**Design of an Ion Source for Low Pressure IEC Operation in \(^3\)He**

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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.

![IEC Device Operating at ~7 mtorr](image)

- Present gridded IEC devices operate at relatively high pressures, which substantially degrades ion energy. This makes fusion of fuels such as \(^3\)He problematic.

\[
\begin{align*}
\text{\(^3\)He} & \rightarrow \text{Proton} \\
\text{\(^3\)He} & \rightarrow \text{\(^4\)He} \\
\text{\(^3\)He} & \rightarrow \text{\(^3\)He} + \text{Proton}
\end{align*}
\]

The \(^3\)He-\(^3\)He reaction

Reducing neutral pressure will reduce losses, and should make \(^3\)He fusion observable.

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### Helicon Ion Source

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

![Helicon Ion Source](image)

- A Nagoya III antenna and ~1 kG is used to generate high density plasma.

- Inductive Discharge

- Helicon Discharge

- High density of helicon mode enables larger ion currents to be extracted from smaller apertures according to Bohm criterion:

\[
I_B = 0.61 \times n q A \left( \frac{kT}{m_i} \right)^{1/2}
\]

- For plasma density \(~ 10^{12} \text{ cm}^{-3}\), a hole of 1 cm\(^2\) gives a current of \(~ 30 \text{ mA}\) in helium or deuterium.

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### Ion Extraction System

- A differentially pumped ion extraction region separates remaining neutral gas from the ion beam.

- Extraction system capable of beam voltages up to 30 kV.

![Ion Extraction System](image)

- Helicon source and ion extraction system should be capable of delivering up to 50 mA at P < 50 \(\mu\text{torr}\).

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### Results

- Ion extraction currents have been measured as high as 40 mA.
- Beam current delivered to IEC has been measured as high as 10 mA, optics improvements yet to come.
- IEC cathode has been run up to 135 kV at 2 mA \(^4\)He beam current.

- \(^4\)He beam discharging into IEC at 10 mA 25 kV.

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### Summary

- Relatively high current, low pressure ion source needed for \(^3\)He-\(^3\)He fusion.
- Helicon ion source constructed and tested in multiple gases including \(^2\)H, \(^4\)He and \(^3\)He.
- Ion source, extraction system, and IEC have been operated together successfully.
- Future experiments with fusionable gases (\(D_2, \(^3\)He\)) are planned.