Néel institut

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

Vous trouverez dans ce recueil les sujets de stage proposés par les chercheurs de l'Institut Néel. Les domaines scientifiques et technologiques sont extraordinairement variés, à l'image des activités de nos équipes. S'y côtoient 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 des sciences de l'univers.

Cette brochure regroupe les offres de stage de Master proposés pour l'année universitaire 2022-2023. Ce sont principalement des stages de Master 2 avec pour la plupart une possibilité de continuation en thèse. Si vous commencez votre master, vous trouverez aussi des propositions de stage de Master 1. De nombreux sujets de Master 2 peuvent aussi être déclinés en sujets de Master 1. L'Institut Néel vous souhaite la bienvenue, au moins virtuellement par cette brochure et au travers de notre site web www.neel.cnrs.fr ! N'hésitez pas à contacter les chercheurs de l'Institut Néel afin de nous rendre visite.

La direction de l'Institut Néel

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2022-2023

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Spectroscopic study of free, only optically trapped fluorescent nano-disks	Fick Jochen
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Dynamic control of optical trapping in air	Fick Jochen
Study of electronic transport properties in AlN-based power devices	Ferrandis Philippe
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Contribution to the building and use of haloscopes for Astrophysics and Cosmology	Grenet Thierry
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Search for the origin of the room temperature superconductivity in bulk twisted graphite	Núñez-Regueiro M.
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Chiral textures in magnetic thin films	Stefania PIZZINI Ranno Laurent
A bright source of entangled photon pairs	Poizat Jean-Philippe
Eco-Refrigeration with elastocaloric materials	Porcar Laureline
Graphene based superconducting quantum circuits	Renard Julien
Probing a quantum phase transition using superconducting qubits	Roch Nicolas
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A new approach coupling experiments and ab initio calculations to describe the solid-liquid electrochemical interfaces	Soldo Yvonne
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IUT - DUT	
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MASTER 1

NÉEL INSTITUTE Grenoble

Topic for Master 1 internship – Academic year 2022-2023

Electronic Flying Qubits

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

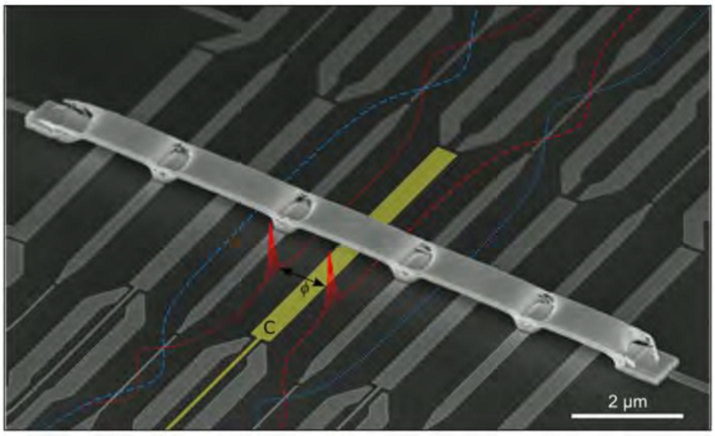

Fig. 1. SEM image of a multi-qubit flying electron architecture. The image shows four quantum interferometers that can be simultaneously operated owing to a common bridge that connects the islands of each device. The dashed lines schematically indicate the paths of two single-electron wave packets in two neighboring interferometers. The intermediate gate C (highlighted in yellow) allows for controlled Coulomb coupling of the single-electron wave packet and thus in-flight entanglement.

Research topic: The aim of the proposed M1 internship is to participate in the development of an original flying qubit architecture using ultra-short single-electron charge pulses. Such an electron flying qubit can be realized through an electronic Mach-Zehnder interferometer as shown in the figure to the right.

References:

- Bäuerle et al., Rep. Prog. Phys. 81, 056503 (2018) ; arxiv.org/abs/1801.07497, Edlbauer et al., EPI Quantum Technology 9: 21 (2022); in COLLECTION ON "QUANTUM INDUSTRY", REVIEW ARTICLE; https://doi.org/10.1140/epjqt/s40507-022-00139-w

Possible collaboration and networking: This project is part of the priority projects of the French National Strategy on Quantum Technologies. It is realized in close collaboration with the nanoelectronics group in Saclay (C. Glattli & P. Roulleau), the THz group of IMEP-LaHC laboratory at Univ. Savoie Mont-Blanc (J.F. Roux), the theory group of CEA Grenoble (X. Waintal) as well as the Quantum Metrology group (AIST), Tsukuba, Japan (S. Takada) & the Quantum Device group, RIKEN, Japan (M. Yamamoto)

Required skills:
We are looking for an excellent and highly motivated student to participate in this ambitious research project. The candidate should have a good background in quantum mechanics and solid-state physics. Programming skills in Python would be a plus.

Starting date: spring 2023

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INSTITUT NEEL Grenoble

Proposition de stage Master 1 - Année universitaire 2022-2023

Elaboration de cuivre épitaxié sur saphir pour la croissance de graphène
Cadre général :

La croissance de graphène de très haute qualité (monocouche, continue, monodomaine) est réalisée par dépôt chimique en phase vapeur (CVD) sous ultra-vide (UHV) sur des monocristaux de métaux de transition. Le choix des matériaux qui présentent une faible solubilité au carbone favorise la croissance d'une seule couche de graphène, c'est le cas du cuivre qui est utilisé pour la croissance CVD « classique » du graphène de grande dimension. L'optimisation du graphène de grande dimension a été réalisée sur des feuillets de cuivre polycristallins, avec la présence de multicouches et de plis. Nous souhaitons proposer un « gabarit » de cuivre épitaxié sur saphir de qualité comparable à celle d'un monocristal massif de cuivre pour maîtriser davantage la qualité du graphène. La rugosité de surface, la taille, le nombre et l'orientation des grains vont fortement influencer la qualité du graphène. Ce sujet s'insère dans la continuité de collaborations avec l'ONERA, le CEA Saclay, l'ESRF, les laboratoires Spintec et Pprime, qui ont permis d'élaborer par sputtering des couches minces hautement texturées, atomiquement plates (Ni,Co,Pt) comme alternative aux monocristaux très onéreux pour la croissance des matériaux 2D (graphène, MoS2 et TaS2, hBN).

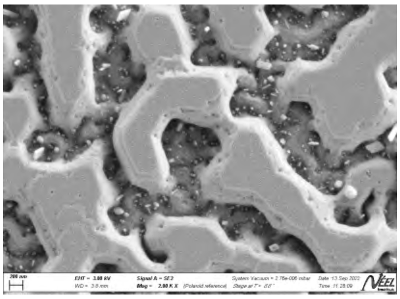

Image MEB de Cu(111)sur saphir

Sujet exact, moyens disponibles :
Nous proposons au sein de l'Institut Néel, la croissance par pulvérisation cathodique de cuivre hautement texturé d'une épaisseur de l'ordre du micron comme alternative aux feuillets de cuivre polycristallins, dans le but de contrôler la qualité du graphène sur des substrats de grande dimension.
Une première étape vise à mettre au point la recette pour épitaxier du cuivre par pulvérisation cathodique sur des substrats de saphir Al2O3 (0001).
La finalité du stage sera de faire croître par dépôt chimique en phase vapeur, du graphène de haute qualité sur ces gabarits de cuivre.
L'étudiant de 2ème année d'école d'ingénieur ou M1 utilisera des techniques d'élaboration (pulvérisation cathodique, dépôt chimique en phase vapeur) couplées à des moyens de caractérisation (diffraction des rayons X, MEB, AFM, spectroscopie Raman) pour optimiser les gabarits de cuivre et caractériser le graphène obtenu.

Interactions et collaborations éventuelles :
Le travail sera réalisé avec les pôles Epitaxie et couches minces, X-press et Optique et microscopies, en collaboration avec l'équipe de recherche Hybrid.

Formation / Compétences :
- Ingénierie et science des matériaux, chimie, physique ou équivalent
- Compétences en élaboration et caractérisation des nanomatériaux
- Bonne capacité de travail en équipe : interactions avec des experts de différentes équipes

Période envisagée pour le début du stage :
Printemps 2023
Contacts :
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Plus d'informations sur : http://neel.cnrs.fr

INSTITUT NÉEL Grenoble

Topic for Master 1 internship – Academic year 2022-2023

Title

Growth of CuO and Fe doped CuO films for spintronic applications.

General Scope :

Over the past half a century, a considerable research activity has been dedicated to the development of magnetic semiconductors (MSC) that can work at room temperature [Q. Cao and S Yan, *J. Semicond.* **40** 081501 (2019)]. These materials are of primary importance for spintronics applications. At the beginning investigations focused mainly on II–VI MSC and III–V dilute MSC. More recently the attention turned towards oxides like e.g. ZnO-based MSC.
Here we are interested in CuO, which is an antiferromagnetic semiconductor with a gap of about 1.4 eV. Its structure is monoclinic, at odd with the other 3d transition metal monoxides (FeO, CoO, NiO,…) that have a rock-salt structure. However, single-phase tetragonal CuO films were elaborated by epitaxial growth on $SrTiO_3$(001) substrates [W. Siemons *et al*., *Phys. Rev. B* **79**, 195122 (2009)], up to a thickness of about 3 nm. This transition from monoclinic to tetragonal structure is associated with an increase of the oxygen-mediated superexchange interaction *J* and hence of the Néel temperature. The scope of this internship will be the growth of epitaxial CuO films with monoclinic and tetragonal structure using molecular beam epitaxy. Several samples will be elaborated and characterized to optimize the structure and properties.

Research topic and facilities available :

During the internship, CuO and Fe-doped CuO thin films with monoclinic and tetragonal structure will be grown by MBE deposition on $SrTiO_3$(001). The films will be prepared and studied *in-situ* using two interconnected ultra-high-vacuum chambers, the first one dedicated to MBE growth, the second one to the characterization by low energy electron diffraction (LEED), Auger electron spectroscopy and scanning tunnel microscopy (STM) techniques. LEED allows to establish the crystallographic symmetry of the films, Auger is used to study the composition and the presence of contaminants, STM will be performed here to study the surface roughness and for a first investigation of the electronic properties. During the internship the student will learn about these techniques and the fundamental of surface science: surface preparation, metal deposition by Knudsen cells, oxidation by mean of thermal gas cracker, etc.

Possible collaboration and networking : SIN team at Néel institute

Required skills : A good background in condensed matter physics, dexterity in experimental work.

Starting date : March 2023

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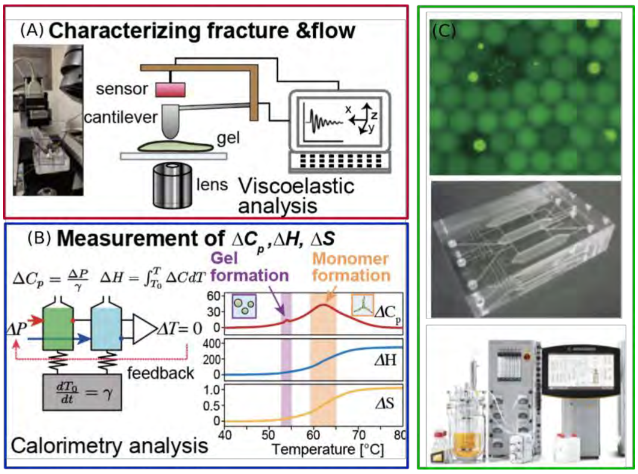
INSTITUT NEEL Grenoble

Topic for Master 1 internship – Academic year 2022-2023

Rational design of functional DNA gels

General Scope :
For soft matter engineering, DNA is the ideal polymer. In addition to being mechanically robust, chemically stable and enzymatically replicable, DNA is a sequence-defined polymer that can be designed to self-assemble into almost any shape, simply by tuning the arrangement of its monomers (the nucleotides). Given some DNA strands, a dynamic programming software can predict their thermodynamics from their sequences: the way they interact (binding energies) but also the structure they form at equilibrium (minimum free energy structure). Therefore, we see DNA as an ideal polymer to design, from the nanoscale, materials with unprecedented mechanical properties at the micro and macro scales.



Research topic and facilities available :
To concretize this vision, we propose in this project to establish Multiscale MechanoProgrammable Gels (MMP gels). In these gels, DNA nanostructures orchestrate the development of function and mechanics at the macroscopic scale through a sequence of hierarchical chemical processes. As a result, we envisage applications where biocompatible and soft materials must change their mechanical properties based on physical and chemical stimuli (artificial skin, intelligent adhesive plasters, adaptable contact lenses, self-healing cartilage, smart stents...). We believe that this will lay the foundation for the rational engineering of soft materials.
In this project, the candidate will focus on measuring and engineering the thermodynamics aspect of MMP gels. Using calorimetry, the candidate will study how thermodynamics values (enthalpy, entropy) are related to mechanical properties at the microscale and macroscale. He will also leverage the vast repertoire of DNA nanotechnology to engineer gels with programmable mechanics and thermodynamics.
In this project, the candidate will focus on measuring and engineering the thermodynamics aspect of MMP gels. Using calorimetry, the candidate will study how thermodynamics values (enthalpy, entropy) are related to mechanical properties at the microscale and macroscale. He will also leverage the vast repertoire of DNA nanotechnology to engineer gels with programmable mechanics and thermodynamics.

Possible collaboration and networking :
This collaborative project involves 3 other partners, two of them are in Lyon one is in a CNRS unit in Japan

Required skills :
Any student with a background in in physics, chemistry or biology is welcome to apply. We are seeking for motivated student willing to work at the interface between different disciplines. Our goal is to improve our fundamental understanding of DNA assembly, sol-gel transition, rheology of soft material thanks to thermodynamic measurements. If theses topics puzzles you, your ideas and creativity is of interest for us, come and visit.

Starting date : Spring 2023
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Plus d'informations sur : http://neel.cnrs.fr

INSTITUT NÉEL Grenoble

Topic for Master 1 internship – Academic year 2022-2023

Graphene transistors decorated with optically active and biosourced molecules

General Scope :
2D materials exhibit a 2D electron gaz which can be tuned by stacking layers (van der Waals heterostructures). Another approach mixes dimensionalities as for 0D-2D heterostructures. Small molecules are naturally quantum due to 0D confinement, and 2D materials are ultimately thin (semi-)conductors, therefore extremely sensitive to their environment.
We work on graphene transistors decorated with chromophores which are light-sensitive small molecules (porphyrins, terpyridins...). The molecule-graphene interaction allows quantifying the amount of molecules, thus realizing a sensor [1]. These hybrids are closely related to graphene transistors with an optical gate made of chlorophylls [2]. Affinity between aromatic molecules and sp2 carbon allows charge transfer between the two, in particular *via* tunneling [3]. This family of pigments plays a key role in natural photosynthesis : they absorb light and convert it into charges cascading towards the primary electron donors in photosystems.
This internship aims at using natural molecules asociated to low dimension materials for an efficient collection of light-generated electrons. This takes place within the very beginning of "semi-artificial photosynthesis" [4] which proposes to couple efficient generation and collections of charges.

Research topic and facilities available :
This internship is a follow-up of the host team activities, turning now towards bio-sourced carotenoïds. The affinity between graphene and the molecules has been demonstrated in the group. The interns shall now seek for an optoelectronic response of the decorated graphene transistor. Therefore, the intern will fabricate batches of transistors in the cleanroom, using graphene synthesized at NEEL and decorated them with carotenoïds from CEA Saclay. Electron transport and vibrational spectroscopy (Raman) will provide information on the graphene/molecule interaction and the possibility to separate the light-induced charges and generate a photocurrent. The internship will at first involve isolated carotenoïds and then go towards more complex aggregates from plants.

Possible collaboration and networking :
Work in close collaboration with staff from cleanrooms (Nanofab), CVD graphene ovens (pôle Epitaxie), and from pôle Optique et Microscopies in Néel. This work will be performed in collaboration with I2BC (CEA Saclay) providing the molecules.

Required skills :
Degree in Condensed Matter Physics or Nanoscience, good notions in physics of semiconductor would be appreciated, taste for cleanroom fabrication.

Starting date : Spring 2023, possible to join the team as soon as october in the frame of an in-lab training

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

References :

[1] M. Lopes, A. Candini, M. Urdampilleta, A. Reserbat-Plantey, V. Bellini, S. Klyatskaya, L. Marty, M. Ruben, M. Affronte, W. Wernsdorfer, and N. Bendiab. ACS Nano, 4 :7531, 2010.
[2] S. Y. Chen, Y. Y. Lu, F. Y. Shih, P. H. Ho, Y. F. Chen, C. W. Chen, Y. T. Chen, and W. H. Wang. Carbon, 63 :23, 2013.
[3] Y. Chen, L. Marty, and N. Bendiab. AdvancedMaterials, 31 :1902917, 2019.
[4] N. Kornienko, J. Z. Zhang, K. K. Sakimoto, P. Yang, and E. Reisner. Nature Nanotechnology, 13 :890, 2018.

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Quantum transport in superconducting/semiconducting Al/Ge/Al heterostructure

General Scope :
The internship and the PhD is motivated by our recent investigations of the ultra-scaled hybrid superconducting/semiconducting aluminum/germanium (Al/Ge) devices. By tuning a gate voltage, they reveal a very rich quantum electronic physics ranging from single charge quantum dot, Coulomb diamonds to proximitized superconductivity. These properties were achieved thanks to the unique monolithic monocrystalline Al/Ge/Al nanowire heterostructure with remarkable atomically sharp interfaces between Al and Ge [1]. These promising devices open the way towards quantum technologies in particular superconducting gatemon qubit or the study of Majorana fermions.
[1] Al–Ge–Al nanowire heterostructure: from single -hole quantum dot to Josephson effect,
J. Delaforce, M. Sistani, et al, Advanced Materials, Wiley-VCH Verlag, 2021, 33 (39), 2101989 (2021).

