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ION FLOW OBSERVED IN AXIS-SYMETRIC TOROIDAL PLASMA

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Abstract

By using a floating directronal probe, an ion flow has been studied in a small toroidal plasma with a major radius of 12 cm and a minor radius of 4 cm. The preliminary result shows a presence of an ion counterflow to the plasma current.

1 Introduction

A plasma flow which is linked to the plasma potential through the force balance equation has been observed in some magnetic confinement systems, for example, θ - pinch [1], RFP [2], TOKAMAK [3], [4] etc. On the other hand, it is also shown that when the plasma confinement is improved by some operational mode a negative plasma potential develops. These facts suggest that the plasma flow or potential in magnetic confinement system is closely related to the confinemente capability.

The CECI aparaturs has been developed with aiming to produce RFP plasma which tends to fall in the state of minimum energy through the relaxation process. This experiment has been done on the object for studying the plasma flow in the energy relaxation process. In this paper, the preliminary result of the plasma flow obtained by using a floating directional probe is described.

2 Directional Probe and Experimental Setup

To measure the ion flow we use a directional probe as shown in Fig.1. This directional probe has two electrodes been separated by a ceramic isolator, and a third electrode of tube with non-directionality. The ion flow was measured by two different modes shown in Fig.1.

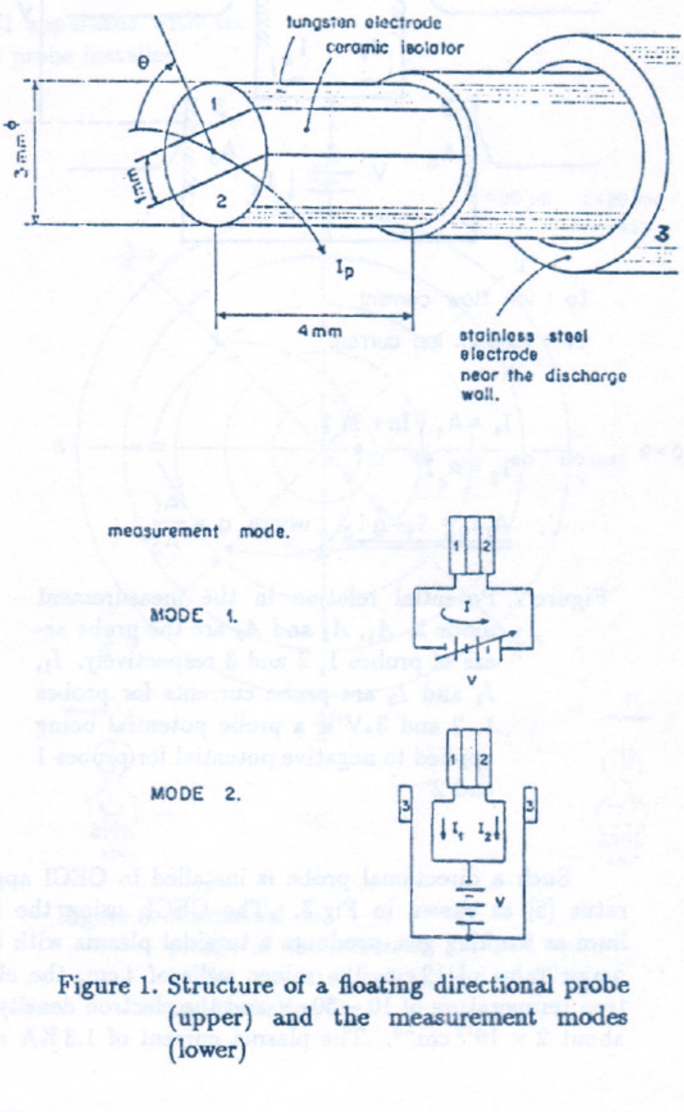
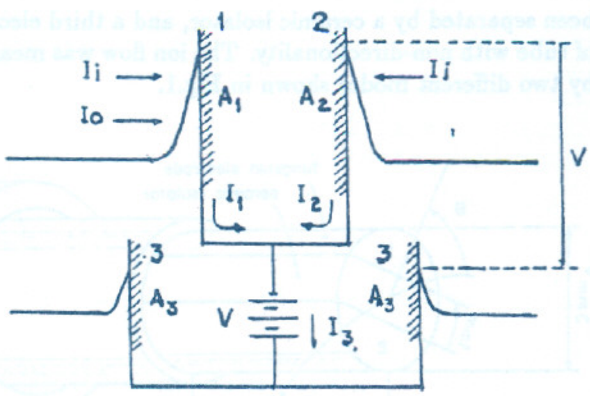


Figure 1. Structure of a floating directional probe (upper) and the measurement modes (lower)

Mode 1 is the same as a floating double probe measurement, which measures the ion saturation current in the higher voltage region. Mode 2 is a type of single Langmuir probe. As ion flow by mode 2 is measured by applying a sufficiently high negative bias to the separated electrodes against the third electrode. Fig.2, shows the potential relations in measurement mode 2. From Fig.2, it is shown that two ion saturation currents of I_1, and I_2 limit the total probe current of I_3, and the difference of I_1 and I_2 is caused by the difference of probe area and the presence of ion flow. Since the difference of probe area can be obtained experimentally from the measurement of mode 1, a current by the ion flow I_0 is given by a equation of $A_1 I_0 = I_1 - g I_2$ where A_1 is an area of probe 1 and g is ratio of A_1 and A_2. Mode 2 is also used to the measurement of the plasma potential corresponding to the battery voltage at $I_3 = 0$ on $V - I_3$ characteristic curve.



