Production of spin polarization of atoms in superfluid helium using a pulsed Ti: sapphire laser

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We are developing a new laser spectroscopic technique "OROCHI" to determine nuclear spins and moments of RI atoms. In this technique, superfluid helium (He II) is used as a material for trapping short-lived RI atoms. We utilize optical pumping to produce atomic spin polarization, and laser - radio frequency (RF) /microwave double resonance method to investigate Zeeman and hyperfine splittings of the RI atoms, respectively. In He II spin polarization can be maintained for a long time (>2 s in the case of Cs),[1)] which enables us to produce a high degree of spin polarization. As for optical pumping, CW lasers are generally used to produce spin polarization. High-repetition-rate pulsed lasers can be superior in producing spin polarization owing to the large pumping rate. Using pulsed lasers, we expect to produce spin polarization efficiently for various atomic species that have not been spin-polarized yet. We here report on the production of spin polarization and RF resonance of Rb atoms in He II using a tunable pulsed Ti: sapphire (Ti: Sa) laser operated at 1-3 kHz.

We have constructed a pulsed Ti: Sa laser with a z-shaped cavity[2)] originally developed at Mainz University (see Fig. 1). The Ti: Sa laser can lase in wide range of wavelength from 670 to 1050 nm[3)] and UV output can be easily obtained by second harmonic generation. The Ti: Sa crystal is pumped by a second harmonic output of a Nd: YLF laser. The laser cavity contains four mirrors for light of wavelength ranging from 750 to 850 nm. The tunable range of wavelength using a birefringent filter is 749-790 nm. For the Rb experiment, the laser is tuned to the excitation wavelength of Rb atoms in He II (780 nm)[4)]. At this wavelength the achieved output power is >150 mW at 1 kHz, and >200 mW at 2 and 3 kHz.

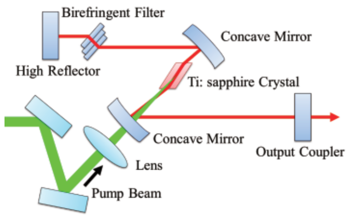

Fig. 1. Schematic diagram of the Ti: sapphire laser layout

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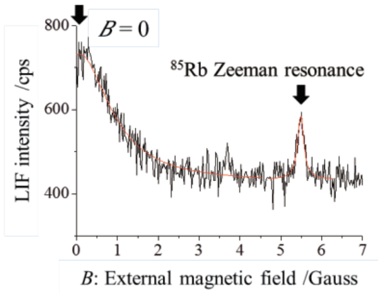

Fig. 2. RF resonance of ^{85}Rb obtained by applying RF frequency of 2.35 MHz. We can see the resonance peak at B = 5.4(9) Gauss and peak of LIF intensity with no spin polarization at B = 0 Gauss. The repetition rate of the pulsed laser was 3 kHz and the output power was 7.5 mW.

Using this pulsed Ti: Sa laser, we conducted experiments for Rb atoms in He II with optical pumping and laser-RF double resonance method.

Figure. 2 shows laser induced fluorescence (LIF) signal from Rb atom by the magnetic field swept from 0 to 7 Gauss. At B = 0, the LIF intensity was larger than that with magnetic field because spin polarization of atoms was not conserved. With increasing external magnetic field, the LIF intensity decreased due to the increase in spin polarization. When the RF frequency is in resonance with Zeeman splittings, the spin polarization was decreased and then LIF intensity was increased. In Fig. 2, we can see the RF resonance of the ^{85}Rb Zeeman transitions in He II. These results reveal that the produced spin polarization using pulsed laser was sufficient to observe RF resonance clearly. In the case of using pulsed lasers under 10 mW at 1 to 3 kHz repetition rate, we could produce comparable spin polarization to the CW laser experiment[4)] and observe RF resonance.

In the future, we plan to use the pulsed Ti: Sa laser for optical pumping of atomic species that have not yet been spin-polarized and develop a technique to produce spin polarization of various atoms. The excitation wavelength of In atoms is 370 nm in He II[5)]. We expect to produce spin polarization of In atoms using a second harmonic generation of the pulsed Ti: Sa laser.

References

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