Development of an off-axis electron beam source for cold highly charged ion generation in a linear combined ion trap

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Some particular transitions in highly charged ions (HCI) are sensitive to possible time variation of the fine structure constant. High-precision spectroscopy of such transitions can be a new probe for the verification of fundamental physics.[1,2] To perform such spectroscopy, ion trapping and cooling of HCI are indispensable. Schmöger *et al.*[3] observed Coulomb crystallization of highly charged Ar in a linear RF trap; however, no spectroscopy has been performed yet. We designed and constructed a compact cryogenic setup in which a microscopic electron beam ion trap (μ-EBIT) and a linear RF trap are enclosed.[4] In this setup, HCI are generated in the μ-EBIT, while laser-cooled Be^+ ions are stored in the linear RF trap. Since the two traps are arranged collinearly, the center axis line must be reserved for the cooling laser path. Additionally, preserving the super-high vacuum necessary for storing HCI precludes the use of any hot electron source. We developed a cold cathode electron beam source with an “off-axis” geometry to fulfill such constraints.

Figure 1 shows the geometry of the electron beam source with electron beam trajectories, which are simulated by SIMION8.0 code. The cold cathode has a through hole for the laser path, and a Coniferous Carbon Nano Structure (CCNS) is generated on the surface in advance.[5] When a high voltage is applied to the anode, field emission electrons are extracted from the cathode surface. The emitted electrons fly according to the electron optics, and some fraction of them will reach the trap region with the energy given by the cathode voltage.

After an aging process was performed by applying high voltages for a long time under ultra-high vacuum condition, we obtained an I-V characteristic plot of the electron beam source, as shown in Fig. 2. The circle plots represent the electron beam intensity reaching the trap region and the square plots represent the total emission from the cold cathode. The electric current (I) and voltage (V) were measured by monitoring the power supply output while changing the anode voltage. The cathode voltage was fixed at 300 V. A typical intensity of >0.1 mA at 300 eV in the trap region with an efficiency of >50% was achieved.

In order to focus the electron beam in the μ-EBIT, a strong magnetic field needs to be applied using hand wound coils of a superconducting wire.[4] As the next step, will generate HCI such as Ho^{14+} in the μ-EBIT, and try to crystallize the HCI in the linear RF trap by sympathetic cooling with laser-cooled Be^+.

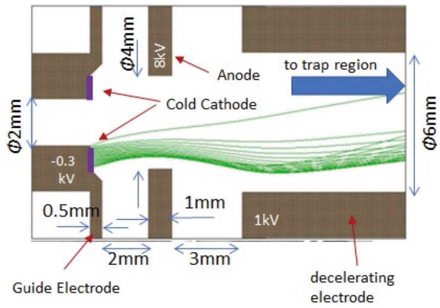

Fig. 1. Sketch of electron beam source with trajectories calculated using SIMION 8.0.

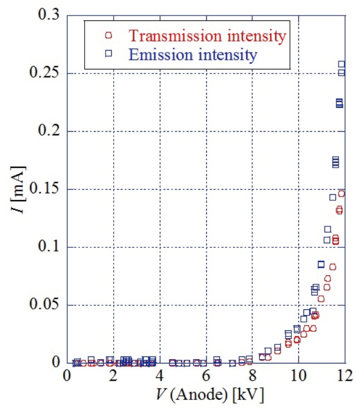

Fig. 2. I-V plot of electron beam of 300 eV.

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