Time-resolved laser-induced fluorescence spectroscopy with a continuous-wave diode laser for the investigation of ion sheath dynamics

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Laser-induced fluorescence spectroscopy (LIF) is an optical technique to measure the density and movement of target particles without disturbance. In low-temperature plasma studies, the LIF method has been utilized to measure ion velocity distribution functions (IVDFs) in and at the edge of plasmas [1]. To investigate the dynamic behaviors of ions in the ion sheath, where an AC bias voltage is applied to the electrode, the LIF system must possess a time resolution shorter than the AC-voltage period. In this study, we developed a time-resolved LIF system with a continuous-wave diode laser with a time resolution of less than 1 μs. The performance of the LIF system to measure the temporal evolution of IVDF is reported in the presentation.

In this study, we diagnosed an ECR plasma in Ar gas at 0.05 Pa. The LIF target species was metastable Ar ion (Ar^{+m}). An amplitude of the excitation laser at 668.6 nm ($3d^4F_{7/2} \rightarrow 4p^4D_{5/2}$) was modulated at 20 MHz by an EOM. A PMT detected the fluorescence through a bandpass filter at 442.6 nm ($4p^4D_{5/2} \rightarrow 4s^4P_{3/2}$) [2]. The temporal evolution of LIF signal intensity was recorded through a phase-sensitive detector (PSD) with an output bandwidth of 2 MHz (Fig. 1(a)). We applied an AC sinusoidal voltage at 100 kHz with an amplitude of 20 V and an offset of −11.23 V ($= V_f + V_{DC}$) to a bias plate placed in the ECR plasma. The excitation laser propagated perpendicular to the bias plate and passed its hole at the center. The detection optics was focused on the laser beam axis at 1 mm from the bias plate. Figure 1(b) shows the temporal evolution of IVDF plotted with a bias-voltage waveform. We found that the ion velocity does not follow the bias voltage (delay for ~1 μs) in t = 0~2 μs. This result suggests that the time-resolved LIF developed in this study can contribute to plasma science and technology by investigating the dynamic behavior of particle (ions, excited species, radicals…) in plasmas.

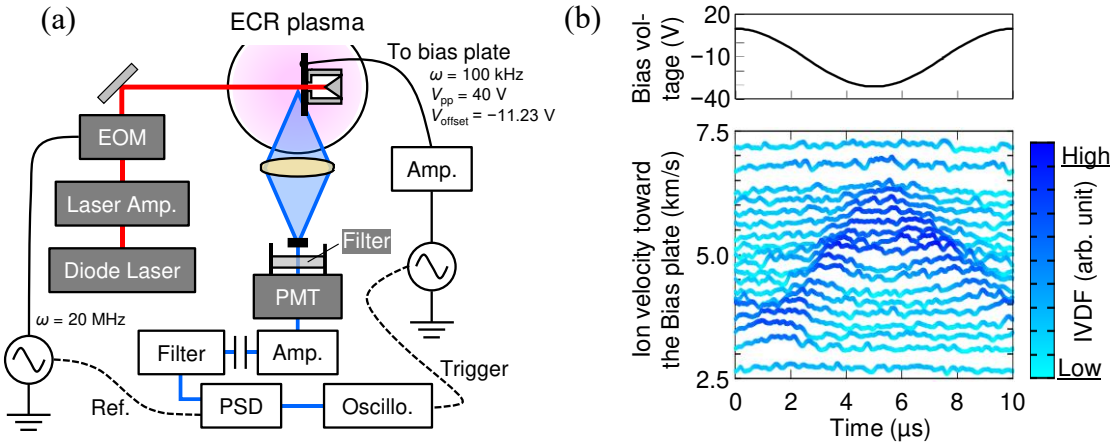

Figure 1. (a) Schematic diagram of time-resolved LIF system. (b) Temporal evolution of IVDF measured at 1 mm from the bias plate plotted with the bias-voltage waveform at 100 kHz.

[1] N. Claire *et al.,* Phys. Plasmas **13**, 062103 (2006).
[2] R. Takahashi *et al*., Proc. 75th GEC / 11th ICRP, HW6.00018 (Sendai, Japan, 2022).

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