§43. Thomson Scattering System for Measurement of Ion Temperature Using a Quasi-Optical Gyrotron as a Radiation Source

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Collective Thomson scattering (CTS) has been traditionally used for measuring the electron and ion temperature in laboratory plasmas. Thus CTS play an important role in research into magnetic confinement of thermonuclear plasmas. The detected (scattered) signal is the one that originate due to the scattering of the electromagnetic radiation by the Debye cloud of electrons, which effectively surround each ion. The scattered radiation power $P_s(\omega)$ per frequency interval $d\omega$ into solid angle interval $d\Omega$ is:

$$P_s(\omega)d\Omega\, d\omega = P_i \Psi r_0^2 n_e L_{pl} S(\boldsymbol{k},\omega) d\Omega\, d\omega, \quad (1)$$

where P_i is source power, r_0^2 is classical electron radius, Ψ and L_{pl} are geometrical factors for the incident/scattered microwave beams and ω represents the differential frequency $\omega = \omega_S - \omega_I$ (the difference between scattered and incident ones).

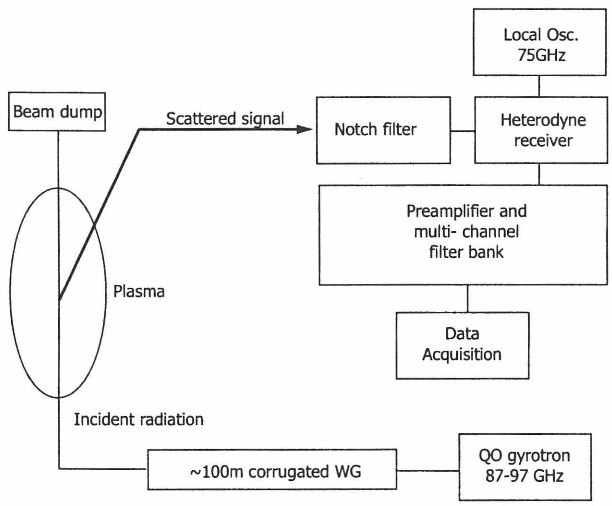

Fig. 1: Schematic layout of the scattering system

The proposed system (Fig. 1) for LHD will utilize the quasi-optical (Q. O.) gyrotron as a power source. The Q. O. gyrotron designed for operation at the fundamental frequency in the range of 92 ± 5 GHz. The advantages of Q. O. concept are the frequency tunability and the geometric separation between the spent electron beam and the microwave output. Above mentioned characteristics offers flexibility for experiments on fusion devices, where it may be advantageous to change the localization of power deposition zone (even for diagnostic usage) without changing the magnetic field and therefore affecting the plasma properties.

The expected scattered spectrum from LHD neutral heated plasma as a function of a Doppler shifted frequency from the gyrotron centered frequency is shown on the Fig. 2. For evaluating of the scattered form factor, so-called Salpeter approximation has been used[1].

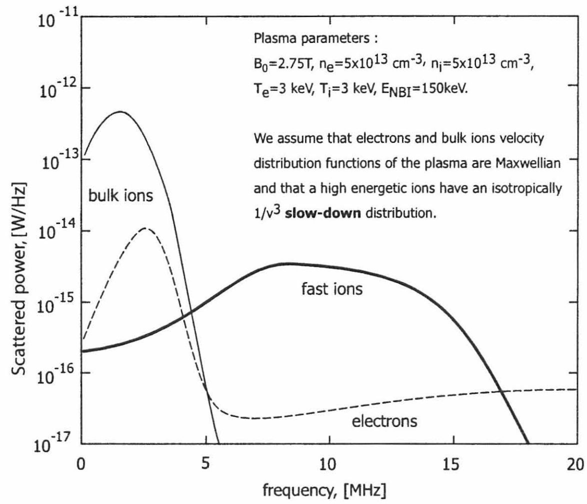

Fig. 2: Expected scattered power for LHD plasma

We have performed initial design of the LHD CTS system based on the Q. O. gyrotron as a radiation source. The main advantage of the using gyrotron as a radiation source instead CO_2 laser is as follows. In the case of lasers, the spectrum changes very rapidly with angle, only small-angle scattering can be used. This complicates obtaining high spatial resolution. In contrast, at gyrotron frequencies, much larger scattering angles are available, the spectra change on slowly with angle, and reasonably large collection solid angles can be used - limited only by coherence requirements for heterodyne detection The choice of the scattered angle will depend primarily on effects of plasma refraction.

At the present time the spectrum of the bulk ions fracture can be obtained by means of other diagnostics. That is why the proposed diagnostic is targeting to measure 'fast ion fracture' spectrum mainly. Preliminary estimates show that the scattered spectrum mostly consist (starting from the 6 MHz in differential frequency) of 'ion feature' that will exclusively gives the ion temperature information. The errors in the spectrum that will come from the electron component will be diminished.

The middle-power gyrotron with power of up to hundred watts, and pulse duration about $1-2$ sec is a good contender for collective thomson scattering diagnostic power source and will provide valuable information on ion spectrum/temperature.

Reference

[1] E.E. Salpeter, *Phys.Rev.*, **120**, (1975), 1528.