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Effect of neutral gas flow on plasma structure formation in an ECR plasma

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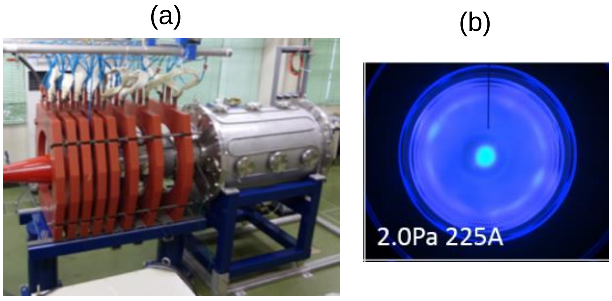
Partially ionized plasma can be ubiquitously found in nature, laboratories, and the edge region of magnetically confined plasmas [1,2], and the neutral gas in plasma plays an important role in the physical processes and the organization of plasma discharges. A plasma fluid is coupled with a neutral fluid via collision and radiation processes, and hence, understanding the characteristics of neutral gas transport is important. In our recent experiments, various phenomena associated with plasma-neutral coupling, e.g., high-temperature bubble formation [3], generation of asymmetry distribution function in a neutral depletion structure [4], and axial flow reversal of neutral gas [5], have been observed

Experiments have been performed in the HYPER-II device (Kyushu Univ.) [6], which is shown in Fig. 1(a). The HYPER-II device consists of two cylindrical vacuum vessel: one is the plasma production chamber with 0.3 m in inner diam. and 0.95 m in axial length, and the other is the plasma diffusion chamber with 0.76 m in inner diam. and 1.3 m in axial length. An argon plasma is produced by electron cyclotron resonance (ECR) heating with a 2.45 GHz microwave as shown in Fig. 1 (b). To clarify the general characteristic of partially ionized plasma, we have also utilized the HYPER-I device (NIFS) [7].

In order to directly measure the velocity distribution function of both the ions and neutral particles, we have utilized a laser induced fluorescence (LIF) spectroscopy method [5,8]. A tunable diode laser tuned at 668.61 nm (vac.) and a TiS laser tuned at 696.73 nm (vac.) are used for the measurements of metastable ions and metastable neutral particles, respectively. By using those narrow spectral band width lasers, it is possible to precisely trace the velocity distribution function of target particles by scanning the laser wavelength.

An example indicating the importance of neutral particles in plasma is shown in Fig. 2: the filling gas pressure dependence of (a) the axial ion flow velocity and (b) the axial neutral flow velocity. The sign of axial neutral flow velocity changes around the filling pressure of 0.1 Pa. It is worth pointing out here that the flow structure does not depend on the gas inlet position, which indicates that the neutral transport is organized by the presence of plasma and is not affected by the change in external conditions. Furthermore, the magnitude of axial ion flux (positive) is almost the same as that of axial neutral flux in the low pressure conditions (< 0.1 Pa). Total mass conservation is sustained in the axial direction, and hence, axial transport of neutral gas is important in practical circumstance. On the other hand, in the high pressure conditions (> 0.1 Pa), the total mass flux is clearly positive, and the neutral flux is much larger than that of the ion flux, where the neutral density is estimated by using the density at the filling gas pressure. This implies that inhomogeneity of neutral flux in the axial direction is necessary to sustain a steady state discharge. In the presentation, we will present experimental techniques for the neutral flow measurement in plasmas and discuss the importance of plasma-neutral coupling on the structure formation of partially ionized plasma.



(a) (b)

Fig. 1. (a): HYPER-II device and (b): typical end view image of an Ar plasma.

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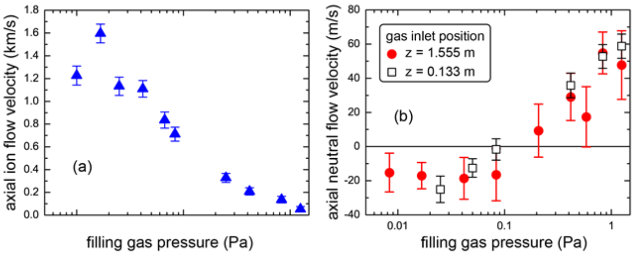

Fig. 2. Filling gas pressure dependences of (a) axial ion flow velocity and (b) axial neutral flow velocity.

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