HTc-SQUID beam current monitor at the RIBF[†]

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For measuring the DC current of heavy-ion beams non-destructively at high resolution, we developed a high critical temperature (HTc) superconducting quantum interference device (SQUID) beam current monitor for use in the radioactive isotope beam factory (RIBF) at RIKEN[1)]. Because of its low vibration, a pulse tube refrigerator cools the HTc fabrications that include the SQUID such that the size and operational costs of the system are reduced. Two years ago, we significantly reinforced the magnetic shielding system. The new strong magnetic shielding system can attenuate the external AC magnetic noise by 10^{-10}. With the aim of practical use in acceleration operation, we disassembled the prototype high-Tc SQUID current monitor (SQUID monitor), installed improved parts, and re-assembled it. Last year, we installed the SQUID monitor in the beam transport line in the RIBF. We are presently using the SQUID monitor for measuring of the current of beams of heavy-ions such as uranium.

To increase the beam current resolution of the SQUID monitor, we investigated the improvement of the coupling efficiency between the magnetic field that is generated at the bridge circuit and the input coil of the HTc SQUID. We developed a new HTc SQUID[2)] with a high-permeability core that was installed in the two input coils of the HTc SQUID. Furthermore, to increase the magnetic field produced by the bridge circuit, we successfully fabricated an HTc current sensor with two coils using a newly developed spraying machine[3)]. In general, the performance of monitors such as the SQUID monitor is determined by the signal to noise ratio. To improve the measurement resolution, it is important to attenuate external magnetic noise. Therefore, we developed a hybrid magnetic shielding method based on the properties of perfect diamagnetic materials (superconductors) and ferromagnetic materials[4)].

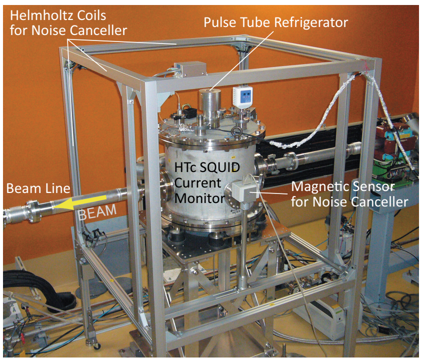

Fig. 1. SQUID monitor equipped with the noise canceller system, which was installed in the transport line between the fRC and the IRC .

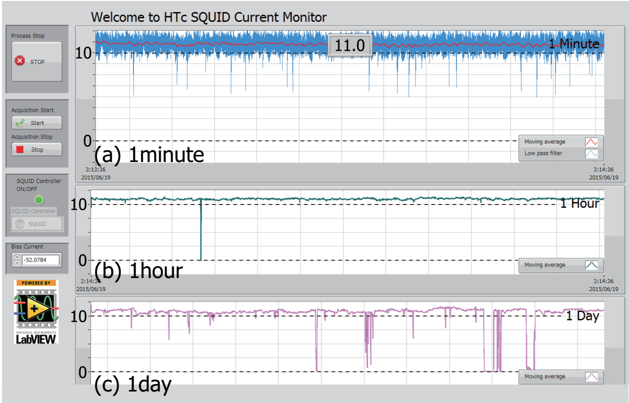

Fig. 2. The 11 μA ^{78}Kr^{36+} intensity of the beam (50 MeV/u) was successfully measured with a 500 nA resolution.

Figure 1 shows the SQUID monitor equipped with the noise cancellation system, which was installed in the transport line between the fRC and the IRC. We successfully measured the intensity of an 11 μA beam of ^{78}Kr^{36+} (50 MeV/u) with a 500 nA resolution (Fig. 2). We calibrated the SQUID output voltage with a simulated beam current beforehand. Prolonged 1 min, 1 h, and 1 day recordings of the Kr beam current extracted from the fRC were achieved. In these recordings, several dips in beam intensity due to the ECR ion source discharge can be observed. The amplitude of the ripples in the modulated beam current increased with the beam current. Although we can measure the intensity of a sub-μA beam, a two orders of magnitude lower current resolution is required at the RIBF. Therefore, we are now investigating the possibility of coating a thin layer (70 μm) of Bi_2-Sr_2-Ca_1-Cu_2-O_x (Bi-2212) on a silver (Ag) substrate capable of corresponding to the complex shape.

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References

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