2004년도 한국물리학회 봄 학술논문발표회
4. 23 – 4. 24
성균관대학교

Plasma and Beam Characteristics of ECR Ion Source according to Resonant Magnetic Field Position

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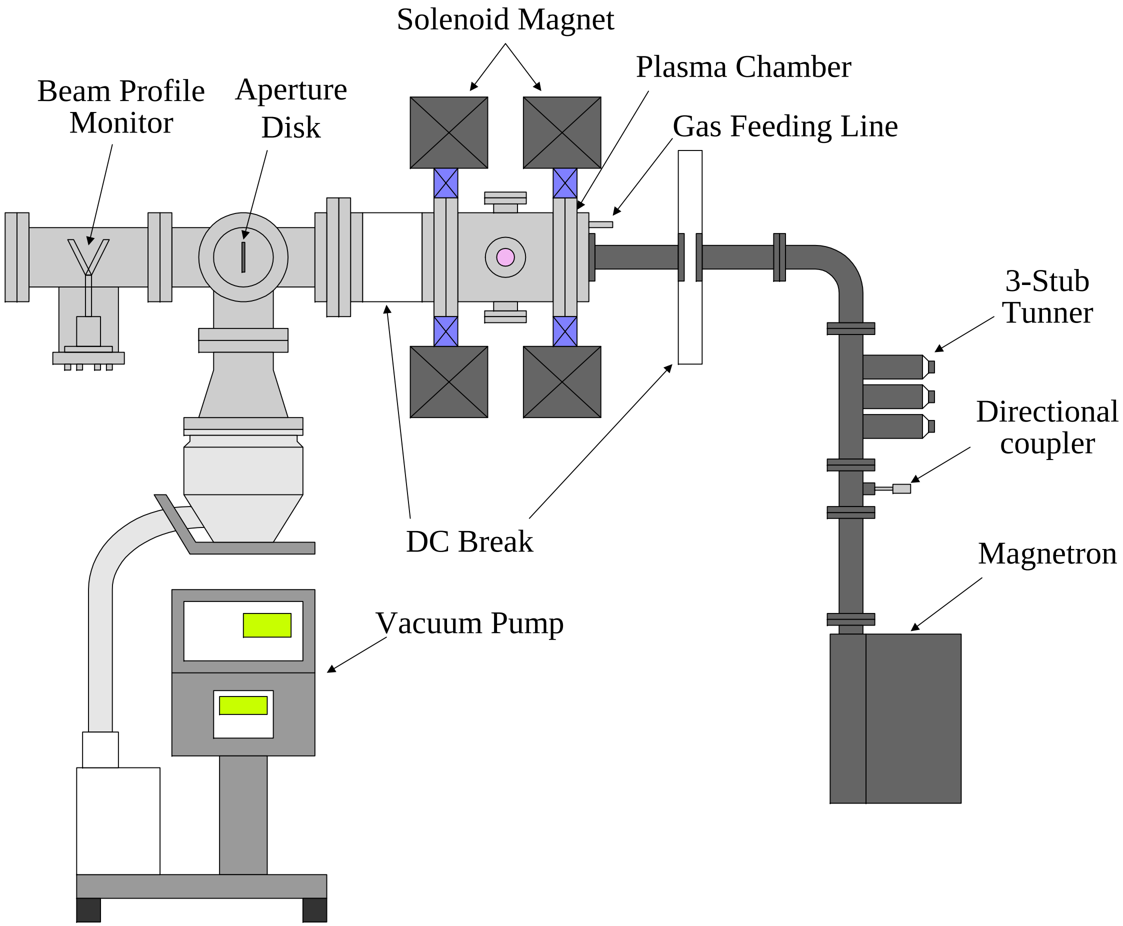
* Work supported by KAERI's KOMAC Project

Abstract

2.45 GHz 마이크로 웨이브 플라스마 챔버에 두 솔레노이드 자석으로 공명 자기장을 인가하여 수소 ECR 플라스마를 발생시키고, 삼극 빔 인출극을 이용하여 발생된 플라스마로부터 양성자 빔을 인출하였다. 두 솔레노이드에 다양한 전류를 흘려 공명 자기장이 형성되는 부분을 진공 윈도우에서 빔 인출부까지 변화시켜 가면서 플라스마의 특성 및 인출되는 빔 전류의 특성을 조사하였다. 공명 자기장의 위치에 따라 변화되는 플라스마의 특성은 원통형 랑뮤어 탐침을 통하여 측정하고, 인출된 빔의 전류는 원형 디스크를 이용하여 측정하였다. 빔의 프로파일과 빔 사이즈는 듀얼 베인 프로브를 구동하여 측정하였다.

