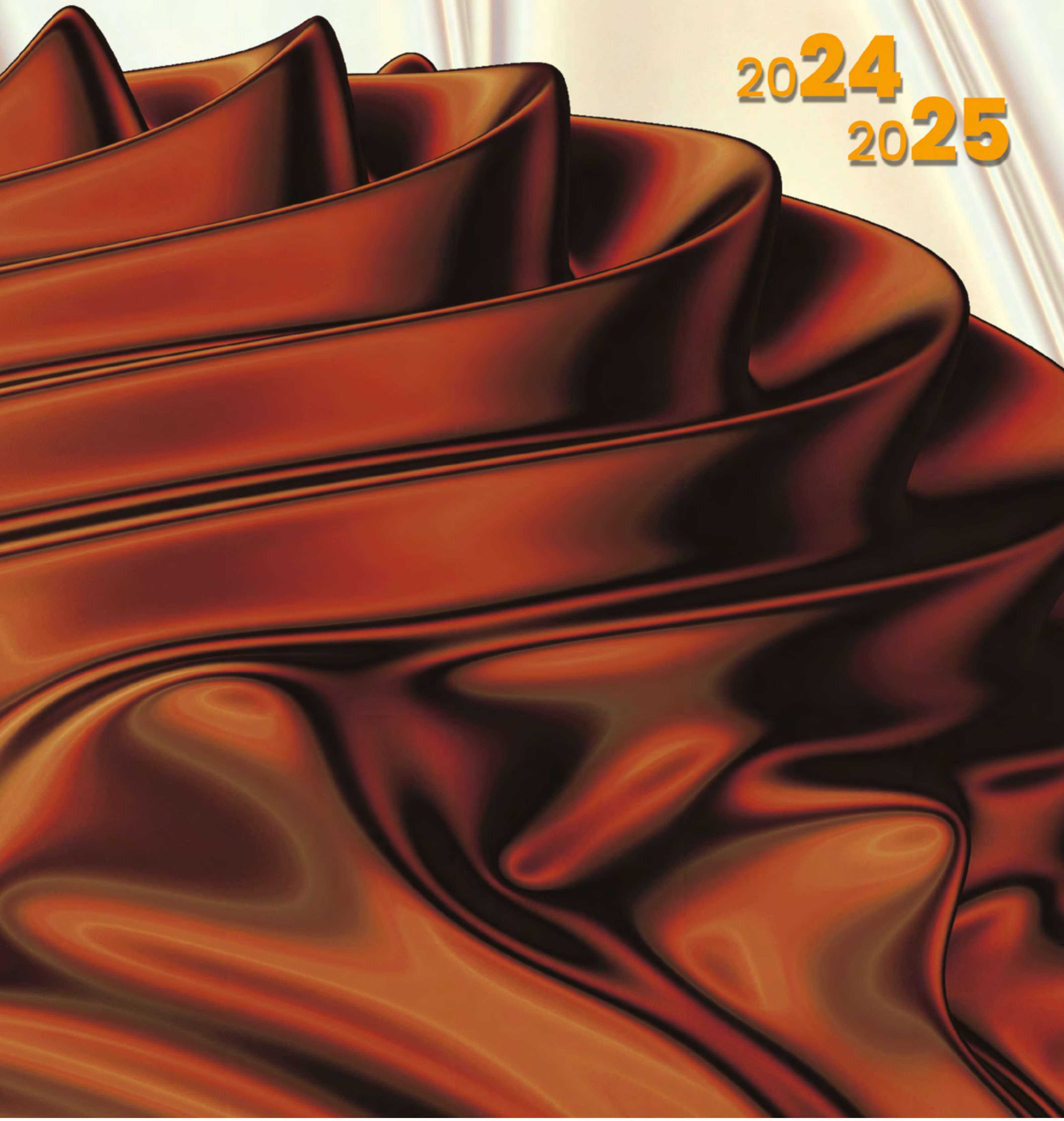
Néel institut

INTERNSHIP

2024
2025



Université Grenoble Alpes

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

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

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

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

Cette brochure regroupe les offres de stage de Master proposés pour l'année universitaire 2024-2025. Ce sont principalement des stages de Master 2 avec pour la plupart une possibilité de continuation en thèse. Si vous commencez votre master, vous trouverez aussi des propositions de stage de Master 1. De nombreux sujets de Master 2 peuvent aussi être déclinés en sujets de Master 1. L'Institut Néel vous souhaite la bienvenue, au moins virtuellement par cette brochure et au travers de notre site web www.neel.cnrs.fr ! N'hésitez pas à contacter les chercheurs de l'Institut Néel afin de nous rendre visite.

