Rapid Communications

Ion Transport Pulsation in the Potential Well of a Magnetized Plasma

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(Received 31 October 2003 / Accepted 17 November 2003)

Abstract

Pulsating behavior of the ion transport has been discovered in the potential well of a magnetized plasma. Observation of the ion density distribution on a plane perpendicular to the magnetic field reveals that the ion transport pulsation is caused by alternation of ion accumulation and release via a spiral density structure.

Keywords:

ion transport pulsation, magnetized plasma, spiral ion release, two-dimensional observation

The local structure of the radial electric field in magnetized plasmas provides a key physics of enhanced plasma confinement, such as H mode. Recently, the dynamical behavior of plasma transport associated with the radial electric field has attracted attention as a way of understanding the mechanisms of nonlinear transport physics. In the CHS Heliotron/Torsatron plasma [1], an electric pulsation has been discovered, in which the radial potential profile swings repeatedly between two distinctive states. These states are interpreted as the creation and annihilation of the internal transport barrier [2].

Here, we present the first direct observation of ion transport pulsation in a potential well of a linear magnetized plasma. The temporal behavior of the ion density measured on the two-dimensional plane perpendicular to the constant axial magnetic field reveals an alternate reaction of ion accumulation and release in the plasma. Similar spiral structures in plasmas have been observed and discussed [3-5].

The experimental apparatus for the observation of ion transport pulsation is shown in Fig.1. An electrode assembly placed at the end of a stainless steal chamber (27.0 cm $^{\phi}$ × 1.2 m) consists of three concentric nickel plates: an ion collector (0.8 cm $^{\phi}$), an electron emitter (1.0–7.2 cm $^{\phi}$), and a cathode (8.0–19.4 cm $^{\phi}$). All of these plates are coated with $BaSrO_2$ and heated by a tungsten heater. The electron beam extracted by an anode (8.0–19.4 cm $^{\phi}$) ionizes argon gas and produces a hollow plasma in a magnetic field of 1.25 kG. The gas pressure is 1.5×10^{-3} Torr. Inside the hollow plasma (r < 8 cm, being the radial position from the central axis), a diffused plasma is formed, consisting of ions diffused from the hollow plasma and electrons from the electron emitter. The bias voltage $V_{\text{A–E}}$ of the anode with respect to the electron emitter is 1.5 V. The density and the electron temperature of the diffused plasma is 10^9 cm^{-3} and 0.3 eV, respectively. The ion temperature is less than 0.3 eV. Ion transport around the central axis of the diffused plasma is investigated by applying a voltage

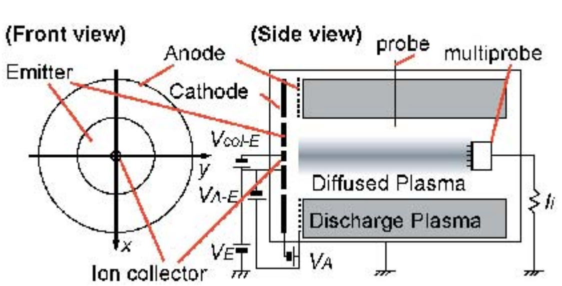

Fig. 1 Experimental apparatus. A diffused plasma is formed inside a discharged hollow plasma. Ions are accumulated around the central axis by a negative voltage of the ion collector.

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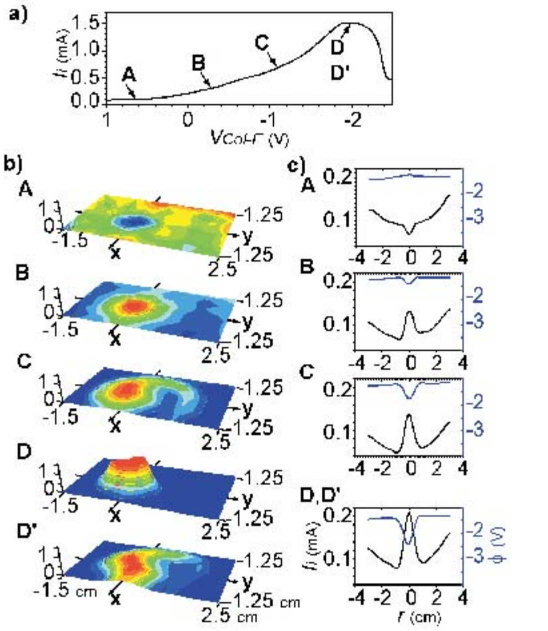

