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HYPER-I装置における光渦を用いたレーザー吸収分光
Laser Absorption Spectroscopy Using Optical Vortex in the HYPER-I Device

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We have recently been developing a novel plasma diagnostics utilizing so-called *optical vortex* which is a propagation mode of light with orbital angular momentum (OAM) [1]. Optical vortex has a potential to realize a new Doppler velocimetry, because an atom in the optical vortex beam experiences not only conventional axial Doppler shift but additional azimuthal Doppler shift [2]. In other words, not only the parallel movement of the atoms against the beam axis but the perpendicular one causes the Doppler shift of their resonant absorption frequency. The Doppler shift is given by the following equation:

$$\delta_{LG} \approx -kV_z - \left(\frac{l}{r}\right)V_\phi , \qquad (1)$$

where k is the wavenumber of optical vortex, V the atomic velocity, l the topological charge that defines the OAM of light, and r the distance from the beam axis.

Optical vortex can be created as a Laguerre-Gaussian (LG) beam which is a cylindrically symmetric solution of the Helmholtz equation. There are several methods to create LG beams in laboratory. Because of the controllability of topological charge, we used holographic approach to convert a plain-wave-like Hermite-Gaussian (HG) beam into a LG beam. An external cavity diode laser (ECDL, TOPTICA DL100) was used as the light source, of which center wavelength was set to 696.735 nm (in vacuum) corresponding to the resonant absorption frequency of a metastable argon neutral. In the holographic method, the HG beam was converted into the LG beam as the first-order diffracted light from a computer -generated hologram (CGH) displayed on a spatial light modulator (SLM, Hamamatsu LCOS-SLM X10468-07). The quality of the LG beam has been improved by optimizing the hologram pattern.

As a proof-of-principle experiment of optical vortex plasma spectroscopy, we have performed laser absorption measurement in the HYPER-I device at the National Institute for Fusion Science. The LG beam was injected into the plasma from a side viewing port. The transmitted LG beam was observed by a beam profiler, since the azimuthal Doppler shift depends on the position. By analyzing obtained two-dimensional intensity profile of the transmitted LG beam, we have found the angle dependence of Doppler shift. Detailed discussion will be given in this talk.

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