HNB source에서 collimator의 인가 전압에 따른 플라즈마 인자에 미치는 영향에 관한 연구

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Abstract

Collimator로 분리된 TCP source는 surface neutralization method를 이용한 hyperthermal neutral beam (HNB) 생성 source로 사용될 수 있다. 여기서 collimator는 energetic ion을 hyperthermal neutral로 바꾸는 역할을 하며 RF window로부터의 거리를 조절하므로써 collimator에 충돌하는 ion의 양을 조절할 수 있다. 또한 collimator에 negative voltage를 인가하여 collimator에 도달하는 ion의 에너지를 변화시킬 수 있다. 이와 같은 ion의 flux와 energy의 변화는 생성되는 HNB의 flux와 energy에 직접적인 영향을 끼칠 것이다. Helium gas를 사용한 이번 실험에서 collimator는 RF window로부터 8 cm 되는 곳에 위치 시켰을 때 ion의 current density는 대략 5mA/cm^2 로 최대값을 갖고 이 때 예상되는 HNB flux는 약 ~10^{15} #/cm^2 이다. 또한 collimator는 -70 V 까지 전압을 인가 시킬 수 있어 ion energy는 최대 60 eV 까지 가질 수 있었다. 이 ion은 대략 15 eV 의 HNB를 만들게 된다.

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Introduction

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To make a diagnosis of edge region of the high temperature plasma, HNB (Hyperthermal Neutral Beam) reactor was constructed. This reactor consists of RF window, ground side wall and collimator to accelerate ions. Source type is ICP(Inductively coupled plasma) and aspect ratio (H/D) in the shape of cylinder is 0.32 where H and D are height and diameter of chamber, respectively.

Diagnostic HNB must be able to control energy, have high energy resolution and high flux. It was studied the effect of the large area collimator on plasma potential and ion density in this research. Finally, HNB will be controlled by these plasma parameter.

1. Plasma potential

Plasma potential is the important parameter to determine ion energy of the collision between ion and collimator.

$$\tilde{V}_p(t) = V_{DC} + \tilde{V}_{rf} \sin \omega t$$

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where V_{DC} is DC plasma potential, V_{rf} peak to peak RF fluctuation voltage, and ω applied RF frequency.

Therefore, ion energy that ion collided with biasing collimator is directly proportional to plasma potential and is controlled by V_{bias}.

$$E_{ion} = e\left(\tilde{V}_p - V_{Bias}\right)$$

It is possible to predict HNB energy from this ion energy. And HNB energy resolution is proportional to plasma potential fluctuation.

$$HNB\ energy = energy\ efficiency \times ion\ energy \times \#\ of\ collision$$

2. Ion density or ion saturation current

HNB flux is determined by ion current density.

$$\#\ of\ neutral\ particles = reflection\ coefficient \times \#\ of\ ions$$

Position and applied voltage of collimator should be optimize to derive the maximum HNB flux.

