Experimental Identification of Electron Scale Drift Mode in Linear Device

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Electron scale instability including electron temperature gradient (ETG) mode is a possible source to induce anomalous transport of electrons in magnetically confined plasmas. We developed a wide band Langmuir probe (WBLP) system to experimentally study electron scale turbulence associated with ETG mode in magnetized plasma. WBLP is equipped with high cutoff frequency of 2.5 MHz and maximum azimuthal wave number k_θ of 0.8×10^3 m^{-1} which satisfy required resolution to diagnose the ETG instability in a magnetic mirror plasma device MPX (Magnetized Plasma eXperiment). WBLP can simultaneously measure fluctuations of ion saturation current and floating potential. Parameter survey of dispersion relation of electrostatic wave in slab geometry including the ETG mode predicts frequency of 1MHz as the frequency range of the ETG mode in MPX. We have most recently initiated electron cyclotron heating (ECH) experiment to produce steep gradient of electron temperature and destabilize ETG mode by utilizing a high power (30kW) magnetron system.

The MPX device

Experimental investigation of the ETG mode was conducted in the MPX device at plasma and space science center (PSSC) of national cheng kung university (NCKU) in Taiwan. Figure 1 shows schematic of the MPX device. The MPX device is a mirror device that has capability to generate maximum magnetic field strength of 0.15

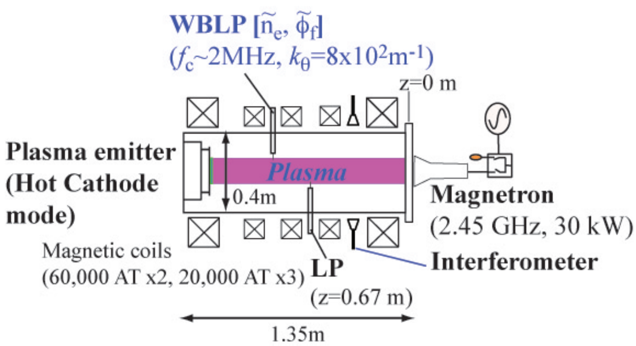

Fig. 1 Schematic of the MPX device. The newly developed wide band Langmuir probe (WBLP), a conventional Langmuir probe and a microwave interferometer are installed into the MPX device.

Tesla. Inner diameter and axial length of the vacuum chamber are 0.4 m and 1.35 m, respectively. The plasma emitter including a hot cathode is installed at the end of the cylindrical chamber. The MPX device is equipped with a magnetron system to inject electron cyclotron wave. The newly developed wide band Langmuir probe (WBLP), a conventional Langmuir probe and a microwave interferometer are installed into the MPX device.

In order to grasp proper parameter of the MPX experiment for the ETG mode measurement, we solve a dispersion relation of slab ETG mode derived from kinetic equation [1]. In a homogeneous, collisionless plasma with magnetic field $\boldsymbol{B} = B\hat{z}$, evolution of gyro phase-averaged distribution function of electrons for electrostatic oscillation follows the drift-kinetic equation. Lectlinear motion is considered for ions because $\omega, \gamma >> \Omega_i$, where γ and Ω_i are growth rate of the instability and ion cyclotron frequency. If we neglect density gradient, the dispersion relation is written as,