La direction de l'Institut Néel

INSTITUT NEEL - CNRS

LISTE DES SUJETS PROPOSES – 2024 - 2025

MASTER 1	
Single-electron detector for flying electron wavepackets	Bauerle Christopher
Measurement of the tunneling probability of Cooper pairs in superconducting quantum circuits	Messelot Simon
Protected superconducting qubit with a graphene Josephson junction	Renard Julien
MASTER 2	
Quantum capacitance of an anyon box in bilayer graphene	Assouline Alexandre
Single-electron detector for flying electron wavepackets	Bauerle Christopher Urdampilleta Mathias
Many body entanglement with flying electron wave packets	Bauerle Christopher
THz Quantum Nanoelectronics	Bauerle Christopher
Beyond Fourier heat transport in 2D materials	Bendiab Nedjma Bourgeois Olivier
Spin-photon interface for individual magnetic atoms in semiconductors	Besombes Lucien
Highly-sensitive infrared thermoelectric detectors	Bourgault Daniel Garden Jean-Luc
Superconducting qubits: from fundamental to applications	Buisson Olivier
Frustration-induced exotic physics in many-body systems through tensor networks	Canal Benjamin Jeanne Colbois
Quantum memory integration of rare-earth doped crystals	Chaneliere Thierry
Ultra-cold Nanomechanics	Collin Eddy
Measuring electric fields at nm length scales using 4D scanning transmission electron microscopy	Den Hertog Martien
Low temperature transport and Transmission Electron Microscopy of silicon aluminum interfaces	Den Hertog Martien Naud Cécile
Engineering the Next Generation of Solid-State Electrolytes	Diaz-Lopez Maria
Ultra-Coherent Nanomechanical Resonators	Fefferman Andrew
Investigation of living bacteria using optical fiber tweezers	Fick Jochen
Nanowire betavoltaics	Jacopin Gwenole Daudin Bruno
Attempt to nano-engineer flat bands to increase critical superconducting temperatures	Lévy-Bertrand Florence Naud Cécile
Spectrometers based on Kinetic Inductance Detectors (KID)	Lévy-Bertrand Florence Naud Cécile
Quasi-ballistic charge transport in ultra-pure diamond	Pernot Julien
Protected superconducting qubit with a graphene Josephson junction	Renard Julien
Hybridizing superconductivity and quantum Hall physics	Sacépé Benjamin Sellier Hermann
Sputtering growth of ZnO for flexible piezoelectric energy harvesters	Songmuang Rudeesun
Magnétisme non-conventionnel dans des matériaux en nid d'abeille	Songvilay Manila Mangin-Thro Lucile Simonet Virginie
Unconventional magnetism in honeycomb lattice materials	Songvilay Manila Mangin-Thro Lucile Simonet Virginie
High Tc superconductivity in layered Lnn+1NinO3n+1 nickelates	Toulemonde Pierre
Controlling and detecting spins with an engineered acoustic interface	Viennot Jérémy
Quantum microwave-to-optics interface	Viennot Jérémie Renard Julien

MASTER 1

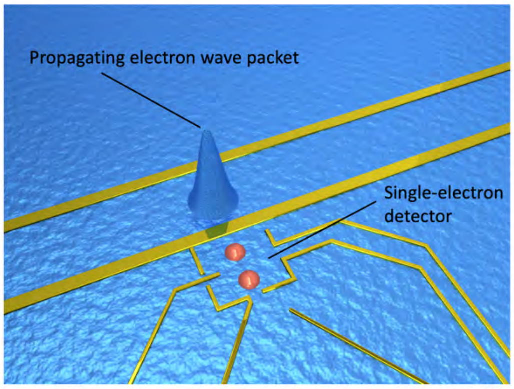
NÉEL INSTITUTE Grenoble

Topic for Master 1 internship – Academic year 2024-2025

Single-electron detector for flying electron wavepackets

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

Research topic: The remaining brick to be developed for the implementation of a fully-fledged flying electron qubit is a single-shot single-electron detector. The aim of the proposed M1 internship is to participate in the design and characterisation of such a detector based on a double quantum dot to detect a propagating electron wave packet (see Fig. 1). The idea is to use the extreme sensitivity of a quantum system to detect in flight an electron propagating in a ballistic conductor. This will be realized by capacitive coupling of the single flying electron to a spin/charge qubit based on previous experimental work in our group. To enhance the sensitivity, we will develop this detector with a new quantum material, strained Ge heterostructures, which have shown recently the best coherence time for spin qubits.



