§37. Potential Formation Due to Local ECR in Inhomogeneous Magnetic-Field

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Plasma potential formation is a topic of general interest in laboratory, space and fusion-oriented plasmas because it is connected with important nonlinear phenomena such as particle acceleration and transport-barrier generation. In particular, a plug potential with thermal barrier in tandem-mirror devices has attracted special attention because of its validity for plasma confinement. We have demonstrated the novel scenario of this potential formation in basic Q-machine experiments[1], where it has been pointed out that a single electron cyclotron resonance (ECR) point is sufficient to provide the potential structure. In this experimental investigation, however, it is not clarified what determines the scale-length of the potential structure or how the potential structure depends on ion and electron energy distributions.

In our work, a two-and-a-half dimensional particle simulation is performed on a configuration similar to that of the Q-machine experiments to clarify more details of the potential formation due to ECR in a plasma flow along a magnetic-mirror field B (Fig. 1). Here, the plasma is injected into the system from a grounded emitter placed at $x/\lambda_{DeS} = 512$ and a floating collector as a plasma terminator is placed at $x/\lambda_{DeS} = 0$. A right-hand polarized wave for ECR is assumed to propagate from $x/\lambda_{DeS} = 0$ to the right and the ECR takes place at $x/\lambda_{DeS} = 256$. The wave amplitude $\widehat{E}_\mu (\equiv E_\mu/(T_{eS}/e\lambda_{DeS}))$ is spatially constant because we apply the low density plasma.

A typical example of the spatial profiles of potential ϕ at $\omega_{peS}t = 2400$ for $\widehat{E}_\mu = 0.0$ (dotted line) and 0.2 (solid line) are presented in Fig. 1, where the plasma injection with a constant rate starts at $\omega_{peS}t = 0$. For $\widehat{E}_\mu = 0.0$, the potential ϕ slightly decreases due to the expansion of the plasma flow along magnetic well. For $\widehat{E}_\mu = 0.2$, on the other hand, there appears a negative potential dip $\Delta\phi_d$ around the ECR region, being accompanied by a large positive potential hump $\Delta\phi_p$, which is agree with the experimental result in Ref. 1. This potential formation is explained by the selective electron trap around the magnetic well owing to ECR heating and electrostatic ion-deceleration self-consistently caused in accordance with the quasi-neutrality condition in the ECR region.

Dependence of $\Delta\phi_p$ on $\widehat{E}_\mu$ is presented in Fig. 2(a). With an increase in $\widehat{E}_\mu$, $\Delta\phi_p$ increases and saturates for $\widehat{E}_\mu > 0.2$. Since the amount of the reflected electrons increases with an increase in $\widehat{E}_\mu$, $\Delta\phi_p$ which is thought to reflect ions increases in order to maintain the charge neutrality condition. Here, we measure an ion energy distribution function parallel to the magnetic field in the upstream region $x/\lambda_{DeS} = 416 \sim 480$ as shown in Fig. 2(b) ($\varepsilon_{i\parallel}$: ion energy parallel to the magnetic field). The energy distribution has a peak at $\varepsilon_{i\parallel}/T_{eS} = 2$ resulting from the ions accelerated by an electron sheath in front of the plasma emitter and has a high energy component whose maximum value is about $\varepsilon_{i\parallel}/T_{eS} \simeq 7$. Judging from these results, $\Delta\phi_p$ is considered to saturate around the value of the ion energy including the high energy component ($\varepsilon_{i\parallel}/T_{eS} \simeq 7$), plugging most of the ions not to pass through the magnetic gradient.

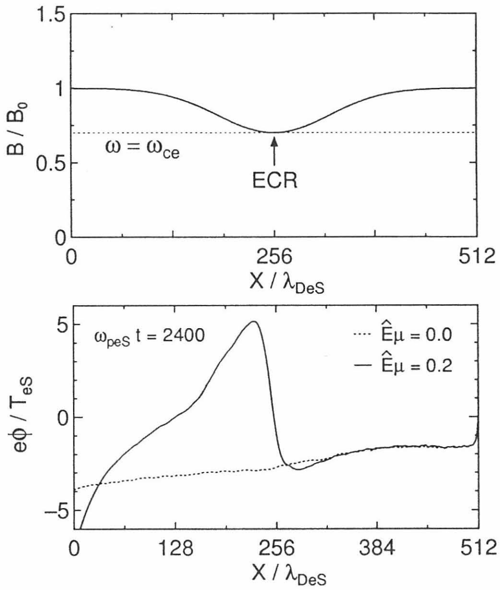

Fig. 1. Spatial profiles of plasma potential ϕ at $\omega_{peS}t = 2400$, together with magnetic field B configuration.

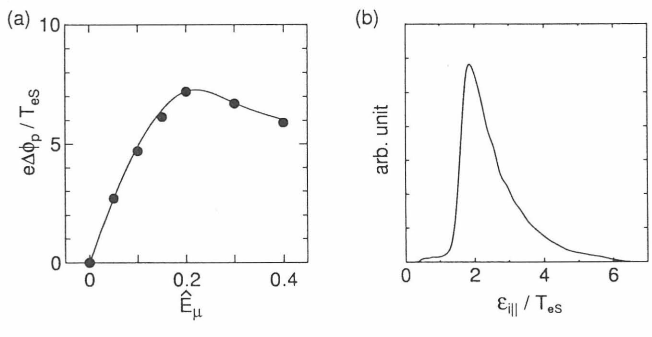

Fig. 2. (a) Potential difference $\Delta\phi_p$ as a function of $\widehat{E}_\mu$ and (b) ion energy distribution function in the upstream region $x/\lambda_{DeS} = 416 \sim 480$.

Reference

1) Kaneko, T., *et al.*, Phys. Rev. Lett. **80**, (1998) 2602.