Measurement of total muonium emission yield from silica aerogel using μSR method

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We are working towards the development of producing slow muon beams, as a source of the accelerated cold muon beam, to be used for the muon g-2/EDM measurement planned at J-PARC.[1)] We observed at TRIUMF that the muonium (Mu = μ^+e^-) emission rate from silica aerogel to vacuum is enhanced by surface ablation.[2,3)] By ionizing the muonium with an intense laser, high intensity slow muon source can be obtained. However, the present muonium yield measurement by tracking of the muon decay positron is limited to a region away (∼5 mm) away from the surface owing to the large background from the muoniums decaying in aerogel, whereas we plan to ionize muoniums in the vacuum region less than 5 mm from the surface because most of the muoniums emitted are expected to stay there. Although we can extrapolate the measured muonium yield to the region closer to the surface with modeling, it is much preferable if we can get the information directly.

We performed a new measurement using a completely different method, muonium spin rotation (MuSR) under applied magnetic field (∼0.22 mT). The muonium precession is kept during its diffusion in aerogel and even after its emission to vacuum. Here, if we put a metallic foil such as gold attached to the aerogel surface, the muonium entering the metal will become diamagnetic and the muonium precession will stop. This will decrease the precession amplitude with the time after muon beam injection and can be observed as the relaxation in μSR spectra. For example, if 10% of the formed muonium has reached the foil by a given time, the precession amplitude should decrease to 90%. Thus, the precession spectrum gives us information on the timing distribution of the muoniums reaching the foil.

We set an aerogel sample with a gold foil stacked at the downstream surface in the ARGUS μSR spectrometer at the RIKEN-RAL Muon Facility. First, we set the muon beam momentum to stop the muons in the middle of the aerogel and measured the intrinsic muonium spin relaxation. The relaxation (0.0389 (11) μs^{-1}) was subtracted as the background in all the following measurements. Then, we set the momentum to snsure that the muon stopping distribution peaked at the downstream surface edge of the aerogel, thereby contributing to the largest muonium emission probability. In this half stopping condition, it is evident that the muonium precession relaxes faster, indicating the gradual loss of muoniums due to transfer to the gold foil. MuSR measurement was also performed for different foil distances (10 and 20 mm) to obtain detailed timing and space information on muonium distribution in vacuum.

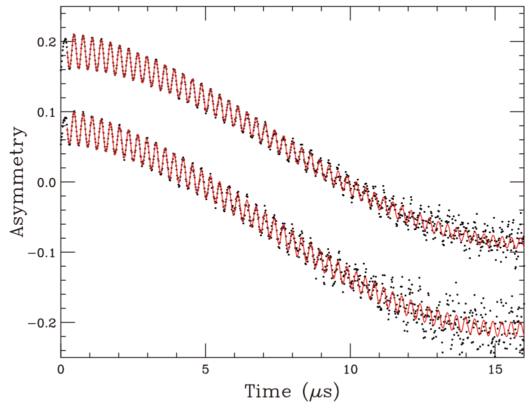

Fig. 1. MuSR spectra under 0.22 mT with muons stopping near the downstream surface of silica aerogel with the gold foil placed at 0 mm (above) and 20 mm (bottom) from the surface. The precession signal with approximately 100 times the period of muonium is due to the diamagnetic muons that did not form muonium.

The MuSR spectra with the gold foil at 0 mm and 20 mm are compared in Fig. 1. The initial muonium precession amplitude was approximately 2.5% in both cases and the relaxation rates after subtracting the background rate were 0.0355 (20) μs^{-1} and 0.0146 (31) μs^{-1}, respectively. The result can be understood by considering the different timing distribution of the muoniums reaching the foil. A detailed analysis to extract the muonium emission rate and timing from the relaxation spectra is in progress.

References
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