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Measurement of ion temperature and flow in RF start-up plasmas on Spherical Tokamaks

球状トカマクにおけるＲＦプラズマのイオン温度及びフロー計測

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Visible Doppler spectroscopy is widely used as a method for measuring plasma flow and ion temperature of tokamak plasmas. The method has been applied to a low density plasma (n_e~$1\times10^{17}m^{-3}$) of in the TST-2 spherical tokamak device, where the plasma current was sustained by lower hybrid wave (LHW) power. Since precise spectroscopic measurement was difficult due to the low-density and the low-temperature feature of the plasma, a new measurement system has been constructed. As a result high precision measurement for low-density plasma has become possible.

1. Introduction

The realization of economical nuclear fusion reactor is one of the most important targets of nuclear fusion research. Economically competitive tokamak reactor may be realized at low aspect ratio ($A = R_0/a$) configuration if the central solenoid (CS) can be eliminated [1]. Therefore, spherical tokamak (ST) has been attracting attention as an efficient and compact fusion reactor. Formation of advanced tokamak plasma without CS was achieved on JT-60U [2]. Plasma current ramp-up by lower hybrid wave (LHW) power in ST was demonstrated in TST-2 [3]. In TST-2, LHW is launched from a capacitively-coupled combline antenna (CCCA), which is located just inside the vacuum vessel [5].

The diagnostics of the LHW sustained plasma is very important in order to elucidate the physical phenomena. However it is necessary to maintain the density at a low value to keep the current drive efficiency. In such a situation, impurity line emission from the plasma is very weak, and visible Doppler spectroscopy becomes difficult. Therefore, a new measurement system has been constructed.

2. Experimental setup

2.1 *TST-2 Spherical Tokamak*

The Tokyo Spherical Tokamak-2 (TST-2) device is a small sized tokamak located at the Kashiwa campus of the University of Tokyo. Typical parameters of TST-2 are major radius R ~ 0.38 m, minor radius a ~ 0.25 m, aspect ratio A ~ 1.5, magnetic field strength at the center of the plasma B = 0.3 T, plasma current for Ohmic discharges I_p < 120 kA and the discharge duration t ~30 ms, for LHW start up, plasma current I_p < 15 kA and the discharge duration t ~120 ms.

2.2 *Visible Doppler spectrometer system*

Since impurity ions emits specific line spectra, it is possible to identify the impurity ions from their wavelengths. Furthermore, using a spectrometer with a good spectral resolution, the Doppler shift and the Doppler broadening of a line spectrum can be measured. As a result, it is possible to measure the ion temperature and the ion flow. For the case of the present target plasmas. The visible spectrometer system consists of a collection lens, bundle optical fiber, grating monochromator and a multi-anode photomultiplier tube (PMT). The fiber is used to transfer the plasma light focused by the collection lens to the entrance slit of the spectrometer.

In order to measure the absolute velocity of the flow, pairs of symmetric lines of sight are measured. When we measure the toroidal (poloidal) flow, we measures the two symmetrical lines of sight in the equatorial plane (poloidal plane) and calculate the difference of the velocities. As long as the flow has the toroidal (up-down) symmetry, we can eliminate the offset (zero velocity point) in measured velocity. Thus, a new multiple line of sight system was designed and fabricated. The system has many drilled holes, into which we insert the optical fiber, and the line of sight can be tilted vertically and horizontally as a result. The system is attached to a vacuum window. Top view of the lines of sight and the other optical components are shown in Fig.1. The red circle indicate the inside area of the outboard limiter (R = 585 mm).

As mentioned earlier, the line of sight can be tilted vertically and horizontally symmetrically.