Schematic of ECR Ion Source



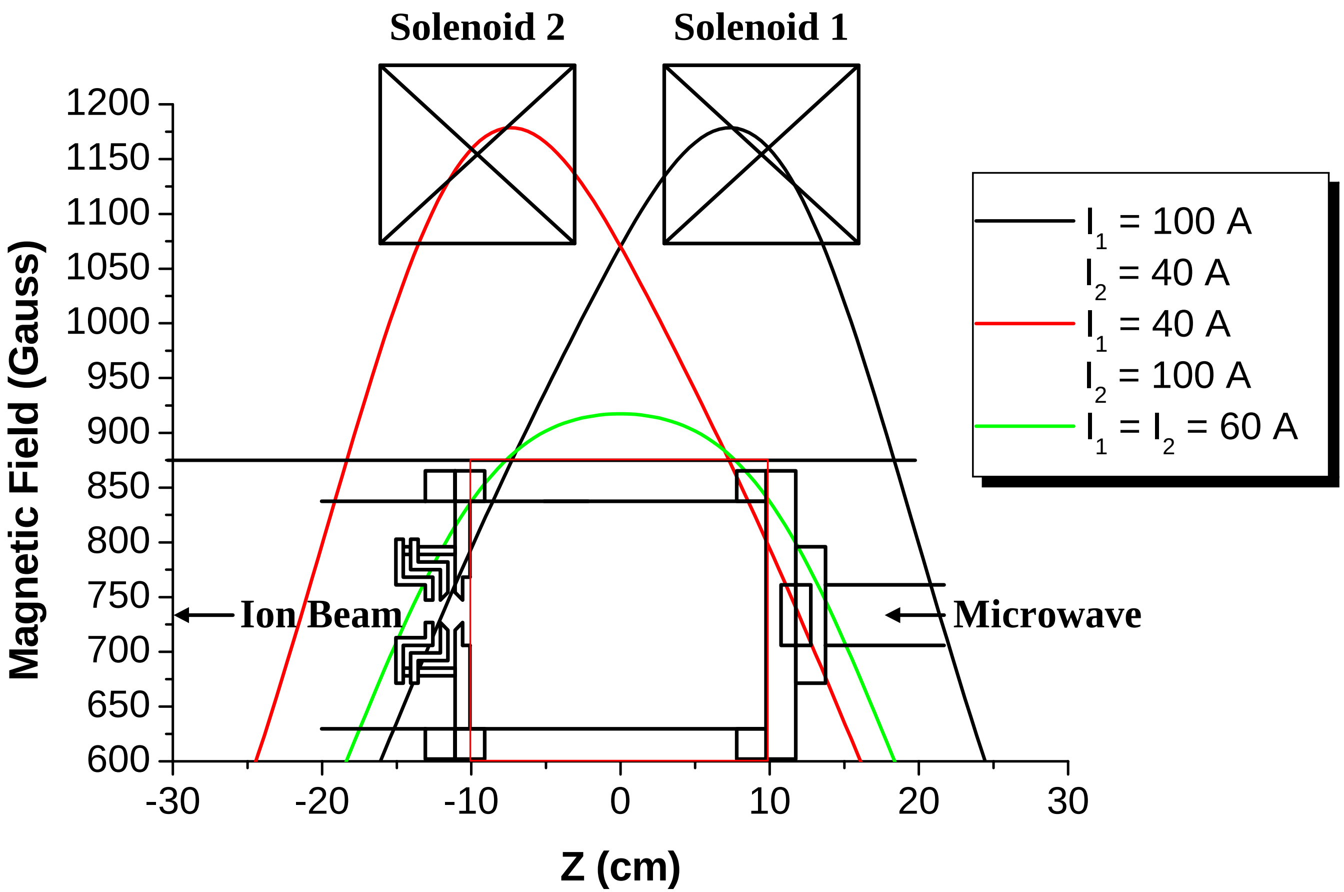
Gas : H_2

Microwave
- **2.45 GHz**
- **100~500 W (Max 900W)**

Aperture disk
- **4.5 mm aperture size**
- **340 mm from electrode**

Beam profile monitor
- **Dual vane (X and Y-axis)**
- **220 mm from slit**

Schematic of ECR Chamber and Two Solenoid Magnet



ECR Chamber

- **20 cm length**
- **15 cm diameter**

Solenoid Magnet

- **15 cm inner radius**
- **27 cm outer radius**
- **13 cm thickness**
- **6 cm apart**

