§6. Development of Power and Polarization Monitor for EC Wave

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For control and optimization of electron cyclotron resonance heating (ECRH) and electron cyclotron current drive (ECCD), it is essential to measure power and polarization states of injected EC waves. The polarization states of injected EC waves determine the mode excitation purity in relation to the direction of magnetic field and the wave propagation vector near the last closed surface. It largely affects the power absorption and current drive in plasmas. A monitor measuring power and polarization states of high power EC wave have been developed for ECRH/CD on LHD.

The polarization states can be evaluated from phases and amplitudes of two orthogonal polarizations. Two orthogonal polarizations are detected using the monitor, which is composed of bi-linear polarization directional coupler, orthomode transducer and heterodyne interferometer[1,2]. A part of high power EC wave in main corrugated waveguide of the ECRH transmission line is picked-up and separated to two orthogonal polarizations. Each of two orthogonal polarizations is down-converted by heterodyne interferometer and detected by Fast ADC with FPGA (Field Programmable Gate Array). Amplitudes and phase difference of the electric field of two orthogonal polarizations can be obtained by taking fast Fourier transforming (FFT) to the data acquired by the fast ADC.

The power and polarization monitor was set on a miter-bend in the ECRH transmission line. 1118 kW 77 GHz ECRH were injected and polarization was scanned in real time. Figure 1 and 2 show polarization angle α and ellipticity β scan experimental results, respectively. ECRH injection power was modulated to evaluate the power absorbed by plasmas. Absorbed power can be evaluated from the difference between the time derivative of the stored energy just before and after ECRH injection. Power absorption changes with polarization change. Polarization angle α and ellipticity β measured by the monitor are approximately consistent in setting parameter of EC waves.

Time resolution of measurements of polarization states is limited by the data transfer speed from ADC to PC. Data acquisition and transfer is controlled by FPGA. 65536 data points were transferred and applied FFT every ~60 ms in the experiments shown in Fig. 1, 2. Recently, sampling rate of polarization measurements improved from 15-70 ms to a few hundred μs by optimization of FPGA programming for 10 sec typical discharge experiments. Using FPGA leads to flexible fast analysis and feedback control of polarization states in the future.

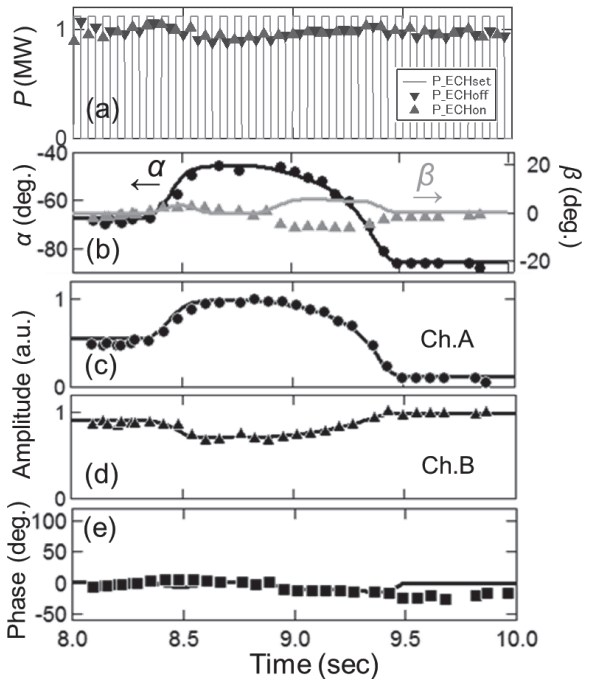

Fig. 1. Time trace of (a) EC wave injection power (line) and power absorption in plasmas (markers), (b) polarization angle α and polarization state β, (c), (d) amplitudes and (e) phase difference of two orthogonal polarizations in α scan experiments. (b) – (e) Lines are setting parameter of ECRH system and markers are measured values.

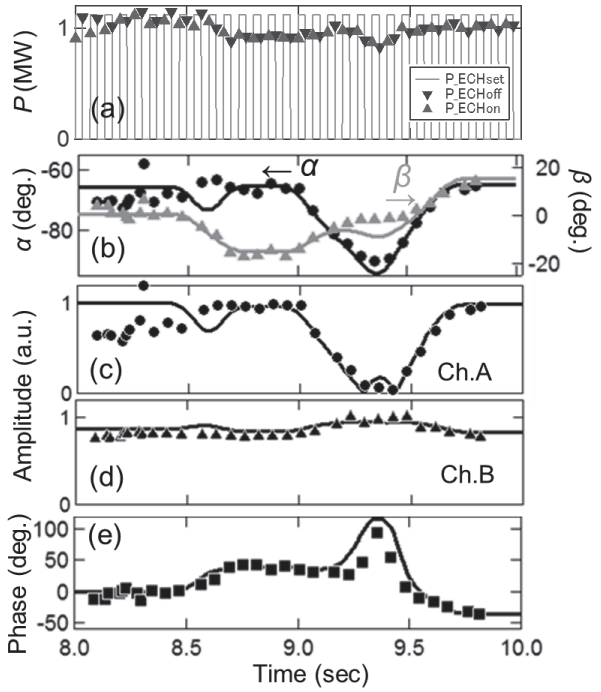

Fig. 2. Plots similar to Fig.1 in β scan experiments.

1) Ryohei, M. *et al.*: Plasma and Fusion Research **9**, (2014) 3405024.
2) Ryohei, M. *et al.*: Rev. Sci. Inst **85** (2014) 11D831.