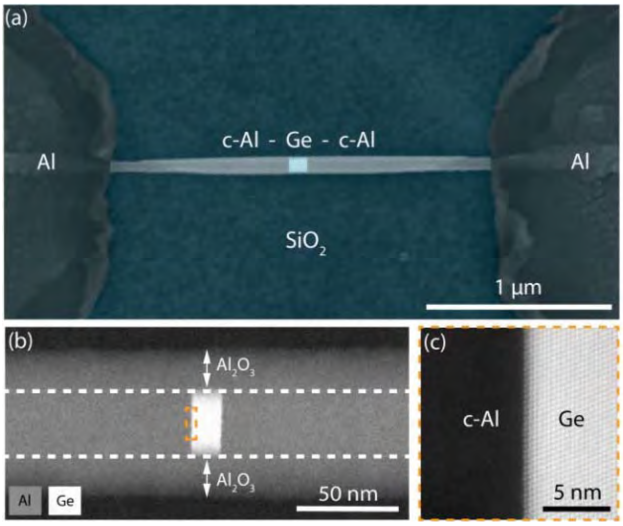

Figure 1: (a) SEM image of the nanowire heterostructure with self-aligned Al leads contacting a Ge segment connected to large aluminum pads deposited on SiO2 layer. (b) TEM image showing a zoom of the Al/Ge/Al heterostructure device. The central white segment is the germanium. (c) TEM image showing the Ge atoms and the atomically sharp interfaces

Research topic and facilities available :
Our research aims at exploring promising superconductor/semiconductor hybrid devices based on ultra-scaled Al/Ge heterostructures. Inside the consortium, we will develop novel quantum devices and their integration in functional quantum circuits to study gatemon superconducting qubit, Andreev qubits, multiterminal junctions. We will measure their electronic transport properties in a homemade He3 cryostat which allows to measure down to 350 mK and their qubit properties in the microwave domain in a dilution fridge. The internship is aimed to be followed by a PhD.

Possible collaboration and networking : The internship proposal is related to a joint project between the Néel Institute and the Technical University of Vienna (Austria).

Required skills: Master or Engineering degree. Skills on solid state physics or quantum transport will be appreciated. Motivation on experimental quantum device is needed.

Starting date : March or April 2022 for internship.
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NÉEL INSTITUTE Grenoble

Topic for Master 1 internship – Academic year 2022-2023

Graphene based superconducting quantum circuits

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

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

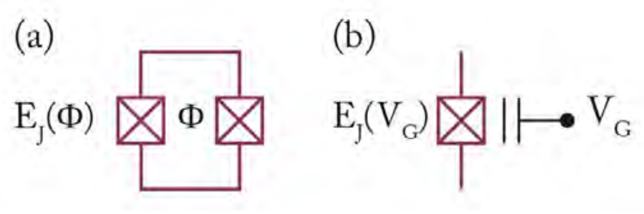

Figure 1: tunability of the Josephson energy E_J in standard Josephson junctions necessitates a loop geometry and a magnetic flux Φ (a). The introduction of a semiconductor allows simple electrical gating with a gate voltage V_G (b). This is the essence of the project.

Possible collaboration and networking : The student will be part of the Hybrid team, which has a multidisciplinary expertise (growth, nanofabrication, electronic transport, spectroscopy...). The team has also several external collaborations worldwide (France, Switzerland, Germany, Canada, US).
Required skills: The internship will require a solid background in solid state/condensed matter physics. The work will be mainly experimental. The candidate is expected to be strongly motivated to learn the associated techniques (nanofabrication in clean room, radiofrequency electronics, cryogenics...) and engage in a hands-on experimental work.
Starting date : March 2023 (flexible)

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INSTITUT NEEL Grenoble

Proposition de stage Licence ou Master 1

Année universitaire 2022-2023

Dispositif cryogénique d'étude des Mégafeux

Cadre général :

Les incendies de très grande superficie (*mégafeux*) modifient localement la circulation atmosphérique, ce qui en retour affecte la propagation du feu. On parle de *couplage mutuel feu-atmosphère*.

Cette rétroaction est difficile à étudier sur le terrain, pour des raisons évidentes. L'étude en laboratoire se heurte aussi à diverses difficultés, dont l'impossibilité d'y reproduire la convection ultra-intense présente dans l'atmosphère. Cette dernière pourrait toutefois être levée dans des maquettes ou *systèmes modèles* de mégafeux exploitant le moins visqueux de tous les fluides : *l'hélium cryogénique*.

Figure 1. Mégafeu en Californie . Photo de Bill Peters, U.S. Forest Service [wikipédia].

Figure 1 . Exemple de prototype cryogénique (design différent de celui envisagé pour le stage).

Sujet exact:

Le but du stage est de réaliser un prototype d'une matrice de chauffages-thermomètres d'étude de la propagation des mégafeux et fonctionnant en environnement cryogénique (4 – 10 K).

Concrètement, le stagiaire développera un réseau bidimensionnel (de résolution 3x3 ou 4x4) de « pions » équipés de chauffages et thermistances, adressables individuellement et fonctionnant dans l'hélium à 4 K. L'ensemble sera commandé par une électronique utilisant des composants à semi-conducteurs en dehors de leur plage de température nominale.

Un des enjeux du stage est d'identifier une conception mécanique et électronique transposable à un réseau de résolution supérieure (50x50) sans explosion ni du coût de fabrication ni du temps d'assemblage.

Formation / Compétences :

Formation attendue : formation généraliste en Physique ou Ingénierie.

L'étudiant devra avoir des connaissances de base dans la mise en œuvre de circuits électroniques et en conception mécanique. Il sera formé aux techniques de base en physique des basses températures (azote et hélium liquide, vide, thermométrie, ..) et aux techniques d'instrumentation et de mesures bas bruit.

Période envisagée pour le début du stage : année universitaire 2022-2023.

Contact : Philippe Roche, Institut Néel – CNRS/ UGA, per@neel.cnrs.fr http://hydro.cnrs.me
Pour candidater : merci d'envoyer un bref CV + date/durée du stage (lettre de motivation inutile).

INSTITUT NEEL Grenoble

Proposition de stage L3 ou Master 1
Année universitaire 2022-2023

Modèle d'anthropocène : régionalisation d'un modèle dynamique global

Cadre général :

La période récente de l'anthropocène est marquée par une *grande accélération* démographique, industrielle, agricole, technologique et économique de l'humanité. Cette accélération repose sur une exploitation mondialisée de ressources non renouvelables et une dégradation irréversible de milieux et d'écosystèmes.

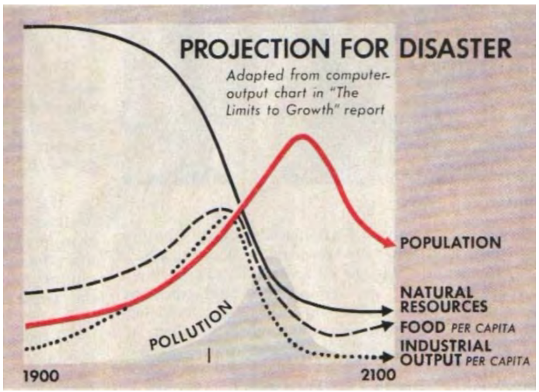

Figure 1. Illustration du scénario standard *du modèle* World3 *de «* The limits to Growth *», [Meadows et al.]. Time magazine 24/1/1972*

Comment l'épuisement ou la dispersion des ressources dites non renouvelables (hydrocarbure, phosphate, …), l'évolution des milieux planétaires (climat, pollution, eau douce,..) et la dégradation des écosystèmes (extinctions, perte de biomasses,…) peuvent-ils affecter la trajectoire de l'humanité à l'échelle du siècle ?

Une approche à cette difficile question a été popularisée par le modèle World3 de Denis Meadows, Jay Forrester et leurs collaborateurs (MIT / Club de Rome) dans les années 70. Elle repose sur une modélisation dynamique des dépendances entre un jeux réduit de variables globales, telles que la population mondiale, la production agricole, les stocks de carburants fossiles, les gains de productivité industrielle, etc… en fonction des politiques publiques.

Le but du stage est d'étudier la robustesse des trajectoires prédites par les systèmes dynamiques à variables globales, tel que World3, lorsqu'une « régionalisation » des variables extensives est introduite.

Sujet exact :

Dans un premier temps, un modèle dynamique global simplifié (par rapport à World3) sera implémenté. Une analyse automatique des prédictions de ce modèle sera développée pour explorer efficacement leur typologie dans l'espace des phases des paramètres du modèle.

Ensuite, le modèle sera généralisé pour être distribué sur un ensemble arbitraire de régions modèles en interaction. Un modèle physique et économique sous-jacent, développé durant le stage, assurera la cohérence de l'ensemble.

Enfin, une étude de sensibilité/robustesse/résilience sera conduite sur les trajectoires temporelles en fonction des caractéristiques des entités régionales sur lequel le modèle est distribué.

Formation / Compétences :

Formation attendue : formation généraliste en Physique ou Mathématique (type ENS) ou Grande Écoles. L'étudiant devra avoir un goût pour la modélisation et la programmation.

Période envisagée pour le début du stage : année universitaire 2022-2023.

Contact : Philippe Roche, Institut Néel – CNRS/ UGA, per@neel.cnrs.fr
Pour candidater : merci d'envoyer un bref CV + date/durée du stage (lettre de motivation inutile).

MASTER 2

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2022-2023

Mesure nano-mécanique ultrasensible de champs de force

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

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

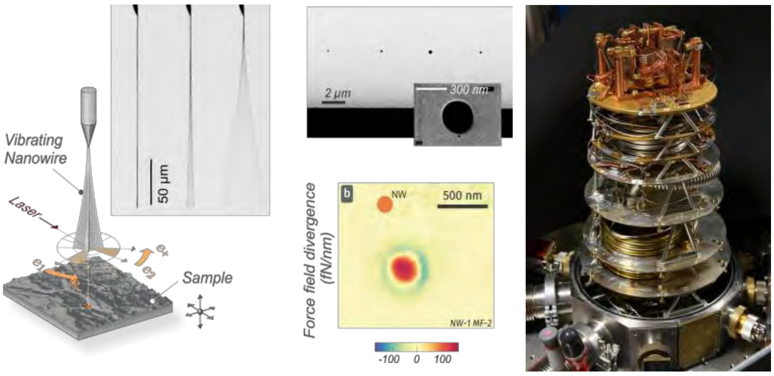

Figure. Image TEM de la sonde de force mécanique, un fil de carbure de silicium, attaché à une pointe de tungstène. La mesure de ses vibrations permet de remonter aux forces exercées sur son extrémité vibrante par un échantillon. Image MEB d'une membrane métallique percée de trous réalisés au FIB. La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

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

Ce stage pourra se poursuivre par une thèse

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

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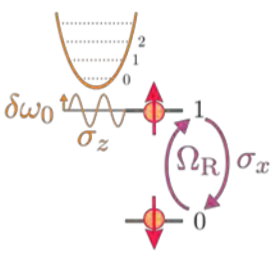
[1] O. Arcizet et al, Nature Physics 7, 879 (2011).
[2] A. Gloppe et al, Nature Nanotechnology (2014).
[3]S. Rohr et al., PRL 112, 010502 (2014)
[4] B. Pigeau et al, Nature Comm. (2015).
[5] L. Mercier de Lépinay et al., Nature Nano (2017).
[6] F. Fogliano et al, Nature Comm. (2021)
[7] F. Fogliano et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

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2022-2023

Systèmes Hybrides Spin qubit-Nanorésonateurs mécaniques



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

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

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

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

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

Ce stage pourra se poursuivre par une thèse

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

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

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Solid-State Electronic Flying Qubits

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

Research topic: The aim of the proposed M2 internship is to participate in the development of an original flying qubit architecture using ultra-short single-electron charge pulses. Such an electron flying qubit can be realized through an electronic Mach-Zehnder interferometer as shown in Fig.1. Based on our recent experiments with such an electron flying qubit, we aim at coupling two electron flying qubits to realise quantum entanglement of 2 injected electron wave packets through Coulomb interaction (C) as highlighted in the figure.

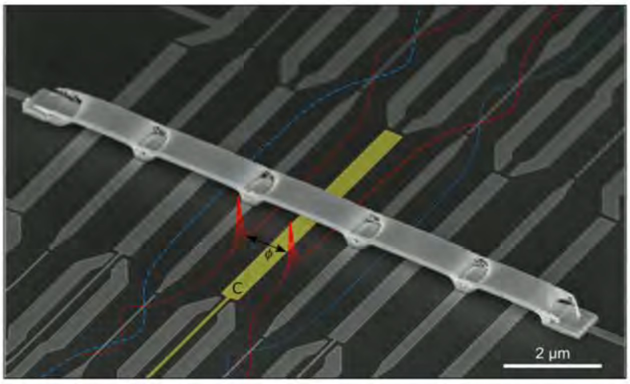

Fig. 1. SEM image of a multi-qubit flying electron architecture. The image shows four quantum interferometers that can be simultaneously operated owing to a common bridge that connects the islands of each device. The dashed lines schematically indicate the paths of two single-electron wave packets in two neighboring interferometers. The intermediate gate C (highlighted in yellow) allows for controlled Coulomb coupling of the single-electron wave packet and thus in-flight entanglement.

References:

- Bäuerle et al., Rep. Prog. Phys. 81, 056503 (2018) ; arxiv.org/abs/1801.07497, Edlbauer et al., EPI Quantum Technology 9: 21 (2022); in COLLECTION ON "QUANTUM INDUSTRY", REVIEW ARTICLE; https://doi.org/10.1140/epjqt/s40507-022-00139-w

Possible collaboration and networking: This project is part of the priority projects of the French National Strategy on Quantum Technologies. It is realized in close collaboration with the nanoelectronics group in Saclay (C. Glattli & P. Roulleau), the THz group of IMEP-LaHC laboratory at Univ. Savoie Mont-Blanc (J.F. Roux), the theory group of CEA Grenoble (X. Waintal) as well as the Quantum Metrology group (AIST), Tsukuba, Japan (S. Takada) & the Quantum Device group, RIKEN, Japan (M. Yamamoto)

Possible extension as a PhD: we are looking for a candidate who is motivated to pursue the M2 internship towards a PhD; (PhD fellowship can be obtained)

Required skills:
The candidate should have a good background in quantum mechanics and solid-state physics. Programming skills in Python would be a plus.

Starting date: open (preferentially beginning 2023)

Contact:

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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

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.

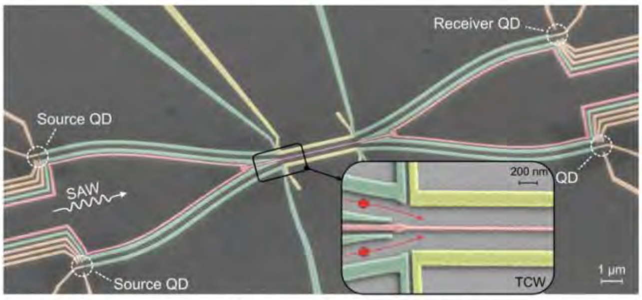

Fig. 1: SEM image of a two-electron collider. A pair of single electrons (red dots) is transferred via a SAW train between distant quantum dots (QD) along two quantum rails (green and yellow surface gates). Along a length of 40 µm, the two rails form a tunnel-coupled wire (TCW) where they are only separated by a narrow potential barrier (see inset).

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". The student will participate in an ongoing experiment on two-electron collision (see Fig. 1) and will realize quantum transport simulations with the actual quantum device structure.

References:

- Takada et al., Nature Communications 10, 4557 (2019) ; Wang et al, Phys. Rev. X 12, 031035 (2022) & Physics ; Edlbauer et al., EPI Quantum Technology 9: 21 (2022); in COLLECTION ON "QUANTUM INDUSTRY", REVIEW ARTICLE; https://doi.org/10.1140/epjqt/s40507-022-00139-w

Possible collaboration and networking: This project is part of the French National Strategy on Quantum Technologies. It 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: we are looking for a candidate who is motivated to pursue the M2 internship towards a PhD; (PhD fellowship can be obtained)

Required skills: The candidate should have a good background in quantum mechanics and solid-state physics. Skills in Python programming would be a plus.

Starting date: open (preferentially beginning 2023)

Contact:
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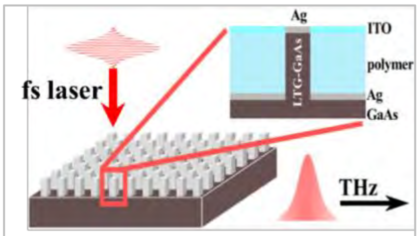
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Optoelectronic THz source for Solid-State Quantum Electronics

General Scope: The association of Terahertz (THz) optoelectronics and solid-state quantum electronic opens the way to a new branch of electronic quantum studies. Indeed, using femtosecond laser and ultrafast photodetectors allows for the generation of sub-picosecond, THz, electrical pulses that can be used to excite and coherently control single electrons propagating in a semiconductor-based quantum circuit. This allows for the measurement of fundamental properties of the electron wave-packet such as coherence length, velocity and damping. Moreover, the single electrons can also act as electronic flying qubits, and THz optoelectronic allows to perform quantum operations during their time of flight.
Such challenging physics relies on the development of smart electronic and optoelectronic circuits where both quantum electronics and ultrafast optoelectronic components are co-integrated. Among the different possible technologies, III-V semiconductor and especially GaAs allow for the fabrication of components with outstanding performances thanks to the very high electron mobility of 2D electron gases (AlGaAs/GaAs heterostructures) and the ultrafast carrier trapping time of Low Temperature Grown GaAs layers.
In order to keep the optical power budget as low as possible, it is mandatory to design very highly efficient THz photodetectors. For that, we have designed different nanophotonics detectors based on electromagnetic resonances (see figure). These structures have now to be investigated experimentally and optimized in order to render possible the optoelectronic excitation of single electrons and demonstrate in-flight manipulation of electronics flying qubits.



Highly efficient photodetector

Research topic: The aim of the proposed M2 internship is to participate in the design, the fabrication and the test of an original optoelectronic component (see reference and figure) dedicated to the excitation of flying qubit using ultra-short single-electron charge pulses. The work will be done in close collaboration in between Institut Néel (fabrication of the device, time resolved quantum experiment) and IMEP-LAHC (design and test of the THz photodetector).

