NÉEL institut

INTERNSHIP

2023 2024

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UGA Université Grenoble Alpes

Institut NEEL/CNRS
25 rue des Martyrs
BP 166
38042 Grenoble cedex 9
France
Tél. :
Mail :
neel.cnrs.fr

L'Institut Néel est un grand laboratoire de recherche en physique avec près de 450 membres. Sa force collective s'exprime dans de nombreuses collaborations internationales et nationales, la présence en son sein de plate-formes technologiques aux performances exceptionnelles, et un niveau de production scientifique remarquable.

Vous trouverez dans ce recueil les sujets de stage proposés par les chercheurs de l'Institut Néel. Les domaines scientifiques et technologiques sont extraordinairement variés, à l'image des activités de nos équipes. S'y côtoient entre autres magnétisme, supraconductivité, fluides quantiques, nouveaux matériaux, cristallographie, science des surfaces, nano-électronique quantique, nano-mécanique, optique nonlinéaire et quantique, spintronique… Par-delà notre cœur de métier qu'est la physique de la matière condensée, nous travaillons aussi aux interfaces avec la chimie, l'ingénierie et la biologie. Dans tous ces domaines, notre activité principalement expérimentale se développe en lien avec de fortes compétences transversales en physique théorique analytique et numérique.

L'Institut Néel développe une expertise technologique au plus niveau, essentielle pour mener à bien de nombreux projets de recherche. Enfin, nous nous impliquons activement dans la valorisation de nos recherches et de nos savoir-faire dans les domaines de l'électronique, de l'instrumentation aux très basses températures, de l'énergie, de la santé, **des technologies quantiques** et aussi des sciences de l'univers.

Cette brochure regroupe les offres de stage de Master proposés pour l'année universitaire 2023-2024. Ce sont principalement des stages de Master 2 avec pour la plupart une possibilité de continuation en thèse. Si vous commencez votre master, vous trouverez aussi des propositions de stage de Master 1. De nombreux sujets de Master 2 peuvent aussi être déclinés en sujets de Master 1. L'Institut Néel vous souhaite la bienvenue, au moins virtuellement par cette brochure et au travers de notre site web www.neel.cnrs.fr ! N'hésitez pas à contacter les chercheurs de l'Institut Néel afin de nous rendre visite.

La direction de l'Institut Néel

INSTITUT NEEL - CNRS

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Spatiotemporal dynamics of 2D frustrated lattices	Coraux Johann Rougemaille Nicolas
2D superconductivity in cuprate oxychlorides	D'Astuto Matteo Rodiere Pierre
Combinatorial studies of hard magnetic materials	Dempsey Nora
Electron beam induced current study of p-n junction electrical properties	Den Hertog Martien Jacopin Gwenolé
Magnetic manipulation of nanoparticles in a microfluidic chip	Devillers Thibaut
Electrical characterization of diamond diodes for application in power electronic or high frequency	Eon David
Dependence of dissipation of nanomechanical resonators on superconducting state	Fefferman Andrew
Ultra-Coherent Nanomechanical Resonators	Fefferman Andrew
Fabrication de composants de puissance en oxyde de gallium	Ferrandis Philippe
Fabrication of gallium oxide power devices	Ferrandis Philippe
Highly tunable single-photon sources emitting in the telecom bands	Hocevar Moïra Claudon Julien
Imaging the mechanical and thermal properties of nanowires in an electron microscope	Hocevar Moïra Pairis Sébastien
Investigation of magnetization processes in R-M intermetallic compounds	Isnard Olivier
p-type doping of AlN nanowires for UV-C LEDs realization	Jacopin Gwénolé
Exotic superconductivity in flat band materials	Levy-Bertrand Florence Naud Cécile
Nm scale characterization of p-n junction electrical properties by Transmission Electron Microscopy	Monroy Eva Den Hertog Martien
Current-driven manipulation of the magnetisation of magnetic insulator thin films	Pizzini Stefania Ranno Laurent
Graphene based superconducting quantum circuits	Renard Julien
Optical probing of electronic excitations in van der Waals heterostructures	Renard Julien
Microwave quantum optics with superconducting meta-materials	Roch Nicolas
Combining coherent X-rays and nano-calorimetry to study the atomic motion and relaxation processes in glass-formers at high pressures	Ruta Beatrice
Implementation of a Fourier Transform spectrometer to record the spectrum of a THz light generated in new nonlinear crystals	Segonds Patricia Boulanger Benoît Jegouso David
Sputtering growth of ZnO nanostructures and thin films for piezoelectric energy harvester	Songmuang Rudeesun
Cavitation in superfluid helium	Spathis Panayotis
Pressure induced high T c superconductivity in Ln 3 Ni2 O7 nickelate	Toulemonde Pierre
Circuit quantum acoustics	Viennot Jérémie

MASTER 1

INSTITUT NEEL Grenoble

Proposition de stage Master 1 - Academic year 2023-2024

Etude de matériaux magnétiques à base d'élément de terre-rare et de cobalt ou fer

Cadre général :
Le sujet s'inscrit dans le cadre des recherches effectuées par une équipe travaillant sur les propriétés physiques et structurales de matériaux. Nous cherchons à améliorer les propriétés des matériaux actuels et aussi à élaborer de nouveaux composés dont il faut comprendre les propriétés fondamentales.

Les matériaux de cette famille peuvent, selon leur composition et leurs propriétés, avoir des applications variées allant des aimants permanents utilisés dans l'électrotechnique, ou les détecteurs aux matériaux pour l'enregistrement de haute densité ou la microélectronique moderne dite de spin.

Sujet exact, moyens disponibles :
Ce stage comporte une partie d'élaboration de ces composés, mais aussi de caractérisation de leurs propriétés physiques. La diffraction des rayons X sera utilisée pour étudier la structure cristalline tandis que la microscopie électronique sera mise en œuvre pour analyser la composition chimique. Au-delà des propriétés structurales nous nous intéresserons plus particulièrement aux propriétés magnétiques de ces matériaux à savoir : aimantation, température d'ordre, type d'ordre magnétique retenu par le composé en fonction de l'élément de terre rare. Ce stage est essentiellement à caractère expérimental, il sera aussi l'occasion de manipuler divers concepts plus fondamentaux vus au cours de l'année. Les équipements nécessaires pour mener ces recherches à l'Institut Néel sont opérationnels tant au niveau de la synthèse que de la caractérisation des propriétés physiques.

Interactions et collaborations éventuelles :
Ces travaux s'effectuent dans le cadre de collaborations incluant d'autres équipes nationales et internationales.

Formation / Compétences : Le profil est celui d'un(e) étudiant(e) de Master 1 ou d'Ecole d'Ingénieur intéressé(e) par la physique expérimentale, désireux (se) de compléter sa formation et d'approfondir ses connaissances scientifiques et techniques en cristallographie et magnétisme au travers d'un stage au sein d'une équipe de recherche.

Période envisagée pour le début du stage : printemps 2024

Contact : Isnard Olivier
Institut Néel - CNRS 04 76 88 11 46 courriel : olivier.isnard@neel.cnrs.fr
Plus d'informations sur : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 1 internship – Academic year 2023-2024

Graphene based superconducting quantum circuits

General Scope :
The recent progresses in reproducible fabrication and understanding of quantum systems have brought us to the following situation: it is now possible to build devices that not only present quantum properties but in which quantum states can be initialized, manipulated and readout. The building blocks of quantum circuits are quantum bits and quantum limited amplifiers. Superconducting circuits is the most advanced platform in this context and it has reached several key milestones in the realization of a quantum computer. Despite such celebrated successes, other platforms are studied in order to gain flexibility and compatibility with current semiconductor technologies. In particular, hybrid platforms that couple superconducting and semiconducting properties are expected to bring a decisive advantage by allowing electrical control of the system.

Research topic and facilities available :
In this internship, we will bring electrical tuning at the core of superconducting circuits by introducing a gapless semiconductor graphene, in the key element: the Josephson junction (see Figure). With such electrically tunable Josephson element, we can build the building blocks for a quantum platform: quantum bits and Josephson parametric amplifiers. In the team we have already demonstrated the fabrication of such graphene based Josephson junctions and their use in quantum circuits [1]. The next step, which is the goal of this work is to demonstrate that it can have functionalities and performances to be competitive with other platforms.
A one atom-thick sheet of graphene will thus have to be integrated into superconducting circuits using nanofabrication techniques available at the Institute. Such sample will then be measured at very low temperature (20mK) in a dilution refrigerator using radiofrequency (1-10 GHz) techniques. Measurements will be carried out to extract the figure of merit of the devices: lifetime of the Qubit, noise of the amplifier...
[1] G. Butseraen et al *Nature Nanotechnology* 17,1153 (2022); arXiv:2204.02175

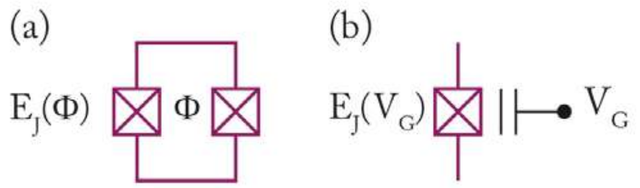


Figure 1: tunability of the Josephson energy E_J in standard Josephson junctions necessitates a loop geometry and a magnetic flux Φ (a). The introduction of a semiconductor allows simple electrical gating with a gate voltage V_G (b). This is the essence of the project.

Possible collaboration and networking : The student will be part of the Hybrid team, which has a multidisciplinary expertise (growth, nanofabrication, electronic transport, spectroscopy...). The team has also several external collaborations worldwide (France, Canada, US).
Required skills: The internship will require a solid background in solid state/condensed matter physics. The work will be mainly experimental. The candidate is expected to be strongly motivated to learn the associated techniques (nanofabrication in clean room, radiofrequency electronics, cryogenics...) and engage in a hands-on experimental work.
Starting date : March 2024 (flexible)

Contact :
Name: Julien Renard Institut Néel - CNRS
Phone: 0456387176 e-mail: julien.renard@neel.cnrs.fr http://perso.neel.cnrs.fr/julien.renard/

More information : http://neel.cnrs.fr

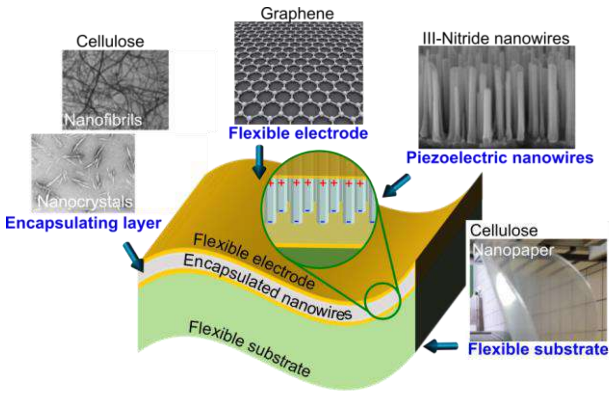
INSTITUT NÉEL Grenoble

Topic for Master 1 internship – Academic year 2023-2024

III-Nitride nanowire-nanocellulose composites for flexible piezo energy harvesters

General Scope:

As a promising route toward small-scale smart electronics/sensor networks, nanowire piezoelectric harvesters offer inherent flexibility and stretchability for integration with relevant soft surfaces in biomedical, wearable, and human interactive applications. Driven by environmental concerns, next-generation electronics should be bio-degradable/compatible and use fewer toxic elements. The challenging question is how this technology can be continuously developed, without affording the environmental degradation in terms of electronic waste and energy consumption, and without compromising its functionalities. Therefore, this project aims at synthesizing inorganic-organic flexible piezoelectric hybrid films as an alternative building block for future piezo harvesters.



Research topic and facilities available:

We will explore the combination of three nanomaterials: piezoelectric nitride nanowires, plant-based nanocelluloses, and graphene flake. Piezoelectric III-Nitride nanowires are used as an active element to harvest mechanical energy into usable electrical one. A typical way to fabricate nanowire devices is to embed the nanowires into insulating polymers to improve their stability and processability while preserving their mechanical compliance. The encapsulated nanowires are usually transferred on flexible plastic sheets which are easier integrated with various surfaces than rigid substrates. These plastic substrates cause ecological problems since they are based on non-renewable petrochemical products and cannot be decomposed through biodegradation as organic materials. Here, the eco-unfavourable passive components will be replaced by eco-friendly materials, that is, using plant-based cellulose nanopapers and graphene to substitute plastic substrates and metallic electrodes.

The student will involve with the fabrication process and characterization of inorganic-organic composite flexible films. He/she will intensively study the encapsulating and transferring process of the high-density III-Nitride nanowires on nanopapers, as well as transfer graphene sheets as flexible electrodes for nanowire piezo-harvesters. Together with the team, the student will contribute to the large-scale characterization of electrical and electromechanical properties to gain essential information associated with the device's key parameters such as output power, sensitivity, detection limit, linearity, response time, stability, etc. The fabrication process will be readjusted according to the effective output signal. The intern will join regular meetings with the staff involved in the project.

The experiments will be performed at Néel/Grenoble and strongly collaborate with CERMAV teams. The student will have an opportunity to access the facilities for nanofabrications (metal evaporation, chemical bench, lithography, etc.), as well as electrical, structural, and optical characterizations (scanning electron microscopy, atomic force microscopy, etc).

Possible collaboration and networking: Néel (NPSC, Hybrid, and Optima), CERMAV
Required skills: Nanofabrications, Semiconductors, Nanomaterials, Solid State Physics
Starting date: February/March 2024 (The starting date is flexible)

Contact:
Name: SONGMUANG Rudeesun
Institut Néel - CNRS
Phone : e-mail : Néel, rudeesun.songmuang@neel.cnrs.fr

More information: http://neel.cnrs.fr

MASTER 2

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2023-2024

Mesure nano-mécanique ultrasensible de champs de force

Le projet de recherche vise à développer et exploiter de nouvelles méthodes de mesure de champs de force bidimensionnels à l'aide de sondes nanomécaniques ultrasensibles, des nanofils suspendus de carbure de silicium, afin d'explorer les interactions fondamentales à l'échelle nanométrique.

La lecture optique des vibrations d'un nanofil suspendu, oscillant au-dessus d'un échantillon à mesurer permet de mesurer les champs de force latéraux qu'il subit via la perturbation induite sur ses propriétés de vibration. Ces sondes de force exceptionnelles permettent d'atteindre des sensibilités record de l'ordre de l'attonewton (en 1s) à température ambiante [2,5,7] et quelques 10 $zN/Hz^{0.5}$ à 20 mK [6]. Nous les utilisons actuellement dans des projets d'optomécanique quantique en cavité [7], pour la mesure des forces de proximité (électrostatique et Casimir) apparaissant au-dessus d'échantillons nano-structurés ainsi qu'en interaction forte avec des qubits de spin électronique [1,3,4].
Le projet de stage vise à mettre en œuvre les techniques de mesure développées dans le groupe dans une expérience réalisée dans un cryostat à dilution, entièrement développé au sein du laboratoire pour étudier des échantillons de la nano-électronique quantique. Le projet de thèse quant-à lui pourra aborder les différentes thématiques de recherche du groupe [8].

