§12. Real-Time Control of an Injected EC Wave Polarization during a Long Pulse Discharge

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An effective ECRH requires the appropriate wave polarization, which is characterized by polarization angle, α, and the ellipticity, β, at the plasma boundary, and depends on the injection mode and injection angle. As shown in Fig. 1a), α is the angle of the longer axis of the polarization ellipse formed with respect to the x-axis, which is the direction of the magnetic line of force at the plasma boundary, for example. The parameter β indicates the ellipticity of the polarization. The polarization state of the injected wave is usually controlled by a pair of rotatable corrugated reflectors ($\lambda/4$ and $\lambda/8$ plates) installed at the miterbends. Figure 1b) illustrates a polarizer system consisting of one rotatable grooved mirror.

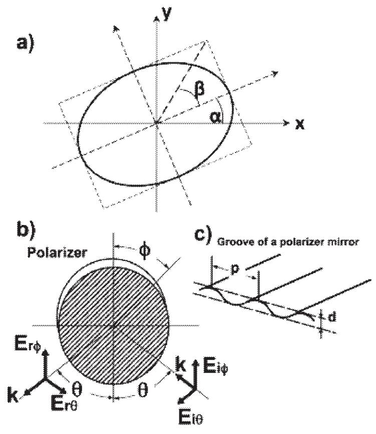

Fig. 1: Notation of polarization state and schematic configuration of the grating polarizer.

Generally a wave beam is injected on the grooved mirror with an incident angle of θ, which is normally 45 degrees in a miterbend. Adjusting the rotation angle of the mirror, ϕ, changes the direction of corrugation. The electric field components of the reflected wave are related to those of the incident wave by θ, ϕ and a phase delay, τ. The parameter, τ, represents the difference of the phase-shift between the parallel and perpendicular components of the electric vector with respect to corrugation after reflection. τ depends on the corrugation period, p, and depth, d, shown in Fig. 1c) and the angles, θ and ϕ. Practically, ϕ is the only variable for the parameter, τ, in the polarizer used in an actual ECH system. τ is approximately represented by the Fourier series of ϕ. In the case of a system consisting of two polarizer mirrors, such as $\lambda/4$ and $\lambda/8$ corrugated reflectors, the matrix operation should be repeated using the reflected wave beam parameters as the next incident wave parameters.

Because the optimal polarization likely changes during a plasma discharge according to the change in plasma density at the boundary and the change in the boundary position itself, feedback control for the injected wave polarization during a single pulse becomes important to determine the maximum wave absorption. We have planned a feedback control system for the injected wave polarization, which corresponds to the response of the plasma electron temperature. The electron temperature at the plasma core, which can be obtained by the electron cyclotron emission measurement, is acquired and digitalized by a fast A/D convertor and a computer. Then depending on electron temperature, the polarizer mirrors are rotated to maximize the electron temperature. The polarization state should be measured by the polarization monitor. A proof-of-principle study has been performed with a pair of corrugated mirrors and crystal detectors in the low power millimeter-wave test stand [1, 2].

Initial test of feed-forward control was performed in a long pulse discharge. A plasma with parameters R_{ax} = 3.6 m, B_0 = 2.8 T suitable for first harmonic ECH experiments was used as a target plasma. The plasma was created using 82.7 GHz gyrotrons for a short period, and sustained using one or two 77 GHz gyrotrons. The available pulse length of the 77 GHz gyrotron (for which the transmission line contained the polarizers) was extended to about 1 minute. The $\lambda/4$ plate was rotated from 38 deg. to 48 deg. in 10 sec. (linear polarization change). During the last 5 sec., the line averaged density was almost constant as shown in Fig. 2. During this period, a gradual increase of the electron temperature, T_{ECE}, was observed. It is obvious that the optimization of the polarization is necessary during a plasma discharge.

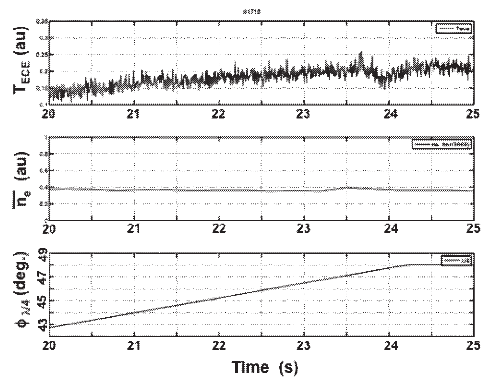

Fig. 2: The time trace of the discharge for pre-programed rotation of the polarizer plate.

1) F. Felici, *et al.*, Rev. Sci. Instrum., (2009) Vol.80 013504.

2) T. Shimozuma, *et al.*, J. Microwave Power and Electromagnetic Energy, (2009) Vol 43 60–70.