References:

- G. Georgiou, C. Geffroy, C. Bäuerle, and J.-F. Roux, ACS Photonics 2020 7 (6), 1444-1451 , https://arxiv.org/abs/2001.01341; Edlbauer et al., EPJ Quantum Technology 9: 21 (2022); in COLLECTION ON "QUANTUM INDUSTRY", REVIEW ARTICLE; https://doi.org/10.1140/epjqt/s40507-022-00139-w

Possible collaboration and networking: This project is part of the priority projects of the French National Strategy on Quantum Technologies. This project is realized in close collaboration in between the QuantECA team at Neel (C. Bäuerle), the THz group of IMEP-LaHC at USMB (J.F. Roux), and the theory group of CEA (X. Waintal).

Possible extension as a PhD: we are looking for a candidate who is motivated to pursue the M2 internship towards a PhD; (PhD fellowship can be obtained)

Required skills:
The candidate should have a good background in optics, electromagnetism and solid-state physics. Strong interest in experimental science is mandatory. Programming skills in Python would be a plus.

Starting date: open (preferentially beginning 2022)

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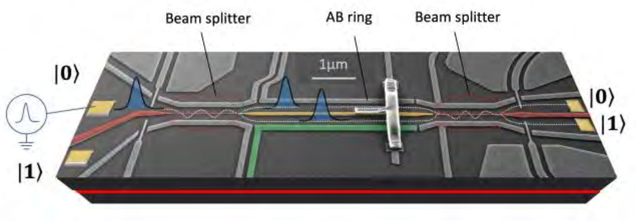
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Aharanov-Bohm oscillations with flying qubits

General Scope: The ability to build scalable quantum information devices based on single flying electron qubits require the coherent manipulation of single electrons over large distances. A promising architecture to study long-distance qubit manipulation is an electronic Mach-Zehnder interferometer. Similar to its optical analogue, the electron wave packet can take different paths through engineered electronic waveguides. A tunable tunnel barrier serves as a beam splitter and applying an external magnetic field allows to measure quantum oscillations of the current at the exit of the device. These so-called Aharonov–Bohm (AB) oscillations are a direct measurement of the coherence and allow probing flying qubit manipulation, a key requirement for quantum computing.

Research topic: The aim of the proposed M2 internship is to obtain a better understanding of ongoing flying qubit experiments in electronic Mach-Zehnder interferometers using numerical simulations. Realistic simulations of the device, as shown by the figure on the right, have been performed with the *Kwant* and *Nextnano* softwares and point out the role of reflections for the visibility of the AB oscillations. The goal of the internship is to perform numerical simulations in order to determine the best possible device design with increased coherence properties. In addition, new experiments using ultrashort single-electron wave packets show an increased visibility of AB oscillations. A route to understand these new findings is to use time-dependent simulations using the *Tkwant* code.



Scanning Electron Micrograph of an electronic Mach-Zehnder interferometer. Single electrons are injected into the upper quantum rail (state I0>) using ultrashort voltage pulses. The MZ interferometer is composed of two tunnel-coupled wires acting as beam splitters and connected to an Aharonov-Bohm (AB) ring.

References:

- Yamamoto *et al., Nature Nanotechnology* 7, 247 (2012); arXiv:1709.08873, Bautze *et al., Phys. Rev. B* 89, 125432 (2014); arXiv:1312.5194, Bauerle *et al., Rep. Prog. Phys.* 81 056503 (2018); arXiv:1801.07497, Groth *et al., New J. Phys.* 16, 063065 (2014), arXiv:1309.2926, Birner *et al., IEEE Transac.*, 54 2137 (2007), Kloss *et al., New J. Phys. 23, 023025 (2021); arXiv:2009.03132.*

Possible collaboration and networking: This project is part of the priority projects of the French National Strategy on Quantum Technologies. It is realized in close collaboration with the theory group of CEA Grenoble (X. Waintal).

Possible extension as a PhD: we are looking for a candidate who is motivated to pursue the M2 internship towards a PhD; (PhD fellowship can be obtained)

Required skills:
The candidate should have a good background in quantum mechanics and solid-state physics. Programming skills in Python are recommended.

Starting date: open (preferentially beginning 2023)

Contact:

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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Spin-photon interface for individual magnetic atoms in a semiconductor

General Scope:
Individual spins in semiconductors are promising for the development of quantum information technologies. Thanks to their expected long coherence time, spins localized on individual defects are a choice medium for storing quantum information and the semiconductor platform offer interesting integration perspectives. For long distance coupling of localized spins acting as quantum nodes a spin-photon interface is required. Such interfaces typically rely on specific optical selection rules. For non-optically active magnetic impurities, an optical interface can be realized through their exchange interaction with the carriers of the semiconductor. This has been demonstrated for transition metal elements (Mn, Cr, Fe, Co, …) inserted in a semiconductor quantum dot. These magnetic elements offer a large choice of localized electronic spins, nuclear spins as well as orbital momentums.

Research topic and facilities available:
We want to exploit the optical properties of a quantum dot to probe and control the coherent dynamics of the coupled electronic and nuclear spins of an embedded magnetic atom. We will combine radio frequency excitation and resonant fluorescence for the coherent control and probing of an individual spin. We will analyze the quantum dynamics under continuous resonant optical measurement to show how the quantum Zeno effect can help to increase the storage time of the quantum information in such system.
The internship will focus on the development of a resonant fluorescence experiment for the detection of the magnetic resonance of the coupled electronic and nuclear spin of a Mn atom in a strain free quantum dot. We will also start the modeling of the spin-induced fluctuations of optical signals from a resonantly driven magnetic quantum dot in a micro-pillar cavity, a necessary step for the dimensioning of the future spin-photonic devices.
The optical experiments will be realized on a micro-spectroscopy set-up equipped with a magneto-optic cryostat (1.5 K, 9T/2T vectorial magnet, good optical and radio-frequency access), tunable single mode and pulsed (ps) lasers for resonant optical excitation and high-resolution monochromator for the detection.
References: V. Tiwari *et al.*, Physical Review B 106, 045308 (2022); V. Tiwari *et al.*, Physical Review B Letter 104, L041301 (2021).

Possible collaboration and networking:
This work will be realized in the «NanoPhysique et Semi-Conducteurs» group (CNRS/Institut Néel & CEA/IRIG) and in collaboration with the University of Tsukuba in the framework of the International Research Laboratory J-FAST for the growth of some of the samples.
Possible extension as a PhD: Yes
Required skills: Master 2 (or engineering degree) with good knowledge in solid state physics (electrical, optical, magnetic, mechanical properties), quantum mechanics, general optics, light matter interaction.
Starting date: March 2023
Contact:
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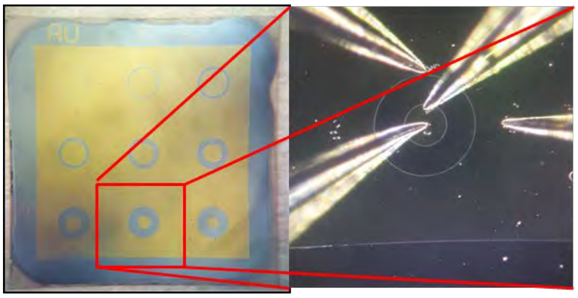
INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2022-2023

Etude des propriétés thermoélectriques de couches minces de type Fe_2VAl

Cadre général :

L'objectif de ce stage est d'étudier les propriétés physiques de couches minces de type Heusler Fe-V-Al pour des applications de microgénération électrique ou de microrefroidissement thermoélectrique. Au cours de ce stage, des films minces seront développés par co-pulvérisation magnétron et recuits dans différentes conditions. Des mesures de concentration et de mobilité des porteurs seront effectuées sur les films minces obtenus. Ces expériences couplées aux propriétés thermoélectriques (effet Seebeck S, résistivité électrique ρ, et conductivité thermique λ pour les meilleurs échantillons) permettront d'optimiser le facteur de mérite $ZT=S^2\sigma T/\lambda$ qui est caractéristique du rendement thermoélectrique. Les compositions, les phases en présence et les microstructures des films minces seront analysées par diffraction des rayons X, SEM-FEG et EDX. Les effets du dopage sur les propriétés thermoélectriques des composés hors-stoechiométrie de type n et de type p $Fe_{2-x}V_{1+x}Al$ seront également étudiés.
Seront également étudiées dans ce stage, les résistances de contact entre métal et matériaux thermoélectriques de type n et de type p en utilisant la méthode CTML (Circular Transmission Line Method).



Couche mince thermoélectrique lithographiée pour des mesures de résistance de contact par la méthode CTML (Circular Transmission Line Method).

Interactions et collaborations éventuelles :
Le stage se déroulera au sein de l'équipe TPS (Thermodynanique et Biophysique des Petits Systèmes) avec le soutien des pôles technologiques de l'Institut Néel. Des interactions fortes entre différents chercheurs et personnels techniques seront nécessaires pour mener à bien ce travail.

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

Formation / Compétences :
Le candidat devra avoir des bases en physique du solide et ainsi qu'un goût prononcé pour l'expérimentation. Des connaissances en dépôt de couche mince seront tout particulièrement appréciées mais pas forcément nécessaires.

Période envisagée pour le début du stage :
Mars 2022

Contact :
Daniel Bourgault
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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Transport thermique dans des géométries moléculaires contrôlées

General Scope :

Le transport de chaleur par conduction à l'échelle macroscopique est bien décrit pas la loi de Fourier. Dans les solides cristallins les modes collectifs de vibrations du réseau, les phonons, définissent le cadre formel permettant une description quantitative du processus de transport de chaleur. Les phonons sont caractérisés par une longueur d'onde, une quantité de mouvement et des processus de diffusion qui permettent de relier leurs propriétés à la conductivité thermique des solides cristallins. Aux petites échelles et a fortiori aux échelles moléculaires les vibrations collectives sont plus compliquées à déterminer et la notion même de température peut être mal définie. Le stage propose d'explorer expérimentalement ces concepts en se basant sur des géométries moléculaires contrôlées et auto-assemblées sur le principe d'origami d'ADN et sur une nouvelle méthode de microscopie thermique à balayage développée au sein de l'équipe.

Research topic and facilities available :
La microscopie thermique à balayage ou Scanning Thermal Microscopy (SThM) est basée sur le même type de sonde que celles utilisées pour l'AFM. Il faut néanmoins user de plusieurs stratégies afin de les instrumenter et d'optimiser le transfert thermique avec l'échantillon à l'échelle de quelques 100 nm. Une partie du stage servira à concevoir, réaliser, caractériser et modéliser les sondes thermiques. Un travail minutieux qui se base sur une expertise technique développée et maintenue au laboratoire. Une seconde partie devra se focaliser sur la conception, l'assemblage et la caractérisation d'Origami d'ADN ayant des configuration adéquate pour réaliser des mesures thermiques à l'échelle de 10 nm. Il faut concevoir des assemblages hiérarchiques et des méthodes d'immobilisation sur des surfaces adaptées au transfert thermique. Un AFM est disponible afin de réaliser ces expériences, l'instrumentation pour les mesures thermiques est présente.

Possible collaboration and networking :

De nombreuses collaborations sont envisageables avec des physiciens numériciens notamment. Au sein du laboratoire des collaborations avec des chimistes ou des biophysiciens sont aussi envisageables afin de développer la thermométrie à l'échelle moléculaire ou les mesures thermiques sur des systèmes vivants.

Possible extension as a PhD : non

Required skills:
L'étudiant recevra une formation à l'état de l'art dans le domaine de la microfabrication et le dépôt de couches minces, l'instrumentation bas bruit et l'imagerie AFM, la modélisation éléments finis et la mesure thermique par SThM. L'étudiant développera ses compétences pour concevoir et caractériser des nanostructures d'ADN par SThM. L'étudiant développera ses compétences en informatique afin de piloter des expériences et traiter des données (python, labview). Le sujet a une forte composante de nano-physique et est tourné vers la chimie et la biologie. C'est un sujet interdisciplinaire.
Starting date :

Contacts:
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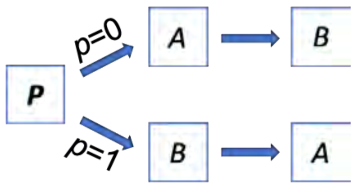
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Dynamical superpositions of causal orders

General Scope :
Understanding the causal relations between different events that one observes is at the very heart of science. Classically, causal orders are well-defined: e.g., either a single event A can be the cause of another single event B (let's denote it $A < B$), or B can be the cause of A ($B < A$), but not both. Beyond such simple fixed causal orders, one can also envisage dynamical causal orders, where the order between events is not fixed a priori but can depend on past events: e.g., a past event P could decide whether A comes before B (resulting in the causal order $P < A < B$), or vice-versa ($P < B < A$) – cf Figure.



Things become less trivial when entering the quantum world [1]. Considering that the events under consideration are quantum operations, it has been realized that their order can be coherently controlled by a "control qubit", depending on its state $|0\rangle$ or $|1\rangle$, so that the causal order becomes a superposition of the kind (roughly speaking)

$$|0\rangle \otimes |\text{“}A < B\text{”}\rangle + |1\rangle \otimes |\text{“}B < A\text{”}\rangle.$$

This new kind of process, called the *"Quantum switch"* [2], has attracted a lot of interest recently, both for the very fundamental questions it raises on the status of causal relations in quantum theory, and for the new types of applications it allows for in terms of quantum information processing.

Research topic:
Beyond the *"Quantum switch"* above, in some recent work [3] we have introduced new types of quantum processes, that involve both coherent control and dynamical causal orders. This combination of the two features is however still poorly understood. The objective of this internship will be to clarify what dynamical orders really involve. The student will first further investigate dynamical orders of quantum operations by themselves, exploring in which fundamental sense they are different from fixed orders, or how they could bring advantages for certain quantum information processing tasks. In a second step, dynamical order will be combined with coherent control, and we will investigate how exactly this can be understood and characterized.

[1] Č. Brukner, *Quantum causality*, Nat. Phys. **10**, 259 (2014).
[2] G. Chiribella *et al.*, *Quantum computations without definite causal structure*, Phys. Rev. A **88**, 022318 (2013).
[3] J. Wechs *et al.*, *Quantum Circuits with Classical vs Quantum Control of Causal Order*, PRX Quantum 2, 030335 (2021).

Possible collaboration and networking :
There will be close collaborations with Alastair Abbott from Inria Grenoble. This internship also fits in part with a new ANR project obtained in collaboration (in addition to A. Abbott) with Alexei Grinbaum at CEA Saclay and Pablo Arrighi at University of Saclay, with whom networking will also be possible. The student will also work in close contact to the other theory students in our group.

Possible extension as a PhD : Funding is not secured yet, but good candidates can apply and hope to get a PhD fellowship from the Ecole Doctorale, or from the Grenoble Quantum PhD programs (we will help with and support such applications).

Required skills: Good knowledge of the formalism of quantum theory; interest in the foundations of (quantum) physics. Prior experience in the field of quantum information will be a plus.

Starting date : 1st semester 2023

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

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Superconducting qubits: from fundamental to applications

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 (see Fig). We propose to study its physical properties of this open quantum system such as quantum-non-demolition measurement, quantum trajectories, simultaneous measurements and to build a superconducting four-qubits plateform based on this new readout and on our recent achievement on quantum limited amplifiers [2].

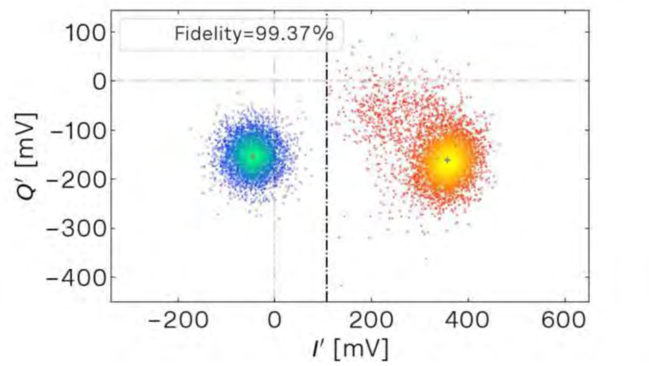

Figure: Histograms of ten thousand single shot QND measurements of the microwave transmitted signal when the qubit is prepared in its ground state |g> (blue points) and excited state |e> (orange points). The two states are very well separated by the measurements leading to a very high readout fidelity.

[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 experiments at very low temperature to study original quantum properties. She/he will participate to the development of the superconducting four qubits 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 the French Quantum Plan and benefits from collaborations with theoretical groups in Madrid (Spain) and Sao Carlos (Brazil).

This internship can be pursued with 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/ April 2023.

Contact: BUISSON Olivier

Institut Néel- CNRS : phone: +33 4 56 38 71 77 email: olivier.buisson@neel.cnrs.fr

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

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Electrical characterization of CMOS-based Si spin qubits.

General Scope :

As part of the Quantum Silicon Grenoble project, teams at Néel Institute, CEA-LETI and CEA-IRIG aim at building a quantum accelerator with silicon spin quantum bits (qubits). Compatible with large-scale production, existing integration processes on Si are a real advantage for the scalability of these qubits (see Fig.1). However, the reproducibility of charge and spin characteristics of these devices are yet to be explored and improved. This requires extensive/statistical electrical characterization and continuous feedback to process integration team.

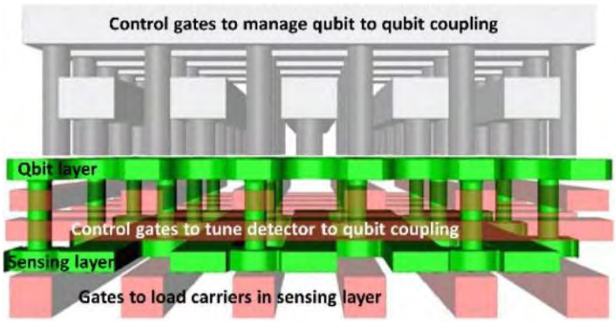

Figure 1- Example of scalable integration of multi-qubits proposed by the Quantum Silicon Grenoble (credit: M. Vinet).

