§7. Development of Supersonic Metastable Helium Pulsed Beam for Plasma Diagnostics

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We have tried to measure the electric field (*E*-field) formed in various plasmas by means of laser-induced fluorescence (LIF) polarization spectroscopy. In this scheme, atoms in the metastable helium level, 2 ^1S, are excited to n ^1D levels (n=3 or 4) due to forbidden excitation using a dye laser, and only the polarization of the subsequent LIF is observed, because it is a function of the *E*-field. For plasmas without helium gas, however, the metastable helium atoms have to be introduced into the plasma of interest. Moreover, to measure the *E* field with high spatial and temporal resolution, the development of an intense, collimated, short pulselength, metastable helium beam source is essential.

We have developed a helium atomic beam and examined the spatiotemporal behavior of it using a fast ionization gauge (FIG). As a result, a supersonic beam with short pulselength (~300 μs), narrow divergence (~1.1°), and high density (~1.4×10^{14} cm^{-3}) at a distance of 20 cm from the beam source exit was obtained. The detail of this beam source is described in Ref. [1].

In this fiscal year, the excitation of the metastable atoms in the pulsed atomic beam was performed by a Penning-type discharge, in which a pair of disk cathodes, an anode, and permanent magnet disks behind each cathode were installed at a distance of 20 cm from the skimmer. This particular configuration of the electrodes and the magnets allows the electrons to ionize the atoms efficiently even at less than 10 mTorr. The magnetic field strength on the beam axis was ~300 G, and the discharge voltage applied between the electrodes was V_d=1 to 3 kV. Spectroscopic observations were carried out using a visible spectrometer (NIKON G500, f=50 cm, *F*/10, 1200 grooves/mm) with a charge coupled device (CCD) camera for measuring time-integrated spectra and a photomultiplier tube for measuring the temporal evolution of specific spectral lines.

The temporal evolutions of atomic spectral lines at 492.2 nm (2 ^1P-4 ^1D), 501.6 nm (2 ^1S-3 ^1P), and the He^+ ion spectral line at 468.6 nm (3*D*-4*F*) are shown in Fig. 1 (V_d=3 kV). For reference, the temporal profile of the helium atomic beam measured using the FIG is also represented. As is clearly shown, the spectral emissions of neutral atoms follow the atomic beam. Moreover, the fact that emission from He^+ ions was also observed implies that it is likely that a high-temperature plasma is produced by the Penning discharge.

The dependence of spectral intensity (388.9 nm (2 ^3S-3 ^3P) and 501.6 nm) on the discharge voltage applied between the electrodes was also examined (see Fig. 2). It was found that, upon increasing the voltage, the emission intensity increased almost linearly. This suggests that the population densities of excited levels increase with discharge voltage.

In summary, the excitation of metastable helium atoms in the supersonic atomic beam was performed using a Penning-type discharge. Spectroscopic observations indicated that the temporal behaviors of neutral atom and ion emissions were almost the same as that of a helium beam density profile and, upon increasing the discharge voltage applied between the electrodes, the spectral intensity increased almost linearly. Moreover, the fact that ion emission was observed showed that a high-temperature plasma would probably be generated by the Penning discharge.

1) Namba, S., Andruczyk, D. *et al*., Jpn. J. Appl. Phys. **45** 10B (2006) 8099.

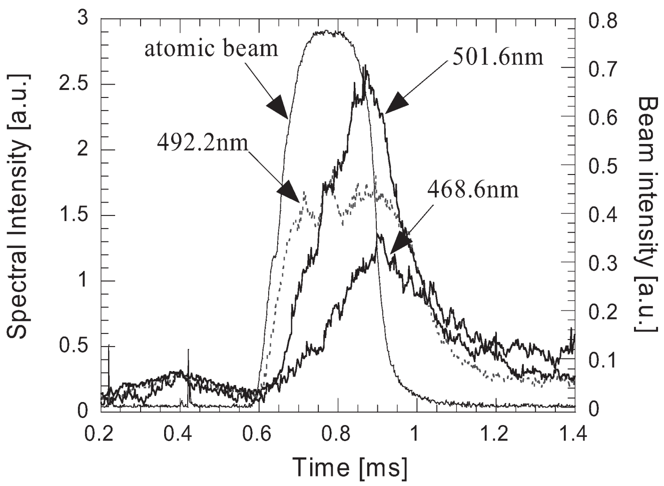

Fig. 1. Temporal behaviors of atomic (492.2, 501.6 nm) and ionic (468.6 nm) emissions. For reference, time evolution of atomic beam is also shown.

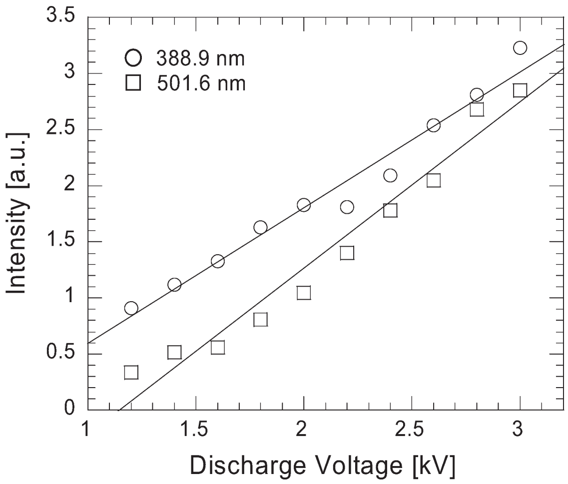

Fig. 2. Dependence of emission intensity of 388.9 nm (2 ^3S-3 ^3P) and 501.6 nm spectral lines on discharge voltage.