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GAMMA 10におけるThomson散乱計測システムの進展
Progress of the Thomson scattering system in GAMMA 10

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Thomson scattering (TS) measurement is one of the most reliable diagnostic to measure the electron temperature and density in plasmas. In GAMMA 10, the yttrium-aluminium-garnet (YAG)-TS system has been constructed with the large solid angle of TS collection optical system. In the former experiments, we could measure the electron temperature and density at only one radial position in a single plasma and laser shot. We added the observing channels with adding the optical fibers, polychromators and oscilloscopes. We successfully obtained the multi-positions radial electron temperatures and densities in a single plasma and laser shot. We had successfully constructed double-pass TS system of a polarization based system with image relaying optics and had the doubly increased TS signals. In order to increase TS signals more, we are developing the multi-pass TS method of a polarization based system. This scheme can be implemented by modifying a basic single-pass TS system with the addition of polarization devices, a high-reflection mirror, and lenses for the image relaying of the laser beam. We successfully constructed the multi-pass TS system.

GAMMA 10 is an effectively axisymmetrized minimum-B anchored tandem mirror with barrier and plug at both end-mirrors. In GAMMA 10, the typical electron density, electron and ion temperatures are about 2×10^{12} cm^{-3}, 0.1 keV and 5 keV, respectively. The YAG-TS system is constructed with the laser, the incident optics, the light collection optics, the signal detection electronics, and the data recording system. A 10 Hz Nd:YAG laser (Continuum, Powerlite 9010) with an energy per pulse of 2 J and a pulse width of about 10 ns, operating at the fundamental wavelength of 1064 nm is used. The laser beam is injected to the plasma from the down side port though the a focusing lens of f = 2 m. The laser beam diameter at the plasma center is about 1 mm. For the light collection optics, we used the spherical mirror with $Al:SiO_2$ coated, curvature radius of 1.2 m and diameter of 0.6 m. The scattered light is collected by the spherical mirror, reflected and reaches a bundled optical fiber with cross-section of 2×7 mm. The magnification of the collection optics is 2.2. The length of scattering volume along the laser is 15.4 mm and scattering angle is 90°. A solid angle of 0.078 sr can be realized of the light collection optics. After passing through the plasma, the laser beam is ejected from the upper side port and absorbed by the beam dump. The 6.67 m long bundled optical fiber (Mitsubishi Densen, FS10-43001A) is connected to the 5 channel polychromator. The bundled optical fiber has 5 channels and each channel is constructed by 48 fibers with the core diameter of 400 μm and the very large numerical aperture of about 0.47. The 5 channel polychromator (TS139) is on loan from the national institute for fusion science (NIFS). We constructed new two polychromators (TS056 and TS149) with new Si-APDs (PerkinElmer, C30659-1060-3AH) with preamplifier. Four-channel high speed oscilloscopes (Tektoronix, DPO4034B, and two IWATSU, DS5524) were used to measure four wavelength channels simultaneously with bandwidth of 350 MHz and 200 MHz, and sampling rate of 2.5 GS/s and 1 GS/s, respectively.

We apply the YAG-TS system to measure electron temperature and density in the GAMMA 10 plasma. The radial electron temperature and density profiles are successfully obtained. Moreover, we show the newly constructed multi-pass TS system that uses polarization optics, and we demonstrate the results of the multi-pass TS system installed in GAMMA 10 with Rayleigh and Raman scattering experiments.