Research topic and facilities available:

Urgent needs on information of variability and reproducibility of spin qubits characteristics rise as fast as the need of integrating a large number of qubits on chip. With the popularization of new low temperature characterization tools (such as cryogenic probe stations and multiplexed matrices) to extract statistical information on the qubit and understand more deeply their properties, the development of measurement procedures, automation and efficient analysis methodologies appear as important tasks. The candidate will work on such tasks, in particular, to help our team to improve our actual knowledge on the reproducibility of charge and spin characteristics of FDSOI CMOS-based qubits. She/he will study different devices architectures and evaluate their performance, providing understanding on the associated physical effects. For this, the candidate will have the opportunity to use the low noise and ultra-low temperature electrical measurement techniques available in the spin qubit team.

Possible collaboration and networking:

This work is part of a large collaborative effort to develop and push the technology of spin qubit in silicon and investigate its potential scalability. The candidate will work in a consortium made of Néel Institute, CEA-LETI and CEA-IRIG researchers, at the interface between the characterization and the integration teams.

Required skills:

We are looking for a motivated student, with a background in microelectronics and/or condensed matter physics. It is essential to have good knowledge of semiconductors physics, in particular of the CMOS technology. Good Python skills, as well as good written and spoken English skills are required, on the same way as communication, ability of writing reports and team work.

Possible extension as a PhD : Yes
Starting date: in between January and April 2023

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MEUNIER Tristan, CNRS, Néel Institute, tristan.meunier@neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Quantum memory integration of rare-earth doped crystals

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: as solids, they offer perspectives of integration, while keeping atomic properties (narrow lines) when interacting with light (optical or RF). Erbium is particularly appealing in this prospect because its optical transition falls in the telecom range, and can naturally be used as a support for optical quantum memories and more generally as a fast and versatile element of control on the qubit.

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

Possible collaboration and networking :

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

Possible extension as a PhD : Yes – Grant already available

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

Starting date : First semester 2023

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

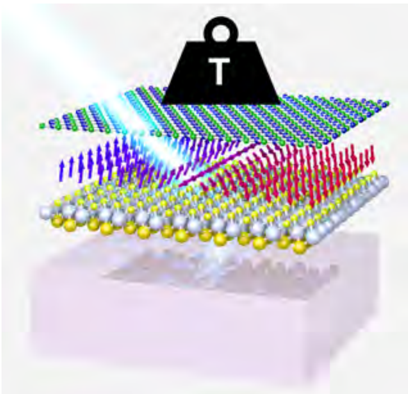
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Physics of magnetic states and their coupling to excitations in two-dimensional crystals

General Scope:
The exploration of magnetism at reduced dimensions, especially in dimension 2 (2D), is rich in non-intuitive phenomena. Unconventional kinds of magnetic orders, non-trivial disordered states (analogous to liquids), intriguing phase transitions (described with topology concepts) have been predicted and/or observed. Starting from 2016-2017, new platforms have been discovered with which these phenomena can be studied: they are lamellar materials, that can be thinned down to the ultimate thickness of a monolayer (one/few-atom-thick). These 2D materials can be manipulated in different ways, either by preparing artificial stacks with other kinds of monolayers, or by applying mechanical constraints. Besides magnetic states, they host photonic and phononic excitations that can couple to magnetism, which further enriches the study of 2D magnetism [1,2].

Research topic and facilities available:



We propose a fundamental research project, focused on a family of magnetic materials recently discovered in Grenoble [3,4]. These chromium-based compounds are remarquable for their magnetic ordering at room temperature, a very rare property making them promising for future applications in spintronics. The objective is to explore the means to manipulate 2D magnetism in these materials. To reach this objective, we can subtly tailor the material's composition, apply pressure, and use magnetic fields. To understand the magnetic properties, the link between magnons (i.e. spin waves), phonons, and the coupling between these excitations, we will use optical spectroscopy techniques, especially Raman scattering in a very broad range of conditions — down to very low temperature, up to high pressures (giga-Pascals), and in presence of intense magnetic fields (tens of Teslas) [1,2].
The project will be carried out in two laboratories that are implanted on the same geographical site, Néel Institute, where sample fabrication is mastered and advanced magnetic characterisations (imaging, magnetometry) will be performed, and the High Magnetic Field National Laboratory (LNCMI), where spectroscopy will be performed under extreme conditions.

Possible collaboration and networking:
The work will be mainly experimental, and will benefit from interaction between local experts in materials synthesis and complementary spectroscopy approaches. The project is part of a large-scale national project, involving seven laboratories.

Possible extension as a PhD:
Funding for a PhD grant is secured (funded national-scale project). PhD works may start in Fall, 2023.

Required skills:
The applicant should have a strong solid state physics background, and have keen interest for experimental work, which will comprise fabrication of samples suited to different kinds of measurements. This experimental work will require strong commitment, especially for experiments under extreme conditions of temperature, magnetic field and pressure.

Starting date: Spring, 2023

Contact: Dr. Johann Coraux (Néel Institute; johann.coraux@neel.cnrs.fr), Dr. Clément Faugeras (LNCMI; clement.faugeras@lncmi.cnrs.fr)

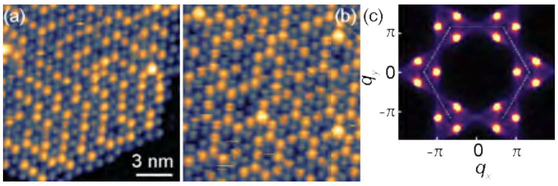
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Emulating frustrated spin Hamiltonians with molecular lattices

General Scope: In 1935, Linus Pauling explained why ice crystals exhibit residual entropy, even down to absolute zero. This property contradicts the third law of thermodynamics (at least in its often-taught formulation) and stems from the positional (local) disorder of the protons within the oxygen crystal [1]. Since then, physicists have found formidable playgrounds in ice-like systems, with which exotic states of matter and unconventional phenomena can be be studied. For instance, in magnetic and artificial analogues of ice, we unveiled, directly in real space, the existence of massively degenerate and disordered ground states violating the third law [2]. Very recently, in the framework of a Ph.D. thesis now ending, we have reconsidered Pauling's viewpoint and demonstrated that two-dimensional layers of fullerene (C_{60}) molecules (see figure) also exhibit striking analogies with water ice [3] and proved to be a fascinating platform to challenge the third law. Besides, seminal predictions from frustrated spin Hamiltonians can actually be directly tested and revisited using such molecular layers. The panel of exotic phases and unconventional collective behaviours that can be investigated accordingly appears considerable.



(a,b) Frustrated lattices of C_{60} molecules imaged by scanning tunneling microscopy. (c) Magnetic structure factor, calculated for a model Hamiltonien describing (b).

[1] L. Pauling, *Journal of the American Chemical Society*, vol.57, p.2680 (1935).

[2] Y. Perrin, B. Canals, N. Rougemaille, *Nature*, vol.540, p.410 (2016). — B. Canals *et al. Nature Communications* 7, 11446 (2016)

[3] M. Alfonso-Moro *et al.*, Corrugation in a molecular C_{60} monolayer as a spin liquid candidate. — M. Alfonso-Moro *et al.*, Coexisting metal-fullerene surface alloys: local three-dimensional strains and rotations, order/disorder. *Articles soon published*

Research topic and facilities available: The project focuses on frustrated spin Hamiltonians in which exotic phases of matter and non-conventional phase transitions are expected, possibly in connection with topological properties. We will also investigate potential experimental means to manipulate the molecular assemblies at the level of individual molecules, seeking to trigger global changes and understand to what extent local excitations propagate. Our approaches are both experimental (scanning tunneling microscopy, cf. figure) and theoretical, relying on Monte Carlo simulations and analyses of the thermodynamic properties of the systems of interest.

Possible collaboration and networking: The work will rely on strong interactions with several researchers from Institut Néel, who are experts in the physics of frustrated spin systems and in the study of molecular layers on surfaces. The student will hence be involved in strongly collaborative working and will benefit from significant technical support. Besides, high resolution microscopy measurements are envisaged, in the framework of a collaboration with another laboratory.

The internship can lead to a PhD project

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

Starting date: Spring, 2023

Contact: Dr. Johann Coraux (Néel Institute; johann.coraux@neel.cnrs.fr), Dr. Nicolas Rougemaille (nicolas.rougemaille@neel.cnrs.fr)

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

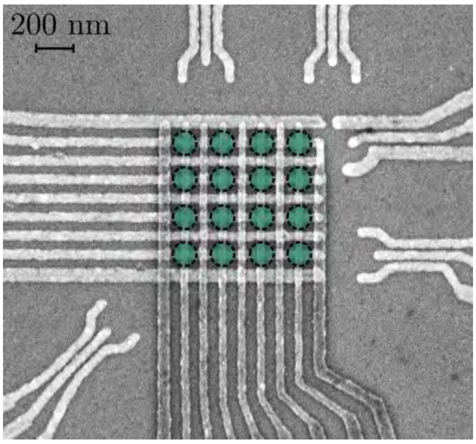
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Quantum dot arrays control, characterization and automatic tuning

Context: Quantum information processing requires to be able to control many qubits with long coherence times. In this context, the electronic spin of a single electron trapped in a Si quantum dot has been identified as a promising platform to both its long coherence time and the possibility to leverage the well-established fabrication of Si foundries. However, quantum dots require to be finely tuned to operate in the right regime which becomes extremely time consuming as the size of the system grows. The QUANTECA team has been a pioneer (PA Mortemousque et al, Nature Nano 2020) in the demonstration and use of the isolated regime in which one or several quantum dots are isolated from the leads allowing to tune the system with a constant number of electrons in the structure hence reducing the dimensionality of the space to explore. The extension of this technique to larger arrays and the exploitation of device symmetries offer interesting perspective to scale systems while keeping the complexity of the tuning under control.

Objectives and means available: The aim of this project is to develop both characterization and automatic tuning procedure for arrays of quantum dots filled with electron spins. The Neel team has extensive knowledge on GaAs dot array devices which are highly tunable and an ongoing collaboration with CEA-LETI to access Si devices fabricated in their industrial foundry. The project will focus on both type of dot array sample. Nowadays, GaAs samples are more mature when it comes to larger arrays and bi-dimensional structures. The idea of the project will eventually be to transfer the demonstrated control to Si quantum devices Si quantum samples. As the project moves forward, some procedures may be optimized with fast electronics in collaboration with CEA-Leti and embedded in custom electronic developed at the Néel institute.



2D array of Quantum dots using 2 layers of gates on GaAs

Interactions and collaborations: This work is part of a collaborative effort between the CEA-IRIG, CEA-LETI and CNRS-Institut Néel to push the technology of spin qubit in silicon and investigate its potential scalability. Therefore, the candidate will work in close collaboration with the LETI's device characterization team to investigate 2D array in Si devices while he will benefit from interaction with the CNRS Institut Néel when it comes to larger devices. A common data acquisition platform shared between the CEA and the CNRS will ensure a smooth collaboration on the automation tools.

Skills and training: The experimental project relies on the knowledge accumulated in the field of few-electron quantum dots and its new implementation in Si devices. All along this project, the candidate will acquire important skills in the field of quantum nanoelectronics: qubit integration, cryoelectronics, cryogenics at mK, low-noise electronics, computer control, characterization of CMOS quantum devices…

Foreseen start for the beginning of the internship: From January to April 2022

Possibility of continuation as a PhD on the same subject with funding already secured.

Contacts: Pierre André Mortemousque CEA Leti Pierre-andre.mortemousque@cea.fr	**Contacts**: Matthieu Dartiailh CNRS- Institut néel matthieu.dartiailh@neel.cnrs.fr	**Contacts**: Tristan Meunier Institut Néel CNRS tristan.meunier@neel.cnrs.fr

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

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

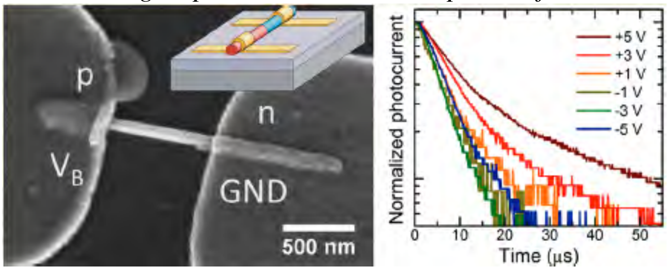
P-n junction nanowires for solar cells

General scope:

Semiconductor nanowires (NWs) with controlled composition and dimensions can be fabricated using optimized growth conditions (bottom-up method) or by lithography and etching of a suitably designed substrate (top-down method). Moreover, it is possible to tune the electrical properties by doping, so that p-n junctions can be implemented within the NWs. These structures are interesting, for example for application as NW solar cells or high-speed photodetectors. Among others, NWs present one major advantage for such applications: they act as antennae and therefore can absorb the light more efficiently using less material. However, challenges remain to control and measure the doping levels in such nano-objects with nm precision. Furthermore, the role of the NW surface on their electrical properties requires further investigation.

Research topic and available facilities:

Left: SEM image of a contacted NW with schematic in the inset. Right: photocurrent time response of the NW.



The aim of this internship is to contribute to the study of p-n junction semiconducting NWs regarding their opto-electrical properties. The student will integrate a multi-institute, multi-disciplinary research group. His/her role will be to fabricate electrical contacts to p-n junction NWs of different materials, including GaN and InP. The NWs will be electrically contacted on membrane chips compatible with transmission electron microscopy (TEM) measurements, and the student will be in charge of their electrical and electro-optical characterization. This includes current-voltage measurements and complete characterization as a photodetector (responsivity, linearity, spectral selectivity, time response). These results will be correlated to detailed characterization by transmission electron microscopy, performed on exactly the same single NW. Combining in-situ biasing with the 4D Scanning TEM techniques sensitive to the electric field, we may obtain a quantitative description of the electrical properties of this object at the nm scale. Using this combination of techniques, we will improve our understanding of NW doping, which will aid device fabrication, for instance for NW solar cells.

The student's work will involve:

- Nanowire contacting in a cleanroom environment. It implies training in nanowire dispersion, mapping using scanning electron microscopy, making drawings of the contact lines, assisting electron beam lithography and finally preforming lift-off.
- Surface passivation of the nanowire may be necessary prior to contacting.
- Current-voltage measurements and electro-optical characterization as a photodetector.
- The electron beam lithography step for nanowire contacting and TEM experiments will be performed by a postdoctoral researcher, but the student will participate in the experiments.
- The student will be involved in the correlation of electro-optical and 4D STEM results.

Possible collaboration and networking: The internship will be in collaboration with Eva Monroy (CEA-IRIG, PHELIQS).
Possible extension as a PhD: Not granted in advance, but we are open to support applications for a PhD grant.
Required skills: Interest in solid-state physics, electrical and optical properties of semiconductors and advanced characterization techniques like transmission electron microscopy.
Starting date: Jan/Feb 2023 or earlier.
Contact: den Hertog Martien & Eva Monroy
Institut Néel - CNRS : tel: 0476881045 mail: martien.den-hertog@neel.cnrs.fr & eva.monroy@cea.fr
More information at: http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Emergent Properties of Novel High Pressure 1322-type Perovskite Oxides

General Scope: High pressure, high temperature (HPHT) synthesis methods can be used to stabilize metastable materials which cannot be prepared at ambient conditions. These conditions open up synthesis routes to a wide range of scientifically and technologically interesting complex transition metal oxides showing emergent properties such as high temperature superconductivity, piezoelectricity, ferroelectricity, magnetism, multiferroicity, and catalytic activity.

We are particularly interested in a family of materials known as 1322-type perovskites (FIG. 2). These materials have general formula $AA'_3B_2B'_2O_{12}$ and can accommodate transition metal cations at the A', B, and B' sites. In these materials, there a range of competing interactions result in a wide range of unusual magnetic behaviour. In this family, HPHT conditions are needed to stabilise transition metal cations in the square planar A' sites.

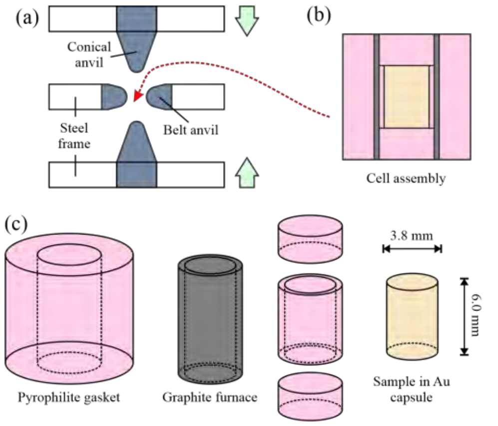


FIG 1. Schematic of a belt-type press (a) and cell assembly (b and c) for HPHT synthesis.

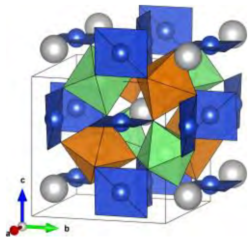


FIG 2. The 1322-type perovskite crystal structure.

Research topic and facilities available: The goal of this project is the synthesis of novel 1322-type perovskite oxides using the HPHT facilities at the Néel Institute, and to characterise their structural, physical, and magnetic properties. Structural characterisation will be carried out using the in-house X-ray diffractometers as well as nearby large-scale facilities (ESRF, ILL). A variety of physical, magnetic, and transport property measurement systems are available at the Néel Institute for sample characterisation.

Possible collaboration and networking: The intern will be working within the Materials, Radiation and Structure (MRS) team of the Néel Institute. They will collaborate closely with several researchers of the MRS team (experienced chemists, crystallographers and physicists) and work with the technical staff of the laboratory (for HPHT synthesis, physical characterisation, X-ray and neutron diffraction). There are possibilities for further collaboration with international researchers (UK, Japan, Taiwan).

Possible extension as a PhD: This master's internship could be extended into a PhD within the same research subject 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: The candidate must have a background in condensed matter physics, materials science, or solid-state chemistry and interest in the synthesis and characterization of new materials.

