January 2014 Date of Issue: January 15, 2014

Superconductivity Web21

Published by International Superconductivity Technology Center
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Feature Article: SQUID Applications ･Medical Applications - Magnetocardiography Measurements in Small Animals Using A Low Temperature Superconducting SQUID

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The genes of small animals such as mice and rats can be relatively easily manipulated and using artificial models, allowing the realization of diseases due to genetic disorders. A number of small animals have been used in experimental trials to model diseases to enable a better understanding of the causes of genetic disorders and ways to treat diseases in humans. The author and his group have investigated magnetocardiograms (MCGs) as a non-invasive method that allows electrophysiological signals emanating from the heart of a small animal to be measured. The findings here will contribute to both a better understanding of disease models as well as allow innovative drug discoveries and developments to be made. Here, high-throughput screening tests can be done effectively and efficiently with a number of small animals without the need to shave their hairs to implant or attach electrodes to their bodies.

For MCG measurements a low temperature superconducting SQUID magnetometer array has been fabricated as shown in Figure 1 [1)]. A 9-channel directly coupled SQUID magnetometer array arranged in a 3 x 3 square matrix has been fabricated onto a 10 mm x 10 mm silicon chip, with a distance of 2.75 mm between the sensors. This array has a 2.5 mm diameter pick up coil on each sensor. The magnetic field resolution of each sensor was 8 fT/Hz$^{1/2}$ measured at white noise frequencies.

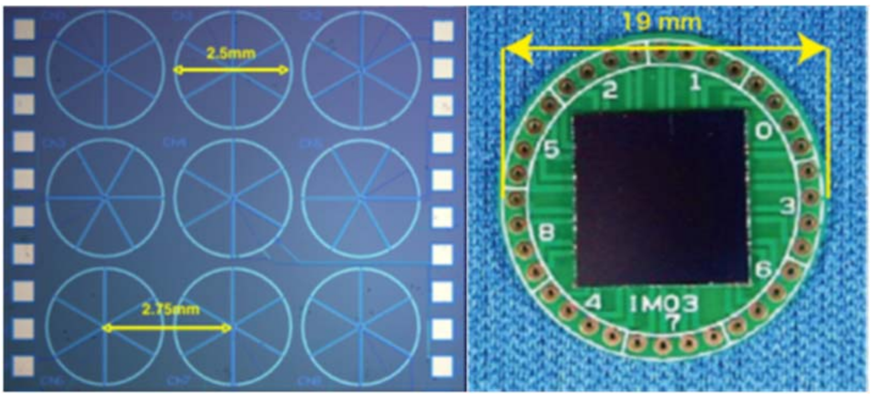

Fig. 1 Integrated 9-ch SQUID sensor (left), and an assembled SQUID sensor with a printed circuit board (right).

The MCG system has been constructed with the SQUID magnetometer array attached to a suspended dewar containing liquid helium, as shown in Figure 2 (left). The system is structurally designed so that a liquid helium reservoir is positioned outside the magnetically shielded box and only the sensor is positioned close to the center of shielded box. The cool-to-warm-separation of sensor was less than 2 mm. A one-time supply of around 6-liter volume of liquid helium in the reservoir is able to sustain superconductivity of the

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sensor for more than ten hours. The complete system overview is shown in Figure 2 (right). The shielded box is composed of two permalloy layers and an electromagnetic shield layer, realizing attenuating characteristics of around 60 dB at commercial power supply frequency bands. A reference sensor is assembled to capture and subtract the environmental noise signal within liquid helium dewar, which otherwise cannot be cancelled by magnetic shielding [2].

