§4. Laser Induced Fluorescence with Wave-length Monitoring for Pulsed Laser

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Measurement of flow velocity field is an important method to understand self-organization in plasmas. A variety of vortical flow structures, for example, have been observed in an electron cyclotron resonance plasma. These vortices have eccentric features; one has a supersonic rotation$^{1)}$, the other has a counter-$E \times B$ rotation induced by neutral pressure gradient$^{2)}$. Therefore, measurement methods required for such experimental research should be (1) less perturbative for flow structure, (2) applicable to wide range of flow velocity with robust physical model, and (3) direct measurement of local flow velocity. Measurement of Doppler-shifted fluorescence induced by a tunable laser (LIF) matches those requirements$^{3)}$. In the LIF Doppler spectroscopy, the accuracy of absolute velocity depends on that of laser wavelength. Therefore, a laser wavelength monitoring system is required for experimental studies of precise flow structure, especially when a pulse operating dye laser is used for the LIF method. While an accurate wavelength is obtained using general wavelength-meters, data acquisition rate is usually lower than the laser repetition rate (10-50 Hz). A compensative monitoring system, which returns relative wavelength deviation in real time with a few pm precision, has been developed. Simultaneous measurement of LIF spectrum and laser wavelength monitoring signal has been performed in this fiscal year.

The wavelength monitoring system consists of a Fabry-Perot interferometer (FPI) and gated sampling electronics (boxcar integrators)$^{4)}$. A part of the laser beam emitted from a pulsed dye laser is injected into the entrance aperture as shown in Fig. 1. Two biased silicon photodetectors are used in the FPI. One measures light intensity directly, while the other measures an interfered light intensity. Most of the laser beam is injected into a plasma, and laser induced fluorescence is detected through an interference filter by a photo multiplier tube. By using gated sampling electronics, the interfered, the reference, and the fluorescent light intensities are held until the next laser pulse comes.

The free spectrum range (FSR) of the FPI signal is determined by the thickness of the etalon. Two etalons with thickness t = 1mm and t = 1.5mm were prepared. Interference signals shown in Fig. 2(b) suggest that FSRs are 0.12 and 0.08 nm, respectively. Since the wavelength range required for covering the Doppler shifted and Doppler broadened spectrum of ions is about 0.1 nm as shown in Fig. 2(a), the etalon with t = 1mm is appropriate for indicating wavelength within a monotonical change.

An LIF spectrum shown in Fig. 2(a) was measured for an argon plasma in the HYPER-I device. The spectrum is well fitted by two Gaussian with the same broadening; wavelength difference of two peaks is 0.018 nm. Because the laser was injected along the magnetic field and was reflected at an quartz window in the other end, argon ions flowing along the magnetic field suffered from resonant excitation by co- and counter-going laser. Half of the wavelength difference indicates that the parallel flow velocity $v_{\parallel} = 4.4\text{km/s}$.

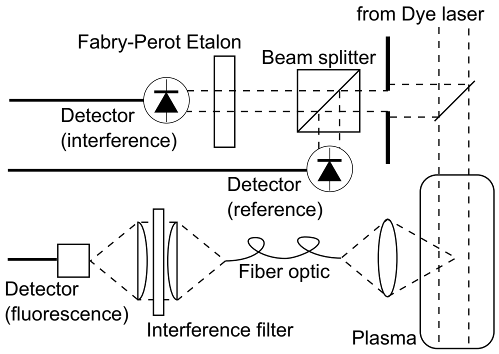

Fig. 1: Schematic of the experimental setup.

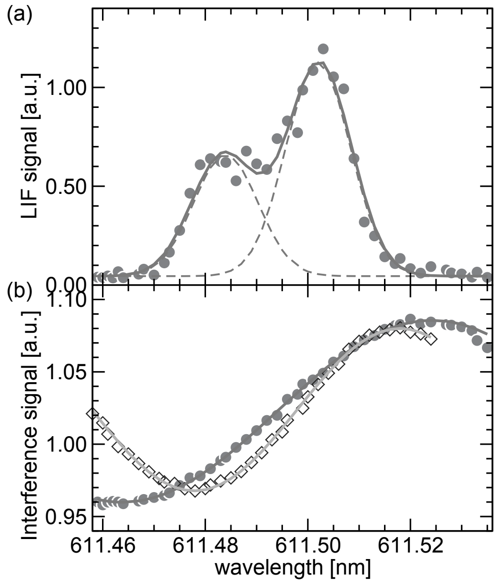

Fig. 2: (a)Laser induced fluorescence simultaneously measured. (b)Interference signal of two different thickness etalons. Open diamonds represent that for t = 1.5mm, filled circle for t = 1mm. Solid curves represent sinusoidal fittings.

1) Okamoto, A. et al.: J. Plasma Fusion Res. SERIES **6** (2004) 606.

2) Okamoto, A. et al.: Phys. Plasmas **10** (2003) 2211.

3) Okamoto, A. et al.: J. Plasma Fusion Res. **80** (2004) 1003.

4) Okamoto, A. et al.: Ann. Rep. NIFS (2012-2013) 457.