NÉEL institut

INTERNSHIP

2020 2021

CNRS

UGA Université Grenoble Alpes

Institut NEEL/CNRS
25 rue des Martyrs
BP 166
38042 Grenoble cedex 9

L'Institut Néel est un grand laboratoire de recherche en physique avec près de 450 membres. Son dynamisme collectif s'exprime dans de nombreuses collaborations internationales et nationales, la présence en son sein de plateformes technologiques ouvertes 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 en effet magnétisme, 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'énergie, de la santé et aussi les sciences de l'univers.

Cette brochure regroupe les offres de stage de Master proposés pour l'année universitaire 2020-21. 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. Je vous souhaite la bienvenue à l'Institut Néel, 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.

Etienne BUSTARRET
Directeur, Institut Néel
Septembre 2020

Institut NEEL/CNRS
25 rue des Martyrs
BP 166
38042 Grenoble cedex 9

Institut Néel is a major research laboratory in physics, with about 450 members. Its collective strength is expressed in numerous national and international collaborative projects, in open technological platforms of exceptional quality, and by a remarkable level of scientific production.

This booklet presents the internship topics offered by NÉEL researchers. These cover a wide range of scientific and technological fields, reflecting the diversity of our teams. Magnetism, quantum fluids, new materials, crystallography and surface science mingle with quantum nanoelectronics, nanomechanics, non-linear and quantum optics, spintronics, etc. Beyond our core expertise in physics of condensed matter, we also work at the interface with chemistry, engineering, astrophysics and biology. In all these fields, our mainly experimental activity benefits from the local presence of many worldclass experts in theoretical, analytical and computational physics.

Institut Néel fosters a technological expertise that is essential to bring our research projects to the highest level, through often unique house-made or in house designed instruments. We are also actively involved in creating value from our research in the sectors of electronics, energy, health and space.

This booklet contains the Master internship offers for the 2020-21 academic year. Most of them are Master 2 projects, offering often the possibility of going on as a PhD student. If you are starting your Master degree, you will also find Master 1 project proposals. Many of the Master 2 topics may also be adapted to Master 1 projects.

You are welcome to a virtual visit of Institut Néel through this booklet and our website, www.neel.cnrs.fr. Please get in touch with NÉEL researchers and come around for a real visit !

Etienne BUSTARRET
Director, Institut Néel
September 2020

LISTE DES SUJETS PROPOSES

2020 -2021

MASTER 1	
Mise en évidence expérimentale d'une dualité onde-particule à macro-échelle	Poulain Cédric
Probing the Classical Nucleation Theory of cavitation with helium	Spathis P.S. – Wolf P.E.
2D superconductivity in cuprate oxychlorides	D'Astuto Matteo - Chaix Laura
MASTER 2	
AI-assisted 3D image analysis of the microstructure of catalysts to reduce air pollution	Da Silva Julio
Caractérisation électrique et électro-optique de composants à base de semi-conducteurs à ultra large bande interdite	Ferrandis Philippe
Circuit-QED: quantum limited microwave amplification	Roch Nicolas
Coupling molecular spin qubits to superconducting circuits	Balestro Franck et Viennot Jérémie
Development of a Fibered Photonic Force Microscope	Fick Jochen
Electrodynamics of Superconductors investigated by resonant cavity measurements.	Lévy-Bertrand Florence – Rodière Pierre
Electronic flying qubits	Bauerle Christopher
Graphene based superconducting quantum bit	Renard Julien
Guided interactions with rare-earth luminescent centers for quantum information processing	Chanelière Thierry
Higgs mode in Superconductors	Measson Marie-Aude
High temperature superconducting oxychlorides : a light element model for cuprates	D'Astuto Matteo
Laser cooling of solids for a new generation of spatial cryocooler	Nogues Gilles
Low-dose EDT for highly sensitive MOFs	Klein Holger
Métallisation de VO2 sous pression	Bouvier Pierre
Molecular spin devices for quantum information processing	Franck Balestro
Multiscale Brain Interface	Delacour Cécile
Nanomechanics at ultra-low temperatures	Fefferman Andrew
Non-invasive X-ray powder diffraction and fluorescence measurements on medieval artworks by using an in-house-built mobile instrument	Martinetto Pauline
Optomechanics with a quantum fluid of light	Richard Maxime
Probing the Classical Nucleation Theory of cavitation with helium	Spathis P.S. – Wolf P.E.

Quantum acoustics with spin qubits	Viennot Jérémie
Quantum nanophononics at low temperature: towards heat manipulation at the nanoscale	Bourgeois Olivier - Saminadayar Laurent
Recycling of end of life REFeB (RE=rare earth) magnets for RE recovery	Rivoirard Sophie - Julien Leclaire
Recycling of end of life NdFeB magnets	Rivoirard Sophie
Repulsion par effet Casimir : peut-on faire léviter des microparticules par effet Casimir acoustique ? /M2	Poulain Cédric
Search of high temperature superconductivity in bulk nickelates	Lepoittevin Christophe - Toulemonde Pierre
Superconducting qubits	Olivier Buisson
Search for superconductivity under pressure in mono and bi-layer graphene	Nunez-Regueiro Manuel
Transport quantique de la chaleur à très basse température : vers la manipulation d'un phonon unique à l'échelle nanométrique	Bourgeois Olivier et Saminadayar Laurent
2D superconductivity in cuprate oxychlorides	D'Astuto Matteo - Chaix Laura

MASTER 1

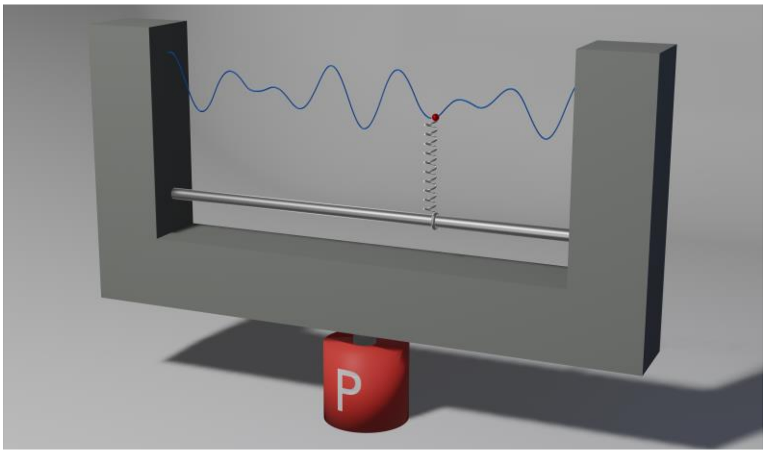
INSTITUT NEEL Grenoble

Proposition de stage Master 1 - Année universitaire 2020-2021

Mise en évidence expérimentale d'une dualité onde-particule à macro-échelle

La mécanique quantique dans son ensemble repose sur la célèbre dualité quantique impulsée par Louis de Broglie en 1927, étendant aux ondes de matière la dualité déjà proposé par Einstein pour les photons quelques années auparavant. L. de Broglie décrit une particule massique comme une horloge, de fréquence et d'énergie bien déterminée. En s'appuyant sur la relativité restreinte, il montre que cette horloge doit rester en phase avec une onde de phase, l'onde de la mécanique quantique, ouvrant la voie à la célèbre équation de Shrodinger.

Dans l'équipe, nous avons proposé récemment (cf lien vers article en bas de page) un modèle acoustique (donc classique) se comportant dans une très large mesure comme un système quantique.



Plus précisément, un oscillateur jouant le role de la particule-horloge et porté par une corde vibrante (cf figure) obéit à des équations du mouvement s'apparentant à un système quantique unidimensionnel.

Ce modèle-jouet permet en effet de faire surgir une onde de phase, ainsi que la fameuse dualité entre l'oscillateur et le champ, associée à une équation de Schrodinger.

Sujet exact, moyens disponibles :
Au cours de ce stage, nous nous proposons de réaliser pour la première fois cette expérience, très proche de celle initialement imaginée par L. de Broglie lui-mme.
Le stage consistera à mettre en place un banc expérimental dans l'esprit de la figure. Des mesures de l'onde de phase et de l'onde de groupe par imagerie ultra rapide et stroboscopie seront réalisées. Il s'agira de démontrer l'harmonie des phases intuitée par L. de Broglie et confirmée dans notre modèle théorique, à savoir le fait que la particule est à chaque instant en phase avec l'onde de phase qui la porte. Un gout prononcé pour la théorie et les fondements de la physique est nécessaire pour mener à bien ce stage.

Une collaborations avec le Pr. Jerome Duplat (UGA / Service des basses températures) ainsi que des interactions nourries avec des chercheurs de l'équipe Nano-Optique et Force (NOF) de Néel (notamment A. Drezet et B. Pigeau) sera mise à profit.

Formation / Compétences :
Master 1 ou 2 en physique ou mécanique. Gout pronomcé pour l'expérimental.

Période envisagée pour le début du stage : Possible à partir de Février 2021

Contact : Poulain Cédric
Institut Néel - CNRS / Tel 04 76 88 74 30, courriel: cedric.poulain@neel.cnrs.fr

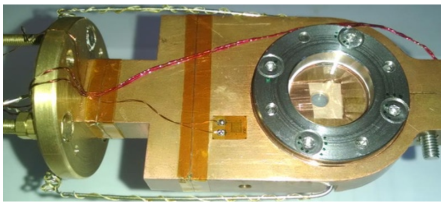
Plus d'informations sur : http://neel.cnrs.fr et https://arxiv.org/abs/2002.08147

NÉEL INSTITUTE Grenoble

Topic for Master 1 internship – Academic year 2020-2021

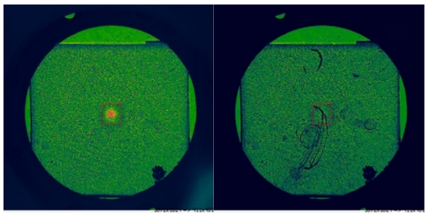
Probing the Classical Nucleation Theory of cavitation with helium

General Scope: Cavitation, the thermally activated nucleation of a vapor bubble in a stretched liquid, is a ubiquitous phenomenon, from engineering to natural sciences. Away from surfaces, cavitation is expected to obey the homogeneous Classical Nucleation Theory (CNT). Up to recently, precise checks only relied on transient, acoustically driven, cavitation. In contrast, an alternative, static, method introduced in 2008 [1], the so-called artificial tree technique, failed to confirm the CNT. Using a forest of such trees, tailored in a nanoporous alumina membrane, we recently provided the first experimental verification of the CNT based on the artificial tree concept [2]. This result opens the way to further studies, such as understanding the influence of nanoconfinement on cavitation, or, using helium as a fluid, the possible influence of quantum effects on cavitation.



Left : Cell for helium measurements.

Right: optical detection of hexane cavitation in an alumina membrane



Research topic and facilities available: The candidate will contribute to the development of cavitation studies of helium at cryogenic temperatures. He/she will take part to experiments on helium cavitation in nanoporous alumina membranes, so as to become familiar with the involved concepts and cryogenics. In parallel, using room temperature hexane as a fluid, and an existing set-up, he/she will test different schemes for building a single artificial tree device, that is a macroscopic cavity connected to the external world through a nanoporous plug [1]. Time permitting, he/she will integrate capacitive measurements of the liquid density and pressure to the device, with the long-term goal of measuring the equation of state of helium at negative pressures down to the cavitation threshold.

Possible collaboration and networking:
This project involves a close collaboration (funded by ANR) with partners in Paris (LPENS and INSP). We also interact with colleagues in Lyon (ILM), Grenoble (LiPhy), in France, and Padova in Italy.

Required skills: A solid background in condensed matter physics (including statistical physics and/or soft matter) is required. The candidate should also have a broad interest for physics and experimental techniques (thermodynamic concepts, materials synthesis and characterization, capacitive and optical measurements, cryogenics, …), be self-motivated and have a strong curiosity about new phenomena.

Starting date: Any time in the year

Contact:
Name: PS. Spathis or P.E. Wolf
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More information: http://neel.cnrs.fr

[1] Wheeler T. D. and Stroock A. D., The transpiration of water at negative pressures in a synthetic tree, Nature 455, 208 (2008).
[2] Doebele V., et al, Direct observation of homogeneous cavitation in nanopores, https://arxiv.org/abs/2007.03521

INSTITUT NÉEL Grenoble

Topic for Master 1 internship – Academic year 2020-2021

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. Recently we obtained puzzling results on their superconducting properties that are highly anisotropic. This could be due to intrinsic properties of the superconducting nature of these materials, which can made pair-density-wave in an electronic structure already modulated by charge-density-wave (also a recent results of our team). Or it could be the result of an intrinsic bi-dimensional electronic structure, that would made them the equivalent, in superconductivity, of graphite for the 2D graphene layers. This anisotropy would be highly unusual and will allow to study 2D phenomenology in a bulk sample, a fascinating possibility.

