Microwave system for atomic beam resonance method

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A spin-polarized radioactive isotope (RI) beam is important for nuclear structure studies and their applications in material science. The spin polarization of an RI beam is achieved using the atomic beam resonance (ABR) method.[1)] The ABR apparatus in our laboratory currently under development adopts double spin selection utilizing magnetic field gradients produced by sextupole and quadrupole magnets, and spin flipping achieved by microwave (MW) irradiation within a homogeneous magnetic field generated by a dipole magnet. In this study, we report on the results of the MW system for realizing efficient spin flipping.

In this development, we employed the stable isotope ^{85}Rb ($I = 5/2$, $J = 1/2$) for the laser-MW double resonance method. The ^{85}Rb atoms enclosed in a glass cell within a static magnetic field were irradiated with a 795 nm circularly polarized (σ^-) laser, resulting in spin polarization into the ground state $S_{1/2}$, $F = 3$, $m_F = -3$. In this state, the atoms no longer absorbed the laser light, and laser-induced fluorescence (LIF) ceased. When a MW corresponding to the resonance transition ($S_{1/2}$, $F = 3$, $m_F = -3$) $\rightarrow$ ($S_{1/2}$, $F = 2$, $m_F = -2$) was applied, spin flipping occurred via a hyperfine structure transition. Consequently, the polarization was broken and LIF reappeared. Experiments were conducted using a box-shaped loop fabricated based on Ref. 2) and a loop antenna to investigate the effects of shape on transition intensity and linewidth and optimize the MW system. The schematic drawing of both loops is shown in Fig. 1. The loop antenna has a diameter of 30 mm, while the box-shaped loop has a cubic structure with each side measuring 25 mm.

Figure 2 shows the transition intensity as a function of MW frequency for both the loop antenna and box-shaped loop. The transition intensity is the ratio of LIF emitted by atoms that underwent the transition to the total LIF in the unpolarized state with no magnetic field applied. A peak in the LIF was observed for both the loop antenna and box-shaped loop when the MW frequency was swept, which confirmed the spin-flip induced by MW irradiation. The MW power was estimated from measurements of the incident and reflected waves: 1.5 W and 1.8 W for the loop antenna and box-shaped loop, respectively.

A comparison of the results revealed that the box-shaped loop achieved a line width that was approximately eight times narrower than that of the loop antenna. Meanwhile, the loop antenna was superior in terms of intensity and statistics. The narrower line width observed with the box-shaped loop can be attributed to the reduced effect of magnetic field inhomogeneity. One possible explanation is that the MW irradiation area was more confined in the box-shaped loop, which could have provided the uniform magnetic field distribution within the irradiation area.

The experiments demonstrated that differences in shape can significantly affect the resonance intensity and line width. The box-shaped loop produced a narrower line width, whereas the loop antenna showed higher intensity. The characteristics of the loops will be explored further to optimize the MW system, with the performance evaluated using various prototypes.

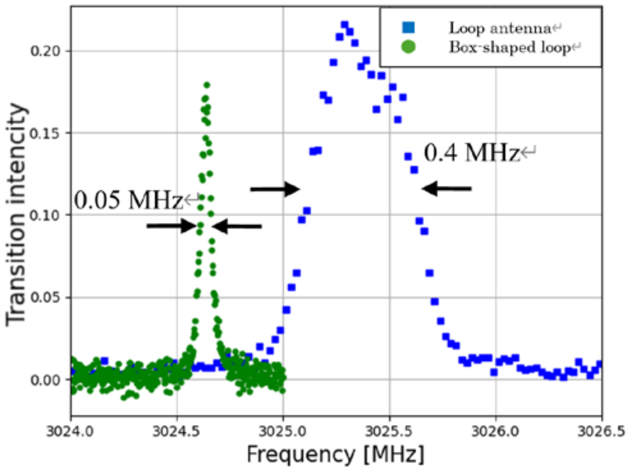

Fig. 1. (a) Schematic of the loop antenna. (b) Schematic of the box-shaped loop.

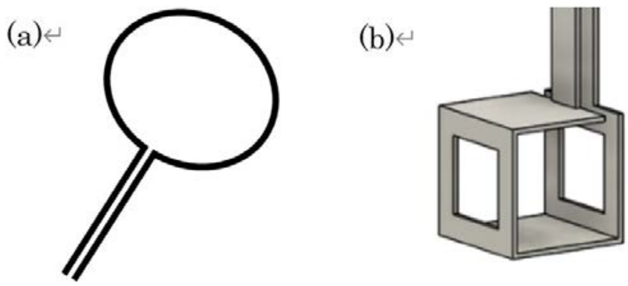

Fig. 2. Transition intensity as a function of MW frequency using the loop antenna and box-shaped loop.

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