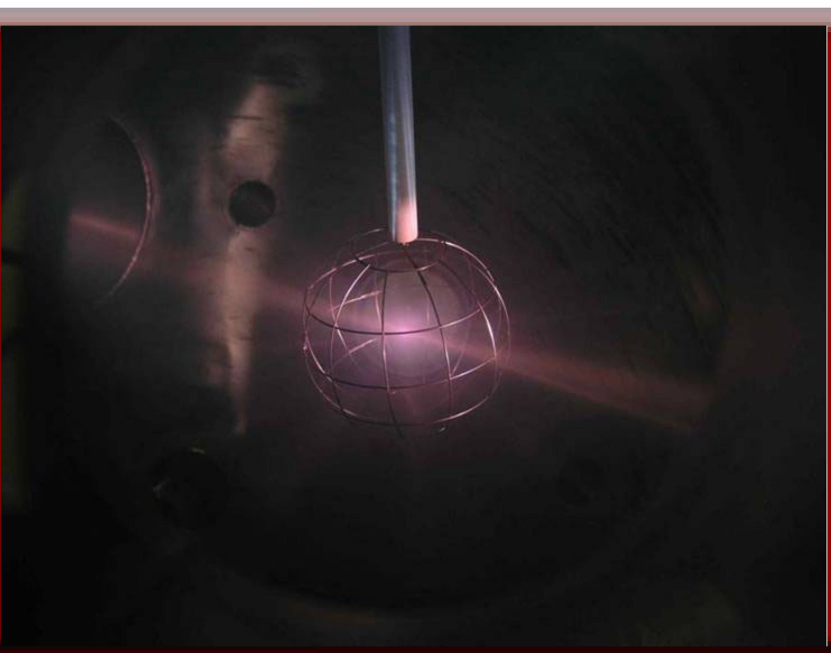

Improved Inertial Electrostatic Confinement Device for ^{3}He-^{3}He Fusion

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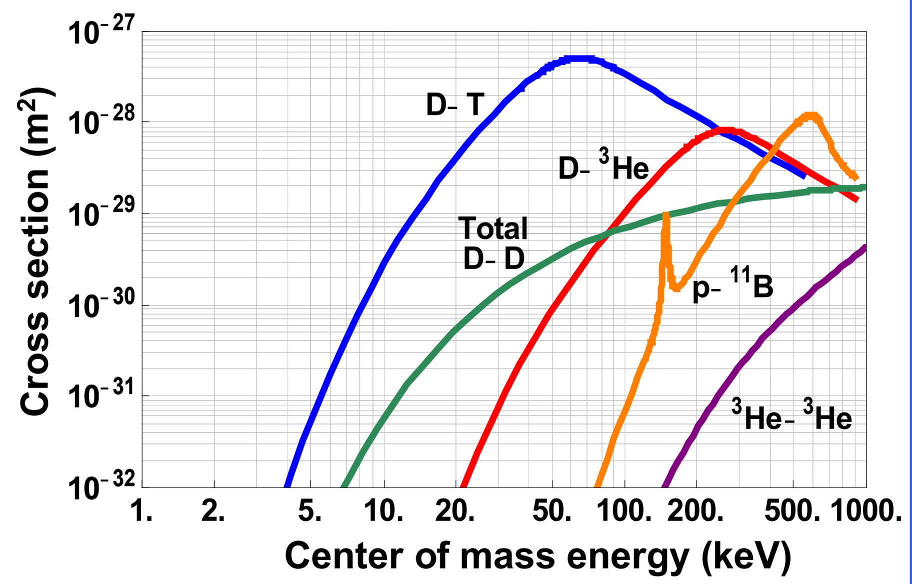
^{3}He-^{3}He Fusion

Neutron rate per watt of fusion (from fuel only)	
Reaction	Neutrons/s (MeV)
D-T	4×10^{11} (14.1)
D-D	9×10^{11} (2.45)
D-^{3}He	2×10^{10} (2.45)
^{3}He-^{3}He	~0

