Concept design for cold highly charged ion generation toward time variation detection of fine structure constant $\alpha$

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A ground unification theory approves that fundamental physical constants have a time dependence.¹) Over recent decades, time-variation detections of fundamental physical constants have been attempted through several approaches. In astrophysical research, J. K. Webb et al. reported that a variation of fine-structure constant $\alpha$ was observed as $\delta \alpha/\alpha = 0.72(\pm 0.18) \times 10^{-5}$ by comparison with quasar spectra.²) Recently, V. V. Flambaum et al. have focused on achieving a high enhancement factor $K$ of highly charged ion (HCI) atomic transitions and suggested high-sensitivity measurements for the detection of $\alpha$-time variation by Ho⁺⁴⁺ precision spectroscopy.³) Additionally, they proposed special enhanced measurements using highly charged Actinide ions Cf¹⁵⁺ and Es¹⁶⁺.⁴)

As mentioned above, HCI precision spectroscopy is expected to be a candidate for the next-generation atomic clock for conducting the constancy test of fundamental physical constants. We plan to measure the frequency difference between a Sr optical lattice clock and a clock transition of HCI using an optical-clock and a clock transition of HCI using an optical-external HCI injection system. We plan to generate an HCI Coulo-precise cooling method with an electron beam. The off-axis cold cathode injects an electron beam into a trap region while maintaining the cryogenic thermal condition and cooling laser path. A superconductive Nb:Ti wire will be looped on quadrupole rods directly. This wire will become a solenoid coil and generate a strong magnetic field for Penning trap driving and the concentration of the electron beam. Generated HCI ions are transported to the 3rd area by electrical manipulation and cooled by the prepared Be⁺ Coulomb crystal.

A function test of this instrument will be performed by observations of Be⁺ trapping and cooling. After this test, we will try to perform HCI generation and sympathetic crystallization.

![HCI trap (without coils and print circuits).](image)

![Cryogenic chamber system.](image)

References