Precise Control and Diagnostics of Plasma Using Tunable Diode Lasers

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Recently the range of the available wavelength of commercial laser diodes is getting wider, and the external-cavity diode laser (ECDL) based on the commercial laser diodes has become a useful tool for the experimental study of plasma physics. Since the emission of the ECDL is a narrow line width and tunable, the velocity distributions of ions and atoms in plasma become accessible using the compact, economic laser source. In this talk, the following three topics of the precise plasma spectroscopy will be presented.

1. Control of the ion velocity distribution for the study of strongly coupled plasma
Gas, liquid, and solid phase one-component plasmas are able to be generated under well controlled condition using a laser cooling method and an ion trap. We developed a low perturbative laser induced fluorescence (LIF) system using a weak probe laser for the detailed study of the spectrum shape [1]. The ion temperature was derived nondestructively.

2. Detection of small Doppler shift of the velocity distribution of neutral atoms
The experiments were performed using the high density plasma experiment (HYPER-I) device at the National Institute for Fusion Science, Japan. Anti-E×B type vortexes have been found in the device. The momentum exchange between neutral atoms and ions is considered to play an important role in the formation mechanism of this type of vortexes. Thus, the measurement of the slow neutral-gas flow is fundamentally important. We developed a high-accuracy laser induced fluorescence (LIF) spectroscopy system to detect the neutral flow as the Doppler shift of velocity distribution. The minimum detectable flow velocity of the newly developed LIF system was ±2 m/s [2], and this performance remains unchanged in a long-time experiment.

3. Improvement of flexibility of laser spectroscopy using optical vortex
The solutions of the Helmholtz wave equation in cylindrical coordinates are called as Laguerre-Gaussian (LG) modes or optical vortices. Since the optical vortex has a spiral phase structure in space, the atoms in the wave feel the multidimensional Doppler effect [3]. We are developing a three dimensional Doppler laser spectroscopy method using the optical vortex. The latest experimental results will be presented.

[1] M. Aramaki, et. al. *Non-Neutral Plasma Physics VIII, AIP Conf. Proc.* **1521**, 184-190 (2013).
[2] M. Aramaki, et. al., *Rev. Sci. Instrum.* **80**, pp. 053505-1 – 053505-4, (2009).
[3] L. Allen, et. al., *Optics Communications* **112**, 141-144 (1994).