§8. Simulation Study for Technology Development to Make Reflectometer Highly Accurate

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For burning plasma such as ITER, electron temperature is expected to be several ten's keV. For such plasma, the relativistic effect of electrons becomes important in fusion researches. We study the effects of the relativistic correction of electron mass on microwave diagnostics [1-4]. The dispersion relation of ordinary (O) mode for a relativistic Maxwellian plasma is given by

$$\frac{kc}{\omega} = N = \left[1 - \frac{1}{A}\left(\frac{\omega_{pe}}{\omega}\right)^2\right]^{1/2}, \qquad (1)$$

where A denotes the relativistic correction of electron mass for O-mode cutoff, and is given by, for $\rho << 1$,

$$A = \frac{3K_2(\rho)}{\rho^2 \int_0^\infty dp(p^4/\gamma^2)e^{-\rho\gamma}} \approx 1 + \frac{5}{2\rho}, \qquad (2)$$

with $\rho = m_e c^2/T_e$, $\gamma = (1+p^2)^{1/2}$, $p = |\boldsymbol{p}|/(m_e c)$, m_e the electron mass, c the light speed, T_e the electron temperature, and $K_2(\rho)$ is the modified Bessel function. In Ref.3, the relativistic correction $A = (1+5/\rho)^{1/2}$ is proposed, which is approximately equal to eq.(2) for $\rho >> 1$. We see that $A \to 1$ as $T_e \to 0$. We show $A = 1+5/2\rho$ as a function of T_e in Fig.1 and it is found that $1+5/2\rho$ is in good agreement with the exact form A up to 60keV of T_e.

In interferometry, the phase difference in plasma and vacuum propagation is important in the density profile reconstruction, and is given by

$$\phi = \int_{y_1}^{y_2} (k_0 - k)dy = \frac{2\pi}{\lambda}\int_{y_1}^{y_2} (1-N)dy, \qquad (3)$$

where $k_0 = \omega/c = 2\pi/\lambda$ is wave number in vacuum. When $\omega >> \omega_{pe}$, eq.(3) is approximated by

$$\phi(r) = \frac{\pi}{\lambda n_c}\int_{y_1}^{y_2} \frac{n(r)}{A}dy = \frac{\pi}{\lambda n_c}\int_x^a \frac{n(r)}{A}\frac{rdr}{\sqrt{r^2 - x^2}}, \ r > x, \qquad (4)$$

where $n_c = \omega^2 m_e \varepsilon_0/e^2$ and a is a plasma–vacuum boundary. The Abel inversion equation with the relativistic mass correction of electron is given by

$$n(r) = -A\frac{\lambda n_c}{\pi^2}\int_r^a \frac{d\phi}{dx}\frac{dx}{\sqrt{x^2 - r^2}}, \quad x > r. \qquad (5)$$

Therefore, the reconstructed density profile of eq.(5) is taken into account of the relativistic mass correction of electron by the factor A. The relativistic correction is also important in reflectometry.

Recently, LHD plasma has been achieved over ten keV of electron temperature. The example of such high temperature plasma experiment is shown in Fig.2. In this discharge, the center electron temperature is over 15 keV and the line-averaged correction factor is 1.017. Then, the interferometer signal needs to be modified by 1.7 % correction.

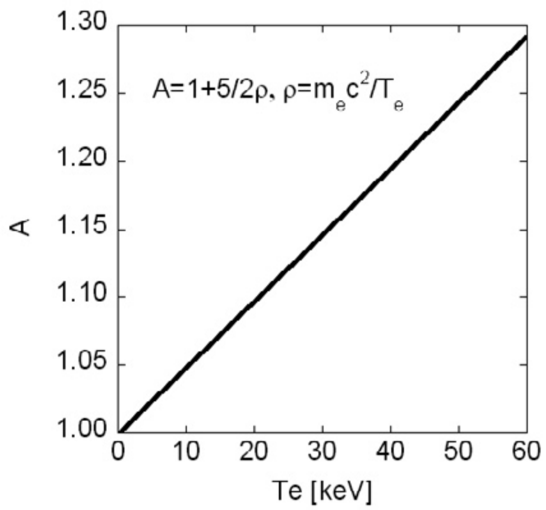

Fig. 1. Relativistic mass correction of electron

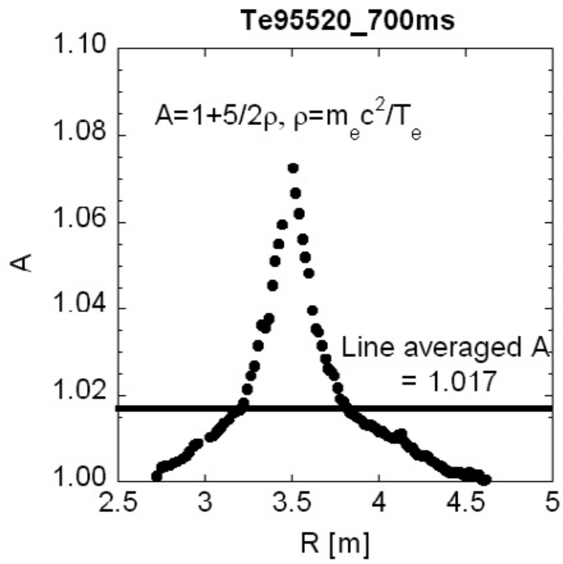

Fig. 2. Radial profile of relativistic electron mass correction at the high electron temperature plasma experiment in LHD

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3) E. Mazzucato, Phys. Fluids **B4** (1992) 3460.
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