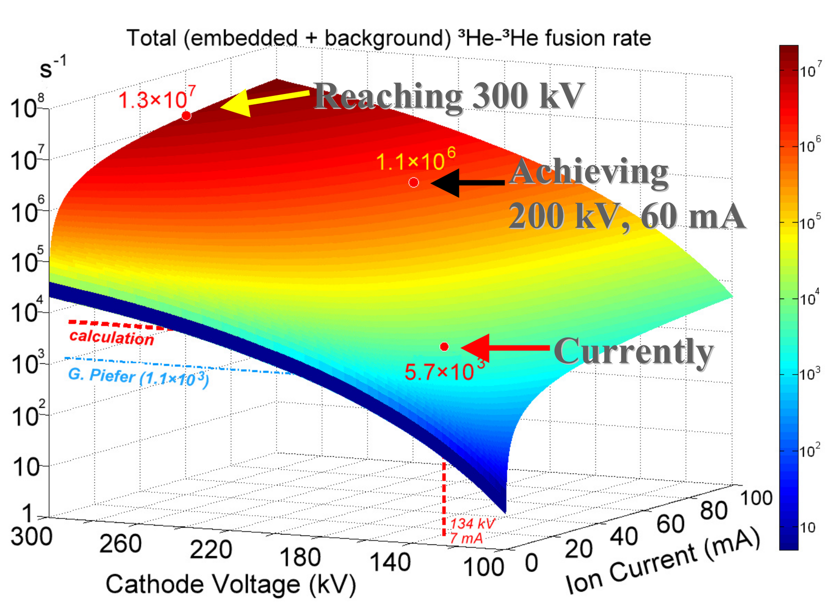
- The ^{3}He(^{3}He,2p)^{4}He reaction produces virtually no high-energy neutrons, plus all nuclei are stable.
  → very reduced radioactivity levels and material damage to the walls due to neutrons.



- Research of IEC operation with ^{3}He can yield better understanding of the reaction, with relevance to nuclear and solar physics.
- Techniques can be developed and applied to other advanced fuels requiring high ion energies, e.g. p-^{11}B.

Approach

- Piefer (2006): detected first ^{3}He-^{3}He fusion protons in an IEC experiment. The record rate is 1.1×10^3 reactions/s at -134 kV cathode voltage, 7 mA ion current [1]: still too low for studying reactant energy profiles and spatial distribution of fusion events and for experimentally benchmarking the single-atomic-species formalism of the Emmert-Santarius integral-equation code [2].
- **Objectives:**
  1. Enhance high-voltage capabilities beyond 200 kV in order to significantly raise the ion energy and thus the ^{3}He-^{3}He fusion cross section.
  2. Optimize the helicon ion source to extract ~60 mA of ^{3}He ion current.



- If these improvements are achieved, the total ^{3}He-^{3}He fusion rates may be increased by ~3 orders of magnitude, enough for diagnostic studies of IEC physics, as well as testing of theoretical predictions.

