24P136-P

Parallel Energy Distribution of an Electron Vortex During E×B Drift Rotation
E×Bドリフト周回運動をする電子渦糸のエネルギー分布計測

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Investigations of energy distribution of a pure electron plasma column rotating around the axis of cylindrical vessel due to an E×B flow are presented. An abrupt relaxation of energy distribution was observed in an electron string trapped for a few microseconds after injection from an electron emitter. A macroscopic E×B drift rotation of the single electron column is mainly dominated by their microscopic energy distribution determining an each position of reflection, namely, a radial electric field attributed to an external trap potential exerted on the particle.

1. Introduction

Many features of dynamics in 2D Euler fluids have been examined experimentally by using electron plasmas confined in Malmberg-Penning trap [1]. The macroscopic dynamics in an electron plasma, trapped axially by an electrostatic potential and radially by a strong homogeneous magnetic field, is isomorphic to that of two-dimensional (2D) inviscid fluid, as long as the axial bouncing motion of the electrons is much faster than the transverse E×B drift motion of their guiding centers. In the presence of the electric field $\boldsymbol{E} = -\nabla\phi(x,y)$ under a uniform magnetic field $\boldsymbol{B} = B_o\boldsymbol{e}_z$, the flow velocity of the guiding centers is given by $\boldsymbol{v}_d = \boldsymbol{E}\times\boldsymbol{B}/B_o^2 = \boldsymbol{e}_z\times\nabla\phi(x,y)/B_o$. Here, $\boldsymbol{e}_z$ is the unit vector parallel to the machine axis.

An electron column is expected to rotate around the center of the cylindrical vessel under the influence of the radial electric field from the image charge and from the bounce-averaged confining field. Here, we report experimental verifications of a mechanism of an E×B rotation using a single electron column by a measurement of time resolved parallel energy distribution.

2. Experimental apparatus and method

The electron plasma is confined in a Malmberg-Penning trap that combines radial constraint with a homogeneous magnetic field of B_o= 0.1 T and axial reflections between -80 V potential dips at both ends. As shown in Fig. 1, the potential is created by negatively biasing the end cylindrical electrodes and by axially aligned 9 conducting cylindrical electrodes.

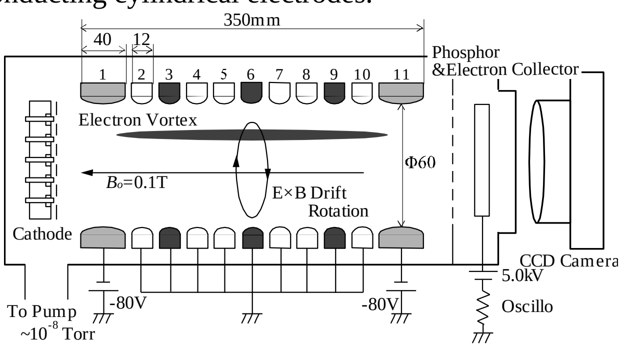

Fig.1. Schematic configuration of the electron plasma trap.

Among the 11 electrodes, which are numbered from 1 to 11 from the cathode side, the 3th, 6th, 9th, electrodes are azimuthally divided into four sectors with a uniform separation of 90°. We generate the electron string by injecting electrons from a cathode.

A system to measure the image current is shown in Fig. 2. We connect one of 6th sectored electrodes to the virtual ground of a current amplifier through a small resistance 15 kΩ. It is known that unbalanced grounding or even careless connection of a high gain amplifier can cause unstable oscillations of the electron column [2]. We should carefully adjust resistance of the sector while all other electrodes are directly grounded to the vacuum chamber wall.

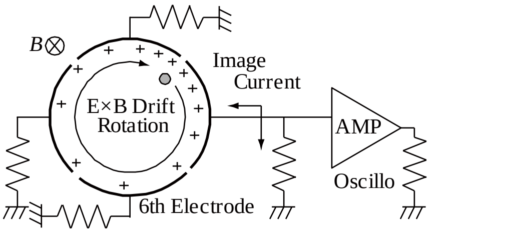

Fig.2. System of image current monitor and 6th electrode.

