22P111-P

Electron Temperature and Density Measurements by Using Thomson Scattering System in GAMMA 10

GAMMA 10 における Thomson 散乱計測システムを用いた
電子温度・電子密度計測

Masato Morimoto[1], Masayuki Yshikawa[1], Yoriko Shima[1], Junko Kohagura[1], Mizuki Sakamoto[1], Yosuke Nakashima[1], Makoto Ichimura[1], Tsuyoshi Imai[1], Kazuo Kawahata[2], Ichihiro Yamada[2], Ryo Yasuhara[2], Hisamichi Funaba[2], Takashi Minami[3], Yoshiaki Miyata[4]
森本真人[1], 吉川正志[1], 嶋頼子[1], 小波蔵純子[1], 坂本瑞樹[1], 中嶋洋輔[1], 市村真[1], 今井剛[1], 川端一男[2], 山田一博[2], 安原亮[2], 舟場 久芳[2], 南貴司[3], 宮田良明[4]

[1]Plasma Research center, University of Tsukuba, 1-1-1 Tennoudai, Tsukuba, Ibaraki 305-8577, Japan
[2]National Institute for Fusion Science, 322-6 Oroshi-cho, Toki-city, Gifu 509-5292, Japan
[3]Institute of Advanced Energy, Kyoto University, Gokasho, Uji-city, Kyoto 611-0011, Japan
[4]Japan Atomic Energy Agency, Naka Fusion Institute, 801-1 Mukouyama, Naka, Ibaraki, 311-0193, Japan
[1]筑波大学プラズマ研究センター　〒305-8577 茨城県つくば市天王台 1-1-1
[2]核融合科学研究所　〒509-5292 岐阜県土岐市下石町 322-6
[3]京都大学エネルギー理工学研究所　〒611-0011　京都府宇治市五ケ庄
[4]日本原子力開発機構　那珂核融合研究所　〒305-0193　那珂市向山 801-1

Electron temperature and density are important parameters to describe a state of plasma. In GAMMA 10, a YAG-Thomson scattering (YAG-TS) system was constructed in order to measure electron temperature under National Institute for Fusion Science collaboration program. We can successfully measure the electron temperatures shot-by-shot. We tried to estimate the electron density by comparing the results of TS experiments and the Rayleigh scattering experiments. We can successfully obtain the electron temperature and electron density by using the Thomson scattering system in GAMMA 10.

1. Introduction

Electron temperature and density are important parameters to describe a state of plasma. TS measurement is a highly reliable measurement of electron temperature and density in fusion devices and in the GAMMA 10 device. GAMMA 10 is the tandem mirror device that confines plasmas with magnetic mirrors and electrostatic potentials. In GAMMA 10, plasma is produced and heated by ion cyclotron radio frequency (ICRF) heating. In addition the electron in the central cell is directly heated by electron cyclotron resonance heating (ECRH).

In GAMMA 10, YAG-Thomson scattering (YAG-TS) system was introduced in 2009, and the first signal by the TS was obtained in 2010.

2. Thomson scattering

The TS is the elastic scattering phenomena by the free electron when an electromagnetic wave is injected. The incident electromagnetic wave is scattered and the wavelength of it is affected by Doppler shift by the electron thermal motion. The scattered spectrum has the Maxwell distribution and its half width of half maximum (HWHM) given by following expression (1),

$$\mathrm{HWHM} = 4\left(\frac{\lambda}{c}\right)\sin\left(\frac{\theta}{2}\right)\sqrt{\frac{2k_b T_e}{m_e \log 2}} \qquad (1)$$

Here, λ, c, θ, k_b, T_e and m_e are the wavelength of the incident electromagnetic wave, the velocity of light, the scattering angle, Boltzmann constant , electron temperature, and the electron mass, respectively.

According to the equation (1), all quantities except the electron temperature are given, and then the electron temperature is estimated by measuring HWHM of scattering spectrum.

In GAMMA10, we observed the scattering light of 90 degrees. The side view of the TS system in GAMMA 10 is shown in Fig1.

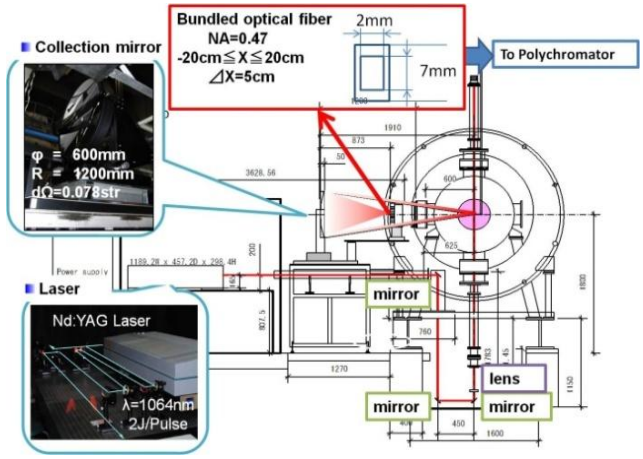

Fig. 1. The side view of the TS system in GAMMA 10.

3. Rayleigh scattering experiments

The Rayleigh scattering is the elastic scattering with atoms and molecules. In Rayleigh scattering experiment, we filled nitrogen gas in the GAMMA 10 vacuum vessel and reduced power of YAG-laser is injected in. Then we measured the scattering light. The Rayleigh scattering experiment is used for adjusting the optical system and calibration of optical sensitivity of total measuring system. It is important for estimation of the plasma electron density by the total measured photons in the TS signals.

4. Electron temperature and density measurement

In GAMMA 10, we can measure electron temperature to 500 eV and the signal to noise ratio is about 3 to 5. We can obtain electron temperature about 50eV during ICRF heating periods. With application of ECRH, electron temperature increased to about 100eV.

The numbers of the photons in the scattering phenomenon is given by the following equation (2),

$$N_f = \frac{P}{hc/\lambda} \cdot n \cdot L \cdot \sigma \cdot \Delta\Omega \cdot C_T \qquad (2)$$

Here, N_f, P, n, L, h, σ, $\Delta\Omega$, C_T, and λ are the number of photons, the laser energy, the density, the scattering length, the Plank constant, the scattering cross section, the solid angle, the transmission efficiency, and the laser wavelength, respectively.

We obtained the electron density at the plasma center $n_e = (2.1 \pm 0.5) \times 10^{18} m^{-3}$ during the ICRF period. The electron density obtained by the microwave interferometer is $n_e = 1.9 \times 10^{18} m^{-3}$. The electron density obtained by using the TS system is accord with that obtained by microwave interferometer. Then, we can successfully obtain the electron temperature and density by using the TS system in GAMMA 10.

5. Summary

In GAMMA 10, we successfully measure the electron temperature and density by using TS system. We obtained electron temperature about 50eV and electron density about $(2.1 \pm 0.5) \times 10^{18} m^{-3}$ during ICRF heating periods.

References

[1] M. Yoshikawa, et al., Plasma Fusion Res. 6, (2010) 1202095.
[2] K. Narihara, I. Yamada, H. Hayashi and K. Yamaguchi, Rev. Sci. Instrum. 72, (2001) 1122.