II. 3. Development of an Electric Field Application System toward the Electron EDM Search Experiment

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A permanent electric dipole moment (EDM) of a particle, an atom or a molecule plays an important role in testing the new physics beyond the standard model (SM) of elementary particles, since the EDM is sensitive to CP-violation in the theories beyond the SM[1)]. So far, a finite value of the EDM has not been observed[2)]. We plan to search for an electron EDM by using laser cooled francium (Fr) atoms. Since Fr is the heaviest alkali atom, the enhancement factor of the electron EDM is largest in alkali atoms[3)]. The laser cooling technique can localize atoms. The localized atoms would then have a long coherence time, and hence be able to suppress a statistical error and some systematic errors because of the velocity of the atom, such as a motional magnetic field[4)]. From these features, we have chosen the laser cooled Fr atoms as a substance in which the EDM is searched for.

Experimentally, the EDM is deduced from a change of spin precession frequency induced by the reversal of an electric field applied along a magnetic field. Since the magnitude of the frequency change is proportional to the electric field, the application of the strong electric field is a key issue for the EDM experiment. Our planned experiment will utilize Fr atoms trapped in a three-dimensional optical lattice. In order to realize the three-dimensional optical lattice, three-dimensional optical access is required. We employed disk-shaped glass plates coated with indium tin oxide (ITO) as transparent electrodes. The size of the glass plates was 4 cm and 1 cm thick. The transmittance of electrode was measured to be about 85% at a wavelength of 780 nm. The surface resistance of ITO was about 20 Ω/cm^2. This finite resistance of ITO, which can suppress the stray magnetic field induced from a Jonson noise current, is of advantage to the EDM experiment[5)].

We constructed the electric application system using the ITO electrodes as shown in

Fig. 1. The distance between the electrodes was fixed to be 1 cm with insulators made of ceramic. A calculated gradient of electric field was less than 1 V/mm^2 at the center between electrodes. The electrodes were installed inside a chamber with a vacuum pressure of 10^{-8} Pa. A leakage current across the electrodes was measured with a Pico ammeter which was protected from sudden discharge by inserting a low-pass filter. When positive voltage was applied, we applied the voltage up to 43 kV without discharge. On the other hand, when negative voltage was applied, we observed a sudden increase in leakage current at the voltage of -18 kV as shown in Fig. 2, and the breakdown occurred at a voltage of -20 kV. We are now investigating the difference between the positive and negative voltage applications.

In order to confirm the field strength of the electric field applied to the laser-cooled atom, we measured a DC Stark shift of a rubidium (Rb) atom trapped in a magneto-optical trap (MOT). The DC Stark shift of ^{87}Rb D1 line $\Delta\nu$ is $\Delta\nu = \alpha E^2/2h$, where α = 0.122306(16) Hz/(V/cm^2)[6)] is the D1 scalar polarizability of the ^{87}Rb atom, E is the strength of the electric field and h is the Plank constant. Since α is well known, the strength of the electric field is deduced from the DC Stark shift. The ^{87}Rb atoms were trapped in the center between the electrodes. When voltage of 20 kV was applied, the observed DC Stark shift was 26(10) MHz, which corresponded to the strength of the electric field of 21(4) kV/cm. The result showed that the proper electric field was applied to the Rb atoms trapped in MOT, since the distance between the electrodes was 1 cm.

After the improvement of the negative voltage application, we will try the pilot Rb atomic EDM experiment by using the electric field application system.

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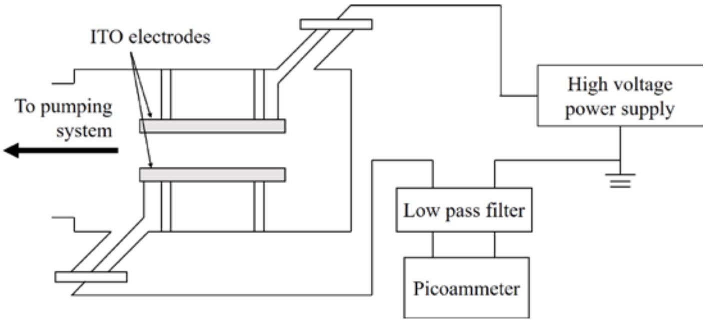

Figure 1. Schematic view of the constricted electric field application system.

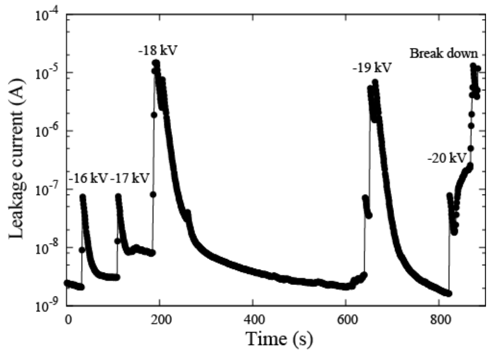

Figure 2. Leakage current with negative voltage application.