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High-Resolution Optical Measurement of High-Density Helicon Plasma.
高密度ヘリコンプラズマの高分解能分光計測

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In order to realize a long-term space missions, a new type of electrodeless plasma rocket engine is promising. Our proposed scheme is based on a high-density (~10^{13} cm^{-3}) helicon plasma source with an electrodeless electromagnetic acceleration. However, characterization of helicon plasma parameters and a demonstration of this scheme are not enough. To characterize plasma parameters, we have developed an optical measurement system, which has no perturbation to plasma and has a flexible positioning with high-time resolution. In this presentation, we will report a development of multi-channel (32 channels) photomultiplier system with a Czerny-Turner monochromator, followed by an axial distribution of an ion velocity using a single channel photomultiplier tube (PMT).

1. Introduction

It is important for a long-term space missions to extend lifetime of a plasma rocket engine. However, it has a problem of erosion and contamination of electrodes due to direct contact with plasmas. To overcome this problem, we have been developing a new type of an electrodeless plasma rocket engine [1]. Our proposed scheme is based on a high-density (~10^{13} cm^{-3}) helicon plasma source with an electrodeless electromagnetic acceleration.

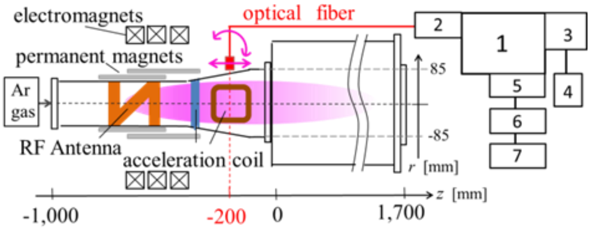
Since a demonstration of the scheme and characterization of helicon plasma parameters are not enough, for the purpose of finding optimum experimental conditions, the plasma flow measurement is essential. Here, an optical method has advantages such as non-invasive and convenient system, e.g., [2].

This study aims to measure an ion flow velocity and its temperature by using a high-resolution spectrometer (Ritu Oyo Kougaku Co., ltd., Czerny-Turner type MC-150: focal length of 1.5 m, 2400 lines/mm grating, 0.006 nm resolution). Since a Czerny-Turner type monochromator can take the line emission spectrum from plasma, rotating a diffraction grating is required to obtain the spectral distribution. However there are some problems that the diffraction grating motor causes backlash error and time resolution is pooh. In order to solve these problems, a multi-channel photomultiplier tube (PMT) array (Hamamatsu H7260-20: 32 channels) system is necessary.

We will show a measurement result of an ion velocity distribution using a scanning system with a single PMT, and then initial setup of the developed optical system with the multi-channel PMT.

2. Experimental Setup

Experiments using a single PMT have been carried out in the Large Mirror Device (LMD) [3], as shown in Fig. 1.



1: monochromator, 2: optical fiber,
3: photomultiplier (PMT), 4: high voltage supply,
5: motor unit, 6: drive unit, 7: motor controller.

Fig. 1　Schematic diagram of spectroscopic measurement system and Large Mirror Device.

This device consists of a quartz tube part and a vacuum chamber one. The quartz tube has a tapered shape [1,000 mm in axial length and 100~170 mm in inner diameter (i.d.)] to prevent a wall loss of plasma. The vacuum chamber (1,700 mm in axial length and 445 mm i.d.) has several windows for observations. Plasma is generated by a radio frequency (rf) power through a half-helical antenna. The pulsed discharge duration time is 75 ms with a duty of 1/20.

Receiver optics of spectrometer uses an object lens and an optical fiber. In order to extend the measurement area including the generation and the acceleration area, we have developed a scanning system; We can observe the region of z = -700 ~ -100 mm and r = -80 ~ 80 mm.

3. Experimental Results by Single PMT

Figure 2 shows ion velocity distribution functions (IVDF) obtained by Ar discharges using the LMD and an Ar glow lamp. From IVDF we can obtain an ion velocity as shown in Eqs. (1).

$$v = c\Delta\lambda/\lambda_0 \qquad (1)$$

Here, c is the speed of light, $\Delta\lambda$ is the wavelength of the ion Doppler shift, and λ_0 is the original wavelength. Figure 2 shows ion velocity of ~2,200 m/s at z = -230 mm and r = 0 mm.