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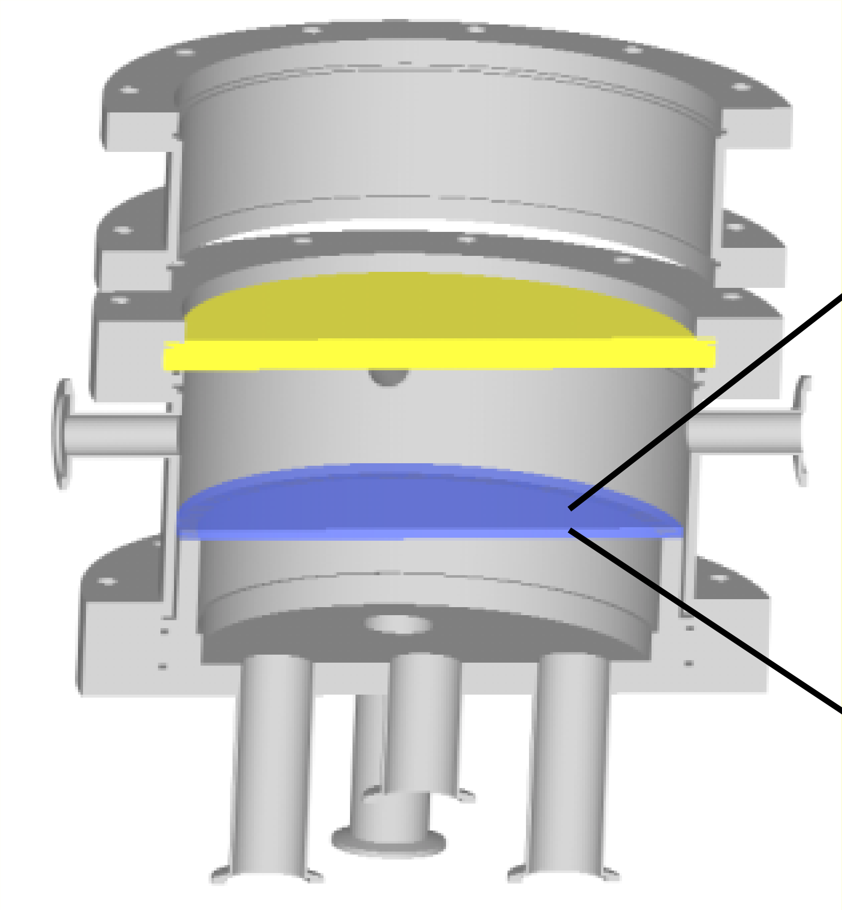
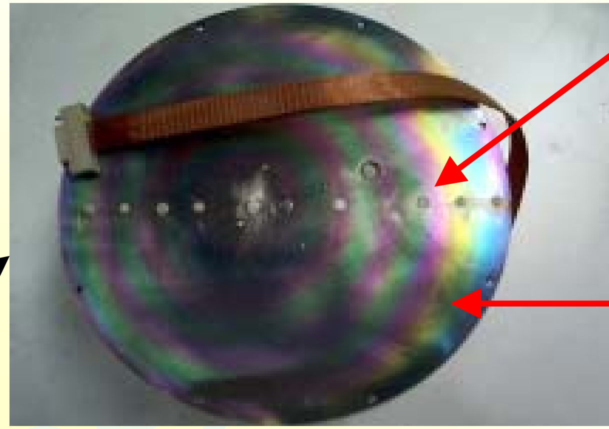
Experimental Setup

ICP source main chamber





Array Langmuir Probe ;
Type : Plane
Size : Dia. 1 mm
Material : W wire
# of probes : 10

