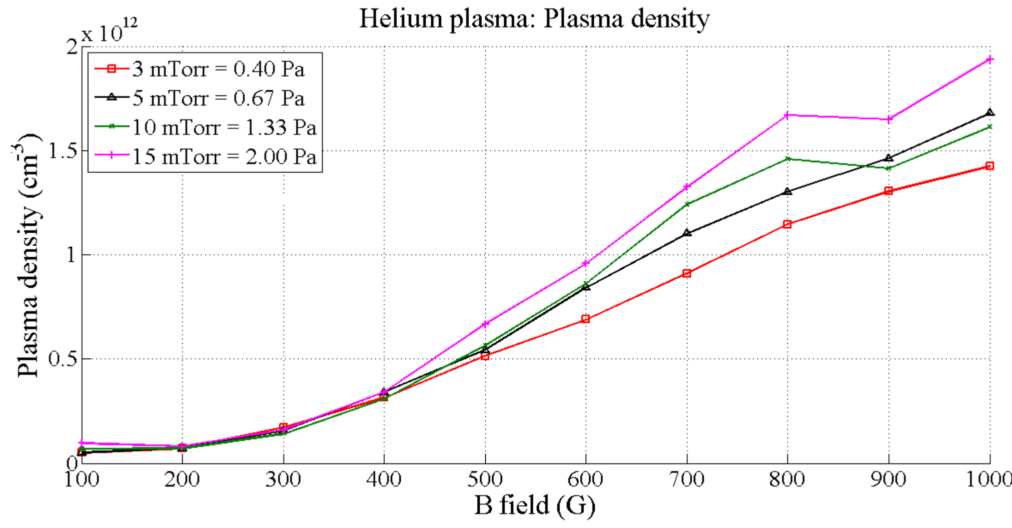


- A Faraday cup has been constructed and will be used to obtain a more reliable ion current measurement, since it is independent of secondary emission characteristics.
- A suppression electrode is impractical given the large observed beam size; instead, magnets are used to provide a transverse magnetic field (up to ~500 G) to confine the secondary electrons to the cup.

Helicon Plasma Characterization

- Double probe measurements of n_0 and T_e were made near the ion extraction aperture at P_{rf} = 1 kW, $B_0 \leq 1$ kG and p = 1–15 mTorr.
- Plasma densities are low for the helicon wave mode, suggesting the source is likely operating in the inductively coupled mode.
- Hydrogen density unexpectedly peaks at an intermediate field strength, possibly due to increased end losses at higher B_0.





- Similar density peaking using deuterium may indicate that probe measurements are only reliable up to an ion-mass-dependent threshold field strength.
- Helium-4 densities increase monotonically within B-field range.
- Previous witness-plate ion current measurements [1,2] are significantly lower than the predicted Bohm current to the aperture according to previous line-intensity-ratio spectroscopic measurements with hydrogen [3] and these double probe results.

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[1] G.R. Piefer, "Performance of a Low-Pressure, Helicon Driven IEC ^{3}He Fusion Device," Ph.D. thesis, UW–Madison (2006).

[2] S.J. Zenobia, "Effects of Helium Ion Implantation on the Surface Morphology of Tungsten at High Temperature for the First Wall Armor and Divertor Plates of Fusion Reactors ," Ph.D. thesis, UW–Madison (2010).

[3] E.C. Alderson, "Spectroscopic Diagnosis of a Dense Hydrogen Plasma Source," M.S. thesis, UW–Madison (2008).