EMRP Call 2012 – Open Excellence, Industry and SI Broader Scope

Selected Research Topic number: **SRT-x04**
Version: 1.0

Title: Nanoscale magnetic detection close to the quantum limit

Abstract

Quantum metrology requires magnetic detection with ultimate sensitivity in the micro- and nano-scale at low temperature. Such nano-magnetic systems are used in spin-imaging, temperature measurement and solid-state Quantum Information Processing. This SRT seeks an extension of the capability of conventional Superconducting Quantum Interference Devices (SQUIDs) into the area of nanoscale detection and the imaging of single magnetic entities to magnetic detection in the r.f. frequency range, close to the quantum limit.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Industry & Fundamental Metrology on pages 25 and 32.

Keywords

Quantum limited detection, non-invasive magnetic detection, nano-magnetic systems, nanoelectronics, SQUIDs, high frequency magnetic sensors

Background to the Metrological Challenges

At the micro- and nano-scale, the smaller dimensions and higher sensitivity require ever smaller amounts of energy to be detected and hence, lower operational temperatures and weaker back action of the measuring devices. SQUID based magnetic detection techniques can be used for this, however the metrological characterisation and calibration of the detectors is currently extremely difficult. Furthermore, the application of SQUIDs for measuring techniques such as NMR (at very low temperatures) suffers from insufficient magnetic coupling, poor spatial resolution and large uncertainties due to the back action of conventional or superconducting detection tools.

Recently, SQUID operation at very low temperatures e.g. <1 K has shown serious limitations in sensitivity in the lower frequency range (<10 kHz) due to increasing noise which can exceed the noise level measured at 4.2 K. Novel material combinations for the fabricated of SQUIDs could be used to address this problem, but, the temperature of the SQUIDs cannot be decreased significantly below 200 mK because of weak electron-phonon coupling. Normal-metal/insulator/superconductor (NIS) junction micro-coolers have already been investigated as stand-alone devices, however implementing these novel coolers on SQUID chips could be a new approach.

SQUIDs are unparalleled in their magnetic detection sensitivity, however in order to meet the needs described above, novel SQUID concepts are required, such as extending their capability to the nanoscale i.e. NanoSQUIDs and high frequency and mK SQUID operation.

Scientific and Technological Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP-Protocol.

The JRP shall focus on extending the known quantum-limited capability of conventional SQUIDs to the area of nanoscale detection and imaging of single magnetic entities and to magnetic detection in the r.f. frequency range.

The specific objectives are

1. To develop novel SQUID sensor configurations exploiting state-of-the-art technological achievements and junction technologies
2. To explore a novel microwave multiplexing approach for reading-out arrays of SQUIDs.
3. To overcome the current limitation of operational temperature and to enable mK operation in cryostats with higher base temperature
4. To exploit novel material combinations for the realisation of SQUIDs aiming at a reduction of low-frequency noise of these devices at very low temperature.
5. To investigate possible applications of Superconducting Quantum Interference Proximity Transistors (SQUIPT).

Proposers shall give priority to work that enables new metrological methods and techniques in the future through excellent science. The project need not address metrology directly.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this and how it will use or extend the knowledge developed in iMERA-Plus JRP T4 J02 ‘Nanomagnetism and Spintronics’ the JRP IND08 ‘Metrology for advanced industrial magnetics’ MetMags and the FP7 Integrating Activity project ‘European Microkelvin Collaboration’.

The total eligible cost of any proposal received for this SRT is expected to be around 1.8 M€ guideline for proposals in this call. The available budget for integral Research Excellence Grants is 84 months of effort.

Potential Impact

The project should be designed to bring together the best scientists in Europe and beyond whilst exploiting the unique capabilities of the National Metrology Institutes and Designated Institutes. Significant non-NMI/DI and international participation in the projects is expected and proposers should make full use of the larger budget for Research Excellence Grants available for this SRT.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology and includes the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.