§5. Impact of the LHD Peripheral Region on Incident EC Wave Polarization

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Optimal injection settings of electron cyclotron resonance heating (ECRH) are essential for achieving desired power deposition and reducing the stray radiation in the vessel. Refraction of rays in the LHD (Large Helical Device) peripheral region cannot be neglected due to a finite density gradient. Incident wave polarization has to be adjusted in order to excite the pure ordinary/extraordinary (O/X) mode at the resonance layer through the peripheral region with a finite magnetic shear. The effects of refraction and pure mode excitation are also important in tokamak plasmas, although the conventional ray-tracing calculations have neglected those effects in the peripheral region. Those effects have been recently taken into account in the upgraded ray-tracing code *LHDGauss*.[1,2] Here, the impact of the LHD peripheral region on incident EC wave polarization is discussed.

The equilibrium map with the electron density (n_e) profile is virtually extrapolated into the outside of the last closed flux surface (LCFS), as shown in Fig. 1. The treatment of the plasma/vacuum interface region enables the modeling of propagation of EC waves in the entire region. The mode ratio is determined by solving the 1D full-wave equation along propagation from a launcher to a target, so that the effects of the n_e profiles and the magnetic shear in the peripheral region are taken into account, as shown in Figs. 2(a)-(d). With the n_e profile extrapolation, the incident linearly-polarized wave of the polarization rotation angle of $\alpha \simeq 45°$ is optimal to excite the pure O mode, which is in good agreement with the experimental result of the maximal absorbed power, although $\alpha \simeq 35°$ in the case without the n_e profile extrapolation gives rise to the lower absorption rate in the experiment. Here, α is defined as the rotation angle to the toroidal direction. Figure 2(e) shows deviation of the optimal incident wave polarization as defined by mode purity η on the parameter space of the scale length of the density, λ_n, and that of the magnetic shear angle, τ_ϕ, in the peripheral region. The result indicates that the experimental data locate on the line with $\eta \simeq 90\%$ ($< 100\%$), so that the incident wave polarization should be carefully selected to realize the optimal coupling. The impact of a plasma peripheral region on pure excitation of the O/X mode is a common characteristic in magnetically confined plasmas with comparable λ_n and τ_ϕ, e.g., the stochastic region of LHD plasmas, or tokamak pedestal/SOL (scrape-off-layer) plasmas.

1) Ii Tsujimura, T. *et al.*: Nucl. Fusion **55** (2015) 123019.

2) Tsujimura, T. I. *et al.*: Plasma Fusion Res. **11** (2016) 2402016.

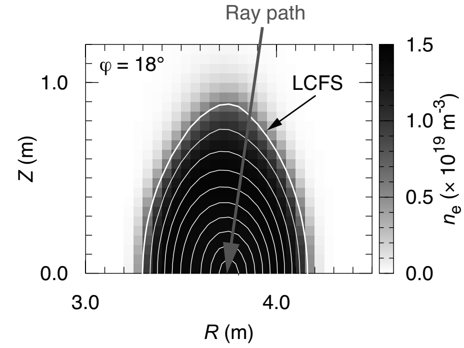

Fig. 1. Magnetic flux surfaces along with the n_e profiles using the equilibrium map virtually extrapolated into the outside of the LCFS on a poloidal plane.

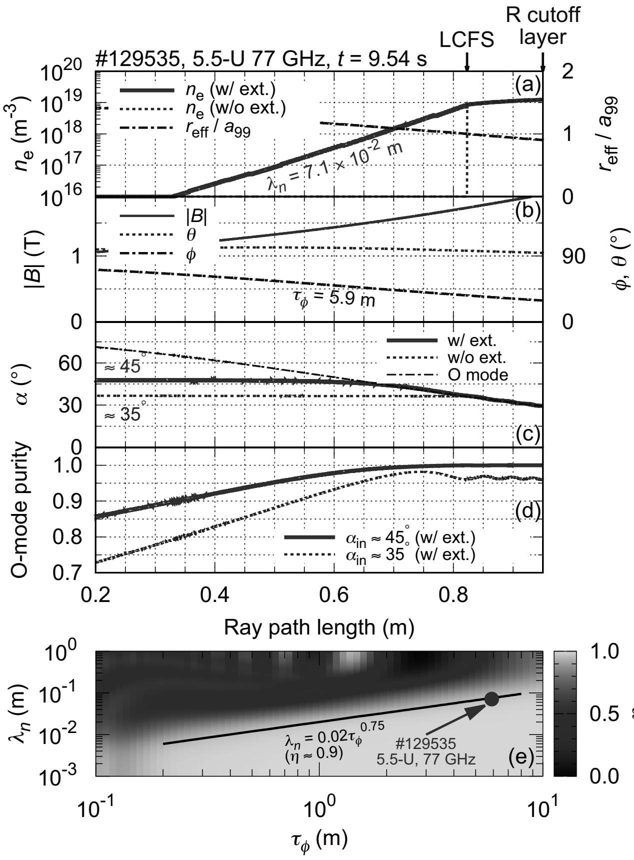

Fig. 2. (a) n_e with/without the extrapolation and normalized minor radius r_{eff}/a_{99}, (b) the magnetic field strength $|\boldsymbol{B}|$, the propagation angle θ, and the magnetic shear angle ϕ, (c) the polarization rotation angle α with/without the n_e profile extrapolation and α_{O-mode}, and (d) the O-mode purity for the incident linearly-polarized waves of $\alpha \simeq 45°$ and 35°, respectively, with the n_e profile extrapolation, in the propagating direction. (e) Mode purity in τ_ϕ-λ_n space for $n_{e,LCFS} = 1.0 \times 10^{19}$ m^{-3}.