Intensity evaluation of laser-RF double resonance signal of Rb atoms in superfluid helium cryostat

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A laser spectroscopy technique named OROCHI (Optical Radioisotope atom Observation in Condensed Helium as Ion-catcher) has been developed in RIKEN. Owing to the intriguing properties of superfluid helium as a host matrix of atoms, high energetic ions provided from accelerator facilities can be efficiently utilized to measure nuclear properties such as nuclear spins and moments[1)]. In the OROCHI experiment, energetic ions are injected into superfluid helium and neutralized during their stopping process. By applying a circularly polarized laser, neutralized atoms exhibit spin polarization. We observe the variation intensity of emitted photons from atoms using laser-RF (radio frequency)/MW(microwave) double resonance spectroscopy to measure Zeeman/hyperfine splitting of atoms. The measurement enables us to deduce the nuclear spin/moment values. Thus far, we have conducted a series of experiments using $^{84-87}$Rb ion beams at the RIPS separator[2)]. The successful measurement of Zeeman splitting of Rb atoms and the deduction of the nuclear spin value of $^{84-87}$Rb show the applicability of the OROCHI method to rare isotopes.

However, there are several technical difficulties when applying OROCHI to low-yield spices also emerged. One of the main difficulties is the low intensity of the double resonance signal induced by RF or MW fields. The resonance signal observed in the on-line experiment was approximately three times lower than that observed in the off-line test experiments. To identify the cause of this discrepancy, we conducted experiments to evaluate the appropriate signal intensity of the double resonance using a pyrex gas cell that contains Rb and He gases using two types of setups. One was basically the same scheme as the off-line test experiment described in Ref 1). The difference was that the gas cell was placed in a quartz cubic cell instead of a superfluid helium liquid. In the other setup, the gas cell was placed at the center of the cryostat used for the on-line experiment. In the experiments, we used an external cavity laser diode (ECLD) as a pumping laser with on intensity was of approximately 1.0 mW (with a diameter of 3 mm, and a wavelength of 795 nm). Both the static magnetic field and fixed-frequency oscillating RF field were applied to atoms using Helmholtz coils and RF coils, respectively. Magnetic resonance peaks caused by the RF field were obtained by sweeping the strength of the statistic magnetic field.

Figures 1(a) and (b) show the intensity dependence of the resonance peak against the RF field intensity using the off-line and on-line setups, respectively. As seen in Fig.1, we find that the resonance signal of the off-line setup reaches the saturation region with an RF intensity of two orders of magnitude smaller than the case of the on-line setup. This large discrepancy in RF intensity dependence is attributed to the followings. In the setup used for the on-line experiment, the transmission line to provide RF power is approximately 10 times longer than that used in the off-line test experiment. This long transmission line may be the reason for the significant loss in the RF field. The second possible reason is the difference in the shapes of the RF coils. The RF coils used in the on-line experiment is slightly smaller than the coils used in the off-line experiment because of the geometric limitation of the cryostat for the beam experiment. This might have lowered the intensity of the applied RF field. The third reason is the large width of resonance spectra due to the inhomogeneity of the static magnetic field. Broadened resonance spectra require a larger RF field power to saturate the resonance peaks. The improvement in the experimental setup to solve the problems mentioned above is now in progress.

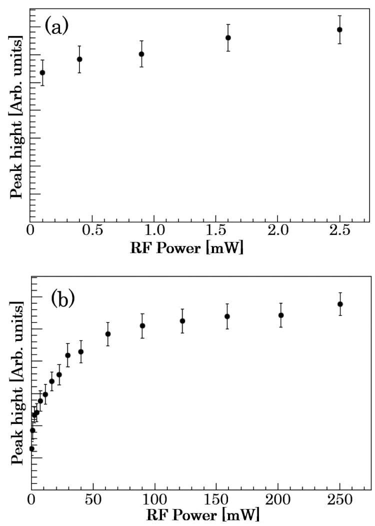

Fig. 1. RF power dependence of resonance peak heights

References
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