Reflector ;
Material : Stainless steel

Array Langmuir probe & end plate

Collimator;
500 holes in Dia. 3 mm
Material : Stainless steel

Reflector ;
Material : Stainless steel

Collimator & reflector for production of HNB

Operating Condition

Gas : Helium
Power : 500 W
Pressure : 10 mTorr

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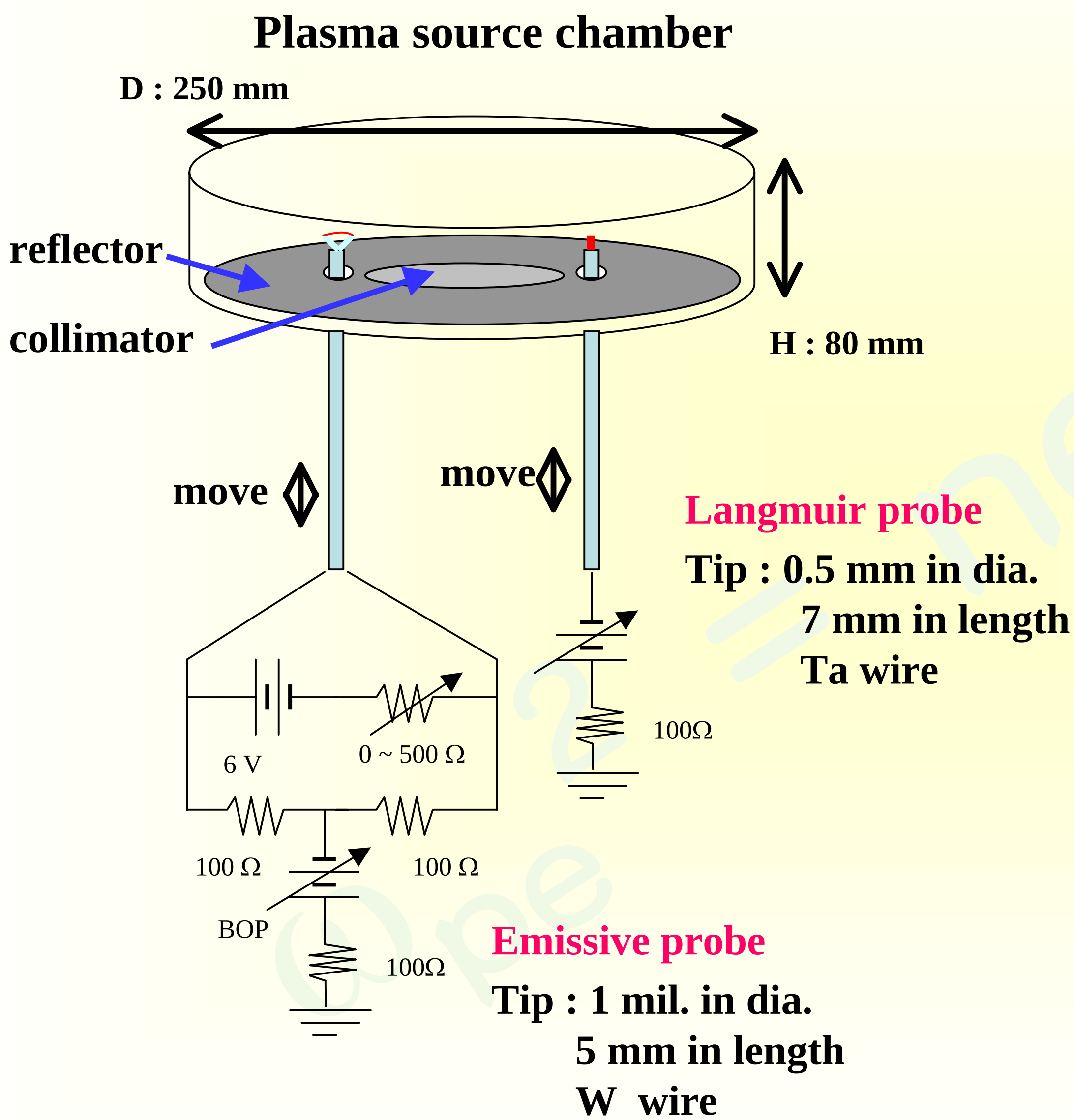
Experiments



1. Langmuir probe

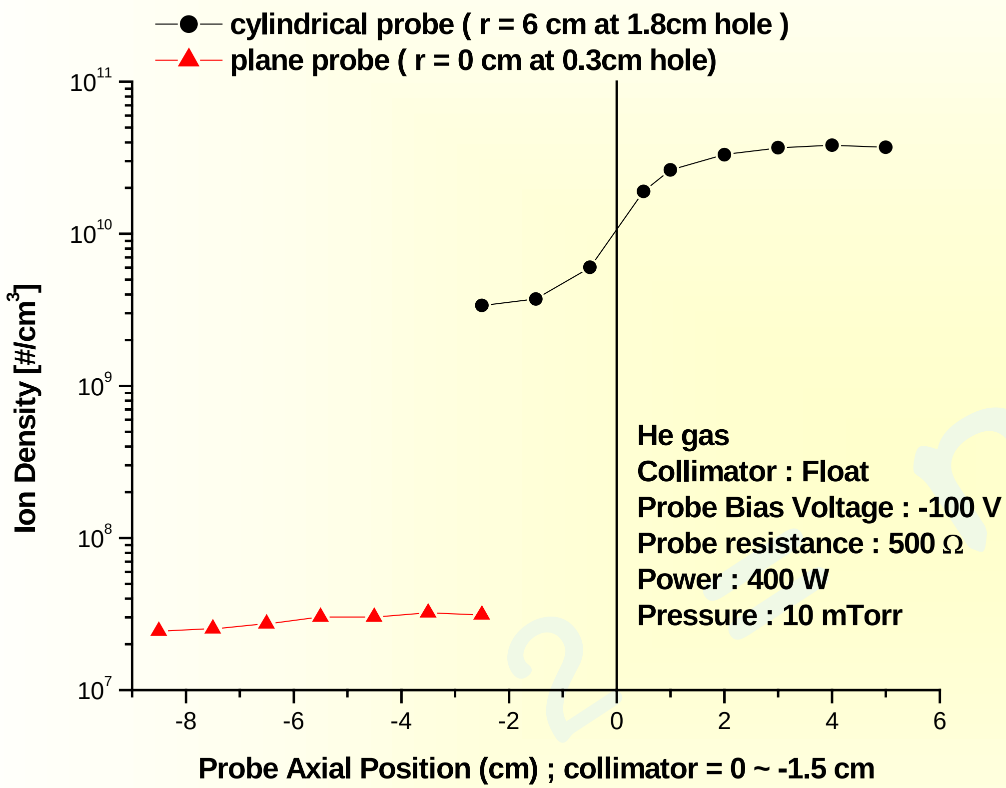
The probe get the I-V characteristic basically. This I-V characteristic has several features that make it easy to estimate plasma parameters. These are the knee, the slop below the knee, the electron saturation current, and the floating potential.

