§10. Laser-induced Fluorescence Spectroscopy with Femtosecond Laser Pulses

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Laser-induced fluorescence spectroscopy is a powerful tool for plasma physics [1]. It is capable of measuring the velocity distribution functions of ions and neutrals in a plasma. The flow velocities can be determined by the Doppler-shifts of the distribution functions. Very high resolution measurements of flow field of the ions and neutrals in a plasma becomes possible by using tunable diode lasers.

Since wavelength of diode laser lies in visible and infrared rages, LIF spectroscopy with diode laser is usually applied to excited atoms. When enough number of excited atoms are present in the plasma, LIF method is very useful to precisely measure the distribution function. However the population of excited atoms is affected by the plasma conditions, and as a result, the applicability of LIF spectroscopy with diode laser highly depends on the experimental conditions. To overcome this difficulty, LIF spectroscopy for ground state particles is desirable, however an ultraviolet laser is needed to build up the system, and the optics is complicated and difficult to manipulate.

We propose a simple two-step LIF method consisting of excitation (pump) and diagnostics (probe) systems. To produce the excited atoms, we utilize non-resonant interaction of femotosecond laser pulses. The system becomes robust against the change in experimental conditions, and the optics of new system is simple and tractable.

Figure 1 shows the schematic diagram of new LIF system. A femtosecond laser excites the ground state atoms, and LIF with a tunable diode laser is applied to the excited atoms to determine the distribution function. By using a femtosecond laser, the excited atoms are continuously generated regardless of experimental conditions.

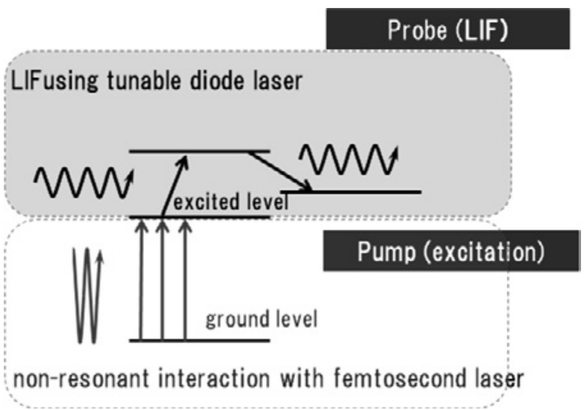

Fig.1 Two-step excitation diagram of LIF system with femtosecond laser.

In 2011, we set up the LIF system for neutral argon atoms and tested the system performance. The diode laser (696.54 nm) pumps up the excited atoms ($3s^23p^5(^2P^o_{3/2})4s$) to an upper level ($3s^23p^5(^2P^o_{1/2})4p$). The fluorescence photons of 826.45 nm ($3s^23p^5(^2P^o_{1/2})4$ - $3s^23p^5(^2P^o_{1/2})4s$) have been collected by a lens and detected by a photomultiplier tube. To improve the signal-to-noise ratio, the laser output is modulated by an electro-optical modulator and lock-in detected. By tuning the laser wavelength, we have obtained the LIF spectrum as a function of laser frequency, which is proportional to the velocity distribution function. A DC discharge plasma (argon) has been used as a test plasma. The average velocity and temperature have been determined by taking the moments of the LIF spectrum.

Figure 2 shows the LIF spectrum obtained in the experiment. The LIF spectrum is quite well fitted by a Gaussian distribution with a temperature 0.0306 eV(355 K). From the Doppler shift of the distribution function, the average velocity is found to be 1.75m/sec, which is

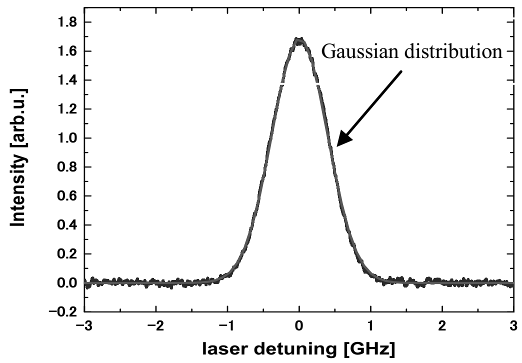

Fig.2. LIF spectrum for argon neutral particles.

considered to be driven by the electron current toward the electrode.

We have demonstrated that the probe LIF system with tunable diode laser has a very high resolution for distribution function measurement. Simultaneous operation of probe LIF system and femtosecond pump laser system will be carried out this year.

1) M. Aramaki, K. Ogiwara, S. Etoh, S. Yoshimura, and M. Y. Tanaka: “High resolution laser induced fluorescence Doppler velocimetry utilizing saturated absorption spectroscopy”, Rev. Sci. Instrum. **80**, (2009) 053505-1 – 4.