Investigation of the secondary rubidium beam profile at HIMAC towards laser spectroscopy in an optical cryostat

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We are developing a laser spectroscopy technique named Optical RI-atom Observation in Condensed Helium as Ion-catcher (OROCHI) for the study of nuclear spins and moments. In the OROCHI experiment, we catch highly energetic ion beams in superfluid helium (He II) in our cryostat to neutralize them and conduct in-situ laser spectroscopy. We irradiate the neutralized atoms with circularly polarized laser light to produce spin polarization and measure the atomic Zeeman and hyperfine splitting of the atoms using the laser-radio-frequency and laser-microwave (mw) double resonance method.

In the previous online experiment,[1] our group observed the laser-rf double resonance spectra for $^{84-87}$Rb ion beams. It was reported that the atoms in superfluid helium shows a hyperfine structure constant slightly lager than that of a free atom by ∼1%.[2,3] Now, based on our interest in the hyperfine anomalies of the atoms in superfluid helium, we plan to measure the hyperfine splitting of the radioactive Rb, Ag, Cs, and Au isotopes, to which this method has not been applied.

We plan to apply this method to radioactive Rb isotopes provided by the HIMAC SB2 beam line at NIRS in FY 2020. As a prerequisite online experiment, we measured the beam yields of a ^{84}Rb beam produced in proton pickup reactions by a ^{84}Kr beam of 350 A MeV on a Be target of 12 mm thickness to investigate the beam profile of ^{84}Rb ions stopped in a laser-induced fluorescence (LIF) observation region (ϕ2 mm × 5 mm).

The beam yields were counted with two plastic scintillation counters. One plastic scintillator ("PL1": 30 mm square × 0.1 mm thickness) was placed in a chamber, which we call the "pre-cryo chamber," in front of the cryostat. Another plastic scintillator ("PL2": 10 mm square × 0.5 mm thickness) was placed at the center of the cryostat. A variable energy degrader system was placed upstream of PL1, and one of the collimators having various diameters can be set just upstream of PL1 in the pre-cryo chamber. A figure for the setup and the role of PL2 is described in the report by M. Nishimura *et al.*[4] in this progress report.

We measured the beam yields using PL1 as a function of the collimator diameter in order to investigate the transverse beam profile. The coincidence pulses of two photomultipliers mounted at the left and right sides of PL1 were counted by a multichannel scaler (Techno AP APG7400A USB-MCA4) with a dead time of 1.5 μs. Figure 1 shows the collimator diameter dependence of PL1 counts. The primary beam intensity was 2×10^8 particles per spill (the repetition cycle of the beam spill was 3.3 s) for this measurement. Because the beam purity was ∼40%, which was evaluated from the particle identification, we found that ^{84}Rb beams of 3.8×10^4 particles per spill were provided from the HIMAC SB2 line at the full primary beam intensity of 5.9×10^8 particles per spill with a dead-time correction. This value agrees with a LISE++ calculation result. Currently, we are carefully analyzing the data and evaluating the beam profiles of ^{84}Rb and impurity ^{82}Kr, assuming the beam profiles follow a Gaussian distribution.

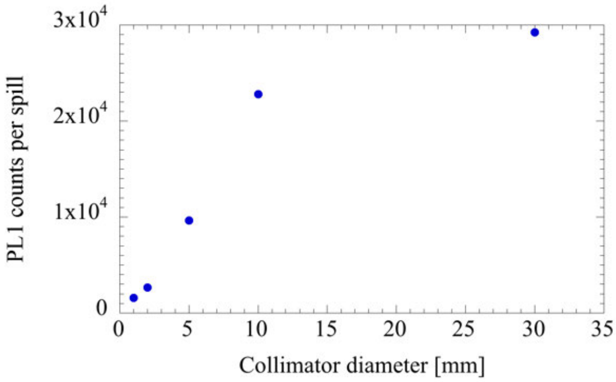

Fig. 1. Collimator diameter dependence of the yield of the secondary beam.

In summary, we evaluated the secondary beam yield variations by changing the collimator size to investigate the transverse profile of the beam. Combined with the results for the longitudinal distribution of the stopped atoms in the cryostat using PL2 counts,[4] the estimation of the yield and profile of ^{84}Rb atoms in the LIF observation region is in progress. We will verify the feasibility of the hyperfine structure constant measurements for various Rb and Ag isotopes at the HIMAC SB2 beam line.

References

1) X. F. Yang *et al.*, Phys. Rev. A **90**, 052516 (2014).
2) Y. Takahashi *et al.*, Z. Phys. B **98**, 391 (1995).
3) T. Furukawa, Ph.D. thesis, Osaka University (2007).
4) M. Nishimura *et al.*, in this report.

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