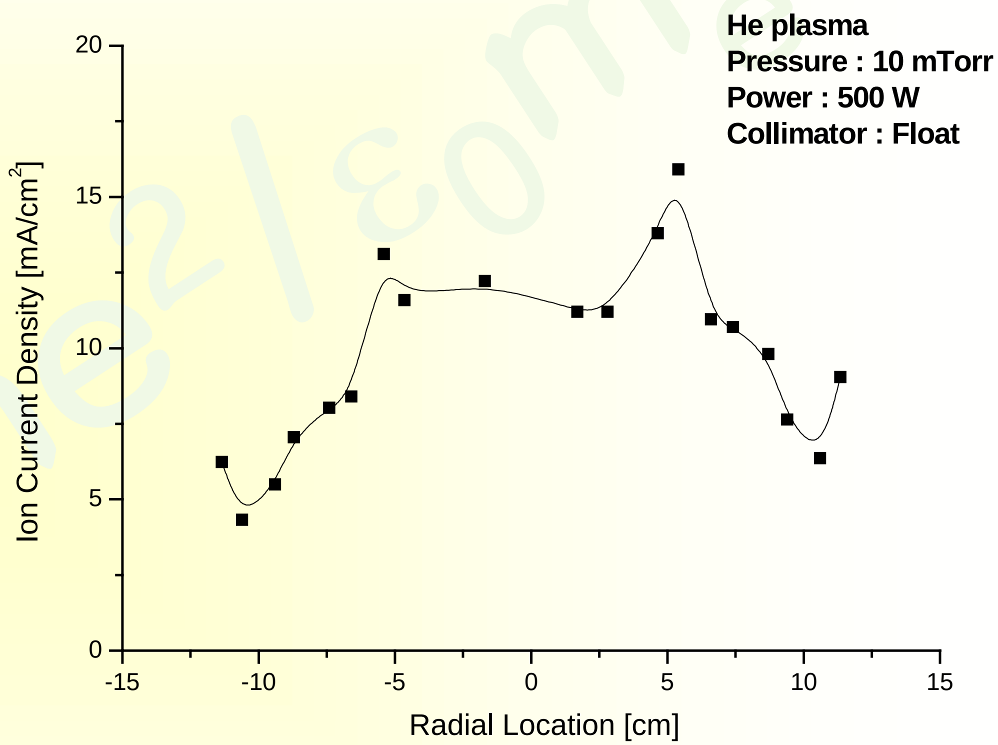
2. Emissive probe

The inflection point method in the limit of zero emission was used to determine the plasma potential in the bulk plasma. Space charge effects associated with the emitted electrons go to zero in the limit of zero electron emission. The inflection point is readily determined by taking the derivative dI/dV_B. And note the shift in the inflection point associated with increases in emission and that the shifts become greater as the probe radius is increased.

Basic plasma parameters Ⅰ

Radial and axial profile of Ion density





Ion density above the collimator is few thousand times higher than that below the collimator.

Density of bulk plasma is axially uniform. This value is about 3×10^{10} #/cm^3.