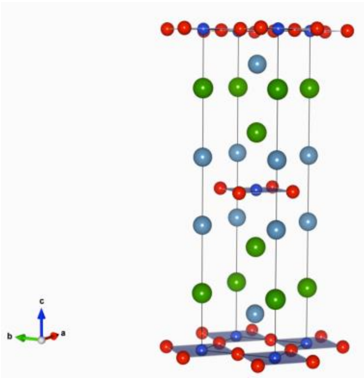


Figure 1: Unit cell of $Ca_2CuO_2Cl_2$ (Cu blue, O red, Cl green, Ca cyan), with the square unit of the CuO_2 plane visible, where the superconductivity take place.

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 this superconducting anisotropy relate with the normal state resistivity one?
During the internship we will start to address part of these questions, using magnetization and resistivity measurements as a function of the crystallographic directions.
Preparation of these experiments will require special care, as these materials are sensitive to air, with a special glove box at the Néel institute. We will also use on-site facilities for crystal growth (large volume press), as well as crystalline (x-ray diffraction) and superconducting (magnetometry/resistivity) characterisation.

Possible collaboration and networking:

Sample synthesis will be made in collaboration with the group of Prof. I. Yamada (Univ. of Osaka, Japan), P. Toulemonde (Inst. Néel) and M. Azuma (Tokyo Inst. Of Technology).

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: Spring 2021 (Standard M1) September 2020 (RIT)

Contact:
Name: D'ASTUTO Matteo, CHAIX Laura
Institut Néel - CNRS
Phone: (+33)(0)4 76 88 12 84e-mail: matteo.dastuto@neel.cnrs.fr , laura.chaix@neel.cnrs.fr

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

MASTER 2

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

AI-assisted 3D image analysis of the microstructure of catalysts to reduce air pollution

General Scope:

The importance of catalysis is unequivocal in terms of economy, the impact on the quality of life, and in the fight against pollutant emissions. Additionally, catalyst is viewed as a key enabling technology, identified as one of the 12 principles of green chemistry. Progress in catalysis has always been motivated by societal needs, such as environment, energy, fuels, with the goal of improving the efficiency of the catalytic process on a technical scale. Technical catalysts are complex multicomponent bodies, ranging from dozens of µm to several cm, consisting of active phases, supports, and additives in shaped forms suitable for their application. They differ strongly from a research catalyst, i.e., the laboratory-developed materials constituted by a single bulk or supported active phase, which are the predominant focus of academic investigations. Yet despite tremendous relevance, understanding the complexity of these catalysts and their structure-property-function relationships has been largely neglected, mainly due to limitations of the characterization techniques. Ptychographic X-ray Computed Tomography (PXCT) is the 3D X-ray nanoimaging technique that overcomes these shortcomings. However, data post-processing to extract physical parameters out of the data is still challenging, but crucial for the optimization of these catalysts in oil-industry.

Research topic and facilities available:

This project comprises, among others, samples of Hydrodesulfurization (HDS) catalysts, and Fluid Catalytic Cracking (FCC) catalysts. Big data volumes obtained from the catalysts in synchrotron facilities will be available. This master project aims at the post-processing of 3D data for efficient quantitative characterization of the morphological structure and composition of the oil-industry technical catalysts using advanced 3D image processing tools and artificial intelligence. The outcome of this work will contribute to the manufacture of more efficient and less expensive catalysts. High-performance computing resources and adapted Python-based software will available for 3D image segmentation, assisted by deep-learning (E.g. UNet, DenseNet, FusionNet), to extract the required physical parameters out of the 3D image data.

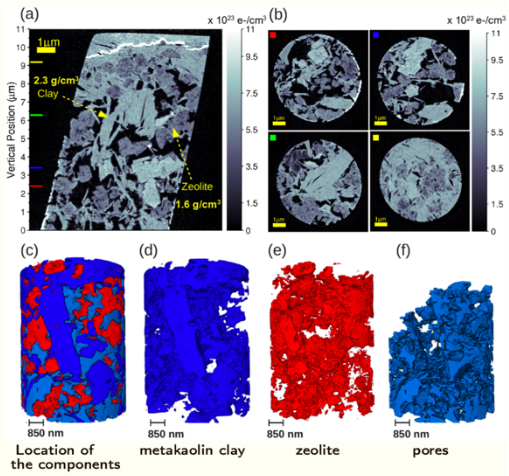


Figure 1 - (a-b) PXCT data obtained with FCC catalyst. (c-f) 3D image segmentation of the different catalyst material phases

Possible collaboration and networking:

The project will be carried out in collaboration including CNRS Institut Néel, French CRG beamlines at ESRF (FR), and KAUST catalysis center (KCC), Saudi Arabia. The 3D data will come from different synchrotron source facilities. Additionally, Grenoble is an important scientific hub hosting important research institution and technological companies

Possible extension as a PhD:

Depending on the intern performance and interest, there is a possible extension as a PhD if funding for a PhD thesis is obtained via a research project grant (already submitted) or Ph.D. contract award by the Physics Graduate School of University Grenoble Alpes.

Required skills:

Master in Physics, Chemistry, Materials sciences, Digital signal processing, or related domains. Scientific programming and/or image processing skills will be an asset.

Starting date: February 2021

Contact:

Name: Julio Cesar DA SILVA
Institut Néel – CNRS, PLUM department
Phone: +33 4 76 88 74 11 e-mail: julio-cesar.da-silva@neel.cnrs.fr

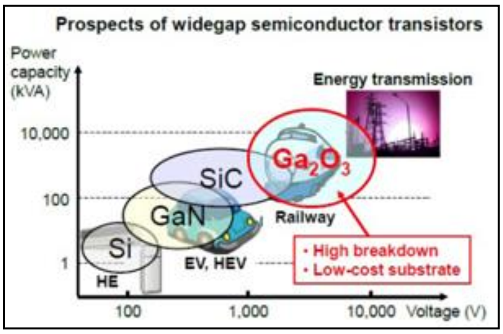
More information: http://neel.cnrs.fr

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2020-2021

Caractérisation électrique et électro-optique de composants à base de semi-conducteurs à ultra large bande interdite

Cadre général :



Les semi-conducteurs à large bande interdite (SiC et GaN) et ultra large bande interdite (Ga_2O_3, diamant et AlN) sont étudiés pour proposer des composants de puissance et de radiofréquence supportant de hautes tensions (plusieurs kV) à haute température et permettant des commutations à haute fréquence (au-delà de la centaine de GHz). Alors que le SiC a aujourd'hui atteint une maturité industrielle et que le GaN commence à entrer en phase de production, les autres matériaux à ultra large bande interdite, pressentis pour repousser les limites des performances des composants, nécessitent encore un effort de recherche. Des défauts électriquement actifs sont formés pendant la croissance des couches semi-conductrices et au cours des étapes technologiques de fabrication des dispositifs. Capturant des charges électriques, ces défauts réduisent les capacités de fonctionnement statiques et dynamiques des composants (diodes et transistors).

Sujet exact, moyens disponibles :
L'objectif du stage est de détecter les défauts électriquement actifs dans les couches actives des composants par des mesures de courant-tension, capacité-tension, spectroscopie de transitoires de niveaux profonds électrique et optique, spectroscopie d'admittance, etc… Ces différentes techniques permettent de déterminer la signature électrique des défauts, leur concentration et leur localisation. Ce travail s'inscrit dans le cadre de programmes collaboratifs dans lesquels l'Institut Néel est engagé au niveau national et international. Des composants en diamant et en Ga_2O_3 seront étudiés pendant le stage.

Interactions et collaborations éventuelles :
DiamFab
Université de Tsukuba (Japon)

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

Période envisagée pour le début du stage :
Avril 2021

Contact :

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04 76 88 74 64
philippe.ferrandis@neel.cnrs.fr

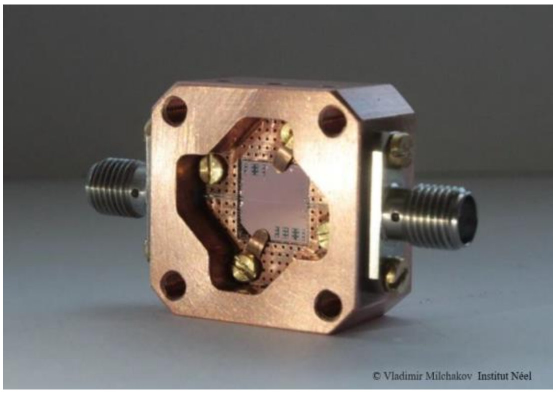
Plus d'informations sur : http://neel.cnrs.fr

NÉEL institut

NÉEL INSTITUTE Grenoble
Topic for Master 2 internship – Academic year 2020-2021

Circuit-QED: quantum limited microwave amplification

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).



Picture of a quantum-limited amplifier and its copper housing. From [2]

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).

Measuring these microwave photons with very high quantum efficiency remains a tremendous challenge, since the energy conveyed by a single microwave photon is hundreds thousand times smaller than the one of usual optical photons. Yet signals at the single-photon level can be measured using Josephson parametric amplifiers. In our team we are now using superconducting metamaterials (see figure) to engineer the next generation of parametric amplifiers [1]. These new devices allow us to explore the quantum limits of amplification [2,3], to read out superconducting qubits with very high fidelity [4] as well as to perform microwave quantum optics experiments.

[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] *Physics* Synopis: A Simple Solution for Microwave Amplification.
[4] 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).

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 the theoretical modeling of the superconducting parametric amplifier. She/He will then carry out the measurements of the device at very low temperature (20mK), using one of the four fully equipped dilution refrigerators of the team. 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. R. Vijay at TIFR, Mumbai, India, and Prof. I. Pop at KIT, Karlsruhe, Germany.

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 Josephson parametric amplifiers.

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 2020-2021

Coupling molecular spin qubits to superconducting circuits

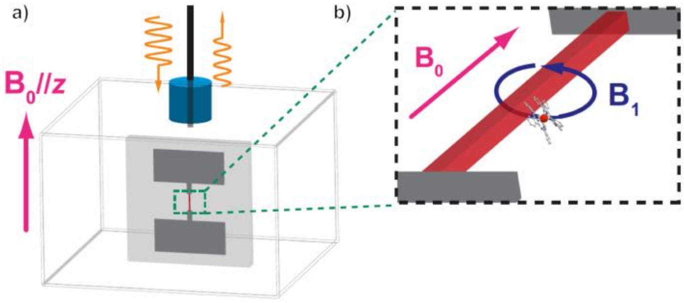


Fig.: extracted and adapted from Haikka et al., Phys. Rev. A (2017). a) 3D microwave cavity in which the superconducting resonator is integrated. b) The superconducting LC resonator consisting of 2 pads (capacitance C) and a nanowire (inductance L), interacts with a single magnetic moment carried by a molecular magnet.

Context: The realization of an operational quantum computer is one of the most ambitious technological goals of today's scientists. In this regard, the basic building block is generally composed of a two-level quantum system (a quantum bit). It must be fully controllable and measurable, which requires a connection to the macroscopic world. Among the different solid-state candidates, spin based devices are very attractive since they already exhibit long coherence times. Electrons possessing a spin 1/2 are conventionally thought as the natural carriers of quantum information, but alternative concepts make use of the outstanding properties of molecular magnets. In our team, we fabricate, characterize and study molecular spin qubits in order to manipulate them [1] and read them out [2] to perform quantum operations [3]. A current major limitation of our architecture is the readout speed. By coupling molecular spin qubits to superconducting resonators, we aim to improve readout speed by several orders of magnitude, and possibly enable the coupling of distant qubits via microwave photons.

[1] S. Thiele, F. Balestro, R. Ballou, S. Klyatskaya, M. Ruben, W. Wernsdorfer, Science 2014.
[2] R. Vincent, S. Klyatskaya, M. Ruben, W. Wernsdorfer, F. Balestro. Nature 2012.
[3] C. Godfrin, R. Ballou, S. Klyatskaya, M. Ruben,W. Wernsdorfer, F. Balestro, Phys. Rev. Lett. 2018.

