Performance testing of a photomultiplier tube in a beam diagnostic vacuum chamber for laser spectroscopy of unstable Rb atoms in superfluid helium

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A laser spectroscopic technique[1)] based on superfluid helium (He-II) is being developed to study the nuclear structure of low-yield unstable nuclei. Previously, we succeeded in observing laser-induced fluorescence and laser-radio frequency/laser-microwave double resonance signals from ^{87}Rb atoms introduced into He-II using a 66 MeV/nucleon beam at the RIKEN projectile-fragment separator (RIPS).[2,3)] In the upcoming experiment, we will be using the ^{84}Rb beam produced from ^{84}Kr (70 MeV/nucleon) spallation reaction with an energy of 47 MeV/nucleon at the downstream of RIPS. The experimental set up is shown in Fig. 1. Aluminum (Al) energy degraders and a plastic scintillation counter are installed in a beam diagnostic chamber connected to a cryostat chamber. Because the ^{84}Rb beam energy is lower than that of a stable beam, a beam diagnostic chamber is required to pump the lead beams to the observation region in He-II.

In this study, we investigated the performance of a plastic scintillation counter in a vacuum chamber and compared it to that in air. The thickness of the scintillator was 0.5 mm and its cross-sectional size was 18 mm^2. Two photomultiplier tubes (PMTs) (Hamamatsu Photonics model number: R1450PXASSY) were attached to the scintillator on the left and right sides. Coincident signals from the PMTs were counted by changing the high voltage (HV) within the maximum voltage (−1800 V). In the beam diagnostic chamber, a beta radiation source (^{90}Sr/^{90}Y, 370 kBq) was placed 13.5 mm away from the plastic scintillator and the count rates were compared. No reflective material was wrapped around the scintillator.

The typical PMT pulse height was −230 mV when −1300 V was applied, and the threshold was set to −30 mV. Figure 2 shows the PMT one-pulse signal in air and in vacuum (9.71×10^{-2} Pa).

Upon comparing the curves, no significant difference between the two is observed. The PMTs work without any discharge in vaccum, and we used them in a vacuum chamber without any problems. Figure 3 shows the relationship between voltage and scintillation count rates under standard atmospheric conditions (dashed line) and in a vacuum of 9.71×10^{-2} Pa (closed circles).

The results show that the count rates are equivalent

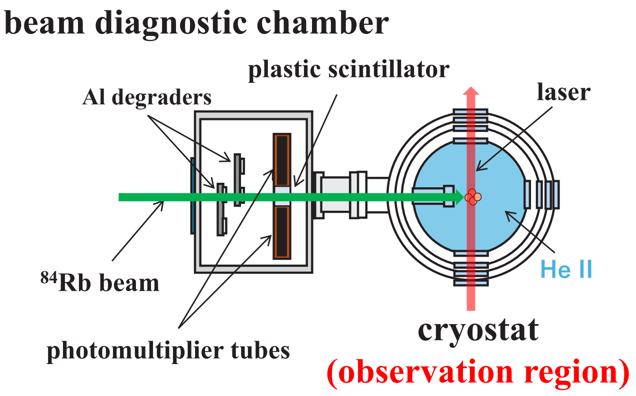

Fig. 1. Schematic of the beam diagnostic chamber.

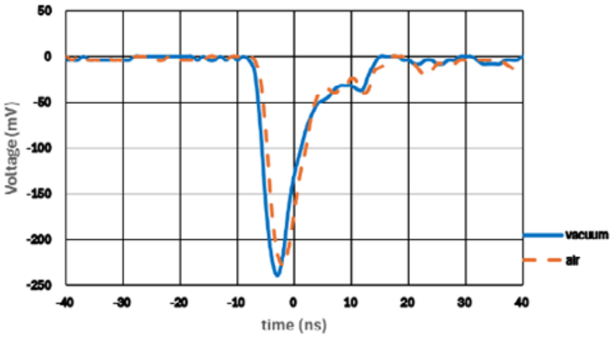

Fig. 2. One pulse signal of PMT in air and in vacuum (−1300 V applied).

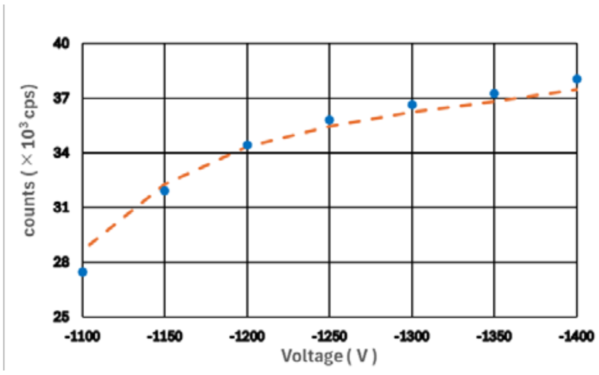

Fig. 3. Scintillation count rates as a function of supply voltage under atmospheric (dashed line) and vacuum (closed circle) conditions.

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to the expected dose from β-rays (29,820 Bq), considering that a solid angle of approximately -1125 V was applied. We confirmed that the measurements can be performed in air and vacuum with no significant difference in the results, nor were the results different from those of the one-pulse signal.

During the upcoming beam time spanning several days, we will evaluate the stability of the PMT.

References

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