Starting date: Any time

Contact:

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

NÉEL INSTITUTE Grenoble

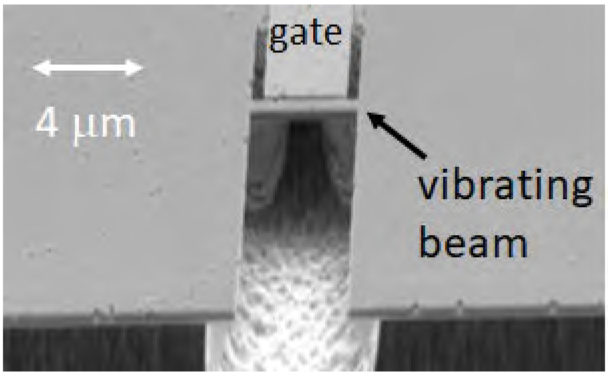
Topic for Master 2 internship – Academic year 2022-2023

Dependence of dissipation of a nanomechanical resonator on its superconducting state

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

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

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



Possible extension as a PhD: Yes

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

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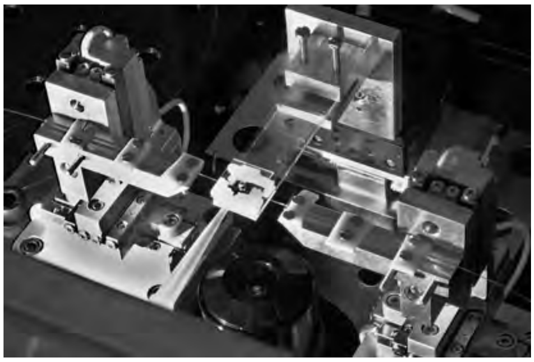
More information: https://neel.cnrs.fr/equipes-poles-et-services/ultra-basses-temperatures-ubt

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Spectroscopic study of free, only optically trapped fluorescent nano-disks.

General Scope : Since their introduction in 1986 by A. Ashkin (Nobel Prize 2018), optical tweezers become an essential non-invasive observation, characterization and manipulation tool in microbiology, chemistry, and solid state physics. The majority of optical tweezers are actually optimized for trapping particles in suspension. Optical trapping in air is a more challenging task as one has to compensate the stronger Brownian motion and consider the very strong adhesion forces of particles on a surface. On the other hand, it opens interesting possibilities for studying light matter interactions or to investigate the optical properties of small particles without any environmental perturbation. In this context, we have developed a fiber-optical air-tweezers allowing very efficient particle trapping on only one single interference fringe. The main scope of the present internship is to use our original tweezers set-up to trap fluorescent nano-disks. and to implement the spectroscopic equipment in order to study the particle emission.



Optical Tweezers setup developed at Institut Néel.

Research topic and facilities available : In a first step the student will optimize the optical tweezers set-up for trapping fluorescent nano-disks. After the investigation of the trapping efficiency, he/ she will implement the required spectroscopic equipment. Finally the fluorescence emission of the particles will be studied with special interest of the spatial intensity and polarization dependency.

Possible collaboration and networking : The nano-disks are elaborated in a collaboration with L. Maia from Univ. Goiás (Brazil) and A. Ibanez from Instutut Néel. If necessary we will use specific lensed fiberes printed in H. Giessens' group at Univ. Stuttgart (Germany) and get theoretical support from O. Hellesø from Univ. Tromsø (Norway).

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.

Contact :

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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

In-situ optical tweezers reconfiguration using photochromic nano-disks

General Scope : Optical trapping has been intensively studied for various scientific and engineering purposes. The objective of this technique is the trapping of small particles. The properties of the particles themselves are usually assumed to be constant over time during optical trapping. However, the addressability by light could dynamically configure the properties of the material under study, meaning that the method of optical trapping itself could be reconfigured. In the present project we are optically trapping photochromic microcrystals using near-infrared light while dynamically changing the absorbance of the trapped particles. Photochromic materials exhibit drastic changes in absorbance upon light irradiation: visible light makes them transparent, whereas UV irradiation makes them opaque. Here we are using microcrystals of photochromic diarylethene, which exhibits photoisomerization in the crystalline state. Small disks of these crystals were already trapped and a weak influence of the photochromatic transition could be observed.
The main scope of this internship is to reconsider the experimental set-up in order to optimize different parameters such as the optical trapping efficiency, the control of the photocromatic transition, and the impact of this transition on the optical trapping. The modified set-up should result in a clear effect of the photochromic transition, a precondition for the realization of optical switching.

Research topic and facilities available : In a first step the student will study the photocromatic transition dynamics with the light sources used for trapping and switching the trapped crystals. Then he/ she will contribute to the design of an optimized/ optical trapping arrangement which he/ she will implement to the actual optical tweezers. Finally the student will use this modified tweezers for running optical trapping experiments with the scope to reveal a clear effect of the photochromatic transition on particle trapping.

Possible collaboration and networking : This project is based on a close collaboration with K. Uchiyama from Univ Yamanash (Japan), a great specialist of photochromatic materials. If necessary we will use specific lensed fiberes printed in H. Gissens' group at Univ. Stuttgart (Germany) and get theoretical support from O. Hellesø from Univ. Tromsø (Norway).

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 2022-2023

Dynamic control of optical trapping in air

General Scope : Since their introduction in 1986 by A. Ashkin (Nobel Prize 2018), optical tweezers become an essential non-invasive observation, characterization and manipulation tool in microbiology, chemistry, and solid state physics. The majority of optical tweezers are actually optimized for trapping particles in suspension. Optical trapping in air is a more challenging task as one has to compensate the stronger Brownian motion and consider the very strong adhesion forces of particles on a surface. On the other hand, it opens interesting possibilities for studying light matter interactions or to investigate the optical properties of small particles without any environmental perturbation. In this context, we have developed a fiber-optical air-tweezers allowing very efficient particle trapping on only one single interference fringe.
In our configuration with two counter-propagating laser beams the optical trapping properties can be dynamically modified by controlling for example (i) the relative polarization of the two beams, (ii) the relative intensity of the two beams, and (iii) the distance of the two optical fibers facing each-other. The main scope of this internship is to investigate these features in order to realize a high speed, feedback optical tweezers reconfiguration which is of great interest for studying the light-matter interactions.

Research topic and facilities available : In a first step the student will study the influence of the above listed parameters by “manually” modifying them. After this calibration step the dynamic control will be realized by adding the required equipment (e.g. Pockels-cell, ...) and implementing the feedback loops into the control software. Running dynamically stabilized optical trapping experiments will be the final part of the internship.

Possible collaboration and networking : If necessary we will use specific lensed fibers printed in H. Giessens’ group at Univ. Stuttgart (Germany) and get theoretical support from O. Hellesø from Univ. Tromsø (Norway).

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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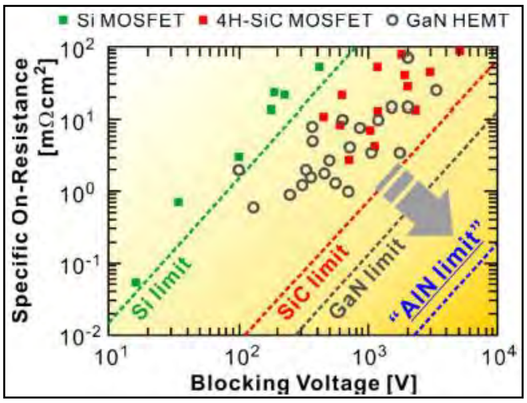
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Study of electronic transport properties
in AlN-based power devices

General Scope :



This internship takes part of the HBV (High Breakdown Voltage) and ACTION (Novel AlGaN channel transistors for high voltage applications) projects, funded by the French agency "Agence Nationale de la Recherche". The scope of these projects is to provide leading edge technologies in the field of III-V semiconductor compounds through the development and the improvement of AlGaN-based technologies for high voltage applications (> 1 kV). A high Al content is required to take advantage of the excellent voltage withstand of AlN. However, to achieve strong breakdown fields, material purity and technological steps have to be improved. Thus, a better knowledge of the defects introduced during manufacturing and their impact on the static and in operation performance of the devices is crucial. Control or removal of defects that act as traps will result in a reduction of the trapping effect and therefore a decrease of the leakage current, an increase of the electron mobility and a higher breakdown voltage.

Research topic and facilities available :

The aim of the internship is to detect electrically active defects in main layers of the devices by measurements of current-voltage, capacitance-voltage, electrical and optical deep level transient spectroscopies, admittance spectroscopy, etc… These techniques allow the signature, the concentration and the localization of the defects to be determined. Measurements will be done on devices (diodes, transistors, Hall bars, Van Der Pauw structures) provided by the project partners. Along with this work, AlN-based diodes voluntarily contaminated by impurities will be fabricated in the clean room Nanofab of the Néel Institute. The study of these diodes will provide data on the formation and diffusion of defects in Al-rich AlGaN layers.

Possible collaboration and networking:

CRHEA (Valbonne) et IEMN (Villeneuve-d'Ascq)

Possible extension as a PhD:

Yes if a scholarship from the doctoral school of Physics of Grenoble is obtained

Required skills:

The candidate should be a master 2 or engineer school student and should have a good background in physics of semiconductors and devices. Knowledge in electrical characterization of microelectronic devices would be an advantage.

Starting date:

February 2023

Contact:

Philippe FERRANDIS
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philippe.ferrandis@neel.cnrs.fr
More information: http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Development of epitaxial Ga_2O_3 thin films for next generation power electronics

General Scope:

The demand for power electronic devices keeps increasing due to the rapid development of industries related to electricity, automotive and consumer electronics. In order to meet this demand, the use of ultra wide bandgap semiconductors such as diamond, aluminum nitride or gallium oxide (Ga2O3) has emerged as a potential avenue for development. Among these materials, β-phase Ga2O3 has many advantages, such as an large bandgap energy (4.6-4.9 eV), a particularly high breakdown voltage (8 MV/cm) as well as a high electron mobility (≈ 250 cm2/Vs). In addition, the availability of large and reasonable-cost Ga2O3 substrates makes it possible to consider this semiconductor as building block for next-generation power devices.

Research topic and facilities available:

The target of this internship is to develop the epitaxial growth of Ga2O3 thin films by pulsed liquid injection metalorganic chemical vapor deposition using a semi-industrial reactor, in which different chemicals as precursors will be explored. A wide range of morphological and structural characterization techniques will be used, including scanning and transmission electron microscopy, X-ray diffraction, and Raman spectroscopy, to finely assess and optimize the thin film growth mechanisms involved as well as the interface properties with the substrate. The optical and electrical properties of Ga2O3 thin films will be further characterized by optical absorption, Fourier Transform infrared spectroscopy, I-V, and photoconductivity measurements.

Possible collaboration and networking:

The candidate will work in the Materials and Physical Engineering Laboratory (LMGP), in the Nanomaterials and Advanced Heterostructures team (NanoMAT), as well as in Institut Néel, in the Wide Band Gap Semiconductor team (SC2G). The research project is part of the PowerAlps Cross-disciplinary research project funded by UGA, aiming at developing materials, functions and systems for next generation power electronics taking into account sustainability and industrialization issues.

Possible extension as a PhD: Yes. Funding already available.

Required skills:

The applicant should be an Engineering School or Master 2 student in the fields of materials science and engineering and/or semiconductor physics. Specific skills for teamwork and oral and written English expression will be appreciated. We are looking for dynamic, highly motivated candidates, who are interested to pursue a PhD thesis.

Starting date: February to April 2023, for 5 to 6 Months long

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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Contribution to the building and use of haloscopes for Astrophysics and Cosmology

General Scope : This internship is part of the GrAHal project, an aim of which is to determine whether Dark Matter is mainly made up of Axions. These pseudoscalar particles come from a chiral symmetry that had been proposed to explain why we do not detect neutron dipole moment. We can search for the possible Axions of the Dark Matter Halo of our Galaxy in which we are immersed by their resonant conversion into radiofrequency photons under an intense magnetic field in a cavity at the lowest temperatures. This defines a haloscope. Another objective of GrAHal is to study the innovative perspectives offered by haloscopes for the detection of high-frequency gravitational waves by the inverse graviton → photon Gertsenhstein effect, which would open windows of observation on the primordial cosmology of the universe.

Research topic and facilities available : A first haloscope has just been built at the Néel Institute. It consists in a cylindrical copper cavity, cooled down to 4 K and subjected to a magnetic field of 14 T supplied by superconducting coils, very low noise amplifiers and spectrum analyzer. It was operated in the fundamental mode TM_{010} of frequency 6.375 GHz of the copper cavity. A slight tuning of this frequency was achieved by modifying the helium pressure in the cavity. A first objective of the internship will be to make contact with this prototype, take part in the conception and test of a tuning mechanism, collect and analyze data in a wider frequency range. A second objective of the internship will be to participate in the construction phase of a second-generation haloscope operating at very low temperature around 50 mK and using a quantum signal amplification technique for better sensitivity.

Possible collaboration and networking : The internship will take place within the framework of the GrAHal collaboration bringing together researchers from the Néel Institute, the LNCMI and the LPSC combining all the technical, experimental, numerical and theoretical skills necessary to achieve the targeted objectives.

Possible extension as a PhD : It is anticipated that this internship will continue with a thesis based on the second generation haloscope under construction.

Required skills : Masters of Physics (second year) / Knowledge of cryogenic techniques and/or microwave assemblies and/or of finite element calculation tools (like COMCOL Multiphysics) would be appreciated but is not necessary.

Starting date : february-march 2023

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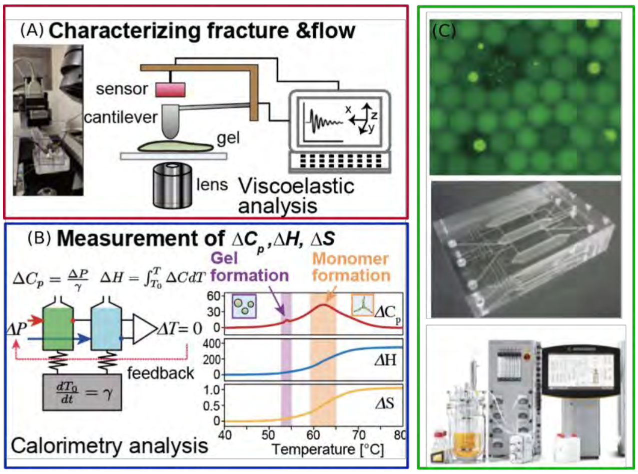
INSTITUT NEEL Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Rational design of functional DNA gels

General Scope :

For soft matter engineering, DNA is the ideal polymer. In addition to being mechanically robust, chemically stable and enzymatically replicable, DNA is a sequence-defined polymer that can be designed to self-assemble into almost any shape, simply by tuning the arrangement of its monomers (the nucleotides). Given some DNA strands, a dynamic programming software can predict their thermodynamics from their sequences: the way they interact (binding energies) but also the structure they form at equilibrium (minimum free energy structure). Therefore, we see DNA as an ideal polymer to design, from the nanoscale, materials with unprecedented mechanical properties at the micro and macro scales.



Research topic and facilities available :

To concretize this vision, we propose in this project to establish Multiscale MechanoProgrammable Gels (MMP gels). In these gels, DNA nanostructures orchestrate the development of function and mechanics at the macroscopic scale through a sequence of hierarchical chemical processes. As a result, we envisage applications where biocompatible and soft materials must change their mechanical properties based on physical and chemical stimuli (artificial skin, intelligent adhesive plasters, adaptable contact lenses, self-healing cartilage, smart stents...). We believe that this will lay the foundation for the rational engineering of soft materials.

In this project, the candidate will focus on measuring and engineering the thermodynamics aspect of MMP gels. Using calorimetry, the candidate will study how thermodynamics values (enthalpy, entropy) are related to mechanical properties at the microscale and macroscale. He will also leverage the vast repertoire of DNA nanotechnology to engineer gels with programmable mechanics and thermodynamics.

In this project, the candidate will focus on measuring and engineering the thermodynamics aspect of MMP gels. Using calorimetry, the candidate will study how thermodynamics values (enthalpy, entropy) are related to mechanical properties at the microscale and macroscale. He will also leverage the vast repertoire of DNA nanotechnology to engineer gels with programmable mechanics and thermodynamics.

Possible collaboration and networking :

This collaborative project involves 3 other partners, two of them are in Lyon one is in a CNRS unit in Japan

Possible extension as a PhD : yes, for student with excellent academic background application to the doctoral school can be programmed. ANR funding is not guaranteed yet.

Required skills:

Any student with a background in in physics, chemistry or biology is welcome to apply. We are seeking for motivated student willing to work at the interface between different disciplines. Our goal is to improve our fundamental understanding of DNA assembly, sol-gel transition, rheology of soft material thanks to thermodynamic measurements. If these topics puzzle you, your ideas and creativity are of interest for us, come and visit.

Starting date : Winter - Spring 2023

Contact : Guillou Hervé

Institut Néel - CNRS : tél 04 76 88 12 10 mel herve.guillou@neel.cnrs.fr

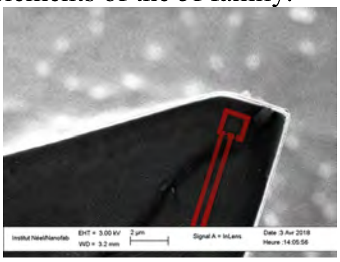
Plus d'informations sur : http://neel.cnrs.fr

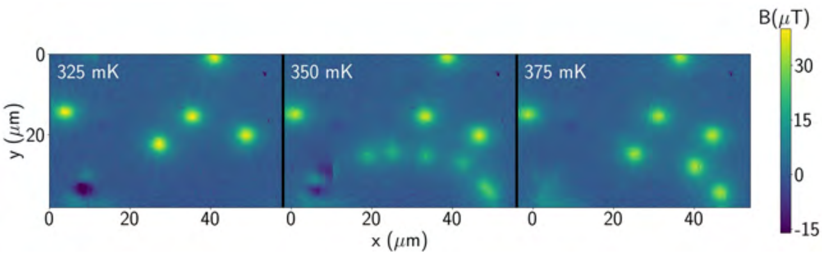
NÉEL INSTITUTE Grenoble

Topological superconductivity imaged by scanning SQUID microscopy

General Scope :
The aim is to discover manifestations of topological superconductivity using vortex matter as indicator. Topological superconductivity is a phenomenon in which surface (2D/1D) effects are different from bulk properties. Our approach is to study superconductors with 5f electrons (Uranium compounds UPt_3, UCoGe UTe_2) being natural candidates for topological superconductivity as suggested by their complex superconducting phase diagrams.
Finding topological superconductivity will allow us to manipulate novel quantum states and to further the theoretical understanding of these states.