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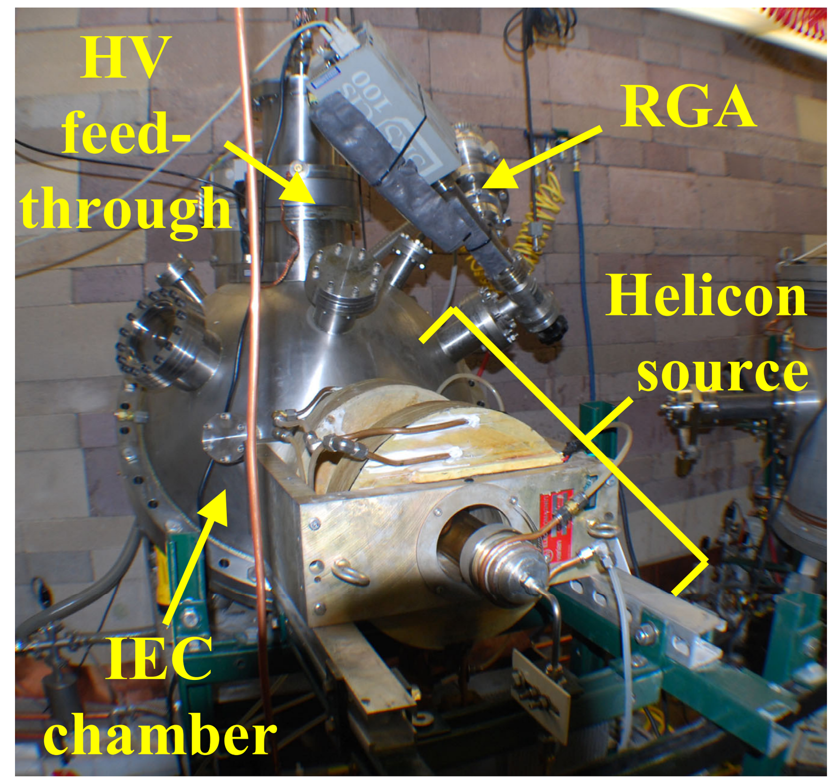
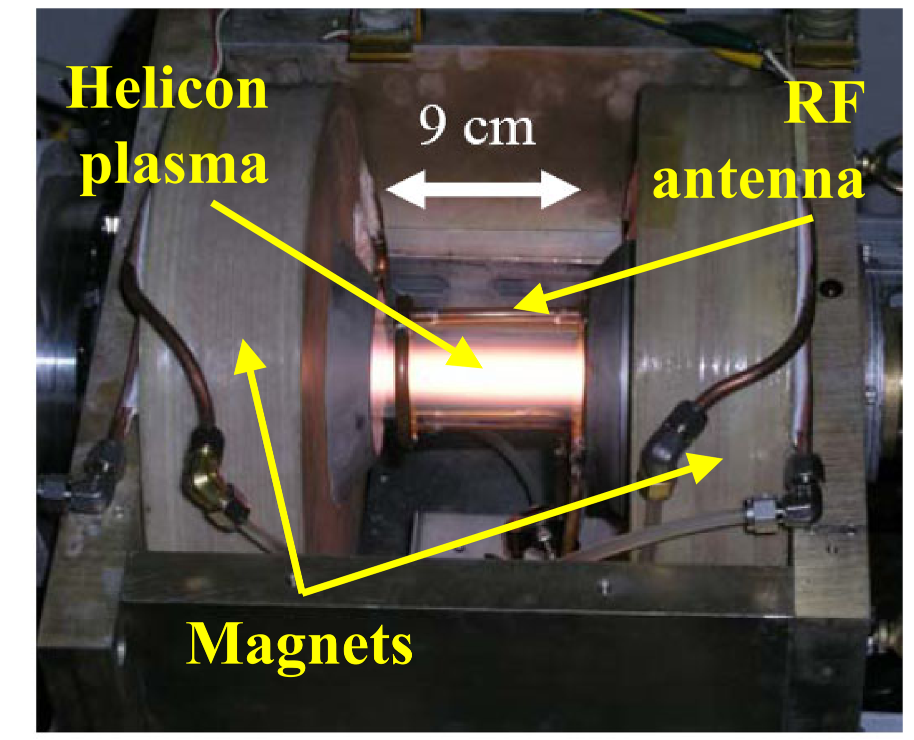
Experimental Setup