Fig. 2 Plasma behaviors as a parameter of the well potential ($V_{Col-E} < 0$). a) Ion current of the probe at $r = 0$. b) Density profiles on a plane perpendicular to the magnetic field. c) Time averaged density and potential versus radial position. Each figure of b) and c) corresponds to the positions A, B, C and D (D′) of a).

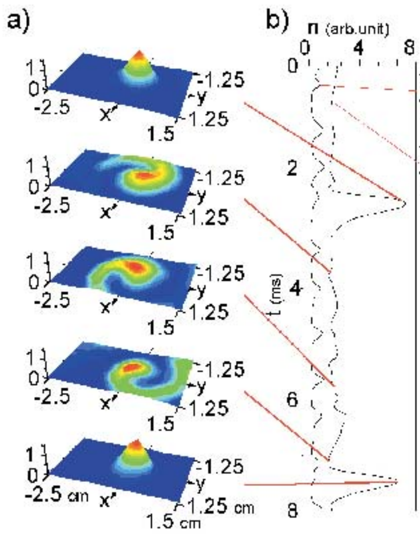

Fig. 3 Ion transport pulsation. a) Two-dimensional density profiles. b) Temporal behavior of pulsation.

V_{Col-E} (< 0) between the ion collector and the electron emitter, as shown in Fig.2. The dynamical behavior of the ion density around the central axis is detected by a multiprobe (a bundle of 160 single probes covering an area of 2.5 cm × 4.0 cm). We point out that all of the ions in the diffused plasma are created in the discharge volume and some of them are lost by charge exchange with neutral atoms.

The dependence of the ion current of the probe at $r = 0$ cm on the ion collector voltage V_{Col-E} is shown in Fig.2 a). The ion current increases with decreasing V_{Col-E} and abruptly decreases at $V_{Col-E} = -2.3$ V. The top figure of Fig.2 b) indicates a density profile of the diffused plasma on the two-dimensional plane at point A of $V_{Col-E} = 0.7$ V. In Fig.2 b) and Fig.3 a), the density is normalized by 10^{10} cm^{-3}. By decreasing V_{Col-E}, Fig.2 b) shows ion concentration around the center axis (B), spiral rotation of the ion density pattern (C), and ion transport pulsation (D, D′). The pulsation arises from alternation between a concentrated density distribution (D) and an extended spiral density distribution (D′). The time-averaged density and potential are measured in the radial direction as seen in Fig.2 c). At C of $V_{Col-E} = -1.1$ V, the spiral density structure rotates rather stably.

The temporal behavior at $V_{Col-E} = -2.0$ V is clarified in Fig.3 in detail. Figure 3 b) indicates the ion densities on the center axis ($x = 0$ cm, $y = 0$ cm) and at a periphery ($x = 0.75$ cm, $y = -1.0$ cm). The fluctuation of the signal at the periphery exhibits the rotation of the spiral tail. The two-dimensional density profile is illustrated in Fig.3 (a) for each time. At $t = 2.5$ ms, the density on the center axis grows. This is followed by relaxation to a spiral density structure. The spiral structure rotates several times and leads to elongation of the spiral arm. This elongation gives rise again to an abrupt ion concentration in the region around the central axis. Thus, the ion transport pulsation is caused by alternation of the ion accumulation and release via a spiral density structure.

The large negative voltage of $V_{Col-E} < -2.0$ V brings about the strong decrement of the ion current flowing into the region around the central axis, where the spiral structure is not observed at all. Thus, a transport barrier for ions may be established around the central axis. Such an ion transport barrier will be discussed in another paper.

In summary, an ion transport pulsation has been observed in the potential well of a magnetized plasma. The elongation of a spiral arm gives rise to abrupt ion accumulation around the central axis.

This article is in partial fulfillment of the doctor thesis of S. Yasuda.

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