Sensitivity improvement and miniaturization of HTc-SQUID beam current monitor

T. Watanabe,[*1] N. Fukunishi,[*1] S. Inamori,[*2] and K. Kon[*2]

To measure the DC current of heavy-ion beams nondestructively at high resolution, we have developed a high- critical- temperature (HTc) superconducting quantum interference device (SQUID) beam current monitor (SQUID monitor) for use in the RIBF. We have completed the development of a prototype of the SQUID monitor and installed it in one of the beam transport lines in the RIBF.[1)] Presently, we have been using the SQUID monitor for current measurement of heavy-ion beams. Furthermore, with the aim of higher sensitivity and miniaturization of the SQUID monitor, we have started the investigation for developing a new method.[2)]

We investigated a low- critical- temperature (LTc) SQUID monitor, which was expected to be use for monitoring the beam of the Antiproton Accumulator in the Fermi National Accelerator Laboratory.[3)] Furthermore, we considered why an LTc SQUID monitor has a high sensitivity, which was developed for atomic-physics experiments on the electron-ion collision processes in the cooler synchrotron TARN II ring.[4)] As a result of consideration, we concluded that it is essentially important to improve the coupling efficiency between the SQUID and the magnetic flux produced by a beam current. To achieve strong coupling, a highly permeable magnetic core with large inductance is necessary. Fig. 1 shows a new scheme of an HTc SQUID monitor. Both an HTc shielding ring and an HTc induction ring are fabricated by dip coating a thin Bi_2-Sr_2-Ca_1-Cu_2-O_x (Bi-2212) layer on a Ag substrate. The Bi-2212 layer is approximately 100-μm thick. When a charged-particle beam passes along the axis of the HTc induction ring, a shielding current produced by the Meissner effect flows in the opposite direction along the wall of the HTc induction ring. The shielding current acts to eliminate the magnetic field produced by the beam. The shielding current also flows on the shielding ring in the same manner. Since a permeable core with a magnetic gap is installed in the induction ring, the magnetic flux produced by the current flow is strongly coupled with the magnetic core. An HTc SQUID installed in the magnetic gap of the induction ring can detect the magnetic flux. We theoretically estimated the expected signal voltage[2)] and made several parts (Fig. 2 (a)-(c)) to verify whether the theory is correct. After all parts were cooled by liquid nitrogen, the test was performed using a simulated beam current of 0.5 mA at 20 Hz. Fig. 2 (d) shows the output voltage from the HTc SQUID controller, which was analyzed in the frequency domain. Since the theoretically expected voltage was 2.6 V_{pp} and the measured voltage was 2.2 V_{pp}, it was confirmed that the theoretical estimation was correct.

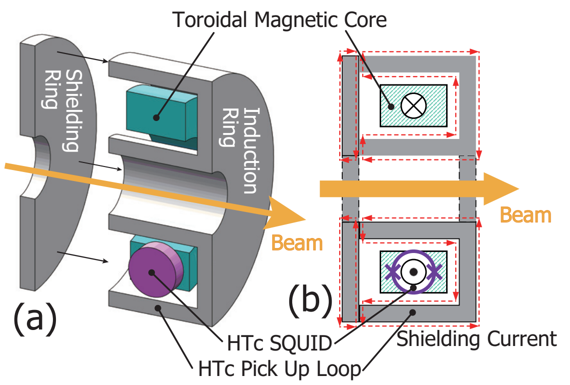

Fig. 1. New scheme of a HTc SQUID monitor.

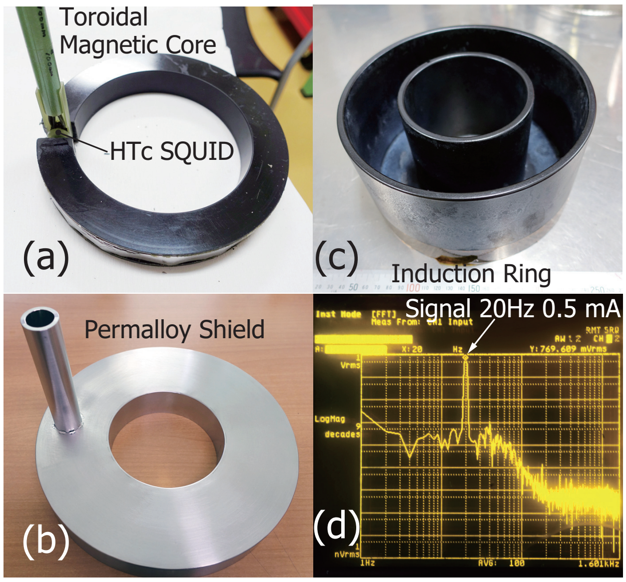

Fig. 2. Several parts for testing (a)-(c) and measured result (d).

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*1 RIKEN Nishina Center
*2 TEP Corporation

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