Measurement of stopping-position width of highly energetic Rb ion beams in liquid nitrogen

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We are developing a laser spectroscopy technique named optical RI-atom observation in conduced helium as ion catcher (OROCH) for the study of nuclear properties of unstable nuclei. In this method, highly energetic ion beams are stopped in superfluid helium (He II) and neutralized, following which atoms are subjected to in-situ laser spectroscopy. The combination of optical pumping and the laser radiofrequency (RF) of microwave (MW) double-resonance methods enables us to determine the Zeeman and hyperfine splittings of atoms, from which the nuclear spin and moment are deduced. The method is promising particularly for low-yield nuclei because the stopping efficiency of He II is nearly 100%. We have successfully observed laser-induced fluorescence (LIF) from ^{85}Rb atoms of about 200 pps injected into He II as a 66 AMeV beam in the RIKEN RIPS beamline.[1)]

However, the above energy beams could just reach the center of the optical cryostat after travelling for several millimeters in He II. In order to apply this method to heavier elements such as Ag, Cs, and Au, a beamline of higher energy is necessary to transport beams to the LIF observation region (ϕ2 mm $\times$ 5 mm).

As the first step, we plan to apply this method to radioactive Rb isotopes provided by the HIMAC SB2 beamline at NIRS. To verify the feasibility of an online experiment, we investigated beam yields and beam profile using a ^{84}Rb beam produced from a primary ^{84}Kr beam on a Be target of 350 AMeV. We observed photons from plastic scintillators to estimate the number of ^{84}Rb ions stopped in the LIF observation region. Liquid nitrogen was used as a stopper instead of superfluid helium in this experiment.

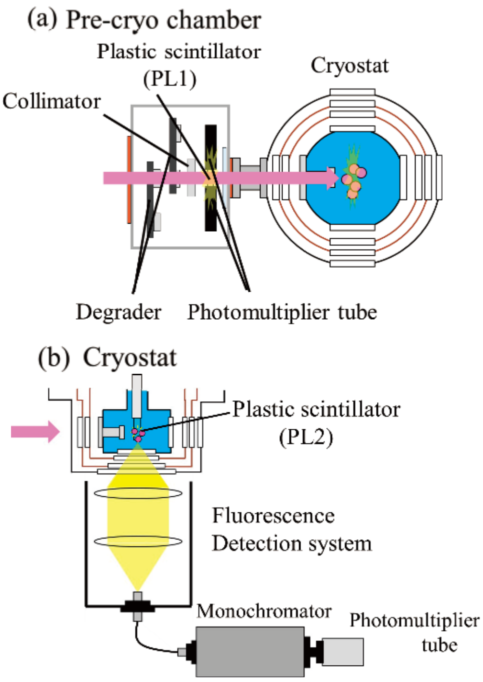

Fig. 1. Schematic of (a) the pre-cryo and (b) the cryostat chambers.

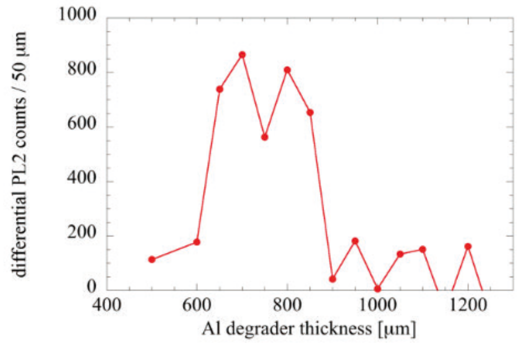

Fig. 2. Differential PL2 counts as a function of the Al degrader thickness.

Figure 1 shows the schematics of the "pre-cryo" and cryostat chambers where two plastic scintillators PL1 and PL2 are placed. Details of the apparatus and measurement method are described elsewhere[2)] in this progress report.

The result of the PL1 counts acquired to investigate the transverse beam profile is reported in Ref. 2). In order to measure the longitudinal stopping position of the beam, we counted the PL2 photons as a function of the thickness of aluminum energy degrader. The degrader thickness was changed in steps of 50 μm. Figure 2 shows the differential counts between neighboring thicknesses, which correspond to the number of stopped ions. That is, the differential counts indicate the range distribution for the beam if the stopper material is regarded as aluminum. We found that the optimal degrader thickness was $\sim$750 μm. The beam was stopped within a longitudinal width of 0.3 mm in aluminum. From this result, we roughly determined that the beams were stopped in a width of 1 mm in liquid nitrogen. If we convert this value to the stopping-position width in He II, the beams are estimated to be stopped in a width of 6 mm, considering the material density of He II. Further analysis to estimate the ^{84}Rb atom yields in the LIF observation region combined with the transverse beam profile is in progress.

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References
1) K. Imamura *et al.*, Appl. Phys. Express **12**, 016502 (2019).
2) K. Tsubura *et al.*, in this report.