After plasma is confined for few seconds, the electron column is dumped by a lowered, but nonzero, confinement potential. The electrons move along magnetic field lines and are collected phosphor screen. We get total electron number and luminosity distribution. This procedure is repeated with several potentials. So, we measured Parallel energy distribution [3].

3. Parallel Energy Distribution

When electron plasma is injected, the plasma is generally not near thermal equilibrium but shows the sharp distribution at 13 eV corresponding with the injection energy (blue in Fig.3). Time for which an electron column is confined is defined as a holding time. Parallel energy distribution shows that a loosely expanded distribution from low energy to high energy "36 eV" at holding time 1 usec for which the electrons reflect three or four times between -80V potential dips at both ends and doesn't rotate mostly. This result shows that energy distribution rapidly expands when electron plasma is confined. We speculate that switching potential of an end electrode partially accelerated injected electrons.

A peak-energy rapidly decreases while the electron column is rotating once or more times for holding time from 100 usec to 1 msec, and stabilize at 1 eV after 2 msec as shown in Fig.4. An average energy slowly decreases during 1 sec due to cyclotron radiation.

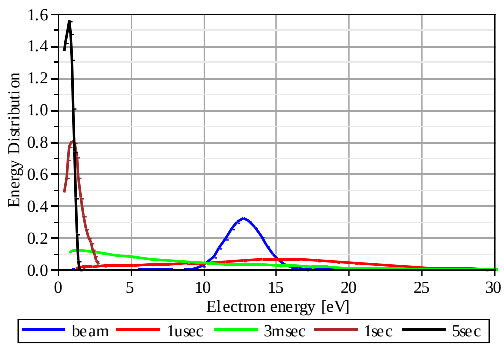

Fig.3. Parallel energy distribution of electron vortex.

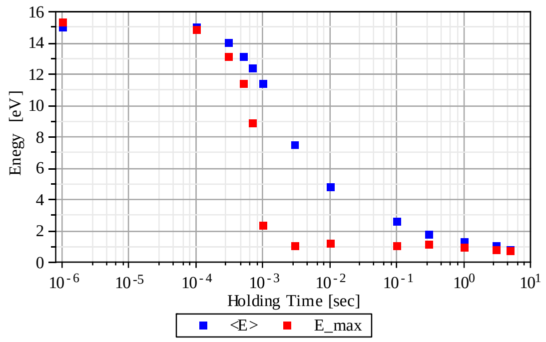

Fig.4. Average energy <*E*> is calculated by <*E*>=∫*dE Ef(E)*, E_max is maximum energy of *f(E)* .

5. E×B Rotation Frequency

The measured E×B rotation frequency ω_{exp} of a single electron column plotted in Fig.5 (■) is in good agreement with the calculated frequency ω_{cal2}(■) mainly contributed by a bounce-averaged external electric field E_{exp}. A rotation due to an electric field E_i of the image charge (indicated by symbols ● in Fig.5) doesn't affect the macroscopic rotation ω_{exp}.

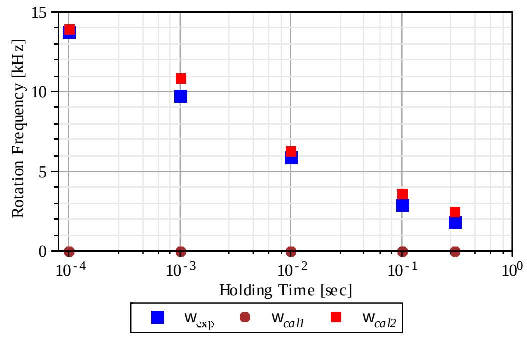

Fig.5. E×B drift rotation frequency versus holding time. Experimental result is ■, calculated result is ● and ■, the former is consist of E_i, latter is E_i+E_{ext}

6. Summary

In summary we investigated a mechanism of an E×B rotation using a single electron column by a measurement of parallel energy distribution. The macroscopic E×B drift rotation of the single electron column is mainly dominated by their microscopic energy distribution determining an each position of reflection, namely, a radial electric field attributed to an external trap potential exerted on the particle.

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