Improvement of time resolution in optical vortex laser absorption spectroscopy using quadrant photodiodes

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We are developing optical vortex laser absorption spectroscopy (OVLAS) [1], which substitutes the probe beam of tunable diode laser absorption spectroscopy (TDLAS) with an optical vortex. OVLAS can measure the velocity component across the beam axis, which is undetectable with conventional TDLAS. Azimuthal Doppler shift in the optical vortex varies by each position, assuming uniform flow across the optical vortex beam. Therefore, using a camera as the detection system, the observed absorption spectrum indicates different Doppler shift for each pixel. Current OVLAS has successfully measured transverse flow velocity using a camera to accurately observe azimuthal Doppler shift distribution. However, the time resolution of the OVLAS, which is limited by data transfer and exposure times, needs to be improved for real-time measurement of time evolving velocity distribution function in plasma. To improve this, we employ a quadrant photodiode (QPD), a device that, unlike single-element conventional photodiodes, divides the photosensitive area into four sections. Furthermore, by using a lock-in amplifier, the azimuthal Doppler shift is measured at high speed.

Fig. 1 shows a schematic of the OVLAS using a QPD and a lock-in amplifier. The frequency of the ECDL is modulated, and the absorption signal from the QPD is input to the lock-in amplifier. Since the lock-in amplifier detects variations in absorption within the modulation frequency range as a DC component, a derivative waveform signal of the absorption spectrum can be observed by performing a frequency sweep of the laser. The Doppler shift corresponds to the point where the derivative value becomes zero. Therefore, the azimuthal Doppler shift can be conveniently measured with high time resolution by simply sweeping the frequency near the resonant absorption frequency. The details of the attempt at real-time OVLAS will be reported in this presentation.

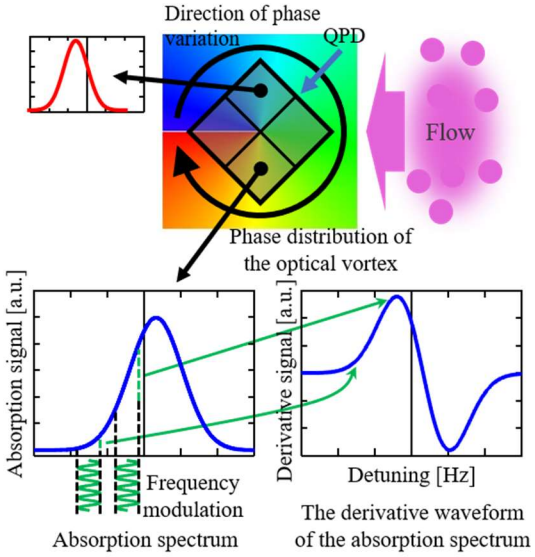

Fig.1. Schematic of derivative waveform signal measurement of absorption spectrum using OVLAS with QPD.

[1] H. Minagawa *et al*., Plasma Fusion Res.**17**, 1401099 (2022)
[2] L. Allen *et al*., Opt. Commun. **112**, 141 (1994).

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