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Pure Electron Plasma experiments simulating the pulse compression of the charged particle beam

荷電粒子のパルス圧縮を模擬した純電子プラズマ実験

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Experimental study on dynamics during the pulse compression of a charged particle beam by a pure electron plasma confined in a cylindrical Malmberg-Penning trap has been started. Because non-neutral plasmas in the trap are physically almost equivalent to beams seen from the rest frame of reference, we can observe beam emittance by measurements of the axial temperature and radial density profile on the plasma. An axially extended electron plasma is compressed in the axial direction by applying negative voltage to ring electrodes placed at a region in which the plasma exist. Preliminary experiment shows that application of negative bias to five electrodes successively from one end is more suitable for beam compression than simultaneous application to the electrodes.

1. Introduction

In the heavy ion fusion devices, longitudinal pulse compression section is constructed in front of the implosion section on any type of accelerator systems [1]. Since the effective implosion of a target is disturbed by an increase in emittance of the compressed ion beam, a clear understanding is necessary about transient phenomena of space charge dominated beam during the pulse compression. But the production of an intense heavy ion beam requires a large particle accelerator, so ion beam is not suitable for the experimental study.

A pure electron plasma has been expected to use for the investigation of the fundamental properties of space charge dominated beam. The purpose of this study is to investigate dynamics during the pulse compression of a charged particle beam by a pure electron plasma. The idea is based on the simple fact that beams seen from the rest frame are physically almost equivalent to pure electron plasma in confinement cylindrical trap [2].

In this experiment we examine energy distribution of the plasma after compression by two different methods of compression.

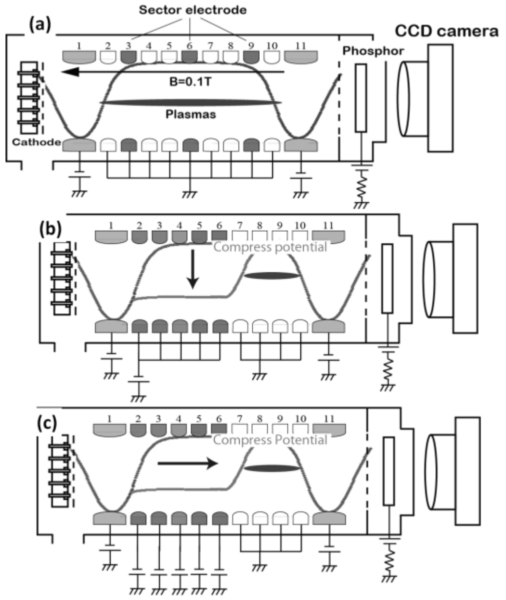

Fig.1：Schematic configuration of electron trap (a). Electrons are compressed by changing trap potential with simultaneous (b) and successive (c) application of negative voltage to ring electrodes.

2. Experimental method

The schematic configuration of the compression experiment device is shown in Fig. 1(a). The device

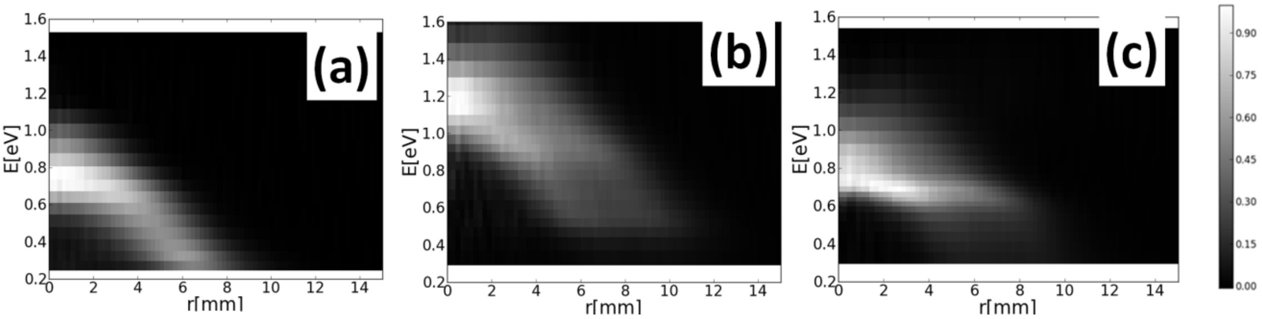

Fig.2: Longitudinal kinetic energy distribution at initial state (a) and after compression by method I (b) and method II (c). The luminosity increases with number of particles normalized by each maximum value.

is composed of an electron source and a cylindrical vacuum vessel, ring electrodes mm in a diameter, magnetic field coils, a phosphor screen and CCD camera. The basic scheme of the electron confinement consists of the homogeneous magnetic field B = 0.1 T along the z-axis and the saddle shaped axisymmetric potential with negative barriers at both ends. We use an electron plasma, cylindrical in shape with an equilibrium state, as the initial profile for the experiment.

Methods of plasma compression are schematically shown in Fig. 1(b) and (c). Axial compression is achieved by applying negative voltage to five ring electrodes placed at a region in which the plasma exist. We adopt two compression methods: I. applying a voltage to all electrodes at the same time (Fig.1(b)) and II. applying a voltage to electrodes successively from left end (Fig.1.(c)).

3. Result

Longitudinal kinetic energy distributions before and after compression are shown in Fig. 2. Average longitudinal kinetic energy is 0.52 eV in the initial state. After compression the energy increases at 0.91 eV in the method I and at 0.75 eV in the method II.

We define an electron temperature as a spread of the energy distribution. The average temperature estimated by radial profiles of temperature shown in Fig.3 also increases from 0.09 eV to 0.13 eV in the method I and to 0.14 eV in the method II.

4. Discussion & Conclusion

In method I, average energy and temperature are increase after the compression. Plasma temperature is important since it directly influences the emittance of the beam. As shown in Fig.3 the temperature is increased in the center of density distribution. But the increase of temperature is required to be suppressed to keep uniform energy deposition to the fuel target in ion fusion. Therefore method I is not valid for a compression of heavy ion beam.

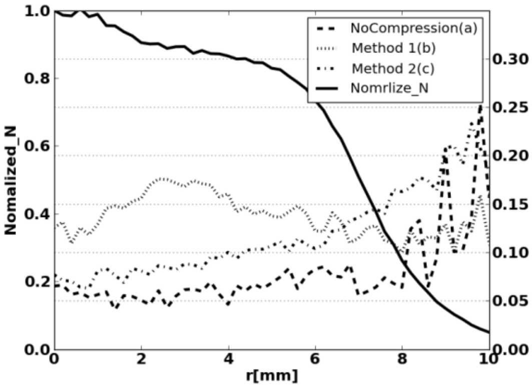

Fig.3 : Radial profiles of the observed density distribution (solid line) and the electron temperature (dot lines).

In method II although the average temperature increased, the temperature in the center is almost constant after compression shown in Fig.3. The increase of temperature around the periphery of the profile occurs due to a gradient of the density. Therefore this increase could be suppressed by using electron beam with a uniform density. As a result method II could be a candidate for a beam compression technique. However in this experiment electron density doesn’t reach to space charge dominated region. We should prepare more dense plasma in future work.

In conclusion we examined energy distribution of the plasma after compression by two different methods of compression. Application of negative bias to five electrodes successively from one end is more suitable for beam compression than simultaneous application to the electrodes.

5. Reference

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