When operating pressure becomes higher, the position of the maximum density off set from the center of chamber

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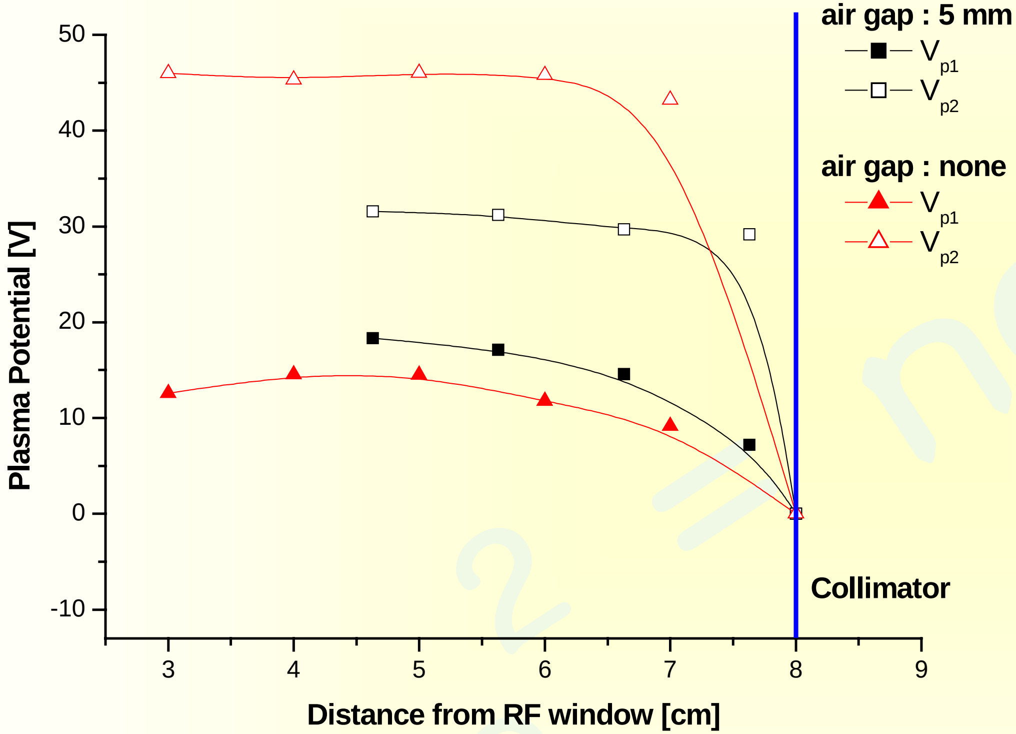
Basic plasma parameters Ⅱ



In grounded collimator, plasma potential is measured using the emissive probe.

In plasma potential versus probe location away from RF window, air gap between RF window and antenna decreases plasma potential fluctuation.

Both plasma potential and plasma potential fluctuation are axially very uniform.

