Baseline correction system for precision measurement of the hyperfine structure of Rb atoms in superfluid helium

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We have been developing a laser spectroscopic method for the atoms injected into superfluid helium (He II) with the objective of studying the nuclear structure of unstable nuclei with low production yields and short lifetimes. In this method, laser-induced fluorescence (LIF) is observed by applying the laser-radiofrequency (RF)/microwave (MW) double resonance method to atoms in He II to measure Zeeman splitting and hyperfine structure (HFS). It enables us to determine the nuclear magnetic moments and nuclear spins that reflect nuclear structure.

One of the effective ways to introduce atoms to He II is a two-step laser sputtering method. In a previous experiment, we successfully measured the hyperfine structure of ^{133}Cs atoms in He II with an uncertainty of 10^{-5} via the laser-microwave double resonance method.[1)] In order to discuss the hyperfine anomaly of atoms in He II, it is necessary to measure hyperfine structure splittings for at least two isotopes. We attempted to show the feasibility of deducing hyperfine splittings with an accuracy and a precision of 10^{-6} for Rb, which has two stable isotopes. However, it has been difficult to realize measurement with a sufficiently high precision owing to the fluctuation of the number of observed photons when we use the two-step laser sputtering method to supply atoms to He II. To overcome this difficulty, a baseline correction system to cancel the fluctuation of the number of atoms was developed.[2)]

The baseline correction system consists of an electro-optic modulator (EOM) to switch the polarization of the excitation laser quickly and a multichannel scaler (MCS) equipped with multi-channel inputs to count photons for circular and linear polarizations. It has been successfully demonstrated by observing the LIF count difference between spin-polarized and unpolarized atoms that the baseline correction system works properly.[2)]

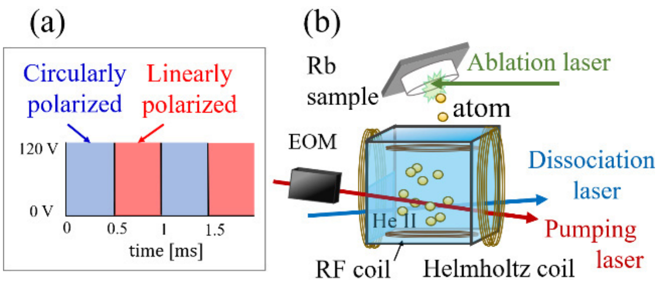

Fig. 1. (a) Switching of the polarization of the excitation laser by EOM. (b) Schematic of the experimental setup in a cryostat.

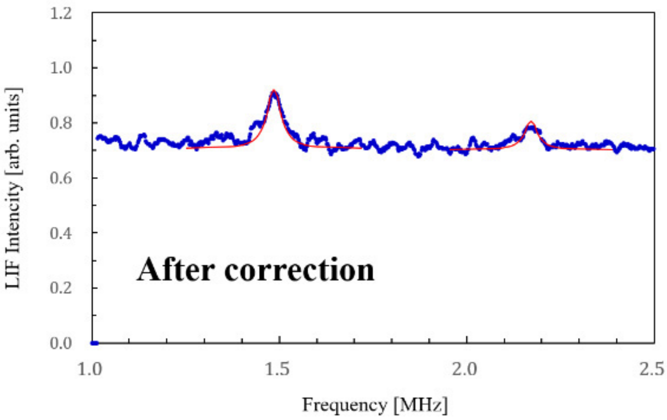

Fig. 2. Laser RF double-resonance spectrum of ^{85,87}Rb obtained using the baseline correction system.

Next, we applied this system to a double-resonance experiment. With circularly polarized laser light irradiation, we expect to observe fluorescence from atoms only when the RF/MW frequency is resonant with the Zeeman splitting or hyperfine structure while scanning the RF/MW frequency. On the other hand, when the laser light is linearly polarized, all the atoms are excited; thus, the observed number of photons was proportional to the number of atoms.

We performed an RF double-resonance experiment for Rb atoms injected into He II using the baseline correction system. Rb atoms were irradiated with a 120-mW Ti:Sa laser (wavelength: 780 nm, laser diameter: 2 mm) of either circular or linear polarization. Figure 2 shows the spectrum obtained when we swept the RF frequency. We observed two fluorescence peaks. The peaks on the left and right correspond to resonance for the Zeeman splitting of ^{85}Rb and ^{87}Rb, respectively. The center frequencies of both peaks were consistent with the resonance frequencies estimated from our experimental condition. This result indicates that the baseline correction system works well in the double-resonance experiment as well as the previous work.[3)]

In the future, the present research will be extended by measuring the hyperfine structure of Rb with the baseline correction system to evaluate the hyperfine anomaly of Rb isotopes in He II, which requires a MW double-resonance experiment with a long sweep time and, hence, an increased fluctuation in the number of atoms.

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References
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