Hard X-ray Measurement on the TST-2 Spherical Tokamak Plasma Driven by Lower Hybrid Wave Power

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

低域混成波で駆動されたTST-2球状トカマクの硬X線計測

The University of Tokyo, 5-1-5, Kashiwanoha, Kashiwa, Chiba 277-8561, Japan

Hard X-ray measurements are a method of estimating the fast electrons in RF plasmas. The measurements in the TST-2 spherical tokamak were performed for discharges with the injection of lower hybrid wave. There are two types of antenna for the RF injection; a grill antenna and a capacitively coupled combine antenna. Hard X-rays of the current driving direction (Co direction) and the anti-current drive direction (Ctr direction) were measured at the same time. It was found that the Co direction energy flux of hard X-rays is 10 times higher than the Ctr direction energy flux.

1. Introduction
The capability of plasma current start-up and ramp-up using lower hybrid wave in spherical tokamak (ST) has been investigated. Even in STs, lower hybrid wave (LHW) can be used for the plasma start-up phase if the plasma density is kept sufficiently low. Hard X-ray (HXR) measurements revealed that the fast electrons produced through the Landau damping of the LHW were responsible for the current drive [1].

Bremsstrahlung is emitted by electrons in the plasma, and HXRs imply the presence of fast electrons. Assuming that the fast electrons have a Maxwell distribution, it is possible to estimate the effective temperature of the fast electrons from the energy spectrum of HXR. X-ray measurements during LHW injection by using the grill antenna have been performed in the TST-2 [2]. Currently, X-ray is measured by using a capacitively coupled combine antenna (CCCA) [3]. Fast electrons exist to the Co direction, therefore it is examined that it is responsible for the current.

2. Measurement system
NaI scintillators and photomultiplier tubes (PMTs) are used for the HXR measurement. When a HXR enters the NaI scintillator, it emits visible light, and the number of photons is proportional to the HXR energy. In the PMT the visible light is converted to photo electrons and they are multiplied in the PMT. There are two same systems, they measure HXR of plasma center (Rtan = 410 mm) to Co and Ctr direction respectively.

The PMT and the NaI scintillator are covered by lead blocks and a lead collimator is placed in front of the scintillator. It is used to specify the direction of X-rays. Angular resolution of the lead collimator is Gaussian of $\sigma = 1.5^\circ$. Therefore, solid angle is $3.516 \times 10^{-4}$ sr. Here $^{57}$Co (122 keV) is used as the source. Both measurement and simulation results are generally consistent (Fig.1.).

![Angular resolution](image)

Fig.1. Angular resolution.

3. Measurement result
3.1 Measurements of Co and Ctr directed HXRs
Measurements of Co and Ctr directed HXRs were performed for the plasma with LHW injection. Maximum plasma current was 14 kA, and LHW power was 20 kW between 10 ms and 100 ms.

Spectra of the energy flux are shown in Fig.2. Here, the data from 10 discharges with
HXR measurements of LHW injected plasma has been performed. Fast electrons with the Co direction by using CCCA were more dominant by using grill antenna. Radial emission profile indicates that the fast electrons are concentrated near the plasma center.

**Acknowledgments**

This work is supported by Grants-in-Aid for Scientific Research (S) (21226021) of JSPS, Japan, The Second A3 Foresight Workshop on Spherical Torus, and by NIFS Collaborative Research Program NIFS14KOCR001.

**References**

