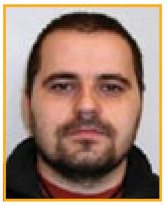
Low-Temperature nanofabricated magnetometer for the study of topologically frustrated nanomagnets



Principal investigators

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Laboratories: NEEL, LNCMI

The main objective is the development of a nanofabricated Faraday magnetometer at the Institut Néel, which will enable us to perform absolute magnetization measurements under extreme conditions: very low temperature (30 mK), high magnetic fields (16 T) and small samples, including nanomagnets and thin magnetic films. This unique set-up will reach a very high sensitivity thanks to a microelectromechanical system (MEMS) made of a nanofabricated silicon membrane, and will be of great interest for magnetic studies in the LANEF laboratories. We will especially investigate the magnetic properties of topologically frustrated spin-1/2 based quantum nanomagnets, suspected to stabilize novel collective magnetic states, at very low temperature and in high magnetic field.

Description

We are developing a new magnetometer, which can work at temperatures down to 30 mK and under magnetic field up to 16 T with a very high sensitivity. The purpose is to be able to measure in these extreme conditions absolute values of the magnetization of small samples or nanostructured magnetic devices. These requirements (low temperature, high fields, high sensitivity, small samples) led us to opt for a magnetometer using a capacitive detection of the Faraday force, which is especially suited for high fields and low temperature measurements. In addition, the use of a suspended silicon membrane provides a high sensitivity and a large flexibility in the design, adapted to the samples to measure.

This set-up will complete the Grenoble instruments in very low temperature magnetometry, and is developed in parallel with a set-up suitable for the 34 T LNCMI coils, in collaboration with Gabriel Seyfarth. Together with the existing magnetometers (including micro-SQUID, low temperature SQUID, torque magnetometers), our nanofabricated magnetometer will make Grenoble a unique centre of high sensitivity and low temperature magnetometry, in a large range of fields (0-34 T).

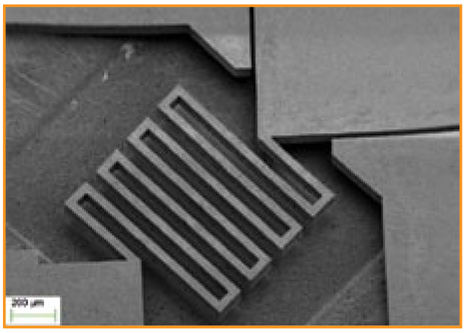
This project has implied experimental developments in several technological fields in which the Institut Néel has a strong expertise: i) cryogenics, with the building of a ^{3}He-^{4}He dilution refrigerator to reach very low temperatures, ii) electronics, with the development of a cold amplifier needed to reach a high sensitivity, iii) nanofabrication, in the Nanofab and PTA clean room facilities, for the fabrication of the MEMS sensor.

Ovidiu FLOREA's work has allowed to optimize the dilution fridge and to implement the detection line with a cold amplifier. He has also designed a new capacitive sensor, adapted to samples with a larger magnetic signal.
Today, the magnetometer is operational for measurements, and we are performing tests on a magnetic sample with a known magnetic behaviour to characterize precisely both magnetic sensitivity and background contributions.

This magnetometer will be suitable for a large variety of exotic materials under investigation in the Lanef laboratories (mainly Institut Néel, LNCMI and INAC). Initially, we are interested in quantum frustrated clusters which are the appropriate systems to study the frustration role on quantum spins S=1/2. This project has started within Ovidiu Florea's PhD thesis, by performing magnetic measurements in existing magnetometers up to 8 T on molecular frustrated Cu samples synthesised in A. K. Powell's group (Karslruhe Institute of Technology, Germany). The first results are promising, although problems of sample stability are not solved yet. Indeed, we have evidenced a magnetization plateau, characteristic of the presence of entangled quantum excited states in the system. Our Faraday magnetometer is now required to fully explore these states at the lowest temperature as possible.

During his PhD thesis, Ovidiu FLOREA also performed other studies on frustrated magnets.

Outcomes: Updating the phase diagram of the archetypal frustrated magnet $Gd_3Ga_5O_{12}$ Phys. Rev. B 91, 014419 (2015).



Pictures of the capacitive sensors:
Left: zoom of a silicon spring of the MEMS sensor. Right: "macroscopic" sample holder, made with a 3D printer

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