Research topic and facilities available: We will first design, fabricate and characterize microwave resonators made out of superconducting materials that are resilient to magnetic fields. Molecular magnets will then be deposited on the resonators and external magnetic fields will be used to measure the spin-photon coupling rates and perform spin readout. The student will fabricate the samples using the clean room facilities of the Néel Institute. She/he will carry out the measurements of the device at very low temperature (20mK), using one of the five fully equipped dilution refrigerators of the team.

Possible collaboration and networking: This multidisciplinary research field is based on years of collaborations with teams from different scientific and technical cultures (cleanroom, technicians, collaborations with chemists and theoreticians, etc), in the framework of European projects and different national and regional funding.

Possible extension as a PhD: Yes

Required skills: We are looking for a motivated student who is interested in experiments that are challenging from the experimental point of view.

Starting date: Flexible

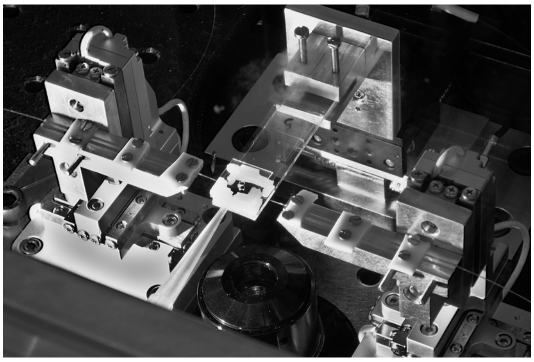
Contact:
Franck Balestro, Phone: +33 4 76 88 79 15 e-mail: franck.balestro@neel.cnrs.fr
Jeremie Viennot, Phone: +33 4 76 88 79 05 e-mail: jeremie.viennot@neel.cnrs.fr
Institut Néel – CNRS-UGA. More information: http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Development of a Fibered Photonic Force Microscope

General Scope: Since their introduction in 1986, optical tweezers become a standard tool for non-invasive manipulation in microbiology, chemistry, and solid state physics. The importance of this device was underlined by the attribution of the Nobel Prize 2018 to Athur Ashkin, the "Inventor" of the optical tweezers. One less known application of optical tweezers is the Photonic Force Microscope (PhFM). This device allows to measure a surface topology with sub-micron resolution by measuring the shift of a trapped object during scanning over the surface. Its principle is quite similar to that of an Atomic Force Microscope (AFM). In contrast to the AFM, the very small magnitude of the optical forces allows us, however, to characterize very soft samples, thus us biological cells.



Optical Tweezers setup developed at Institut Néel.

In this context we are developing an optical fiber based Photonic Force Microscope. This original approach allows us to overcome one of the major limitations of the actually developed PhFM, i.e. the optical aberrations due to trapping laser beam scattering by the studied sample. This effect alters the trapping properties/ efficiency and interferes with the trapped particle position measurement. In a fiber based PhFM, the trapping laser beam does not transmit through the sample. Moreover, the particle position can be precisely measured by means of the back-reflection of the trapping laser by the trapped particle, which automatically will be coupled into the optical fiber.

Research topic and facilities available: In a first step the student will characterize the optical trapping of micro- and nano-spheres using an original nano-structured optical fiber, allowing us to trap with one single fiber. Special concern will be given to the back-scattered signal which will allow to measure the forces impinging on the trapped particles. In a second step, the student will study trapping of original nano-structured particles. The cylindrical particles with an sharp point at one side allows to significantly increase the lateral resolution of the PhFM. It is intended that at the end of the training first results with "real" samples are obtained. During the training, the student will participate in the optimization of to existing optical tweezers setup for the specific requirements of the future PhFM.

Possible collaboration and networking: This work is part of an ongoing collaboration with the University Stuttgart, Germany and a starting collaboration with University Montpelier.

Possible extension as a PhD: Yes

Required skills: Knowledge in optics/ photonics including integrated optics, fiber optics and optical trapping. The student should also have skills in optics experiments and basic knowledge in LabView-programming would be useful.

Starting date: free, as a function of the students program.

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NÉEL INSTITUTE Grenoble

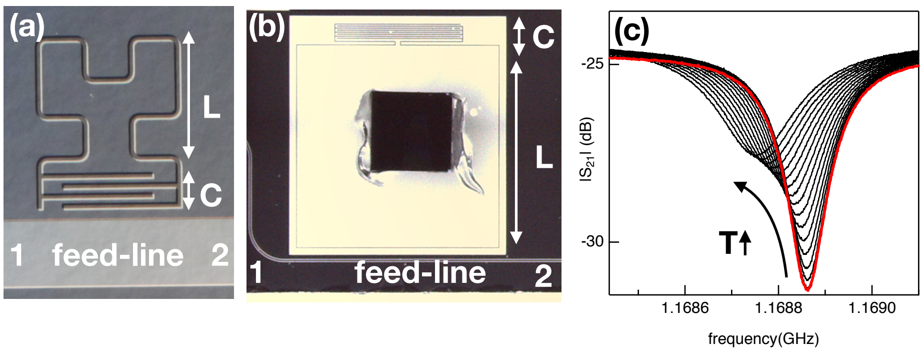
Topic for Master 2 internship – Academic year 2020-2021

Electrodynamics of Superconductors investigated by resonant cavity measurements.

General Scope:
Superconductivity is a 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.

Counterintuitively the materials achieving the highest critical temperatures at ambiant pressure are not the metallic ones, but rather ceramic materials: the high temperature superconductors or cuprates. A priori, the conventional electron-phonon coupling mechanism cannot explain such high critical temperatures. Unraveling the mystery of the physical mechanism leading to high temperature superconductivity remains one of the most challenging issues of modern solid-state physics.

Research topic and facilities available:
The phD student will look at an unconventional heavy fermions superconductor: UPt3 by means of two techniques of resonant cavity measurements. Such measurements give access to the electrodynamics of superconductors. The electrodynamics is very fundamental because it is directly related to the density of electrons forming the superfluid condensate and the density of quasi-particles generating dissipation. Its provides information on the symmetry of the superconducting order parameter ans thus hint on the probable glue.



Caption of the figure : Superconducting LC circuit probes the high frequency conductivity the superconducting thin films. The LC circuit can be directly etched in the film (panel a). An alternative way, is to disturb a LC circuit made of NbN by placing the superconducting sample at the center of the circuit (panel b). Panel (c) shows a typical measurement of the transmission of the feed-line at various temperature (from 100mK to 900mK by step of 50mK).

Possible extension as a PhD: yes

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

Starting date: March or April 2021

Contact: Institut Néel - CNRS :
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Pierre Rodière, 04 76 88 10 26, pierre.rodiere@neel.cnrs.fr

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NÉEL INSTITUTE Grenoble

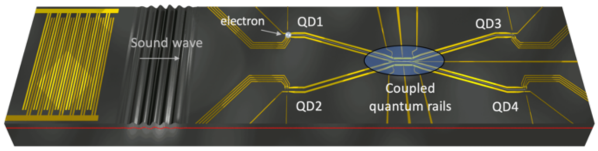
Topic for Master 2 internship – Academic year 2020-2021

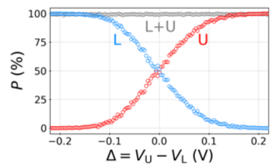
Electronic flying qubits

General Scope: Control and coherent manipulation of single electrons is one of the important ingredients towards single electron circuitry as well as the realization of flying qubit architectures using single electrons.

With this M2 internship project we would like to explore a novel platform for quantum electron optics with the goal of bringing it to the level of its photonic counterpart. The advantage of performing quantum optics experiments with flying electrons is the existing Coulomb coupling between the electrons. Photons are basically non-interacting quantum particles and they therefore have a longer coherence time than electrons. However, due to the absence of interactions it is more difficult to construct a two-qubit gate, which operates at the single-photon level.

We will leverage on the recent progress on single-electron transport using surface acoustic waves (SAW) and we propose to develop coherent control of single flying electrons in waveguide nanostructures. This will on the one hand open the possibility to perform quantum optics experiments at *the single-electron level* and on the other hand lay the grounds to exploit this novel system in quantum technologies.





Schematic (top) of a quantum device allowing to realizeof a tunable beam splitter for sound-driven single electrons. Gate electrodes (in yellow) at the surface of a semiconductor define the quantum circuit. The electron initially trapped in the upper source quantum (QD1) dot is partitioned at will in the coupled quantum rails. Right: Transfer probability P of an electron ending up in the upper/lower receiver quantum dot (QD3/QD4) (*see S. Takada et al., Nature Communication 2019*)

Research topic: The aim of the proposed M2 internship is to participate in an ongoing research project to realize flying qubit architectures by propelling single electrons with sound. The fact that electrons transported by sound waves travel 5 orders of magnitude slower than the speed of light allows to implement real-time manipulation of the quantum state of the electrons “in-flight”. This novel real-time control will be developed during the Masters project within the QUANTECA team of the Néel Institute.

References:

- Hermelin et al., Nature **477**, 435 (2011); Bertrand et al, Nature Nanotechnology **11**, 672 (2016), Takada et al., Nature Communications **10**, 4557 (2019)

Possible collaboration and networking: This project is realized in close collaboration with the Quantum Metrology laboratory (NMJI-AIST), Tsukuba, Japan and the theory group of CEA Grenoble (X. Waintal)

Possible extension as a PhD: yes

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: open (preferentially beginning 2021)

Contact:

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Topic for Master 2 internship – Academic year 2020-2021

Graphene based superconducting quantum bit

General Scope:
The future of nanoelectronics will be quantum. The downscaling in electronics has now reached a point where the size of the devices (less than 10 nm) means that their quantum behavior must be taken into account. While this might be seen by some industries as a major problem this also gives a real opportunity to imagine and build devices with new quantum functionalities.
A key building block for future quantum electronics systems is the quantum bit (Qubit). Such system has two possible states (0 and 1) that follow the laws of quantum mechanics. One example is that one might build any superposition of 0 and 1. This will have implications for building future quantum computers.
Research topic and facilities available:
In this work we will build a new type of device to implement a Qubit that would have strong advantages over other competing systems. We will use the know-how that has been developed in the superconducting Qubit community over the past 20 years and integrate in the core of the system a semiconducting material to bring novel electrical functionality to the device, in the form of a voltage-tunable energy. We will use graphene, a two-dimensional zero-band-gap semiconductor, because of the potential scalability of such approach. Such device is expected to behave as a quantum two-level system with an energy structure that can be tuned with an electric field (gate) thanks to graphene (see figure).
A one atom-thick sheet of graphene will thus have to be integrated into a superconducting Qubit design 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. After the demonstration of the electrical tunability, more advanced measurements will be carried out in the following PhD project: lifetime, coherence, coherent manipulation...

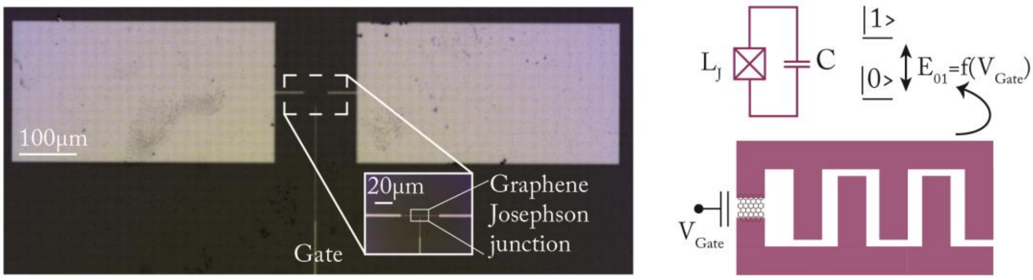

Figure 1: Optical image of the first generation of graphene based superconducting qubit. The graphene link (Josephson junction), 200nm long, is not visible at this scale. On the right, the equivalent electrical circuit shows that this device will behave as an electrically tunable quantum two-level system.