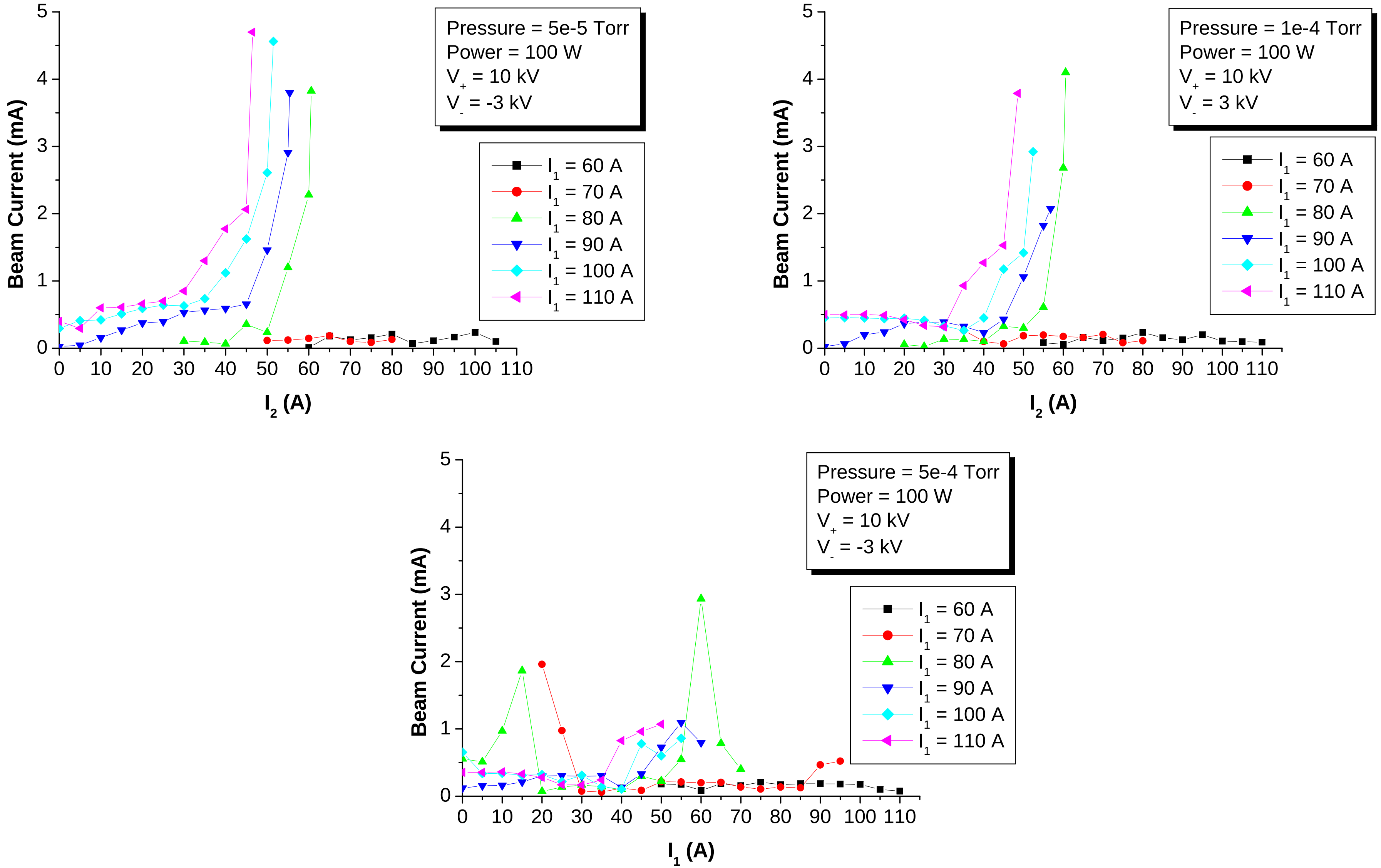
Beam Parameters

- Beam current, profile, and size are measured.
- They are affected by gas pressure, microwave power, magnetic field profile, and extraction voltage.
- Beam current is a function of plasma density:

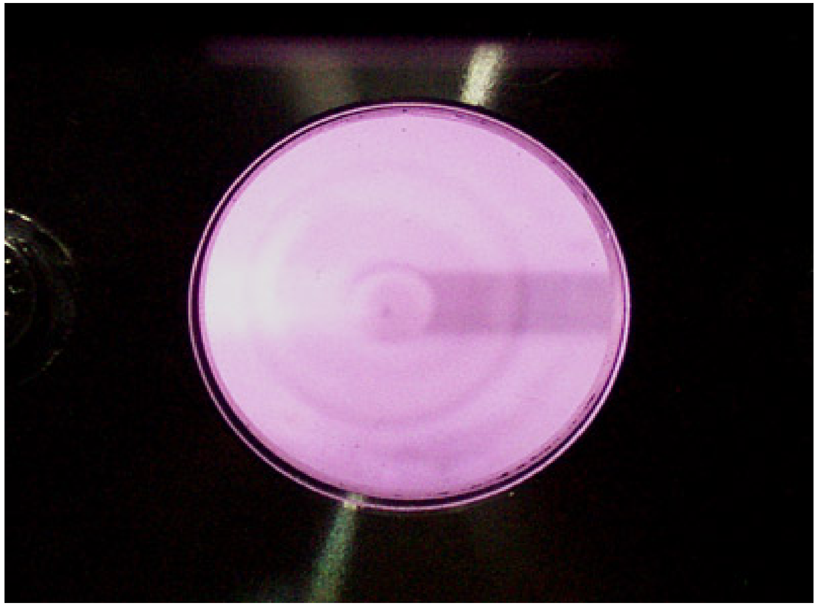
$$j = qn_i v_i = en_e v_i \quad \Rightarrow \quad (n_e \uparrow \;\rightarrow\; j \uparrow)$$

- Beam current is measured by the disk with an aperture at the center. Our ECR system does not have beam focusing magnet. The aperture disk provides small size hydrogen beam to beam profile monitor.
- Profile is measured by beam profile monitor. The beam profile monitor receives hydrogen beam having passed through aperture disk.