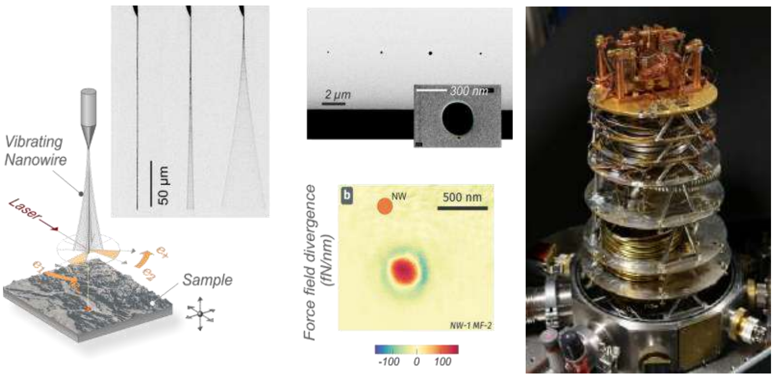


Figure. Image TEM de la sonde de force mécanique, un fil de carbure de silicium, attaché à une pointe de tungstène. La mesure de ses vibrations permet de remonter aux forces exercées sur son extrémité vibrante par un échantillon. Image MEB d'une membrane métallique percée de trous réalisés au FIB. La carte représente la divergence du champ de force mesuré en balayant le fil à la surface de l'échantillon lorsqu'on applique une tension sur ce dernier. Droite : photographie du cryostat à dilution et de l'expérience actuelle.

Interactions et collaborations: NEEL, labo. Kastler Brossel, LOMA, labo. Charles Coulomb

Ce stage pourra se poursuivre par une thèse

Formation / Compétences : Ce travail de thèse, largement expérimental mais requérant un intérêt pour la modélisation, permettra d'acquérir un savoir-faire en nano-optique, en nanosciences, en cryogénie et en manipulation de système quantiques.

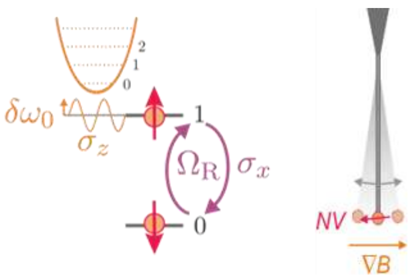
Contact : Arcizet Olivier- Benjamin Pigeau, Institut Néel - CNRS : 04 76 88 12 43
olivier.arcizet@neel.cnrs.fr benjamin.pigeau@neel.cnrs.fr Plus d'info. sur : http://neel.cnrs.fr

[1] O. Arcizet et al, Nature Physics 7, 879 (2011).
[2] A. Gloppe et al, Nature Nanotechnology (2014).
[3]S. Rohr et al., PRL 112, 010502 (2014)
[4] B. Pigeau et al, Nature Comm. (2015).
[5] L. Mercier de Lépinay et al., Nature Nano (2017).
[6] F. Fogliano et al, Nature Comm. (2021)
[7] F. Fogliano et al, Phys Rev X (2021)
[8]https://hal.archives-ouvertes.fr/tel-03763535/

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2023-2024

Systèmes Hybrides Spin qubit-Nanorésonateurs mécaniques



Le refroidissement et l'observation d'un oscillateur mécanique macroscopique dans son état quantique fondamental, réalisé en 2010-2011 dans plusieurs laboratoires, permet maintenant d'envisager la génération d'états mécaniques non-classiques. Pour ce faire une stratégie consiste à coupler ce résonateur mécanique ultrafroid à un autre système quantique, un qubit, dans le but de transférer sa nature quantique à l'oscillateur. Ce faisant on réalise un système hybride mécanique couplant les deux briques de bases de la mécanique quantique [1,2].

Le groupe de recherche Nano-optomécanique quantique hybride de l'Institut Néel [8] explore une voie dans laquelle des nanofils de carbure de silicium sont couplés au spin électronique d'un centre coloré du diamant, le centre NV (pour Nitrogen-Vacancy). Des premières expériences de principe [1, 4] ont été réalisées, elles ont permis d'explorer ce système hybride spin-oscillateur constitué d'un centre coloré NV hébergé dans un nanocrystal de 50 nm de diamètre déposé à l'extrémité vibrante d'un nanofil suspendu de SiC. En immergeant le système dans un très fort gradient de champ magnétique, par effet Zeeman, le spin du centre coloré devient couplé à la position de l'oscillateur. On a ainsi pu montrer que les vibrations de l'oscillateur étaient encodées sur le spin électronique [1,4] et estimer les constantes de couplage hybride.

L'objectif est maintenant d'étudier le couplage qubit-oscillateur en sens inverse, c'est-à-dire de **mesurer mécaniquement la force générée par un spin unique**. Ceci permettra de démontrer la possibilité d'encoder l'état du qubit de spin sur la position de l'oscillateur, reproduisant ainsi l'expérience de Stern et Gerlach avec des objets macroscopiques.

Pour ce faire on utilisera des protocoles avancés de manipulation du qubit de spin [3,4]. Une sensibilité en force extrême est requise car la force exercée par le spin sur l'oscillateur est seulement de l'ordre de ~20 aN pour un gradient de 1e6 T/m. De tels niveaux de sensibilité sont néanmoins largement accessibles comme on l'a démontré dans une succession de travaux utilisant les propriétés exceptionnelles des nanofils pour mesurer de très faibles forces, à température ambiante [2,5,7] et en dilution [6].

Interactions et collaborations: NEEL, ENS, labo. Kastler Brossel, Uni-Basel.

Ce stage pourra se poursuivre par une thèse

Formation / Compétences : Ce travail de thèse, largement expérimental mais requérant un intérêt pour la modélisation, permettra d'acquérir un savoir-faire en nano-optique, en nanosciences, en cryogénie et en manipulation de système quantiques.

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[7] F. Fogliano et al, Phys Rev X (2021)
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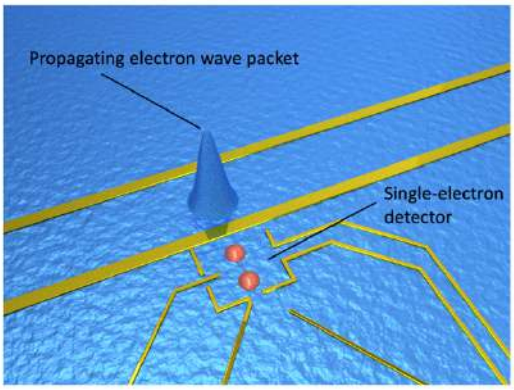
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Single-electron detector for flying electron qubits

General Scope: Coherent manipulation of single electrons in solid-state devices is attractive for quantum information purposes because they have a high potential for scalability. Depending on the system used, the charge or the spin may code binary qubit information. A particular appealing idea is to use a single flying electron itself as the conveyor of quantum information. Such electronic flying qubits allow performing quantum operations on qubits while they are being coherently transferred. Information processing typically takes place in the nodes of the quantum network on locally controlled qubits, but quantum networking would require flying qubits to exchange information from one location to another. It is therefore of prime interest to develop ways of transferring information from one node to the other. The availability of flying qubits would enable the possibility to develop new non-local architectures for quantum computing with possibly cheaper hardware overhead than e.g. surface codes.

Research topic: The remaining brick to be developed for the implementation of a fully-fledged flying electron qubit is a single-shot single-electron detector. The aim of the proposed M2 internship is to participate in the design and characterisation of such a detector based on a double quantum dot to detect a propagating electron wave packet (see Fig. 1). The idea is to use the extreme sensitivity of a quantum system to detect in flight an electron propagating in a ballistic conductor. This will be realized by capacitive coupling of the single flying electron to a spin/charge qubit based on previous experimental work in our group.



A single-electron wavepacket is propagating along an electron waveguide in the Femi sea. The charge detector based on a double-quantum-dot qubit detector is placed next to the trajectory and records the passage of the passing electron.

References:

- Edlbauer et al., EPI Quantum Technology 9:21 (2022);
  Thiney et al., Physical Review Research 4, 043116 (2022), Roussely et al. Nature Com. 9, 2811 (2018)

Possible collaboration and networking: This project is realized in close collaboration with the quantum transport and spin qubit group at Osaka University.

Possible extension as a PhD: yes; PhD funding available

Required skills:
The candidate should have a good background in quantum mechanics and solid-state physics. We are looking for a motivated candidate who is interested in continuing this research project towards a PhD degree.

Starting date: spring 2024

Contact:

BAUERLE Christopher
Institut Néel – CNRS, Grenoble
e-mail: christopher.bauerle@neel.cnrs.fr

More information : http://neel.cnrs.fr

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2023-2024

Thermal properties and heat transport on suspended 1D and 2D systems

General context :
Thermal transport physics is a major challenge with important fundamental and technological implications for thermal management of electronic nano-components or the conception of new thermoelectric devices. In this context, graphene and other 2D materials exhibit outstanding thermal properties, however they are not yet fully understood. Different experimental techniques have been used such as electronic transport, optical and Raman spectroscopy. Since the contribution of electrons to the thermal conductivity (**κ)** in atomically thin materials has been estimated to be lower than the phonons counterpart, Raman spectroscopy has been widely used as a non-contact thermal probe at the micrometer scale to access the thermal conductivity of graphene (1,2,3). All these works report an extremely high thermal conductivity but a large dispersion of values ranging from 500 to 3000 W/m/K. One important point is that all these experimental values of **κ** are obtained from a setup in which the same laser is used to heat the membrane and to measure its temperature.
Recently, a more insightful approach was developed by Reparaz *et al.* (4) and at NEEL for graphene. This new approach uses two distinct lasers, one as a heater and the second as a non-invasive thermal probe, measuring temperature profiles outside the heated region. The first measurements of suspended graphene membranes using this method has been achieved at NEEL and demonstrated its efficiency to access spatial mapping of temperature within graphene (4). Moreover, temperature profiles show very interesting anomalies which cannot be explained by a simple Fourier model and drive us to develop with our collaborators a multi-linear non-local Fourier model.

Description of the project and facilities:

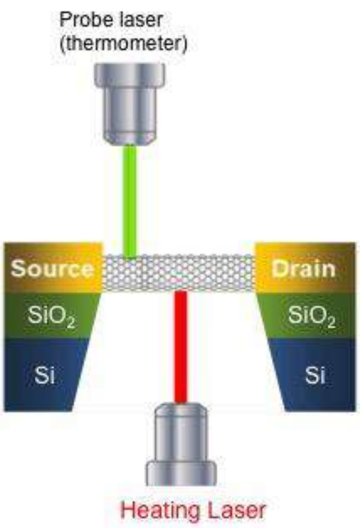


Figure 1: Schematic of the two-laser experiment.

The Master 2 internship aims to find out more about how defects, substrate interactions and environment can change thermal properties. As a start, the simplest circular geometry will be used at room temperature. A two-laser setup will be used to heat the system and measure the optical phonons (see figure). Raman imaging will provide information about spatial distribution of hot phonons and will allow inferring issues on electron-phonon coupling, strain and heating in the system (3,4).
The student will be in charge of the full spectroscopic characterization of the devices. She/He will fabricate the samples and develop the next generation of substrates with electrical wiring. The simultaneous use of Raman spectroscopy and electron transport at this single nano-object level is almost unique and promising compared to conventional methods used separately until now. The setup in ambient conditions is fully operational.

References :

1) A.A. Balandin, S. Ghosh, W. Bao, I. Calizo, D. Tewelde-brhan, F. Miao, and C.N. Lau, Nano Lett. 8, 902-907 (2008).
2) W. Cai, A.L. Moore, Y. Zhu, X. Li, S. Chen, L. Shi, and R.S. Ruoff , Nano Lett. 10, 1645-1651 (2010).
3) C. Faugeras, B. Faugeras, M. Orlita, M. Potemski, R.R. Nair, and A.K. Geim, ACS Nano 4, 1889-1892 (2010).
4) J.S. Reparaz, E. Chavez-Angel, M.R. Wagner, B. Graczykowski, J. Gomis-Bresco, F. Alzina, and C.M. Sotomayor Torres, Rev. Sci. Instr. 85, 034901 (2014).)
5) P. Singh, S. Sarkar, D. Jegouso, L. Del Rey, A. Claudel, B. Fernandez, P. Bouvier, L. Marty, J. Chaste, M. Lazzeri and N. Bendiab, Submitted to PRB.

Interactions and collaborations :
The student will join the Quan2m team gathering experts in materials science, optical spectroscopy, condensed matter physics, mesoscopic transport. Close collaborations outside the lab involve J. Chaste

from C2N for nanofabrication and optical measurements, Michele Lazzeri from IMPMC for Ab initio calculations and Konstantinos Termentzidis from INSA Lyon for Monte Carlo computing.

Required skills :
A master 2 in Condensed Matter Physics or Nanosciences is required along with motivation for experimental work.

Start date : February/March 2024
Contact : Nedjma Bendiab, Laëtitia Marty
Institut Néel - CNRS : nedjma.bendiab@neel.cnrs.fr / laetitia.marty@neel.cnrs.fr
More information on : https://neel.cnrs.fr/equipes-poles-et-services/quan2m

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Spin-photon interface for individual magnetic atoms in semiconductors

General Scope:
Individual spins in semiconductors hold great promise for the development of quantum information technologies. Thanks to their long-expected coherence times, localized spins on individual defects are a medium of choice for quantum information storage, and the semiconductor platform offers interesting integration prospects. For long-range coupling of localized spins acting as quantum nodes, a spin-photon interface is required. These interfaces are generally based on specific optical selection rules. For non-optically active magnetic impurities, an optical interface can be realized through their exchange interaction with semiconductor carriers. This has been demonstrated for transition metal elements (Mn, Cr, Co, Fe, ...) inserted in a semiconductor quantum dot (QD). These magnetic elements offer a wide choice of localized electron spins, nuclear spins and orbital moments.

Research topic and facilities available:
We aim to exploit the optical properties of a QD to probe and control the coherent dynamics of the coupled electronic and nuclear spins of an embedded magnetic atom. We will combine radio frequency (RF) excitation and resonant fluorescence for the coherent control and probing of an individual spin. The internship will focus on developing a resonant fluorescence experiment for the detection of the magnetic resonance of the coupled electronic and nuclear spin of a Mn atom in a strain free QD. We will also start to model the spin-induced fluctuations of optical signals from a resonantly driven magnetic QD in a micro-pillar cavity, a necessary step for the dimensioning of future spin-photonic devices under development. We will analyze the quantum dynamics under continuous resonant optical readout to show how the quantum Zeno effect can contribute to increasing the storage time of the quantum information in such a system. In collaboration with our partners, we will also investigate magnetic ions with a large spin to strain coupling (Cr^{2+}, Co^{2+}) that could be coherently controlled with the strain field of surface acoustic waves. We will work on modeling the influence of local strain distribution on the magneto-optic spectra of the dots to estimate their spin to strain coupling.
Experiments will be carried out on a micro-spectroscopy facility equipped with a magneto-optical cryostat (1.5 K, 9T/2T magnet, optical and RF access), tunable single mode and pulsed (ps) lasers for resonant optical excitation and high-resolution spectrograph for the detection.

References: L. Besombes *et al.,* Phys. Rev. B 107, 235305 (2023); V. Tiwari *et al.*, Phys. Rev. B 106, 045308 (2022); V. Tiwari *et al.*, Phys. Rev. B Letter 104, L041301 (2021).

Possible collaboration and networking:
This work will be realized in the NanoPhysique et Semi-Conducteurs group (NPSC, CNRS/Institut Néel & CEA/IRIG) in collaboration with the University of Tsukuba and the University of Warsaw for the growth of some of the samples.

