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Density and flow field structures of partially ionized plasma in laboratories

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Partially ionized plasma is frequently observed in nature. It has been recognized that the effect of neutral particles, i.e., plasma-neutral coupling, plays an important role in the structure formation and transport phenomena, such as atmosphere-ionosphere coupling, blob dynamics and neutral depletion in laboratory plasmas, and so on. The plasma (electrically conducted fluid) is coupled with the neutral fluid though collisions, e.g., the Sena effect, and the interplay between the plasma and neutral gas results in a characteristic structure formation. In order to understand the structure formation of partially ionized plasma, measurement of neutral particles as well as charged particles is required.

We have experimentally studied the effect of flow on the structure formation of partially ionized plasma in the HYPER-I device[1] (NIFS, Japan), which is shown in Fig. 1(a). An electron cyclotron resonance (ECR) plasma is produced with a 2.45 GHz microwave. A high resolution laser induced fluorescence (LIF) spectroscopy system[2] is to measure the local velocity distribution function of neutral particles or ions.[3,4] To confirm the universality of structure formation in partially ionized plasma, we have also used the HYPER-II device[5] (Kyushu Univ., Japan) shown in Fig. 1(b), in which the plasma production and measurement methods in this device are the same with that of HYPER-I.

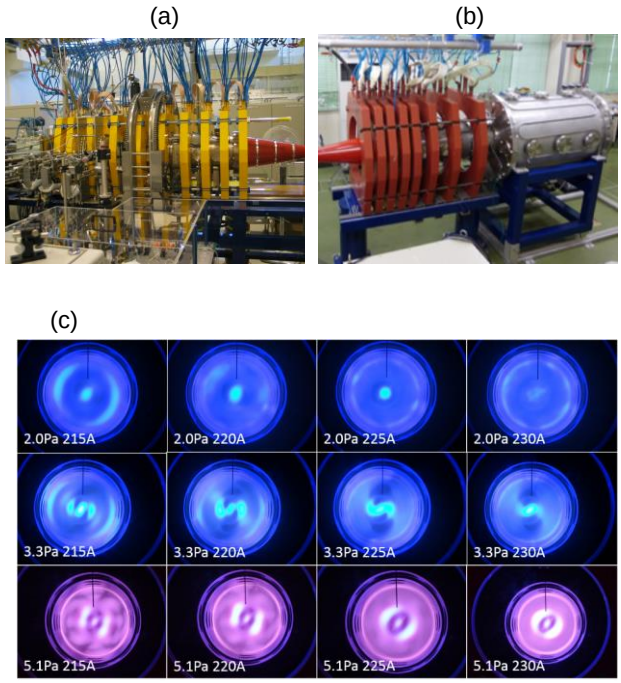

Fig. 1. Experimental devices: (a): HYPER-I; (b): HYPER-II. (c): Various emission pattern (density structure) associated with neutral depletion in the HYPER devices.

Figure 1(c) shows the spatial distributions of line-integrated emission intensity (visible) in some discharge conditions, and various plasma structure associated with neutral depletion have been found. We have observed the asymmetry of velocity distribution function in a neutral depletion structure [Fig. 2(a)] and shown the skewness of distribution function (magnitude of asymmetry) is proportional to the density gradient. It has also been revealed that the skewness of distribution function is proportional to the inhomogeneity-induced flow shown in Fig. 2(b), and a simple relation between the skewness and the normalized flow velocity has been obtained and confirmed in the experiment.[4]

In recent other our experiment, we have also found the creation and annihilation of neutral depletion hole.[6] These experiments show that momentum transport between the plasma and neutral particles is important for vortex formation and gas circulation. We will present the experiments with the HYPER devices and a new analytical method using the skewness to determine the inhomogeneity-induced flow, and discuss the importance of plasma-neutral coupling on the structure formation of partially ionized plasma.

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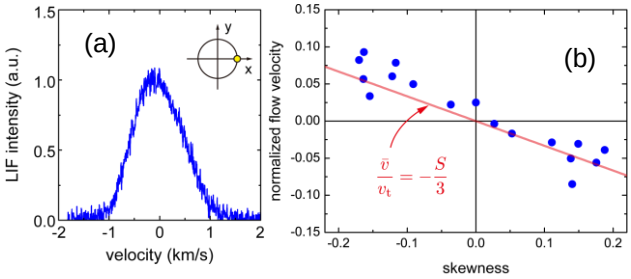

Fig. 2. (a): Asymmetry velocity distribution function of neutral particle in a neutral depletion structure. (b): Relationship between the skewness and the normalized flow velocity.

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