Improvements of sensitivity and utility in the scanning superconducting quantum interference device (SQUID) microscope

*Yusuke Kubota[1], Joseph Kirschvink[2,1], Isaac Hilburn[2], Jennifer Buz[3], Atsuko Kobayashi[1,2], Chie Kato[4]

1. Tokyo Institute of Technology, 2. California Institute of Technology, 3. Northern Arizona University, 4. Kyushu University

Superconducting quantum interference device (SQUID) microscopes have been used for mapping the distribution of ferromagnetic materials in a variety of industrial, biological, and geological materials. The advantage of the SQUID microscope is the wide dynamic range and spatial resolution down to the 25 μm scale, as well as the ability to quantify the direction and intensity of extraordinarily tiny magnetic dipoles. However, a major drawback of earlier versions of this instrument has been the need to cool the superconducting sensors with liquid helium and nitrogen, which limits the system's utility and drives up maintenance costs. One previous instrument (at Caltech) incorporated a closed-cycle pulse-tube cryocooler and managed to achieve good sensitivity by averaging precisely over one pulse cycle to remove the periodic magnetic signal from the pulse tube ferrite chain. In this study, we report a new design of SQUID microscope at TokyoTech that improves substantially on this. First, a large-volume μ-metal shielded room provides an environment with low spatial magnetic gradients, although it does allow ~ 5 nT low-frequency signals from local train lines to penetrate. Next, the pulse-tube is encased in a superconducting shield made of Pb, lowering the noise from that source. Finally, we placed a second SQUID sensor, parallel to the axis, ~4 cm from the first and calibrated it to correct for background fluctuations. The final system is approximately 5-10 times more sensitive than the previous configuration and is being applied to a variety of biological and single-crystal rock magnetic studies.

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