§8. Comparison of the ECH Performance between the Ray-tracing Calculation and Experimental Results

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It is very important to estimate the power deposition profile of the EC wave accurately to investigate the effect of the electron cyclotron heating (ECH) on the confinement, characteristics of the heat and momentum transport, the current profile driven by EC wave and so on. The ray-tracing calculation is a powerful tool to predict the propagation and the power absorption of the electron cyclotron (EC) wave. Appropriate selections of the magnetic field profile, electron density profile, dispersion equation and the incident beam profile are required for accurate theoretical prediction.

In the 16th (2012) experimental campaign, for the cases of launching from the upper port inner (Ui) antenna the power deposition position and heating efficiency for various aiming of the launched EC wave was investigated systematically with 25Hz modulated electron cyclotron heating (MECH) and electron cyclotron emission (ECE) measurement to compare with the results given by a ray tracing code "LHD-Gauss". The center of the power deposition was experimentally estimated from the bottom position of the phase delay and the peak position of the modulation amplitude of 25Hz component obtained by fast Fourier transformation (FFT) analysis. As shown in Fig. 1, the bottom of the phase delay (upper) and the peak of the modulation amplitude (lower) shift with change of the aiming point. For the calculation, the following form $y = a_0*[a_1-a_2+(1-a_1+a_2)*(1-(x/r_a)^p)^q + a_2*\{1-\exp(-(x/r_a/a_3)^2)\}]$, where x/r_a is the normalized minor radius, is adopted to give the electron density and temperature profile. The coefficients a_0-a_3 and the multiplier factors p, q were chosen to look like the profiles experimentally obtained by Thomson scattering measurement. The magnetic equilibrium data named "lhd-r360q100b000 a8020.flx" that assumes β=0% was used to give the normalized minor radius. The non-relativistic dispersion equation in the hot plasma was adopted in the calculation. In the bottom graph in Fig. 1, power absorption profiles of the ordinary (O-) mode given by "LHD-Gauss" are shown. The peak of the power absorption profile is located close to the bottom of the phase and peak of the modulation amplitude. In Fig. 2, the normalized minor radius at the bottom of the phase and the peak of the power deposition predicted by "LHD-Gauss" are plotted as functions of the aiming point. In the calculation, the EC wave is refracted in a direction away from the plasma core thus the peak of the power deposition is located outside the intersection of ECR layer and the straight launched beam that passes through the center of the final mirror and the aiming point. The bottom of the phase is also located outside the intersection point. The peak of the power deposition and the bottom of the phase are located nearby however do not coincide with. To improve the accuracy of the prediction more, effects of given parameters used in the ray-tracing should be investigated systematically. The heating efficiency estimated by change of the temporal differentiation before and after start/end of the EC wave launching is plotted as a function of the aiming point in the lower graph in Fig. 2. For all case of the aiming, the heating efficiency is 40% lower than that of the O-mode predicted by "LHD-Gauss". The reason has not been specified yet. Low coupling efficiency from the launched wave to the ordinary mode, miss of the estimation of the launched power, some physical mechanisms of the power loss are possible.

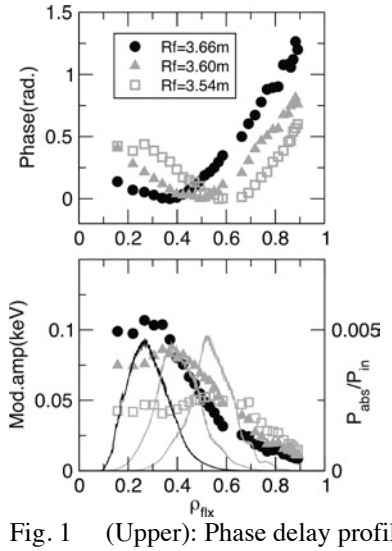

Fig. 1 (Upper): Phase delay profiles of 25Hz component. (Lower): Profiles of 25Hz modulation amplitude(●, ▲, □). Absorbed power (solid lines) profiles given by ray-tracing calculation. Cases of aiming point R_f, = 3.66, 3.60, 3.54m on the equatorial plane are plotted.

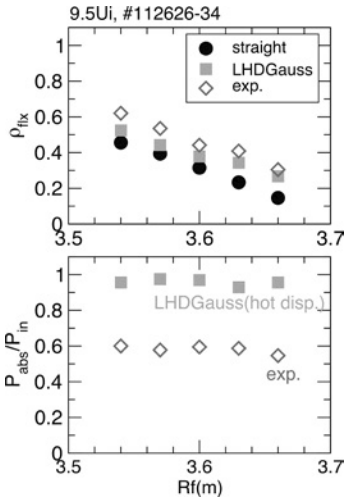

Fig. 2 (Upper): Normalized minor radius(ρ_{flx}) at the intersection of the ECR layer and the straight launched beam (●), at the peak of the power deposition predicted by ray-tracing code (■), at the bottom of the phase of 25Hz component (◇). (Lower) Heating efficiencies given by ray-tracing and estimated from the experiment.