Radioactive ion beam transportation for the fundamental symmetry study with laser trapped atoms


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The observation of the fundamental-symmetry violation in a radioactive isotope (RI) is one of the promising candidates for the precision tests of the standard model and its possible extensions. The subtle signal due to the symmetry violation is enhanced in the RI such as a francium (Fr). To realize the high precision measurement, the large amount of the RIs is required. At CYRIC in Tohoku University, Fr is produced via the nuclear fusion reaction using a melted Au target, and the maximum extraction efficiency with about 40% is realized. We report the results of the Fr ion transportation including the Rb ion pilot experiments, and discuss the performance of the transport system.

I. EDM (Electric Dipole Moment)

Permanent EDM in elementary particle
Violation of T-symmetry

Predicated value for EDM in Standard Model (SM): <1×10⁻12 e·cm

Some theoretical models beyond SM predict much larger values, current experimental technique would reach that values.

・EDM of francium (Fr)

Enhancement factor of EDM : K=895


・Francium (Fr) + Laser cooling and trapping techniques

Search for EDM of d~−1×10⁻15 e·cm would be possible.

II. Fr production at CYRIC

The fusion-evaporation reaction

\[ ^{19}\text{O} + ^{197}\text{Au} \rightarrow ^{215}\text{Fr} + xn \]

Fr isotopes are produced in the gold and ionized at surface.

Ionization process is described by

\[ \text{Saha-Langmuir equation.} \]

III. Design and construction of Fr ion beam line

Ion-to-atom converter

Magneto-optical trap

Neutralized Fr atoms are trapped by six orthogonal lasers and a quadrupole magnetic field.

IV. Experimental results

・Fr experiment

Melted gold target

Maximum extraction efficiency : 40%

Also, we succeeded in Fr ions transportation from BD1 to BD4.

- Conventional assignment of polarity
  - 55 V
  - 80 V
  - 38 V

- Reversed polarity assignment
  - 38 V
  - 46.5 V
  - 38 V

1.6% → 29%

Transport efficiency was drastically improved!

Summary and future plan

・The maximum transport efficiency of 29% and Rb-MOT of 10⁸ atoms was achieved.

・Optimization of the transport conditions using ion trajectory simulation is necessary to realize the better efficiency.

・Next step, we will perform Fr-MOT experiment for high-precision EDM measurement.