LIF observation of Rb atoms in superfluid helium by picosecond pulsed laser pumping

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Our research group has been developing a laser spectroscopic method named OROCHI. The system uses superfluid helium (He II) as a trapping medium of atoms, and the interaction between the immersed atoms and the surrounding helium atoms leads to a unique property of the spectroscopic environment. In particular, the Stokes shift of the immersed atoms is important for understanding the dynamics of He II. In this study, we focus on the "atomic bubble" that causes the Stokes shift.

When atoms are introduced into He II, the surrounding helium atoms are pushed out by the exchange (Pauli) repulsion force.[1)] The resulting vacuum region is called an atomic bubble. When the shape of the outer electron orbit of the atom changes owing to a state transition such as excitation or absorption, the deformation of the atomic bubble follows. This cycle is repeated at each excitation (Fig. 1).

The absorption and emission occur within about 10^{-15} s, while it is estimated that the deformation of the bubble occurs on a timescale of a few picoseconds.[1)] However, this relaxation time has not been directly measured in the picosecond time scale so far. To clarify the dynamics of the atomic bubble system, we combined the laser spectroscopic technique in He II and an ultrafast laser spectroscopic technique.[2)] In this research, we started with Rb as a target atom because its characteristics in He II has been well studied.[3,4)] We here describe the current status of preparation for the first measurement of the relaxation time.

The wavelengths of atomic transitions in He II shift between absorption and emission owing to this deformation cycle.[3)] In the excited state, a part of atoms in the observation area are expected to emit photons during the deformation process before the atomic bubble reaches its potential minimum of the excited state. Because the change of the emission wavelength corresponds to the degree of deformation, the relaxation time is measured by observing the time dependence of the emission wavelength.

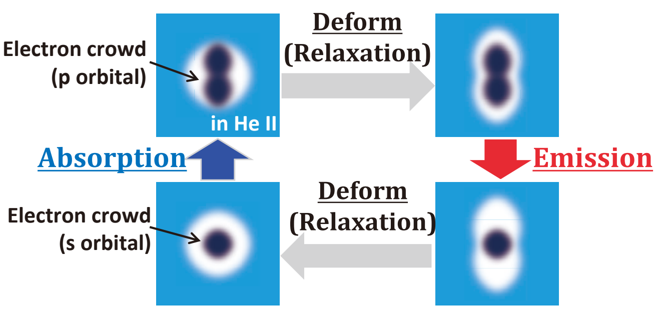

Fig. 1. Deformation cycle of an atomic bubble.

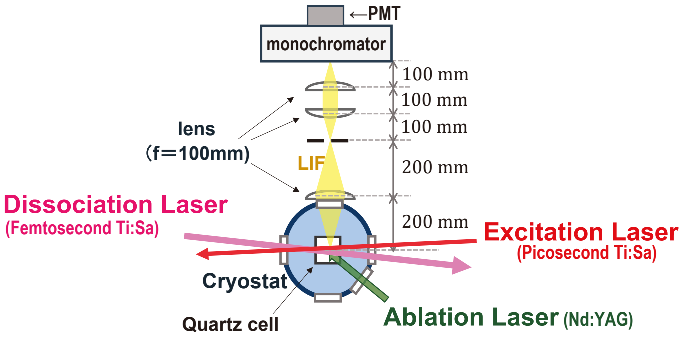

Fig. 2. Experimental setup of LIF detection.

For the observation, we plan to use a time-correlated single photon counting (TCSPC) system with a detector of high time resolution. The TCSPC records the time between the input of the excitation pulse laser signal and the detection of the laser-induced fluorescence (LIF) photon to obtain the time dependence of the LIF intensity. The typical time resolution of the system is 80 ps.

In this method, the pulse width of the excitation laser must be shorter than the relaxation time. Therefore, a picosecond mode-locked Ti: sapphire laser was introduced. The typical pulse width of the laser is 1.6 ps. Since the LIF of atoms in He II with ultrashort pulse lasers has not been observed, we conducted a laser performance evaluation experiment.

The observation was performed using the picosecond laser (laser power: 103 mW, repetition rate: 80 MHz) and an offline experiment setup and a laser sputtering method to introduce atoms. We used a monochromator and a photomultiplier tube for the fluorescence detection system. First, the LIF was measured by a wavelength sweep of the excitation laser. We obtained a spectrum that showed a peak in the fluorescence intensity at a laser wavelength of approximately 778 nm. This wavelength corresponds to the D1 excitation of Rb atoms in He II. Next, by fixing the laser wavelength fixed at the peak position, a wavelength sweep of the monochromator was performed. We observed an LIF spectrum centered at 794 nm, which is the D1 emission wavelength in He II.

In summary, we successfully observed the LIF of atoms in He II using the picosecond laser. We are planning to conduct an experiment of the relaxation time measurement by the TCSPC system.

References
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