§3. Review of Nonneutral Plasmas Confined on Magnetic Surfaces of CHS

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In this academic year of 2009, we numerically found out outward electron orbits that extend to the inward part of closed helical magnetic surfaces (HMS). Those orbits are actually emerged by the existence of negative self space potential ϕ_s of electrons that are injected from an electron gun located outside the last closed flux surface (LCFS). And, as clearly observed in past experiments on CHS, the equi-potential surfaces of ϕ_s have been artifically shifted by 2 cm from the HMS in the calculations. Those findings was published in a paper of Phys. Plasmas[1)] and a subsequent paper has been accepted for publication in a special issue of PFR[2)]. In the following, we will explain the results briefly.

Figure 1 (a) shows a typical time evolution of the electron position. At $t = 0$ μs, the electron is injected into the SMR. Since the position is represented using $\Psi^{1/2}$, the period of $\Psi^{1/2} > 1$ means that the injected electron is circulating in the SMR, i.e., outside the LCFS. On the other hand, when $\Psi^{1/2} < 1$, the electron is inside the LCFS, which thus indicates that the inward penetration of the electron has happened. In fact, in Fig. 1 (a), such penetration can be clearly recognized for the period $t > 4.8$ μs. As recognized, just after the injection, the electron moves outwardly for ~ 2.5 μs, however immediately starts to turn back inwardly. This inward propagation still continues even across the LCFS. In fact, the electron quickly arrives at $\Psi^{1/2} \sim 0.7$ within only ~ 3 μs. During these events, the value of toroidal angle (ϕ) fluctuates around $\sim 330^o$. This indicates that the electron moves as a '*helically trapped particle*'. Also, as seen in Fig. 1 (c), the pitch angle of the electron periodically changes from $\sim 60^o$ to $\sim 120^o$. Such a considerable change in the pitch angle of the electron is apparently due to the presence of ϕ_s, as seen in Fig. 1 (d). The electron always remains in the finite ϕ_s region during the time period. In addition, the magnetic moment μ seems to oscillate quickly, although the total energy of the electron is always conserved.

At $t \sim 8$ μs, the helically trapped electron becomes a toroidally trapped one, which is seen in Fig. 1 (b) where the electron sometimes experiences reflection. During the period, the electron cannot penetrate deeply into the HMS, as seen from Fig. 1 (a). Then, a significant change in the motion occurs at $t \sim 11$ μs. after which time, the electron becomes again a helically trapped particle and drifts outwardly, even across the outermost region of the HMS. However, the electron is never lost. It actually reflects in the SMR where the negative ϕ_s exists, which is recognized from the data at $t \sim 15$ μs in Fig. 1 (a). In other words, the negative ϕ_s region in the SMR acts as a potential barrier[2)]. For $t > 15$ μs, the reflected electron starts again a similar movement. Namely, as clearly seen from the data in Fig. 1 (b), whenever the propagation across the HMS occurs, the electron is certainly trapped in the vicinity of a certain value of ϕ_s. Readers can find out the detail of this motion in Ref. 1).

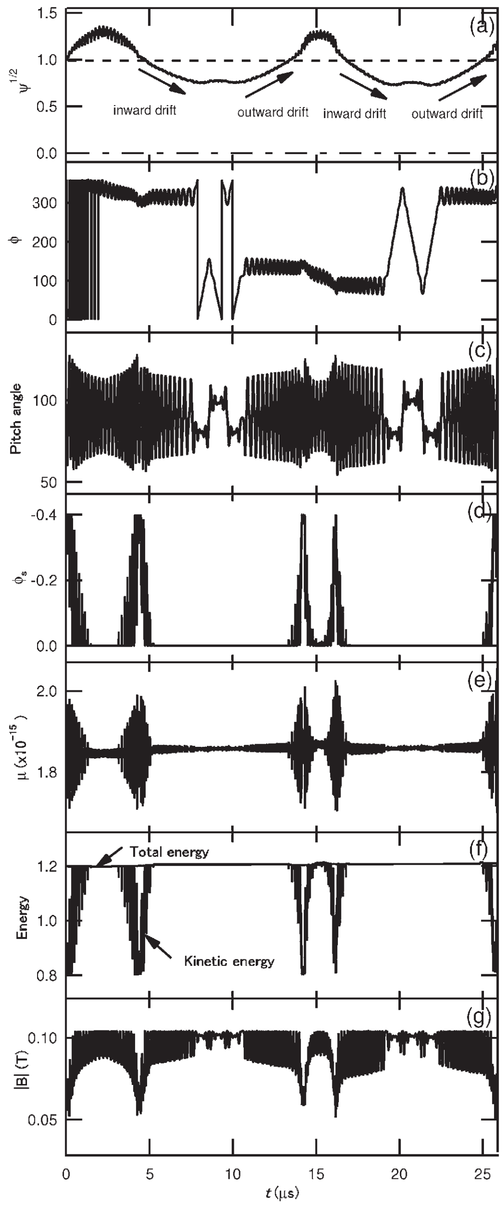

Fig. 1: Typical time evolutions of parameters of the injected electron.

1) H. Himura, K. Nakamura, S. Masamune, M. Isobe, and A. Shimizu, Phys. Plasmas (2010) vol.17 no.3, pp.032507.

2) H. Himura, M. Isobe, A. Shimizu, and S. Masamune, "Role of negative potential barrier formed by electrons confined in stochastic magnetic region of helical nonneutral plasmas", *accepted for publication in a special issue of PFR* (2010).