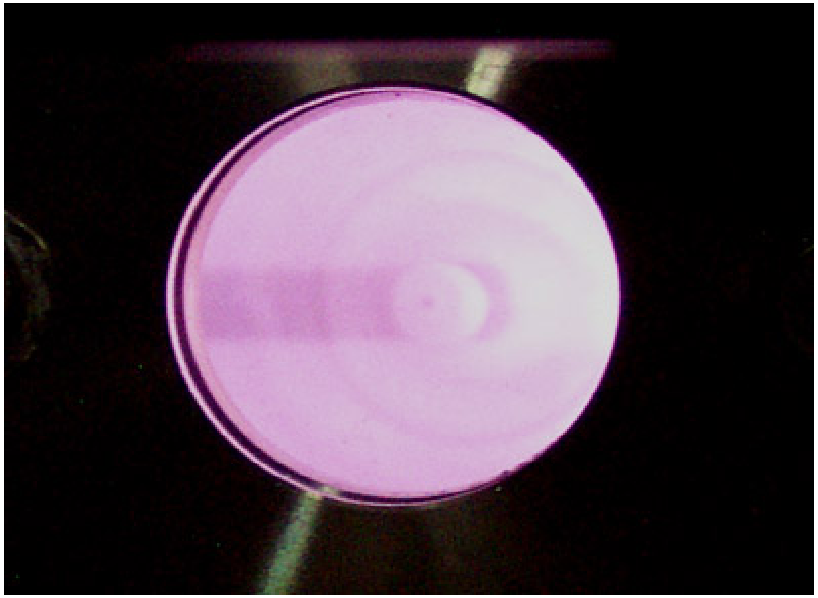
Beam Current vs Magnetic Field



Plasma Density vs Magnetic Field



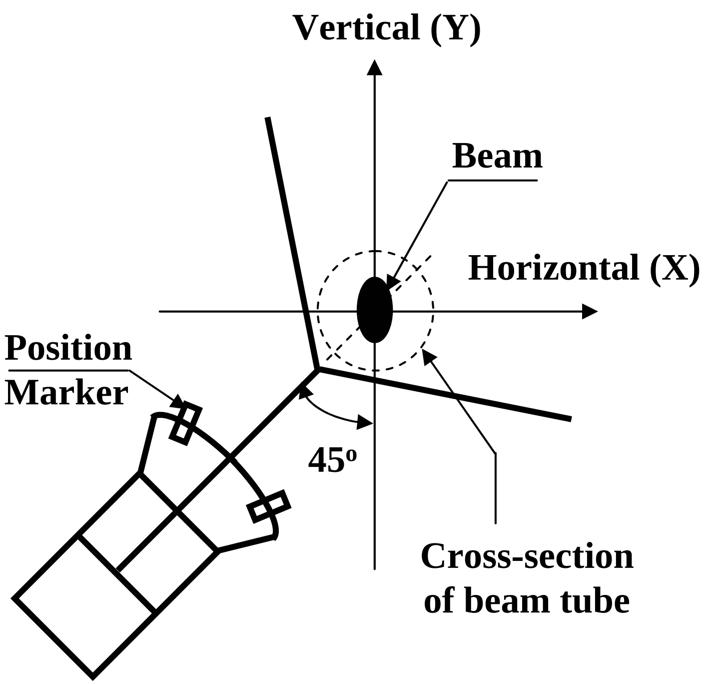
I_1 = 105 A, I_2 = 45 A
(875 G is in left-side)



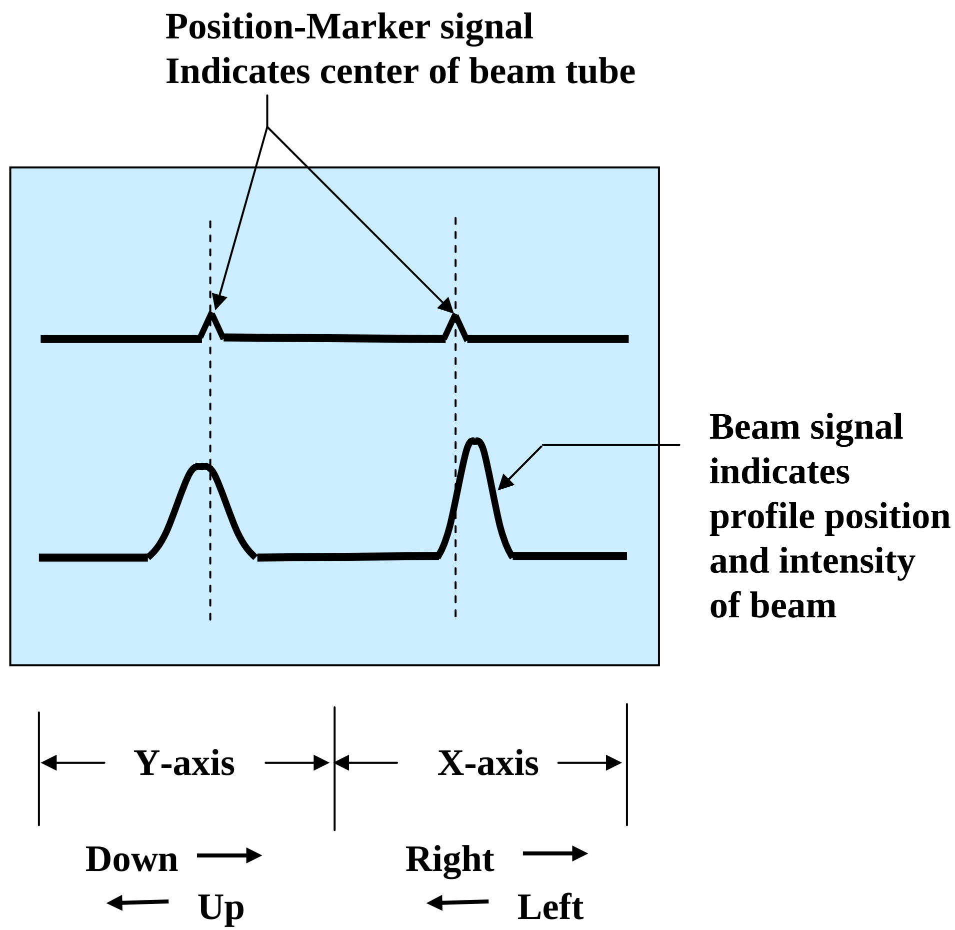
I_1 = 45 A, I_2 = 105 A
(875 G is in right-side)

