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Development of electron plasmas for two-fluid plasma experiments
二流体プラズマ状態検証のための電子プラズマ源の開発と閉じ込め実験

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In order to produce two-fluid plasmas by Li^+ and electron plasmas, we have been developing a new experimental device in which two non-neutral plasmas are confined separately. Up to now, we have successfully finished making a Penning-type trap device, and now we are installing both ion and electron sources in the vacuum chamber. Details on the machine and preliminary results will be presented.

1. Introduction

To examine possibilities of the extended MHD plasma [1] state and impurities-free quantum dots experimentally, we have developed, for the first time, a Penning-type trap which confines pure ion and electron plasmas simultaneously.

2. Positive and negative potential wells

Figure 1 (a) shows the new trap. Ion and electron plasmas are produced, and then confined in bottoms of positive and negative potential wells, respectively: the axial confinement. On the other hand, the radial constraint is attained by a homogeneous magnetic field of $B_0 = 0.1$T.

The potential distribution called harmonic potential [2] is shown in Fig.2. Such a harmonic profile is created by 23 multi-ring electrodes shown in Fig.1 (b). The set of electrodes is 781.5 mm in total length and 50 mm in radius. By applying independent potentials to each electrode, the potential can be formed. The blue lines in Fig. 2 are potential values applied to each electrode externally. On the other hand, the red curve shows the resultant potential profile on the machine axis.

As seen in the Fig. 2, there are two potential wells in the machine. In the positive potential well, the ion plasma is confined, while the electron plasma is confined in the negative potential well.

3. Diagnostics

Several measurements will be performed in experiments. Firstly, to measure image charges induced on the electrodes, we are developing a set of current amplifiers shown in Fig. 3. Here, one can see that there are eight electrodes in Fig. 3. Among ring electrodes, four of them (indicated as shadow parts in Fig.1) are azimuthally divided into eight sectors with a uniform separation of 45 degree. The two of four segmented electrodes are used to measure image charges for both ion and electron plasmas. On the other hand, the rest two of four segmented electrodes are employed to apply a rotating electric field to plasmas. In experiments, the ion density will be close to its Brillion density limit so that the plasma will suffer from the diocotron instability. To avoid it, we will use the technique of the rotating electric field to control the plasma shape even in higher plasma density regime.

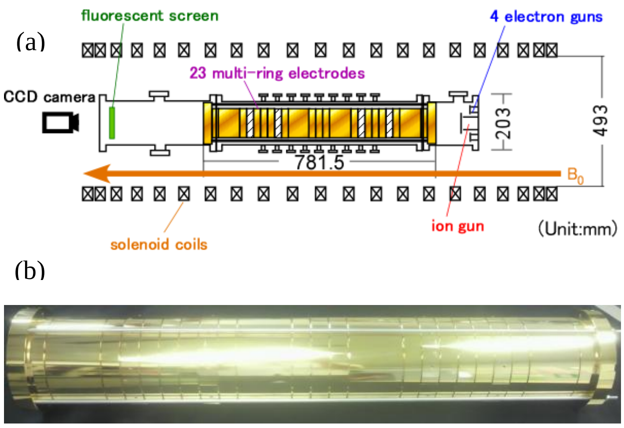

Fig. 1. (a) A schematic drawing of the experimental machine plasma trap, and (b) a photo of the multi-ring electrodes installed in the vacuum chamber.

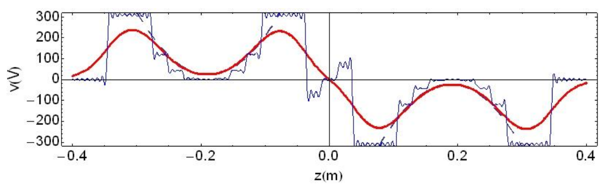

Fig. 2. Axial potential distributions of externally applied voltage (blue lines) and the resultant profile formed on the machine axis (red curve).

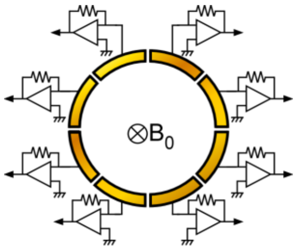

Fig. 3. Schematic drawings of the segmented electrodes on which current amplifiers are connected to measure image charges induced on the electrodes.

