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Thomson Scattering Measurement for Lower Hybrid Driven TST-2 Spherical Tokamak Plasma

低域混成波で駆動されたTST-2球状トカマクプラズマのトムソン散乱計測

Hiro Togashi, Akira Ejiri, Hiroto Homma, Keishun Nakamura, Takashi Yamaguchi, Hirokazu Furui, Kazuhiro Imamura, Takuma Inada, Kenta Nakamura, Takahiro Shinya, Masateru Sonehara, Toshihiro Takeuchi, Shintaro Tsuda, Naoto Tsujii, Satoru Yajima, Yusuke Yoshida and Yuichi Takase

冨樫央，江尻晶，本間寛人，中村京春，山口隆史，古井宏和，今村和宏，稲田拓真，中村建大，新屋貴浩，曽根原正晃，竹内敏洋，津田慎太郎，辻井直人，矢嶋悟，吉田裕亮，高瀬雄一

The University of Tokyo,
Transdisciplinary Science Bldg. 413, Kashiwanoha 5-1-5, Kashiwa 277-8561, Japan
東京大学 〒277-8561 千葉県柏市柏の葉5-1-5 新領域基盤棟413

Non-inductive plasma current drive experiments using the lower hybrid wave (LHW) have been performed on the TST-2 spherical tokamak. In order to measure the electron temperature T_e, Thomson scattering (TS) measurements were carried out in plasmas with plasma current I_p ~10kA and line-averaged electron density $n_e \sim 2\times10^{17}$ m^{-3}. TS signal became detectable by averaging 25 TS data obtained from 25 reproducible discharges. The measured electron temperature was approximately 14 eV with an error of about 10 % near the plasma center.

1. Introduction

Study of spherical tokamak (ST) plasmas is important for fusion research [1]. An ideal ST reactor does not have a central solenoid, while presently it is installed in virtually all conventional and spherical tokamaks. Another scheme of plasma current start-up and ramp-up must be developed. In MAST and NSTX, merging compression and coaxial helicity injection schemes are developed, respectively [2,3]. In TST-2, LATE, and QUEST, one or more types of radio frequency (RF) waves, i.e., electron cyclotron wave (ECW) and lower hybrid wave (LHW) are utilized for the plasma start-up and sustainment [4-6]. In order to understand the behavior of these plasmas, it is important to measure the profiles of electron temperature T_e and electron density n_e, using a reliable technique such as Thomson scattering (TS). However, it is difficult to perform TS measurements in RF-driven plasmas with very low density (e.g., $n_e < 10^{18}$ m^{-3}) because the signal intensity is proportional to n_e. In QUEST, TS signal became detectable by accumulating TS signals obtained from many laser injections in a few long-pulse plasma discharges [7].

2. Experimental Setup

In the present experiment, TS measurements made in 25 discharges with high-reproducibility were used. Typical waveforms are shown in Fig. 1. The plasma current was driven mainly by the LHW and reaches 10 kA. Laser was injected at 80 ms, when the line-averaged electron density is $n_e \sim 2\times10^{17}$ m^{-3}. The major and minor radii of the plasma are R ~ 360 mm and a ~ 230 mm. Typical parameters for the TST-2 TS system are: the scattering angle ~ 120°, the solid angle of scattered light ~ 0.27 sr, the core diameter = 2 mm and the numerical aperture of optical fibers = 0.37. The measurement positions were R ~ 366, 389, 412, and 434 mm. We use a Nd: YAG laser with pulse width ~ 10 ns, energy ~ 1 J, and repetition rate = 10 Hz. TS light is transferred to bright polychromators with fast response [8].

3. Experimental Result

Black waveforms shown in Fig. 2 are background-subtracted TS signals detected by a polychromater (R ~ 389 mm), averaged over 25 laser pulses. In the analysis, the peak time of the TS signal was set at t = 50 ns, and the signal intensity was larger than the averaged intensity of the stray light. Therefore, these peaks are the TS signals. Red curves show fitted pulse shapes for each polychromator channel. Each pulse is integrated, and used for fitting by Maxwell distribution to obtain T_e. Signal intensities for spatial channels at R ~ 366 and 389 mm were relatively high and T_e was estimated to be 14.3 and 14.2 eV with fitting errors of ±2.4 and 0.8 eV, respectively. On the other hand, signal intensities for spatial channels at R ~ 412 and 434 mm were low and were not fitted well. The integrated TS signal intensity was about a factor of 15 lower compared to ohmically heated plasmas with line-averaged density of ~ 5×10^{18} m^{-3}. Therefore, calculated line-averaged density in the present experiment is ~ 3×10^{17} m^{-3} and it is comparable to that obtained by interferometry.

