§27. Study of Measurement System for 400 GHz Collective Thomson Scattering in LHD

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In FIR center, Univ. of Fukui, sub-THz frequency-range gyrotrons have been developed, and 400 GHz high-power pulse gyrotrons are now being developed.[1-5] A feasibility study of a 400 GHz gyrotron as a collective Thomson scattering (CTS) source had been investigated for LHD high density plasma of 10^{20} m^{-3}.[4-5] In result, it was found that the CTS in this frequency range is very attractive for LHD plasma. The CTS condition is satisfied for large scattering angle larger than 90 degrees, which provides good spatial resolution. The sub-THz wave does not suffer from refraction due to cutoff in plasma of the order of 10^{20} m^{-3}. Moreover, it is almost free from cyclotron absorption since its frequency is much higher than harmonics of the cyclotron frequency. Therefore, the background ECE is at a very low level.

This year, we have investigated the contribution of fast ions to the CTS spectrum and discuss the feasibility of detecting the fast ions with 400 GHz CTS measurement. Figure 1 shows a calculated CTS spectrum measured at the position we have investigated. Here, the frequency and the incident power of the probe beam are assumed as 400 GHz and 100 kW, respectively. Velocity distributions of electrons, bulk ions and fast ions are assumed as Maxwellians with the temperature of 0.5, 0,5 and 100 keV, respectively. Plasma density of 10^{20} cm^{-3} and 1 % density fraction of the fast ions to the total density are assumed. Figure 1 shows that the intensity of the fast ion term is dominant at the frequencies separated about several GHz from the center frequency (400 GHz). Thus, there is a possibility that information of the fast ions is obtained by the CTS measurement with 400 GHz frequency.

The usual CTS condition is $\alpha > 1$, where $\alpha = 1/k\lambda_D$, k is wave vector of the fluctuation and λ_D is the Debye length of plasma. However, the condition $\alpha > 1$ only guarantees that spectrum intensity of the bulk ion term is larger than that of the electron term around the center frequency. Thus, $\alpha > 1$ is the condition for the bulk ions and does not apply to fast ions. Since the temperature (energy) of the fast ions is much higher than that of bulk ions, the spectrum intensity becomes superior at the frequencies separated from the center frequency. Whether the fast ion term becomes dominant depends on the intensity of non collective scattering spectrum (electron term). It depends not only the electron velocity distribution function but also the factor $|1-\chi_e/\varepsilon_L|$, where ε_L is the longitudinal part of the dielectric tensor and χ_e is the electric susceptibility for electrons. The behavior of this factor is complicated, and it depends on directions of the incident probe beam, the scattering wave and magnetic field at the scattering point. Thus it is necessary to choose them properly in order for CTS spectrum of the fast ion term to be dominant and to give us the information of their velocity

1) T. Notake et al., Phys. Rev. Lett. **103**, 225002 (2009).
2) T. Saito et al., The Joint 34th International Conference on Infrared and Millimeter and Terahertz Waves, 09030089 (2009).
3) T. Saito et al., The Joint 35th International Conference on Infrared and Millimeter and Terahertz Waves, Th-E1.5 (2010).
4) Y. Tatematsu et al., The Joint 33rd International Conference on Infrared and Millimeter and Terahertz Waves, 1281 (2008).
5) Y. Tatematsu et al., 23rd IAEA Fusion Energy Conference,(http://www-pub.iaea.org/mtcd/meetings/cn180_papers.asp), FTP/P6-31 (2011).

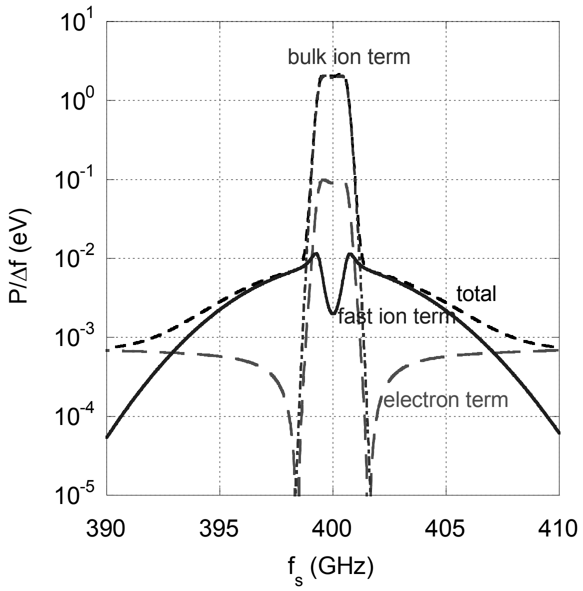

Figure 1: Scattering power spectrum in unit band frequency for $T_e = T_{bulk\ ion} = 0.5$ and $T_{fast\ ion} = 100$ keV, $n_e = 10^{20}$ m^{-3} and $n_{bulk\ ion}/n_e = 0.01$. Dot-dashed, long-dashed and solid lines represent power spectrum of bulk ion, electron and fast ion terms, respectively.