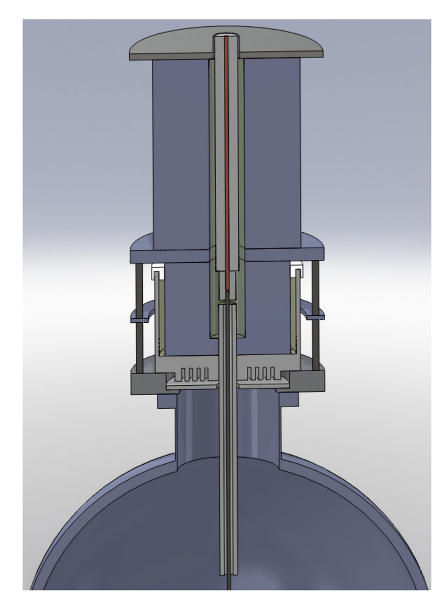


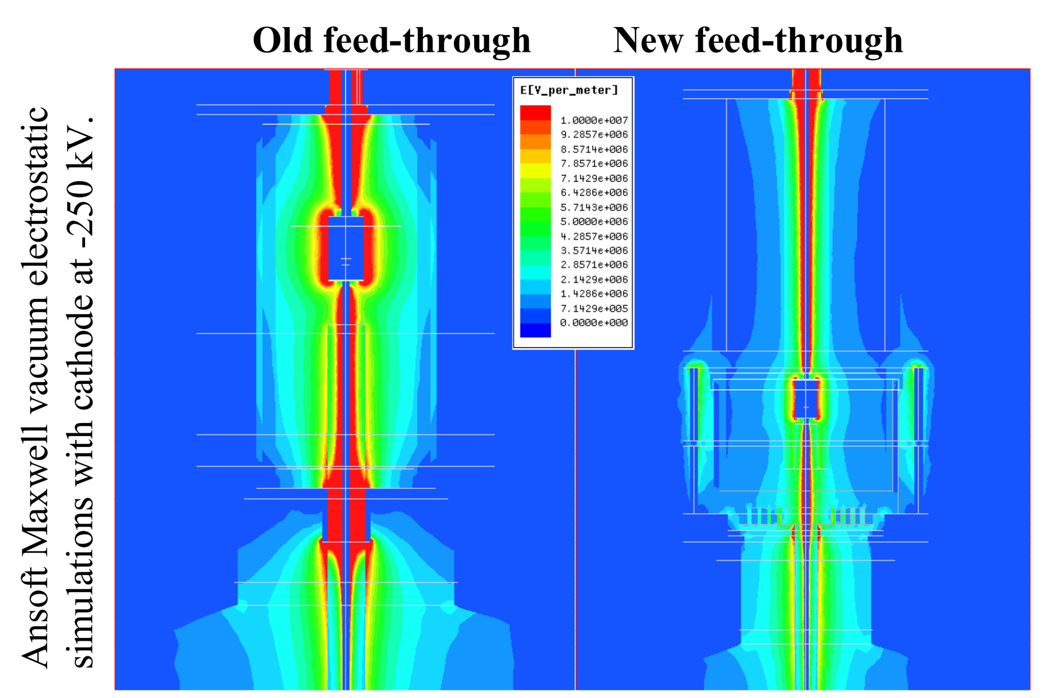
- HELIOS is a spherical IEC device featuring an external helicon ion source, allowing for lower background pressure (~0.2 mTorr) in the vacuum chamber to minimize the ion energy spectrum softening by charge-exchange reactions and other interactions with neutral gas.
- A single grid is used, with the chamber wall acting as the grounded anode and the grid acting as the cathode, being fed the highly negative potential through the high-voltage feed-through.
- Charged-particle detectors are used to measure fusion rates and a residual gas analyzer (RGA) is used to monitor the impurity levels.



High Voltage Capabilities

- A new high-voltage feed-through has been designed and constructed to take advantage of a new 300 kV power supply.
- The new feed-through will increase the surface paths to ground by using non-conducting materials such as quartz and PVC. Electric fields are much reduced, particularly near the vacuum interface, where stalk failures typically happen.