Possible extension as a PhD: Yes
Required skills: Master 2 (or equivalent) with good knowledge in solid state physics (electrical, optical, magnetic properties), quantum mechanics, optics, light matter interaction.
Starting date: March 2024 (flexible)
Contact: L. Besombes, Institut Néel, tel: 0456387158, email : lucien.besombes@neel.cnrs.fr
More information: http://neel.cnrs.fr

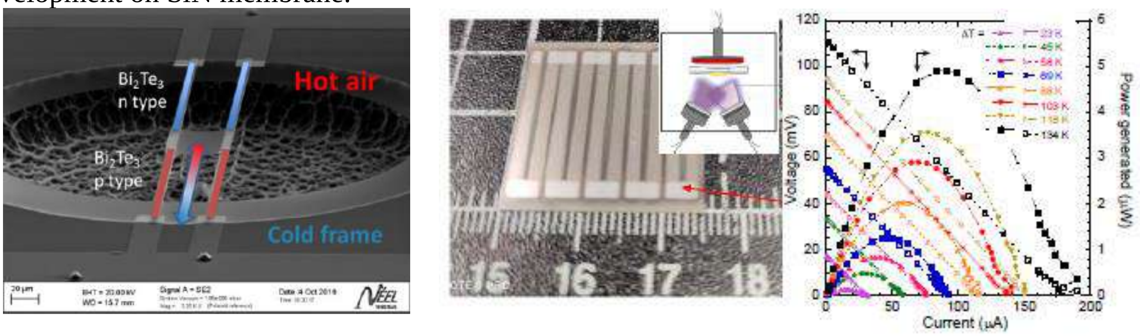
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Suspended Fe_2VAl thermoelectric micro-generators

General Scope :

With the rise of IoT, wireless sensors capturing small energy (100 µW to 1 mW) for autonomy have have seized the interest of both scientific community and industrial sector. Thermal energy, though modest, offers near-ubiquitous availability. In this context, several teams developed planar thermoelectric generators with suspended membranes, enhancing sensitivity to temperature fluctuations. Thermoelectric microgeneration on suspended SiN membrane was validated by TPS (Thermodynamique et Biophysique des Petits Systèmes) team at Neel Institut using Bi_2Te_3 thin films (Figure 1a). Recently, high power factors were achieved with Heusler-type Fe_2VAl (Figure 1b), more abundant, unexpensive, and less toxic than Bi_2Te_3, and these results make it possible to envisage development on SiN membrane.



a) b)

Figure 1 : a) SEM image of an individual micro-thermogenerator developed usinfg Bi_2Te_3 thermoelectric thin films. b) Microwatt power output obtained in thermoelectric microgenerators based on cost-effective and non-toxic Fe-V-Al thin films deposited by a DC magnetron co-sputtering process.

Research topic and facilities available :

The aim of this internship is to deposit and characterize Heusler Fe-V-Al thermoelectric thin films on SiN suspended membrane for electrical microgeneration applications. Thin films will be developed by magnetron sputtering and annealed under various conditions. Carrier concentration and mobility measurements will be carried out on the thin films obtained. These experiments, coupled with thermoelectric properties (Seebeck S effect, electrical resistivity ρ, and thermal conductivity λ for the best samples), will enable us to optimize the figure of merit $ZT=S^2T/\rho\lambda$, which is characteristic of thermoelectric efficiency. The compositions, phases and microstructures of thin films will be analyzed by X-ray diffraction, SEM-FEG and EDX. Part of the internship will also be dedicated to measuring contact resistances between metal and n-type and p-type thermoelectric materials using the CTML (Circular Transmission Line Method).

Possible collaboration and networking :

Strong interaction with the start-up MOÏZ in the frame of an ANR project.

Possible extension as a PhD : Yes. Thesis funding to continue this work has been secured.

Required skills:

The candidate should have a basic knowledge of solid state physics and a strong interest in experimentation. Knowledge of thin-film deposition will be particularly appreciated, but not necessarily required.

Starting date: February-March 2024

Contact:

Daniel Bourgault et Dimitri Tainoff (MOÏZ)
Institut Néel - CNRS
Phone: 0 4 76 88 90 31e-mail : daniel.bourgault@neel.cnrs.fr /dimitri.tainoff@moiz-eh.com

More information: http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Quantum memory integration of rare-earth doped crystals

General Scope :

Rare-earth ions are now well-identified systems for the development of **quantum technologies**. Because of their unique 4f electronic configuration, they form well isolated systems when embedded in crystalline matrices. They have a long coherence time at low temperatures, making them highly promising **solid-state qubits**. As solids, they offer perspectives of **integration** while keeping atomic properties (narrow lines) when interacting with light (optical or RF). **Erbium** is particularly appealing in this prospect because its optical transition falls in the telecom range and can naturally be used as a support for optical **quantum memories** and more generally as a fast and versatile element of control on the qubit.

Research topic and facilities available:

The main objective is to integrate erbium-doped materials into a photonic platform and perform a demonstration of quantum storage using this device. Most of the realizations have so far involved bulk crystals, namely oxide compounds containing yttrium. As compared to glass, silicon, or lithium niobate, rare-earth activated samples are not commercially available as a photonic platform. Based on a recognized national consortium (see below), we first propose to fabricate elementary wafers supporting rare-earth doped crystals. After a secondary integration/fabrication step to produce a waveguide, we will benefit from the light confinement to enhance the interaction. We therefore propose to perform a quantum memory demonstration using this unique device.
The internship will focus on the first steps of the project, combining fabrication processes (polishing and surface adhesion), mechanical characterization of the samples at cryogenic temperatures, and elementary spectroscopy of the ions embedded in the structure to evaluate the local strain. To follow-up, a PhD funding is available for a motivated candidate.

Possible collaboration and networking :

- Institut de Microélectronique Electromagnétisme et Photonique et le LAboratoire d'Hyperfréquences et de Caractérisation (IMEP-LAHC)
- Institut de Physique de Nice
- Institut de Recherche de Chimie Paris
- Laboratoire Kastler Brossel

Possible extension as a PhD : Yes – Grant already available

Required skills:

Experimental skills in one the domains are highly recommended : optics, laser, atomic spectroscopy.
General interest in the optimization of fabrication processes would be appreciated.
Education background in quantum physics and general optics, non-linear optics or light-matter interaction is demanded.

Starting date : First semester 2024

Contact :

Name : Thierry Chanelière
Institut Néel - CNRS
Phone : 04 76 88 10 07 e-mail : thierry.chaneliere@neel.cnrs.fr
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

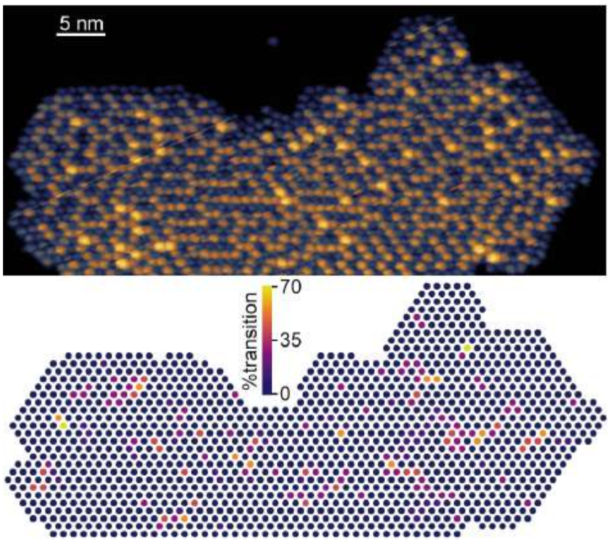
Master 2 research internship – Academic year 2023-2024

Spatiotemporal dynamics of 2D frustrated lattices

General Scope: Since 1935 and Pauling's seminal work on the 0 K residual entropy in solid water (at odds with Planck's formulation of the 3rd law of thermodynamics!), condensed matter physicists have continuously explored frustration phenomena appearing when a crystal lattice hosts a structural or magnetic correlated disorder. Such correlated disorder, distinct from trivial random disorder, can be found in a wide range of systems, either found in nature or made artificially. In our group, we address the physics of various systems at different lengthscales and with different kinds of degree of freedom (μm-scale pseudo-spins, structural configuration of *nm*-scale molecules or of *mm*-scale magnets), all arranged within two-dimensional (2D) lattices. Our approach is to directly resolve the configuration at each lattice site, using *ad hoc* imaging techniques, and thereby to understand the correlated disorder phenomena at play. Using statistical physics tools it is even possible to derive thermodynamic quantities from real space 2D images and to figure out whether model spin Hamiltonians are relevant to account for the observed physics. In the past years we accordingly managed to observe a long-sought-for spin liquid phase, explored the role of extended topological defects, and investigated intriguing coexistences of liquid/solid phases.

A few relevant articles from our group: https://arxiv.org/abs/2302.01652 (under review); Phys. Rev. Lett. 129, 027202 (2022); Nature 540, 410 (2016).

Research topic and facilities available: The focus of the internship is to go beyond the usual static 2D imaging of correlated disorder in frustrated systems, and to analyse, on top of the x,y dimensions, the *time* dimension. The goal is to understand the dynamics of defects, to figure out how disorder evolves, possibly in a spatially and temporally correlated way between different sites of the lattices. This is crucial to understand the creation/ annihilation of defects, cascade events involving numerous lattice sites, and to which extent these bring the system closer to thermodynamic equilibrium. How the lattices will respond to local excitations will be also studied. The methods that will be used include dynamical imaging by optical microscopy (for lattices of *mm*-sized magnets) or scanning tunneling microscopies (for lattices of fullerene molecules, see top image) and image post-processing (see bottom image of the probability of change of molecular state). To interpret the data, numerical Monte Carlo simulations will be used.



Possible collaboration and networking: Work will be done in collaboration between the intern and three senior researchers and two engineers; international collaborations are also foreseen.

Funding for a PhD thesis in the continuity of the internship is secured.

Required skills: Strong background in solid state physics and statistical physics.

Starting date: Spring 2024.

Contact: Dr. Johann Coraux (johann.coraux@neel.cnrs.fr) & Nicolas Rougemaille (nicolas.rougemaille@neel.cnrs.fr)

More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

2D superconductivity in cuprate oxychlorides

General Scope: Cuprates oxychlorides are unique among the high temperature superconducting cuprates (HTSCs) since it: lacks high Z atoms; has a simple I4/mmm 1-layer structure, typical of 214 (LSCO) cuprates, but which is stable at all doping and temperatures; and has a strong 2D character due to the replacement of apical oxygen with chlorine. All these characteristics made them particularly well adapted to calculation including correlation effects, a subject that we are actively investigating (1). Recently we obtained puzzling results on their superconducting properties that are highly anisotropic. This could be the result of an intrinsic bi-dimensional electronic structure, that would made them the equivalent, for superconductors, of graphite for the 2D graphene layers. This would also be highly unusual and will allow to study 2D phenomenology in a bulk sample, instead of a single CuO_2 layer, a fascinating possibility. By the way, an anomalous *in-plane* superconducting penetration depth $\lambda_{ab}(0)$ was already reported (2), but so far not compared to the values in the perpendicular *c* direction, a question we need to explore for a complete understanding of the problem.

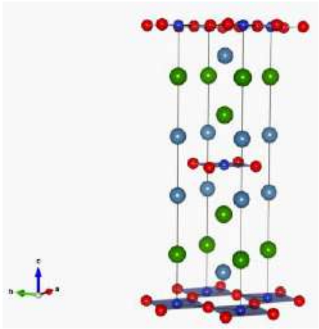


Figure 1: Unit cell of $Ca_2CuO_2Cl_2$ (Cu blue, O red, Cl green, Ca cyan), with the square unit of the CuO_2 plane visible, where the superconductivity take place.

(1) B. W. Lebert, *et al., Phys. Rev. B* **108**, 024506 (2023) ; L. Chaix, *et al., Phys. Rev. Research* **4**, 033004 (2022)

(2) R. Khasanov *et al., Phys. Rev. B* **76**, 094505 (2007).

Research topic and facilities available: The above-mentioned results are very recent, and many points needs to be clarified, namely: do this superconducting anisotropy arise only in a limited part of the phase diagram? How these superconducting anisotropies relate with the normal state resistivity one? During the internship we will start to address part of these questions, using magnetization and penetration depth measurements, using in house Tunnel Diode Oscillator (TDO) system, as a function of the crystallographic direction. Preparation of these experiments will require special care, as the materials are sensitive to air, with a special glove box at the Néel institute, as well as instrument for crystalline properties (x-ray diffraction) and superconducting measurements (magnetometry, TDO).

Possible collaboration and networking : Sample synthesis will be made in collaboration with the group of Prof. Hajime Yamamoto (Tohoku Univ., Sendai, Japan).

Possible extension as a PhD : Yes, this project is part of a PhD program, of which this Master Internship could be a first approach, and during the possible PhD we will extend our investigation to transport properties, measuring resistivity and point-contact-spectroscopy.

Required skills: A good background in electronic properties of material, with the will to have a global approach, from material synthesis and characterization to advanced spectroscopic properties. Team work will be an essential part of the project success.

Starting date : from winter 2024

Contact :
Name : Matteo d'Astuto, Pierre Rodière
Institut Néel - CNRS
Phone : (+33)(0)4 76 88 12 84
e-mail : matteo.dastuto@neel.cnrs.fr

More information : http://neel.cnrs.fr

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2022-2023

Combinatorial studies of hard magnetic materials

General Scope:
The demand for high performance magnets is continuously growing, in particular for the green energy transition (windmills, (hybrid)-electric-vehicles, electric bicycles) but also for robotics. The present reliance on critical rare earth (RE) elements in such magnets is not sustainable. The high throughput thin film combinatorial approach (Fig. 1) holds much potential to explore the use of substitutional elements, so as to reduce dependence on critical RE elements [1]. The experimental data sets generated in such studies can serve as input in the emerging field of machine-learning-led magnet development.

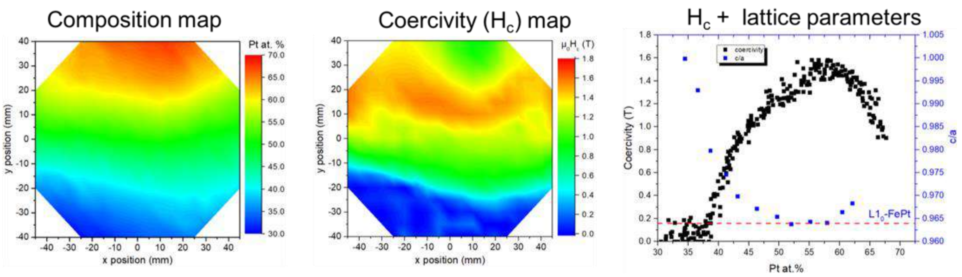


Figure 1: Composition and coercivity maps of compositionally graded Fe-Pt films, dependence of coercivity and lattice parameters on composition

[1] Y. Hong et al., J. Mater. Res. Technol. 18 (2022) 1245 doi.org/10.1016/j.jmrt.2022.03.055.

Research topic and facilities available:
This internship concerns the high throughput fabrication and characterization of thin film libraries of hard magnetic materials. Compositionally graded RE-TM based films will be fabricated by sputtering. The influence of composition and post-deposition annealing conditions (temperature and time) on both structural and magnetic properties will be explored using high throughput scanning characterization techniques. Composition will be characterized by Energy Dispersive X-Ray analysis in a scanning electron microscope, crystal structure by X-Ray Diffraction and magnetic properties will be probed using an in-house developed scanning polar Magneto-Optic Kerr effect system. More detailed structural (SEM imaging of microstructure) and magnetic (M(H,T)) characterization will be carried out on select samples. Experimental data sets will be analyzed to search for trends in the evolution of both intrinsic and extrinsic properties.

Possible collaboration and networking: This internship will be carried out in the framework of a collaboration with the group of Prof. Thomas Schrefl at the Christian Doppler Laboratory for magnet design by machine learning (Danube Unviersity Krems, Austria).

