Experimental evaluation of laser-MW double resonance signal intensity in OROCHI project

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We are developing a laser spectroscopy technique named OROCHI to study the properties of low-production-yield nuclei. In the OROCHI experiment, energetic ions are injected into superfluid helium and are neutralized during their stopping process. We irradiate the neutralized atoms with a circularly polarized laser light to produce spin polarization and measure the atomic Zeeman splitting by laser-radio frequency (RF) double resonance method and the hyperfine splitting by laser-microwave (MW) double resonance method. The measurements enable us to deduce nuclear spin and moment values. We succeeded in observing the resonance signal by the double resonance methods in the online experiment using $^{84-87}$Rb ion beams of an order of 10^4 ions/s.[1,2] However, the resonance signal was smaller than that in the offline experiments, and difficulties were anticipated for the application of this method to lower-production yield nuclides. One of the possible causes for small resonance signal intensity was attributed to an insufficient MW radiation power. So we performed an offline test using Rb vapor which was enclosed in pyrex glass cell with He buffer gas (Rb cell) in order to find the experimental conditions to maximize the MW resonance signal intensity in our experimental setup.

We irradiated Rb atoms in the cell with a circularly polarized laser light for spin polarization and a MW radiation at a fixed frequency. Laser intensity was 1.0 mW (with the diameter 2 mm, wavelength 795 nm). In order to maintain spin polarization, a magnetic field was applied to the atoms in the direction coaxial with the laser axis. We detected fluorescence photons from Rb atoms by using a photomultiplier tube. By sweeping magnetic field strength, we obtained a MW resonance peak (y_r) and a maximum de-excitation peak which corresponds to the signal level of spin unpolarization (y_{max}).[1] We defined resonance intensity(I) as $I = (y_r - y_0)/(y_{max} - y_0)$, where y_0 is the background signal level. We measured the dependence of the resonance intensity on antenna position and MW power.

Figure 1 shows the resonance intensity as a function of distance between the antenna and observation region. MW power was 3.0(3) W. In the previous online experiment, MW of 2-3 W was applied and the antenna was placed about 4 cm away from the observation region. From this result, we estimate that the resonance intensity can be increased by a factor of approximately 5 by bringing the antenna 1 cm away from the observation region.

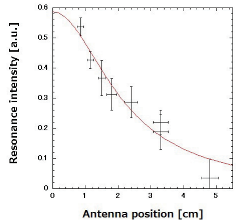

Fig. 1. Resonance intensity dependence on the antenna position. Horizontal axis indicates the distance between the MW antenna and observation region.

We also measured the resonance intensity with different applied MW power (Fig. 2). The Rb cell was placed at the observation region in our cryostat used for online experiments. The antenna was set about 1 cm away from the observation region. De-excitation light from Rb atoms was detected by the newly developed LIF detection system[3]. When the MW power of 8 W was applied to the atoms, the resonance intensity was increased by a factor of approximately 1.2 from that of 3 W.

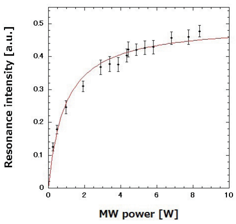

Fig. 2. Resonance intensity dependence on the MW applied power

The two results above showed different resonance intensities at the same condition of MW irradiation due to different optical pumping rates and slightly different antenna orientation. Nevertheless, taking into account of the two factors, namely optimizing antenna position and applied power, the MW resonance signal intensity increment is estimated to be able to reach at least 6 times higher than that of the previous online experiment. In next online experiment, we will evaluate the amplification of the resonance intensity discussed above.

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