§8. Experimental Study on Generation of High Heat Flux by ECH Modulation for ELM Simulation Experiments

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Development of high power gyrotrons and electron cyclotron heating (ECH) systems for the power modulation experiments in GAMMA 10 have been started in order to generate and control the high heat flux and to make the ELM (edge localized mode) like intermittent heat load pattern for divertor simulation studies. ECH for potential formation at plug region (P-ECH) produces electron flow with high energy along the magnetic filed line. By modulating the ECH power, we can obtain arbitrary pulse heat load patterns. The heat flux factor increases almost linearly with ECH power. An intense axial electron flow with energy from hundreds of eV to a few keV generated by fundamental P-ECH is observed.

Figure 1 shows the P-ECH system and locations of the diagnostic systems used in the preliminary P-ECH modulation experiment to generate the high and ELM-like heat flux. In the vessel, a launcher composed of an open ended corrugated waveguide and two mirrors (MP1 and MP2) is installed. It radiated the microwave power to the resonance layer as shown in Fig. 1. The heat flux is measured by the movable calorimeter. This diagnostics instrument is located at 30 cm downstream from the end-mirror coil (z_{EXIT}=30 cm) and can be inserted from the bottom of the vacuum vessel up to the center axis of GAMMA 10. The flux and the energy spectrum of the end loss electrons are measured by a multi-grid energy analyzer (loss electron diagnostics, LED). End loss electrons enter the analyzer through a small hole on an electrically floating end plate that is located in front of the end wall.

Experiment for ECH power modulation is carried out by the use of a plasma discharge after the time of t =101 ms (Fig. 2). During P-ECH from t =101 ms to 161 ms, the pulse of ECH power of about 300 kW is applied six times by 100%, 100 Hz square wave power modulation [gray region between dot-lines in Fig. 2]. The end plate potential is increased during P-ECH injection [Fig. 2(d)]. The end loss electron current is increased during P-ECH injection [Fig. 2(e)], which is measured with LED. The pulse train of the electron current is due to sweep of the repeller voltage for energy analysis. Its envelope represents the electron current. Conversely, the end loss ion current is decrease during P-ECH injection [Fig. 2(f)]. Also its envelope represents the ion current.

By modulating the ECH power, we can obtain arbitrary pulse heat load patterns. By changing the on/off timing, we can simulate the ELM intermittent heat pulses. The heat flux factor ($Qt^{-1/2}$, Q is the ELM deposition energy density and t the ELM deposition time) increases almost linearly with ECH power. The maximum heat flux factor obtained is 0.7 MJ/m^2 s$^{1/2}$ with about 380 kW for 5 ms pulse. This is still far lower than that of ITER ELM (mitigated ELMs in ITER is ~22 MJ/m^2 s$^{1/2}$) but is already to be critical heat load level of long time integrated pulse effect (10^4 – 10^5 cycles).

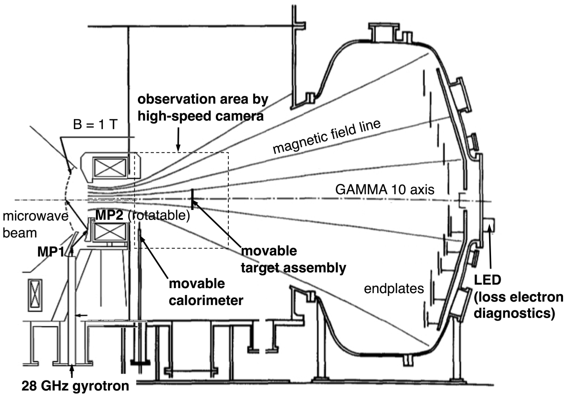

Fig. 1. Cross-section of the plug region and the end region. Microwave power is injected to the 1.0 T surface from the antenna. The LED is installed behind the innermost endplate.

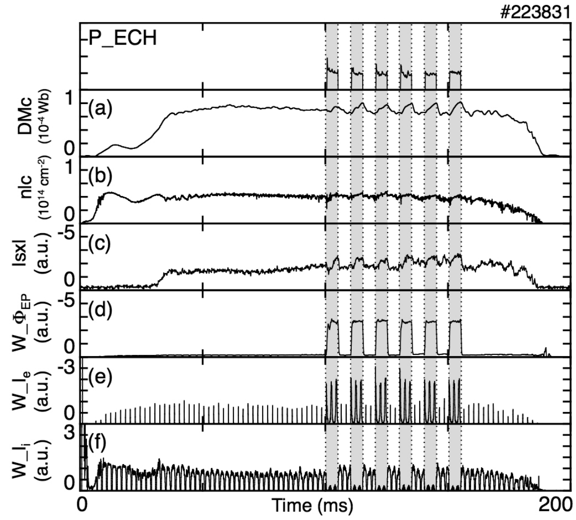

Fig. 2. Temporal evolution of (a) diamagnetisms, (b) line density at the central-chord, and (c) soft x-ray intensity at the central-chord at the central cell. (d) end plate potential at the west end. The end loss (e) electron current and (f) ion current at the west end.