§24. Investigation of Collisionless Electron Penetration via the Stochastic Magnetic Region on CHS

Wakabayashi, H., Himura, H., Fukao, M., Yoshida, Z. (Univ. Tokyo), Isobe, M., Okamura, S., CHS Group

There are many studies of cross field plasma propagation in several research areas such as the penetration of solar wind into the geomagnetic field, plasma-beam injection into a magnetic containment device, inward turbulent particle transport in helical plasmas, injection of energetic electrons into toroidal plasmas to control electric fields. And recently, we have performed experiments of electron penetration into closed magnetic surfaces region (CMSR) via stochastic magnetic region (SMR).

In the experiment, when the SMR is present, some field-following electrons in the SMR move into the CMSR across the last closed flux surface (LCFS) of a stellarator configuration. However, it is never observed for cases where the SMR is lost, nor is the density of the injected electrons low ($n_b < 10^{13}$ cm^{-3}) in the SMR. Another significant feature of the inward propagation of the injected electrons is that the penetration occurs in 100 μs which is much shorter than all collision times; for typical experimental parameters of the experiment, the electron-electron and electron-neutral collision times are 1 s and 4 ms, respectively. This means that the observed penetration is caused by a collisionless process. No significant dependence on the pitch angle between the injected electrons and the magnetic field is observed . In fact, all possible orbital motion of the injected electrons outside the LCFS never extend inside the LCFS. These suggest the existence of cross-field transport that is associated with free-streaming of electrons along the stochastically wandering field lines in the SMR. In order to investigate the detailed mechanism of the collisionless electron penetration, electrostatic fluctuation during the penetration process has been measured in the HMS and SMR.

A Langmuir probe is inserted horizontally on 5-O port in order to measure electron current I_e which penetrates into the HMS. Fig.1(a) shows time evolution of I_e measured at R=120cm, which corresponds to the normalized minor radius of ρ~0.7 when the magnetic axis is at R=101.6cm. Electrons are continuously emitted during 0 μs and 385 μs from the electron gun (e-gun) located on 2-O port outside the LCFS. As seen in Fig.1, I_e starts to rise within 10 μs after the e-gun is turned on and saturates in ~100 μs. After the saturation, I_e equilibrates with slow oscillation of about 100kHz until the e-gun is turned off. Because the penetration takes place within 10 μs after the emission is started, this oscillation seems to be too slow to explain the penetration mechanism. In order to investigate faster dynamics of the penetration process, the electron current fluctuation $\tilde{I}$ is measured by a current transformer which has a frequency response up to 15 MHz. Time evolution of FFT spectrum of $\tilde{I}$ is shown in Fig.1(b) for the same shot as Fig.1(a). During the penetration phase, oscillation of 3.5 MHz and its higher harmonics are recognized in the FFT spectrum. These modes are apparent only on the penetration phase and decay rapidly as the electrons move to the equilibrium phase. We have systematically studied the dependence of the frequency f on some parameters such as the magnetic field strength B, emitted beam electron density n_b and initial electron velocity v_0. n_b and v_0 are coupled in the beam emission current, but are separated in the measurements by keeping other parameter constant. f depends linearly on $n_b^{1/2}$ and v_0 as recognized in Figs.2-3, but does not depend on B. Judging from these facts, these modes are considered to be beam-related electrostatic oscillation and would play a key role in the penetration process. Further investigations of these modes such as wave number measurements are needed.

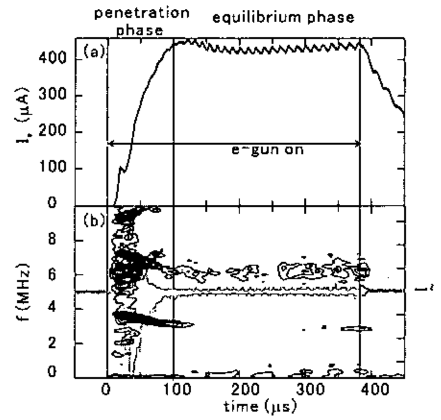

Fig.1 (a) I_e measured at ρ~0.7. (b) Time evolution of FFT spectrum of $\tilde{I}$ with the original waveform on the background. Fast oscillation modes are recognized during the penetration phase.

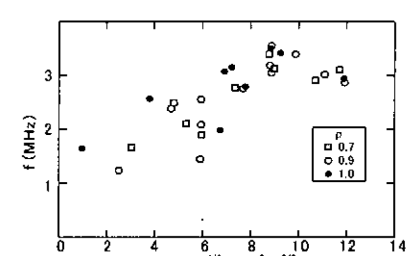

Fig.2 Dependence of f on $n_b^{1/2}$ measured at ρ~0.7, 0.9 and 1. f depends on $n_b^{1/2}$ and no clear difference is seen by position.

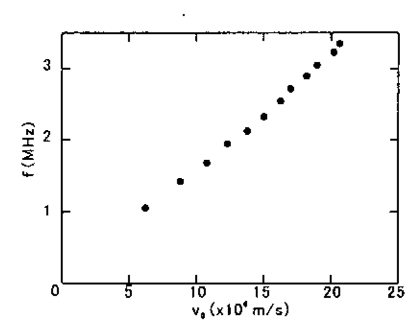

Fig.3 Dependence of f on v_0. f depends on v_0 linearly implying that these modes are some beam-related oscillations.