Io : ion flow current

Ii : random ion current

$$I_1 = A_1 (I_0 + I_i)$$

$$I_2 = A_2 I_i$$

$$\therefore \quad A_1 I_0 = I_1 - g I_2 \quad \text{where } g = \frac{A_1}{A_2}$$

Figure 2. Potential relation in the measurement mode 2. A_1, A_2 and A_3 are the probe areas of probes 1, 2 and 3 respectively. I_1, I_2 and I_3 are probe currents for probes 1, 2 and 3.V is a probe potential being applied to negative potential for probes 1 and 2

Such a directional probe is installed in CECI apparatus [6] as shown in Fig.3. The CECI, using the helium as working gas, produces a toroidal plasma with the major raius of 12 cm, the minor radis of 4 cm, the electron temperature of $10 - 50$ eV and the electron density of about 2×10^{12} cm^{-3}. The plasma current of 1.3 KA and the toroidal magnetic field of 60 G give the safety factor of about 0.3 on the plasma surface which means that the plasma is unstable for MHD. Moreover, if it is assumed that the ion temperature is the same as the electron one, the ion Larmor radius becomes $50 - 120$ mm while the electron one is $1 - 3$ mm. This means that the ion particles are not confined magnetically, but electrostatically. From these things, it seems that the CECI plasma is in a state of turbulence. In such a plasma, the plasma flow at 20 mm from a center of discharge tube was measured.

3 Experimental Results and Discussion

In the measurement of mode 1, a hump of probe current at the rising phase of plasma current was observed. Fig.4 shows that this current hump is not observed is another side ($\theta = \pi$) of probe. Here the basic probe position for an azimuthal angle is defined for the negative electrode of probe to face the upstream side of plasma current. Fig.5 shows the azimythal dependancy of the humped current at 20 μs after discharge. From Fig.5 it is seen that the current rising phase there is an ion counterflow to the plasma current.

On the other hand, the measurement mode 2 had been also used to check the ion flow. Fig.6 shows the azimuthal distribution of the directional ion current at 32 μs after discharge. As is seen in Fig.6, the ion current at $\theta = 0$ is negative, which means a presence of the counterflow of ion particles to the plasma current. This result is consistent with the result of mode 1.

The current density of ion counterflow is about 0.7-A/cm^2 at 20 μs and 0.3 A/cm^2 at 32 μs. While the plasma current densities at 20 μs and 32 μs are roughly 4 A/cm^2 and 20 A/cm^2, respectively. And the equivalent energy for above ion current corresponds to $0.8 - 4$ eV, if the ion density is 2×10^{12} cm^3 which is estimated from the filling pressure of 6.3×10^{-5} Torr. It is noticed, here, that an ion current component in the plasma current can be neglected because of a vey large mass ratio that $m_i/m_e = 7300$ where m_i and m_e are masses fo a helium ion and an electron. Consequently, to produce the above directional ion current, there must be some accelerative mechanism for the ions. This mechanism is not yet cleared.

4 Conclusion

An ion flow in a small toroidal plasma been produced by CECI apparaturs with a major radius of 12 cm and a minor radius of 4 cm has been studied by using a floating directional probe. The preliminary result shows a pres-