Research topic and facilities available :
We have developed a magnetic scanning microscope operating at very low temperatures (0.2 kelvin). It is a well suited tool to study these superconductors as they transit below 2 K into the superconducting state. We use a Superconducting Quantum interference Device (SQUID) as magnetic sensor in our microscope: Flying at a height of a few nanometers above the surface of the superconductor the SQUID probe intersects magnetic flux lines acquiring thus magnetic images. During the M2 internship the student will be familiarized with the cryogenic environment and the scanning probe techniques before acquiring and interpreting magnetic images of superconductors with elements of the 5f family.





Al NanoSQUID probe (Neel Nanofab)

Half Quantum vortex formation and fusion in UPt_3 (thèse P. Garcia Campos thesis link).

Possible collaboration and networking :
This subject is part of a collaboration between teams at ESPCI in Paris and Pheliqs Grenoble and teams in Germany and Japan.

Possible extension as a PhD :
After familiarization with the subject and the instrument, improvements of the SQUID detector are to be achieved using techniques of nanofabrication and characterization with highly sensitive amplifiers. This work will be done in collaboration with the technical services and scientists of the collaboration. Funding may be obtained via the Quantum.PhD calls.
Required skills:
Curiosity for technological aspects of Science, programming, dexterity
Starting date :spring 2023

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More information : http://neel.cnrs.fr & Klaus Hasselbach

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Development of a database of theoretical X-ray absorption spectra, for analysis using artificial intelligence.

General Scope :

With their experience in characterizing advanced materials, the two CRG beamlines FAME and FAME-UHD propose to create a new analysis method based on artificial intelligence using spectroscopy and speciation in biology, chemistry, environmental sciences and geosciences.
Thanks to the improved performance of the equipment (Equipex+ MAGNIFIX project), counting times will be reduced with the improvement of the beam and the detection. The critical step will then be the analysis of the experimental data of the samples. To fully automate it, as well as the measurement and data processing, would allow to increase the flow of characterized samples.

Research topic and facilities available :
To process this "data overflow", the existing software tools must be adapted to face it. In this context, Artificial Intelligence (AI) will allow the analysis of massive and complex data in series.
The first step of this project is to develop the tools to generate a database of theoretical spectra to provide a data set on which to train a neural network.
The first objective of the internship is to calculate a family of theoretical spectra via the FDMNES code (http://fdmnes.neel.cnrs.fr/). The quality of the calculated spectra will then be evaluated with the experimental spectra present in the SSHADE-FAME database (https://www.sshade.eu/db/fame).
Once the first theoretical dataset is validated, it will be inserted into the Materials Project database (https://materialsproject.org/) which provides the scientific community with the infrastructure and tools necessary to develop machine learning to predict the coordination environment.
The development of these tools, will allow the generation of data sets and training of the neural network on other material systems and will allow the analysis of spectroscopic data on fly on the FAME and FAME-UHD beamlines.
The student will have access to the analytical facilities of the two beamlines at ESRF

Possible collaboration and networking :
With the members of the team in charge of the two beamlines, Y. Joly, founder of the FDMNES program at the Néel Institute

Possible extension as a PhD

Required skills:
An interest in Python programming and Artificial Intelligence, notion of X-ray absorption spectroscopy

Starting date : **As soon as possible**

Contact :
Hazemann Jean-Louis/ Mauro Rovezzi
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INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2022-2023

Propriétés électroniques de systèmes non conventionnels

Cadre général :
Ce stage expérimental s'inscrit dans le cadre de l'étude des propriétés physiques de la matière condensée, et plus particulièrement des systèmes corrélés : supraconducteurs non conventionnels, métaux « exotiques » (semi-métaux de Weyl ou en limite ultra quantique), systèmes topologiques (isolants Kondo ou phase de Kitaev) etc… Les effets de corrélation sont en effet un des ingrédients majeurs à l'origine des propriétés *anormales* de la matière condensée et, étudier, analyser, comprendre ces effets est un enjeu majeur de la physique du solide moderne. Le paramètre essentiel gouvernant les propriétés physiques des solides est leur densité d'états au niveau Fermi et dans ce stage il s'agira essentiellement de déterminer ce paramètre avec la plus grande précision, en utilisant pour cela une approche thermodynamique basée sur une technique de mesure de la chaleur spécifique développée au laboratoire dans des conditions extrêmes de température (jusqu'à 0.3K) et de champs magnétiques (jusqu'à 35T).

Sujet exact, moyens disponibles :
Dans ce stage il s'agira donc d'étudier l'effet de la température et du champ magnétique sur les propriétés physiques de systèmes complexes. En fonction de l'étude en cours au moment du stage et de l'intérêt du candidat, cette étude pourra porter soit sur l'étude de nouveaux supraconducteurs (notamment les composés dits *kagome* au sein desquels la supraconductivité entre en compétition avec une onde de densité de charges complexe ainsi qu'avec des effets topologiques qui restent à être précisés) soit sur l'étude de transitions électroniques ou magnétiques dans d'autres systèmes comme par exemple les isolants Kondo dont la structure électronique pourraient contenir des Fermions « sans charge » issus de la « fractionalisation » des quasi-particules.
Le(a) stagiaire sera amené(e) à se familiariser avec notre technique de mesure et sera impliqué(e) dans l'ensemble des phases de l'étude : montage des échantillons, cryogénie, prise des mesures, analyse des données et confrontation avec les modèles théoriques (s'ils existent).

Interactions et collaborations éventuelles
Le(a) stagiaire sera intégré(e) au « groupe supraconducteurs » du département matière condensée et basses températures de l'Institut Néel. Il(elle) sera amené(e) à interagir avec les différents membres du groupe. Par ailleurs il(elle) pourrait être amené(e) à effectuer des mesures en champs magnétiques intenses en collaboration avec nos collègues du LNCMI et à interagir avec nos collaborateurs (notamment Japonais) pour les différents aspects de l'étude.

Ce stage pourra se poursuivre par une thèse.
Oui, financement sur le concours de l'école doctorale (ou autres concours fléchés matière condensée).

Formation / Compétences :
inscrit dans un parcours général en physique de la matière condensée avec une bonne maîtrise des concepts fondamentaux en mécanique quantique et physique du solide.

Période envisagée pour le début du stage :
Mars à Juin 2023.

Contact : Thierry Klein et Christophe Marcenat
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Plus d'informations sur : http://neel.cnrs.fr

Magnetism by machine learning

General Scope : In order to predict new magnetic materials with desired properties on need to be able to scan large number of systems and if possible the whole set of possibilities in a given family of materials. To reach this goal one need to evaluate on-the-fly the magnetic interactions of any given system. The accurate calculation of the latter however presently requires time-consuming procedures. One thus need to change the methodology and use a non-heuristic approach such as machine learning methods. The low computational cost of these new "in silico" methods offers a way to meet the challenge of an "automated" exploration of the field of possibilities.

In the field of magnetic materials, the use of deep learning methods is however quite uncommon and essentially focused on the determination of transition temperature, or phase diagrams and not on the determination of the magnetic interactions.

Research topic and facilities available : In this project, we propose to explore this new field by elaborating a machine learning methodology to predict the magnetic properties of metal-organic-frameworks (MOF). The project will explore the best type of deep learning method to be used, the structural or electronic descriptors needed to predict the magnetic interactions, the construction of the training data sets. The latter will be first developed by collecting data from previous work of the group, then by extending them and producing new data.

This work will be done on French supercomputer facilities. The supervisor will provide the computer hours allocation.

Possible collaboration and networking : This work will be done in close collaboration with a machine learning speciatlist :Jean-Luc Parouty from SIMAP. The student will also be in contact with other theoreticians specialist of evolutionary algorithms (Gilles Frapper and F. Guégan from IC2MP) or neutrons scattering (Elisa Rebolini from ILL) and experimentalists groups working on magnetic MOFs.

Possible extension as a PhD : yes

Required skills: A good knowledge of quantum mechanics is required as well as basic knowledge of python and linux operating system. Some knowledge on machine learning and magnetism will be appraciated.

Starting date : Anytime between february and april 2023

Contact :
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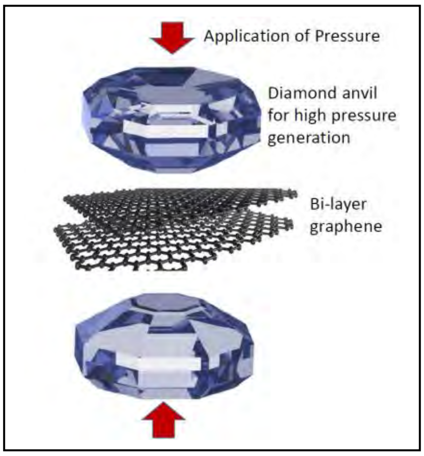
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

High order magic angles in twisted bilayer graphene

General Scope:

Twisted bilayer graphene (TBG) has shown to offer amazing electronic properties at the magic twist angle: strong correlations physics, superconductivity and Mott Insulator transitions. These quantum properties rely on the particular localization effects at the first magic angle (~1° for TBG). An important open question remains: what are the properties and new physics emerging at the higher order magic angles? One way to reach them is by changing the interlayer coupling which can be experimentally performed by application of high pressure.



The main objective of this PhD project is to reach such magic angles using high pressure in diamond anvils cell. The PhD student will perform Raman spectroscopy and electron transport measurements in diamond anvils cells, using cryogenic systems. He/She will work at Néel Institute in collaboration with two teams, one expert in 2D materials for fabrication and their electronic and vibrational properties, the other expert in high pressure and strong correlations physics. Superconductivity will be checked in particular, and the role of phonons and strong correlations on this unconventional superconductivity will be investigated.

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 double layer samples. Good results have already been obtained on this process. The student will thus acquire a solid experience in nanofabrication. He/She will proceed then to make Raman measurements as a function of pressure to track higher order magic angles, and then electron transport measurements at low temperature are envisioned.

Possible collaboration and networking:
Networking: ANR project 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: 2022-2023
Contact: Laëtitia Marty and Marie-Aude Méasson
Institut Néel - CNRS
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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Quantum transport in superconducting/semiconducting Al/Ge/Al heterostructure

General Scope :
The internship and the PhD is motivated by our recent investigations of the ultra-scaled hybrid superconducting/semiconducting aluminum/germanium (Al/Ge) devices. By tuning a gate voltage, they reveal a very rich quantum electronic physics ranging from single charge quantum dot, Coulomb diamonds to proximitized superconductivity. These properties were achieved thanks to the unique monolithic monocrystalline Al/Ge/Al nanowire heterostructure with remarkable atomically sharp interfaces between Al and Ge [1]. These promising devices open the way towards quantum technologies in particular superconducting gatemon qubit or the study of Majorana fermions.

[1] Al–Ge–Al nanowire heterostructure: from single -hole quantum dot to Josephson effect,
J. Delaforce, M. Sistani, et al, Advanced Materials, Wiley-VCH Verlag, 2021, 33 (39), 2101989 (2021).

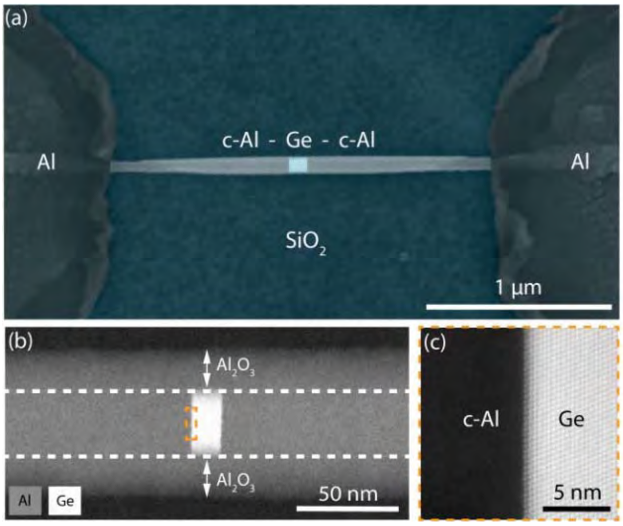

Figure 1: (a) SEM image of the nanowire heterostructure with self-aligned Al leads contacting a Ge segment connected to large aluminum pads deposited on SiO2 layer. (b) TEM image showing a zoom of the Al/Ge/Al heterostructure device. The central white segment is the germanium. (c) TEM image showing the Ge atoms and the atomically sharp interfaces

Research topic and facilities available :
Our research aims at exploring promising superconductor/semiconductor hybrid devices based on ultra-scaled Al/Ge heterostructures. Inside the consortium, we will develop novel quantum devices and their integration in functional quantum circuits to study gatemon superconducting qubit, Andreev qubits, multiterminal junctions. We will measure their electronic transport properties in a homemade He3 cryostat which allows to measure down to 350 mK and their qubit properties in the microwave domain in a dilution fridge. The internship is aimed to be followed by a PhD.

Possible collaboration and networking : The internship proposal is related to a joint project between the Néel Institute and the Technical University of Vienna (Austria).

Required skills: Master or Engineering degree. Skills on solid state physics or quantum transport will be appreciated. Motivation on experimental quantum device is needed.

Starting date : March or April 2022 for internship.

Contact :
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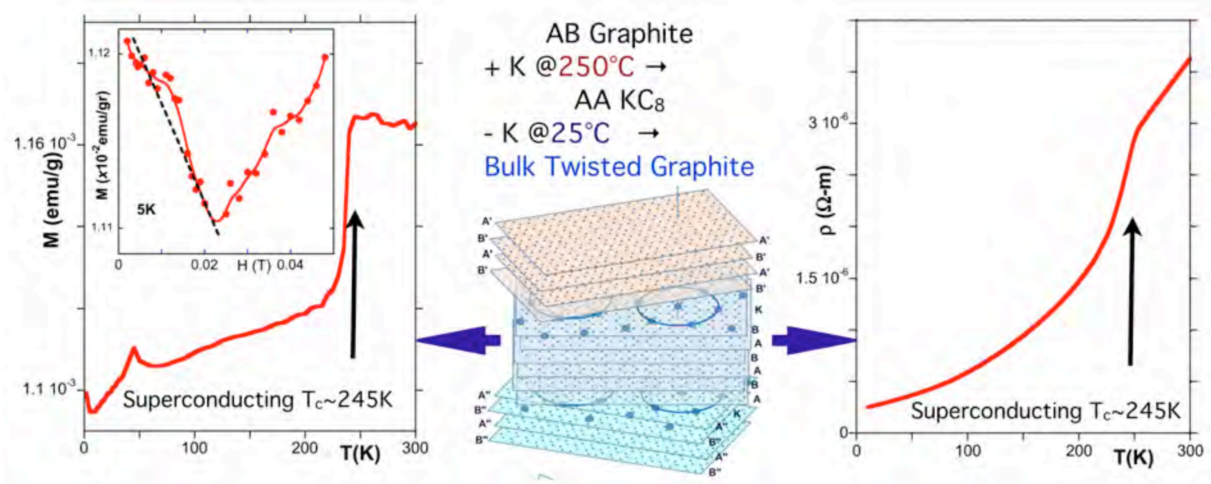
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Search for the origin of the room temperature superconductivity in bulk twisted graphite

General Scope :

For twenty years there have been claims on the existence of room temperature superconductivity in pure graphite[Adv.Mat.24(2012)5826], that have been attributed to defects of the AB graphene infinite stacking of graphite. On the other hand, superconductivity has also been reported by several groups on graphene Moiré stackings, albeit with a transition temperature Tc at low temperatures[Nature 556(2018)43]. Namely, two graphene layers stacked twisted with a "magic" angle (~1.1°). In this case, the origin has been tracked to the extremely flat electronic bands that appear in these twisted structures leading to what is called flat band superconductivity. Following theoretical predictions to increase the low Tc's, experimentalists increase the number of graphene planes (up to five presently), and also change the stacking angles. However, the number of potential arrangements are uncountable and the samples very difficult to make. We have design a synthesis by intercalation and de-intercalation of highly oriented pyrolithic graphite to fabricate in the same sample as many as possible of twisted and doping configurations. When we measure the obtained samples we verify by synchrotron radiation and Raman measurements that all six-fold stackings are present in the nanocrystals. The magnetization and electrical resistance measurements show superconducting transitions at 110K, 245K and 320K(see figure)[ArXiv2205.09358, Carbon(2022)]. We now know that some crystals develop high temperature superconductivity. The next step is to study samples with different preparations, in order to increase the amount of superconductivity and pin down their exact geometry.



Research topic and facilities available :

The subject of the internship will consist in magnetization and electrical resistivity measurements of the samples synthesized by the Cristaux-Massifs service of the laboratory, under the supervision of M. Nunez-Regueiro. Synchrotron radiation measuremetns will also be made in the ESRF (G. Garbarino) and Raman measurements at IN (M-A. Méasson).

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 : october-april 2023

Contact : Name :M. Núñez-Regueiro
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More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Phase diagram determination and growth of Langbeinite type crystals by high temperature solution growth

General Scope:

It has already been demonstrated that a large variety of synthetic langbeinites, based on the structure of $K_2Mg_2(SO_4)_3$, can be stabilized with room temperature non-centrosymmetric structures . Chemically speaking, fully substituting both sulfate $SO4^{2-}$ for phosphate $PO4^{3-}$ group and diamagnetic Mg^{2+} ions for paramagnetic Cr^{3+} cations is possible only if a mixed counter cation ($Na^{+}A^{2+)}$) is introduced on the potassium site. $NaBa_{1-x}Sr_xCr_2(PO_4)_3$ solids, ceramics, with x=0 and 1 were recently reported to show intriguing physical properties (hysteric magneto capacitance signal when x=0 and a parallel magnetic long range ordering when x=1). During this internship we aim to grow single crystals $NaBa_{1-x}Sr_xCr_2(PO_4)_3$, from high temperature solutions, because obtaining single crystals is mandatory to investigate the physical properties/nuclear structure relationships with respect to an external stimulus. This work is developed in the frame of a collaboration project which main goal is the search of multiferroics solids based on polyanionic framworks.