V_{p1} : lowest plasma potential

V_{p2} : highest plasma potential

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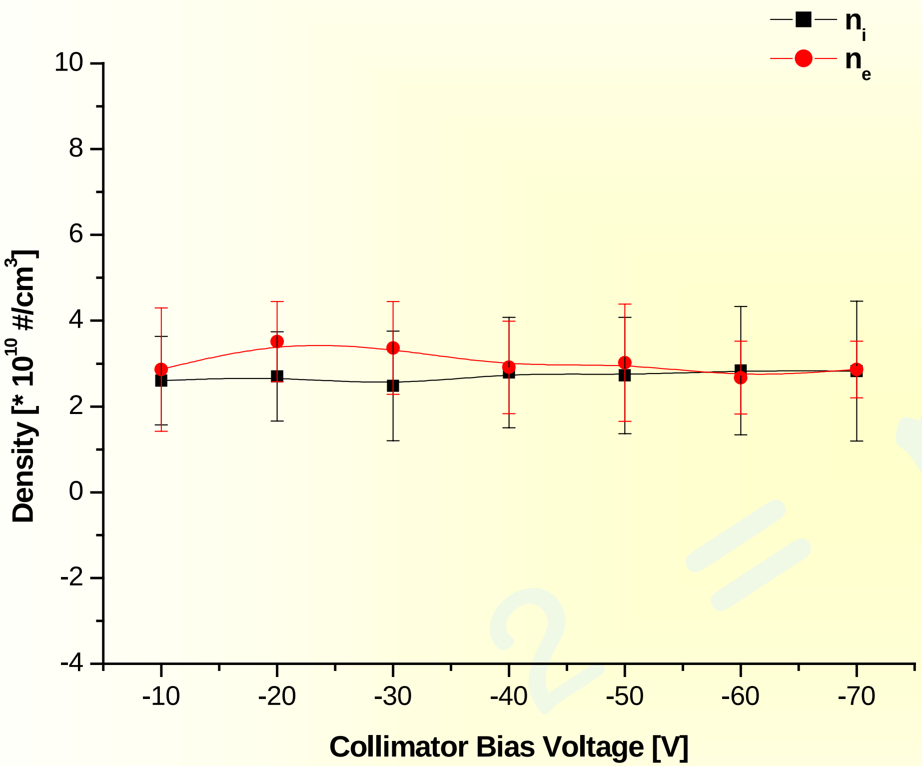
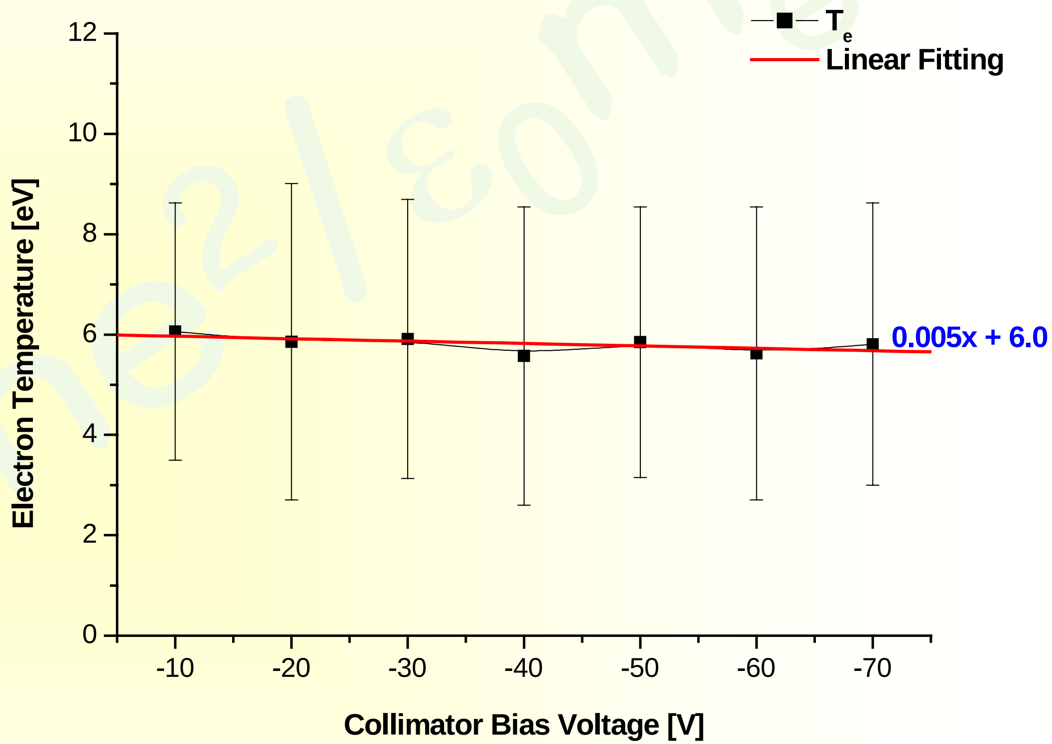
Effect of bias voltage of collimator on plasma parameters Ⅰ





Plasma density and electron temperature are independent on collimator bias voltage.