Other diagnostics are shown in Fig. 1. The fluorescent screen will be used to measure the two dimensional distributions of both ion and electron plasma densities. It is installed at the end of the vacuum chamber. Then, in the reverse side, both Li^+ and electron sources are installed. Figure 4 shows a holder on which both ion and electron sources are mounted. On the holder, the Li^+ source is set on the center of the holder, while four electron sources are located on the off center axis. Using these four electron sources, we will produce electron plasmas on the center axis through a self-organization process [3, 4].

4. *I-V* characteristic of Li^+ source

The pure ion and electron plasmas are made by an ion and a thermal electron sources, respectively. Regarding the ion plasma, it is required to minimize the effect of gravity or maximize the Brillion density limit [5] for this experiment. Thus, the ion species must be light. For this reason, we have chosen Li in this experiment.

Li^+ species are ejected from the indirect heated ion sources made of tungsten impregnated with β -eucryptite. On the other hand, the electrons are emitted from also the indirect heated cathode constructed by tungsten impregnated with barium.

Figure 5 (a) shows the current – voltage (I_d-V_{acc})

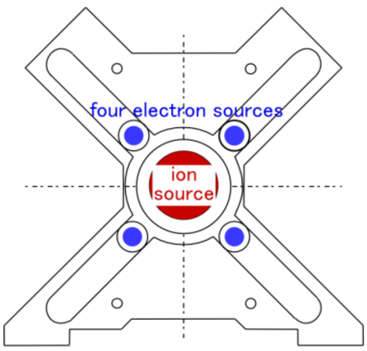

Fig. 4. A schematic drawing of the holder on which the on and four electron emitters are set.

characteristics of the Li^+ source. Red circles are the data obtained from the setup shown in Fig. 5 (b). On the other hand, blue triangles are the data obtained from the setup shown in Fig. 5 (c) that has two electrodes in the gun. As compared the values of blue triangles with those of the red circles, Li^+ can be emitted with relatively lower energy.

In Fig. 5 (c), Li^+ is firstly accelerated between the ion source (anode) and the electrode (indicated by the black solid line) on the left-hand side, and then decelerated between the two electrodes. Therefore, the total energy of the emitted Li^+ corresponds to V_{acc}. The lowest value of V_{acc} is 2 V, which is much lower than the lowest value of the red circles (~ 20 eV). In addition, the value of the emission current I_d is still ~ 2 uA with even such a lower value of V_{acc} (~ 2 V).

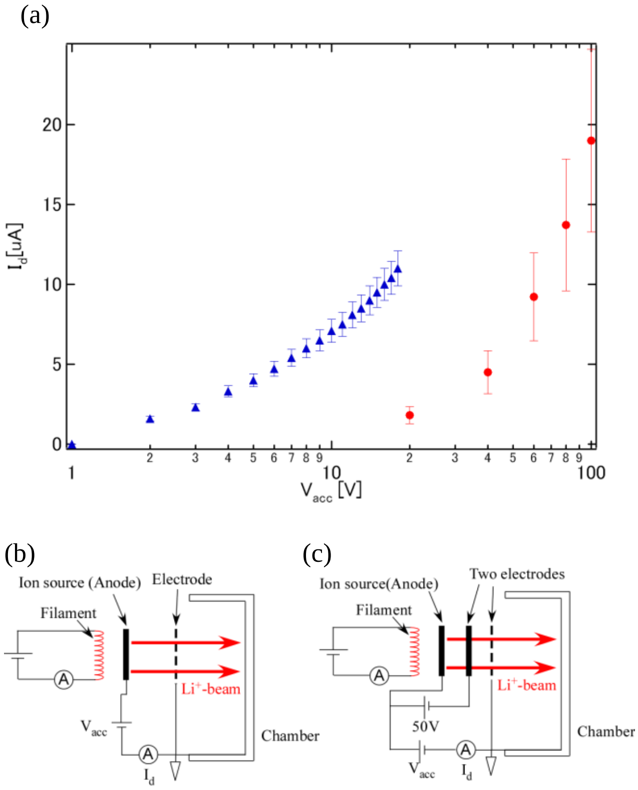

Fig. 5. (a) I_d - V_{acc} characteristics obtained from two different setups: (b) with one electrode (red circles shown in (a)), (c) with two electrodes. (blue triangles shown in (a)).

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