Research topic and facilities available:

Before beginning the growth of crystals of Langbeinite family, ($Na_{1-x}Cu_{1+x}Cr_{2-x}(PO_4)_3$, $NaBa_{1-x}Sr_xCr_2(PO_4)_3$), that are of interest for ANR MultiPhos project, phase diagrams should be determined in order to find the chemical composition allowing to grow and stabilize the phases sought for its exotic magnetic properties. After this step, small crystals will be grown by spontaneous nucleation from high temperature solutions and the ones showing better magnetic properties will then be grown by Top Seeded Solution Growth-Slow Cooling (TSSG-SC) process.

We have already obtained $Rb_2Ti_2(PO_4)_3$ Langbeinite type phase by high temperature solution growth in molten phosphate salts ($Rb_6P_40_{13}$ self flux) at temperatures close to 1000°C. As $M_6P_4O_{13}$ fluxes have already been used to dissolve refractory oxides such as TiO_2 (Tm = 1843 °C) leading to homogeneous growth solutions, they will be used during this internship. Considering that the growth of crystals with Langbeinite phase and adequate stoichiometry may require a perfect homogenization of solutions containing SrO (Tm = 2531°C), Cr_2O_3 (Tm = 2435 °C) and BaO (Tm = 1923 °C) and also growth temperatures higher than 1100 °C, a Nabertherm muffle furnace with working temperatures up to 1400 °C, available at Institut Néel, will be necessary. Moreover, in order to decrease the homogenization temperature of the solution, a molten phosphate-molybdate (or tungstate) salt could be used. These molten salts have been already used to grow $K_2Fe(MO_4)(PO_4)_2$, $K_2Sc(MoO_4)(PO_4)_2$ and $K_2Sc(WO_4)(PO_4)_2$; three langbeinite-related compounds.

Chemical reagents, muffle furnaces, powder X-ray diffractometers and Raman Spectrometer are available to the realization of this internship.

Possible collaboration and networking: CRISMAT (Caen, France), ICMCB (Bordeaux, France)

Possible extension as a PhD: Possible in the frame of the ANR project MultiPhos..

Required skills: Strong interest in materials science and experimental work is needed. Skills in crystal growth will be appreciate.

Starting date: February/March 2023

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

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2022-2023

Chiral textures in magnetic thin films

Cadre général :
The magnetisation of thin films can be manipulated not only by magnetic field but also by an electrical current through the so-called spin transfer torque effects. The dynamics of domain walls - the regions that separate magnetic domains- depends on their internal structure: this is determined by the balance between different energy terms i.e. exchange, anisotropy and magnetostatic. It was recently discovered that in non-centrosymmetric thin films where the magnetic layer is deposited on a heavy metal with large spin-orbit interaction, the presence of interfacial Dzyaloshinskii interaction (DMI) can stabilise magnetic structures *with a fixed chirality*, skyrmions and domain walls with Néel internal spin structure.

The current- and field-driven dynamics of such objects is non trivial and strongly depends on the strength of the DMI. In view of possible applications to spintronic devices, it is important to measure and optimize such interaction.

Two experimental techniques are mostly used to measure the strength of the DMI. The first is based on the study of domain wall dynamics driven by a magnetic field. The second is based on the inelastic scattering of photons by spin waves, whose propagation depends on the chirality of the magnetic texture and can be measured by Brillouin Light scattering (BLS).

Sujet exact, moyens disponibles :

A BLS spectrometer has been recently acquired at Institut Néel. The aim of the internship will be to compare the interfacial DMI of a magnetic multilayer (Pt/Co/Oxide) using domain wall dynamics and BLS. The student will deposit the multilayer with magnetron sputtering. He/she will characterise the magnetic properties (magnetisation, magnetic anisotropy) with classical magnetometry techniques, will carry out domain wall dynamics measurements using magneto-optical Kerr microscopy, will measure the DMI by BLS. The effect of external parameters on the magnetic properties, such as an electric field applied using a gate, will also be tested. If the time allows it, micromagnetic simulations will be carried out to compare experiments with theoretical models.

Available instruments at Institut Néel : magnetron sputtering for magnetic thin film deposition, clean room for optical and electronic lithography, magneto-optical microscopes for magnetic imaging. The Brillouin Light Scattering spectrometer is being constructed and will be operational at the time of the internship.

Interactions et collaborations éventuelles :
Interactions with colleagues of SPINTEC and LPS Orsay are likely

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

Formation / Compétences :
Some notions of magnetism and nanomagnetism are required; having followed magnetism courses in M1 would be a plus.

Période envisagée pour le début du stage :
March-Avril 2023

Contact : Stefania Pizzini, Laurent Ranno
Institut Néel - CNRS : stefania.pizzini@neel.cnrs.fr ; laurent.ranno@neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

A bright source of entangled photon pairs

General Scope:
Entangled photons pairs are a key resource for quantum information processing, in particular for quantum communications. For example, they enable the realization of quantum relays that can extend the distance of quantum key distribution. To be useful, a source of entangled photon pairs has to be bright and tunable, emit indistinguishable photons, and operate on-demand to allow scaling up to many pairs.

This project targets the first demonstration of such a source. On-demand, polarization-entangled photon pairs will be emitted by a semiconductor quantum dot, by exploiting the biexciton-exciton radiative cascade. The cancelation of the excitonic fine structure splitting will be obtained by applying suitable strain [1,2], using piezo-electric actuators and an original electrostatic technique (cf figure). A tapered nanocavity will simultaneously ensure the efficient extraction of both exciton and biexciton photons [3,4] and provide a broadband spontaneous emission speed-up, in order to achieve photon indistinguishability.

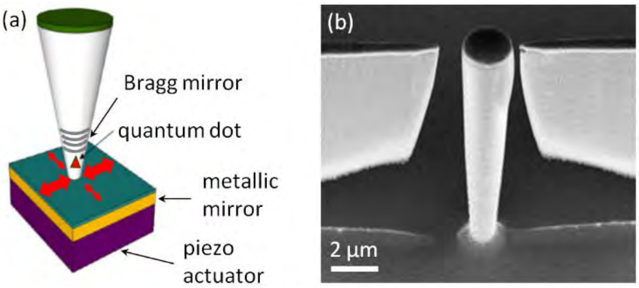

Figure 1 (a) scheme representing the tapered photonic wire containing a quantum dot sandwiched between two mirrors. The piezo actuator will perform the strain tuning of the quantum dot. (b) Scanning electron image showing that the strain tuning will also be performed by electrostatic actuation via closeby electrodes.

Research topic and facilities available:
This is a project connected to a recently obtained ANR grant (IPOD). During the internship, the work will consist in setting up the photon correlation system that will evaluate the fidelity of the entangled photons. Most of the equipement (cryostat, lasers, spectrometer) is already available and will be complemented thanks to the ANR support.

References
[1] I. Yeo et al, Nature Nano **9**, 106 (2014)
[2] D. Tumanov et al, APL **112**, 123102 (2018)
[3] M. Munsch et, Phys. Rev. Lett. 110, 177402 (2013)
[4] H.A. Nguyen et al, Phys. Rev. B **97**, 201106(R) (2018)

Possible collaboration and networking: The samples are fabricated by our colleagues (J. Claudon and J.M. Gérard) from CEA Grenoble. The project involves original samples, and it will therefore be carried out in very close interaction with them.

Possibility to go on with a PhD ? Yes

Required skills: The internship will consist in experimental work in optics and spectroscopy. Good background in optics, and quantum physics is recommended.

Beginning of the internship : early 2023

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

NÉEL INSTITUTE Grenoble

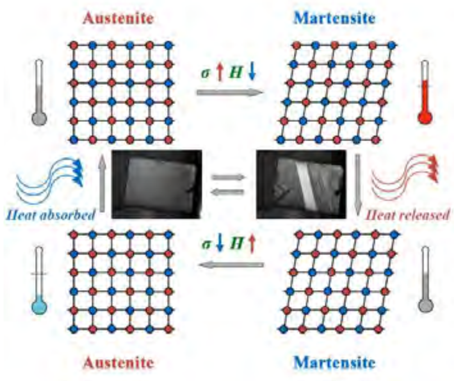
Topic for Master 2 internship – Academic year 2022-2023

Eco-Refrigeration with elastocaloric materials

General Scope:

To decrease energy consumption for ambient cooling is imperative in the context of global warming since it represents 20 % of our CO_2 production... An alternative to classic gaz compresion cycle is the elasto-caloric cycling described below which has attracted significant attention in the literature. Elasto-caloric heat pump technologies emerged as the most promising caloric solution with the highest final score. However to achieve billions of cycles, this process requires fatigue resistant materials. This project targets to develop and study highly recycable materials made of non critical ressource elements,for example FeMn based shape memory alloys.

The heat pump is based on caloric effects where the temperature and entropy changes under the application of an external field to a given material. The elastoc-aloric effect (eCE) is related to the isothermal change of entropy or the adiabatic change of temperature that takes place when an external stress is applied or released to the material. It corresponds microscopically to a solid-solid structural transition (austenite ↔ martensite) triggered by the applied stress (see left figure). Magneto-caloric effect can also exist in some of the elasto-caloric alloys: both external stress and magnetic field can then trigger the phase transition: it brings versatility and the possibility to used them in broad applications. However, the giant caloric effect is inseparable from a thermal hysteresis resulting from the strain incompatibility between the two solid phases and usually responsible for poor mechanical fatigue properties. Several alloy design (optimisation of composition, processing route) can be followed to improve this property: this constitutes the core topic of the training.



Research topic and facilities available:
- improvement of new processing route of metallic micro-wires (Taylor-Ulitovski) and melt-spun ribbons,
- a better understanding of the structural transformation, strain relaxation mechanisms and associated residual structural defects for ferromagnetic Shape Memory alloys,

We offer
-Dynamic environment with rich experimental and original facilities ,
-Multidisciplinary research topic covering physics, materials science and technology,

Possible collaboration and networking:
SIMaP laboratory (Marc Verdier)

Possible extension as a PhD: Yes.

Required skills:
-Strong interest in experimental physics
-Material science
Starting date:March or April 2022 fir internship
Contact:

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NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Graphene based superconducting quantum circuits

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

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

[1] G. Butseraen et al *Nature Nanotechnology*, in press (2022); arXiv:2204.02175

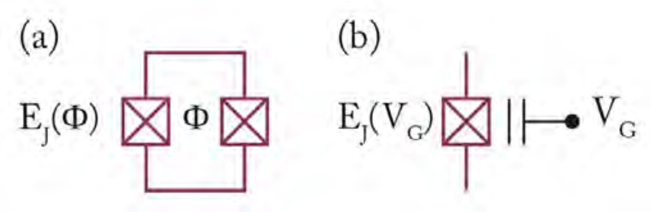

Figure 1: tunability of the Josephson energy E_J in standard Josephson junctions necessitates a loop geometry and a magnetic flux Φ (a). The introduction of a semiconductor allows simple electrical gating with a gate voltage V_G (b). This is the essence of the project.

Possible collaboration and networking : The student will be part of the Hybrid team, which has a multidisciplinary expertise (growth, nanofabrication, electronic transport, spectroscopy...). The team has also several external collaborations worldwide (France, Switzerland, Germany, Canada).
Possible extension as a PhD : Yes
Required skills: The internship (and the PhD thesis) will require a solid background in solid state/condensed matter physics. The work will be mainly experimental. The candidate is expected to be strongly motivated to learn the associated techniques (nanofabrication in clean room, radiofrequency electronics, cryogenics...) and engage in a hands-on experimental work.
Starting date : March 2023 (flexible)

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Phone: 0456387176 e-mail: julien.renard@neel.cnrs.fr http://perso.neel.cnrs.fr/julien.renard/

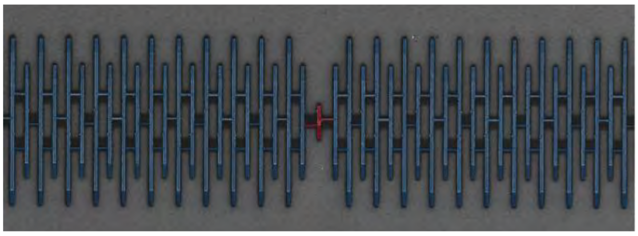
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Probing a quantum phase transition using superconducting qubits

General Scope: One of the present leading technologies for the realization of a universal quantum computer is based on *superconducting quantum circuits*. It exploits superconducting circuits based on Josephson junctions, which are characterized by quantized energy levels and for this reason can be adopted as quantum bits (qubits), the basic units of quantum information. While high quantum coherence has been demonstrated for systems containing a few number of qubits, a full-fledge quantum computer will require the interconnection and manipulation of hundreds of highly coherent qubits. This obviously imposes very challenging engineering issues.



Quantum simulator we recently developed [1,2]. A quantum bit (in red) couples to a superconducting metamaterial (in blue). This metamaterial hosts as many as 100 propagating electromagnetic modes, which are all strongly coupled to the qubit. This forms a complex many-body system, that could display a localized-delocalized quantum phase transition.

Our team focuses on the fabrication and characterization of machines called quantum simulators [1,2], which are dedicated to a given class of physical problems (e.g. quantum impurities, Hubbard models...). The required building blocks (quantum bits) as well as the control electronics are similar to the one of the universal quantum computer but since universality is not required, the overhead developments are less stringent. As such, these simulators allow us to address complex many-body problems with an experimental platform much simpler than a universal quantum computer. More specifically a localized/delocalized quantum phase transition has been strongly debated since the seminal work of Schmid in 1983 [3]. This Master project aims at setting-up a superconducting qubit experiment to shed new light on this phenomenon.

[1] Observation of quantum many-body effects due to zero point fluctuations in superconducting circuits, S. Léger et al. *Nature Communications* **10**, 5259 (2019). [2] Measuring the finite-frequency response of a bosonic quantum impurity, S. Léger et al. arXiv:2208.03053 [3] Diffusion and Localization in a Dissipative Quantum System, A. Schmid, *Physical Review Letters* **51**, 1506–1509 (1983).

Research topic and facilities available: The quanteca team specializes in the coherent control and manipulation of superconducting quantum circuits. The student will use state-of-the-art setups combining very low temperatures (around 10 mK), fast electronics and quantum-limited microwave detection chains. The devices are fabricated in the clean room of the Neel Institute (Nanofab).

Possible collaboration and networking: Our team is part of several national and international networks. For this specific project we are collaborating closely with Serge Florens at the Néel Institute, Denis Basko at LPMMC and with Izak Snyman at the University of Witwatersrand in Johannesburg, South Africa.

Possible extension as a PhD : Yes. This project is funded by the European Union.

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 many-body physics using superconducting quantum circuit.

Starting date : Spring 2023

Contact : ROCH Nicolas
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INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2022-2023

Dispositif cryogénique d'étude des Mégafeux

Cadre général :

Les incendies de très grande superficie (*mégafeux*) modifient localement la circulation atmosphérique, ce qui en retour affecte la propagation du feu. On parle de *couplage mutuel feu-atmosphère*.

Cette rétroaction est difficile à étudier sur le terrain, pour des raisons évidentes. L'étude en laboratoire se heurte aussi à diverses difficultés, dont l'impossibilité d'y reproduire la convection ultra-intense présente dans l'atmosphère. Cette dernière pourrait toutefois être levée dans des maquettes ou *systèmes modèles* de mégafeux exploitant le moins visqueux de tous les fluides : *l'hélium cryogénique*.

Figure 1. Mégafeu en Californie . Photo de Bill Peters, U.S. Forest Service [wikipédia].

Figure 1 . Exemple de prototype cryogénique (design différent de celui envisagé pour le stage).

Sujet exact:

Le but du stage est de réaliser un prototype d'une matrice de chauffages-thermomètres d'étude de la propagation des mégafeux et fonctionnant en environnement cryogénique (4 – 10 K).

Concrètement, le stagiaire développera un réseau bidimensionnel (de résolution 3x3 ou 4x4) de « pions » équipés de chauffages et thermistances, adressables individuellement et fonctionnant dans l'hélium à 4 K. L'ensemble sera commandé par une électronique utilisant des composants à semi-conducteurs en dehors de leur plage de température nominale.

Un des enjeux du stage est d'identifier une conception mécanique et électronique transposable à un réseau de résolution supérieure (50x50) sans explosion ni du coût de fabrication ni du temps d'assemblage.

Poursuite en thèse :
Le stage pourra se poursuivre par une thèse à dominante expérimentale sur un enjeu en lien avec la thématique du changement climatique et/ou de ses conséquences.

Formation / Compétences :
Formation attendue: formation généraliste en Physique ou Ingénierie.

L'étudiant devra avoir des connaissances de base dans la mise en œuvre de circuits électroniques et en conception mécanique. Il sera formé aux techniques de base en physique des basses températures (azote et hélium liquide, vide, thermométrie, ..) et aux techniques d'instrumentation et de mesures bas bruit.

Période envisagée pour le début du stage : année universitaire 2022-2023.

Contact : Philippe Roche, Institut Néel – CNRS/ UGA, per@neel.cnrs.fr http://hydro.cnrs.me
Pour candidater : merci d'envoyer un bref CV + date/durée du stage (lettre de motivation inutile).

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Superconductivity and lattice instability

General Scope :
The superconducting state is characterized by macroscopic electronic coherence. Well known models have provided a deep understanding of the mechanisms in pure compounds and many superconducting alloys. The basis of these models is the attraction between electrons via lattice vibrations, the phonons. However, this electron-phonon interaction can give rise to other electronic instabilities and the formation of new phases such as charge density waves. These instabilities are characterized by a deformation of the lattice. If models have been proposed to explain the formation of these different electronic phases, they have rarely been confronted with real systems.
Currently, the coexistence of superconductivity and lattice instability seems to be far more general than previously expected. The aim of this internship is to study the coexistence of these two states in a model system. The use of hydrostatic pressure allows to modify the energy scales involved and the fundamental states. This technique is opening to many new probes, in particular those associated with synchrotron radiation facilities, and offers a growing field of exploration in the fundamental understanding of superconductivity.