Two pictures show plasma density relates to the axial position of resonant magnetic field 875 G.

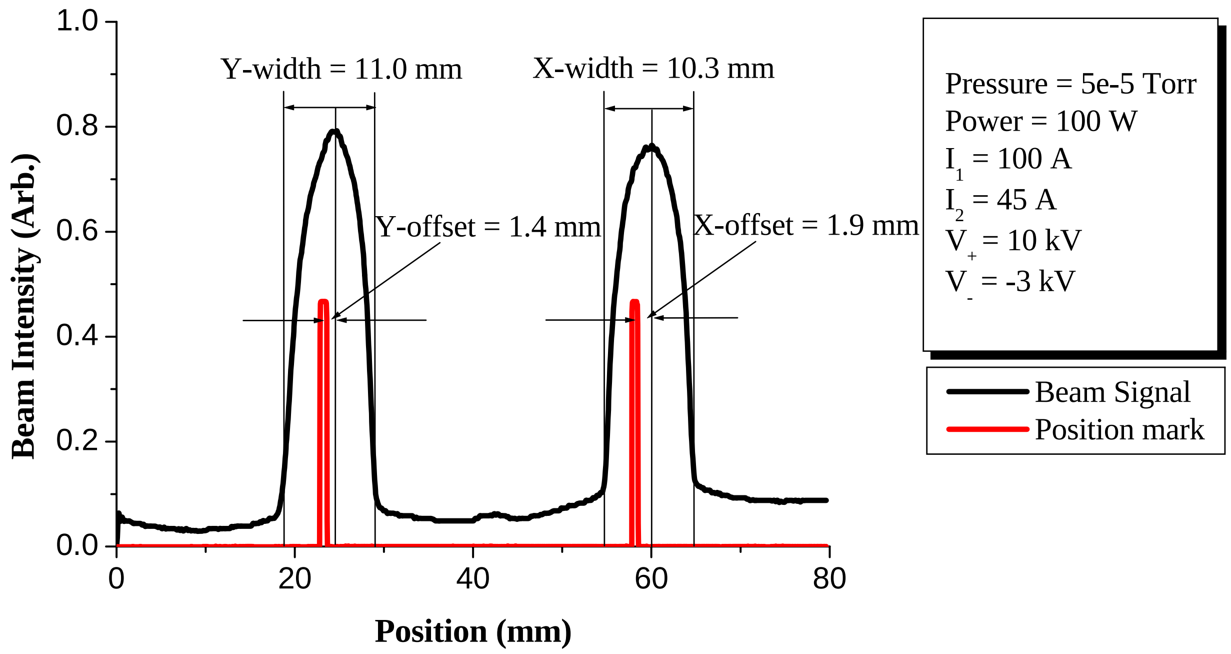
Principle of Beam Profile Measurement

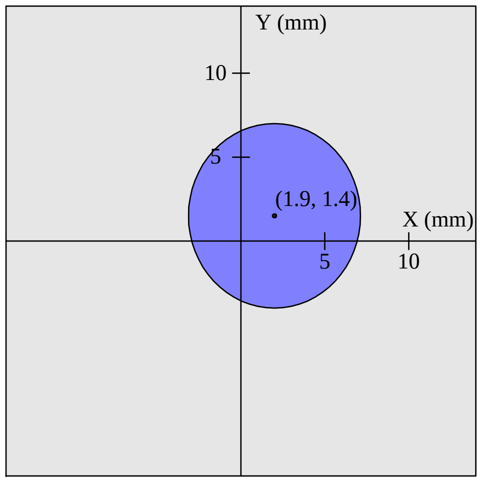


Probe Unit

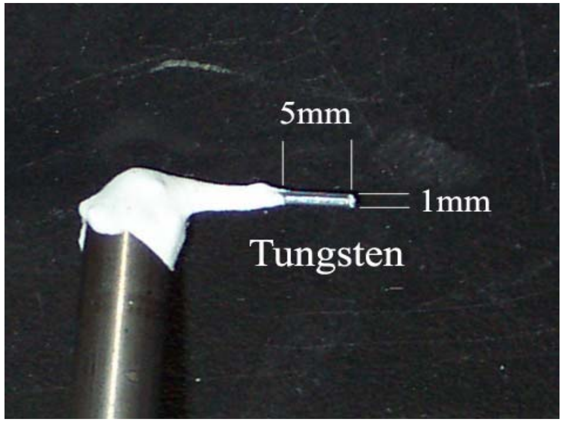


Beam Profile and Position



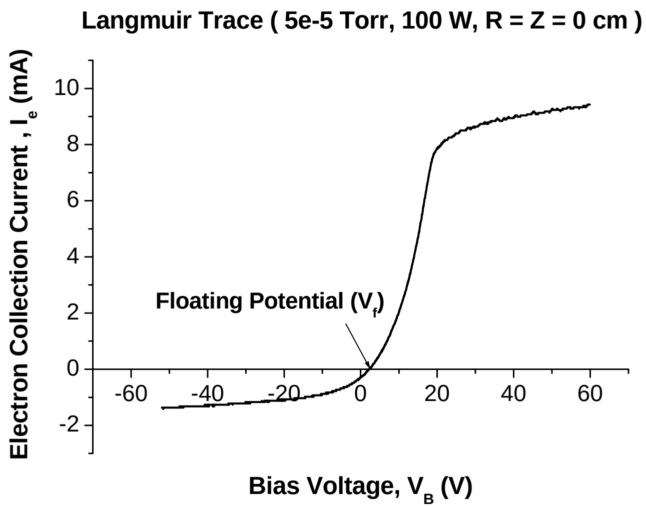


Cylindrical Langmuir Probe[1]



Measured Parameter

- Plasma Potential (V_P)
