§37. Application of Visible Bremsstrahlung to a Density Monitor in Steady State Fusion Reactor

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It is important to measure the electron density in the present toroidal devices in order to study the transport physics. In the fusion reactor, however, the density measurement becomes important in a viewpoint of feedback controls for the fusion output and maintenance of steady state discharges. At present, FIR interferometer and Thomson scattering are generally used for the density measurement. Both diagnostics need an external laser beam as a passive tool. It is very difficult to maintain them over a year in the future fusion reactor. Another reliable density monitor is needed in such a fusion reactor.

In the fusion reactor the electron density is high enough such as $1\times10^{14}cm^{-3}$ and the value of Z_{eff} is below 2 in order to gain the necessary fusion output. Intensity of visible bremsstrahlung is proportional to the square of the electron density if the Z_{eff} is close to unity. Then, the application of the visible bremsstrahlung [1-3] to the density monitor instead of such active diagnostic methods represents a necessary technique to the steady state fusion reactor. For the purpose of the density monitor in high-density plasmas, the visible bremsstrahlung has been measured in LHD and analyzed in comparison with signals from the FIR interferometer.

Visible bremsstrahlung profile has been measured with a combination of 80 optical fibers with a core diameter of 300μm, 80 photomultipliers and an interference filter. The optical fibers with a length of 100m transfer the visible emissions from LHD to a diagnostic room. The radial profiles of the visible bremsstrahlung consist of two sets of horizontal 40 chords, which measure the slightly different poloidal magnetic surfaces cross section. A time response of the photomultiplier tubes is 10μs. The data are normally taken by a 10kHz sampling A/D converter. Figure 1 (a) shows a comparison between temporal behaviors of n_el and the square root of the visible bremsstrahlung signal. Both signals are taken from line-averaged data at the plasma center chord. The density is built up by continuous H_2 gas puff. It is seen that both signals have the similar temporal behavior. Here, a ratio of the square root of the visible bremsstrahlung signal to the n_el is analyzed. Increasing the density during the discharge, the electron temperature decreases as shown in Fig.1(b). As mentioned above, the visible bremsstrahlung signal has weak temperature dependence. Two ratios are, then, considered. The ratios are expressed in eqs.(3) and (4) as follows;

$$R_1 = \frac{\sqrt{I_B}}{n_e l} \quad (3)$$

$$R_2 = \frac{\sqrt{I_B \times T_e^{0.35}}}{n_e l} \quad (4)$$

The eq.(4) corrects the weak temperature dependence included in the visible bremsstrahlung signal. The results are plotted in Fig.1(c).

A similar analysis is done in the repetitively injected H_2 pellet discharge. The density rapidly goes up after the H_2 pellet injection and decays with a core particle confinement time. The ratio with a correction of the temperature dependence denoted by the dashed line (R_2) gives a smoother and constant value during the discharge, although the ratio without the correction gives a slight difference during the discharge.

The present experimental result strongly suggests the use of the bremsstrahlung signal to the density monitor instead of the present density diagnostic methods such as FIR interferometer and Thomson scattering in the future fusion reactor.

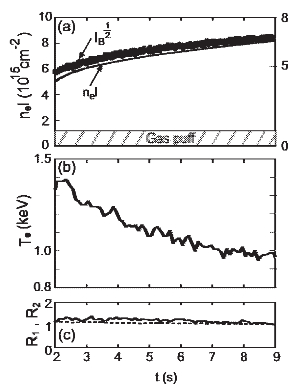

Fig.1

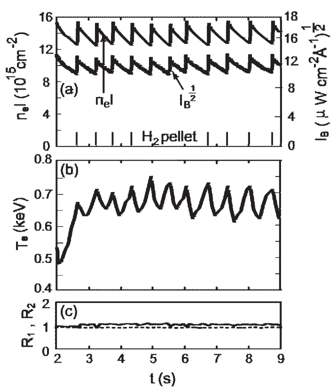

Fig.2

Fig.1 H_2 gas puff plasma. Fig.2 H_2 ice pellet injection plasma; (a) Time evolutions of n_el and the square root of visible bremsstrahlung signal, (b) electron temperature measured by Thomson scattering and (c) ratios of R_1 (solid line) and R_2 (dashed line).

References

1) S.Morita, J.Baldzuhn, in: IPP-report (Garching, Germany), No.199 (1995).
2) S.Morita, R.K.Richards, L.D.Horton, R.C.Isler, E.C.Crume,Jr, M.Murakami in: OAK RIDGE NATIONAL LABORATORY/TM-11737 (1991).
3) K.Kadota, M.Otsuka and J.Fujita, Nuclear Fusion 20 (1980) 209-212.