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, Switzerland, Germany, Canada).
Possible extension as a PhD: Yes (already funded)
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 2021 (Flexible)
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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

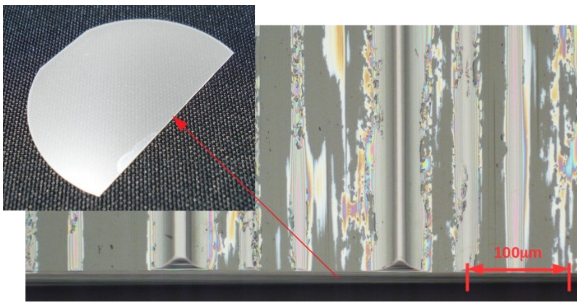
Guided interactions with rare-earth luminescent centers for quantum information processing

General Scope:

Rare-earth ions because of their unique 4f electronic configuration form well isolated systems when embedded in solids. They have long coherence time at low temperature making them highly promising qubits for the development of quantum technologies. Their optical transitions can now be used as a support for optical quantum memories and more generally as a fast and versatile element of control on the qubit. Their technology perspectives are so far limited by the available host material which are bulk optical crystals containing rare-earth as low concentration impurities. Higher integration is desired not only to improve the readiness level of quantum technologies but also to obtain a stronger optical and RF coupling leading to a faster operation time. In this project, we propose to investigate experimentally a new platform for rare-earth based quantum processing by considering epitaxial semiconductors as host matrices instead of bulk oxides

Research topic and facilities available:

The growth and fabrication of III-V semiconductors (see figure) inheriting from years of development in electronics allow to access micro- and nano-size samples. Bulk devices can now be compacted by three orders of magnitude allowing a stronger (optical and RF) fields confinement and a much faster qubit control as a consequence.



GaN on sapphire template (left) grown at CEA. Zoom: Ridge waveguide fabricated by diamond saw dicing

GaN wafers are first grown at CEA/IRIG. The semiconductor layer is then implanted with rare-earth dopants and further studied by spectroscopy at low temperature. We are also considering in parallel advanced nanofabrication technique to produce active nanophotonic structures. At the start of the project and depending on the expectation and the skills of the candidate, the internship can be oriented toward the sample growth and nanofabrication (material science) and/or the design of the optical setup to probe thin epitaxial films (optical spectroscopy).

Possible collaboration and networking: M. Hocevar (Néel), B. Daudin (CEA/IRIG)

Possible extension as a PhD: YES

Required skills: Experimental skills in (at least) one of the following fields: optics, material science and engineering, nanofabrication.

Starting date: between January and April 2021

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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

HiggS mode in Superconductors

General Scope:

When a spontaneous breaking of a continuous symmetry takes place, for instance when crossing the normal to **superconducting** transition, collective excitations of the order parameter emerge:
They are the phase modes and the massive **amplitude Higgs mode** (red arrow in Fig.1).
A mode of Higgs type, of crucial importance in the standard model of elementary particle physics, is also a fundamental collective mode in quantum many-body systems. It is remarkable that such collective Higgs modes predicted by theory many years ago, and lying at the core of the electronic properties of several classes of materials (cold atoms, superconductor, magnetic materials ...) still remain elusive to experimental validation. Even though a theoretical textbook mode, experimental observations of the collective amplitude mode in superconducting materials are scarce and still controversial. Besides, in superconductors, many outstanding and still open questions can be addressed through the study of these Higgs modes. Our purpose is to search for and to reveal the nature of new Higgs mode in condensed matter compounds. It will provide some textbook experimental examples and will help to address fundamental questions in the field of superconductivity and beyond.

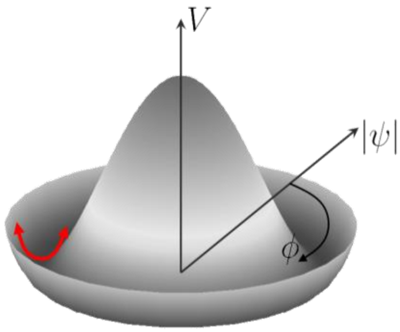

***Fig.1**: Mexican-hat-shaped potential of the free energy as a function of the complex order parameter.There are two types of fundamental collective mode around the new equilibrium state taken spontaneously in the line of minima. One, the amplitude mode in red, is known as a "dark" mode and is the analogous of the Higgs boson. In superconductor, it corresponds to coherent oscillatory pairings and depairings of the Cooper pairs of electrons, the building blocks of this state. Quest of such Higgs mode is at the heart of the Master2-PhD project.*

Research topic and facilities available:
Circumstances of observability of Higgs modes in Superconductors mainly include the presence of an electron-phonon-coupled quantum order, such as charge density wave, coexisting with superconductivity and whose collective mode couples to the Higgs one and makes it Raman active. Up to now, measurements are limited to few compounds in the $NbSe_2$ family. The Master 2 student will investigate new family of compounds thanks to state-of-the-art Raman spectroscopy experiments under extreme conditions of low temperature and high pressure. The facilities will include a new Raman set-up, cryogenics systems and high pressure Diamond Anvils cells. The student will be encompassed in a new ERC project, starting in December 2020. He/she will participate to new technical developments while being able to use present apparatus.

Possible collaboration and networking:
The whole project is included in the ERC project $HiggS^2$, with collaborations in Germany (KIT), Italy (ISC/Roma), UK(Oxford), Netherlands (Nijmegen/High field facility), as well as in-lab collaborations (materials, 2D systems, CDW systems). Networking: $HiggS^2$ ERC project.

Possible extension as a PhD: YES. Recently financed European ERC project.

Required skills: knowledge of condensed matter physics, curiosity, taste for delicate experiments.

Starting date: 2021

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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

High temperature superconducting oxychlorides: a light element model for cuprates

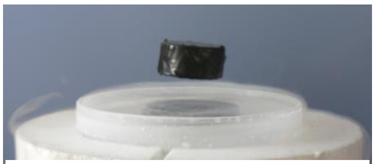

Figure 1: Cuprates allows exploiting magnetic levitation above the liquid Nitrogen temperature, as shown in the picture (Mai-Linh Doan wikimedia commons, © Creative commons).

General Scope: Cuprates were discovered in 1986 to show superconductivity at the highest temperature at ambient pressure, a record they still detain (see figure), but their phenomenology apparently cannot be grabbed by present theory, so that they are considered among the main unsolved problems in physics today. In this context, the discovery of the Na and vacancy doped $Ca_2CuO_2Cl_2$ oxychloride is very promising indeed to bridge the gap between theory and experiment since it: lacks high *Z* atoms; has a simplest crystalline structure for cuprates, stable at all doping and temperatures; and has a strong 2D character due to the replacement of apical oxygen with chlorine. Therefore, advanced calculations that incorporate correlation effects, such as quantum Dynamical Mean Field Theory (DMFT) are easier. However, relatively little is known about $Ca_2CuO_2Cl_2$ from an experimental point of view. We are now filling this gap by a comprehensive experimental study covering the whole phase diagram, in particular of the magnon and phonon dispersion as well as their electronic structure, using advanced approaches based on synchrotron and laboratory spectroscopies.

Research topic and facilities available: During the internship we will complete recent Angle-Resolved-Photoemission-Spectroscopy (ARPES) experiment we have done at Photon Factory (Tsukuba, Japan), to compare with DMTF calculation performed by the group of S. Biermann (Ecole Polytechnique and Collège de France).
In the framework of the PhD project, in order to unveil their electronic properties at a microscopic level, most of the experiments will be planned at synchrotron facilities in Europe and around the world, mainly at ESRF (Grenoble) and SOLEIL (Paris region), together with measurements, at the Instit. Néel, using point contact spectroscopy, in collaboration with H. Cercellier.
Preparation of these experiments will require special care, as the materials are sensitive to air, with a special glove box at the Néel institute, and we will use its facility also for crystal growth (large volume press), as well as crystalline (x-ray diffraction) and superconducting (magnetometry) characterisation.

Possible collaboration and networking: Interpretation of the results will be made in collaboration with group performing *ab-initio* electronic structure calculation including correlation effects in Paris (S. Biermann, Ecole Polytechnique) and USA (L. K. Wagner, University of Illinois, Urbana). Sample synthesis will be made in collaboration with the group of Prof. I. Yamada (Univ. of Osaka, Japan), P. Toulemonde (Inst. Néel) and M. Azuma (Tokyo Inst. Of Technology). Part of the synchrotron spectroscopy studies will be performed in collaboration with L. Chaix and H. Cercellier (Inst. Néel) and M. Dean (Brookhaven National Laboratory).

Possible extension as a PhD: Yes, this project is part of a PhD program, of which this Master Internship could be a first approach.

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 2020

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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2019-2020

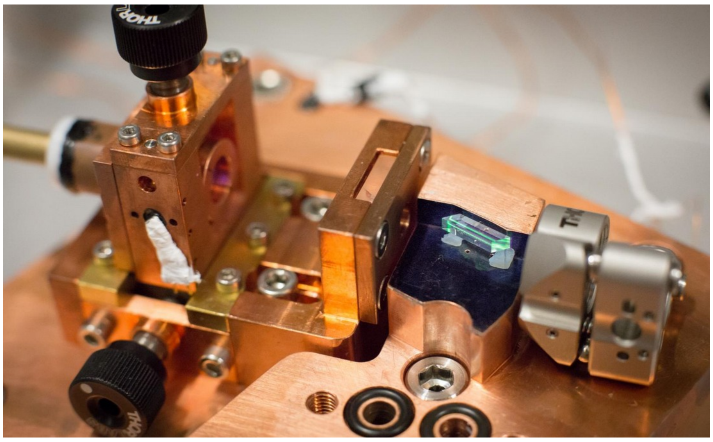
Laser cooling of solids for a new generation of spatial cryocooler

General Scope:

Laser cooling is a full-optical way to extract heat from a solid by pumping optical transitions of rare-earth ions embedded in a crystal matrix. It is seen as a breakthrough technology for a new generation of vibration-free cryocoolers in the ~ 100 K temperature range which are required in many low-earth observation satellite missions.

Research topic and facilities available:

Lasercooling crystals are grown by our colleagues from Pisa University. They are made of Yttrium Lithium Fluoride (YLF) and are doped with Yb rare-earth ions. We have built an experimental setup in order to implement cooling of a crystal in vacuum. The setup is compact and fiber coupled to a laser source in order to meet the criteria for spatial integration.



Lasercooling setup in Grenoble. The cristal is crossed by a 1020nm laser and emits green light under excitation. Under vacuum one is able to cool it down to 110K with 20W of laser power.

During her/his internship the student will have the opportunity to work with the complete setup on the first cooling tests. Numerical simulations by finite-element software will also be undertaken in order to prepare the evolution of the setup.

Collaboration and networking:

Air Liquide Advanced Technologies (Sassenage)
University of Pisa (Italy)

Possible extension as a PhD: current application for a grant.

Required skills: good knowledge of optics, interest for experimental physics
Starting date: any date starting January 2020
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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Low-dose EDT for highly sensitive MOFs

General Scope:

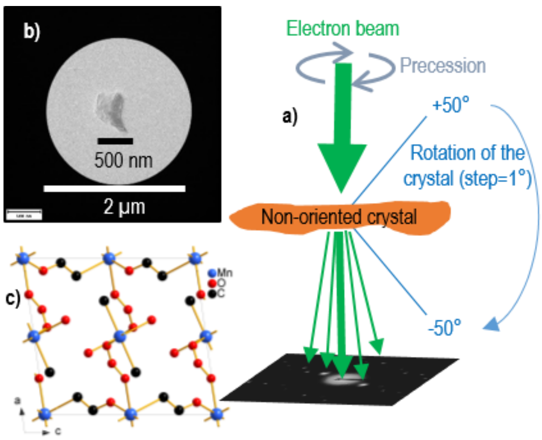
Metal-organic frameworks (MOFs) are materials that can be tailored for their structure and properties by assembling organic functional molecules with metal atoms. The wide range of different MOFs have enabled their use in numerous applications including catalysis, storage of fuels (hydrogen, methane), capture of carbon dioxide, proton conductors for fuel cells, photovoltaics, sensors and electronic materials. In recent years, there is an almost exponential increase of MOF structures in the Cambridge Structural Database (CSD) so that there is no doubt that they will be one of the most important material classes for innovation in the future. The development of these materials is closely dependant on structural characterizations but for most MOFs it is notoriously difficult to obtain large enough crystals of sufficient quality for X-ray structure analysis. Thus, there is a great number of highly interesting compounds that have not yet been studied because of the difficulty of determining their structures. We have recently developed a low-dose electron diffraction tomography (LD-EDT) technique that is well adapted to such difficult materials. In this internship the student will be trained to use the TEM and to apply LD-EDT to different MOFs. The goal is to optimize the experimental parameters of the technique and to solve the structures of relevant MOFs synthesized by our collaborators in Lyon.

Research topic and facilities available:

The goal of this internship is to apply low-dose electron diffraction tomography to study the atomic structure of these sensitive materials. The internship will include several stages:

- Performing electron diffraction experiments under these conditions on MOFs in order to solve their structures.
- Investigation of the optimal experimental conditions yielding the highest quality structure solutions.
- Solving the structures of MOFs from the LD-EDT data.