- Floating Potential (V_f)
- Electron Temperature (T_e)
- Plasma Density (n_e)

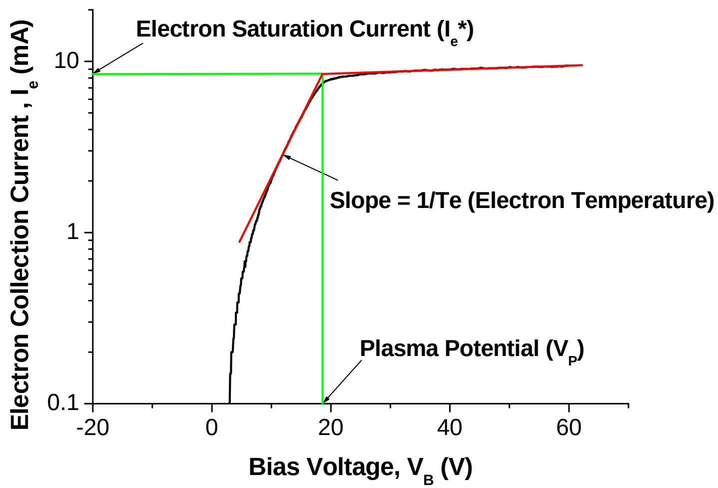


$$I_e = I_e^* \exp[-\frac{e(V_p - V_B)}{T_e}], \ (V_B \le V_P)$$

$$= I_e^* \qquad , \ (V_B \ge V_P)$$

$$where \ I_e^* = eAn_e\sqrt{\frac{T_e}{2\pi m_e}} \ \ (A: probe \ area)$$

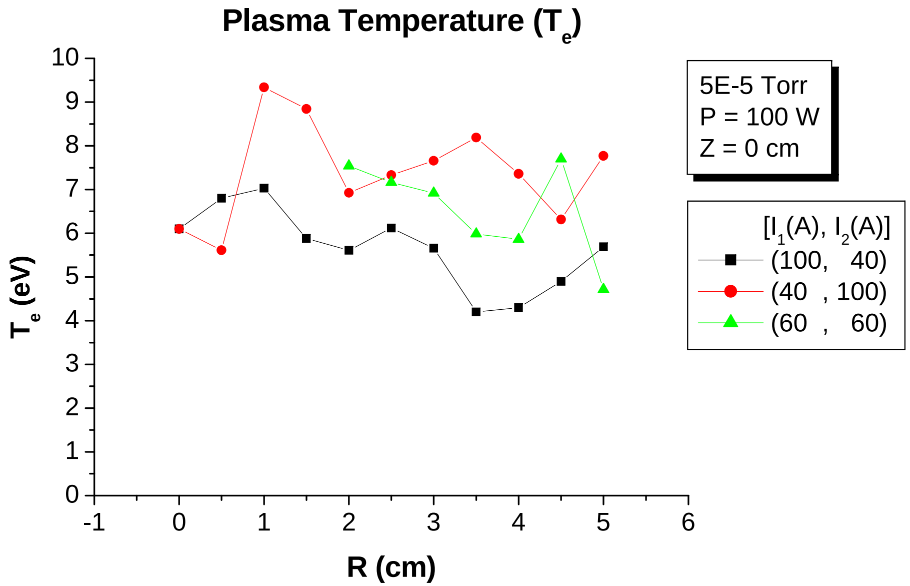
$$n_e(cm^{-3}) = 2.3\times 10^9 \frac{I^*(mA)}{\sqrt{T_e(eV)}}$$

