7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Numerical Analysis on Relaxation Process after Electron Injected into Malmberg-Penning Trap

T. Kikuchi[1], H. Ishii[2], N. Suzutani[1], Y. Park[3], Y. Soga[2], K. Takahashi[1], T. Sasaki[1]
[1] Nagaoka University of Technology,
[2] Kanazawa University,
[3] National Institute of Technology, Anan College
e-mail (speaker): tkikuchi@vos.nagaokaut.ac.jp

An inertial fusion power generation system using massive ions such as heavy ions and giant cluster ions has been proposed [1]. This system requires a kA-class high-current particle accelerator. For a pulse compression process in the final stage, the beam parameters are affected by the strong space charge effect.

Since it is difficult to construct a full-scale heavy-ion accelerator, we are studying the beam physics by compact experimental devices using electrons [2-4]. Using a newly developed kinetic energy measurement method [5], we are investigating the experimentally observed rapid relaxation processes in electrons incident on the Malmberg-Penning trap [6].

In addition to experimental approach, we are also investigating the beam dynamics using theoretical and numerical approaches [7-9]. The relaxation process is separated by the various time scales. During the time scale of 10 μs after the injection of electrons into the Malmberg-Penning trap, the electron cloud with initial velocity distribution truncated with fast particles regenerated the fast particles. The relaxation process was reproduced by the numerical simulation with multi-particle tracking [10,11].

During the time scale of 1 μs immediately after the injection of electrons into the Malmberg-Penning trap, the electron velocity distribution was drastically decayed [6]. In this paper, we report the results of a numerical analysis of the experimentally observed extremely fast relaxation process of electrons incident on the Malmberg-Penning trap.

Figure 1 shows the electron distribution function history at each applied electric field strength in the axial direction. According to the experimental condition [6], we carried out the numerical simulation with three-dimensional multi-particle tracking method [8-11]. The electrons have the offset kinetic energy of 13.7 eV in the axial direction at the initial condition. The initial temperature of electrons was 0.023 eV. The electron bunch length was 160 mm, and the radius was 0.4 mm. Figure 1(a) indicated the fast electrons over the kinetic energy of 20 eV were generated. On the other hand, the fast electrons over the kinetic energy of 20 eV were not observed well as shown in Fig. 1(b). The result implied that the relaxation process with the lower strength of the axial applied electric field is faster than that with the higher strength of the axial applied electric field.

References

[1] K. Takayama, *et al.*, Phys. Lett. **A 384**, 126692 (2020)
[2] T. Kikuchi, Y. Soga, K. Horioka, J. Plasma Fusion Res. **93**, 345-352 (2017) (in Japanese)
[3] Y. Sakai, *et al.*, Nucl. Instrum. Methods Phys. Res. **A733**, 70-74 (2014)
[4] Y. Park, *et al.*, NIFS PROC **93**, 84-87 (2013)
[5] Y. Park, *et al.*, Plasma Fusion Res. **14**, 1201046 (2019)
[6] H. Ishii, *et al.*, NIFS PROC **121**, 44-47 (2021)
[7] Y. Soga, *private communications*
[8] T. Sato, *et al.*, J. Phys.: Conf. Series **717**, 012100 (2016)
[9] T. Kikuchi, *et al.*, IEEE Trans. Plasmas Sci. **44**, 216-220 (2016)
[10] N. Suzutani, *et al.*, High Energy Density Phys. **36**, 100828 (2020)
[11] N. Suzutani, *et al.*, J. Japan Society Simulation Tech. **12**, 15-20 (2020)

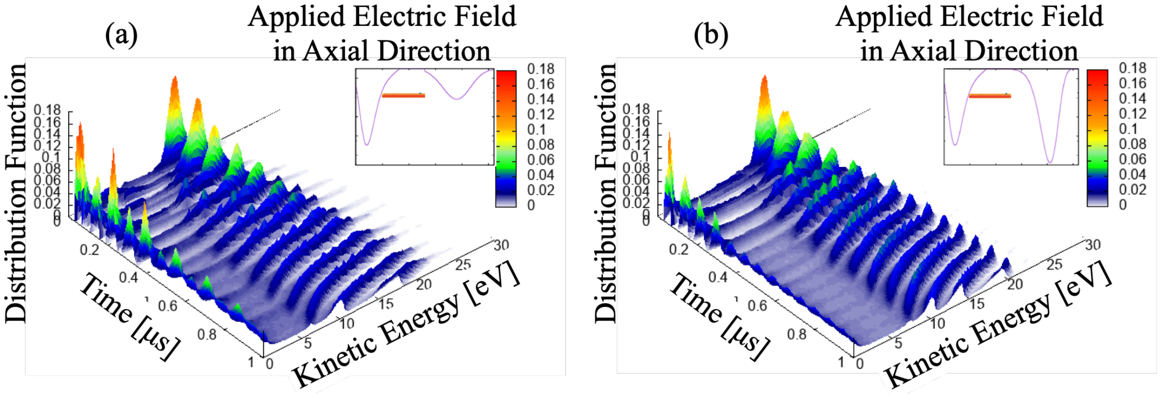

Figure 1. Electron distribution function history for (a) lower and (b) higher cases for applied electric field in axial direction.