§5. Development of a Fabry-Perot Interferometer for Wavelength Calibration of Pulsed Laser

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Measurement of flow velocity field is an interesting topic in the research field of plasma-surface interaction as well as basic plasma physics. 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 an anti-$E \times B$ 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 a general wavelength-meter, data acquisition rate of the wavelength-meter 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, is required. Development of the system is described in this report.

The wavelength monitoring system consists of a Fabry-Perot etalon, an input pulse-energy reference, and gated sampling electronics (boxcar integrators) as shown in Fig. 1. A part of the laser beam emitted from a pulsed dye laser is injected into the entrance aperture. After being split into two beams, the laser beam is detected by biased silicon photodetectors. One of the detector measures light intensity directly for calibration of energy fluctuation in each pulse, while the other measures an interfered light intensity. By using gated sampling electronics, interfered and reference light intensities are held until the next laser pulse comes.

With appropriate etalon parameters, the output signal of the interferometer varies monotonically when the laser wavelength changes; the laser wavelength is uniquely determined from the interferometer signal. The free spectrum range (FSR) of the interferometer signal is determined by the thickness of the etalon. Since the wavelength range for the LIF Doppler spectroscopy is about 0.1 nm, which is required for covering the Doppler shifted and Doppler broadened spectrum of ions, an air-gapped etalon with < 2 mm gap is suitable. The signal amplitude is determined by finesses, which mainly dominated by the reflectivity limited finesse. From intensities at peak (I_{p}) and bottom (I_{b}) in the FSR, the signal amplitude, $(I_{\mathrm{p}} - I_{\mathrm{b}})/(I_{\mathrm{p}} + I_{\mathrm{b}})/0.5$, is estimated. While about 10% of the signal amplitude is modulated for the 4% surface reflectivity, 100% of modulation can be achieved satisfactory with the 50% surface reflectivity.

As a proof-of-principle experiment, an easily available quartz plate was used instead of the air-gapped etalon. The thickness of the quartz plate, 3 mm, is expected to span 42 pm of FSR. The surface reflectivity of the quartz plate, 4%, is expected to modulate 10% of the signal amplitude. Scanning the dye laser wavelength in the range from 611.41 nm to 611.58 nm, output signal of the interferometer is measured. The result, as shown in Fig.2, indicates that 41 pm of FSR is obtained and that the modulation of the signal amplitude is about 10%. This is in good agreement with the designed value. The detailed design of the air-gapped etalon is ongoing with the aid of the proof-of-principle experiment.

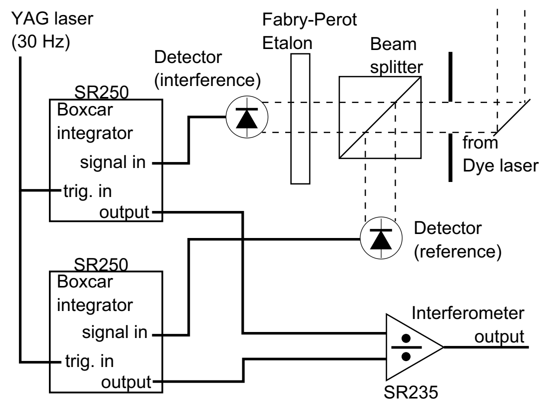

Fig. 1: Schematic of the experimental setup.

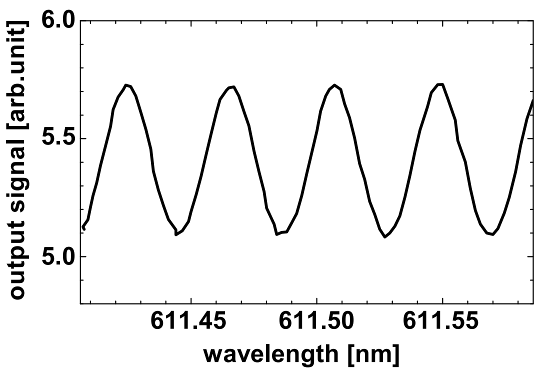

Fig. 2: Output signal of the interferometer as a function of dye laser wavelength.

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.