@ 500 W, 10 mTorr, Helium gas

density : 3×10^{10} #/cm^3

temperature : 6 eV

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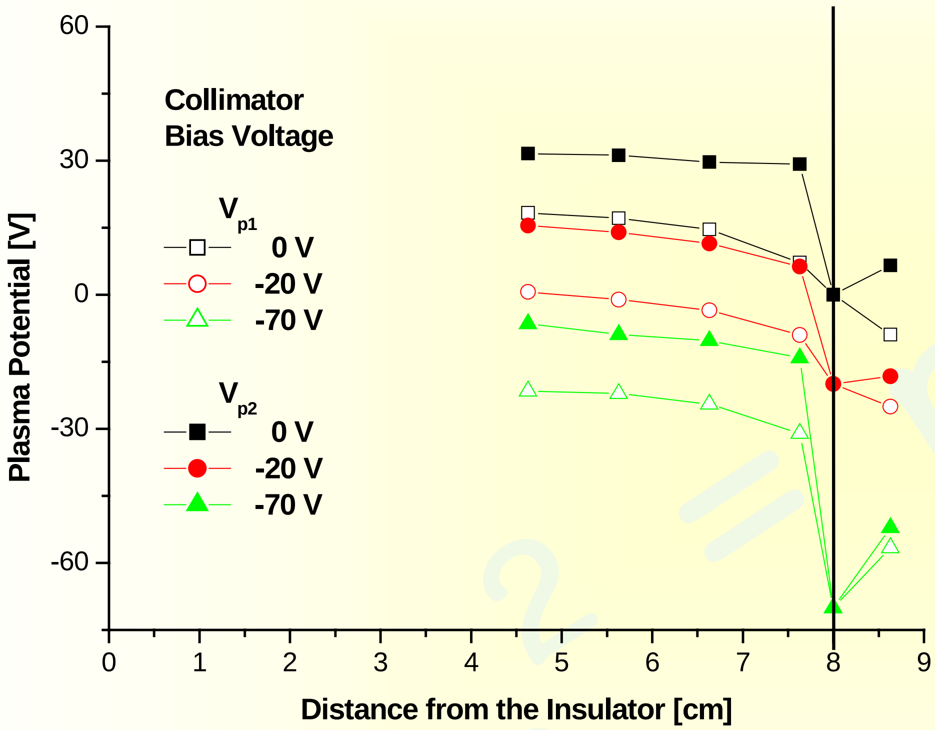
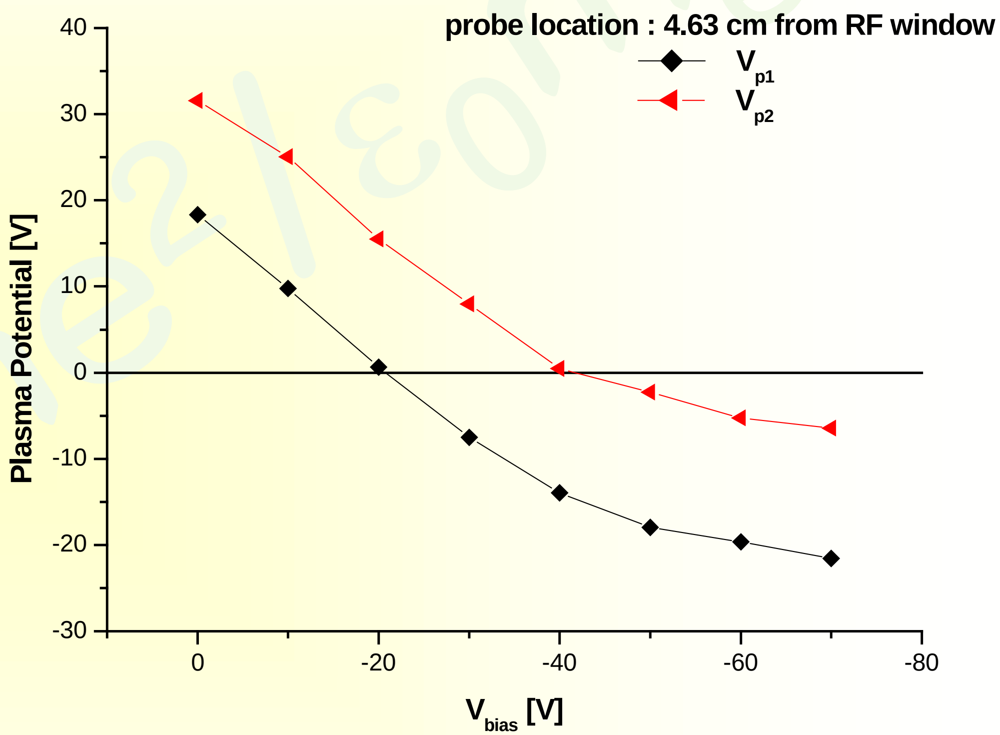
Effect of bias voltage of collimator on plasma parameters Ⅱ





Plasma potential fluctuation (V_{rf}) is little changed with collimator bias voltage.

