§13. Study of Atomic Excitation by Optical Vortex and Its Application to a Novel Laser Spectroscopy

Aramaki, M. (Nihon Univ.),
Toda, Y. (Hokkaido Univ.),
Terasaka, K., Tanaka, M.Y. (Kyushu Univ.),
Yoshimura, S., Goto, M., Morisaki, T.

Although the Doppler laser spectroscopy is a useful technique to detect the motion of atoms in plasma, the obtainable information is limited in the propagation direction of the laser beam. Recently, waves which have twisted phase plane are intensively studied in the field of high resolution microscopy, optical tweezers, etc. Because of the phase structure, the propagation mode of light is called as the optical vortex. Since the optical vortex has a three dimensional phase structure, the motion in the light filed induces the Doppler effect in all the three dimensional directions. The Doppler shift in the optical vortex is described as follows:

$$\delta_{LG} = -\left[k + \frac{kr^2}{2(z^2+z_R^2)}\left(\frac{2z^2}{z^2+z_R^2} - 1\right) - \frac{(2p+|m|+1)z_R}{z^2+z_R^2}\right]V_z - \left(\frac{krz}{z^2+z_R^2}\right)V_R - \left(\frac{m}{r}\right)V_\phi,$$

where V_R, V_z and V_ϕ are the radial, axial and azimuthal velocity components of the atom.[1)] We aim to develop a three dimensional Doppler spectroscopy method using the optical vortex. The phase change in a crosssection is described by $2\pi m$. The number m is called as the topological charge. Since the azimuthal Doppler shift is proportional to m, it is important to be able to generate optical vortices with large m. This year, we have developed a flexible optical vortex light source using a spatial light modulator (SLM).

Figure 1 shows the experimental setup for the optical vortex laser spectroscopy. An external cavity diode laser (ECDL) was used as the light source of the system. The output power of the ECDL was 10 mW, and the wavelength was tuned at 697nm for the excitation of an argon metastable atom. The wavelength and spectrum of the ECDL were monitored by a wave meter and Fabry-Perot interferometer respectively. The laser light was coupled to a polarization maintaining fiber and transported to an optical vortex generation part. The laser light was converted to optical vortex by a computer generated hologram (CGH) displayed on the SLM. Figure 2 shows the CGH used for the generation of the m =1 optical vortex. The center of the vortex locates at the junction of the fork structure. By changing the CGH, higher order optical vortices are easily generated. Figure 3 shows the interference images between optical vortices and a plane wave. The number of the bright and dark spots repetitions corresponds to m. Generation of the optical vortices up to m = 10 is confirmed from the images. In the next year, the newly developed optical vortex source will be applied to the Doppler absorption measurements of the argon metastable in a test plasma.

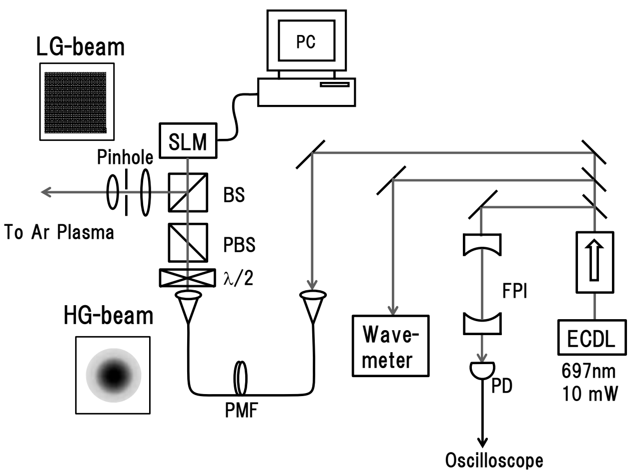

Fig. 1 Experimental setup.

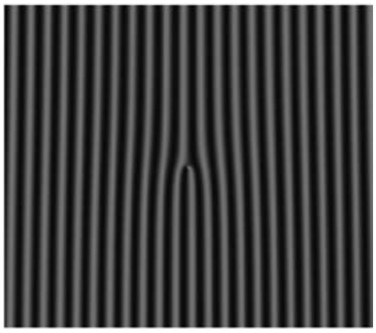

Fig. 2 CGH used for optical vortex generation. The center of the optical vortex locates at the junction of the fork structure.

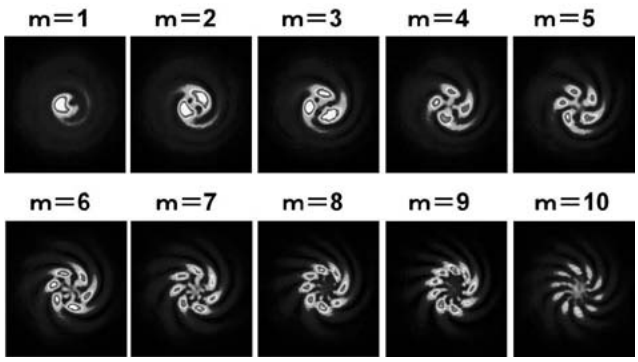

Fig. 3 Interference images between the optical vortices and a plane wave.

1) L. Allen, et al.: Optics Communications **112** (1994) 141-144.