MANIPULATION OF PROTON PLASMA BY ROTATING ELECTRIC FIELD

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We are developing an antiproton trapping system to prepare antiproton beams in the energy range of keV to eV for slow antiproton-atom (molecule) collisions and spectroscopy, *etc*, which includes production of metastable protonium and other antiprotonic atoms. To simulate the behavior of antiproton during trapping, cooling, and extraction, H^- ions and protons are employed. In this report, a manipulation, primarily compression, of a proton plasma is discussed.

To get a proton plasma (or charged cloud), we used the ionization of residual gas by energetic electrons. First, we setup the harmonic potential in an electro-magnetic trap, which is mounted in the bore of 1T superconducting solenoid, and then electrons of 60eV are injected along the magnetic field. Residual gases are ionized with the electrons, which eventually forms a cold plasma. Second, a rotating electric field is applied, which exerts a torque on the proton plasma. Then the plasma is compressed. Third, that potential is ramped up and plasma is extracted at 800eV to observe the radial distribution of the plasma.

We are using a micro-channel plate(MCP) with diameter of $\sim 8\mathrm{cm}$ combined with a phosphor (ZnO) screen to image the profile of plasma, which is then recorded by CCD camera.

Fig.1 shows the image of extracted plasma with (right) and without (left) a rotating field for 1.3×10^6 particles.It is seen that the background is darker and the center part is brighter when the rotating field is applied. The MCP has a 6.4mm hole which shows up as a dark hole in Fig.1 which was used to measure the number of particles compressed below 6.4mm.

We found that a proton plasma is effectively compressed with a particular frequency of the rotating field, *ie*, a kind of resonance. For example, the resonance frequency was about 256 kHz at 4×10^6 particles, and about 266 kHz at 2×10^6. Fig.2 summarizes the experimented finding, which shows that the resonance frequency decreases the efficiency as the particle number increases. As is seen, the resonance frequency strongly depended on the number of particles of the plasma. But it is not practice that we must know the number of particles in advance for manipulating antiproton plasma. Therefore, we applied a broad band rotating field to decrease the efficiency of the particle number, and observed that plsamas which they had different particle number, was compressed each other by a same rotating field.

The plasma which we used was not a pure proton plasma. It consisted of proton and $\mathrm{H_3}^+$ ion, which ratio was about $2:3$. We can compress plasmas which have various ratio of components and change the ratio by applying a electric field along the axis to kick out proton or $\mathrm{H_3}^+$ ion.

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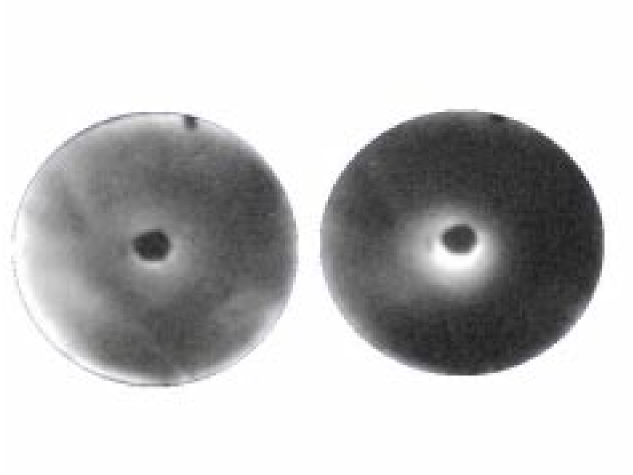

Fig.1 Plasma profiles

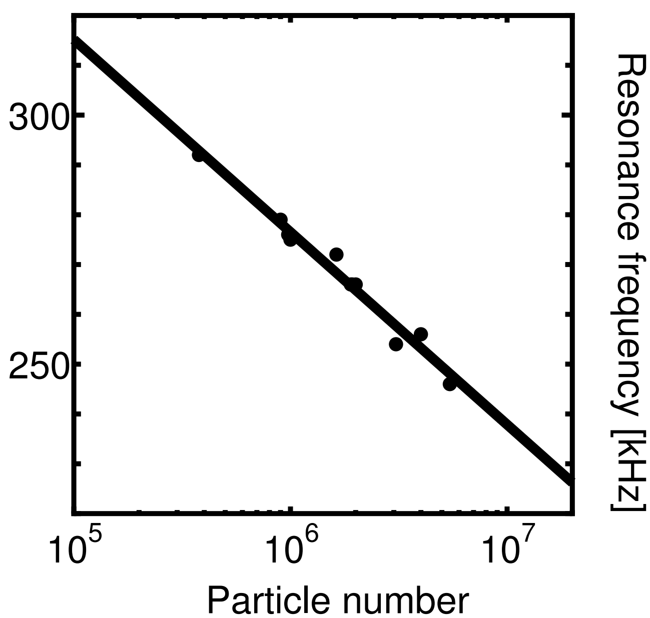

Fig.2 Resonance frequency vs. particle number