Simultaneous cluster dissociation and optical pumping of Ag in superfluid helium using a single UV laser

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We have been developing a laser spectroscopy method for atoms introduced into superfluid helium (He II). We generate spin polarization by the optically pumping the atoms and perform laser-radiofrequency and laser-microwave (MW) double resonance. This method enables us to determine the nuclear spins and electromagnetic moments through measurements of Zeeman splitting and hyperfine structure (HFS) splitting. Moreover, because HFSs in He II shift slightly from the value in vacuum, we are studying such an interaction between He II and atoms.

We have successfully measured HFSs of alkali atoms such as stable ^{85,87}Rb and ^{133}Cs in He II and observed small differences from those in vacuum.[1,2] Currently, we are attempting to apply this method to group 11 atoms to verify whether a similar difference appears in atoms other than alkali metal elements. The HFS transition of the stable isotope ^{197}Au atom in He II was observed using this technique.[3] To discuss the differential hyperfine anomalies between isotopes, it is necessary to measure the HFSs of at least two isotopes. Silver is a good candidate with two stable isotopes, ^{107}Ag and ^{109}Ag, the natural abundance ratio of which is almost 1:1.

In offline experiments, atoms have been introduced into He II using a two-step laser sputtering method, namely, by laser ablation and laser dissociation. As the first step, a metal sample placed above the He II surface is ablated by the second-harmonic pulse of a Nd: YAG laser (wavelength: 532 nm, repetition rate: 10 Hz, pulse width: 8 ns, pulse energy: ∼5 mJ). Only clusters generated by the ablation process can be immersed in He II. Subsequently, atoms are supplied by the dissociation process for the spectroscopy of atoms in He II. Although a femtosecond Ti:Sa laser (wavelength: 800 nm, repetition rate: 500 Hz, pulse width: ∼120 fs, pulse energy: ∼200 μJ) has been efficient in the dissociation for various atomic species, we found this is not the case for Ag clusters.[4] Inspired by a report that Ag clusters in He II droplets show absorption in the range of 330–360 nm instead of 800 nm,[5] our group applied the third-harmonic pulse of Nd:YAG laser (wavelength: 355 nm, repetition rate: 20 Hz, pulse width: 5 ns, pulse energy: 8 mJ) to the dissociation process. The dissociation of Ag clusters was clearly confirmed by the generation of spin polarization of Ag atoms in He II through optical pumping.[6]

For further study of Ag atoms using the laser-RF/MW double resonance method, it is indispensable to increase laser induced fluorescence (LIF) photon counts.

In particular, increasing the power of the pumping laser is promising because the LIF intensity is proportional to the pumping laser power for atoms in superfluid helium.[7] This approach should also be effective if the pumping laser simultaneously function as the dissociation laser.

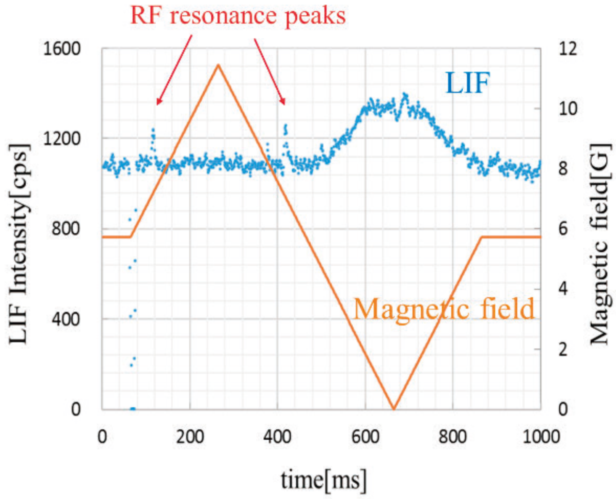

Fig. 1. Variation of LIF intensity with a magnetic field.

Herein, we report the introduction of the forth harmonics of a new DPSS laser (wavelength: 335 nm, repetition rate: 20 kHz, pulse width: ∼20 ns, pulse energy: 5 μJ). The wavelength of the laser matches the wavelength for both Ag cluster dissociation and Ag atomic excitation in He II. Since the output power of the laser is greater than 100 mW on average, it is expected that the laser pulses can dissociate Ag clusters.

Figure 1 shows the result of increase and decrease in LIF intensity when a magnetic field (0–11.5 G) and an RF field (10.0 MHz) were applied to Ag atoms in He II. When a sufficient magnetic field is applied, spin polarization is achieved, and the LIF intensity decreases. In addition, when a constant RF is applied, the LIF intensity increases at the magnetic field that provides the Zeeman splitting energy corresponding to the resonant RF. We confirmed that the single laser can efficiently perform as both the dissociation and pumping laser for Ag atoms. In the next step, we will measure the HFS splitting of Ag atoms in He II by using this laser system.

References

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