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

References:

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

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

Required skills:
The candidate should have a strong background in quantum mechanics and solid-state physics. Programming skills in Python would be a plus. We are looking for a motivated candidate. Female students are encouraged to apply.

Starting date: spring 2025

CONTACT:

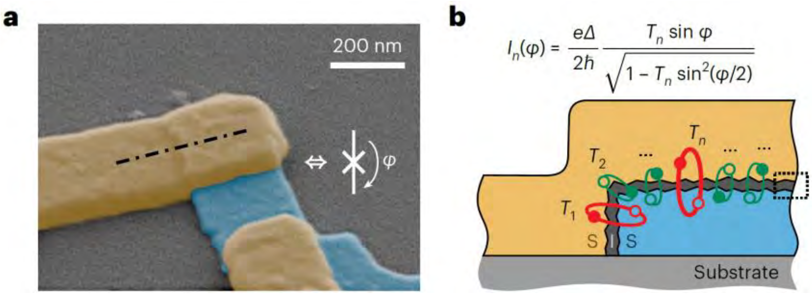
Christopher BAUERLE & Matias URDAMPILLETA
Institut Néel – CNRS, Grenoble
e-mail: christopher.bauerle@neel.cnrs.fr ; matias.urdampilleta@neel.cnrs.fr
web: https://neel.cnrs.fr
https://neel.cnrs.fr/les-chercheurs-et-techniciens/christopher-bauerle

INSTITUT NÉEL Grenoble

Topic for Master 1 internship – Academic year 2024-2025

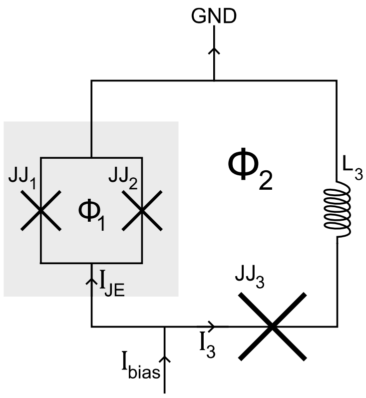
Measurement of the tunneling probability of Cooper pairs in superconducting quantum circuits.

General Scope:



Superconducting circuits have emerged as a powerful and versatile platform for quantum computing technologies. The central element of these circuits, the Josephson junction based on aluminum, rely on the tunneling of Cooper pair through a thin layer of aluminum oxide responsible for a phase φ across the junction. For more than 50 years, they have been used in various devices assuming the canonical current-phase relation (CPR) $I=I_c\sin(\varphi)$. In recent years, however, progress in characterization techniques and extensive use of these components in quantum computing experiments have suggested that this picture is not sufficient to describe very accurately tunnel Josephson junctions [1]. In particular, a non-vanishing transmission probability of Cooper pairs at the tunnel oxide barrier could result in the CPR to include higher order sin(2φ) harmonics resulting from 2-Cooper pairs tunneling events, sin(3ϕ) resulting from 3-Cooper pairs events etc. The observation of these higher order harmonics could this way provide valuable insights of microscopic tunneling events.

Research topic and facilities available:



We recently demonstrated a circuit architecture able to simultaneously control and measure the CPR of superconducting devices, that we used to show dominant sin(2ϕ) harmonics in graphene Josephson junctions [2]. We propose to use this architecture with canonical aluminum/aluminum oxide Josephson junctions to measure higher order harmonics in these junctions. You will first learn the cleanroom fabrication procedure of superconducting quantum circuits based on aluminum/aluminum oxide Josephson junctions, involving e-beam evaporation, oxidation and lithography techniques. Some fabrication parameters could be explored and you will then realize room-temperature DC transport characterization on these samples. When promising samples will have been identified, a few experimental runs in the dilution refrigerator could be performed to measure the CPR of such devices using low temperature DC transport measurement.