Research topic and facilities available :
This subject is fundamental and experimental research. We will carry out measurements of magneto-transport at low temperature and under pressure in the Lu5Ir4Si10 system. This model of the coexistence of charge density wave with superconductivity is much more surprising than initially anticipated. Pressure allows us to destabilise the charge density wave in favour of superconductivity.
The fundamental question is to understand whether this destabilisation is associated with a reduction in the number of charge carriers at the origin of the charge density wave or with a hardening of the lattice dispersion. We will compare our experimental results with existing theories. Depending on the timetable, the student could participate in experiment in large scale facilities (ESRF), related to his main subject.

Possible collaboration and networking :
The student will interact with other members of the Magnetism and Superconductivity team of the Néel Institute. This research subject is directly connected to collaborations with other researchers in Toulouse and at the ESRF. This subject is at the heart of more general questions of national and international research networks around quantum materials and aperiodic crystals.

Possible extension as a PhD : Yes

Required skills:
This experimental internship includes an important part of measurements. The student should have a strong taste for practical work. He/she will handle small samples, but also cryogenic instrumentation. An understanding of the measurement chain is essential. The student will analyse the acquired data and confront them with theoretical models that he/she will have to assimilate well. The student will have a solid background in solid state physics.

Starting date : March

Contact :
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More information : https://neel.cnrs.fr/equipes-poles-et-services/magnetisme-et-supraconductivite-magsup

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

A new approach coupling experiments and ab initio calculations to describe the solid-liquid electrochemical interfaces

General Scope :
Electrochemistry describes the properties of the coupling between matter and electricity. It deals with reactions involving transfer of electrical charges at interfaces between an electrode and chemical species in solution.
Electrochemical interfaces play a crucial role in many systems used for clean energy production, conversion and storage as well as for material processing. The structure of the electrode/electrolyte at the interface, as well as the charge transfer mechanisms, are properties and processes which can crucially affect reactivity and performance of electrochemical applications.
While physical characterization with in situ surface x-ray diffraction experiments at synchrotron sources has enabled the description of the atomic order at the interface, insight into the charge distribution at the interface is still lacking.
We aim at proposing advances into this direction in order to be able to link atomic scale models and the charge distribution at the electrochemical interface.
We recently developed a new approach, coupling in situ surface resonant x-ray diffraction experiments at synchrotron sources with the home-developed first principle simulation software FDMNES. This approach will be able to give access to the charge distribution at the electrochemical interfaces.

Research topic and facilities available :

Using FDMNES software, the student will work on the theoretical description of *in situ* surface resonant x-ray diffraction experimental data obtained on electrochemical interfaces; she/he will directly compare the ab initio calculations against experimental data.

Possible collaboration and networking :

The student will work in SIN team, where all the experimental and theoretical competences are present

Possible extension as a PhD : to be discussed

Required skills:

Condensed matter physics. Taste for numerical simulation

Starting date :
20 February 2023

Contact :
Yvonne Soldo
Institut Néel - CNRS
Phone: 04 76 88 74 12 e-mail: yvonne.soldo@neel.cnrs.fr

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

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Nanoscale probing piezoelectricity in semiconductor Nitride nanowires

General Scope:

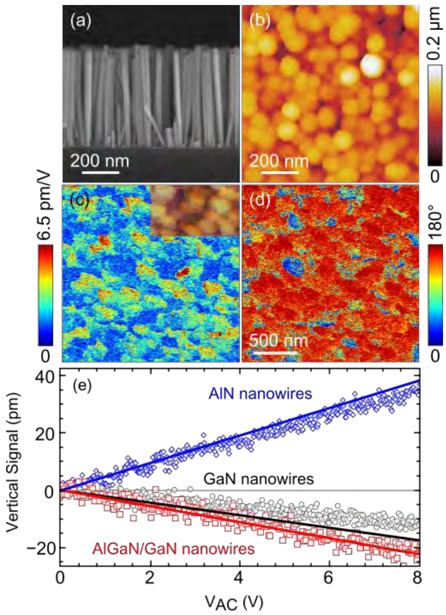
In the last decades, the field of electronics has further moved toward personal, portable, and flexible devices with multi-functional, smart, and self-powered systems. This direction needs interactions between electronics and human activities, which are related to mechanical actions. Piezoelectric semiconductor nanowires such as ZnO or GaN nanowires were suggested as a promising building block for nanogenerators and smart self-powered sensors because of their coexisting high mechanical flexibility, piezoelectric, and semiconductor properties. This characteristic allows the mechanical manipulation of charge carriers in electronic devices which is interesting for smart systems that have increasingly required multifunctionalities. Furthermore, their inherent flexibility and stretchability offer integration with soft surfaces relevant for biomedical, wearable, and human interactive applications.

The mainstream research in this field dedicates its interest to large-scale device fabrications and optimizations. A large number of publications demonstrate nanowire piezo-harvester prototypes, focusing mainly on the electrical amplitude output of the devices. In contrast, fewer experiments have explored the piezoelectric properties of the nanowires at a local scale, which should provide insight into the parameters that play a critical role in charge generation in piezoelectric semiconductors.

Research topic and facilities available:

We will apply different scanning force microscopy (SFM) techniques such as Kelvin Probe Force microscopy (KPFM), Piezoresponse Force Microscopy (PFM), and conductive-AFM to investigate piezoelectric properties of semiconductor III-Nitrides at the nanoscale. The effect of various semiconducting properties on the piezo response from the nanowires will be studied such as surface states, surface charges caused by adsorbates, free charges induced by dopants, and encapsulation matrix. The local probing results will be correlated with the electrical and electromechanical properties of large-scale nanowire piezo harvesters. This work should give a better understanding and a further improvement of nanowire piezo harvesters.

The experiments will be performed at Néel and CERMAV in Grenoble. He/She will have an opportunity to access the AFM platform of both laboratories including the facilities for electrical, structural, and optical characterizations. The samples can be processed by using clean room facilities in NanoFab at Néel.



Possible collaboration and networking: NPSC/ Néel, CERMAV**,** ICMG

Possible extension as a Ph.D.: No funding is currently available, but we support the grant applications.

Required skills: Nanofabrications, Semiconductors, Nanomaterials, Solid State Physics

Starting date: February/March 2023 for 4 to 6 months

Contact: SONGMUANG Rudeesun, Néel, rudeesun.songmuang@neel.cnrs.fr
DAHLEM Franck, CERMAV, franck.dahlem@cermav.cnrs.fr

Reference

L. Jaloustre, S. Le Denmat, T. Auzelle, M. Azadmand, L. Geelhaar, F. Dahlem, and R. Songmuang, ACS Appl. Nano Mater.4, 43 (2021).

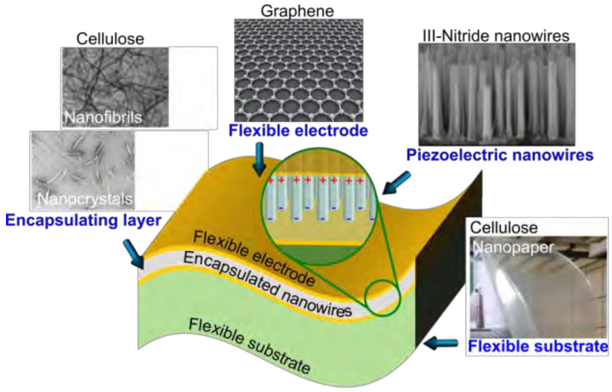
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

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

General Scope:

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



Research topic and facilities available:

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

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

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

Possible collaboration and networking: Néel (NPSC, Hybrid, and Optima), CERMAV

Possible extension as a Ph.D.: No funding is currently available, but we support grant applications.

Required skills: Nanofabrications, Semiconductors, Nanomaterials, Solid State Physics,

Starting date: February/March 2023 for 4 to 6 months

Contact: SONGMUANG Rudeesun/Néel, rudeesun.songmuang@neel.cnrs.fr
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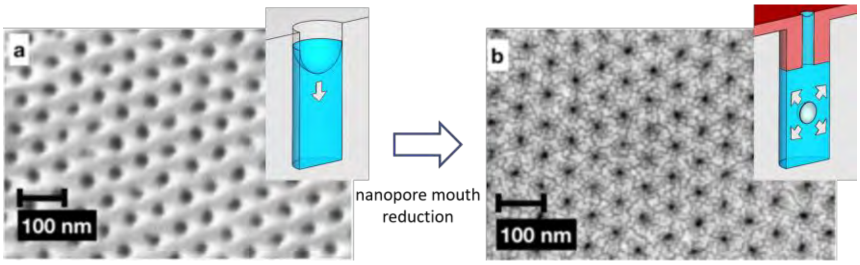
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2022-2023

Cavitation in nanoconfinement

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. We recently provided the first experimental verification of the CNT using a static method, based on an extension of the so-called artificial tree technique [1] to nanoporous membranes [2,3]. Our result opens the way to further studies, such as understanding the influence of nanoconfinement on cavitation, and, using helium as a fluid, the possible influence of quantum effects on cavitation.



Left: in native nanopores, evaporation unfolds through meniscus recession. Right: after pore mouth reduction, the meniscus is pinned and cavitation is induced

Research topic and facilities available: The candidate will develop a new cryogenic set-up to detect cavitation of liquid helium using a capacitive detection scheme. He/she will use this set-up to study cavitation down to 1 K deep into the superfluid phase, in a region where previous experiments using acoustically driven cavitation yield unexplained results. In parallel, the influence of confinement on cavitation will be explored in the normal phase.

Possible collaboration and networking:
This project involves an on-going collaboration with partners in Paris (LPENS and INSP). Its future development may involve collaboration with colleagues in Lyon (ILM) and Grenoble (LiPhy).

Possible extension as a PhD: yes

Required skills: A solid background in condensed matter physics is required. The candidate should have a broad interest for fundamental physics and experimental techniques, be self-motivated and have a strong curiosity about new phenomena.

Starting date: Any time in the year
Contact: Panayotis Spathis Institut Néel - CNRS
e-mail : panayotis.spathis@neel.cnrs.fr

[1] Wheeler and Stroock, The transpiration of water at negative pressures in a synthetic tree, Nature 2008
[2] Doebele et al, Direct observation of homogeneous cavitation in nanopores, PRL 2020
[3] Bossert et al, Evaporation process in porous silicon: cavitation vs pore-blocking, Langmuir 2021

NÉEL institut

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2022-2023

Magnetic bound states in two-dimensional superconductors

The presence of a nanoscale magnetic scatterer (a single atom, a molecule, a quantum dot or an atomic nanowire) on the surface of a superconductor can lead to the emergence of bound states, at energies below the superconducting gap, with peculiar spatial and spectral properties. In particular, these states can be topologically trivial (the case of so-called Shiba states) or not (predicted Majorana zero modes).

In this project we will investigate the properties of superconducting bound states in extremely thin superconductors, down to a single atomic layer. Here, the bound states can have a much longer spatial range, which will allow coupling different such nano-objects among them. Thereby we can engineer novel low energy states with exotic properties.

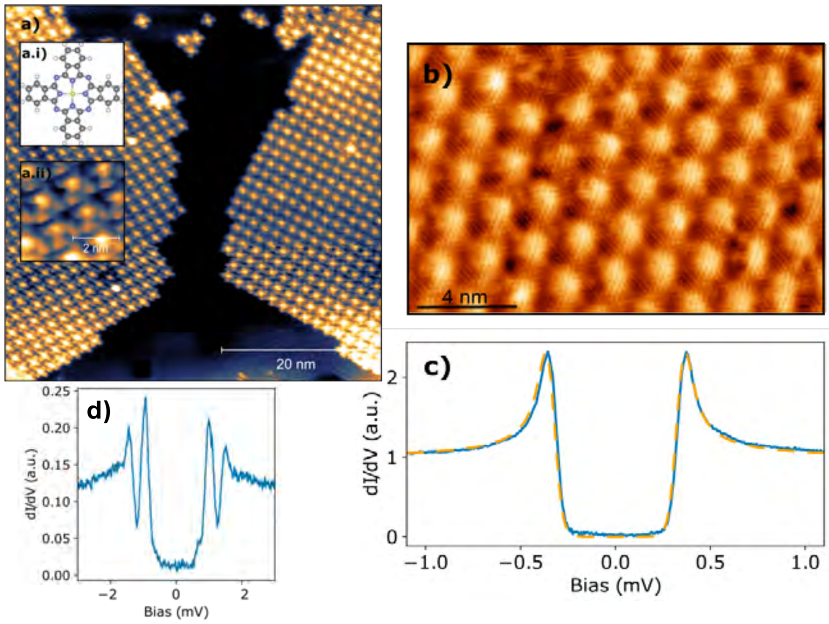


Figure 1 : (a) STM topograph of self-assembled monolayers of MnPc molecules on the Pb(111) surface. (b) STM topograph of the Moiré pattern of graphene on rhenium. (c) Tunneling spectroscopy of superconducting graphene on rhenium. The dashed line is the theoretical prediction. (d) Tunneling spectroscopy of a magnetic bound state on an individual MnPc molecule in (a). Data taken at 50 mK.

Scanning tunneling microscopy/spectroscopy (STM/STS) is an extremely sensitive and versatile tool to investigate atomic scale topographic features and variations in the local density of states. Using a low-temperature STM, we will study the signatures of magnetic interactions and possible topological superconductivity, using novel combinations of superconductors and magnetic nanostructures. The superconducting substrate will be provided either by (i) intrinsic superconductors in the single or few atomic layer limit, or (ii) non-intrinsically superconducting single-layer graphene into which superconductivity is induced from a nearby superconductor. We will study the quantum transport properties of electrons between the tip and the nanostructure, including its response to a microwave excitation and the ability to carry Josephson supercurrent.

The experimental work is at the interface between surface science and quantum transport studies. The experiments will be performed using a milliKelvin STM available in the host group. The work encompasses collaboration between STM groups in Grenoble (both at Néel/CNRS and IRIG/CEA), together with FU Berlin. The work is further supported by strong interactions with theory groups. The student's work will include:

- Preparing and growing combinations of superconducting substrates and magnetic nanostructures, by self-assembly or single-atom manipulation.
- Performing low temperature scanning probe measurements, with a particular focus on quantum transport effects (Josephson effect, photon-assisted tunneling, …)
- Theoretical analysis and interpretation.

Collaboration and networking: The work bases on a strong experimental collaboration between Inst. Néel (C. Winkelmann), IRIG/CEA (V. Renard), Spintec/CEA (M. Jamet), and FU Berlin (K. Franke), as well as several theory groups.

Required skills: MSc level in Physics or Applied Physics. Prior experience in low temperature physics, surface science or nanoelectronics is a plus.

Starting date: 2023

Contact : clemens.winkelmann@neel.cnrs.fr & vincent.renard@cea.fr
Institut Néel - CNRS : 04 76 88 78 36

Plus d'informations sur : http://neel.cnrs.fr/spip.php?rubrique49

DUT

INSTITUT NEEL Grenoble

Proposition de stage DUT - Année universitaire 2022-2023

Nano calorimétrie à thermopile : développement de l'instrumentation et de l'interface utilisateur

Cadre général :
La nano-calorimétrie différentielle à balayage et la calorimétrie isotherme de titration sont deux méthodes expérimentales permettant d'accéder directement aux propriétés thermodynamiques de systèmes et en particulier de macromolécules en solution. Ces caractérisations jouent un rôle important pour le développement de médicaments et pour certains diagnostiques. Dans ce cas il est crucial d'avoir une détection à l'état de l'art car les molécules actives sont généralement diluées dans une solution aqueuse.
Les calorimètres commerciaux sont caractérisés soit par une très bonne sensibilité et un grand volume d'échantillon soit par un petit volume d'échantillon et une sensibilité non optimale. Dans tous les cas les échantillons liquides sont placés dans des containers difficiles à nettoyer. Il en résulte des contaminations croisées qui ne peuvent être réduites qu'au prix de nettoyages complexes et qui réduisent de manière considérable le débit des expériences.
Dans notre équipe nous proposons un nouveau type de nano calorimètre DSC et ITC qui permet de s'affranchir de ces nettoyages fastidieux tout en diminuant le volume d'échantillon et en augmentant la sensibilité des instruments. Les tests réalisés sur un prototype ont validé les performances et l'instrument doit maintenant être développé afin de faciliter son utilisation.

Sujet exact, moyens disponibles :
Le sujet de stage comporte plusieurs volets qui peuvent être adaptés aux aspirations et compétences de l'étudiante ou de l'étudiant.

- Développement de pièces mécaniques et modélisation thermique de l'instrument afin d'anticiper ses futures performances
- Développement de la fluidique, étanchéité et instrumentation afin de réaliser une mesure de titration et établir une preuve de concept pour l'ITC.
- Développement de l'instrumentation et de l'interface et du contrôle du prototype existant pour réaliser des tests quantitatifs avec une solution de biopolymère modèle.

Interactions et collaborations éventuelles :
Le stage se déroulera au sein de l'équipe TPS et en collaboration étroite avec les pôles et services concernés par les différents développements expérimentaux (ThEMA : Thermique Elaboration et Matériaux, Cryogénie et Electronique)

Formation / Compétences :
Vous êtes une étudiante ou un étudiant des BUT GEII, Mesures Physique, GThE ou GMP et voulez réaliser un projet concret en développant des compétences associées à vos formations dans un cadre ou l'exigence se situe sur l'excellence de la réalisation, votre enthousiasme et votre créativité nous intéresse, contactez-nous pour une visite.

Période envisagée pour le début du stage : Printemps 2022

Contact : GUILLOU Hervé

Institut Néel - CNRS 04 76 88 12 10 herve.guillou@univ-grenoble-alpes.fr