In the framework of a collaboration the MOFs are synthesized by D. Luneau in Lyon and will be studied for their structure in the Néel Institute. The intern will be trained in the use of the transmission electron microscope of the Néel Institute. He/she will acquire diffraction data and perform the complete data treatment using specific computer programs that are available at the Néel Institute, which should lead to the resolution of the structures.



Possible collaboration and networking:

The intern will be integrated into the electron microscopy group of the Néel Institute. He/she will collaborate with the chemists that synthesize the materials and the X-ray crystallographers of the Néel Institute.

Possible extension as a PhD: Yes

Required skills: Master in Physics, Solid state chemistry, instrumental physics. Basic knowledge in crystallography and diffraction

Starting date: 2021

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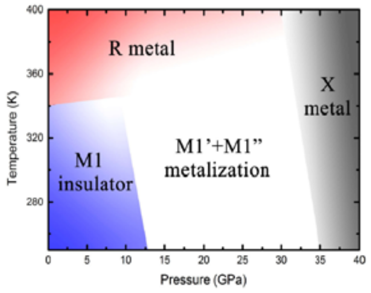
Proposition de stage Master 2 - Année universitaire 2020-2021

Métallisation de VO_2 sous pression



Cadre général :
L'oxyde de vanadium, VO_2, est un composé très connu, notamment parce qu'il présente une transition isolant/métal réversible proche de la température ambiante, qui permet d'envisager son utilisation, dans des dispositifs électroniques (interrupteur thermique) ou des réflecteurs optiques (le passage vers l'état métallique modifie la réflectivité du matériau dans le visible). Malgré une littérature abondante depuis plus de 70 ans, les aspects microscopiques associés à cette transition ne sont toujours pas bien compris. Le passage d'une structure monoclinique (M1 zone bleue du diagramme de phases) vers une structure quadratique (Rutile R zone rouge) modifie l'appariement des paires de vanadium et conduit à former des chaines d'atomes sur lesquelles les électrons peuvent se déplacer. L'application d'une pression, en réduisant les distances entre les paires de vanadium, est susceptible de produire des déplacements d'atomes qui conduisent à la métallisation de l'oxyde VO_2, cependant il n'existe pas, dans la littérature, de données structurales fiables en pression et en température.

Sujet exact, moyens disponibles :
Le projet est donc d'explorer le diagramme de phase par spectrométrie Raman pour caractériser les changements de symétrie en mesurant les phonons optiques mais aussi les structures par diffraction de rayons X et de coupler ces mesures avec des observations optiques en cellule à enclumes de diamant. Nous axerons nos études sur la caractérisation et la compréhension des structures des phases M_1', M_1'' et X sous pression. Il sera particulièrement intéressant de vérifier la présence d'un dôme dans le diagramme de phase. Il a été proposé que la pente dT/dP positive de la frontière M_1/R à basse pression devient négative au-dessus de 15GPa. Cette singularité laisserait présager que la phase métallique haute température pourrait être observée à température ambiante sous haute pression et pourrait correspondre à la phase X. Nous utiliserons les cellules à enclumes de diamant jusqu'à 50GPa et 300°C pour explorer le diagramme de phase de monocristaux de VO_2.

Interactions et collaborations éventuelles :
Des mesures par diffraction de RX au synchrotron (ESRF) seront peut-être envisagées.

Ce stage pourra se poursuivre par une thèse (ou **ce sujet est limité à un stage M2**...).
Une demande de financement ANR sera proposée en 2020. Elle pourra permettre de prolonger en thèse. Une demande de financement via une bourse ministérielle sera aussi envisagée.

Formation / Compétences :
Etudiant physicien ayant des connaissances solides en physique et chimie du solide. Maitrise des interactions Lumière Matière est nécessaire pour la résolution des structures par les méthodes de dynamique des phonons et de diffraction de RX.

Période envisagée pour le début du stage : 2021 mars/avril/mai/juin

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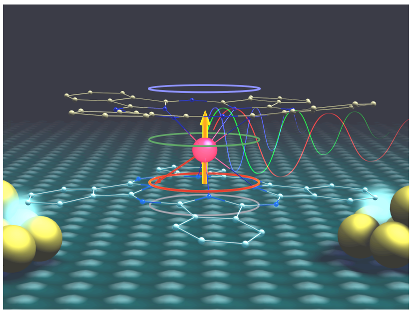
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Title: Molecular spin devices for quantum information processing

General Scope:



For some decades, significant efforts have been invested in quantum information research, with the promise to revolutionise the way information is stored and processed. The strength of quantum computing lies in the possibility of using a coherent superposition of states, and interference between them, which enables a class of algorithms that are not accessible to classical computers. To achieve the fabrication of quantum computers, the first step is to realise a quantum bit. It must be fully controllable and measurable, which requires a connection to the macroscopic world. In this context, solid state devices, which establish electrical connections to the qubit are of high interest. However, beyond the usual two-level encoding capacity of qubits, multilevel quantum systems (also known as qu*d*its with "*d*" being the number of available states) are a promising way to extend and increase the amount of information that can be stored in the same number of quantum objects. In this context, magnetic molecules possessing magnetic memory, better known as Single Molecule Magnets (SMMs), are a promising platform to create spin qudits. Towards this goal, the team combines the different disciplines of spintronics, molecular electronics, and quantum information processing. In particular, we fabricate, characterize and study molecular spin-transistor in order to manipulate[1] and read-out an individual spin[2] to perform quantum operations[3].

[1] S. Thiele, F. Balestro, R. Ballou, S. Klyatskaya, M. Ruben, W. Wernsdorfer, *Science* **2014.**

[2] R. Vincent, S. Klyatskaya, M. Ruben, W. Wernsdorfer, F. Balestro. *Nature* **2012**.

[3] C. Godfrin, R. Ballou, S. Klyatskaya, M. Ruben, W. Wernsdorfer, F. Balestro, *Phys. Rev. Lett.* **2018.**

Research topic and facilities available: Nano-devices addressing single molecular spins will be fabricated and characterized. The team has a strong experience in molecular magnetism, nanofabrication, ultra-low noise transport measurements, microwave electronics and cryogenic equipment. Single molecular units are embedded in scalable electronic circuits and individual spin read out will be performed. The key experiment will be the demonstration of two qubit gate to complete the set of universal gates for scalable architectures. The student will fabricate the samples using the clean room facilities of the Néel Institut. She/he will carry out the measurements of the device at very low temperature (20mK), in order to create, characterize and manipulate single spin using spin based molecular quantum dot.

Possible collaboration and networking: This multidisciplinary research field is based on years of collaborations with teams from different scientific and technical cultures (cleanroom, technicians, collaborations with chemists and theoreticians, ...), in the framework of European projects and different national and regional funding.

Possible extension as a PhD: Yes

Required skills: We are looking for a motivated student who is interested in experiments that are challenging from the experimental point of view.

Starting date: flexible

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NÉEL INSTITUTE Grenoble

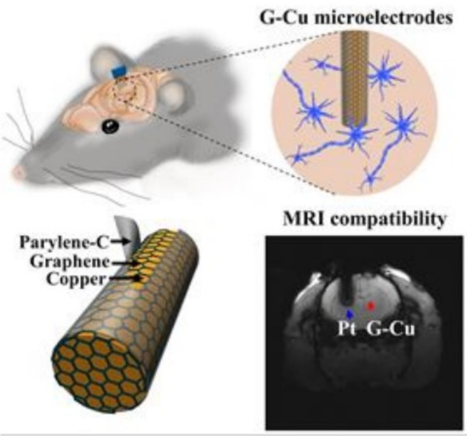
Topic for Master 2 internship – Academic year 2020-2021

Multiscale Brain Interface

The human brain is made up of 100 billion neurons that interact with each other through 100,000 billion connections. While structural maps have reached single cell precision over whole brain, mapping all neuronal signals simultaneously is not achievable today, as those electrical signals are spatially wide spread. In particular, (sub) microscopic mechanisms and their interplays with larger scales remain hidden to the available technology, which impedes to assess all processing abilities of neurons. The aim of the internship is to perform 'pilot' experiment to combine microscale electrical sensing with arrays of graphene field effect transistors (GFETs) and functional Magnetic Resonance Imaging (fMRI) imaging. Signals recorded from neuroimaging data reveals the activity of large assembly of neurons, and are usually complex signals where different frequencies reveals different characteristics of the functioning of the brain. In fMRI, brain connectivity is best evaluated at low frequencies (~0.1Hz). These frequencies are not achievable for standard EEG, but could be obtained with G-FETs. These suitable devices for neural interfaces have demonstrated their ability to detect a wide range of neuronal signals, from slow waves to single spike and ion [1-3]. With the proposed approach, one should therefore be able to simultaneously collect fMRI and electrical low frequency signals, and from there confront them to the mathematical models [4,5].

A first task will focus on the fabrication and characterization of GETs arrays dedicated for long lasting brain recording. Electrical properties of the devices will be followed at the frequencies of interest, and the impact of high magnetic field on the detection performances will be investigated. A second task is to build a dedicated instrumentation of the GFETs array to be compatible with *in-vivo* fMRI measurements, and to characterize the magnetic signature the novel implanted materials. Then, pilots' experiments will be done that combine GFETs recordings and fMRI imaging on anesthetized rodents. Lastly, an important part of the work will be devoted to analyses the recorded signals and confront them to the mathematical models.

The internship is highly interdisciplinary, providing a unique opportunity to combine several expertise (in materials, nano and neuroelectronics, MRI imaging and signal analysis) gathered in three laboratories of Grenoble at Neel Institute, Grenoble Institute of Neurosciences, and Jean Kuntzmann Laboratory. Backgrounds in nanoelectronics or neuro-electrophysiology will be an advantage for the smooth running of the internship.



Schematic of a highly MRI compatible G-Cu neural electrode and the artifact comparison with Pt electrodes of the same size under 7.0 T MRI.

1. Veliev, F. et al. 2D Mater. 5, 045020 (2018).
2. Veliev, F. et al. Front. Neurosci. 11, (2017).
3. Masvidal-Codina, E. et al. Nat. Mater. 18, 280–288 (2019).
4. Achard, S. et al. Phys. Rev. E 77, 036104 (2008).
5. Achard, S. & Gannaz, I. ArXiv181110224 Math Stat (2018).

Right image from Zhao et al., Nano Letters (2016)

Starting date: Jan-Feb 2021 (6 months)

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NÉEL INSTITUTE Grenoble

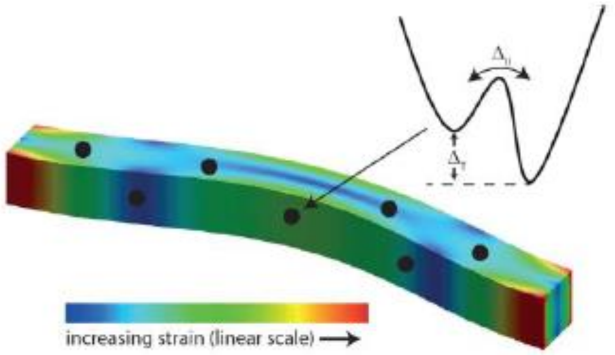
Topic for Master 2 internship – Academic year 2020-2021

Nanomechanics at ultra-low temperatures

General Scope:
The cross-over from atomic-size quantum objects to macroscopic classical systems remains puzzling. We know that macroscopic quantum states exist (e.g. the quantum coherence of the current state in a superconducting loop), but our knowledge is essentially limited to electromagnetic degrees of freedom. Quantum states of moving objects have undergone relatively little experimental study.

Research topic and facilities available:

One of the goals of our research group, to which the intern would contribute, is cooling a glass nanomechanical resonator to the microkelvin range, so that its fundamental mode reaches the quantum ground state. This is essential for probing low energy excitations present in the amorphous lattice of the resonator. New cryogenic technology is required to efficiently carry out this research. In particular, we are developing a continuous nuclear demagnetization refrigerator (CNDR) that will, for the first time, allow measurements below 1 mK on unlimited timescales. Specific activities of the intern will include one or more of the following: development of a superconducting heat switch with ultra-low thermal resistance, which is crucial for the operation of the CNDR; characterization of nanomechanical resonators at low temperatures; characterization of superconducting microwave resonators at low temperatures.



Possible collaboration and networking:
This work may involve collaboration and interactions with researchers at the Institut Néel, elsewhere in Europe, and throughout the world.

Possible extension as a PhD:
Yes

Required skills:
The student should have a strong interest in fundamental research and making challenging measurements at very low temperatures, as well as a thorough understanding of quantum theory at the Master's Degree level.

