Reinforcement of magnetic shield for HTc SQUID beam current monitor at the RIBF†

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To measure the DC current of high-energy heavy-ion beams nondestructively at a high resolution, a high-critical-temperature (HTc) superconducting quantum interference device (SQUID) beam current monitor henceforth referred as HTc SQUID monitor has been developed for use in the radioactive isotope beam factory (RIBF) at RIKEN.[1)] Beginning this year, the magnetic shielding system has been greatly reinforced. Since the measurement resolution is determined by the signal to noise ratio, this resolution is improved by attenuating the external magnetic noise and RF back ground noise. These noises are mainly produced by the distribution and transmission lines from the high-current power supplies and high-power RF cavities of the cyclotrons.

To reinforce the existing magnetic shield, we developed a hybrid magnetic shielding method based on the properties of perfect diamagnetic materials and ferromagnetic materials; we were able to realize a high shielding effect despite the compact system. This system consists of two shielding parts: one for the HTc current sensor and the other for ferromagnetic shielding materials. The HTc current sensor used to produce a shielding current produced by the beam[1)] also works as the superconducting shield via the Meissner effect (perfect diamagnetism). The ferromagnetic shielding materials are composed of high permeability alloys (Permalloy, Mu-metal, etc.). The HTc SQUID is installed inside the frame and onto the HTc current sensor, and the frame is covered by the cap. Consequently, the HTc SQUID is almost completely surrounded by the hybrid magnetic shielding system. A photograph of the completed hybrid magnetic system is shown in Fig. 1.

In the acceleration facility, since there exist AC magnetic noises of 50 Hz and higher order and which are much stronger than terrestrial magnetism, an active magnetic field canceller system (JEOL Ltd.) was designed and introduced to the HTc SQUID monitor. This system is comprised of a magnetic field control unit, combined AC/DC magnetic field sensors, and compensation coils. The compensation coils consist of three pairs of coils that are arranged perpendicular to each other. Each of these pairs forms a so-called "Helmholtz-Coil-Pair," able to produce a homogenous magnetic field in between the pairs; each pair controls one direction (along x-, y-, or z- axis). A photograph of the active magnetic canceller system is shown in Fig. 2.

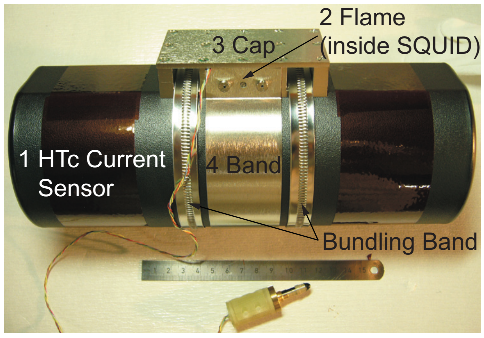

Fig. 1. Photograph of the completed hybrid magnetic system. 1: HTc current sensor with ferromagnetic shielding materials, 2: frame, 3: cap, and 4: band.

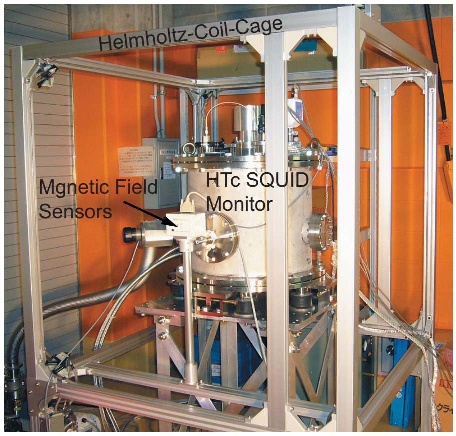

Fig. 2. HTc SQUID monitor with active magnetic field canceller system.

To evaluate the performance of the hybrid magnetic shielding system and the active magnetic canceller system, the output signals of the HTc SQUID were analyzed in the time and frequency domains. The signal was measured in the room next to where the power supplies for RIBF were located, where the leakage magnetic field of the 50 Hz component was measured by a Gauss meter as 4.5 $\times 10^{-4}$ T. On the other hand, the output signal of the 50 Hz component of the HTc SQUID monitor was 6 $\times 10^{-14}$ T. Based on these findings, we consider that the combination of the hybrid magnetic shielding system and the active magnetic canceller system can attenuate the external magnetic noise to 10^{-10}.

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References

1) T. Watanabe et al., Proc. 2010 Beam Instrumentation Workshop (BIW10), Santa Fe, U.S.A (2010) p. 523.