EMPIR Call 2017 – Industry, Fundamental, Normative and Research Potential

Selected Research Topic number: **SRT-i11**
Version: 1.0

Title: Ultra-sensitive cryogen-free magnetic field sensors for industrial applications

Abstract

Ultra-sensitive cryogen-free magnetic field sensors, such as optically pumped magnetometers (OPM), are a low-cost alternative to superconducting quantum interference device sensors (SQUIDS). Measurement platforms using OPMs could be used in a number of applications including energy, healthcare and materials industries, but further development of portable DC (low-bandwidth) and RF (radio frequency) magnetic field sensors is necessary to enable new applications such as magnetic induction tomography, magnetoencephalography and geomagnetic field measurements.

Keywords

Optically pumped magnetometers (OPM), active magnetic noise cancellation, magnetic induction tomography, magnetoencephalography, geomagnetic field measurements.

Background to the Metrological Challenges

OPM are comparable in performance to SQUIDS and are a cryogenically-free alternative. Laboratory demonstrations of OPM operating in open/low shielded environments have paved the way for their application in industrial areas such as medical and security screening, material testing, chemical analysis, and geomagnetic surveying. Current challenges with OPM include miniaturisation of the detector, active noise cancellation, and interfacing of the sensor and electronics.

Although individual OPM sensors are already commercially available, applications such as magnetic induction tomography, magnetoencephalography and geomagnetic field measurements require a new system design which is well beyond the single sensor operation. Magnetoencephalography (MEG) is a biomagnetic imaging technique used for detecting extremely weak magnetic fields produced by neural networks. Operation of individual miniaturised OPMs suitable for a geometrically flexible MEG has already been demonstrated. However, further work is necessary to validate this use and demonstrate its industrial applicability.

OPMs operating at the quantum limit have also been applied to magnetic induction imaging, a non-contact technique that allows the imaging of conductive objects. In addition, OPMs have been used for geomagnetic field measurements, albeit in less demanding applications than SQUIDS. The state of the art for geomagnetic field measurements, with regard to magnetic-field resolution (<1 pT) and bandwidth (≈1 kHz), is set by SQUIDs.

By providing high sensitivity and low-cost ultra-sensitive cryogen-free magnetic field measurements, OPMs will make the next generation of sensors possible. Such development requires a robust magnetic measurement platform, including portable DC and RF magnetic field sensors for measurements in the sub-pT regime and in static fields of more than 10 nT. These sensors should be integrated into multichannel sensor arrays and validated. Active noise cancellation also needs to be developed to enable OPM sensor operation in unshielded environments, i.e. ambient fields of several tens of micro-Tesla, and similar to the earth's field.

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

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maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of ultra-sensitive cryogen-free magnetic field sensors, such as optically pumped magnetometers (OPM) for industrial applications.

The specific objectives are:

1. To develop and to validate radio frequency (RF) and DC (i.e. low-bandwidth) OPM sensors. The target noise level is sub-pT/$Hz^{1/2}$ for operation in static fields of more than 10 nT.
2. To validate the integration of multiple low-bandwidth OPM sensors into a multichannel sensor with a target bandwidth from 0.1 Hz to 1 kHz.
3. To develop and to validate an OPM sensor for operation in ambient fields of several tens of micro-Tesla, i.e. similar to the earth field. This should include the integration of a low-bandwidth OPM sensor and active noise cancellation.
4. To use the outputs from objectives 1-3 to validate three active and passive sensing techniques, in particular (i) magnetic induction tomography, (ii) magnetoencephalography and (iii) geomagnetic field measurements. In addition to evaluate the industrial applicability and commercialisation of the outputs from objectives 1-3.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations (e.g. ISO and CEN) and end users (e.g. healthcare, energy and materials industries).

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the healthcare, energy and materials industries sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include 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 EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.