References:

-[1] Willsch, Dennis, et al. "Observation of Josephson harmonics in tunnel junctions." *Nature Physics* (2024) 1-7.

-[2] Messelot, Simon, et al. "Direct measurement of a sin(2φ) current phase relation in a graphene superconducting quantum interference device." *Phys. Rev. Lett.* (2024)

Possible collaboration and networking:

This work will be carried out in the Quan2m team at Institut Neel in collaboration with other teams specialized in the fabrication of aluminum based superconducting circuits.

Required skills: Master 1 or equivalent.

A basics level in the field of superconductor, condensed matter physics or quantum physics would be useful, as well as prior experience in applied physics experimental works. The candidate should be interested in learning the cleanroom fabrication technique of aluminum superconducting circuits.

Starting date: 2nd semester 2024-2025

Contact : Simon Messelot - Quan2m team - Institut Néel – CNRS, simon.messelot@neel.cnrs.fr

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

NÉEL INSTITUTE Grenoble

Topic for Master 1 internship – Academic year 2024-2025

Protected superconducting qubit with a graphene Josephson junction

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. 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 new functionalities.

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 a qubit with a new property: a gate tunable energy. In the team we have already demonstrated the fabrication of such graphene based Josephson junctions and their use in quantum circuits[1,2]. The next step, is to use the specificities of such junction to build a qubit protected from decoherence, which is the characteristic that makes a qubit usable for future quantum computing.
A one atom-thick sheet of graphene will 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, coherence, gate fidelity...

[1] G. Butseraen et al *Nature Nanotechnology* 17, 1153 (2022); arXiv:2204.02175
[2] S. Messelot et al *Phys. Rev. Lett*, in press (2024); arXiv:2405.13642

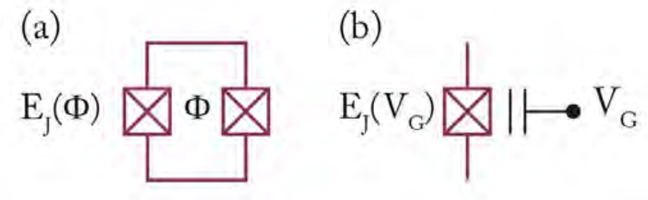


Figure 1: tunability of the Josephson energy E_J in standard Josephson junctions necessitates a loop geometry and a magnetic flux Φ (a). The introduction of a semiconductor allows simple electrical gating with a gate voltage V_G (b). In addition such junction presents original properties that can be used to build a protected qubit

Possible collaboration and networking :
The student will be part of the Quan2m team, which has a multidisciplinary expertise (growth, nanofabrication, electronic transport, spectroscopy...). The team has also several external collaborations worldwide (France, US, Canada).

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 2025 (flexible)
Contact :
Name: Julien Renard Institut Néel - CNRS
Phone: 0456387176 e-mail: julien.renard@neel.cnrs.fr http://perso.neel.cnrs.fr/julien.renard/
https://sqc.cnrs.fr/
More information : http://neel.cnrs.fr

MASTER 2

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Quantum capacitance of an anyon box in bilayer graphene

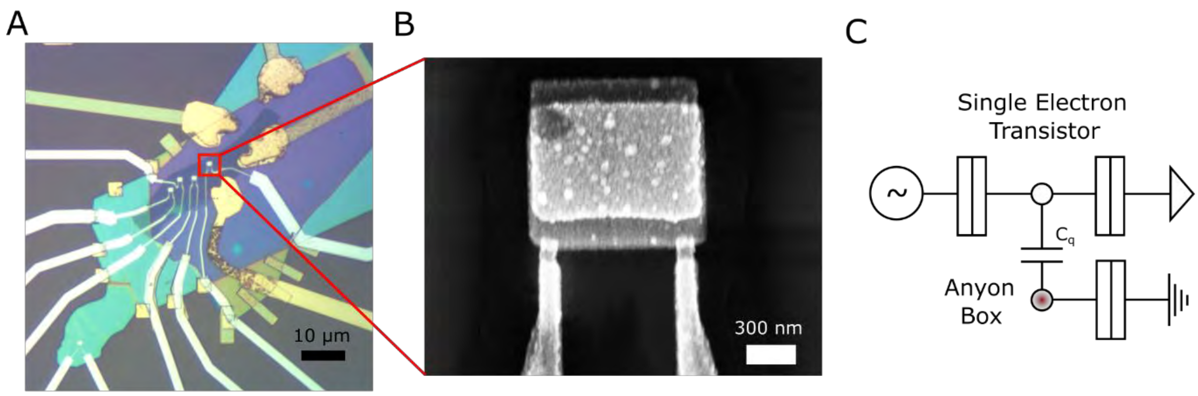
General Scope :