Starting date: Flexible

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More information: http://uni-glass.eu/

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Non-invasive X-ray powder diffraction and fluorescence measurements on medieval artworks by using an in-house-built mobile instrument

General Scope:
This research topic is proposed within the framework of the UGA Cross Disciplinary Program PATRIMALP (https://patrimalp.univ-grenoble-alpes.fr/patrimalp/), which brings together research laboratories studying ancient artworks. The main objective of this project is to use ancient materials as records of artistic habits and gestures and to track significant traces of the origin of the raw materials, manufacturing processes or degradation over time. Here, we focus on the analysis of relief decorations found on artworks of the late Middle Ages. This form of sophisticated decoration, called "applied brocade", proved to be a very convincing illusionistic polychromy technique to imitate fabrics enriched with gold and silver, created by textile craftsmen in Italy in the 15th and 16th centuries: it is based on a sheet of tin foil pressed into a mould previously incised with the decorative pattern, eventually gilded and painted. Our aim is to perform *non-invasive* X-ray powder diffraction (XRPD) and fluorescence (XRF) measurements of artworks *on site*, by using a mobile instrument developed at Néel Institute. Thanks to such an instrument it becomes possible to reach a chemical and structural characterization of cultural heritage artefacts, paintings, sculptures, etc. without the need to displace them or to take samples.

Research topic and facilities available:
A mobile instrument, designed by the technological group X'Press, in collaboration with the MRS team, has been recently built and used to perform XRF measurements on flat surfaces (mural paintings, figure 1). The M2 student will be in charge of optimizing the XRPD measurements (including on "3D objects" such as sculptures) and to improve the overall data collection strategy. He/She will be also in charge of data processing: analysis of XRF spectra and XRPD patterns in order to identify/quantify chemical elements and crystalline phases. Measurements will be conducted (i) on standard samples at Néel Institute, (ii) on site (in museums and/or churches) according to the progress of the project and the accessibility to artworks.

Figure 1. Mobile instrument in front of mural painting (Saint-Jean de Maurienne cathedral, France, 15th century).

Possible collaboration and networking:
This research topic is proposed within the framework of the ongoing PATRIMALP collaboration, labelled Cross Disciplinary Program by IDEX UGA in 2017, regrouping 7 laboratories and large research facilities in materials sciences, art history, restoration/conservation and informatics.

Possible extension as a PhD:
Yes if a funding source for a PhD thesis is obtained (research project grant or PhD contract awarded by the Physics Graduate School of Grenoble).

Required skills:
- Master 2 de Recherche in physics, materials science, chemistry, or closely related science
- A background in physicochemical analysis techniques (X-ray based technics in particular) is desirable

Starting date: February 2021

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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2019-2020

OPTOMECHANICS WITH A QUANTUM FLUIDS OF LIGHT

General Scope:

Owing to spectacular progress in the design and fabrication of solid states quantum systems, the control one can get over photons has become exquisite. At the individual photons level, semiconductor solid-state systems are nowadays moving from laboratories to the market, in which quantum state of light involving one or two photons can be produced and delivered reliably. At this point, a challenge is now to extend this degree of control and understanding, over large number of photons. This is a much harder task due to many-body decoherence and the complexity of the quantum states involved in many-body systems.

In adequately designed systems, light can be trapped in high-Q solid-state cavities, dressed by electronic excitation to engineer tunable two-body interactions (i.e. excitons), and manipulated by optical means. Recently, in collaboration with our Australian partner (Macquarie Uni., Sydney), we have demonstrated the preparation of non-classical states of light in such a many-body photonic system [G. Muñoz-Matutano et al. *Nature Materials* **18**, 213 (2019)].

Research topic and facilities available:

In this project, we build up on this knowledge to investigate how a quantum fluid of light can be used as a quantum working fluid capable of conveying mechanical forces and producing entropy, both in new ways due to its quantum features and to its nonequilibrium character. We will for instance investigate experimentally the motion of particles travelling within, and/or dragged by, the fluid of light, when it is prepared in one of its possible quantum states (e.g. superfluid), and we will investigate a quantum optomechanical engine that we have designed on paper recently and theoretically simulated, and that we will investigate experimentally in this context. (An example of our preliminary results is published in [P. Stepanov et al. *Nature Comm.* **10** 3869 (2019)])

Possible collaboration and networking:

This work involves a close collaborations with a renowned team of theoreticians (A. Minguzzi and colleagues, LPMMC, Grenoble), as well as several international collaborations (Australia and Germany in particular). As an intern, the candidate will participate in the development of a new experimental tool based on Doppler spectroscopy to detect particle motion within the fluid, and in the research of the "first light" signal. The internship can be followed by a 3 year PhD position.

Required skills:

The applicant should have a solid base in one of the following: photonics, quantum mechanics and/or thermodynamics, solid-state physics/optoelectronics.

Starting date: Contact the supervisor.

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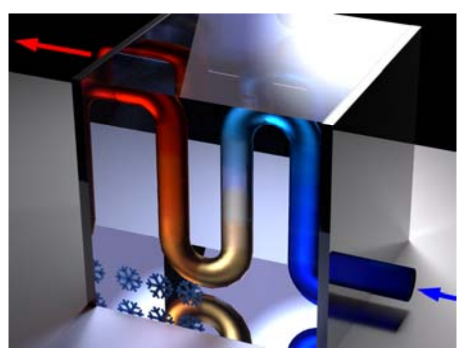
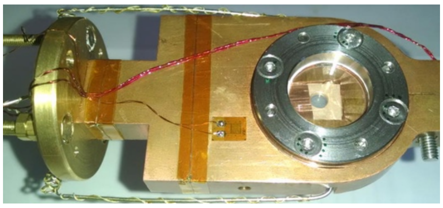


Fig.: *Illustration of a new cooling mechanism that we have demonstrated using a quantum fluid of light* [S. Klembt et al. *Phys. Rev. Lett.* **114**, 186403 (2015)].

NÉEL INSTITUTE Grenoble
Topic for Master 2 internship – Academic year 2020-2021

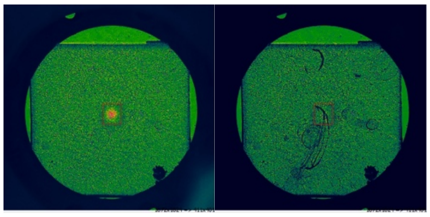
Probing the Classical Nucleation Theory of cavitation with helium

General Scope: Cavitation, the thermally activated nucleation of a vapor bubble in a stretched liquid, is a ubiquitous phenomenon, from engineering to natural sciences. Away from surfaces, cavitation is expected to obey the homogeneous Classical Nucleation Theory (CNT). Up to recently, precise checks only relied on transient, acoustically driven, cavitation. In contrast, an alternative, static, method introduced in 2008 [1], the so-called artificial tree technique, failed to confirm the CNT. Using a forest of such trees, tailored in a nanoporous alumina membrane, we recently provided the first experimental verification of the CNT based on the artificial tree concept [2]. This result opens the way to further studies, such as understanding the influence of nanoconfinement on cavitation, or, using helium as a fluid, the possible influence of quantum effects on cavitation.



Left : Cell for helium measurements.

Right: optical detection of hexane cavitation in an alumina membrane



Research topic and facilities available: The candidate will contribute to the development of cavitation studies of helium at cryogenic temperatures. He/she will take part to experiments on helium cavitation in nanoporous alumina membranes, so as to become familiar with the involved concepts and cryogenics. In parallel, using room temperature hexane as a fluid, and an existing set-up, he/she will test different schemes for building a single artificial tree device, that is a macroscopic cavity connected to the external world through a nanoporous plug [1]. Time permitting, he/she will integrate capacitive measurements of the liquid density and pressure to the device, with the long-term goal of measuring the equation of state of helium at negative pressures down to the cavitation threshold.

Possible collaboration and networking:
This project involves a close collaboration (funded by ANR) with partners in Paris (LPENS and INSP). We also interact with colleagues in Lyon (ILM), Grenoble (LiPhy), in France, and Padova in Italy.

Possible extension as a PhD: yes

Required skills: A solid background in condensed matter physics (including statistical physics and/or soft matter) is required. The candidate should also have a broad interest for physics and experimental techniques (thermodynamic concepts, materials synthesis and characterization, capacitive and optical measurements, cryogenics, …), be self-motivated and have a strong curiosity about new phenomena.

Starting date: Any time in the year

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

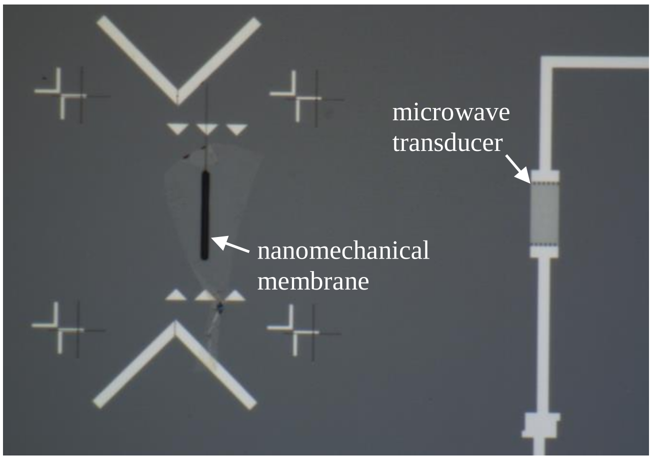
[1] Wheeler T. D. and Stroock A. D., The transpiration of water at negative pressures in a synthetic tree, Nature 455, 208 (2008).
[2] Doebele V., et al, Direct observation of homogeneous cavitation in nanopores, https://arxiv.org/abs/2007.03521

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Quantum acoustics with spin qubits

Context: Acoustic and nanomechanical systems have recently emerged as a powerful quantum technology: these mechanical oscillators have applications ranging from quantum sensing to quantum memories. Using tools from quantum acoustics/nanomechanics now appears as a promising strategy to detect and manipulate solid-state spin qubits. With the prospect of large-scale quantum computing, finding efficient ways to readout, control and couple distant spin qubits is the source of an intense research effort worldwide. To perform quantum acoustics with spin qubits and achieve highly coherent interactions between single spins and single phonons, a central goal is now to push the development of mechanical oscillators with both high frequency and strong quantum fluctuations.



An acoustic device recently developed in the lab. A transducer made out of superconducting circuits (white color) is used to launch and detect acoustic waves at GHz frequencies. This enables us to probe a suspended nanomechanical membrane in the microwave domain.

Research topic and facilities available: During this project, the student will first learn how to design, fabricate and operate devices based on quantum acoustics and nanomechanical oscillators. These devices will be engineered with the goal to enhance interactions with isolated spin qubits hosted in single molecules. This platform will then be used to explore interactions between single spins and single phonons, and exploit them to readout and coherently manipulate spin qubits.

The fabrication will take place in the clean room of the Néel institute, using state-of-the-art nano-fabrication techniques and high performance materials (such as $LiNbO_3$). The microwave measurements (GHz frequencies) will be performed at cryogenic temperatures (20 mK) using a dedicated dilution refrigerator.

Possible collaboration and networking: The quantECA team is involved in many national and international collaborations. This project benefits in particular from collaborations with F. Balestro (Néel Institute) and W. Wernsdorfer (KIT, Germany).

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 variety of skills in experimental condensed matter physics.

Starting date: Flexible

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NÉEL institut

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Quantum nanophononics at low temperature: towards heat manipulation at the nanoscale

General Scope: Phonons, just like electrons, are known to be quantum particles. In a macroscopic material, this quantum nature of the phonons is hidden by the fact that the typical size of the sample is by far larger than the typical wavelength of the phonons. Just like in optics, in this situation, no spectacular effect of the quantum nature of the phonons can be expected. But if you now reduce the dimensionality of a heat conductor down to the limit of the phonon wavelength, then the quantum nature of the phonons should dominate their behaviour: this is a new field of research in which new concepts are still emerging. In this internship, we will focus on how this confinement changes the phonon behaviour and thus the heat transport in 2D structures (membrane) or 1D (nanowires).
As an example, let us ask what happens when the dimensions of the conductor are comparable with the wavelength of the phonons, how can we describe the *transport* of phonons in such structures? The answer is quite subtle, and is related to the transmission of the wavefunction of the phonons through the structure. The most direct evidence of such a wave-nature of the heat transport in such small systems would thus lie in the appearance of plateaus each time the width of the conductor equals an integer times the wavelength of the phonons. This evidence for the quantum nature of heat transport at low temperature is still not clearly experimentally given.

