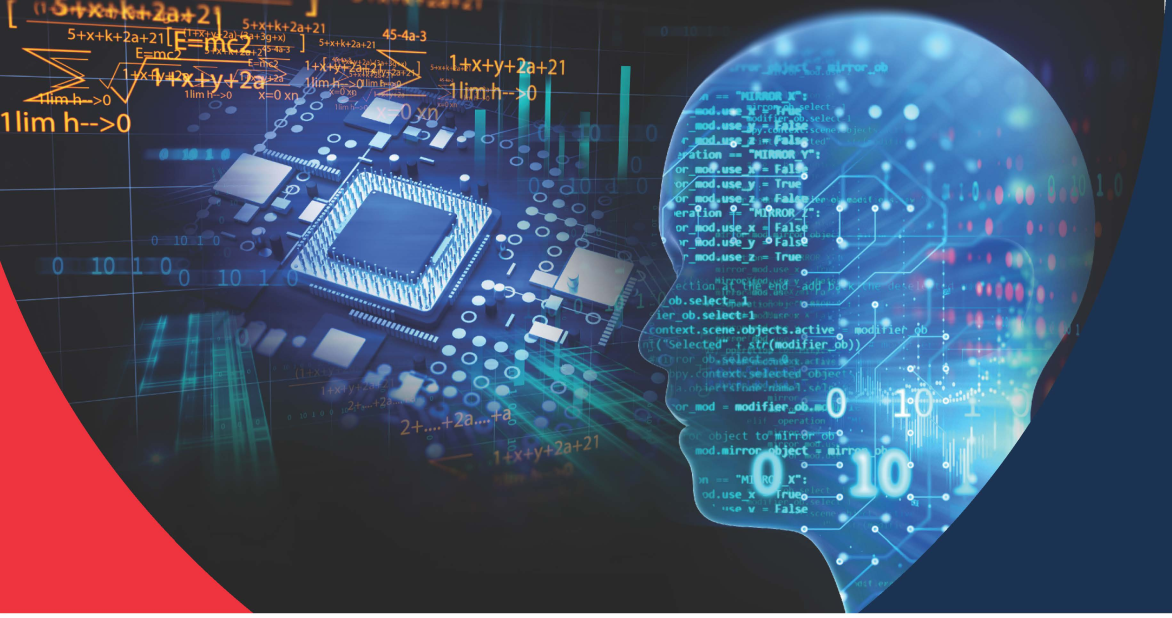

THE UNIVERSITY of ADELAIDE

Superconducting magnetic sensor

A next-generation high-sensitivity and high-resolution superconducting magnetic sensor for medical applications

Benefits

- Unrivalled level of sensitivity to bio-signals.
- Sensor operating in the high-resolution and high bandwidth regimes.
- Ultra-high scalability of the system.

Background

One of the greatest challenges in the field of medical devices is the ability to fully quantify all the different electrical and magnetic signals linked to the human heart and brain activities. Sensing of magnetic fields base on **S**uperconducting **QU**antum **I**nterference **D**evices (SQUIDs) represents a unique opportunity to reach a significant signal sensitivity and, as such, be able to fully investigate important bio-magnetic effects in humans.

Magneto-cardiography (MCG) and Magneto-encephalography (MEG) are two of the most popular techniques used to measure low-frequency bio magnetic signals coming from the heart and the brain, respectively. Typical bio-magnetic signals have amplitudes ranging between 10 fT (spinal cord) to 1 nT (magnetized lung) and frequencies ranging between few Hz to kHz. MCG and MEG are often used in conjunction with other techniques such as Electroencephalography (EEG), Magnetic Resonance Imaging (MRI) or Computed Tomography (CT) scans. Some of the drawbacks of MCG and MEG systems are linked to the resolution and bandwidth limitations that current devices use.

For example, the measurements of bio-signals linked to the neuronal activities in the spinal cord are yet to be achieved in these systems.

Current multichannel superconducting bio magnetic systems can be manufactured in many different fashions; however, they always include more than one SQUID element which are detectors that operate based on quantum mechanical principles and exhibit unsurpassed sensitivity to DC and AC electromagnetic fields. The response of SQUID elements currently used in commercial circuits is somehow affected by their conventional non-linear response and hence require complicated additional circuitry to improve their operation via feedback and modulation effects; which tend to introduce several drawbacks to the performance of these systems.

Firstly, it limits their scalability to a small number of channels that can be in use, limiting the maximum performance of the system.

Secondly, it causes a dramatic limitation on the bandwidth of the circuitry and can cause considerable degradation to the performance of the system.

Technology Overview

Our team has developed and patented a novel kind of superconducting double-loop interferometers (also called bi-SQUIDs) that can produce magnetic flux sensors specifically designed to exhibit a highly linear response. Our bi-SQUID consists of aluminium double-loop bi-SQUIDs based on proximitised mesoscopic Cu Josephson junctions. We also expect the possible use of other Superconducting materials, operating at an higher critical temperature, feasible. Such a scheme provides an alternative fabrication approach to conventional tunnel junction-based interferometers, where the junction characteristics and, consequently, the magnetic flux-to-voltage and magnetic flux-to-critical current device response can be largely and easily tailored by the geometry of the metallic weak-links. Our SQUID systems have already demonstrated large improvements in term of the linearity of their response and due to our unique and patented design, we anticipated that it is possible to improve the performance of our bi-SQUID devices even further during operation, if needed. Hence, if used to replace the conventional SQUIDs currently in use in multichannel superconducting bio magnetic systems, the bi-SQUID geometries that we have developed and tested, are expected to provide a design that may be capable to provide the next generation of high-sensitivity and high-resolution superconducting magnetic sensor for medical applications.

IP Status

Provisional Patent 2021903616. International Search Report deemed all claims to be inventive and novel.

Publications

The paper “Ultra-Highly Linear Magnetic Flux-to-Voltage response in Proximity-based Mesoscopic bi-SQUIDs” G. De Simoni, L. Cassola, N. Ligato, G. C. Tettamanzi and F. Giazotto (https://arxiv.org/abs/2112.09421) is about to be published by the journal Physical Review Applied.

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