Laser spectroscopic spin-polarizations of silver atoms in superfluid helium using a single-frequency DPSS laser

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We are developing a method to study the structure of unstable nuclei produced at accelerators using laser spectroscopy of atoms in superfluid helium (He II).[1] He II is a facsinating material that can stop injected energetic ions with high efficiciency and function as a host matrix of laser spectroscopy with large transparency from UV to radiofrequency. Through the combination of optical pumping and the laser-microwave/radiofrequency double reasonance method, hyperfine and Zeeman splittings are measured, which enables us to derive the nuclear moments and spins. Our group is planning to apply the method for the accelerator experiments on Ag atoms, in particular, neutron-rich and short-lived itotopes.

We have successfully measured HFS spectra of alkali atoms such as stable ^{85,87}Rb and ^{133}Cs in He II using laser ablation to introduce atoms into He II and observed small differences from those of atoms in vacuum.[2,3] Currently, we are attempting to apply this method to group 11 atoms to verify whether a similar difference appears in atoms in He II other than alkali metal elements. In particular, to discuss the difference in hyperfine anomalies between isotopes, we must measure the HFS of at least two isotopes. Silver is a good candidate with two stable isotopes, ^{107}Ag and ^{109}Ag, whose natural abundance ratio is almost 1 : 1.

To introduce Ag atoms in He II, we used two pulsed lasers.[4] First, second-harmonic pulse of a Nd: YAG laser (wavelength: 532 nm, repetition rate: 10 Hz, pulse width: 8 ns, pulse energy: ∼3 mJ) was irradiated to the metal sample placed above the He II liquid surface to perform laser ablation. The produced Ag clusters penetrated into the He II were dissociated into atoms by pulses using the third-harmonic of an Nd: YAG laser (wavelength: 355 nm, repetition rate: 10 Hz, pulse width: 5 ns, pulse energy: 5 mJ). Dissociation of Ag clusters was clearly confirmed by the generation of spin polarization of Ag atoms in He II using the optical pumping method.[4]

We aim for higher pumping-laser power to increase laser induced fluorescence (LIF) photon counts, to further study of Ag atoms using the laser-RF/MW double resonance method.[5] Additionally, this enhances Ag cluster dissociation due to similarity of the required wavelength.

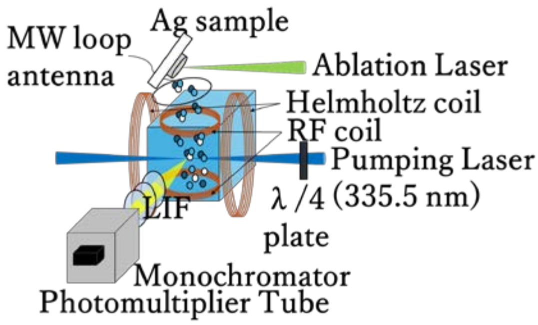

Fig. 1. Experimental setup.

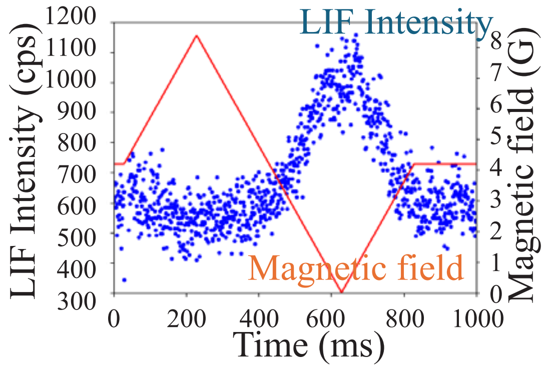

Fig. 2. Variation in LIF intensity with a magnetic field.

We introduced the fourth-harmonics of a diode-pumped solid state (DPSS) laser (wavelength: 335 nm, repetition rate: 20 kHz, pulse width: ∼20 ns, pulse energy: 6 μJ, model: IDOL335). The wavelength of the laser matches with both Ag cluster dissociation and Ag atomic excitation wavelength in He II.[6] Because the output power of the laser is more than 120 mW on average, we expect that the laser pulses can dissociate Ag clusters without independently using a dissociation laser. In this paper we report spin polarization production using the DPSS laser. Figure 1 shows the experimental setup.

Figure 2 shows the result of increase and decrease in LIF intensity when the magnetic field strength produced by a pair of Helmholtz coils was ramped up and down (0–8.4 G) in one second in each measurement cycle. When a sufficient magnetic field was applied, spin polarization was achieved and LIF intensity decreased. The applied magnetic field reached the maximum after about 200 ms. We confirmed that the DPSS laser can perform as both dissociation and pumping laser for Ag atoms efficiently. In the next step, we will measure Zeeman splittings and HFS of Ag atoms in He II using this laser system.

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