V_{DC} is directly proportional to V_{bias} in the range of 0 to -40 V.

Below -40V V_{bias}, both V_{p1} and V_{p2} are negative value and V_{DC} is saturated.

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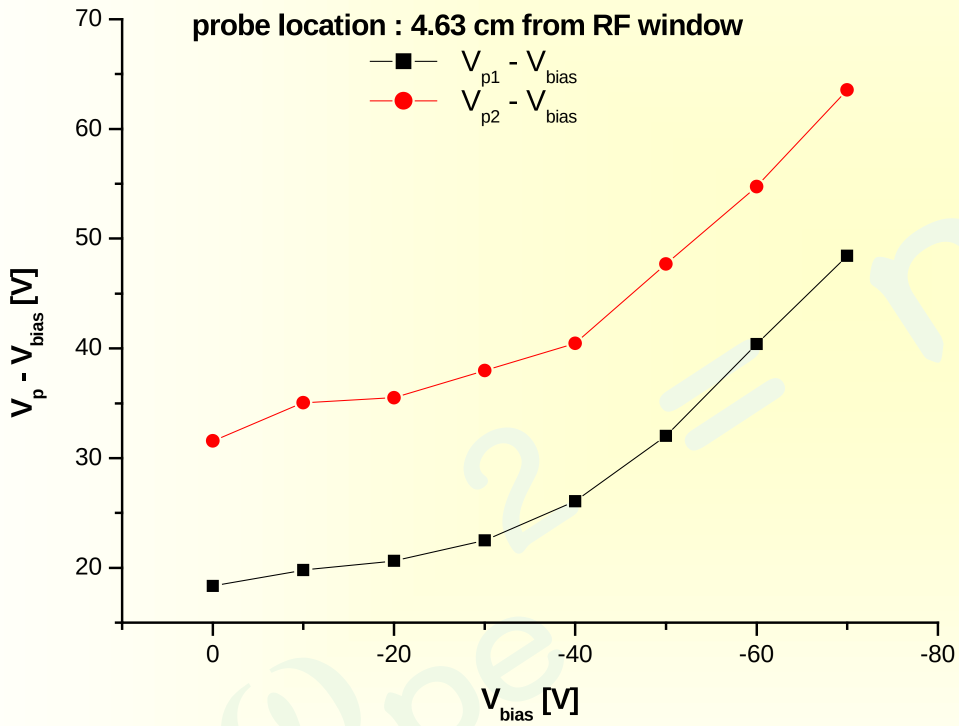
Effect of bias voltage of collimator on plasma parameters Ⅲ



Ion energy

$$E_{ion} = e\left(\tilde{V}_p - V_{Bias}\right)$$

$E_{ion,max}$ = about 60 eV at V_{bias} -70 V

*** HNB Calculation**

At V_{bias} -70 V

Neutral beam energy : 15 eV

(band width ~3 eV @ fluctuation voltage 15 eV)

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Discussion

In the case of floated collimator (with pressure 10 mTorr, power 500 W, and gas Helium), density of bulk plasma was axially uniform. This value was about 3×10^{10} #/cm^3. Radial density profile was similar to antenna shape.

In this plasma when negative bias voltage (from -10 V to -70 V) is applied on the collimator, plasma density and electron temperature are independent on it. However plasma potential is decreased in 30 V to -5 V.

How can make the plasma with negative plasma potential !
If the negative bias voltage of collimator is larger, the loss of ion through the collimator also is larger. In order to satisfy charge neutrality plasma potential is low and then electron is loss. Plasma potential is negative in Our device with a large loss area of ion.

In spite of increase of ion loss and electron loss, plasma density is not decreased. It is the reason that secondary electron made in the collision of ion on the collimator ionize the background neutral particles. But if loss rate is more than ionization rate, plasma is unstable and finally turn off. Then limited voltage is -70 V.

When bias voltage of the collimator is -70 V, ion energy and energy band width is 52 V and 12 V, respectively. The energy and energy band width of HNB produced by these ions is estimated 13 eV and 3 eV, respectively.