Development of active laser-induced fluorescence spectroscopy using a femtosecond laser

フェムト秒レーザーを用いた能動的LIF分光計測システムの開発

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It is found that strong laser field of a femtosecond (FS) laser can control the atomic excited level. We have been developing an active laser-induced fluorescence (LIF) spectroscopy which is possible to generate excited atoms (LIF target) using a FS laser. It has been observed that there is an increment in a plasma emission intensities when irradiating a FS laser. We have experimentally demonstrated that the excited atoms by the FS laser are measured by the active LIF spectroscopy when the FS laser and LIF spectroscopy are simultaneously applied.

1. Introduction

Laser-induced fluorescence (LIF) spectroscopy is a powerful method to measure, in high sensitivity, the local velocity distribution function of target particles in a plasma using a narrow-bandwidth tunable laser [1]. An accuracy of Doppler shift measurement more than 10^{-6} has been obtained. It is possible to measure neutral particle flows, which are very slow velocity of the order of 10 m/s. This method will be widely introduced in plasma physics.

The conventional LIF methods strongly depend on the population of target particles and therefore the experimental plasma conditions. It is desirable that the practical measurement system is free from various plasma conditions. We have been developing an active LIF spectroscopy system using a FS laser. The nonlinear interaction with electrons is expected to produce the target particles in an excited level. We have experimentally demonstrated that FS laser can control the population of target particles.

2. Experimental Methods

In this experiment, interaction between a FS laser and an argon plasma has been examined by measuring emission spectrum intensities with a CCD spectrometer. An increment of emission intensities generated by the FS laser has been measured. The velocity distribution function has been measured under simultaneous application of FS laser and LIF spectroscopy, and compared with the result of conventional LIF method.

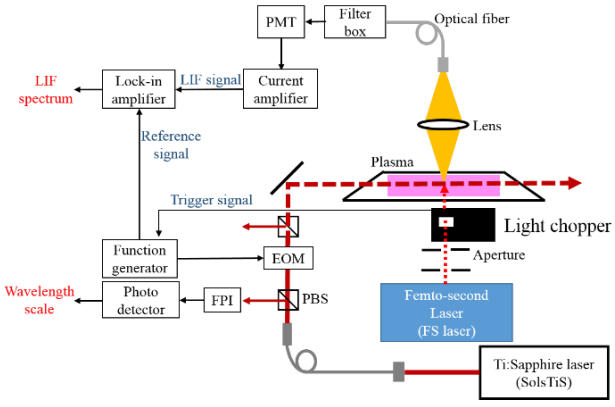

Fig.1. Schematic diagram of active LIF spectroscopy system using femtosecond laser

The schematic diagram of active LIF spectroscopy system is shown in Fig.1. A narrow-bandwidth tunable Ti:Sapphire (TiS) laser is used as a probe laser. The TiS laser is tuned to the resonance line of argon, and the velocity distribution function is measured. The wavelength

of FS laser pulses is 780±20 nm, repetition rate is 80 MHz, and the pulse width is 70 fs. The FS laser intensity is 10^6 W/cm^2. The LIF signal is collected by a lens, and detected by a photo multiplier tube and finally detected by a Lock in amplifier. The FS laser and the TiS laser are injected perpendicular to each other, and intersect at the focal point of the collecting lens.

3. Experimental Results and Discussion

3.1 CCD spectroscopic measurement

Figure 2 shows the increment of emission spectrum obtained by subtracting the emission spectrum without the FS laser. The wavelengths shown in Fig.2 are the resonance absorption lines of neutral particle of argon. There are substantial increments in several excited levels. This indicates that the population of these excited levels is increased through the interaction of the FS laser. We have measured the velocity distribution function of these resonance lines by simultaneously applying the FS laser and the TiS laser.

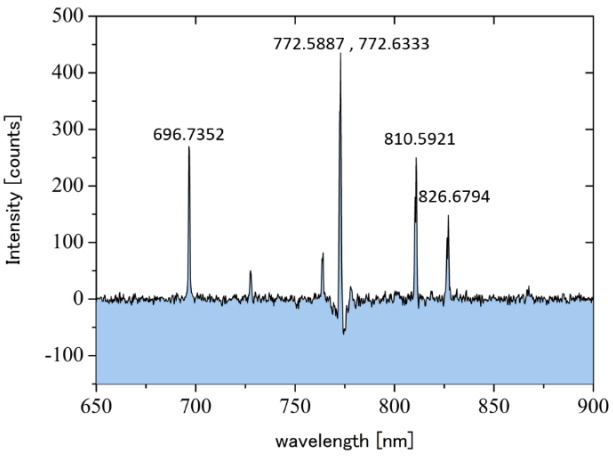

Fig.2. The change of emission spectrum by irradiating a FS laser

3.2 *active LIF spectroscopy*

The velocity distribution function has been measured by tuning the wavelength of TiS laser. Figure 3 shows LIF spectrum with and without the FS laser. The TiS laser is tuned to a wavelength 696.7352 nm. The argon neutral particles are excited to the upper level, are deexcited to the lower level, and emit photons of 826.6794 nm.

As seen in Fig.3, the peak intensity of the LIF spectrum increases 15 % by FS laser compared with the conventional LIF method. The temperatures of velocity distribution function for two cases are almost the same (~0.03 eV) and the difference of LIF spectrum is attributable to the effect of the FS laser. Figure 3 shows that the population of excited atoms is increased by the FS laser, and that the generated atoms are measured with the probe LIF system. The detailed results will be given in the poster session.

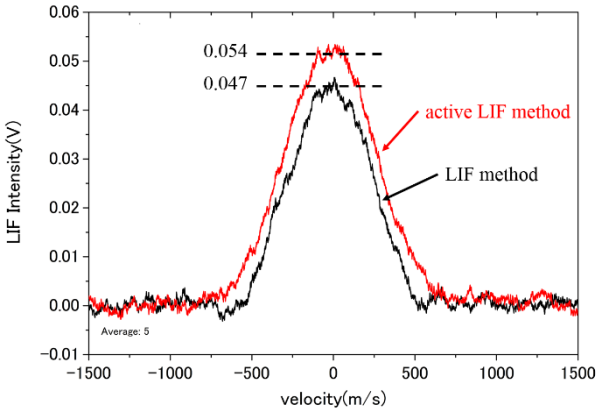

Fig.3. Velocity distribution function measured by active LIF spectroscopy

4. Conclusion

In this experiment, the interaction with a FS laser and an argon plasma has been examined by measuring in the change of plasma emission spectrum. It has been confirmed that the excited atoms are generated by the FS laser. Active LIF spectroscopy has been applied to 5 different of wavelengths, and all the intensity of the velocity distribution functions have increased. We have confirmed in the experiment that the application of FS laser may improve conventional LIF system by using FS laser.

To improve the active LIF method, it is desirable to decrease the noise from LIF signal because the stray light from the FS laser is collected by the optics. Secondly, it will be important to increase the FS laser power by focusing the FS laser beam. It is expected to increase the population of target particles.

Acknowledgments

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References

[1] M. Aramaki et al., Rev. Sci. Instrum. 80 (2009) 053505