Possible extension as a PhD: Yes

Required skills: Materials science / condensed matter physics, experience with coding (python) for data analysis would be very useful

Expected start of internship: February 2023

Contact : Dempsey, Nora
Institut Néel - CNRS : mail : nora.dempsey@neel.cnrs.fr
More information at : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Electron beam induced current study of p-n junction electrical properties

General scope:

The electrical properties of semiconducting materials can be engineered by adding dopant atoms to the lattice, that donate or accept an electron from conduction or band valence, respectively. In this way the density of mobile charges can be tuned over several orders of magnitude. It is very well known that a transition from one type of dopant to the other kind will generate a so-called p-n junction, giving rise to rectifying current voltage characteristics and potentially light emission, for example in light emitting diodes. However, challenges remain to control and measure the electrically active doping levels in semiconducting materials with nm precision, especially in wide bandgap materials with high dopant activation energies. At nm scale the build in electric field at the pn junction gives rise to an electron beam induced current, allowing to study the junction properties.

Research topic and available facilities:

The aim of this internship is to contribute to the study of p-n junction semiconducting materials regarding their electrical properties, in particular studied at nm length scales. The student will integrate a multi-institute, multi-disciplinary research group.

His/her role will be to fabricate electrical contacts to p-n junction nanowires of GaN or AlN, potentially first thinned down by FIB. The p-n junctions will be electrically contacted on membrane chips compatible with transmission electron microscopy (TEM) measurements, and the student will be in charge of their preliminary electrical characterization by current-voltage measurements. The junction will then be studied by electron beam induced current (EBIC) both in scanning electron microscopy (SEM) as well as TEM. The aim is to compare SEM and TEM to carry out EBIC experiments and compare junction qualities between them, to improve our understanding of doping, which will aid device fabrication, for instance for NW solar cells or light emitting diodes.

The student's work will involve:

- Nanowire contacting in a cleanroom environment. It implies training in nanowire dispersion, mapping using scanning electron microscopy, making drawings of the contact lines, assisting electron beam lithography and finally preforming lift-off.
- Current-voltage measurements.
- The electron beam lithography step for nanowire contacting and microscopy experiments will be performed by the supervisor, but the student will participate in the experiments.
- The student will be involved in the data analysis of EBIC results.

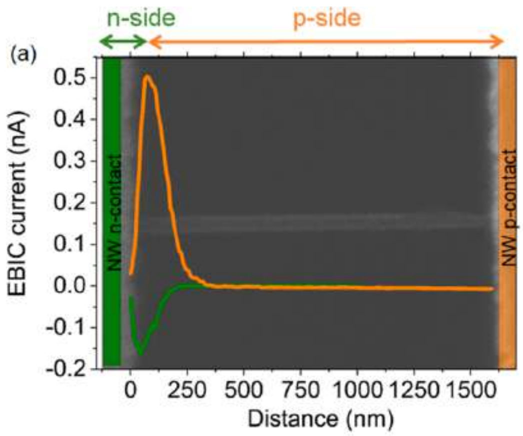


Figure 1a) EBIC scan along a single GaN NW overlaid on an SEM. The orange and green EBIC line scans correspond to the current collection from the n-side and the p-side of the NW, respectively.

Possible collaboration and networking: The internship will be in collaboration with Gwenolé Jacopin (NEEL, SC2G).

Possible extension as a PhD: Not granted in advance, but we support applications for a PhD grant.

Required skills: Interest in solid-state physics, electrical and optical properties of semiconductors and advanced characterization techniques like transmission electron microscopy.

Starting date: Jan/Feb 2023 or earlier.

Contact: den Hertog Martien & Gwenolé Jacopin

Institut Néel - CNRS : tel: 0476881045 mail: martien.den-hertog@neel.cnrs.fr & gwenole.jacopin@neel.cnrs.fr

More information at: http://neel.cnrs.fr

INSTITUT NÉEL Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Magnetic manipulation of nanoparticles in a microfluidic chip

General Scope :

Magnetic nanoparticles are commonly used in biomedical applications such as magnetic resonance imaging (MRI), magnetic particle imaging (MPI), drug delivery, diagnosis, but also to manipulate biological entities such as cells, proteins, DNA … The displacement of magnetic nanoparticles under an external magnetic field, also called magnetophoresis, requires magnetic field gradients, which should be especially high as the size of the particles decreases. To manipulate particles in the 10-nm range, the required magnetic field gradients can only be produced by micromagnets that have a very short range of action. Therefore, controlling magnetically the motion of magnetic nanoparticle requires the development and integration of micrometric magnets inside microfluidic channels where the magnetic landscape can be designed precisely. Furthermore, such devices can be advantageously used to selectively act on magnetic nanoparticles in order to separate them and refine their distribution.

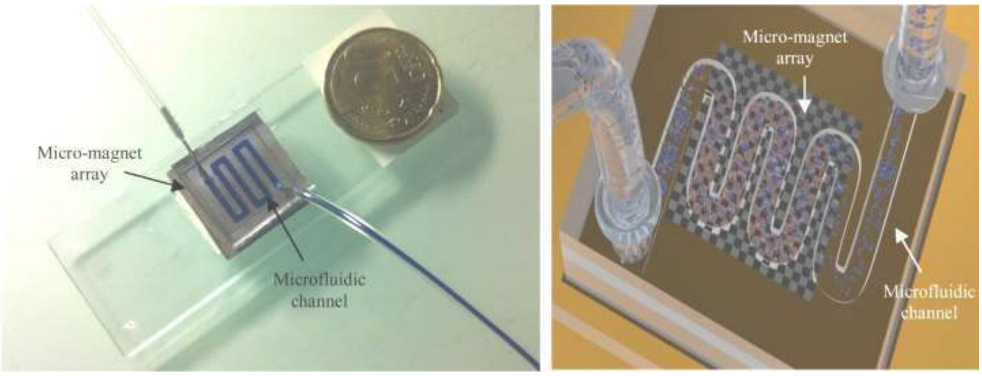


Figure 1: examples of a microfluidic chips with embedded micromagnets: (left) photograph, (right) a schematic of magnetic cell sorting (Pivetal et al, Sensors and Actuators B- Chemical, 2014 , https://doi.org/10.1016/j.snb.2014.01.004)

Research topic and facilities available :

This internship aims at exploiting magnetic forces at the microscale for purification and separation of magnetic nanoparticles. Micromagnets will be designed and produced with methods established in Institut Néel (topographic patterning, thick film deposition, thermomagnetic patterning and regular lithography processes). Magnetically hard materials (permanent magnets), soft magnets (that can be remotely turned "on" and "off") in combination with a variable external magnetic field will be used to induce trapping, release, trajectory deflection and ultimately separation of magnetic nanoparticles according to their magnetic moment, susceptibility and volume. Micromagnets will be integrated into polymer-based microfluidics systems to manipulate the trajectories of magnetic particles in microfluidic channels. This new degree of control combined with established tools such as chromatography or electrophoresis will allow for the development of a new generation of systems for analytical chemistry.

Possible collaboration and networking : The internship and the following PhD are part of a funded project in collaboration with Institut Galien (Paris-Saclay) and Phenix Lab (Sorbonne University, Paris)

Possible extension as a PhD : Yes

Required skills: Background in material sciences, physics, or soft matter is required with a taste for experimental physics

Expected start of internship: Early 2024

Contact : Thibaut Devillers, Institut Néel - CNRS
e-mail :thibaut.devillers@neel.cnrs.fr
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Electrical characterization of diamond diodes for application in power electronic or high frequency

General Scope :
Diamond is a semiconductor material with exceptional properties, like its high carrier mobility, excellent thermal conductivity and high breakdown voltage, which make it an ideal candidate for power electronic devices. Institut Neel is world leader in the fabrication of high-power diamond Schottky diodes and is continuously exploring ways for further improvements.

Research topic and facilities available :
The Schottky potential barrier, formed at the junction between a metal and a semiconductor, is highly advantageous for rapid switching and maintaining a low voltage drop in the forward bias region. In the construction of Schottky diodes using diamond as the semiconductor material, our approach involves depositing a metal electrode onto a surface of oxygen-terminated or OH-terminated p-type (boron-doped) semiconducting diamond epilayer. This epilayer is situated atop a metallic ("p++") diamond epilayer, serving as the back contact, resulting in the creation of a vertical structure. Our primary research focus has been on optimizing metal-diamond interfaces to achieve rectifying behavior. We have demonstrated that zirconium (Zr) [1], a metal susceptible to oxidation, is an exceptional candidate for efficiently forming Schottky barriers. Unfortunately, the current leakage in the reverse bias region remains unacceptably high for power applications. Additionally, the restricted size of the contact presents challenges in achieving high forward bias current [2].
To address these challenges, our team at the Neel Institute, specializing in wide bandgap semiconductors, has recently explored an innovative growth approach. This approach involves growing thin diamond layers doped with a nitrogen layer (n-type) prior to Schottky metal deposition. The underlying concept is to induce a reverse band bending effect distinct from that of the p-type layer, which should enhance the barrier for holes. Simultaneously, efforts have been directed towards optimizing diamond growth to increase the dimensions of the diamond substrate and enhance the diode's current-carrying capacity.

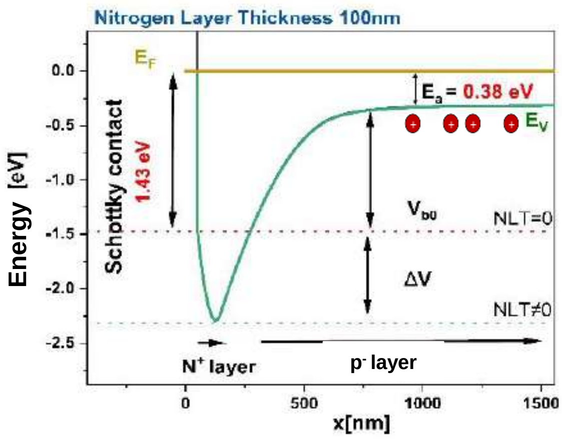


Figure 1 : Numerical modelling of Schottky contact on p-type diamond layer with a thin intermediate nitrogen layer

The assigned student will be responsible for characterizing various diamond components that have already been grown using a range of electrical techniques, including current-voltage and capacitance-voltage-frequency measurements. Additionally, the influence of temperature, a critical parameter for the power application of diamond diodes, will be examined [3]. Depending on the timeframe, the student may also participate in the diamond growth process to expand the surface area available for experimentation and application.

1. Traoré, A. *et al.* Zr/oxidized diamond interface for high power Schottky diodes. *Appl. Phys. Lett.* **104**, (2014).
2. Eon, D. & Cañas, J. General optimization of breakdown voltage and resistivity on power components in terms of doping level and thickness. *Diam. Relat. Mater.* **136**, 110032 (2023).
3. EON, D. Self-heating in a diamond Schottky diode influenced by U-shaped resistivity. *Diam. Relat. Mater.* **130**, 109414 (2022).

Possible collaboration and networking :
The student will interact with engineers of Diamfab a startup hosted by the laboratory.

Possible extension as a PhD :
According to the classification of the candidate a continuation of the project in thesis is possible

Required skills:
Any master in physics or electronic engineering with minimum knowledge in semiconductor physics.

Starting date : February 2024

Contact :
EON David
Institut Néel - CNRS : 0456 38 1079 david.eon@neel.cnrs.fr
Plus d'informations sur : http://neel.cnrs.fr

More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

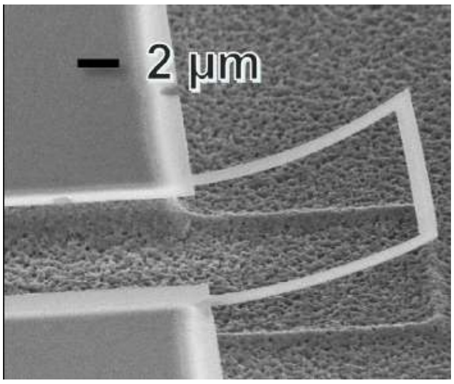
Topic for Master 2 internship – Academic year 2023-2024

Dependence of dissipation of nanomechanical resonators on superconducting state

General Scope:
Nanomechanical resonators are sensitive mass and force detectors. They can also be used to probe the conflict between quantum mechanics and general relativity and to detect individual atomic scale tunneling systems. The mechanical dissipation determines the sensitivity of the nanomechanical resonator. However, the dependence of the dissipation on the superconducting state of metal in nanomechanical resonators is not well understood: different studies of similar nanomechanical resonators report strikingly different findings [1,2]. The region of the nanomechanical resonator in which dissipation is concentrated and the dependence on resonator material is therefore unknown.

[1] Lulla *et al*., "Evidence for the Role of Normal-State Electrons in Nanoelectromechanical Damping Mechanisms at Very Low Temperatures", *Physical Review Letters* **110**, 177206 (2013).
[2] Kamppinen *et al*., "Dimensional control of tunneling two-level systems in nanoelectromechanical resonators", *Physical Review B* **105**, 035409 (2022).

Research topic and facilities available :
We will study the dependence of nanomechanical resonator dissipation on composition, geometry and superconducting state in order to test potential explanations for the contrasting observations referenced above. The work will be carried out in the Ultra-Low Temperatures group of the Institut Néel. Preliminary measurements will be carried out on a liquid-helium based 1 kelvin cryostat. Tests of the dependence of damping on superconducting state will be made with a cryogen-free dilution refrigerator reaching temperatures below 10 mK. The devices are fabricated in the local Nanofab facility.



Possible extension as a PhD: Yes

Required skills: A strong interest in physics and making challenging measurements at low temperatures.
Starting date: Negotiable

Contact:
Name: Andrew Fefferman
Institut Néel - CNRS
Phone: 04.76.88.90.92 e-mail: andrew.fefferman@neel.cnrs.fr

More information: https://neel.cnrs.fr/equipes-poles-et-services/ultra-basses-temperatures-ubt

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Ultra-Coherent Nanomechanical Resonators

General Scope : The unparalleled sensitivity of quantum sensors promises a plethora of important applications. In particular, resonators with mechanical coherence times of order 10 to 100 milliseconds at 10 mK have recently been demonstrated. These devices could be used as quantum memories in hybrid systems for quantum communication and computation. They could also be used for testing fundamental aspects of quantum mechanics. At the same time, nuclear demagnetization refrigeration (NDR), yielding microkelvin cryostat temperatures, has been applied to microwave optomechanics, yielding passive ground state cooling of ~10 MHz mechanical modes. However, researchers in these two fields have not yet combined NDR with functionalized ultra-high Q mechanical resonators with mechanical coherence times exceeding 10 ms. Since the mechanical damping rate Γ_m of these devices increases with temperature even at 10 mK, present experiments appear to lack the full potential mechanical coherence time $1/(\Gamma_m \bar{n}_{\text{th}})$ for thermal phonon occupation $\bar{n}_{\text{th}}$ that can be achieved by cooling to lower bath temperatures.

Further reading: D. Cattiaux *et al*. Nature Communications, **12**, 6182 (2021) https://doi.org/10.1038/s41467-021-26457-8; A. Youssefi *et al*. *Nature Physics* (2023) https://doi.org/10.1038/s41567-023-02135-y

Research topic and facilities available : We will use state-of-the-art optomechanical devices fabricated by the Kippenberg group (https://www.epfl.ch/labs/k-lab/) for the project. The devices are known to have exceptionally low mechanical dissipation near 10 mK. Using the microkelvin microwave optomechanics cryostats of the Néel Ultra-Low Temperatures group, which are unique in the world, we will cool the devices to temperatures below 1 mK in order to achieve a record mechanical quantum coherence time of 1 second. We will then apply this extreme coherence to quantum memory protocols and experiments probing the implications of general relativity in quantum mechanics.

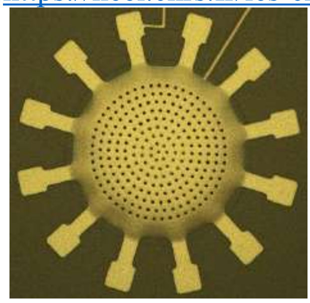
Possible collaboration and networking : As mentioned above, the project relies on a collaboration with the Kippenberg group at EPFL, Switzerland.

