Observation of hyperfine resonance of ^{87}Rb in superfluid helium toward laser spectroscopy of atoms with exotic nuclei

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We have developed a new nuclear laser spectroscopy technique called OROCHI (Optical RI-atoms Observation in Condensed Helium as Ion-catcher). OROCHI is a laser spectroscopy method based on the combination of the laser-microwave (MW)/radio frequency (RF) double resonance technique and superfluid helium (He II) as a host matrix[1]. In OROCHI, a highly energetic ion beam is injected into He II. The Injected ion is decelerated, neutralized, and slowly floated in He II. We measure the Zeeman and hyperfine structure (HFS) splitting energy to determine nuclear spins and moments. So far, we have successfully deduced the nuclear spins and moments of stable ^{85,87}Rb, ^{133}Cs, ^{107,109}Ag, and ^{197}Au atoms introduced into He II using the laser ablation technique. Furthermore, we successfully observed the Zeeman resonance of ^{85}Rb and radioactive ^{84}Rb produced by the projectile fragmentation[2]. Since the transition probability of the HFS resonance is small than that of the Zeeman resonance, HFS splitting of the injected Rb atoms is not observed in He II. Recently, we observed for the first time the HFS resonance of an energetic ion beam of ^{87}Rb atoms injected into He II.

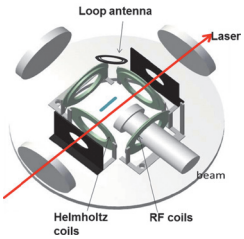

Fig. 1. Schematic layout of the experimental setup.

Figure 1 shows the schematic layout of the experimental setup in the superfluid helium cryostat. The ^{87}Rb beam from the RIPS separator was injected into He II. The stopping position of the genetic ion beam could be adjusted using two Al degraders of various thicknesses located in front of the cryostat[3]. The stopped ^{87}Rb atoms were subjected to irradiation by circularly polarized CW Ti:S laser light (laser power: 100 mW, laser diameter: 2 mm). The laser wavelength was tuned to the D1 absorption line of Rb atoms in He II (780 nm)[4]. The laser-induced florescence photons from laser-excited ^{87}Rb atoms were collected, wavelength-separated, and detected using a photodetection system[5]. To preserve the atomic spin polarization, we applied a static magnetic field of 2.2(1) G using a pair of Helmholtz coils placed along the laser beam axis. In addition, we irradiated MW (power: typically a few watts) generated by an oscillator and an amplifier through an MW loop antenna located above the detection region. By sweeping the MW frequency, we observed HFS resonance as shown in figure 2. The obtained spectra clearly show the effect of the HFS resonance. Since the resonance frequencies of the spectra shift depending on the polarization of the laser light, we observed the case for both σ^+ and σ^- polarization. By taking the average of two frequencies, we could obtain the HFS splitting energy of ^{87}Rb atoms in He II. The asymmetric shape of the spectra is mainly attributed to the inhomogeneity of the applied magnetic field.

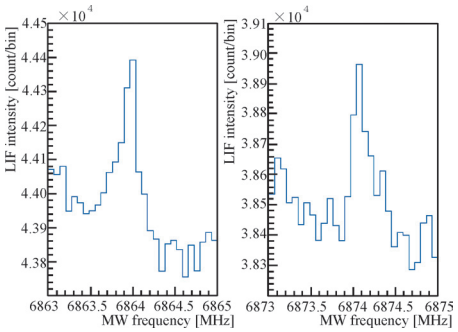

Fig. 2. Observed spectra with an applied static field of 2.2(1)G. The laser polarization is a) σ^+ and b) σ^-.

In conclusion, we have been developing OROCHI that can be applied to investigate the structure of unstable nuclei. We successfully performed double resonance experiments using energetic ion beams. From these results, we confirmed the feasibility of OROCHI, and we are now ready to extend our method to atoms with exotic nuclei.

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