Generation of supersonic plasma flow in DiPS-2

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Flow measurements near X-points including E × B shear velocity and supersonic flow are still under debate [1, 2] in fusion devices, although the progress of edge plasma physics has been advanced in recent years. Various kinetic and fluid models have been developed on plasma flow phenomena at fields of fusion plasmas. However, subsonic plasma flow has been mostly studied for verification of models, which requires further verification for supersonic plasmas. Also, the generation and measurements of supersonic plasma flow have been studied at pulsed plasma system or transient phenomena, which are still insufficient in steady state plasma conditions, even.

In this experiments, a concept of ion extraction system [3] has been adopted to generate supersonic plasma flows ($M_\infty > 1$) at weakly magnetized plasma in steady state condition. A cylindrical ion extraction electrode of stainless steel, which has a diameter = 5 cm and an axial length = 4 cm, was used. In test for generation of supersonic plasma flow, the first result on the ion velocity distribution with supersonic plasma flow (M_∞ = ~ 1.2) was obtained in a capacitively coupled plasma with electron temperature (T_e) ~ 2 eV and plasma density (n_e) ~ 10^{10} cm^{-3} by using Mach probe.

Ion extraction system was applied to a linear plasma device called DiPS-2 (Divertor Plasma Simulator - 2: length = 3560 cm, diameter = 20 cm, source = LaB_6 cathode, average density ~ 10^{11} - 10^{13} cm^{-3}, T_e ~ 1 - 20 eV for Ar plasmas) [4]. To analyze drift velocity in supersonic plasma flow in terms of discharge currents and biased voltages to ion extraction electrode, a laser induced fluorescence (LIF) system was adopted with measurement of Mach probe. The LIF system composes of a tunable diode laser with a master oscillator power amplifier (MOPA), which has typical ouput power = 10 - 100 mW, line width = 1 MHz, coarse tuning range = 665 - 675 nm with a rotating grating, fine tuning range = 0.45 nm with piezo-electric actuator control from 0 to 100 Volt, and a mode-hop free tuning region > 16 GHz, with current coupling method, to pump Ar II transition $3d^4F_{7/2}$ metastable level to the $4p^4D_{5/2}$ level at 668.43 nm. The 442.60 nm fluorescence light emitted from $4p^4D_{5/2}$ level to $4s^4P_{3/2}$ level was collected to determine drift velocity in supersonic plasma flow. For validity of experimental results on supersonic plasma flow, LIF data was compared with Mach probe results with various calibration factors introduced from Mach probe theory.

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