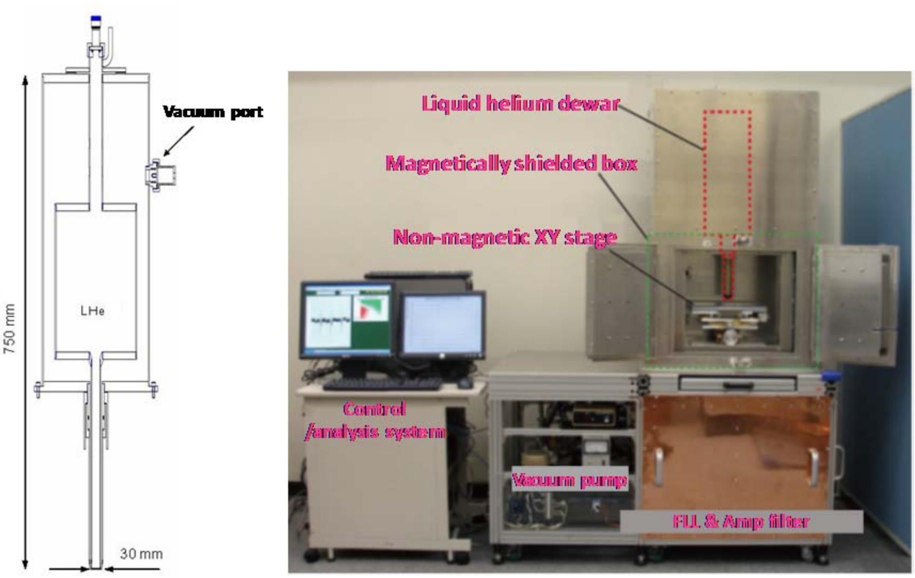

Fig. 2 Structure of a suspended dewar (left) and the overview of the MCG system designed for small animals (right)

Figure 3 (left) shows a set detecting a cardiac magnetic field emanating from a guinea pig utilizing the system developed. Simultaneous electrocardiogram measurements have been undertaken in order to ascertain the validity of the data. An example of the measured cardiac signal waveform from a guinea pig is shown in Figure 3 (center). The signals emanated from 135 heartbeats during a 30-second measurement interval were averaged with the reference trigger. P-QRS-T waves are clearly confirmed in all 9 channels of a magnetometer array. Figure 3 (right) shows a contour map of the R~S waves.

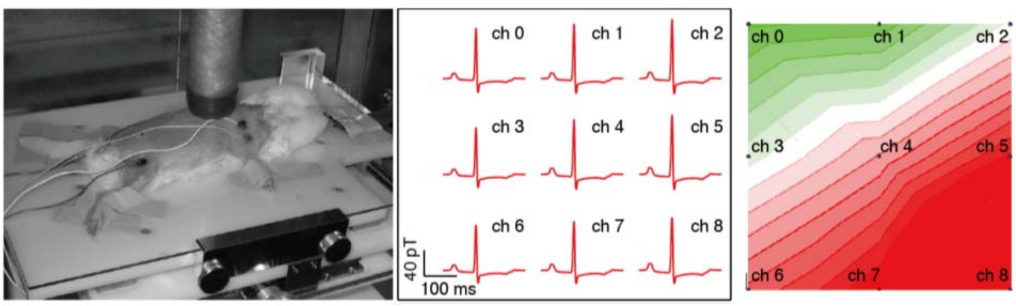

Fig. 3 The set detecting cardiac biomagnetism emanating from a guinea pig (left), Example of MCG signal waveform (center), and the distribution of the MCG signals measured (right). The waveform peaks represent the magnetic field source. On the contour map, the red-areas represent the magnetic field source whilst the green represents the magnetic field sink. The distance between the contour lines is 300 fT.

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The above-mentioned MCG system designed for small-animal experiments is being exploited for analysis of QT prolongation, the aims of which are to investigate disease models as well as a determining how medicines affect the heart [3]**.** An improved dewar assembly is utilized for the measurement system investigating the magnetoencephalography signals in small animals. The system is currently utilized in hearing research of small animals. The future plan is to capitalize on the remarkable progress of SQUIDs in recent years and integrate them in low-field MRI technology. Thus further research and development will lead to low-field MRI system designed for small animals [4].

References:

1) J. Kawai *et al.* "Fabrication and characterization of an integrated 9-channel superconducting quantum interference device magnetometer array", IEEE Trans Applied Superconductivity, 15, 821–824, 2005.
2) M. Miyamoto *et al,* "Development of an MCG/MEG system for small animals and its noise reduction method", Journal of Physics: Conference Series, 97, 012258, 2008.
3) K. Komamura *et al*, "Micro-magnetocardiography system with a single-chip SQUID magnetometer array for QT analysis and diagnosis of myocardial injury in small animals", IEEE Trans Biomedical Circuits and Systems, 2, 260–268, 2008.
4) D. Oyama *et al,* "Development of SQUID-Based Compact Low-Field MRI System", IEEE Trans Applied Superconductivity, 23, 1601604, 2013.

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