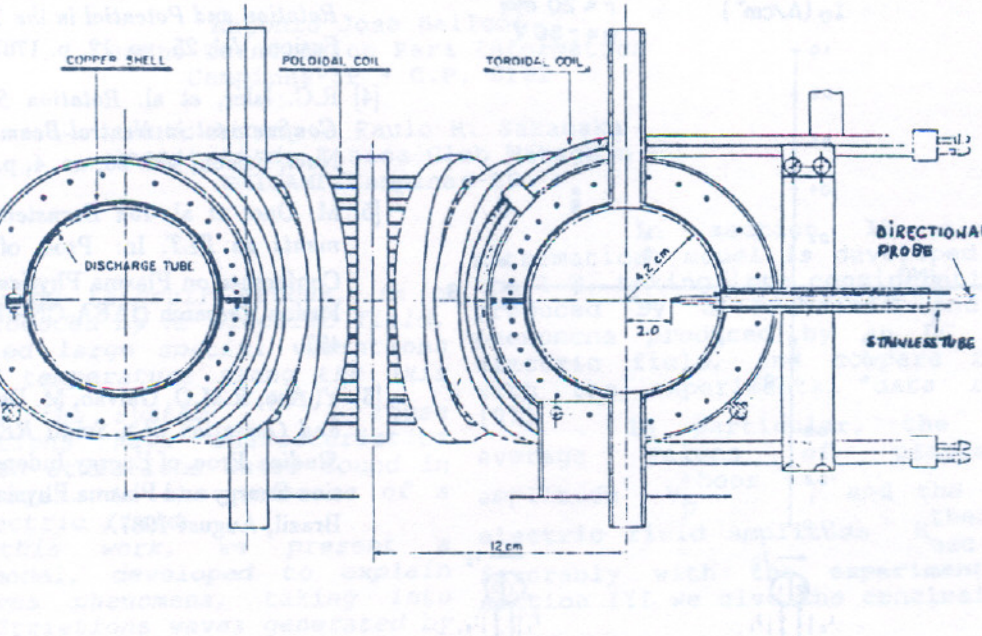


Figure 3. Schematic of CECI apparatus with the floating directional probe installed

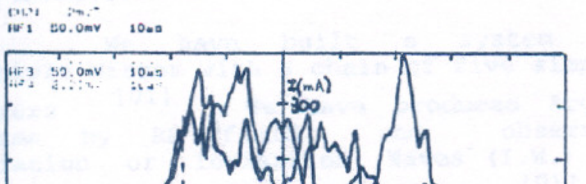


Figure 4. Ion saturation current in the measurement mode 1 (upper) and the plasma current (lower). $V = -40$ V, $r = 20$ mm. The probe direction is defined as $\theta = 0$ for the negative potential side to face an upstream side of the plasma current

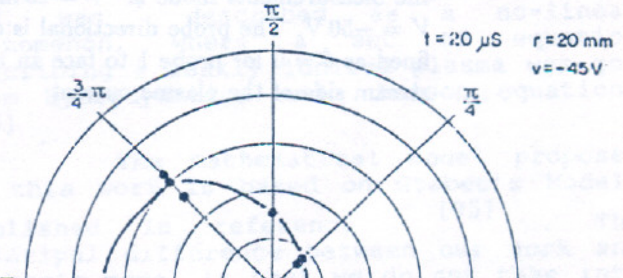


Figure 5. Azimuthal profile of the observed humped current in the measurement mode 1 at 20 μs after discharge

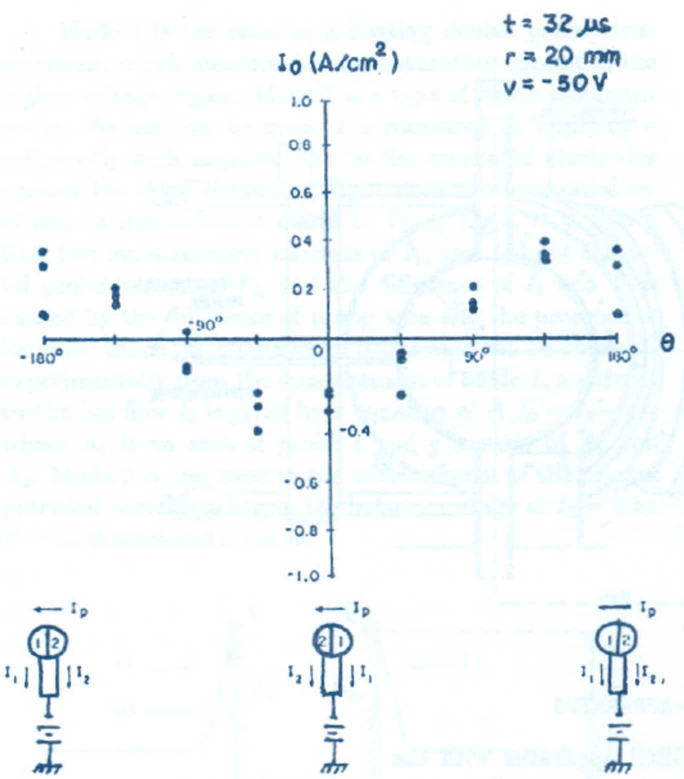


Figure 6. Azimuthal distribution of the ion saturation current at $32\,\mu s$ after discharge in the measurements mode 2. $r = 20\,\text{mm}$. $V = -50\,\text{V}$. The probe directional is defined as $\theta = 0$ for probe 1 to face an upstream side of the plasma current

ence of ion counterflow to the plasma current under the folllowing conditions; $T_e \sim 10-50\,\text{eV}$, $n_e \sim 2\times10^{12}\,\text{cm}^{-3}$, $I_p \sim 1.3\,\text{kA}$. $B_t \sim 60\,\text{G}$ and $q \sim 0.3$ on plasma surface. The equivalent energy of the counterflow ions is about $0.8-4\,\text{eV}$ which corresponds to reoughly 10% of the total plasma energy.

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