Real-time measurement of azimuth Doppler shift induced by transverse flow velocity

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We have successfully demonstrated a method for measuring the flow velocity across the beam by analyzing the two-dimensional distribution of the azimuthal Doppler shift in the absorption spectrum at each position on the cross-section of the optical vortex beam. We call this method optical vortex laser absorption spectroscopy (OVLAS), which enables observation of flow transverse to the line of sight [1]. In the current OVLAS, the azimuthal Doppler shift is evaluated from the absorption spectrum. Therefore, the time resolution is limited by the laser frequency sweep required to observe that spectrum. In this study, we demonstrate the real-time flow velocity measurement by evaluating the azimuthal Doppler shift from the derivative signal of the absorption spectrum.

When performing laser absorption spectroscopy by modulating the laser frequency with a small amplitude at a high-modulation frequency and detecting with a lock-in amplifier, the signal obtained is proportional to the derivative of the Gaussian absorption spectrum. Here we use a quadrant photodiode (QPD) to observe the beam cross-section divided into four quadrants. Figure 1 shows the derivative signal of the Doppler-shifted absorption spectrum observed by one quadrant of the QPD. The zero-crossing frequency of this derivative corresponds to the center frequency of the absorption spectrum. The laser-source frequency is locked to the resonant frequency ν_0 of the plasma, which is determined by saturated absorption spectroscopy. We control the optical vortex beam frequency by applying a modulation frequency Δf to an acousto-optic modulator (AOM) so that the derivative signal in one quadrant becomes zero. Therefore, this method does not require sweeping the laser frequency across the entire absorption spectrum. Because the AOM modulation frequency equals the absolute value of the Doppler shift, we can measure the shift in real-time. By continuously controlling the AOM modulation frequency to maintain the zero crossing of the derivative signal, we achieve real-time measurement of the transverse-flow velocity. This presentation reports in detail our attempt at high-speed measurement of the azimuthal Doppler shift using the optical vortex and AOM.

[1] H. Minagawa *et al.*, Sci Rep **13**, 15400 (2023).

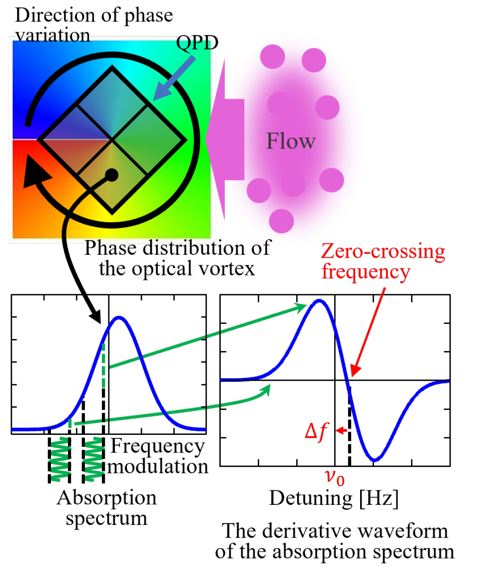

Fig. 1. Derivative signal and zero-crossing frequency of absorption spectrum.

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