§2. Proposal of *In Situ* Density Calibration for Thomson Scattering Measurement by Microwave Reflectometry

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The density measurement with the Thomson scattering has some difficulty compared to the temperature due to the dependency on transited calibration factor. Because the density measurement requires to measure accurately an amount of the scattered light, the calibration factor is affected by the misalignment of a laser path, a collective system of the scattered light, the sensitivity of polychromators and detectors, a laser beam profile and so on, thus the factor have decades of continuous change. Most popular method for the Thomson density calibration is a gas scattering method, which utilizes Raman or Rayleigh scattering of molecule[1]. However, the gas scattering method has a drawback: because a vacuum vessel needs to be filled with N_2, Ar or H_2 gases to an atmospheric pressure level, the calibration in parallel with the density measurement is difficult. Consequently, another *in situ* calibration method is required for the precise measurement of the plasma density. A preferable technique for the *in situ* calibration is a method using plasma density values measured with the other plasma diagnostic. Therefore, we propose that the method of the density calibration by a microwave reflectometer for the multipoint Thomson scattering system.

The Thomson scattering calibration factor C^T for the density measurement is defined as $n_e = C^T S$, where n_e is the plasma density, S is an amount of the Thomson scattered light. The purpose of the calibration method by the microwave reflectometry is improving the calibration factor to the real value by the reflectometer measurement. The reflectometer utilize a laws of physics that a wave propagating in the plasma is reflected at the cut off point. The plasma density can be measured by detecting the reflected wave from the cut-off layer, because the location of the cut-off layer depends on the plasma density. The calibration is performed by the simultaneous density measurement with both the multi point Thomson scattering system and the reflectometer, as shown in fig.1.

Because the compact and simple system is preferable as the reflectometer for the density calibration due to the small space around the thomson scattering device, we choose the FM type reflectometer. The FM reflectometer consists of a launching antenna, a receiving antenna, a direct coupler, a mixer, waveguides and a oscillator with frequency swept over wide ranges[2]. The FM reflectometer measures phase delay ϕ of the reflected wave at the cut-off layer. The injected wave frequency is swept from 26GHz to 40GHz, and the required sweep time is less that 10-100μsec. Because of the phase delay at lots of different frequencies by the sweep oscillator so that the function $\phi(\omega)$ can be constructed. When the injected wave is ordinary mode, the location of the cut-off layer is derived from [3]

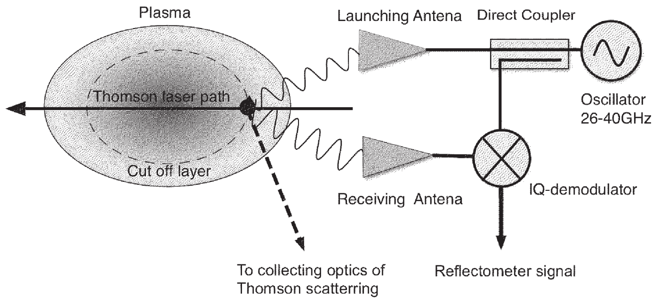

Fig. 1: Conceptual diagram of Thomson density calibration by microwave reflectometry.

$$r_c(\omega) = a - \frac{c}{\pi}\int_0^{\omega} \frac{d\phi}{d\omega'} \frac{d\omega'}{(\omega^2 - \omega'^2)^{1/2}} \tag{1}$$

, where the 'a' is a location of the plasma surface, 'c' is a speed of light. The FM reflectometer has drawback that the measurement accompany some error that is caused by a fringe jump[2]. However, the error is reduced by the repetition of the reflectometer measurement. In LHD case, if the oscillator frequency is swept from 26 GHz to 40 GHz, the Thomson channels that corresponds to the almost half region of the plasma cross section can be calibrated by measuring the different density plasmas. However, a peaked density profile is more preferable, because the accuracy of the location of the cut-off layer is better than the flatten profile.

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[2] A.Ejiri J. Plasma and Fusion Res. vol. 79 No.9 (2003) p.921-928

[3] I.H.Hutchinson, "Principles of plasma diagnostics second edition" Cambridge Univ. Press. p.146-147