CIII line emission was observed by spectroscopy, while OV emission was not observed. Equilibrium temperatures of maximum abundance for these impurity ions are 5 and 20 eV, respectively. This indicates that the measured T_e of 14 eV is reasonable.

Hard X-ray measurements indicate the presence of fast electrons with an effective temperature of around 40 keV. Results of TS and X-ray measurements suggest that LHW generates fast electrons, which drives plasma current but does not contribute significantly to plasma heating due to their low collision frequency (low density) and poor confinement (low plasma current).

4. Summary

Electron temperature T_e measurement for ST plasma with ECH and LHCD in TST-2 has been performed. T_e was estimated from TS signals averaged over 25 TS data from 25 discharges with high-reproducibility. As a result, T_e was about 14 eV near the plasma center. Profile measurement of T_e and n_e will be carried out in near the future.

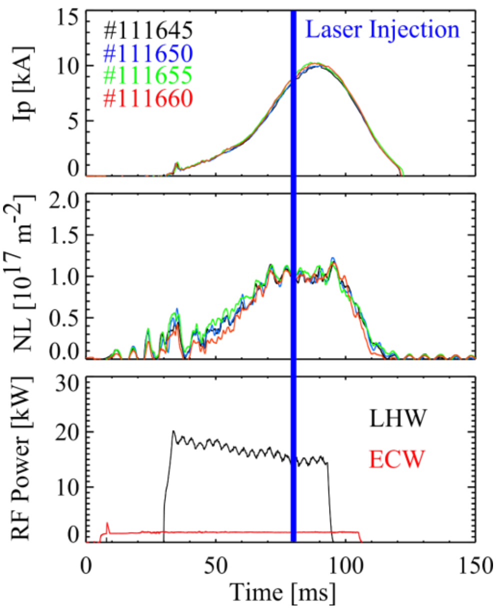

Fig.1. Typical waveforms in the present experiment. Blue line indicates the timing of laser injection at 80 ms.

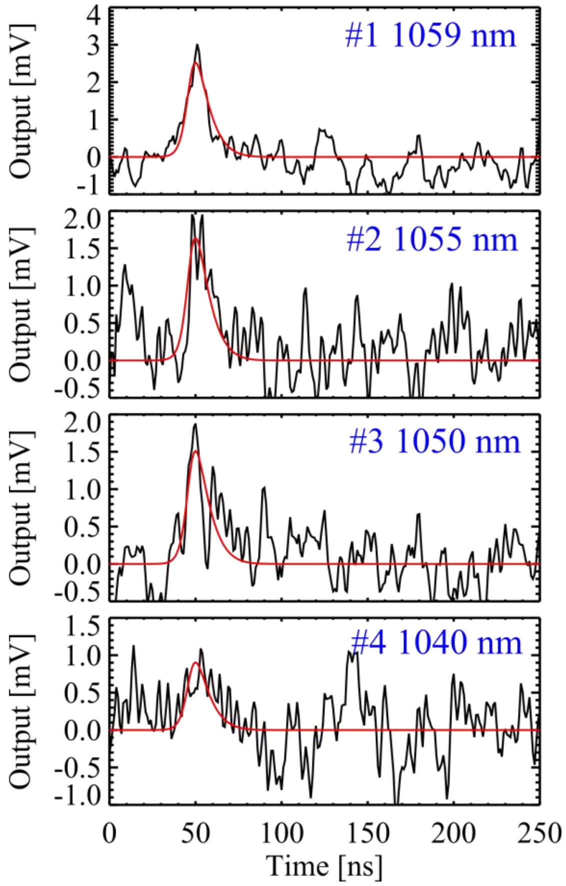

Fig.2. Background-subtracted TS signals detected in a polychromator at R ~ 389 mm (black) and the pulse shape fitting (red). Each channel is sensitive around a wavelength (blue) written in each plot.

5. Acknowledgements

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