Development of magnetic field coils for laser spectroscopy of atoms in He II

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Nuclear spins and electromagnetic moments are important properties for investigating nuclear structures. To determine these properties of low yield exotic nuclei, we have been developing OROCHI (Optical RI-atom Observation in Condensed Helium as Ion-catcher) method, which is a laser spectroscopic method using superfluid helium (He II) as a stopping material for energetic ion beams. In this method, we measure the atomic Zeeman and hyperfine structure (HFS) splitting energies of neutralized atoms in He II using laser-radio frequency (RF)/microwave (MW) double resonance method[1)]. Then, the nuclear spins and moments are deduced. The effectiveness of the OROCHI method was confirmed by the experiments using energetic $^{84-87}$Rb beams at the RIPS beam line, RIKEN[2)]. In addition, the Zeeman and HFS splittings of stable Rb, Cs, and Au atoms in He II have been observed in offline experiments. Improvement of measurement accuracy and precision leads us to discuss higher order effects such as hyperfine anomaly. Recently, the measurement accuracy is successfully improved by one order of magnitude by scanning the MW frequency using phase-locking[3)]. In order to increase the precision, we installed a new set of magnetic field coils to suppress the inhomogeneity of an applied magnetic field. We here report the current status of HFS measurement of stable Au atoms.

Figure 1 shows our offline experimental apparatus. An open-topped cubic quartz cell was fully filled with He II. The Au sample was placed 1 cm above the He II surface. The Au atoms were prepared in He II by laser sputtering of the sample with two pulsed lasers[4)]. The atoms were optically pumped by irradiation with the frequency-quadrupled laser radiation of an LD-pumped pulsed 1054 nm Nd:YLF laser at a 3 kHz repetition rate. We set RF coils and an MW loop antenna for the double resonance method. The emitted laser-induced-fluorescence (LIF) photons were focused onto a photomultiplier tube (PMT) through a monochromator for wavelength selection.

In the previous experiments, a pair of circular coils was located near the quartz cell. The obtained resonance peaks, which are expected to be Lorentzian shapes, were distorted because it was difficult to apply a uniform magnetic field in the observation region due to limitations of space inside the cryostat[5)]. In our new setup, we constructed a set of large square coils, which can be placed outside the cryostat. The coils are represented in orange in Fig. 1. Figure 2 shows the resonance spectrum obtained using the new coils. The measurement precision was improved by one order of magnitude as compared with the previous work[5)] owing to the reduced inhomogeneities in the applied magnetic field as well as the increment of the LIF counts. The achieved precision is satisfactory for the discussion of hyperfine anomaly. However, the obtained spectrum was slightly distorted by the inhomogeneities of the magnetic fields, presumably due to environmental magnetic fields.

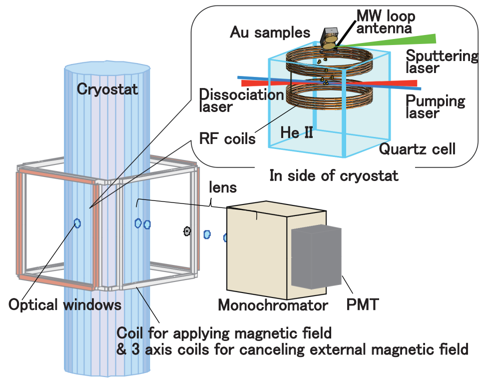

Fig. 1. Experimental apparatus.

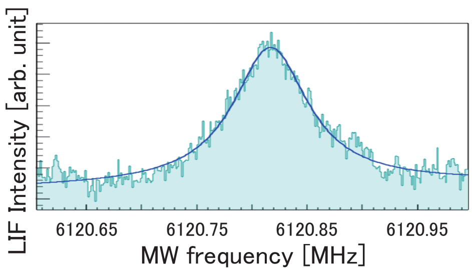

Fig. 2. MW resonance spectrum of ^{197}Au.

Next, we plan to measure HFS splittings using three-axis coils for canceling environmental magnetic fields, shown as gray coils in Fig. 1. After the test experiment, we will start the measurement for stable Ag atoms, which belong to the same group of atom as Au and have two stable isotopes.

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References

1) S. Lang et al.: Europhys. Lett. **30**(4), 233 (1995).
2) X.F. Yang et al.: Phys. Rev. A **90**, 052516 (2014).
3) K. Imamura et al.: Hype. Interact. **230**, 73 (2015).
4) T. Furukawa et al.: Phys. Rev. Lett. **96**, 095301 (2006).
5) T. Fujita et al.: RIKEN Accel. Prog. Rep. **47**, 212 (2014).