Figure 3 shows axial profiles of ion velocities by the monochromator, a laser-induced fluorescence (LIF) method [4] and a Mach probe. Here, the trend of the velocity by the monochromator is fitted to the trend by the others. We have developed an optical system with a single PMT.

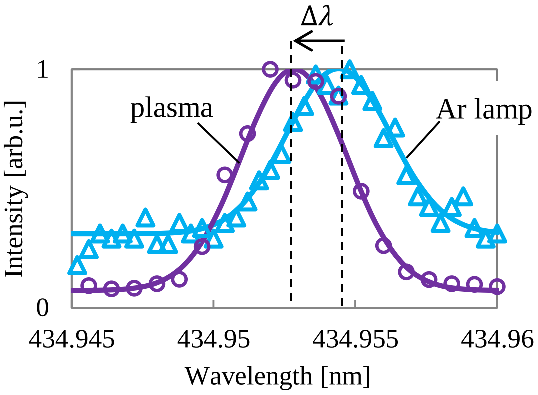


Fig. 2 IVDF at z = -230 mm and r = 0 mm.

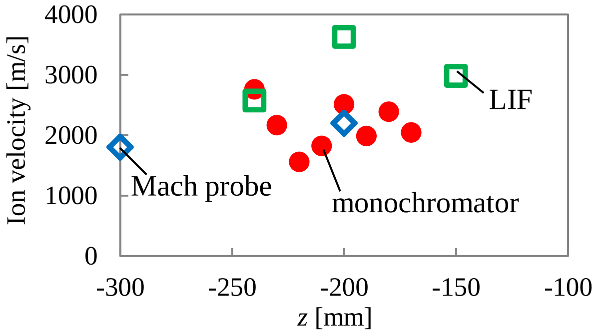


Fig. 3 Axial profiles of ion velocity distribution.

4. New Optical System Using Multi-channel PMT

We need to reconstruct the optical system using the multi-channel PMT. Figure 4 shows details of this system with two cylindrical lenses used to magnify the image approximately 200 times in the wavelength direction. After making a rack for additional lenses and mirrors, as shown in Fig. 5, we will make initial calibration leading to the measurement.

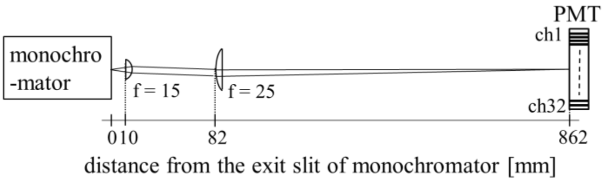


Fig. 4 Magnifying optical system.

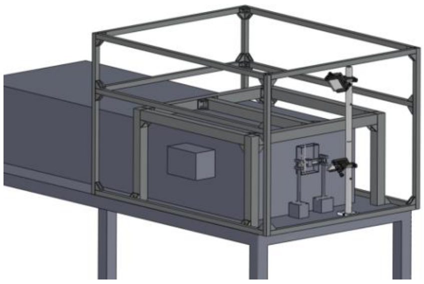


Fig. 5 The rack for multi-channel optical system.

5. Conclusion

In order to measure the plasma parameters, we have been developing a new spectroscopic system with multichannel PMT.

In this presentation, we will show measurement results of an axial distribution of ion velocity with single PMT followed by the developed optical system with multi-channel PMT.

References

[1] S. Shinohara, H. Nishida, T. Tanikawa, T. Hada, I. Funaki and K.P. Shamrai, IEEE Trans. Plasma Sci. **42** (2014) 1245.

[2] S. Waseda, H. Fujitsuka, S. Shinohara, D. Kuwahara, M. Sakata, H. Akatsuka, Plasma Fusion Res. **9** (2014) 3406125.

[3] S. Shinohara, S. Takechi and Y. Kawai, J.Appl. Phys. **35** (1996) 4503.

[4] N. Teshigahara, S. Shinohara, Y, Yamagata, D. Kuwahara and M. Watanabe, Plasma Fusion Res. **9** (2014) 3406055.

[5] H. Yamada and S. Hamaguchi, J. Appl. Phys. **96** (2004) 6147.