Laser-RF double resonance spectroscopy of $^{84-87}$Rb isotopes trapped in superfluid helium†

X.F. Yang,[*1,*2] T. Furukawa,[*1,*3] T. Wakui,[*1,*4] K. Imamura,[*1,*5] T. Fujita,[*1,*6] Y. Mitsuya,[*1,*5] M. Hayasaka,[*1,*7] Y. Ichikawa,[*1] Y. Ishibashi,[*1,*9] H. Shirai,[*1,*8] T. Suzuki,[*1,*8] Y. Ebara,[*3] A. Hatakeyama,[*10] M. Wada,[*1] T. Sonoda,[*1] Y. Ito,[*1] T. Kobayashi,[*11] S. Nishimura,[*1] M. Kurata-Nishimura,[*1] Y. Kondo,[*1,*8] K. Yoneda,[*1] H. Ueno,[*1] T. Shinozuka,[*4] T. Shimoda,[*6] K. Asahi,[*1,*8] and Y. Matsuo[*1,*12]

Laser spectroscopy measurements of various isotopes have provided a number of valuable results, such as nuclear spins, moments, and charge radii. However, to further study exotic atoms that are far from stability, higher efficiency and higher resolution are strongly required to overcome certain experimental limitations (low yield, limited beam time, large contaminations, and so on). Therefore, a new method called OROCHI was developed for laser spectroscopy measurements of radioactive isotopes (RIs) in superfluid helium (He II) using a small and controllable number of atoms.[1)] In this method, using He II as the trapping medium for the energetic ion beam and matrix for trapped atoms, we aim to systematically determine the nuclear spins and moments of RIs with a low yield. This measurement is based on the observation of Zeeman and hyperfine structures by optical pumping and the double resonance method. Recently, we have succeeded in trapping, polarization, and laser spectroscopy measurements of $^{84-87}$Rb isotopes in He II.

A general introduction to the experimental principle and method has been presented elsewhere.[2)] In this experiment, both stable ^{85,87}Rb and unstable ^{84,86}Rb energetic ions produced from the RIPS were counted accurately and implanted into He II. The number of atoms injected into He II was on the order of 10^4 pps for the current setup. Using the trapping position control system, we confirmed the precision of the trapping site (around 1 mm) of atoms in He II by detecting laser-induced fluorescence (LIF).[3)] On the basis of the trapping volume ($\pi \times 5 \times 5 \times 1$ mm^3) of atoms in He II (ion beam spot size: $\phi \approx 10$ mm), and the observation range ($5 \times 2 \times 2$ mm^3) of the LIF detection system, we estimated that more than 20% of the trapped atoms were used for laser spectroscopy measurements. From the number of injected ions and detected LIF photons, the number of detectable LIF photons from one injected atom was estimated to be approximately 0.2 - 0.3.

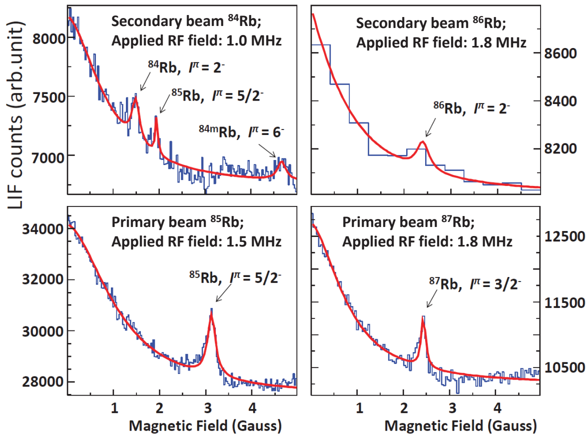

Fig. 1.: LRDR spectra of Rb isotopes trapped in He II. The red solid line is the fitting function, as described in Ref.[4)]

After the precise trapping of $^{84-87}$Rb in He II, the atoms were optically pumped and polarized with a polarized laser light. In addition, laser-RF double resonance spectra of the $^{84-87}$Rb atoms were measured by monitoring the LIF signal as a function of the scanned external magnetic field with a fixed-frequency transverse RF field applied to the atoms, as shown in Fig. 1. Relatively high spin polarization (above 40%) was achieved for the $^{84-87}$Rb isotopes,[4)] which was estimated from the difference in the LIF intensity between the linearly and circularly polarized laser. The resonance peaks provide information regarding the Zeeman splitting of atoms in a magnetic field. From these Zeeman resonance peaks, nuclear spin values for $^{84m,84-87}$Rb isotopes were determined with reasonable accuracy, after eliminating the effect of the background magnetic field.

In conclusion, we performed the effective trapping and laser spectroscopy measurements of $^{84-87}$Rb isotopes with a controllable number of atoms in He II using the newly developed method. The achievement of high trapping efficiency and high spin polarization and the determination of the nuclear spins of RIs in He II suggest the potential application of this method to the study of various exotic particles in He II.

References
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*1 RIKEN Nishina Center
*2 Nuclear and Radiation Physics Section, KU Leuven
*3 Department of Physics, Tokyo Metropolitan University
*4 Cyclotron Radioisotope Center, Tohoku University
*5 Department of Physics, Meiji University
*6 Department of Physics, Osaka University
*7 Department of Physics, Tokyo Gakugei University
*8 Department of Physics, Tokyo Institute of Technology
*9 Department of Physics, University of Tsukuba
*10 Department of Applied Physics, Tokyo University of Agriculture and Technology
*11 Laser Technology Laboratory, RIKEN
*12 Department of Advanced Sciences, Hosei University