Effective suppression of stray laser light for fluorescence detection from ^{85}Rb atoms injected into superfluid helium

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We have been developing a laser spectroscopy technique named Optical RI-atom Observation in Condensed Helium as Ion-catcher (OROCHI) for the investigation of nuclear properties such as nuclear spins and moments. In OROCHI experiments, we catch highly energetic ion beams in superfluid helium (He II) to neutralize them and apply laser-rf and laser-microwave double resonance methods to the stopped atoms. It is known that the optical absorption spectrum of an atom in He II is greatly blue-shifted compared with the emission spectrum[1)]. Therefore, the laser-induced fluorescence (LIF) from the atoms can be spectrally isolated from the stray laser light that results in a background in spectra. We have developed an LIF detection system (LDS) which enables the detection of LIF with an extremely low background. In a previous online experiment[2)], we successfully observed LIF from $^{84-87}$Rb isotope atoms and double resonance spectra using LDS II[3,4)] equipped with interference filters for wavelength selection (Fig. 1(a)). However, we observed background signals of $\approx 10^3$ counts with a laser radiation of 100 mW while the LIF intensity was also of the same order for the injected beam intensity of the order of 10^4 pps. This is because the filter transmission shifts to shorter wavelengths for oblique incident light. We require a higher wavelength selectivity for the application of OROCHI to lower-production yield nuclei.

In order to reduce the background due to stray laser light more efficiently, we developed LDS III (Fig. 1(b)). It consists of a set of lenses, bundled optical fibers and a monochromator. The fluorescence light is collected and collimated through lens1 and focused by lens2 onto the entrance of the fibers. It is resolved in the monochromator according to the wavelengths. The focal lengths of lens1 and lens2 are optimized for the LIF collection and transmission. This configuration makes it possible to suppress the stray laser light that reaches the monochromator through the fibers by a factor of 10^{-9}.

In order to confirm the effective reduction of the background, we investigated the background induced by the stray laser light in LDS III. We measured the dependence of a photomultiplier tube (PMT) signal on the irradiated laser power (Fig. 2). As shown in Fig. 2, the detected signal attributed to the stray laser light was four cps per 100-mW laser radiation power. From this result, we concluded that the stray laser light was reduced by three orders of magnitude compared with the case of LDS II and the background was near the level of dark counts in the PMT. After confirming the reduction of background counts, we installed LDS III for the online experiment using a ^{85}Rb beam delivered from RIPS[5)]. The evaluation of the applicable ion beam intensity in the LDS III is in progress now.

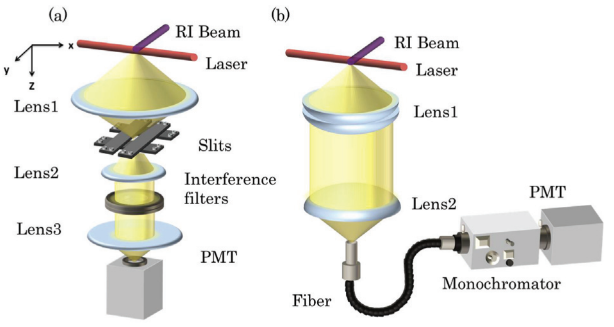

Fig. 1. Laser-induced fluorescence detection system (a) LDS II and (b) LDS III.

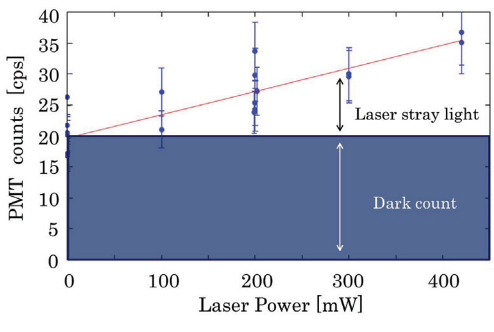

Fig. 2. Background signals due to the stray laser light in He II as a function of the incident laser power.

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