Possible extension as a PhD : Yes

Required skills: Enthusiasm for carrying out challenging experiments at ultra-low temperatures and a strong background in quantum mechanics.

Starting date : Negotiable

Contact :
Name : Andrew Fefferman
Institut Néel - CNRS
Phone : 04.76.88.90.92 e-mail : andrew.fefferman@neel.cnrs.fr
https://neel.cnrs.fr/les-chercheurs-et-techniciens/andrew-fefferman-overview



Left: A nanomechanical "drum" fabricated at EPFL. Right: an ultra-low resistance superconducting heat switch for nuclear demagnetization refrigeration fabricated at Institut Néel/CNRS

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2023-2024

Fabrication de composants de puissance en oxyde de gallium

Cadre général :

La transition écologique dans laquelle s'engage de plus en plus de pays conduit l'industrie microélectronique à s'orienter vers la durabilité. Basée sur cette tendance, la nouvelle génération de composants de puissance intègre désormais des matériaux semi-conducteurs à large bande interdite, tel que l'oxyde de gallium. Ils permettent de fabriquer des composants qui supportent des tensions élevées avec de faibles pertes d'énergie en fonctionnement et par échauffement. Le stage s'inscrit dans ce contexte et celui du projet ALOFET (2024-2028) financé par l'Agence Nationale de la Recherche. Ce projet vise à développer une nouvelle architecture de transistors à haute mobilité d'électrons à base d'oxyde de gallium, capable de supporter des tensions supérieures au kilovolt. Ces transistors ont pour vocation d'intégrer des convertisseurs de tension, des onduleurs, des hacheurs, … qui seront ensuite insérés dans des véhicules électriques, des installations de panneaux solaires, des parcs d'éoliennes, etc... Les composants de puissance en oxyde de gallium ont le potentiel pour répondre aux applications couvertes par les technologies SiC et GaN, tout en donnant accès à de nouveaux champs applicatifs.

Sujet exact, moyens disponibles :

L'objectif du stage est de fabriquer des condensateurs et des diodes en oxyde de gallium. Ces composants constitueront les premières briques technologiques qui conduiront ensuite à la réalisation plus aboutie d'un transistor. Pour effectuer ce travail, la ou le stagiaire aura à sa disposition les outils de la salle blanche NanoFab (banc de chimie, lithographie, gravure, dépôt) et les moyens de caractérisation morphologique, électrique et optique de l'Institut Néel. Les composants seront fabriqués à partir de substrats d'oxyde de gallium et de couches minces fournies par les partenaires du projet ALOFET (LMGP et PHELIQS). Les résultats expérimentaux obtenus sur les couches minces seront confrontés aux études structurales menées en parallèle par les autres partenaires (LMGP, MEM).

Interactions et collaborations éventuelles :

LMGP (CNRS-Grenoble), PHELIQS (CEA-Grenoble), MEM (CEA-Grenoble)

Ce stage pourra se poursuivre par une thèse (ou **ce sujet est limité à un stage M2**...).

Oui, le stage pourra se poursuivre par une thèse.

Formation / Compétences :

De niveau master ou école d'ingénieur, la ou le candidat(e) doit avoir des connaissances en physique des semi-conducteurs et composants. Une expérience en caractérisation et/ou fabrication de dispositifs microélectroniques serait un plus.

Période envisagée pour le début du stage :

Février/Mars 2024 (limite de candidature due à une longue procédure administrative : décembre 2023)

Contact :

Philippe FERRANDIS
Institut Néel - CNRS
04 76 88 74 64
philippe.ferrandis@neel.cnrs.fr

Plus d'informations sur : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Fabrication of gallium oxide power devices

General Scope :

The ecological transition to which more and more countries are committing themselves is driving the microelectronics industry towards sustainability. Based on this trend, the new generation of power devices now incorporates wide-bandgap semiconductor materials such as gallium oxide. They enable the fabrication of devices that can withstand high voltages with low energy losses during operation and overheating. The internship falls within this context and that of the ALOFET project (2024-2028) funded by the French National Research Agency (ANR). The aim of this project is to develop a new architecture of high electron mobility transistors based on gallium oxide, capable of withstanding voltages in excess of one kilovolt. These transistors are used to integrate voltage converters, inverters, choppers, etc. These transistors will be integrated into voltage converters, inverters, choppers, etc., which will then be inserted into electric vehicles, solar panel installations, wind farms, etc... Gallium oxide power devices have the potential to meet the needs of applications covered by SiC and GaN technologies, while opening up new fields of application.

Research topic and facilities available :

The aim of the internship is to manufacture gallium oxide capacitors and diodes. These devices will constitute the first technological building blocks which will then lead to the more accomplished realization of a transistor. To carry out this work, the trainee will have access to the NanoFab cleanroom tools (chemistry bench, lithography, etching, deposition) and morphological, electrical and optical characterization resources of the Néel Institute. The devices will be fabricated from gallium oxide substrates and thin films supplied by the ALOFET project partners (LMGP and PHELIQS). Experimental results obtained on thin films will be compared with structural studies carried out in parallel by other partners (LMGP, MEM).

Possible collaboration and networking :

LMGP (CNRS-Grenoble), PHELIQS (CEA-Grenoble), MEM (CEA-Grenoble)

Possible extension as a PhD :

Yes, the internship can be followed by a thesis.

Required skills:

The candidate must be a master 2 or engineering school student with a good background in physics of semiconductors and devices. Experience in electrical characterization and/or fabrication of microelectronic devices would be an advantage.

Starting date :

February/March 2024 (application deadline due to lengthy administrative procedure: December 2023)

Contact :

Philippe FERRANDIS
Institut Néel - CNRS
04 76 88 74 64
philippe.ferrandis@neel.cnrs.fr
More information: http://neel.cnrs.fr

INSTITUT NEEL Grenoble

Master internship 2

Highly tunable single-photon sources emitting in the telecom bands

Context:
Efficient sources of non-classical light are key devices for photonic quantum technologies. Ideally, such sources should emit in telecom bands, be compatible with on-chip integration notably with the well-established silicon technologies. Monolithically integrated telecom-band single photon sources (SPSs) have been realized using III-V semiconductor quantum dots (QDs) and optically active defects in SiC or Si. Semiconductor quantum dot-nanowires (QD-NWs) constitute an appealing platform, with exceptional attributes: over 99% single photon purity, 0.72 collection efficiency, and a 1.2 ns coherence time. They are also capable of generating high-brightness entangled photon pairs and emit in the O and C telecom bands. Finally, QD-NWs offer tunable geometries for controlled photonic properties. However, a major challenge arises due to the inherent variations in emission wavelength among the QDs, hindering large-scale integration for quantum devices using photons as qubits.

We aim to address this very challenge by creating highly-tunable SPSs in the telecom band on silicon substrates. We propose to embed a III-V semiconductor QD-NW within a phase change material (PCM) shell. The concept relies on using PCM crystallization-induced volume changes to strain the QD-NW and adjust its emission energy in situ with a focused laser beam. This project focusses on the development of single photon sources using InGaAs/GaAs quantum dot nanowires grown by molecular beam epitaxy (MBE).

This research will explore two fabrication routes: the bottom-up approach (vapor-liquid-solid (VLS) growth) and the top-down approach (etching to define nanowires embedding a single or few QDs). On the one hand, the bottom-up fabrication route – more exploratory – features promising assets. On the other hand, the top-down approach has already demonstrated excellent results in terms of performance. To control the QD optical properties, we will apply a strain on the QD by controlling the phase change of a capping HfO_2 shell.

Objectives and means available:
The primary objectives of this M2/PhD proposal are as follows:

- To develop single photon sources using GaAs/InAs QD nanowires, employing both bottom-up (VLS) and top-down (SK and etching) approaches.
- To investigate the optical properties and performance of the fabricated single photon sources, focusing on the brightness and linewidth of the emitted single photons.
- To evaluate the influence of strain on the optical emission characteristics of the QD nanowires by capping them with a layer of HfO_2 and studying the resulting optical response.

Contact : Moïra Hocevar (Néel) and Julien Claudon (IRIG Pheliqs)
Phone : 0438783513
Mail : moira.hocevar@neel.cnrs.fr and julien.claudon@cea.fr

INSTITUT NEEL Grenoble

Master internship 2

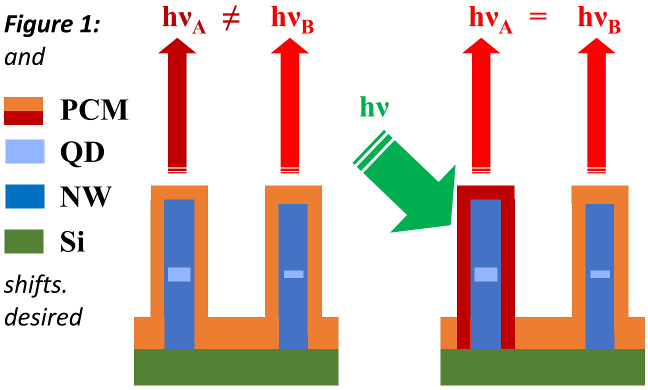


Figure 1: *and* *shifts.* *desired* <u>*Concept of the project:*</u> *QD-NWs are grown on Si capped with an amorphous PCM used as a shell. They emit single photon sources at two different wavelengths. The PCM crystallization state of one nanowire is controlled by heating with a laser light. Strain appears between the core and the shell of the nanowire due to the change in volume of the PCM. Consequently, the emission wavelength of the QD The amount of strain is tuned carefully to reach the wavelength.*

The available resources include a III-V molecular beam epitaxy (MBE) system for growing nanostructures, atomic layer deposition (ALD) equipment for depositing HfO2 shells, scanning electron microscopy (SEM), and access to cleanroom facilities. Optical characterizations will be conducted using micro-photoluminescence spectroscopy setups cooled to cryogenic temperatures. Additionally, the student will receive support from colleagues involved in the development of top-down structures in the cleanroom, which will help expedite the achievement of the project's goals.

The internship/PhD will take place within the ANR SONATE (granted in 2023). The different partners (material scientists, theoreticians and experimentalists) exchange regularly during meetings and research visits.

Possible collaboration and networking :

ANR SONATE partners: INL-Lyon, ILM-Lyon, IRIG-PHELIQS
Research Networks: GdR Matepi

Required profile :

We are looking for a student interested in experimental research. Knowledge in materials science and physics are mandatory. We are looking for a person curious with organizational skills and with ability to perform delicate experiments.

Possible extension as a PhD : yes, through the Quantalps PhD program (Spring 2024)

Contact : Moïra Hocevar (Néel) and Julien Claudon (IRIG Pheliqs)
Phone : 0438783513
Mail : moira.hocevar@neel.cnrs.fr and julien.claudon@cea.fr

INSTITUT NEEL Grenoble

Master internship 2

Imaging the mechanical and thermal properties of nanowires in an electron microscope

Context :

A major challenge in studying nanoscale objects is that many of their inherent physical properties are out-of-reach. Typical examples are semiconductor nanowires developed based on many materials for various applications. One important driving force in studying nanowires is their large thermoelectric figures of merit. These can be extracted directly but only after electronic devices are fabricated. However, when prototyping and optimizing the growth process, this method is costly, time-consuming and therefore not sufficient to build statistical measures based on numerous nanowires.

In this project, we develop a method for evaluating the mechanical and thermal properties that is fast, minimally invasive and works for rapid and statistical diagnosis prior to device integration. We shall use the electron beam from a conventional scanning electron microscope (SEM) as a local probe. The beam plays a dual role. First, it heats the nanowire locally. Second, the natural mechanical vibrations of the nanowire (Brownian motion) modulate the secondary electron (SE) current and can be detected[Nigues-2015]. The electron beam has typical waist of ~1 nm, which is much tighter than that available with light. In preliminary results, we have demonstrated that it is possible to address the mechanical properties of free-standing nanowires [Nigues-2015],[Pairis-2019] and nanotubes [Tsioutsios-2017]. The mechanical modes appear as peaks in the frequency spectrum of the SE signal. The sensitivity of this technique cannot be achieved by any other techniques. For example, we can detect the vibrations of tiny nanowires (20 nm in diameter and 700 nm long) as grown, whereas optical schemes are not suitable at this scale, on top of requiring suitable procedures in order to isolate the sample of interest.

In parallel, we have worked on a theoretical framework based on the extension of the fluctuation dissipation theorem that accurately describes the Brownian motion of a resonating beam subject to a heat flux. We have experimentally showed that within this framework, using interferometry, one can probe the local properties (temperature, mechanical damping) of a silicon cantilever within various settings (e.g. bare or coated), by coupling the mechanical modes to the laser-driven temperature field [Geitner-2017]. At the intersection of those approaches, **this project proposes to exploit electro-mechanical coupling inside an SEM in order to evaluate the thermal and mechanical properties of nanowires.**

Objectives and means available :

Within this project, the thesis objectives are twofold. First, the student will determine the global mechanical properties of nanowires (elastic moduli, mechanical damping) using electro-mechanical coupling inside the microscope in a minimally invasive configuration. Then, he/she will study the effect of the microscope settings on the nanowire mechanical response in order to understand the refined interaction between the electron beam and nanoscale oscillators. This will enable the development of thermal maps of the nano-objects heated by the beam with nanometer scale resolution.

Contact : Moïra Hocevar (Néel) and Pierre Verlot (Lumin)
Phone : 0438783513
Mail : moira.hocevar@neel.cnrs.fr and pierre.verlot@universite-paris-saclay.fr
More information: http://neel.cnrs.fr

INSTITUT NEEL Grenoble

Master internship 2

Nanowires will be available at the beginning of the thesis and the student will participate in growth campaigns. The student will have access to a scanning electron microscope to perform the experiments. In addition, measurement campaigns will take place in a cathodoluminescence setup at low temperature to correlate the mechanical properties with the optical properties.

The internship will take place within the ANR IMAGIQUE (granted in 2022). The different partners (material scientists, theoreticians and experimentalists) exchange regularly during meetings and research visits.

Possible collaboration and networking :

ANR IMAGIQUE partners: LUMIN, ENS-Lyon, IRIG-PHELIQS
Research Networks: GdR MecaQ, GdR Matepi

Required profile :

We are looking for a student interested in experimental research, statistical analysis and programming. Knowledge in materials science and physics are mandatory. We are looking for a person curious with organizational skills and with ability to perform delicate experiments.

Possible extension as a PhD : yes

Contact : Moïra Hocevar (Néel) and Pierre Verlot (Lumin)
Phone : 0438783513
Mail : moira.hocevar@neel.cnrs.fr and pierre.verlot@universite-paris-saclay.fr
More information: http://neel.cnrs.fr

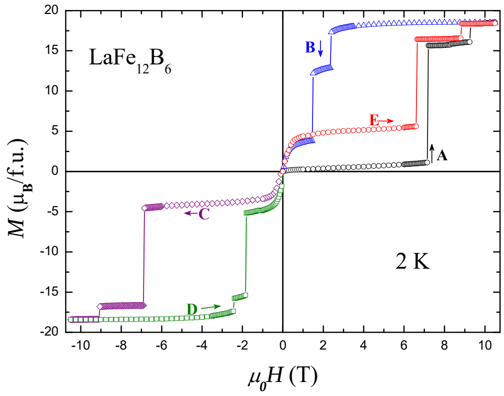
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Investigation of magnetization processes in R-M intermetallic compounds

General scope : The R-M phases based on rare-earth (R) and transition metals (M) are fascinating materials from both applied and fundamental viewpoints. Indeed, R-M have led to the first modern magnets like Sm-Co ($SmCo_5$ and Sm_2Co_{17} type) and latter to the high performance Nd-Fe-B magnets. Other examples are the (Dy,Tb)Fe_2 type Terfenol ® alloys which are by far the best magnetostrictive materials to date and are widely used in sensors and actuators leading to many applications (Sonar). Other R-M alloys have also contributed to the development of various techniques such as magneto-optic recording on thin films (Gd-Co). Some compounds are now also considered for new applications such as spintronic devices (Gd-Co), magnetic refrigeration using magnetocaloric materials (LaFeSi, RCo_2..). The R-M compounds are however complex materials and need fundamental studies to master their magnetic properties and optimize their performances. Indeed, they are combining two types of magnetism, the localized magnetic moment originating from the inner 4f electronic shells of the R element with the delocalized magnetic moments carried by the itinerant 3d electrons of the M transition metals. Depending upon the atomic concentration one can thus play with different origin of the magnetization. From a fundamental point of view, the R-M compounds are ideal systems to probe solid state magnetism since they are presenting a wide range of unusual magnetic behaviour.

