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Axial and radial momentum fluxes lost to a radial wall of a helicon plasma thruster

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Momentum flux in plasmas, corresponding to a force density, is one of the fundamental physical quantities associated with acceleration, transport, and confinement of various plasmas. One of the direct applications of the plasma momentum flux is an electric propulsion for spacecrafts. In the field of the electric propulsion, a force exerted to a propulsion device is often directly measured by attaching it to a pendulum called thrust balance and sometimes estimated by using a pendulum target located in the plasma plume. In one of the advanced plasma thrusters called a helicon plasma thruster, which consists of a helicon plasma source and magnetic nozzle [1, 2]. It is known that the thrust force is given by the sum of a pressure force (T_s) exerted on a back wall terminating the plasma upstream, an axial force (T_w) exerted on a radial wall, and a Lorentz force (T_B) exerted on the magnetic field due to a plasma-induced electric current [3]. The previous individual measurement of T_w integrated over the wall has implied that the axial momentum is transferred to the radial wall by the ions accelerated axially in the plasma core and lost to the wall [4]. The spatially resolved measurements of the fluxes of both the radial and axial momentums lost to the radial wall will give new insights into the plasma dynamics and the thruster development, as investigated using a particle-in-cell simulation [5]. In addition, the previous studies have shown that a larger thrust is obtained with the propellent gas injection from downstream than upstream due to the density profile [6].

Figure 1 shows the schematic diagram of the momentum vector measurement instrument (MVMI), which is designed to independently and simultaneously measure two differently directed components of a force [7]. A momentum detector plate having the detector area of 20 mm × 30 mm is mounted on a rotational arm attached to a pivot, which is further mounted on an axially movable pendulum stage. When imparting the radial force to the detector, the arm is rotated. Similarly, the movable stage supported by two flexible plates moves in the axial direction when the axial force is exerted on the detector surface. The radial and axial force components can be independently obtained by measuring the radial and axial displacement, where multiplying calibration coefficients relating the displacements to the forces yield the absolute values of the forces.

Figure 2 shows the typical displacement signals (V_r and V_z) of the radial and axial sensors located near the radial wall, where the solenoid currents I_B and the rf power are turned on for t = 10-40 sec and t = 20-30 sec, respectively, and the oscillation components of the pendulums are eliminated via a digital filter. The positive displacements in V_r and V_z by turning on the rf power shows that the radially outward and axially downward momentum fluxes are lost to the radial wall.

The MVMI structure is further mounted on an axially-movable motor stage installed inside the vacuum chamber, enabling the spatial measurement of the momentum fluxes. The effects of the magnetic field and the location of the gas injection port will be shown in the presentation.

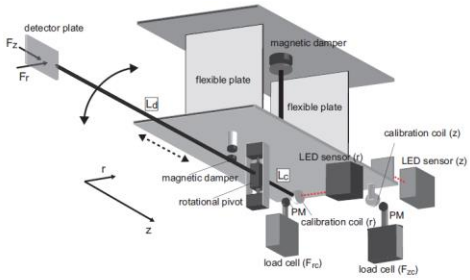

Fig. 1. Schematic diagram of the MVMI.

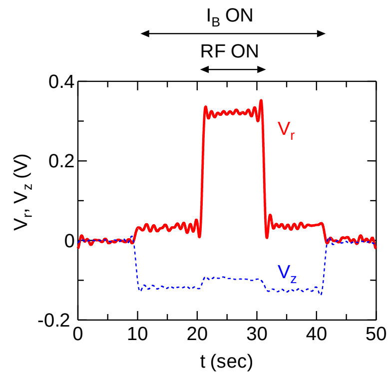

Fig. 2. Typical displacement signals (V_r and V_z) of the radial and axial sensors.

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