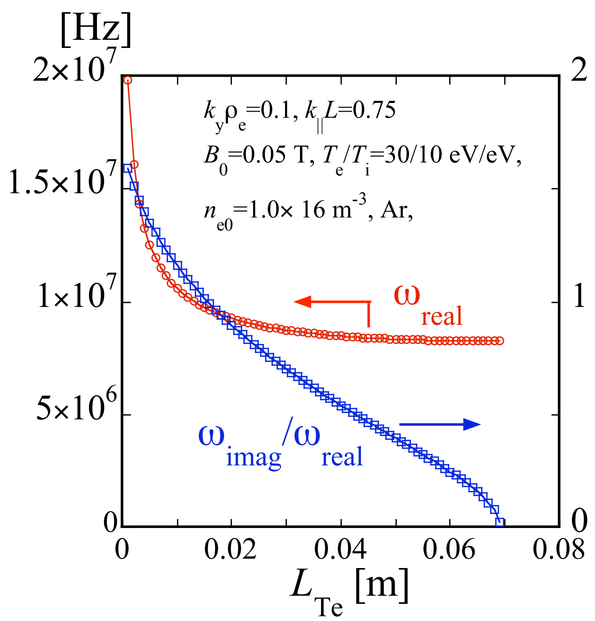

Fig. 2 The angular frequency $\omega_{\rm real}$ and the growth rate $\omega_{\rm imag}$ as a function of characteristic length of ETG $L_{\rm Te}$ under the condition of the typical MPX plasma.

$$\left[1+\zeta_e Z_0(\zeta_e)\right]+\eta\left[\left(\frac{1}{2}-\zeta_e^2\right)Z_0(\zeta_e)-\zeta_e\right]+\tau\left[1+\zeta_i Z_0(\zeta_i)\right]$$
$$=-k^2\lambda_D^2 \equiv -\kappa,$$

where $\tau \equiv T_e T_i^{-1}$, $\eta \equiv \omega_T k_{//}^{-1} v_{the}^{-1} = k_y \rho_e k_{//}^{-1} L_T^{-1}$, $L_T = \left(\frac{d \ln T_e}{dr}\right)^{-1}$ and $\omega_T = \frac{k_y T_e}{eB}\frac{d \ln T_e}{dr}$. Figure 2 shows the angular frequency $\omega_{\rm real}$ and the growth rate $\omega_{\rm imag}$ as a function of characteristic length of ETG L_{Te} under the condition of the typical MPX plasma. Expected fluctuation frequency $f = \omega/2\pi$ is about 1.5-2 MHz. L_{Te} smaller than 7 cm is required to excite the ETG mode.

Development of the wide band Langmuir probe

Figure 3 shows schematic drawing of WBLP. WBLP can simultaneously measure fluctuations of ion saturation current I_{is} and floating potential V_f. It is equipped with four electrodes in order to diagnose azimuthal wave number k_θ of I_{is} and V_f. Measureable maximum azimuthal wave number k_θ is 0.8×10^3 m^{-1}. Frequency response of WBLP was tested in advance of application to the MPX experiment. Figure 4 is frequency response of I_{is} channel (top) and V_f (bottom) channel of WBLP. Cutoff frequencies of I_{is} and V_f were 8 MHz and 2.5 MHz, respectively. WBLP is able to cover the ETG frequency range predicted by the calculation of the slab ETG dispersion relation.

