§17. Development of GHz Spectroscopy System for Electric Field Measurement by Stark Spectroscopy

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In fusion plasma research and development, Doppler spectroscopy of line emission from plasma or impurity ions is a standard technique to measure ion temperature and flow velocity. Although this measurement is a "line-integretad" observation, it has an advantage of non-contact diagnostic without degrading the plasma performance. Under the strong magnetic field or electric field, the line spectra are broadened by the Zeeman effect and the Stark effect, respectively. Therefore, information about magnetic or electric fields can be extracted from this non-contact measurement of spectroscopy. In recent research on the Tore Supra, which is a large Tokamak device, the electric field on the front of the Lower Hybrid (LH) wave antenna was measured from its Stark effect [1]. This system employs the Dynamic Stark measurement technique, which analyzes the time integrated emission spectra from deuterium atom in high frequency electric field region. It's a powerful tool to measure the electric field; however, this technique cannot directly measure the AC electric field or fast phenomenon which generates the electric field. Therefore, we are developing a new diagnostic system which can measure high frequency electric fields for measuring the ICRF AC electric field (20-40 MHz), or transient electric field induced in magnetic reconnection event (less than 30 μs). Since the spectroscopic measurement requires many photons for statistical processing, we employ the conditional averaging technique after the GHz photon counting.

Development of the new system was carried out on the Large Mirror Device (LMD) at the Tokyo University of Agriculture and Technology (TUAT), which is shown in Fig. 1 (a). This device aims the particle acceleration using the helicon antenna (7 MHz), therefore the measurements of accelerated ion flow or 7 MHz fluctuation are necessary to evaluate the performance of the helicon plasma. Figure 1 (b) shows the optical part of the system, constructed with the monochromator (f=1.5 m, 2400 groove/mm), three lenses, two mirrors, 32 channel Photomultiplier tube (PMT) array, I/V converter circuits, and 32 channels digitizer (1 GHz sampling, 200 MHz frequency bandwidth). Figure 2 shows the time evolution of the measured output signal of the test photon detected on the PMT. The pulse length is less than 5 ns using 51 ohm resistance as an I/V converter circuit, and digitizer frequency bandwidth of 200 MHz. As the achieved performance of the spectroscopy, the instrumental FWHM is 0.01 nm, reciprocal liner dispersion is 0.0013 nm/ch, and measurable region is 0.04 nm. As the result of this lens alignment, the spectroscopic system was developed with GHz-ordered fast response and with good wavelength resolution.

Since the effects of the assumed ion flow velocity (less than 10 km/s) and electric field (less than 1 kV/cm) are sufficiently small, the ion flow and electric field can be measured in the measurable region of current alignment. However, because the effects are small, the instrumental FWHM and reciprocal liner dispersion should be smaller than the current alignment to reduce the error. The better alignment and the experiment for the demonstration of this system are future works.

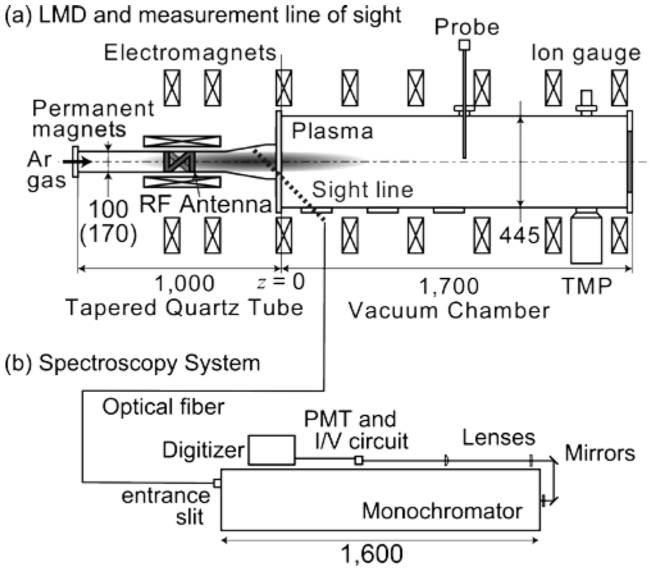

Fig. 1. (a) Cross-sectional view of the LMD, Helicon plasma and the line of sight of the system. The ion flow accelerated by the RF antenna can be measured by the system. (b) The spectroscopy system with a monochromator, three lenses, a PMT array, I/V circuits, and 32 channels GHz sample digitizer.

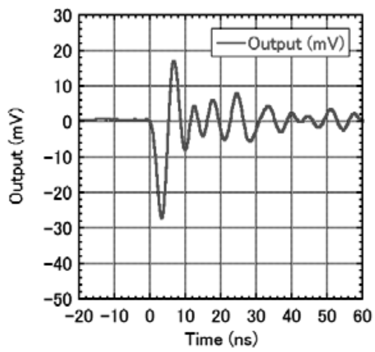

Fig. 2. Time evolution of the measured output signal of the test photon detected on the PMT.

1) Klepper, C. C. et al.: Phys. Rev. Lett. **110,** 215005 (2013).