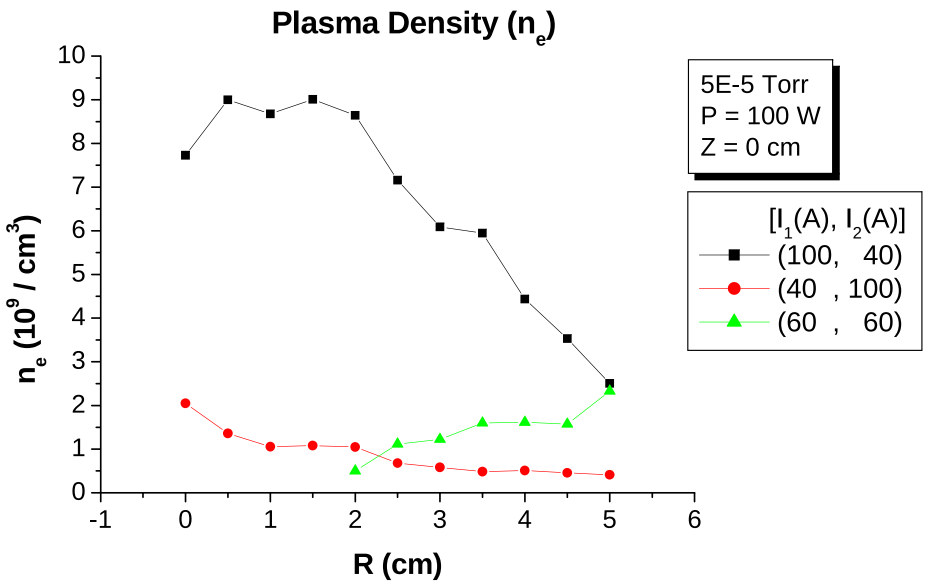


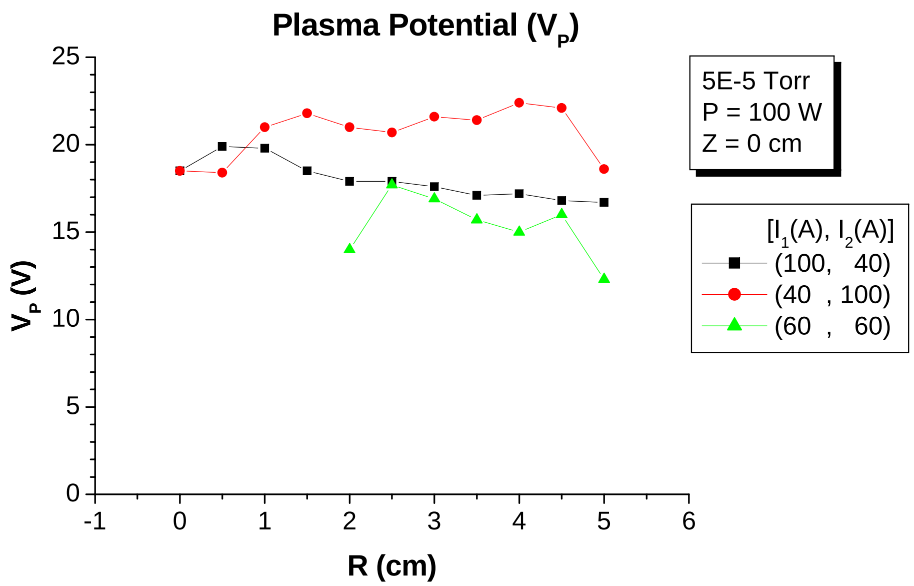
[1] Orlando Auciello, Daniel L. Flamm, *Plasma Diagnostics*, Academic Press, Inc., 1989, Vol. 1, Chapter 3.

Radial Distribution of Plasma Parameters

at Center Plane of Plasma Chamber







- Density at I_1=100A and I_2=40A is higher than density at other magnetic field distribution.
- Density depend on magnetic field distribution sensitively.
- Temperature and potential are similar in different magnetic field.