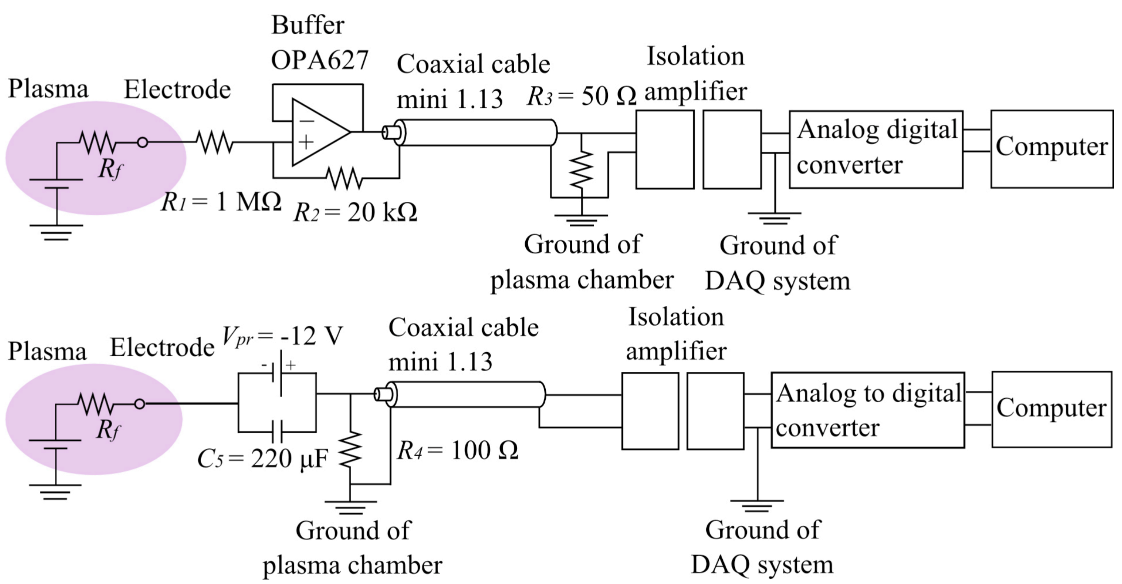

Fig. 3 Schematic diagrams of the wide band Langmuir probe system. Diagram of potential fluctuation measurement (top) and diagram of fluctuation of ion saturation current measurement (bottom).

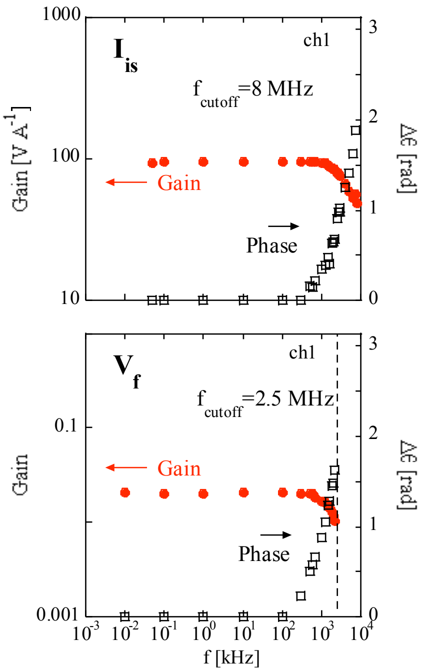

Fig. 4 Frequency response of ion saturation current channel (top) and floating potential channel (bottom) of WBLP.

Electron cyclotron heating (ECH) experiment

ECH experiment was implemented by use of the magnetron. An example of the WBLP measurement result is shown in Fig. 5. ECH wave with power of 3 kW was injected into the hot cathode-produced plasma. Figure 5 shows power spectrum and phase difference between I_{is} of channel 1 and 2 of ion saturation current measured by WBLP. During the ECH wave injection, fluctuation of I_{is} was observed. The observed density fluctuation had frequency of 3.96 kHz and k_θ of 180 m^{-1}. Although this frequency disagrees with frequency expected from Fig 2, k_θ was close to the electron scale ($k_\theta\rho_e$~ 0.012). The MPX have not yet achieved its designed maximum power of the magnetron system. Further increase in the ECH power and optimization are to be implemented.

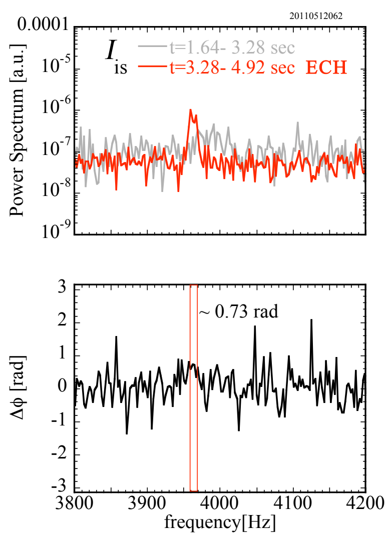

Fig. 5 Power spectrum and phase difference of ion saturation current measured by WBLP.

REFERENCE

1 C. S. Liu., Phys. Rev. Lett. **27**, 1637 (1971).