§34. Potential Formation Due to Local ECR in Inhomogeneous Magnetic Fields

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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. 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 $e\phi/T_{eS}$ at $\omega_{peS}t = 2400$ for $\widehat{E}_\mu = 0.0$ (dotted line) and 0.2 (solid line) is presented in Fig. 1(a), where the plasma injection with a constant rate starts at $\omega_{peS}t = 0$. For $\widehat{E}_\mu = 0.2$, 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 agrees with the experimental result in Ref. 1. Figure 1(b) shows the spatial profiles of ion (dotted line) and electron (solid line) densities n/n_S at $\omega_{peS}t = 2400$ for $\widehat{E}_\mu = 0.2$. It is observed that the spatial separation between the electron and ion density profiles is more prominent around the ECR region, and this causes a charge separation which generates the plug/barrier potential. The peak position of the ion density is found to coincide with that of the plug potential.

In Fig. 2(a), the plug potential $e\Delta\phi_p/T_{eS}$ is plotted as a function of ion drift energy $e\phi_k/T_{eS}$ in the plasma reservoir for $\widehat{E}_\mu = 0.2$. The plug potential linearly increases as the ion drift energy is increased. Here, we show the ion energy $\varepsilon_{i\parallel}/T_{eS}$ distribution function parallel to the magnetic field in the upstream region ($x/\lambda_{DeS} = 416 \sim 480$) as a function of the ion drift energy in Fig. 2(b). The peak of the distribution function which indicates the ion flow energy increases with an increase in the ion drift energy, being accompanied by an enhancement of the high energy part of the tail component. The distribution function has a peak at $\varepsilon_{i\parallel}/T_{eS} \simeq 2$ even for $e\phi_k/T_{eS} = 0$ because the ions are accelerated by the electron sheath in front of the plasma emitter. From these results, it is clarified that the plug potential which increases with an increase in the ion drift energy corresponds to the ion energy of the high-energy tail component. This means that the plug potential is formed large enough to plug most of the ions from the upstream region not to pass through the region of the magnetic variation.

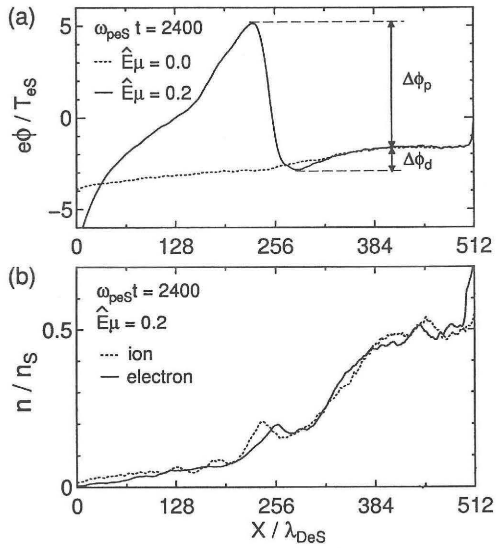

Fig. 1. Spatial profiles of (a) plasma potential $e\phi/T_{eS}$ and (b) ion and electron densities n/n_S at $\omega_{peS}t = 2400$.

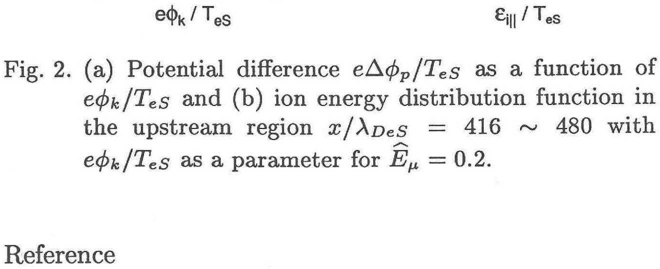

Fig. 2. (a) Potential difference $e\Delta\phi_p/T_{eS}$ as a function of $e\phi_k/T_{eS}$ and (b) ion energy distribution function in the upstream region $x/\lambda_{DeS} = 416 \sim 480$ with $e\phi_k/T_{eS}$ as a parameter for $\widehat{E}_\mu = 0.2$.

Reference

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