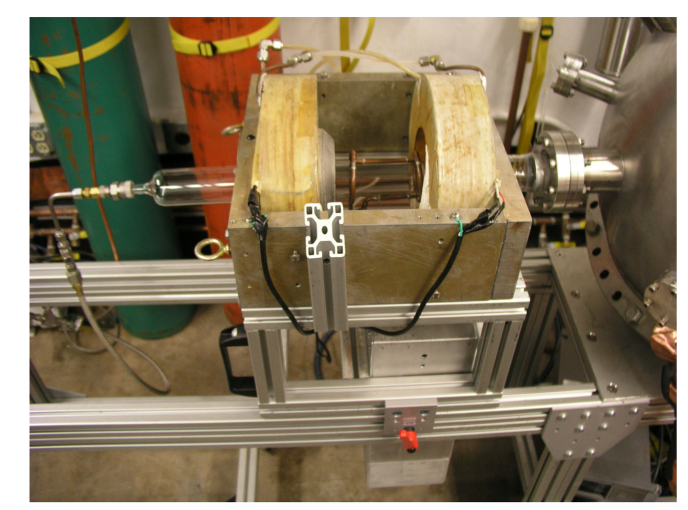


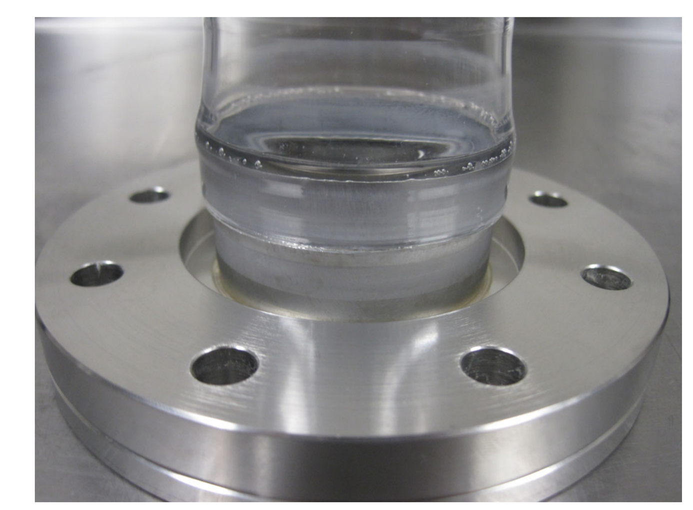
- Furthermore, the high-voltage stalk insulator has been upgraded to a hollow boron nitride rod known to be more robust from simulations and extensive running experience on the UW IEC device HOMER.

[1] G.R. Piefer, "Performance of a Low-Pressure, Helicon Driven IEC ^{3}He Fusion Device," Ph.D. thesis (2006).
[2] G.A. Emmert and J.F. Santarius, *Phys. Plasmas* **17**, 013502 (2010).
[3] D.D. Blackwell and F.F. Chen, *Plasma Sources Sci. Technol.* **6,** 569 (1997).
[4] H.D. Jung et al., *IEEE Trans. Plasma Sci.* **35,** 1476 (2007).

Ion Source Upgrade

- The discharge chamber of the helicon ion source has been replaced with a custom-made assembly featuring a quartz-to-molybdenum seal brazed to a CF flange, rated for temperatures up to 350 ºC, higher than the previous O-ring seal while introducing fewer impurities into the system.





- Plasma densities in helicon sources can be increased by over 50% by changing the RF antenna from a Nagoya type III to a twisted Nagoya geometry [3]. An additional factor of 3-4 can be achieved by applying a non-uniform magnetic field instead of a uniform axial one [4]. These modifications will be tested in the near future to increase the extractable ion current.

Conclusions

- The HELIOS IEC device is undergoing **an upgrade campaign** in order to increase the ^{3}He-^{3}He fusion rates to levels allowing for diagnostic studies and benchmarking a numerical code.
- A new HV feed-through has been built to operate **beyond 200 kV**.
- The ion source has been modified to reduce impurities and allow for higher power levels. Alterations to the RF antenna and magnetic field geometries will be tested to obtain **higher extractable ion currents**.