Anyons are a type of quasiparticle that can be generated in low dimensional (d<3), strongly interacting electronic system. The interest of anyons lies in their new quantum statistics, neither bosonic nor fermionic, which make it possible to manipulate the ground state of an electronic system by exchanging the position of its particles. This controlled exchange of the anyon positions, known as braiding, should lead to topological qubits with exceptionally low error rates [1]. In addition, the possibility of exploring a new quantum statistics beyond the fermion-boson dichotomy is of considerable fundamental interest.

[1] "Non-Abelian anyons and topological quantum computation"
C. Nayak et al. Review of Modern Physics (2008).

Research topic and facilities available :

The most promising route to realizing anyons is the fractional quantum Hall effect, where a 2D electron system is subjected to a strong perpendicular magnetic field. Bilayer graphene has recently been shown to be a promising platform for probing anyons, thanks to the large energy gaps reported for its fractional quantum Hall states. The aim of this project is to trap a single anyon around an electrostatic potential well, in order to investigate the capability of such an "anyon box" structure for topological quantum computing. The candidate will be involved in the sample fabrication process, where aluminum single electron transistors, capable of detecting a single anyon charging event, are capacitively coupled to the anyon box, as shown in the figures below. She/He will be involved in low noise cryogenic measurements of the anyon box quantum capacitance.



A. Optical image showing multiple single electron detectors (white) capacitively coupled to bilayer graphene equipped with electrostatic gates made of 2D materials. **B.** Scanning electron microscope image of an aluminum single electron transistor realized at the Néel Institute. **C.** Schematic of the measurement showing the anyon box capacitively coupled to the single electron transistor.

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Possible collaboration and networking :
University of California Santa Barbara – Young lab.

Possible extension as a PhD :
Possible extension as a PhD.

Required skills:
Background in condensed matter physics.
Interest in experimental condensed matter physics with quantum electrical circuits, from the circuit fabrication to the low temperature measurements.

Starting date : Flexible.

Contact :
Name : Alexandre Assouline
Institut Néel - CNRS
e-mail : alexandre.assouline@neel.cnrs.fr

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

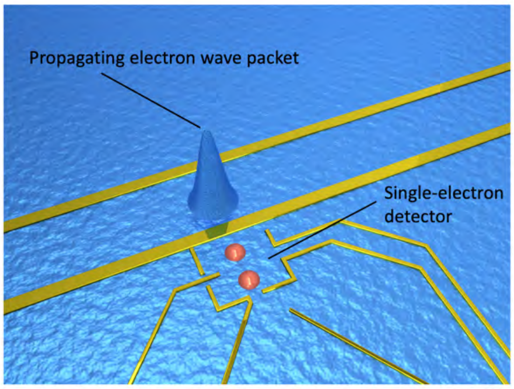
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Single-electron detector for flying electron wavepackets

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

Research topic: The remaining brick to be developed for the implementation of a fully-fledged flying electron qubit is a single-shot single-electron detector. The aim of the proposed M2 internship is to participate in the design and characterisation of such a detector based on a double quantum dot to detect a propagating electron wave packet (see Fig. 1). The idea is to use the extreme sensitivity of a quantum system to detect in flight an electron propagating in a ballistic conductor. This will be realized by capacitive coupling of the single flying electron to a spin/charge qubit based on previous experimental work in our group. To enhance the sensitivity, we will develop this detector with a new quantum material, strained Ge heterostructures, which have shown recently the best coherence time for spin qubits.