Axial Distribution of Plasma Parameters

at Axial Axis of Plasma Chamber

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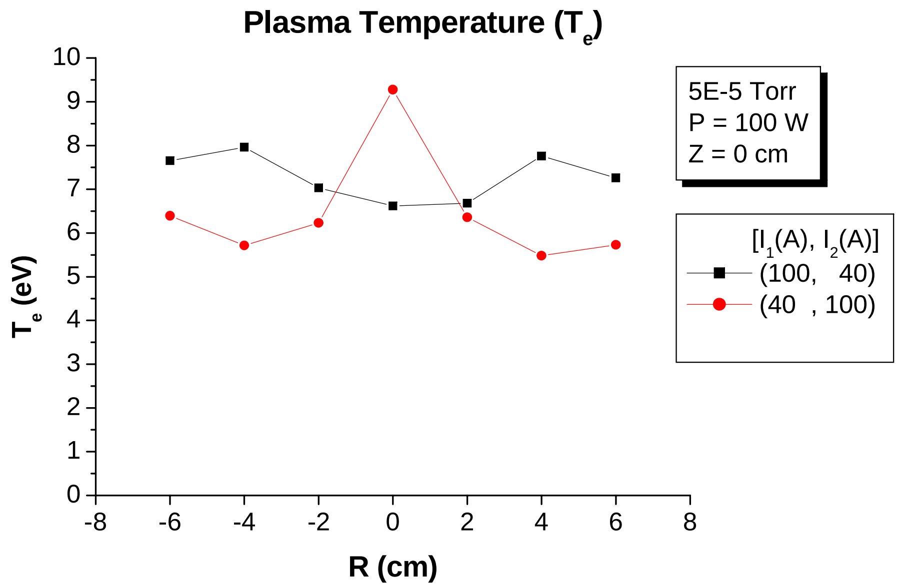

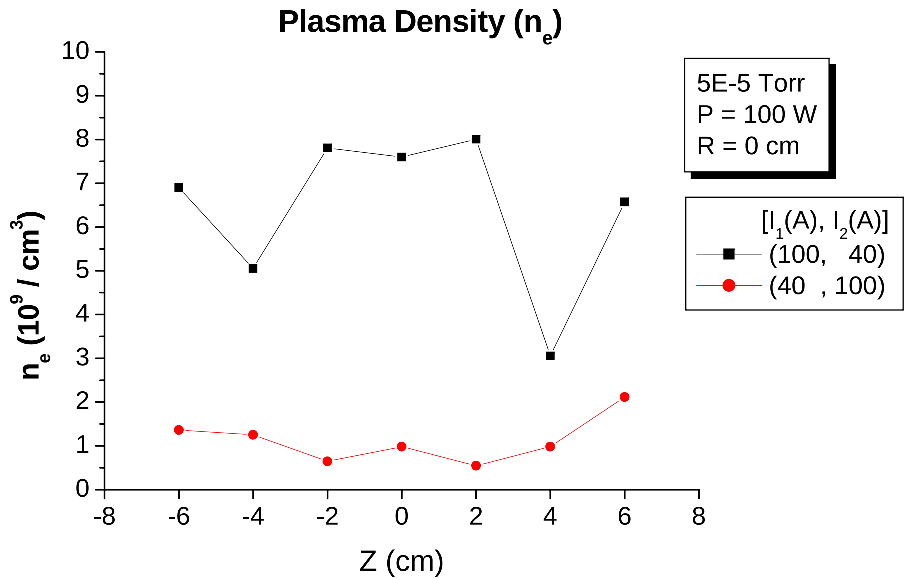

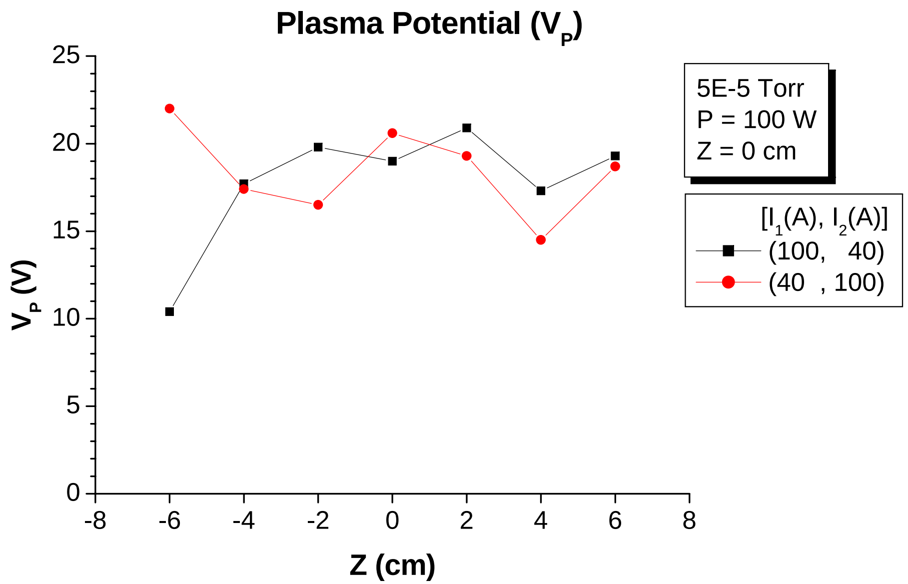

- Plasma parameters have uniform axial distributions.
- Density depend on magnetic field distribution sensitively.
- Temperature and potential are similar in different magnetic field

Conclusion & Further Work

- Beam current is high in asymmetric magnetic fields ($I_1>I_2$).
- Plasma density has different values in different magnetic field. Density high magnetic field agrees with beam current high magnetic field. So beam current is high when plasma density is high.
- Plasma parameters have uniform axial distributions.
- Plasma densities must be measured and compared with the measured beam current in various magnetic field.