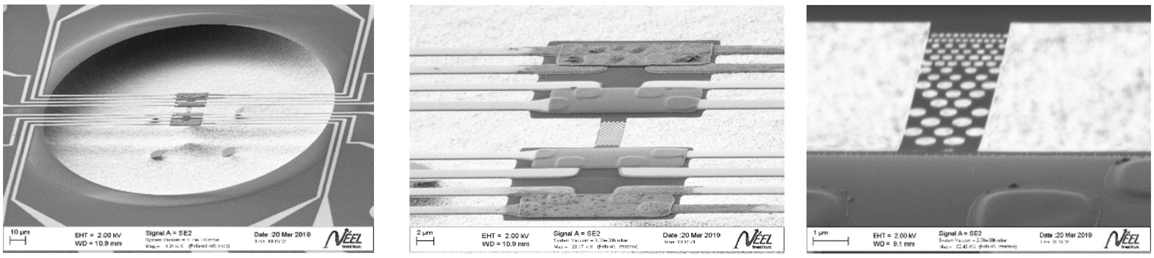

Figure 1 Left: Thermal lab-on-chip sensor composed of two sensing cells for the measurement of thermal conductance of the bridging structure.

Research topic and facilities available: the topic of this thesis holds on phonon transport experiments at very low temperature. These measurements will be carried out in extreme conditions on suspended membranes and nanowires. The experiments will be based on new sensors with sensitivity of the order of Zepto-Joule (10^{-21} Joule), a world record at dilution fridge temperatures (10-50mK).
The goal is to access the quantum regime of phonon transport and thus the quantum regime of heat conduction by optimizing the transmission coefficient. We will demonstrate the potential manipulation of heat flow using non-symmetric nanostructures to evidence thermal rectification. We will manipulate the heat in low dimensionality systems (1D and 2D), a route towards exchange or storage of information using phonon as a carrier.

Possible collaboration and networking: Collaborations with both theoreticians and experimentalists: Natalio Mingo (CEA, Grenoble), David Lacroix (Nancy), Robert Whitney (LPMMC, Grenoble).

Possible extension as a PhD: **The internship could be followed by a PhD**

Required skills: good background in Condensed Matter Physics

Starting date: late winter/early spring

Contact: Olivier Bourgeois (06 88 71 51 86) / Laurent Saminadayar (06 79 66 30 28)
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ICBMS (Lyon University) / NÉEL Institute (CNRS Grenoble)

Topic for Master 2 internship – Academic year 2020-2021

Recycling of end of life NdFeB magnets

General Scope:

In the frame of a collaboration between CNRS-Institut Néel and ICBMS Lyon, your mission will be to develop a new recycling process of NdFeB magnets collected in urban mines. In the proposed process, sintered magnets collected in WEEE (Waste of Electrical and Electronic Equipments) are, first, pulverised into NdFeB powders. In a second step, the development of a non-conventional process for metal extraction (based on CO_2 capture) enables to recover the Rare Earth elements (mainly Nd and Pr) contained in those magnets. Thus, in this internship, attention will be given to study the influence of the processing parameters on the yield of the Rare Earth and Transition Metals elements recovery.
As part of the two teams (and with experiments led both in Grenoble and Lyon), you will conduct tests and characterization (heat treatments, milling, DRX, Microscopy, CO2 capture, extractive chemistry, Spectroscopy, ICP, etc…), exploit the results, report on the results (both written and oral reports).

Research topic and facilities available

In Néel Institute, you will benefit from the expertise of the TEMA group (Processing Elaboration Materials Applications) on the development of processes using magnetic fields, on the recycling processes as well as on the synthesis of alloys in various forms. The team led by Dr. Sophie Rivoirard has recently developed a valorisation process of NdFeB magnets, which is at the origin of the MagREEsource spin-off company. This process enables to extract the magnet from the electronic equipment. As a powder, the magnet is thus ready for further chemical treatment.
In ICBMS (Univ. Lyon 1/ CNRS/CPE-Lyon/ INSA-Lyon), you will benefit from the expertise of the team “Chimie Supramoléculaire Appliquée” led by Prof. Julien Leclaire. You will contribute to the development of an innovative process that already led to 2 patents, valorized in a spin-off company as well, called Mecaware. The process uses amines to capture the CO_2 present in combustion fumes and exhaust gases. These molecules and CO_2 are trapped together to form carbamates which in turn help capture and isolate rare earth metals. You will study and optimize the individual extraction of the main metals contained in the powders prepared by Néel, using CO_2-sourced ligands and both leaching, attrition and precipitation. This part of the project will implement the generation of ligands by CO_2 capture, the screening of extraction conditions, the composition analysis of the generated fractions, the study of the recyclability of the used agents.

Required skills:

-Interest in the recycling and the valorization of by-products.
-General curriculum with a specialty in Materials Science and Chemistry
-Autonomy, initiative and ability to work in a team and to adapt to a collaborative project (you will be the link between two teams in two different locations (Grenoble and Lyon)

Contacts:

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ICBMS UMR 5246 — NÉEL institut

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Recycling of end of life NdFeB magnets

General Scope:
In the frame of the “Sintermagrec” project, funded by the French National Research Agency (ANR-17-ASTR-0014-02), your mission will be to develop a new fabrication process of NdFeB magnets from recycled NdFeB magnets collected in urban mines. In the proposed process, sintered magnets collected in WEEE (Waste of Electrical and Electronic Equipments) are, first, pulverised into NdFeB powders. In a second step, the development of non-conventional sintering techniques using the powder opens up an interesting valorization perspective. Thus, within the framework of the proposed study, attention will be given to study the influence of the processing parameters on the induced microstructure and on the final magnetic properties
As part of the team, you will conduct the tests (heat treatments, milling, DRX, microscopy, etc…), exploit the results, report on the results (both written and oral reports).

Research topic and facilities available
In CNRS/ Néel Institute, you will benefit from the expertise of the TEMA group (Processing Elaboration Materials Applications, 6 persons) on the development of processes using intense magnetic fields, on the recycling processes as well as on the synthesis of alloys in various forms.
Facilities available in the group include high superconducting magnets, various processing tools (induction cold crucible, furnaces, milling facilities, separation tools, etc…) and characterization devices (laser granulometry, ATD/TGA, microscopy, etc…) and all common facilities from Institut Néel available as well (SEM, magnetic measurements, DRX, etc…).

Possible collaboration and networking:
This subject is part of the "Sintermagrec” project, which involves both academic and industrial contacts.

Required skills:
-Interest in the recycling and the valorization of by-products.
-General curriculum with a specialty in Materials Science.
-Autonomy, initiative and ability to work in a team and to adapt to a collaborative project, which includes partners from academic research and industry.
-Knowledge in physicochemical processes and/or metallurgy is welcome.

Starting date: Spring 2021

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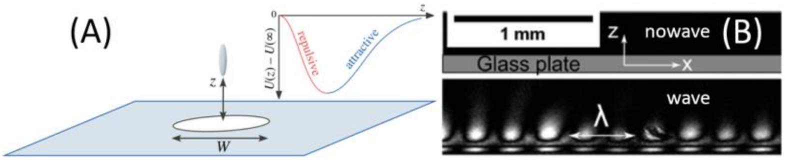
INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2020-2021

Repulsion par effet Casimir : peut-on faire léviter des microparticules par effet Casimir acoustique ?

Cadre général : L'effet Casimir est une des manifestations macroscopiques de l'énergie du vide quantique. Les fluctuations du vide, lorsqu'elles sont contrôlées par des miroirs, peuvent conduire à des forces macroscopiques mesurables. Jusqu'à présent, seules des forces attractives ont été observées mais de nombreux travaux suggèrent l'existence de forces répulsives. En particulier, un régime de lévitation est attendu dans une configuration particule-trou (cf figure) : si l'on place une microparticule au droit d'un miroir percé d'un trou, la particule devrait léviter au-dessus du trou. Dans l'équipe, nous nous intéressons à mettre en évidence des analogues classiques de ces forces quantiques au moyen d'ondes acoustiques. Un bruit acoustique large bande aléatoire joue alors le rôle des fluctuations électromagnétiques du vide. Outre son intérêt purement fondamental dans la compréhension plus fine du mécanisme Casimir quantique, l'existence d'un tel régime ouvrirait certainement la voie à des applications de micromanipulation sans contact d'objets micro- ou même nanoscopiques.



(A) Configuration typique de Casimir répulsif, un objet fait face à un micro-trou La courbe force-distance associée apparait en insert. (extrait de [1]). (B) Champ acoustique évanescent au voisinage d'une plante non percée, obtenue par imagerie Schlieren.

Sujet exact, moyens disponibles :

Un banc expérimental a été monté et testé et a permis d'observer une répulsion acoustique dans la configuration particule-trou. Dans ce stage, nous nous proposons d'étudier expérimentalement ce régime répulsif afin de décrire en détail le mécanisme de lévitation. Des expériences en aquarium insonifié par ultrason couplée à des mesures optiques et acoustiques permettront de mesurer finement cet effet Casimir répulsif. Le champ acoustique évanescent (analogue du champ plasmonique) ainsi que le champ radiatif seront mesurés par hydrophone à aiguille au voisinage du trou.

Interactions et collaborations éventuelles :
Des interactions avec des chercheurs de l'équipe Nano-Optique et Forces (NOF) (notamment B. Pigeau et A. Drezet) sera mise à profit.

Ce stage pourra se poursuivre par une thèse

Formation / Compétences :
Master 1 ou 2 en physique ou mécanique par exemple.

Période envisagée pour le début du stage : Au plus tôt février 2021.

Contact : Cédric Poulain
Institut Néel - CNRS : tél : 04 76 88 74 30 cedric.poulain@neel.cnrs.fr
Plus d'informations sur : http://neel.cnrs.fr et [1] M. Levin, *et al*. Phys. Rev. Lett., 105:090403, 2010.

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Search of high temperature superconductivity in bulk nickelates

General Scope:
Superconductivity is a fascinating macroscopic state of quantum matter showing no resistance to electric current and expulsion of magnetic flux. Very recently, a major breakthrough was the report of superconductivity up to $T_c = 15K$ in a $(Nd_{1-x}Sr_x)NiO_2$ (x up to 0.2, i.e. a formal valence $Ni^{1.20+}$) thin film (obtained after reduction of the perovskite $(Nd_{1-x}Sr_x)NiO_3$ film) made of infinite NiO_2 layers, by the Hwang group at Stanford university [1]. It opens a new area in the story of superconductivity, with already an enormous interest of the scientific community. This discovery is particularly important because $LnNiO_2$ (Ln=La, Nd, Sm…) is isostructural to that of the high T_c cuprate superconductors, discovered more than 30 years ago and not yet fully understood. Those "112" phases present the same filling of electron $3d^9$ (Ni^+) as Cu^{2+} in undoped cuprates, which suggests that this new family could help to a better understanding of superconductivity in these oxides.

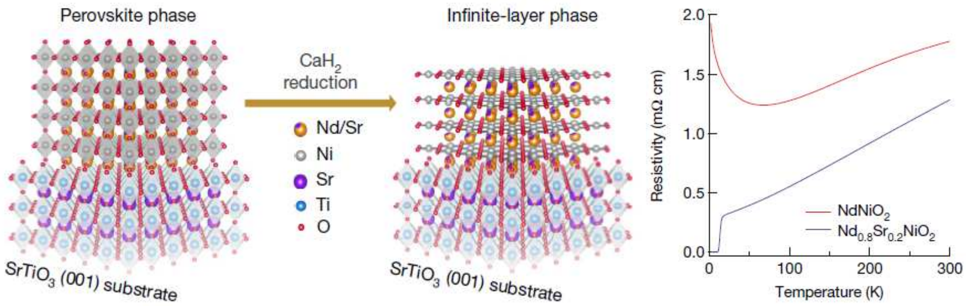


Fig. 1. *Schematic of topotactic reduction of the $(Nd_{1-x}Sr_x)NiO_3$ films epitaxially grown on a $SrTiO_3$ substrate (left) and electrical resistivity of reduced $NdNiO_2$ and superconducting (T_c=9-15K) $Nd_{0.8}Sr_{0.2}NiO_2$ films (right), from Hwang et al. Nature 572 (2019) 624–627. [1].*

Research topic and facilities available:
At the present time the discovery of the Stanford group has been confirmed by two other groups (Singapore and China) working on thin films. At Néel Institute we search for similar layered Ni-based oxides, but in bulk form, where superconductivity could occurs. The related internship will include the synthesis of the samples with one step using an original method, the high pressure – high temperature elaboration. It will also include the study of the structural, magnetic and electronic properties of the synthesized nickelates, thanks to the various experimental setups available in our laboratory. Measurements under very high pressure, in particular x-ray diffraction or transport measurements will be envisaged. Complementary structural characterisation by transmission electron microscopy can be carried out if necessary.

