Baseline correction system of laser-microwave double resonance spectrum for atoms injected into superfluid helium by laser sputtering

M. Sanjo,[*1,*2] K. Imamura,[*2,*3] W. Kobayashi,[*1,*2] Y. Takeuchi,[*1,*2] A. Takamine,[*2] T. Furukawa,[*2,*4] H. Ueno,[*2] and Y. Matsuo[*1,*2]

We have been developing a laser spectroscopic method for the atoms injected into superfluid helium (He II) to measure the hyperfine structure and Zeeman splitting of unstable nuclei with low production yields and short lifetimes. In this method, highly energetic ion beams are efficiently caught as neutralized atoms in superfluid helium owing to its high density. In addition, the absorption wavelength of atoms in He II is largely blue-shifted due to the effect of surrounding He atoms while the emission wavelength is almost the same as that in vacuum. This enables us to detect photons emitted from the atoms with low background by removing the excitation-laser stray light.

So far, in the offline experiment, we succeeded in the measurement of the hyperfine structure constant for ^{133}Cs atoms with accuracy of 10^{-5} via laser-microwave (MW) double resonance method.[1)] In order to discuss hyperfine anomaly of atoms in He II, it is required to measure hyperfine structure splitting using more than two isotopes. To show the feasibility for deducing hyperfine anomaly parameter using the method, we have performed a series of experiment to measure hyperfine splitting with an accuracy and a precision of 10^{-6} using Rb which has two stable isotopes. It has been difficult to realize sufficient measurement accuracy and precision due to fluctuation of the number of observed photons when we use two-step laser sputtering method to supply atoms in He II.[2)] We here report the development of a baseline correction system to cancel the fluctuation of the number of atoms injected into He II and a preliminary experiment performed using this system.

We need to irradiate a circularly polarized laser light and apply a magnetic field to the atoms to generate spin polarization. We can observe fluorescence from atoms when MW frequency is resonant to the hyperfine structure splitting by scanning MW frequency irradiated to spin polarized atoms. On the other hand, when the excitation laser light is linearly polarized light, we observe photons proportional to the number of atoms in the observation region, because spin polarization does not occur. We can correct the fluctuation of the number of observed photons by using the difference in the observed photons for both polarizations.

The correction system consists of an Electrooptic Modulator (EOM) to quickly switch the polarization of the excitation-laser and a Multi Channel Scaler (MCS) equipped with multi-channel inputs to count photons at the circularly and linearly polarization. In the case that we apply a square wave voltage at 1 kHz to the EOM,

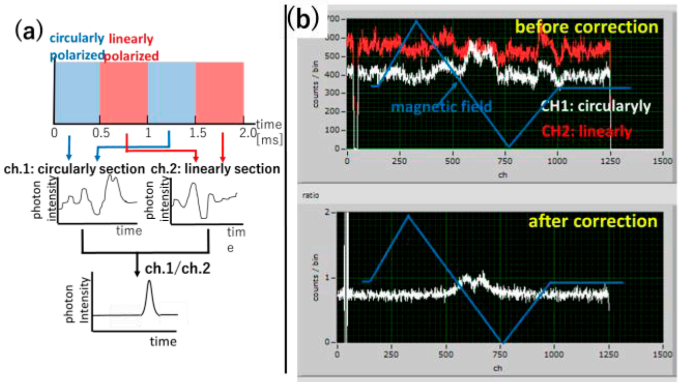

Fig. 1. (a) Scheme of observed photon number calibration via switching of the polarization of excitation-laser with an EOM. (b) Cancellation of the fluctuation of the number of observed photons using Rb in He II.

the polarization is switched as shown in the upper of Fig. 1(a). Next, we detect photons emitted from the atoms at the circularly polarized section (ch. 1) and the linearly polarized section (ch. 2) alternately using coincidence with the signal to EOM as shown in the lower of Fig. 1(a). In ch. 1, hyperfine structure resonance peak superimposed with the base fluctuation caused by the number of atoms variation is observed. In ch. 2, photons proportional to the number of atoms in the observation region is observed. Consequently, it is expected that we can realize measurement free from the fluctuation of number of observed photons by correcting ch. 1 signal counts with ch. 2 ones.

We performed a preliminary experiment for Rb atoms injected into He II by laser sputtering. Atoms are irradiated with a Ti:Sa laser of 100 mW (wavelength: 780 nm) either with circular or linear polarization. Fig. 1(b) shows the spectrum obtained when we swept the magnetic field. We attempted to observe the fluorescence twin peaks when the spin polarization is collapsed at the 0 magnetic field. Channel 1 (white line) in the upper part of Fig. 1(b) shows spectrum in the circularly polarized section, and ch. 2 (red line) shows the spectrum in the linearly polarized section. The lower part of Fig. 1(b) shows the number-of-atoms corrected spectrum. It was confirmed that the baseline fluctuation is clearly canceled. From the result, we concluded that we succeeded in the baseline correction. Future outlook on research is the measurement of hyperfine structure for ^{85,87}Rb in He II with using this system to evaluate hyperfine anomaly for Rb isotopes in He II.

*1 Department of Advanced Science, Hosei University
*2 RIKEN Nishina Center
*3 RIIS, Okayama University
*4 Department of Physics, Toho University

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