Fluorescence observation of Rb atoms in He II during dynamic Stokes shift at several wavelengths

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Our research group is developing a laser spectroscopy technique called OROCHI to study atoms in superfluid helium (He II). Currently, we have applied OROCHI to group 1 and 11 atoms with relatively simple electronic configurations. A small energy shift caused by the hyperfine structure of atoms in He II can aid in determining the unique characteristics of bulk He II.[1)] Clarifying the nature of interactions between superfluid helium and the introduced atoms is crucial to further expand the applicability of OROCHI. In this study, we focus on the "dynamic Stokes shift," which is a key interaction between He II and impurity atoms. The dynamic Stokes shift is a time-dependent change in the emission wavelength of an atom in accordance with the atomic-bubble state deformation.[2,3)] An overview of the process is shown in Fig. 1. Further details are shown in Ref. 3). The goal of this study is to estimate the relaxation time of this process.

In bulk He II, the relaxation time required for dynamic Stokes shift is estimated to be a few picoseconds;[4)] however, it has not been measured experimentally. In our previous work, we successfully observed laser-induced fluorescence (LIF) from Rb atoms in bulk He II at wavelengths inferred to be in dynamic Stokes shift using picosecond laser excitation and detection with time-correlated single photon counting (TCSPC).[3)] Observing such effects at several wavelengths is necessary to discuss the dynamic Stokes shift. In this paper, we report the results of additional observations, which we tentatively attribute to the dynamic Stokes shift.

Details of the experimental setup are provided in Ref. 2). We used a picosecond mode-locked Ti: Sapphire laser (laser power: 100 mW, repetition rate: 90 MHz, pulse time width: 1.6 ps, center wavelength: 776.0 nm) as the excitation laser. LIF was detected using an avalanche photodiode through a monochromator. As indicated in the previous report,[3)] we used an AR-coated container with high transmittance in the near-infrared region for the observation area to minimize the effect of laser scattered light. The measurement results are presentedin Fig. 2.

Figure 2 shows the fluorescence intensity at each measured wavelength normalized to the fluorescence intensity measured at 770 nm. The 770 nm signal, which is free from Rb laser-induced fluorescence contributions, is used as a reference to evaluate fluorescence associated with the dynamic Stokes shift. A normalized intensity larger than 1 corresponds to the fluorescence intensity stronger than the one at 770 nm. This implies that fluorescence is observed at those wavelengths during the dynamic Stokes shift. The normalized intensity is larger than 1 for most wavelengths measured in this study, considering the uncertainty range. In future, we plan to perform the same measurements at wavelengths closer to 793 nm, at the center of spontaneous emission, and attempt to realize the first measurement of the time required for the dynamic Stokes shift in a bulk He II environment.

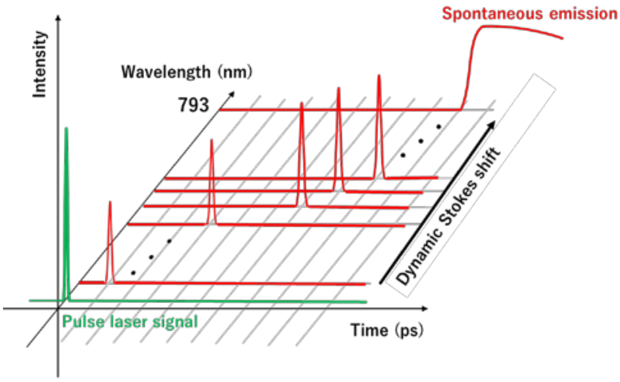

Fig. 1. Diagram of the dynamic Stokes shift.

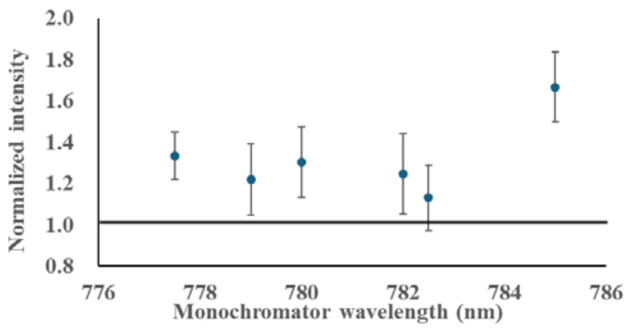

Fig. 2. Normalized LIF intensity at several wavelengths.

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References
1) K. Imamura *et al.*, Appl. Phys. Express. **12**, 016502 (2019).
2) Y. Takeuchi *et al.*, RIKEN Accel. Prog. Rep. **54**, 105 (2020).
3) H. Endo *et al.*, RIKEN Accel. Prog. Rep. **57**, 138 (2023).
4) B. Tabbert *et al.*, J. Low. Temp. Phys. **109**, 653 (1997).

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