Research to be carried out : Among the interesting magnetization process that attracted our attention, we can cite magnetization reversal in hard magnetic materials exhibiting promising magnetic properties for permanent magnet applications. We also recently discovered the occurence of ultrasharp magnetization behaviour in $LaFe_{12}B_6$ see Figure. This manifest itself by unexpected giant metamagnetic transitions consisting of a succession of extremely sharp magnetization steps separated by plateaus. This behavior has been found at low temperature in $LaFe_{12}B_6$. This unprecedent behaviour for a purely 3d itinerant electron system needs to be further investigated since it presents many remarkable properties. For instance, under certain combinations of the external parameters (temperature and magnetic field), the time dependence of the magnetization displays an unusual step-like feature. However, the origin and the underlying mechanism involved in such unusual magnetization process have to be clarified. The internship will include synthesis of polycrystalline samples, measurements of their physical properties (structural, electric and magnetic) and analysis of the observed behavior. This will be done in close interaction with the researchers using equipments already available.



Ongoing collaborations : In the frame of this research work, different collaborations are already established in particular with the Institute Laue Langevin, Czech collaborators specialists of magnetic measurements at high pressure and Brazilian colleagues. This will be an added value to the project.

This internship is aimed to be followed by a Ph. Thesis

Formation / skills : Master 2 in Solid State Physics or Nanophysics or Engineer in Materials sciences Interest for experiments and wish to broaden its knowledge in fundamental and applied sciences.

Starting period foreseen : February or march 2024

Contact: Olivier ISNARD, Dept. PLUM NEEL CNRS : tél 04 76 88 11 46 olivier.isnard@neel.cnrs.fr

INSTITUT NÉEL Grenoble

Topic for Master 2 internship – Academic year 2023-2024

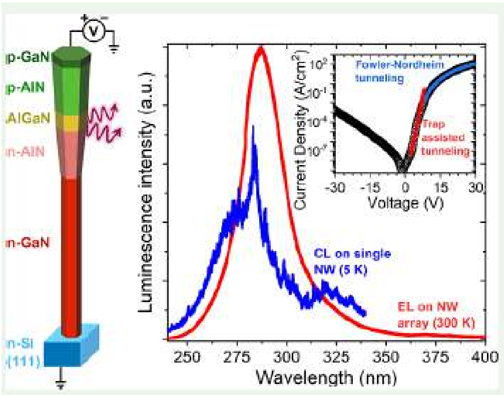
p-type doping of AlN nanowires for UV-C LEDs realization

General Scope :

The realization of efficient UV-C (200-280 nm) ligth emitting diodes (LEDs) is a current challenge to meet the requirements of numerous applications ranging from water, air and surface disinfection to short distance encrypted communication. However the efficiency of conventional UV-C LEDs is still low due to poor p-type doping and limited light extraction. In this context, the CEA/CNRS consortium involved in the realization of such emitters is developing a new strategy by using AlN nanowires (NWs). As a matter of fact, the absence of extended defects in NWs, the higher limit solubility of both Si (n-type) and Mg (p-type) electrical dopants, the eased light extraction intrinsically related to the large "roughness" of an ensemble of NWs make them particularly suitable to the realization of efficient UV emitters.

Research topic and facilities available

A scheme of such LEDs is shown in the figure. The inset shows the current-voltage characteristics which assesses the rectifying character of the device. Finally, an electroluminescence (EL) spectrum is shown assessing the successful realization of a UV-C LED. However, efficiency improvement now requires optimization of p-type doping, which will be the core of the present project, i.e. the growth, structural, optical and electrical characterization of p-type AlN nanowires.



Possible collaboration and networking :

The growth of the structures will be performed by plasma-assisted molecular beam epitaxy in CEA-Grenoble IRIG/PHELIQS-NPSC. Electrical characterization will be made in Institut Néel following NW processing in clean room environment. The optical characterization will be made in collaboration between CEA and Institut Néel.

Required skills: This project requires a strong interest in experimental science (Nanoscience, Nanophysics academic background) and could be extended into a PhD.

Starting date: Jan/Feb 2023

Contact :
Name : Gwénolé JACOPIN & Bruno Daudin
Institut Néel - CNRS
Phone : 047688 11 83 e-mail : gwenole.jacopin@neel.cnrs.fr & bruno.daudin@cea.fr

More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Exotic superconductivity in flat band materials

General Scope :

Superconductivity is a fascinating state of matter corresponding to zero electrical resistance and magnetic field expulsion occurring in some materials cooled down below a critical temperature. Microscopically it corresponds to a condensate of electron pairs. Such a condensate of fermions can occurred only because electron paired up to form Cooper pairs. In conventional superconductors, the glue binding the electron pairs is the exchange of lattice vibrations: the phonons.

In some materials, such as magic-angle graphene superlattices, superconductivity may result from electronic correlations rather than conventional electron-phonon coupling. These electronic correlations would be more pronounced in materials with flat electronic bands. Theory suggests that the flatter the bands, the higher the critical temperament. The challenge of this project is to test this prediction experimentally.

Research topic and facilities available :

The aim of the internship is to produce nanostructure superconductors that reproduce theoretical structures proposed to generate flat bands and measure how the critical temperature varies with the flatness of the bands. To this end, the student will be trained in nano lithography and low-temperature resistance measurement techniques.

Possible collaboration and networking :

The project is part of the Institut Néel's collaboration with the theoretician George Bouzerar. This project has been submitted to the ANR for funding. Thesis funding has been requested.

Possible extension as a PhD : yes

Required skills:
Solid state physic knowledge, taste for experimental manipulation and strong motivation.

Starting date : March or April 2024

Contact : Institut Néel - CNRS :
Florence Lévy-Bertrand, 04 76 88 12 14, florence.levy-bertrand@neel.cnrs.fr
Cécile Naud, 04 56 38 71 76, cecile.naud@neel.cnrs.fr
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Nm scale characterization of p-n junction electrical properties by Transmission Electron Microscopy

General scope:

Semiconductor p-n junctions are basic building blocks for devices like solar cells, avalanche photodetectors or light emitting diodes. To implement the junction, the electrical properties of semiconducting materials are engineered by adding dopant atoms that donate or accept an electron from conduction or band valence, respectively. In this way the density of mobile charges can be tuned over several orders of magnitude. It is very well known that a transition from one type of dopant to the other kind will generate a so-called p-n junction, giving rise to rectifying current voltage characteristics and potentially light emission, for example in light emitting diodes. However, challenges remain to control and measure the electrically active doping levels in semiconducting materials with nm precision, especially in wide bandgap materials with high dopant activation energies.

Research topic and available facilities:

The aim of this internship is to contribute to the study of p-n junction semiconducting materials regarding their electrical properties, in particular studied at nm length scales. The student will integrate a multi-institute, multi-disciplinary research group.

His/her role will be to fabricate electrical contacts to p-n junction nanowires or thin films of different materials, including GaN and AlN. The p-n junctions will be electrically contacted on membrane chips compatible with transmission electron microscopy (TEM) measurements, and the student will be in charge of their preliminary electrical characterization by current-voltage measurements. Combining in-situ biasing with the 4D Scanning TEM techniques sensitive to the electric field, we aim to obtain a quantitative description of the electrical properties of the object at the nm scale and improve our understanding of doping.

The student's work will involve:

- Nanowire contacting in a cleanroom environment. It implies training in nanowire dispersion, mapping using scanning electron microscopy, making drawings of the contact lines, assisting electron beam lithography and finally preforming lift-off.
- Current-voltage measurements.
- The electron beam lithography step for nanowire contacting and TEM experiments will be performed by the supervisor, but the student will participate in the experiments.
- The student will be involved in the data analysis of 4D STEM results.

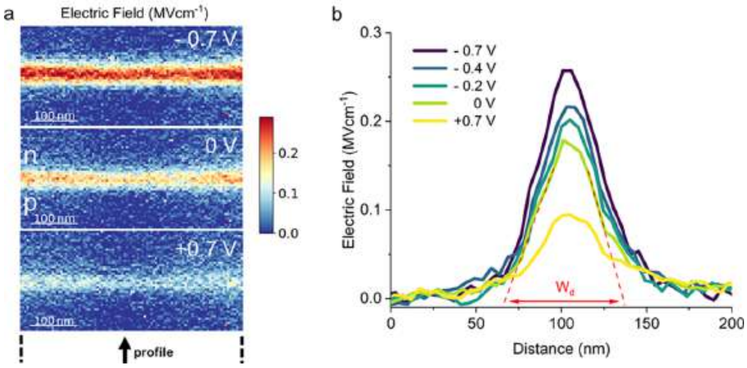


Figure 1. (a) In situ biased 4D-STEM electric field maps of a silicon p−n junction. (b) Profiles of the electric field obtained from the maps shown in (a) by integration along the entire map, as indicated in (a). The measured depletion length for zero bias is indicated. [https://doi.org/10.1021/acs.nanolett.2c03684]

Possible collaboration and networking: The internship will be in collaboration with Eva Monroy (CEA-IRIG, PHELIQS).

Possible extension as a PhD: Not granted in advance, but we support applications for a PhD grant.

Required skills: Interest in solid-state physics, electrical and optical properties of semiconductors and advanced characterization techniques like transmission electron microscopy.

Starting date: Jan/Feb 2023, earlier or later.

Contact: den Hertog Martien & Eva Monroy

Institut Néel - CNRS : tel: 0476881045 mail: martien.den-hertog@neel.cnrs.fr & eva.monroy@cea.fr

More information at: http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Current-driven manipulation of the magnetisation of magnetic insulator thin films

General Scope :
Ferromagnetic thin-films are the main component of hard disks for data storage, magnetic random access memories, magnetic sensor technology based on giant- and tunnel magnetoresistance and also prototypes of logic and memory devices using domain walls. The main characteristics of these devices is their ability to control the magnetic state of the thin films either by magnetic fields or, more interestingly, by electric current pulses.
More recent is the interest of the scientific community for the manipulation of the magnetisation of insulating magnetic oxide films, and in particular of garnet thin films. These materials are of particular interest due to their low damping, and their large magnon diffusion length, which make them promising candidates for spin-wave communication and ultralow-power-dissipation applications
One of the most efficient mechanisms to switch magnetization in thin films, and move domain walls, is the so called spin orbit torque (SOT) associated to the generation of spin currents by spin Hall effect (SHE) in an adjacent heavy metal film (e.g. in Pt/Co or W/CoFeB stacks): the spin currents are transmitted to the ferromagnetic film, which exerts a torque on the magnetisation.
Charge currents cannot flow in magnetic insulators (MI), but it has been recently demonstrated that the spin currents generated by the SHE in platinum layers can be transmitted across the Pt/MI interface and lead to magnetisation switching. The internship will study the possibility to induce spin orbit torques in garnet iron films grown by magnetron sputtering and patterned with different lithography techniques.

Research topic and facilities available :
This is an experimental internship. The student will prepare garnet thin films of different thicknesses with magnetron sputtering techniques, will characterize their structural and magnetic properties and will study the dynamics of domain walls driven by a magnetic field. He/she will then pattern the Pt layer with UV lithography in the Institut Néel cleanroom, either by lift-off and etching techniques. Transport measurements will be carried out to quantify the SHE. By monitoring the magnetisation switching efficiency under the application of current pulses, the spin orbit torque strength in the different samples will be studied and compared, for different treatments of the garnet film surface.
Available instruments at Institut Néel : magnetron sputtering for magnetic thin film deposition, clean room for optical and electronic lithography, structure and magnetic characterization techniques, magneto-optical microscopes (MOKE) for magnetic imaging, etc. A Brillouin Light Scattering spectrometer may be used for complementary measurements.

Possible collaboration and networking :
Interactions with colleagues of SPINTEC are likely

Possible extension as a PhD :
Yes

Required skills:
Some notions of magnetism or nanomagnetism are required; having followed magnetism courses in M1 would be a plus. A pronounced taste for experimental physics.

Starting date : March/April 2024

Contact :
Name : Stefania Pizzini (stefania.pizzini@neel.cnrs.fr); Laurent Ranno (Laurent.ranno@neel.cnrs.fr)
Institut Néel - CNRS - Grenoble
e-mail : stefania.pizzini@neel.cnrs.fr ; laurent.ranno@neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Graphene based superconducting quantum circuits

General Scope :
The recent progresses in reproducible fabrication and understanding of quantum systems have brought us to the following situation: it is now possible to build devices that not only present quantum properties but in which quantum states can be initialized, manipulated and readout. The building blocks of quantum circuits are quantum bits and quantum limited amplifiers. Superconducting circuits is the most advanced platform in this context and it has reached several key milestones in the realization of a quantum computer. Despite such celebrated successes, other platforms are studied in order to gain flexibility and compatibility with current semiconductor technologies. In particular, hybrid platforms that couple superconducting and semiconducting properties are expected to bring a decisive advantage by allowing electrical control of the system.

Research topic and facilities available :
In this internship, we will bring electrical tuning at the core of superconducting circuits by introducing a gapless semiconductor graphene, in the key element: the Josephson junction (see Figure). With such electrically tunable Josephson element, we can build the building blocks for a quantum platform: quantum bits and Josephson parametric amplifiers. In the team we have already demonstrated the fabrication of such graphene based Josephson junctions and their use in quantum circuits[1]. The next step, which is the goal of this work is to demonstrate that it can have functionalities and performances to be competitive with other platforms.
A one atom-thick sheet of graphene will thus have to be integrated into superconducting circuits using nanofabrication techniques available at the Institute. Such sample will then be measured at very low temperature (20mK) in a dilution refrigerator using radiofrequency (1-10 GHz) techniques. Measurements will be carried out to extract the figure of merit of the devices: lifetime of the Qubit, noise of the amplifier...
[1] G. Butseraen et al *Nature Nanotechnology* 17, 1153 (2022); arXiv:2204.02175

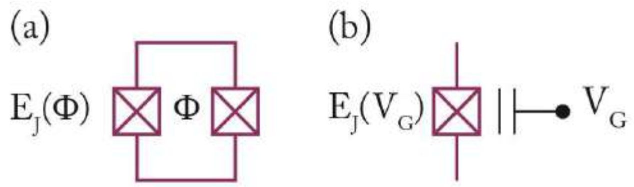


Figure 1: tunability of the Josephson energy E_J in standard Josephson junctions necessitates a loop geometry and a magnetic flux Φ (a). The introduction of a semiconductor allows simple electrical gating with a gate voltage V_G (b). This is the essence of the project.

