ED1-1-INV

Multichannel on-scalp MEG based on high-Tc SQUID magnetometers

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Recent development of high-T_c SQUID magnetoencephalography (MEG) has shown the potential of the technique both as a possible replacement for the traditional low-T_c systems [1-5] and for increased information capacity from the close proximity to the brain [6]. SQUID magnetometers made from single layer high-T_c superconductors usually have an order of magnitude or more higher noise than their multilayer low-T_c counterparts. However, for MEG applications, the simpler cryogenic requirements make it possible to decrease the sensor-to-head distance from 20 mm to approximately 1 mm, retaining the signal-to-noise ratio. Furthermore, higher spatial resolution could be obtained and higher moments of the sources could be resolved from near-field measurements. Here, we report on benchmarking of high-T_c vs. low-T_c MEG and on the development of a multichannel high-T_c MEG system. The system is configured with a densely-packed set of seven 8.6 mm x 9.2 mm high-T_c SQUID magnetometers positioned in a slightly concave hexagonal pattern on a sapphire window connecting thermally to a liquid nitrogen bath. A method of direct feedback injection to the SQUID loops was chosen to minimize crosstalk between the sensors. To improve the field sensitivity, we have developed a new method to produce high-T_c flux transformers for flip-chip arrangements for the next generation MEG system. Finally, we are investigating the possibility to use high-T_c nano-wire based SQUIDs as magnetometers for MEG in future systems.

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Keywords: magnetoencephalography, high-Tc, SQUID, on-scalp

ED1-2-INV

Superconducting Devices Based on Coherent Operation of Josephson Junction Arrays above 77K

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It took a while for Feynman’s famous prediction [1] that multiple Josephson junction devices would eventually improve performance of superconducting devices to be confirmed experimentally [2-5]. Such arrays made of low temperature superconductors operate at 4.2K or below and maintaining such low temperatures is both expensive and difficult to handle. This is why high temperature superconductor Josephson junctions operating coherently at 77K are ideal candidates for re-shaping the electronics industry's future. Their advantages over their semiconducting counterparts (higher operating speed, lower power consumption/electronic noise) can be exploited in practice because of their practicality: cooling down to 77K is both cheap and easy to handle. Several promising applications are considerd here. Firstly, when flux coherency is achieved in large SQUID-arrays connected in series magnetic flux sensors or voltage amplifiers can be build having record values for their output voltage and flux noise sensitivities [6] outperforming even single SQUID-based devices operating at 4.2 K. Secondly, when the coherent flux-flow of vortices in parallel asymmetric SQUID-arrays placed in a uniform magnetic field B synchronizes with the collective ac Josephson effect in the array ones can exploit that for the development of B-tunable microwave generators [7]. The coherent flux-flow can be altered by B leading to record values for current amplification [8], highly efficient ratchets with unidirectional vortex motion or integrated nano-magnetic sensors [9].

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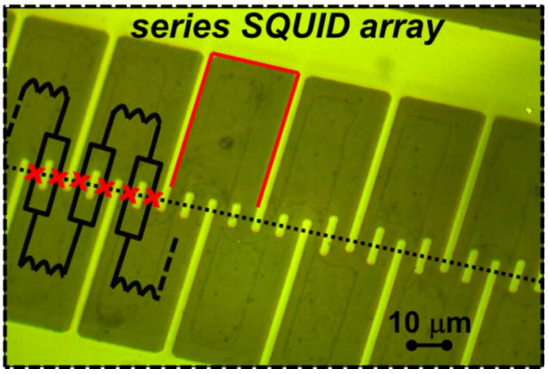

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ED1-3

Magnetometer based on transfer and modulation of magnetic flux using HTS coils

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We developed a new type of magnetometer for measuring low-frequency magnetic fields. The principle of operation is based on the transfer and modulation of magnetic flux using HTS coils. Schematic of the magnetometer is shown in Fig. 1. The magnetometer consists of two coils, namely, pickup and modulation coils made of HTS tape. The two coils are connected with very small joint resistance, and form a closed loop. Using the closed loop with very small resistance, we can transfer the magnetic flux collected with the pickup coil to the modulation coil even at low frequencies.

The magnetic flux transferred to the modulation coil is detected using a newly developed readout scheme based on the inductance modulation of the coil. For this purpose, a magnetic wire was inserted into the modulation coil as shown in Fig.1, and a time-varying current I_B was supplied to the wire. In this case, the permeability of the wire is modulated by I_B, and as a result, the inductance of the modulation coil is modulated with time. Utilizing the time-varying inductance, the magnetic flux is converted to an amplitude-modulated voltage across the modulation coil for the measurement. Following the principle of operation, we call the proposed magnetometer induction modulation scheme (IMS) magnetometer.

For a demonstration of this principle of operation, we fabricated a prototype of the magnetometer using HTS tape. The prototype magnetometer can operate at low frequencies down to $f = 0.01$ Hz without diminishing the response. The noise in the magnetic field signal is 40 pT/Hz$^{1/2}$ at 10 Hz. Further work is necessary to improve the performance of the magnetometer.