§44. Design and Initial Result of Collective Thomson Scattering System Using 77 GHz Gyrotron for Bulk and Tail Ion Diagnostics in The Large Helical Device

Nishiura, M., Kubo, S., Tanaka, K., Tamura, N., Shimozuma, T., Mutoh, T., Kawahata, K., Watari, T., LHD Experimental Group,
Saito, T., Tatematsu, Y., Notake, T. (FIR, Fukui Univ.)

The millimeter wave from 77GHz gyrotron has been recently installed into LHD for auxiliary electron heating and improvement of plasma confinements. The basic performance of 1.2 MW in a short pulse and 300 kW in a cw operation (the design spec is 800 kW with 10 seconds and 200 kW with more than 1000 seconds.) has been already demonstrated in plasma experiments. Now 168 GHz gyrotron is replaced by a new 77GHz one, and the antenna for 82.7 GHz can be used for receiving the scattered radiation. The incident probe and the receiving beams for scattering are steered by a couple of movable mirrors for the local plasma measurement. The steering mirror system can cover almost whole poloidal cross section of elongated plasma. The angle between the incident and scattered rays is more than 90 degrees, and becomes backscattering configuration. The Gaussian beam is used for plasma heating by the ECH system, and is optimized within ~ 5 cm in radius at the waist. Therefore the well defined beam is suitable for the scattering measurements.

The scattered power Ps is estimated using the following relation,

$$P_s = P_i \Gamma r_e^2 n_e d\omega \frac{\lambda_{s0}^2}{2\pi(2r_R \sin\theta_s)} S(k,\omega)$$

where

P_i: incident beam power,
r_e: classical electron radius,
n_e: electron density,
$d\omega$: band width,
r_R: beam radius,
λ_{s0}: wavelength of scattered radiation.

Background noise source would come from the electron cyclotron emission (ECE) practically. The background ECE level on the line of sight toward the receiver antenna is estimated to be a few hundredth and a few thousandth eV for T_e = 5 keV and 1 keV at the frequency of 77 GHz, respectively. The X-mode mainly dominates the background ECE noise in the frequency range. Since the multi reflection is ignored, the background noise level may be underestimated. Typically at the plasma edge, experimental parameters are given by P_i = 1 MW, Γ = 1, n_e = $1\mathrm{x}10^{19}$ m^{-3}, T_e = 1 keV, and $S(k,\omega)$ $=10^{-9}$~10^{-12}. Then $Ps/(d\omega/2\pi)$ introduced from Eq. (1) is compared with the background ECE noise. The SNRs estimated are 2200 for bulk ions and 20 for tail ions. For fast ion diagnostics we consider that the signal level would be very severe because of the influence on other overlapped system noises. Due to its complexity of magnetic field structure, there exists fundamental and second harmonic resonance simultaneously in any settings of magnetic field strength. Selecting the range of magnetic field can minimize the ECE background and avoid the absorption of scattered power.

The LHD shot#91756 is plotted as an initial result of Collective Thomson scattering diagnostics in Fig. 1. The channel numbers from 1 to 8 cover the frequency shift within 3 GHz from the 77 GHz center frequency. From the rough estimate, the measured spectra found to be similar to the theoretical spectrum shape in Fig. 2. The scattered radiation is sensitive to the plasma conditions, and therefore the careful analysis is still required to obtain the velocity distribution for electrons and ions.

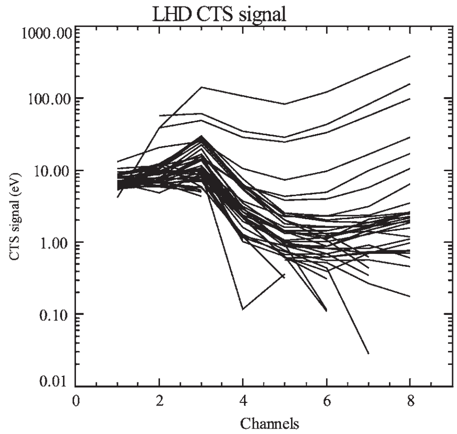

Fig. 1. Time evolution of scattered radiation signals during 3 second discharge of LHD. The scattered radiation within ± 3 GHz from 77 GHz probe beam in LHD is detected successfully by 8 channels every 20 ms.

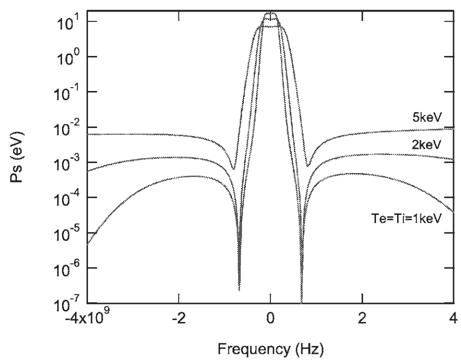

Fig. 2. Scattered power P_s is calculated as a function of frequency in LHD plasmas.

1) M. Nishiura, *et al.*, Rev. Sci. Instruments 79(2008)10E731.
2) S. Kubo, *et al.*, J. Plasma Fusion Res. 84 (2008)877.