Possible collaboration and networking:
Our laboratory has started a joint research work on this subject with CRISMAT laboratory in Caen where nickelates thin films are grown and studied. With our colleagues and three other french laboratories an ANR project has been submitted and is currently under reviewing.

Possible extension as a PhD: yes, possibly. In particular, it will involves measurements using large scale facilities (neutrons and synchrotron sources) to probe in details the changes of the properties with temperature or pressure.

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

Starting date: March/April 2021

Contact: TOULEMONDE Pierre and LEPOITTEVIN Christophe
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More information: http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Superconducting qubits

General Scope:

During the last decade, it has been demonstrated that superconducting Josephson quantum circuits constitute ideal blocks to realize quantum mechanical experiments and to build promising quantum bits for quantum information processing. These circuits appear as artificial atoms whose properties are fixed by electronics compounds (capacitance, inductance, tunnel barrier).

Recently we demonstrated a new quantum measurement [1] which overcomes the usual limitations. We propose to study its physical properties such as quantum-non-demolition measurement, quantum trajectories (Fig.1), simultaneous measurements and to build a superconducting multi-qubit plateform based on this new readout and on our recent achievement on quantum limited amplifiers [2].

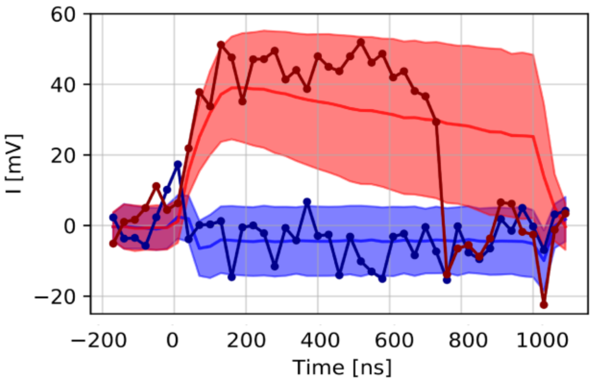

Figure: Real time quantum trajectories (successive 10 ns single shot measurement) when the qubit is prepared in its ground state |g> (blue points) and excited state |e> (red points) at t=0ns. A quantum jump is observed at about 750ns.

[1] *"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).

[2] *"A photonic crystal Josephson traveling wave parametric amplifier"*, L. Planat, et al, Phys. Rev. X 10, 021021 (2020).

Research topic and facilities available:

Our team has a strong experience in superconducting quantum circuit modelization, nanofabrication, microwave electronics, cryogenic equipment and superconducting qubit experiments. The student will carry out quantum experiments at very low temperature. She/he will participate to the development of the superconducting multi-qubit plateform and to the understanding and improvement of the quantum non-demolition measurements

Possible collaboration and networking: Our "Quantum Electronics Circuits Alps" team is part of several national networks. This project on superconducting qubits is financially supported by the National French Funding Agency (ANR) and benefits from collaborations with theoretical groups in Madrid (Spain) and Sao Carlos (Brazil).

This internship can be pursued toward a PhD

Required skills: Master 2 or Engineering degree. We are seeking highly motivated students on quantum mechanics who want to develop experiments on quantum bits.

Starting date: February/ March 2021.

Contact: BUISSON Olivier

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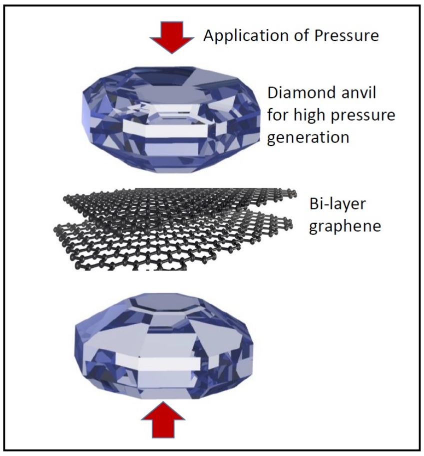
More informations on : http://neel.cnrs.fr

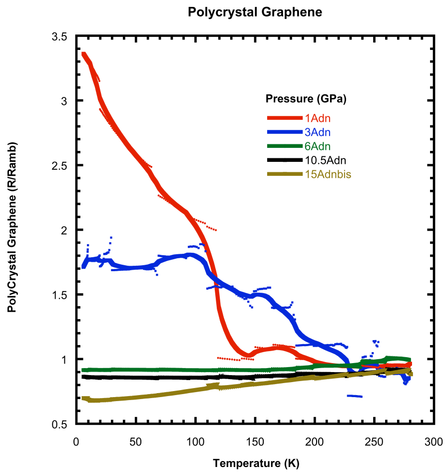
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2020-2021

Search for superconductivity under pressure in mono and bi-layer graphene

General Scope:
The multiplication of the studies on graphene have resulted in a large number of the new applications. However, very few experimental studies have been performed on his electronic properties under pressure. Certainly, few changes are expected under pressure on the graphene mono-layer as it is extremely hard in the basal plane. However, in our preliminary measurements shown in the figure, it is clear that the resistance of the graphene sample changes enormously under pressure due to doping effects. We intend to optimize this doping under pressure to over-dope single layer graphene and attain the level where it has been predicted to be a chiral superconductor [Nature Phys. 8 (2012) 158]. Furthermore, the physics of bi-layers under pressure is certainly very rich. For example, two graphene monolayers, stacked in a Moiré pattern by a small angle rotation, have been recently shown to be superconducting at low temperatures [Nature 556(2018)43]. We plan to study the effect of pressure on the Tc of Moiré bilayers. Finally, Van-der-Waals bonding between two layers of graphene is weak and should be sensitive to pressure, that will deform a bi-layer of graphene towards a diamond symmetry. Theoretical calculations have predicted these structures to be superconductors [PRL 111(2013)066804].





Research topic and facilities available:
The subject of the internship will consist in a first stage in the adaptation, for its assembly in the high-pressure cells, of the graphene single and double layer samples, synthesized in collaboration with L. Marty of the HYBRID Team. The student will thus acquire a solid experience in nanofabrication. He will proceed then to make transport measurements as a function of temperature down to 1K in both piston-cylinder systems (P<2GPa; with P. Rodière, MagSup team) and in Bridgman cells (<30GPa; with M. Nunez-Regueiro and M-A. Measson MagSup Team). These measurements will enrich his knowledge of electronic properties of two-dimensional materials.

Possible collaboration and networking:
Networking: ANR projet obtained in 2019. Teams of the Néel Institute, Institut Lumière Matière (Lyon), Sorbonne University (Paris).
Possible extension as a PhD: YES
Required skills: Good knowledge of condensed matter physics, curiosity, taste for delicate experiments
Starting date:march-april 2021
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NÉEL institut

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Topic for Master 2 internship – Academic year 2020-2021

Quantum nanophononics at low temperature: towards heat manipulation at the nanoscale

General Scope: Phonons, just like electrons, are known to be quantum particles. In a macroscopic material, this quantum nature of the phonons is hidden by the fact that the typical size of the sample is by far larger than the typical wavelength of the phonons. Just like in optics, in this situation, no spectacular effect of the quantum nature of the phonons can be expected. But if you now reduce the dimensionality of a heat conductor down to the limit of the phonon wavelength, then the quantum nature of the phonons should dominate their behaviour: this is a new field of research in which new concepts are still emerging. In this internship, we will focus on how this confinement changes the phonon behaviour and thus the heat transport in 2D structures (membrane) or 1D (nanowires).
As an example, let us ask what happens when the dimensions of the conductor are comparable with the wavelength of the phonons, how can we describe the *transport* of phonons in such structures? The answer is quite subtle, and is related to the transmission of the wavefunction of the phonons through the structure. The most direct evidence of such a wave-nature of the heat transport in such small systems would thus lie in the appearance of plateaus each time the width of the conductor equals an integer times the wavelength of the phonons. This evidence for the quantum nature of heat transport at low temperature is still not clearly experimentally given.

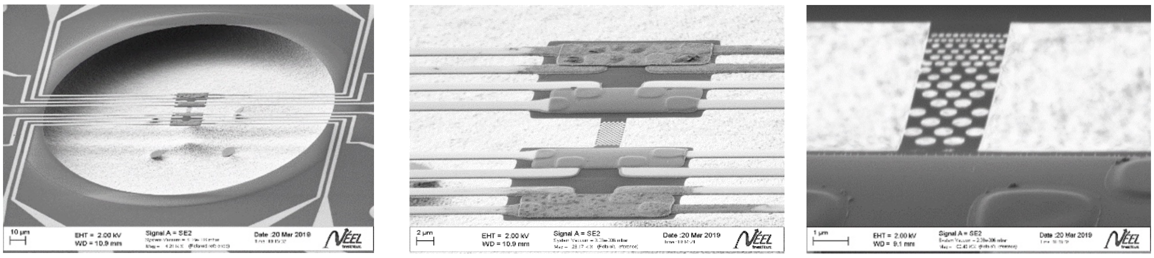

Figure 1 Left: Thermal lab-on-chip sensor composed of two sensing cells for the measurement of thermal conductance of the bridging structure.

Research topic and facilities available: the topic of this thesis holds on phonon transport experiments at very low temperature. These measurements will be carried out in extreme conditions on suspended membranes and nanowires. The experiments will be based on new sensors with sensitivity of the order of Zepto-Joule (10^{-21} Joule), a world record at dilution fridge temperatures (10-50mK).
The goal is to access the quantum regime of phonon transport and thus the quantum regime of heat conduction by optimizing the transmission coefficient. We will demonstrate the potential manipulation of heat flow using non-symmetric nanostructures to evidence thermal rectification. We will manipulate the heat in low dimensionality systems (1D and 2D), a route towards exchange or storage of information using phonon as a carrier.

Possible collaboration and networking: Collaborations with both theoreticians and experimentalists: Natalio Mingo (CEA, Grenoble), David Lacroix (Nancy), Robert Whitney (LPMMC, Grenoble).

Possible extension as a PhD: **The internship could be followed by a PhD**

Required skills: good background in Condensed Matter Physics

Starting date: late winter/early spring

Contact: Olivier Bourgeois (06 88 71 51 86) / Laurent Saminadayar (06 79 66 30 28)
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Topic for Master 2 internship – Academic year 2020-2021

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. Recently we obtained puzzling results on their superconducting properties that are highly anisotropic. This could be due to intrinsic properties of the superconducting nature of these materials, which can made pair-density-wave in an electronic structure already modulated by charge-density-wave (also a recent results of our team). Or it could be the result of an intrinsic bi-dimensional electronic structure, that would made them the equivalent, in superconductivity, of graphite for the 2D graphene layers. This anisotropy would be highly unusual and will allow to study 2D phenomenology in a bulk sample, a fascinating possibility.

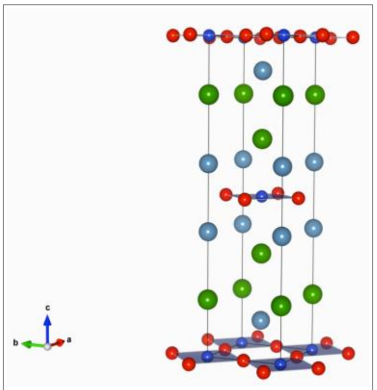

Figure 1: Unit cell of $Ca_2CuO_2Cl_2$ (Cu blue, O red, Cl green, Ca cyan), with the square unit of the CuO_2 plane visible, where the superconductivity take place.

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 this superconducting anisotropy relate with the normal state resistivity one?
During the internship we will start to address part of these questions, using magnetization and resistivity measurements as a function of the crystallographic directions.
Preparation of these experiments will require special care, as these materials are sensitive to air, with a special glove box at the Néel institute. We will also use on-site facilities for crystal growth (large volume press), as well as crystalline (x-ray diffraction) and superconducting (magnetometry/resistivity) characterisation.

Possible collaboration and networking: Sample synthesis will be made in collaboration with the group of Prof. I. Yamada (Univ. of Osaka, Japan), P. Toulemonde (Inst. Néel) and M. Azuma (Tokyo Inst. Of Technology).

Possible extension as a PhD: Yes, this project is part of a PhD program, of which this Master Internship could be a first approach.

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 2020

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