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Development of Thomson scattering system in the tandem mirror GAMMA 10
タンデムミラーGAMMA 10におけるトムソン散乱計測システムの進展

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In the tandem mirror GAMMA 10, the yttrium-aluminium-garnet (YAG)- Thomson scattering (TS) system was constructed for electron temperature and density measurements. We can successfully measure the radial profiles of electron temperature and density in the central cell of GAMMA 10 by using the YAG-TS system in a single plasma shot in a single laser shot. Moreover, in order to increase the TS signal intensities, we have constructed a multi-pass TS system of the polarization based system with image relaying optics. The clear TS scattering signals from first to forth passing lasers through the GAMMA 10 plasma were obtained.

1. Introduction

Thomson scattering (TS) is one of the most important diagnostic to measure the electron temperature and electron density in fusion devices [1-4]. The tandem mirror GAMMA 10 is an effectively axisymmetrized minimum-B anchored tandem mirror with thermal barrier at both end-mirrors [5,6]. The x-axis and y-axis are perpendicular to the magnetic field in the vertical and horizontal directions, respectively. The z-axis is parallel to the magnetic field. In the tandem mirror GAMMA 10, the lengths of central, anchor and plug/barrier cells are 6.0, 4.8 and 2.5 m, respectively. The anchor cells are located at both sides of the central cell and consist of minimum-B mirror field which is produced by a base ball coil. The plug/barrier cells are located at both ends of GAMMA 10, where the electron confinement potentials and ion confinement potentials are produced by the application of plug and barrier electron cyclotron heating (B/P-ECH). The hydrogen plasma is created by plasma guns, and heated and sustained using ion cyclotron heating (ICH) systems. The typical electron density, electron and ion temperatures are about 2×10^{18} m^{-3}, 40 eV and 5 keV, respectively, in normal hot ion mode plasma. The plasma diameter is approximately 0.36 m. In GAMMA 10, a ruby-laser TS system had installed to measure the electron temperature [3]. However, the system experienced problems and removed. In 2008, we started to design yttrium-aluminium-garnet (YAG)-TS system for measuring electron temperature and density in a single plasma shot in a single laser shot. We constructed GAMMA 10 YAG-TS system for measuring electron temperature and density in a single plasma shot in a single laser shot [4]. In order to obtain the radial profile of TS signals in five radial positions in a single plasma shot, we added four filter-type polychromators with avalanche photodiodes (APD) and four high speed oscilloscopes. We apply the multi-position measuring YAG-TS system in the GAMMA 10 plasma to measure the electron density and temperature radial profiles in a single plasma shot and a single laser shot. Moreover, we developed a new multi-pass TS system [7-10]. This multi-pass TS scheme effectively increases the scattering signal intensity from plasmas and can be implemented by modifying a basic single-pass TS system with the addition of polarization control device, a high-reflection mirror, and lenses for the image relaying of the laser beam. The configuration of the multi-pass TS system in GAMMA 10 can be used to realize perfect coaxial multi-passing at each pass.

In this paper, we present the developed GAMMA 10 YAG-TS system and the results of electron temperature and density radial profile measurements in GAMMA 10. Moreover, we show the results of the electron temperature measurements acquired by using the new multi-pass TS system.

2. YAG-TS system in the tandem mirror GAMMA 10

The YAG-TS system is installed at z = 0.6 m in the central cell of GAMMA 10. It is constructed with the laser, the incident optics, the light collection optics, the signal detection electronics, and the data recording system (Fig. 1). A 10 Hz

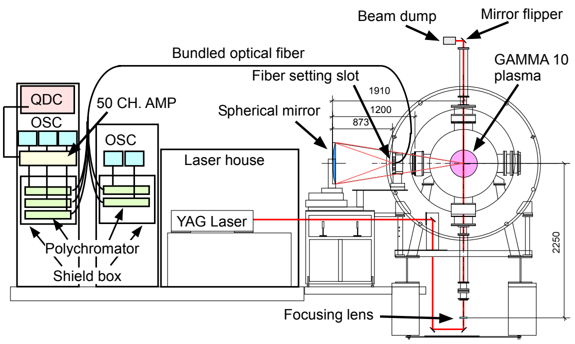

Fig. 1. Schematic diagram of GAMMA 10 TS system.

Nd:YAG laser (Continuum, Powerlite 9010) with 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 diameter at the plasma center is about 1 mm with a focusing lens. The polarization of the laser in the plasma is perpendicular to the plane of the Fig. 1 (z-direction). The 90° scattered light is collected by the spherical mirror, reflected and reaches two sets of five channels of bundled optical fibers. A solid angle of the collection optics is 0.078 sr. The five channels of bundled optical fibers are connected to the five filter-type polychromators with avalanche photodiodes. Four-channel high speed oscilloscopes were used to measure the four wavelength channels, simultaneously.

3. Electron temperature and density measurements

We applied the YAG-TS system to measure the electron temperature and density in GAMMA 10. The plasma is produced for the end divertor-module experiments, and is not the normal hot ion mode plasma. We could successfully obtain the radial profiles of electron temperature and density obtained by using YAG-TS system in a single plasma and laser shots. At the plasma center, the electron temperature and density are about 20 eV and 2×10^{18} m^{-3}, respectively. The radial profiles of electron temperature and density are almost the same as those obtained by using soft X-ray intensity measurement system.

We developed and applied a new multi-pass TS system in the tandem mirror GAMMA 10. The system allows a laser pulse to be focused multiple times onto the scattering volume to increase the number of scattering photons. The integrated TS signals from passes 1–4 in the multi-pass configuration were about three times larger than that in the first pass. The resolution of the electron temperature measurement was improved by the multi-pass TS system. We have successfully constructed the multi-pass TS scattering system and have obtained multi-pass TS signals for electron temperature measurements for the first time.

4. Summary

We can successfully measure the electron temperature and density radial profiles in GAMMA 10 by using YAG-TS system in a single plasma and laser shot. Moreover, we developed the new multi-pass TS system and successfully obtained the four passing TS signals to obtain the electron temperature measurements.

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