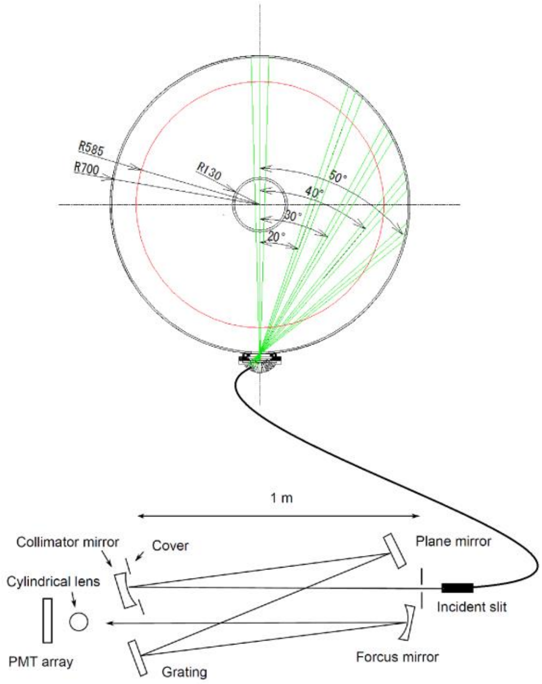

Fig.1. Optical system of the spectroscopy and the line of sight (green line).

3. Experimental results for Ohmic plasma

In LHW sustained plasma on TST-2, CⅢ (464.7 nm) is one of the brightest line emissions in the visible spectrum. Before measuring the plasma, the new system has been tested for Ohmic plasmas in TST-2, and radial distribution of the CⅢ line was obtained. Figure 2 shows a typical time evolution of the plasma current where the measurements were performed. Figure 3 shows the time evolution of the obtained quantities for toroidal lines of sight. Different curves (with different colors) represent the difference of the tangency radius.

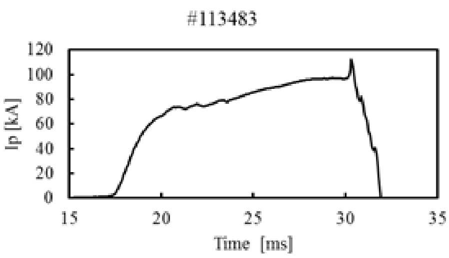

Fig.2. the time evolution of the plasma current for the typical discharge that made the measurement.

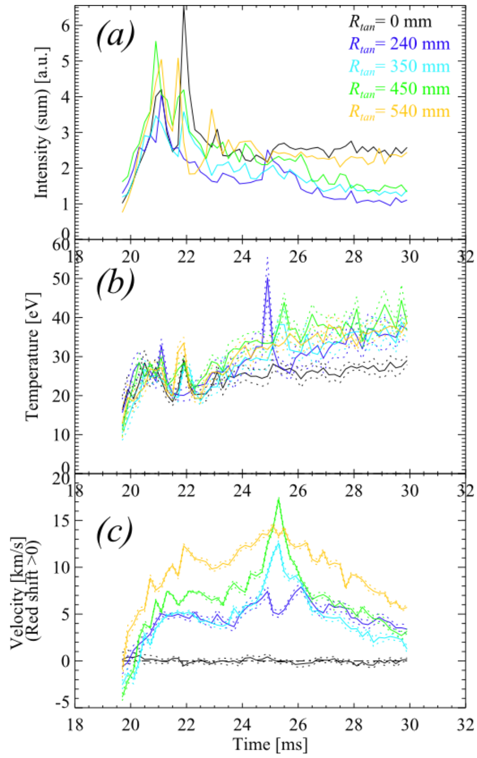

Fig.3. The time evolution of intensity (a), temperature (b) and flow (c) for toroidal lines of sight. Different curves (with different colors) represent the difference of the tangency radius. The flow is defined as a positive when it is directed along the direction of plasma current.

When the tangency radius R_{tan} is 0 - 450mm, the ion temperature shows almost the same behavior. However, the ion temperature becomes higher when R_{tan} is 540mm. Furthermore, the flow flips its polarity when R_{tan} crosses R_{tan} ~ 540mm.

Acknowledgments

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