Development of novel detection system for francium ions extracted from online surface ionizer

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One of the origins of the matter-antimatter asymmetry in the Universe is considered to be the violation of the charge conjugation and parity symmetries.[1)] The existence of a non-zero permanent electric dipole moment (EDM) of an elementary particle is an indicator of symmetry violation.

In particular, electron EDM (eEDM) is enhanced in paramagnetic atoms,[2)] up to 10^3 in the case of francium (Fr), which is the heaviest alkali.[3,4)] We are currently developing an eEDM measurement system using laser-cooled Fr atoms.

Fr atoms are produced in a surface ionizer via the nuclear fusion-evaporation reaction, $^{197}\mathrm{Au}(^{18}\mathrm{O}, xn)^{215-x}\mathrm{Fr}$.[5)] An ^{18}O primary beam is irradiated onto a solid Au target. A fraction of the produced Fr atoms reach the surface via thermal diffusion, where they are released as ions owing to the surface ionization effect on the Au surface. Using electrodes placed next to the target, the ions are extracted at a 45-degree angle at 1 keV energy. The Fr ion production rate depends on the Au target temperature, which is controlled using an infrared heater installed on the opposite side of the beam irradiation surface of the target.

The Fr yield is monitored by detecting the α particles emitted during their decay using a Si solid state detector (SSD). In previous experiments, because the infrared light from the heater acted as a noise source for the SSD, the heater needed to be stopped for each measurement. However, turning off the heater frequently caused the Fr production to become inefficient, owing to the rapid drop in the Au target temperature.

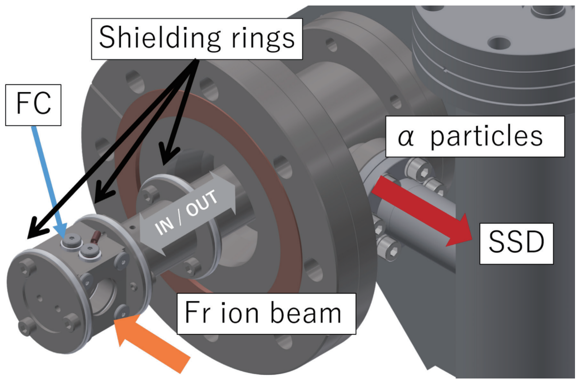

Fig. 1. Developed Fr ion beam detector. Light from infrared heater is shielded by shielding rings.

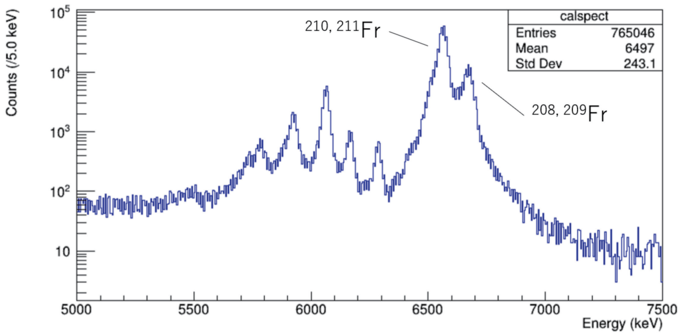

Fig. 2. Typical energy spectrum of α particles emitted during decay of ions captured on FC surface, obtained using the SSD. Labelled peaks within the range of 6.5–6.8 MeV are identified as Fr.

To overcome this problem, we have developed a novel Fr ion detection system that is insensitive to the infrared light of the heater. The detection system, as shown in Fig. 1, consists of an SSD, a Faraday cup (FC), and a moving rod attached to four shielding rings. The extracted Fr ions are first irradiated onto the FC surface, where the beam intensity is observed as electronic current. Subsequently, the FC is moved to the front of the SSD, where the α particles are detected. Throughout the operation, the shielding rings fit to the cylindrical wall of the chamber with a negligible clearance; therefore the light hardly enters the SSD.

In September 2020, an experiment on Fr production was conducted. Figure 2 shows the energy spectrum of the α particles detected by the SSD. The spectrum analysis shows that a ^{210}Fr ion beam of 5×10^6/s was extracted. The Au target was heated to 960°C, and an $^{18}\mathrm{O}^{6+}$ beam of 1 particle μA accelerated to 7 MeV/nucleon using an RIKEN AVF cyclotron was used as the primary beam.

Throughout the experiment, the infrared heater had a negligible effect on the SSD. Therefore, the newly developed Fr ion detection system enables beam detection without stopping the infrared heater, which is advantageous for stable production of Fr ions.

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