Possible collaboration and networking : The student will be part of the Hybrid team, which has a multidisciplinary expertise (growth, nanofabrication, electronic transport, spectroscopy...). The team has also several external collaborations worldwide (France, US, Canada).
Possible extension as a PhD : Yes
Required skills: The internship (and the PhD thesis) will require a solid background in solid state/condensed matter physics. The work will be mainly experimental. The candidate is expected to be strongly motivated to learn the associated techniques (nanofabrication in clean room, radiofrequency electronics, cryogenics...) and engage in a hands-on experimental work.
Starting date : March 2024 (flexible)

Contact :
Name: Julien Renard Institut Néel - CNRS
Phone: 0456387176 e-mail: julien.renard@neel.cnrs.fr http://perso.neel.cnrs.fr/julien.renard/

More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Optical probing of electronic excitations in van der Waals heterostructures

General Scope:
Van der Waals heterostructures are artificial quantum materials made by stacking two-dimensional materials, such as graphene, together. The vast library of materials that can be stacked and the way this stacking is done, for instance with a twist angle between the layers, give access to an extraordinarily rich diversity of electronic phases. This includes unconventional states of matter such as strange metals, superconductors, and charge or spin orders. A very powerful approach to discover novel phases, or understand better those reported recently, is to probe very clean samples with alternative experimental techniques. This is precisely what we propose to do with optical spectroscopy to explore the physics of electronic excitations that emerge in a bilayer of graphene in presence of a perpendicular electric field.

Research topic and facilities available:
Our team fabricates state-of-the-art (i.e. ultra-clean) van der Waals heterostructures and integrates them into electrical micro-devices. The goal of this project will be to fabricate such a device with a bilayer of graphene subjected to a controllable electric field (see Figure). The electric field will be generated by two electrostatic gates placed on top and at the bottom of the bilayer. To avoid direct electrical contact with the gate electrodes, graphene will be sandwiched between two thin layers of another van der Waals material, hexagonal boron nitride. In the bilayer, it is known that a small band gap opens, and that it comes together with electronic excitations whose nature is still an open question. We expect to obtain new answers using optical spectroscopy, by analyzing how these excitations produce inelastic light scattering, via an electronic Raman effect, at cryogenic temperatures. The way the electronic Raman signature will react to variable electric fields, temperature and light polarization will inform us about the quantum nature of the excitations. All the experimental tools required for the project are in place and available.

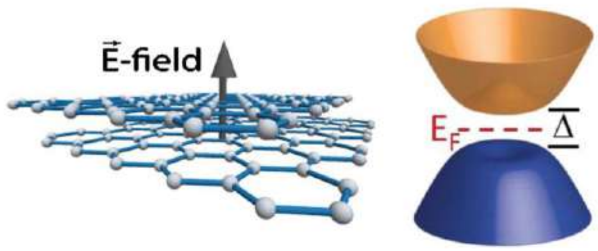


Figure: Illustration of a gapped bilayer graphene. *When subjected to an electric field E (left), a gap (□) opens at the Fermi level (E_F) of a bilayer graphene (right). Images from [1].*

[1] T. Taychatanapat et al, Phys. Rev. Lett. 105, 166601 (2010), L. Ju et al, Science 358, 907 (2017)

Possible collaboration and networking : The student will be part of the Hybrid team, which has a multidisciplinary expertise (nanofabrication, electronic transport, optical spectroscopy...). Collaborations are envisaged, on the medium-term, for measurement campaigns using high magnetic fields.

Possible extension as a PhD : Yes
Required skills: The internship will require a solid background in solid state/condensed matter physics. The work will be mainly experimental. The candidate is expected to be strongly motivated to learn the associated techniques (nanofabrication in clean room, optical spectroscopy, cryogenics...) and engage in a hands-on experimental work.

Starting date : March 2024 (flexible)

Contact : Julien Renard, Institut Néel - CNRS, phone: 0456387176, email: julien.renard@neel.cnrs.fr

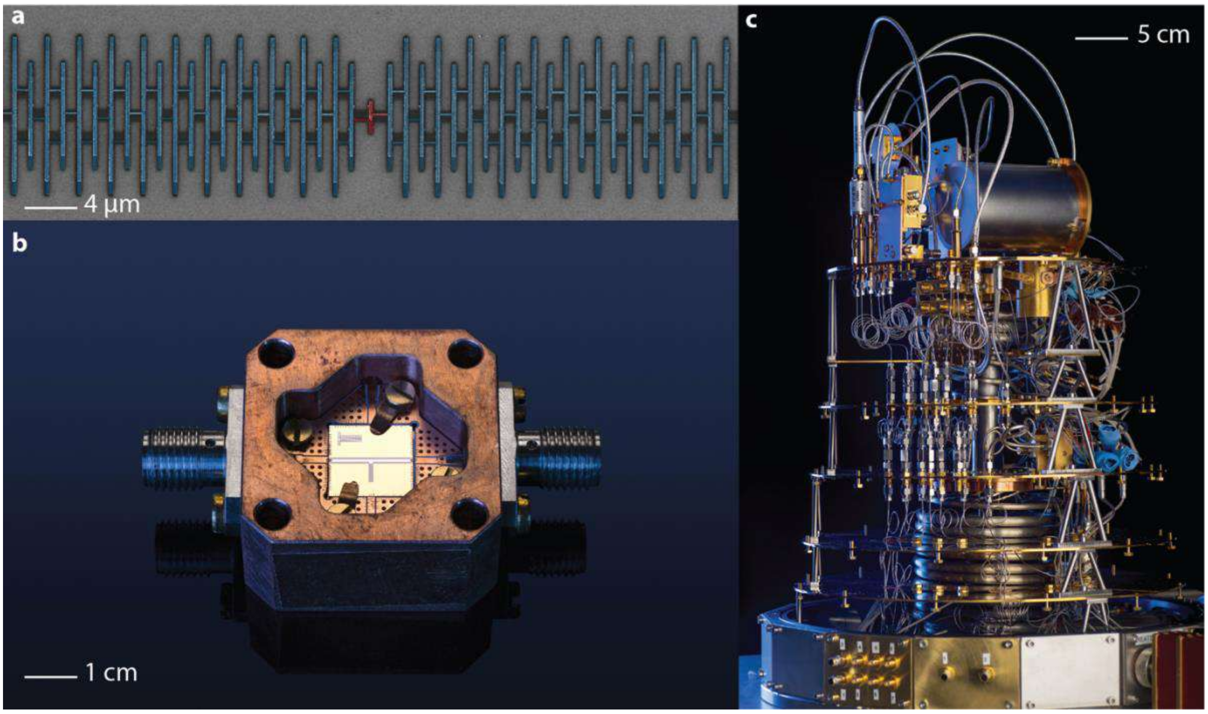
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Microwave quantum optics with superconducting meta-materials

General Scope: During the last decade, it has been demonstrated that superconducting Josephson circuits behave as quantum bits and are very well suited to realize advanced quantum mechanical experiments. These circuits appear as artificial atoms whose properties are defined by their electronic characteristics (capacitance, inductance and tunnel barrier).
Moreover, given their mesoscopic size, these quantum bits couple very strongly to electromagnetic radiations in the microwave range. Thus, it is now possible to perform quantum optics experiments using microwave photons and to unravel light-matter interactions using circuits. This field is dubbed circuit-QED (Quantum Electro-Dynamics).



a. *SEM image of a superconducting meta-material mixing small (red) and large (blue) Josephson junctions. This sample is fabricated in our clean-room using state-of-the-art e-beam lithography. The shape and quantum properties of this meta-material can then be tailored at will.* **b.** *These samples are enclosed in copper housings to ensure proper thermalization down 20mK, while enabling electrical measurements of their quantum properties.* **c.** *Dilution refrigerator and its various cables and shields. It is used to cooldown the samples at 20mK. We then reach the regime* $\boldsymbol{h\omega} \gg \boldsymbol{k_B T}$*, where quantum optical effects become prominent.*

During the last 5 years, our team has acquired a lot of experience in the fabrication of Josephson junction chains (Fig. a) forming a transmission line for microwave signals. In such chains, the propagation of microwave photons shows non-linear behavior due to the Kerr effect, a photon-photon interaction naturally arising from the Josephson junction physics. An example of device leveraging such interaction is the Josephson Travelling-Wave Parametric Amplifier, used for broadband quantum limited amplification of the readout signals of quantum bits [1,2,3,4]. In such devices, the Kerr effect allows for wave-mixing giving rise to an amplification process. In addition, the lines are impedance-matched to 50Ω, the standard impedance of the microwave environment which makes them behave as travelling-wave devices (as opposed to resonant structures). However, these chains are up to now mainly made of Josephson junctions close to their linear regime, where the Kerr interaction is a very small perturbation and does not impact too much the propagation of microwave signals. Yet, as the junctions' size is decreased, the Kerr interaction is increased, yielding stronger interactions between photons possibly up to the single-photon inelastic scattering. We propose to explore the new physics that can take place in

50Ω matched lines made of highly non-linear Josephson junctions. In this regime, strong interactions between microwave photons over a broad band of frequencies are expected to appear, and the applications of the study of such system ranges from the broadband photo-detection of single microwave photons, to single-microwave photons sources.

[1] Fabrication and characterization of aluminum SQUID transmission lines, L Planat, et al., *Phys. Rev. Applied* 12 (6), 064017 (2019).
[2] A photonic crystal Josephson traveling wave parametric amplifier, L. Planat., et al., *Phys. Rev. X* **10**, 021021 (2020).
[3] Fast high fidelity quantum non-demolition qubit readout via a non-perturbative cross-Kerr coupling, R. Dassonneville, et al., *Phys. Rev. X* 10, 011045 (2020).
[4] Kerr reversal in Josephson meta-material and traveling wave parametric amplification, A. Ranadive, et al., *Nat. Commun.* 13,1737 (2022).

Research topic and facilities available: Our team has a strong experience in nanofabrication, microwave electronics and cryogenic equipment. First, the student will be in charge of carrying out experiments on a non-linear 50Ω matched transmission line to try to observe the generation of quantum states of lights when the device is excited with a classical coherent microwave signal. This experiment will be performed at very low temperature (20mK), using one of the four fully equipped dilution refrigerators of the team. She/He will then explore the theoretical modeling of such an effect in a dilute media made of Josephson junctions. The devices are fabricated in the clean room of the Neel Institute (Nanofab). If the candidate is interested in learning these fabrication techniques, she/he can be associated to this part of the project.

Possible collaboration and networking: Our team is part of several national and international networks. For this specific project we are collaborating closely with Prof. K. Murch at Washington University in Saint-Louis, Missouri, USA, Prof. I. Carusotto at Trento University, Trento, Italy. This line of research is carried out in close collaboration with start-up Silent Waves.

Possible extension as a PhD: yes

Required skills: Master 2 or Engineering degree. We are seeking motivated students who want to take part to a state-of-the-art experiment and put some efforts in the theoretical understanding of quantum effects in non-linear transmission lines made of Josephson junctions.

Starting date: Flexible

Contact:
Roch Nicolas, Institut Néel - CNRS
Phone: +33 4 56 38 71 77 e-mail: nicolas.roch@neel.cnrs.fr
More information: http://neel.cnrs.fr & http://perso.neel.cnrs.fr/nicolas.roch

NÉEL INSTITUTE Grenoble

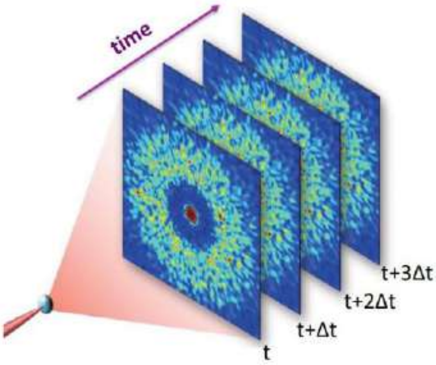
Topic for Master 2 internship – Academic year 2023-2024

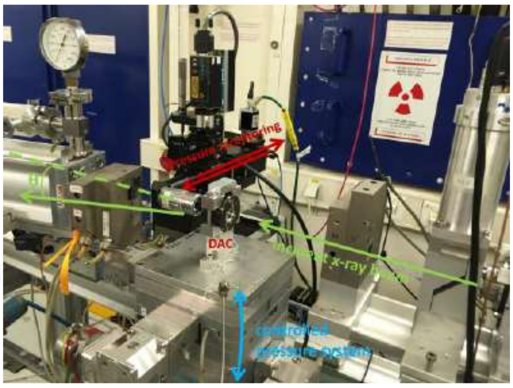
Combining coherent X-rays and nano-calorimetry to study the atomic motion and relaxation processes in glass-formers at high pressures

General Scope :
Glasses are mysterious materials. Fundamental blocks in many natural and technological processes, still, their properties keep puzzling a large community of scientists nowadays. Albeit the apparent differences, materials as diverse as emulsions, gels, pharmaceutical compounds, plastics, and windows do share common features. Following different experimental routes, like decreasing the temperature in a molecular glass-former or increasing the packing fraction in a colloidal suspension these materials can be driven in an out-of-equilibrium configuration which features many intriguing phenomena.
Within the large family of disordered systems, metallic glasses (MGs) play a key role being often considered as archetypes of out-of-equilibrium materials. Discovered in the sixties, MGs have outstanding mechanical and elastic properties with respect to their crystalline counterparts which makes them among the most studied materials nowadays. In our group we have performed the first worldwide studies able to follow the atomic motion in glasses by using the coherent X-rays available in Synchrotron Radiation facilities. Our results have allowed us to unveil a complex dynamical pattern at the atomic level which controls the evolution of many outstanding macroscopic properties of MGs.

Research topic and facilities available :
To further understand the microscopic mechanism controlling the properties of glasses, the student will study the effect of high pressure compression on the atomic motion and stability of metallic glasses. For this purpose, he/she will combine high pressure set-ups (Belt, diamond anvil cell) with the X-ray Photon Correlation Spectroscopy technique available at European synchrotrons. The results will be complemented by standard and chip calorimetry measurements available in our laboratory to obtain a detailed investigation of the relation between kinetics and dynamics under hydrostatic compressions.

References in our group: V. Giordano and B. Ruta, *Nature Commun.*, 6, 10344 (2016); X. Monnier et al. , *Science Adv.* 6 eaay 1454 (2020) ; A. Cornet et al., *Acta Mat.* 255, 119065 (2023).





Possible collaboration and networking : This project will be carried out between the institute Néel and the European Synchrotron ESRF in Grenoble. The group is working on a European ERC-Stg project on the same topic. The student will work in an international environment and collaborate also with the University Politecnica of Barcelona in Spain and the University of Saarbrucken in Germany.

Possible extension as a PhD : Depending on the ongoing funding applications.

Required skills: Master 2 (or equivalent) with good knowledge in solid state physics or material science and light matter interaction.

Starting date : March 2024 (flexible)
Contact : B. Ruta, Institut Néel, tel: 0476881484, email : beatrice.ruta@neel.cnrs.fr
More information : http://neel.cnrs.fr

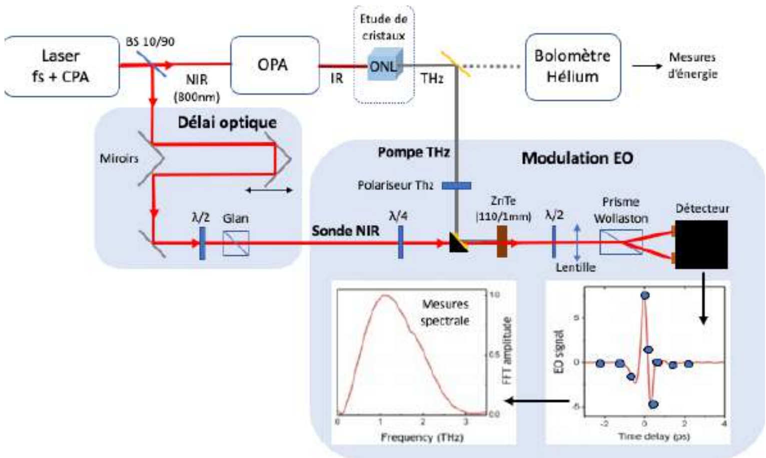
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Implementation of a Fourier Transform spectrometer to record the spectrum of a THz light generated in new nonlinear crystals

General Scope: the scope of this internship is to implement a Fourier Transform (FT) spectrometer designed to record the spectrum of a tunable and energetic THz light. It is generated in new nonlinear crystals with non-linear optical properties, by a second-order frequency differences (DFG) between two Fourier components of a wavelength-tunable femtosecond pulse. Such a THz spectrum corresponding to the frequency range 0,1 - 20 THz *i.e.* to the wavelength range 3000 - 15 µm, is of prime importance for many applications as spectroscopy and medical for example.

Research topic and facilities available: we have the commercial wavelength-tunable femtosecond source and we implemented a THz bench with all the optical components needed for the beams routing and a bolometer to record the mean value of the THz energy generated. We need an analysis of the corresponding THz spectrum. We targeted a FT spectrometer based on a time correlation between a probe pulse (femtosecond) and the THz pulse (picosecond) which, in a ZnTe crystal, will induce an electro-optical effect (EO) via its own electric field as shown in the figure below. A FT of this time-correlation will directly provide the spectrum of the THz pulse.



Such a spectrometer is found in laboratories working in the THz domain. We acquired and will have received at the beginning of the internship all the necessary optical and opto-mechanical components, to implement this FT spectrometer.

Collaboration and networking : This spectrometer will be implemented by the OPTIMA team with David Jégouso from the OPTICS-and-MICROSCOPY technical team of NEEL Institute. We will be carrying out a technology transfer from the team of Frédéric Garet and Emilie Hérault of IMPEP-LAHC in Chambéry with whom we have been collaborating for several years. The used nonlinear crystals for THz generation from DFG were provided thanks to international collaborations.

Required skills: optics, nonlinear optics and lasers. **Starting day** February 2024

Contacts: Patricia Segonds and Benoit Boulanger and David Jegouso
patricia.segonds@neel.cnrs.fr and benoit.boulanger@neel.cnrs.fr and
David.Jegouso@neel.cnrs.fr

https://neel.cnrs.fr/equipes-poles-et-services/optique-et-materiaux-optima

No PHD position next

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Title: Sputtering growth of ZnO nanostructures and thin films for piezoelectric energy harvester

General Scope:

In the last decades, one-dimensional (1-D) piezoelectric nano-objects (nanowires, nanocolumns, nanorods) have emerged as the potential building blocks for piezo-generators and smart self-powered sensors. ZnO, a wurtzite piezoelectric semiconductor, is of highly interest as its nanostructures are formed relatively easily on various substrates, including Silicon which is low-price and compatible with microelectronic technology. Hydrothermal growth is a simple and cost-effective technique which can provide a uniform deposition of 1-D ZnO, but the grown materials usually have poor optical and electrical properties, consequently deteriorating the device performance. Magnetron sputtering, the widely used deposition technique with a reasonable running-cost and feasibility of mass-production, should offer the material with a better quality as they are obtained under high vacuum conditions. Despite numerous studies on ZnO sputtering, it remains crucial to explore a complete picture of ZnO sputtering of nanostructure formation and alloying to achieve desired elements for piezo-devices.

Research topic and facilities available:

In this internship, the student will use a DC/RF magnetron sputtering to deposit ZnO on Si substrate via radio frequency (rf) sputtering technique. The key issue is to optimize the growth conditions to achieve high crystal quality in a controlled morphology and desired crystal orientations that determines the piezoelectric properties. The student will investigate structural, morphological, electromechanical properties of the grown ZnO as a function of the deposition parameters such as deposition pressure, substrate temperature, sputtering power, target–substrate distance, deposition angle, layer thickness, O_2/Ar gas ratio, etc. The growth conditions will be optimized to achieve ZnO nanowires/nanocolumns without using any external catalyst to avoid the incorporation of an undesirable external impurity that likely affect the material quality.

Although ZnO has the highest piezoelectric coefficient (d_{33}) among wurtzite semiconductors, its value is relatively low compared to common piezoelectric ceramics such as PZT, limiting ZnO piezo-device efficiency. The impurity doping or alloying process potentially extends this value beyond the bulk one. For example, the d_{33} of ZnO can be enhanced from its bulk value of 12.5 pC/N to 127 pC/N which approaches that of piezoelectric ceramics, by modulating the chemical state and ionic size of Fe impurity in ZnO. According to the literature, the enhanced d_{33} of Fe-ZnO films is attributed to the substitution of Fe^{3+} for the Zn^{2+}, when the concentration of Fe atoms is less than 2.6 at. % in ZnO film. However, the chemical state of Fe in Fe-ZnO films changes from Fe^{3+} to Fe^{2+} with an increase in the amount of Fe. This challenge task to extend the d_{33} of Fe-ZnO nanostructures might be tested at the end of the internship when the growth conditions of ZnO nanostructures are optimized since it needs a fine tuning of the Fe concentration during the sputtering.

The comprehensive film characterization such as surface roughness, crystallography, piezoelectricity, and electrical resistivity will be performed with various techniques (SEM, AFM, PFM, electrical, etc) available at Néel Institute. The piezoelectric properties of ZnO will be studied and correlated with the electrical and electromechanical properties of large-scale piezo harvesters.

Possible collaboration and networking: Néel (NPSC, Optima, EpiCM) and CEA/Grenoble
Possible extension as a PhD: No funding is currently available, but we support the PhD grant applications.
Required skills: Material science, Semiconductors, Nanomaterials, Solid State Physics
Starting date: February/March 2024 (4 to 6 months), please apply for the position 2 months before the starting date.

Contact :
Name : Rudeesun Songmuang
Institut Néel - CNRS
Phone : - e-mail : rudeesun.songmuang@neel.cnrs.fr

More information: http://neel.cnrs.fr

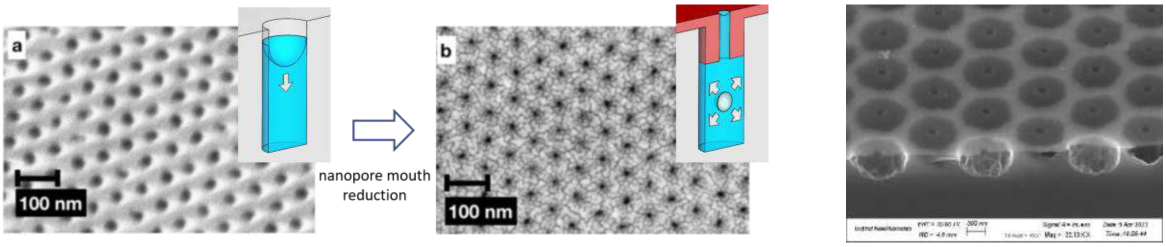
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Cavitation in superfluid helium

General Scope:

Cavitation, the nucleation of a vapor bubble in a stretched liquid, is a ubiquitous phenomenon, from engineering to natural sciences. Our team has recently used an experimental method to induce cavitation inside nanopores (see figure below). Our results show that cavitation occurs in conventional fluids via the thermally activated formation of a bubble nucleus as decribed by the Classical Nucleation Theory (CNT)[1,2], provided that the surface tension is corrected for nanometric bubbles[3] and the diameter of the pores is not too small. However, the situation is still confused for superfluid helium where quantized vortices could act as preferential sites[4] for nucleation.



SEM pictures. Left: in native alumina nanopores, evaporation unfolds through meniscus recession. Center: after pore mouth reduction, the meniscus is pinned and cavitation is induced. Right: SiN/Si artificial porous system developed at Nanofab (coll. T. Crozes).

Research topic and facilities available:

To study the influence of quantum effects on cavitation, we are developing an artificial porous system using recent progresses in nanolithography techniques. The successful candidate will use a highly sensitive capacitive detection technique to study helium cavitation into the superfluid phase. In parallel, the influence of confinement on cavitation will be explored.

Possible collaboration and networking:

This work is part of the project NANOCAV supported by ANR. In this framework, part of the fabrication and specific measurements will be done at Ecole Normale Supérieure in the group of Etienne Rolley (LPS-ENS, Paris).

Possible extension as a PhD: yes, funding available

Required skills:

This project is at the crossroads of low temperature and statistical physics, focusing on porous materials. Experiments combine nanolithography, cryogenics and transport techniques. A solid background in condensed matter physics (including statistical physics and/or soft matter) is required.

Starting date: flexible to the trainee academic program

Contact: Panayotis Spathis panayotis.spathis@neel.cnrs.fr

[1] Doebele et al, Direct observation of homogeneous cavitation in nanopores, PRL 2020
[2] Bossert et al, Evaporation process in porous silicon: cavitation vs pore-blocking, Langmuir 2021
[3] Bossert et al, Surface tension of cavitation bubbles, PNAS 2023
[4] Djadaojee et al, Brillouin Spectroscopy of Metastable Superfluid Helium-4, PRL 2022

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Pressure induced high T_c superconductivity in $Ln_3Ni_2O_7$ nickelate

General Scope :

The search of high T_c superconductivity in other analogous materials than cuprates has started more than 35 years. For Ni, the discovery of unconventional superconductivity in thin film of hole-doped infinite-layer nickelate $Nd_{1-x}Sr_xNiO_2$ (with square planar coordinated Ni^+ in d^9 configuration for x = 0) below T_c = 15 K (for x~0.2) by the group of H.Y. Hwang (Stanford) mid-2019 has suddenly intensified the research in this field. So far, no superconducting bulk nickelates were discovered until very recent report of superconductivity near 80 K in $La_3Ni_2O_7$ (La-327) under high pressure (HP) by M.Wang et al. (Beijing) [Fig.1]. On the contrary of previous nickelates this bilayer compound shows a mixed valency state $Ni^{2.5+}$ (i.e. d^7/d^8) and several theoretical scenarios have been proposed to understand the related high T_c superconductivity mechanism but the question is not yet resolved. Like cuprates, La-327 shows a $3d_{x^2-y^2}$-based Fermi surface but also an additional pocket involving $3d_{z^2}$ orbitals which is potentially crucial to reach superconductivity. In fact, superconductivity occurs just above a structural phase transition at 10-14 GPa, where the Ni-O_{apical}-Ni angle, closely related to oxygen 2p/nickel $3d_{z^2}$ orbitals hybridization, changes from 168° to 180°.

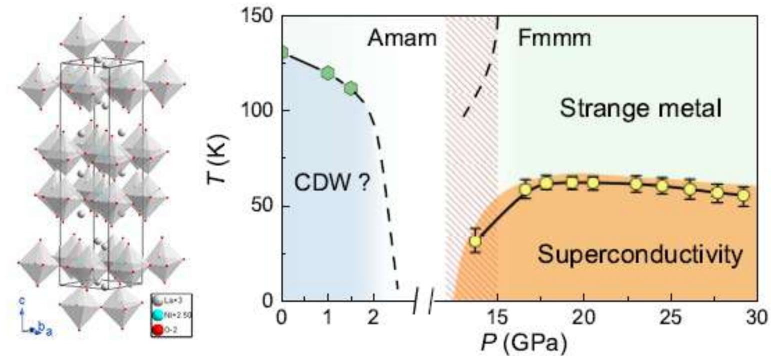


Fig. 1 Left: La-327 orthorhombic Amam crystal structure. Right: P,T phase diagram [Y. Zhang *et al.* Arxiv : 2307.14819]

Research topic and facilities available:

Presently the Chinese discovery has been confirmed by two other groups (in Japan and China). At Néel Institute, in the last three years, we worked on related infinite-layer Ni oxides. In MRS group, we have also synthesized several $Ln_{n+1}Ni_nO_{3n+1}$ compounds, in particular the n = 2 member $La_3Ni_2O_7$. The related internship will include the (high pressure – high temperature) synthesis of $(La_{1-x}Ln_x)_3Ni_2O_7$ samples (with one Ln = Pr, Nd or Sm). The study of the structural, magnetic and electronic properties of the synthesized nickelates, will be carried out as a function of temperature, thanks to the various experimental setups available in our laboratory. Measurements under high pressure (HP) are planned: x-ray diffraction (XRD) and possibly resistivity or Raman spectroscopy measurements in collaboration with MagSup team. The trainee will participate to the XRD/HP experiments at synchrotrons sources (ESRF…), if our submitted proposals are accepted.

Possible collaboration and networking: We have currently a joint research ANR project on nickelates with CRISMAT in Caen and several laboratories in Parisian region.

Possible extension as a PhD: this internship will be extended into a PhD where potential superconductivity in palladates will also be explored. Funding may be obtained via the Physics Graduate School of Grenoble.

Required skills: A good background in material science and condensed matter physics is required.

Starting date: Spring 2024

Contact:

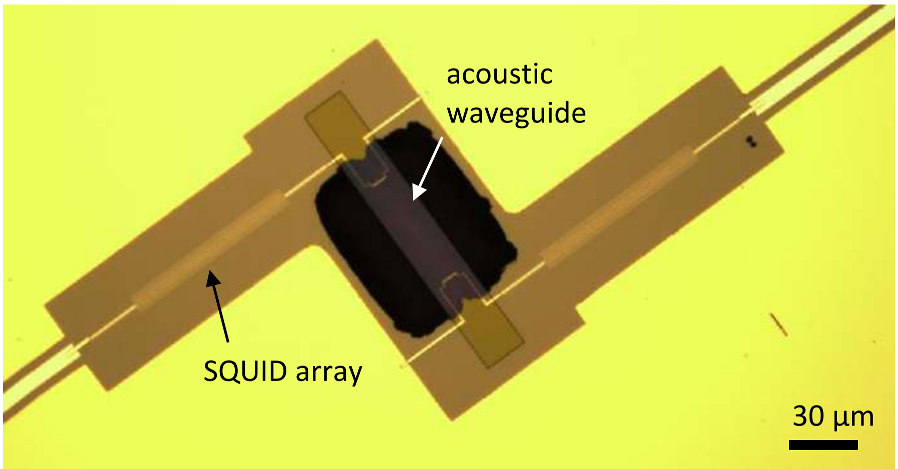
Name: TOULEMONDE Pierre
Institut Néel - CNRS
Phone: 04 76 88 74 21 e-mail : pierre.toulemonde@neel.cnrs.fr
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Circuit quantum acoustics

General Scope : The ability to bring the motion of man-made mechanical systems in the quantum regime is at the origin of a whole research field, with experiments ranging from quantum sensing to quantum information science. Within this field, this project exploits the recently developed circuit quantum acoustics technology, which couples acoustic vibrations with superconducting circuits via the piezoelectric effect. Based on this technology, we aim to provide a novel quantum interface to mechanical oscillators, with perspectives for fundamental investigations and for applied quantum technologies.



Research topic and facilities available : The project aims to continue developping our superconducting quantum acoustics technology and to start interfacing nanomechanical oscillators with large zero-point motion and/or 2D materials.

The student will first learn how to design, fabricate and operate acoustic devices at microwave frequencies (several GHz) and cryogenic temperatures (tens of mK). Our devices are based on high-performance materials (such as $LiNbO_3$) and circuits. The fabrication takes place in the clean room of the Néel institute using state-of-the-art techniques. The cryogenic microwave measurements are performed in a dedicated dilution refrigerator.

Possible extension as a PhD : Yes

Required skills: We are looking for a motivated student, willing to be part of a project involving both technical and fundamental challenges, and wanting to learn a wide variety of skills in experimental physics.

Starting date: Flexible

Contact: Jeremie Viennot
Institut Néel - CNRS
Phone: +33 4 76 88 79 05 e-mail: jeremie.viennot@neel.cnrs.fr
Web: https://neel.cnrs.fr/les-chercheurs-et-techniciens/jjviennot