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

References:

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

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

Possible extension as a PhD: yes

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

Starting date: spring 2025

CONTACT:

Christopher BAUERLE & Matias URDAMPILLETA
Institut Néel – CNRS, Grenoble
e-mail: christopher.bauerle@neel.cnrs.fr ; matias.urdampilleta@neel.cnrs.fr
web: https://neel.cnrs.fr
https://neel.cnrs.fr/les-chercheurs-et-techniciens/christopher-bauerle

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

THz Quantum Nanoelectronics

General Scope: The continuous drive for miniaturization and increased speed in microelectronic devices challenges conventional semiconductor technologies. This trend inevitably pushes both industry and the scientific community into a realm where quantum effects are crucial at the nanoscale. As length scales decrease, the field is moving towards frequencies in the tens of GHz range, where new device functionalities and novel modes of information processing are anticipated. Similar to high-energy physics, where each increase in energy reveals new types of collisions and potentially new particles, quantum nanoelectronics is now at a threshold where increasing the frequency will unlock a wealth of new phenomena. A completely unexplored field is quantum nanoelectronics at ultra-high frequencies (exceeding hundreds of gigahertz), where the wavepacket size is much shorter than the quantum device as shown in Fig. 1b. Reaching this new regime requires the generation of ultrashort electron wavepackets and sufficiently large interferometers to induce interference between the front and back of these wavepackets as depicted in Fig. 1. At these high frequencies, we can access the internal characteristic time scales that govern the quantum dynamics of quantum devices, opening up new opportunities to study the dynamic aspects of quantum mechanics.

Research topic: The aim of the proposed M2 internship is to participate in the development of a novel THz opto-electronic setup to generate voltage pulses down to 1ps. In order to generate such ultra-short electron wave packets, we will leverage on the progress made on THz photon production and use photon to electron conversion devices to engineer THz electronic charge pulses. With this we will pioneer a new area of research in quantum nanoelectronics and demonstrate novel quantum interference effects that unveil the internal dynamics of quantum systems.

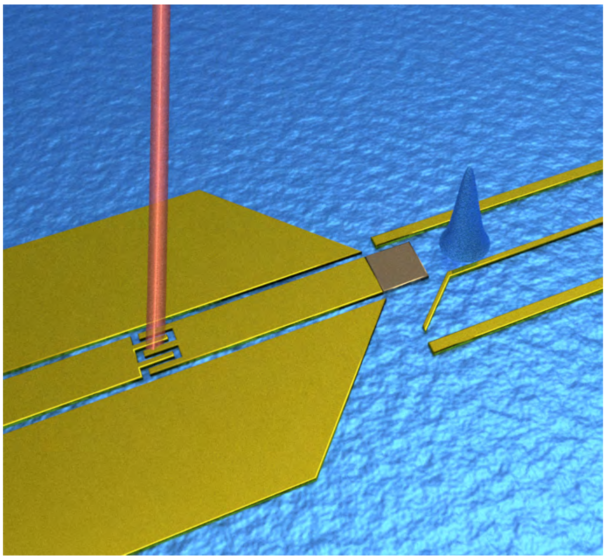


Fig. 1. A femtosecond laser pulse (in red) irradiates a photo-conductive switch deposited on a two-dimensional electron gas (in blue). An ultrashort electron wavepacket is launched into the quantum conductor through an electronic wave guide.

References:

Bäuerle et al., Rep. Prog. Phys. **81**, 056503 (2018) ; arxiv.org/abs/1801.07497, Edlbauer et al., EPJ Quantum Technology **9**: 21(2022); in COLLECTION ON "QUANTUM INDUSTRY" ; Giorgos Georgiou et al., ACS Photonics **7**, 6, 1444–1451 (2020).

Possible extension as a PhD: yes

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

Starting date: spring 2024

Contact:
BAUERLE Christopher
Institut Néel – CNRS, Grenoble
e-mail: christopher.bauerle@neel.cnrs.fr
web: http://neel.cnrs.fr
https://neel.cnrs.fr/les-chercheurs-et-techniciens/christopher-bauerle

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2024-2025

Beyond Fourier heat transport in 2D materials

General context :
Thermal transport is a major challenge with important fundamental and technological implications for thermal management of electronic nano-components or the conception of new thermoelectric devices. Graphene and other 2D materials exhibit outstanding thermal properties. The project here aims at designing asymmetric 2D heat conductors in order to favour a heat conduction direction and therefore perform heat rectification. Raman spectroscopy has been widely used as a non-contact thermal probe at the micrometer scale to access the thermal conductivity of graphene (1,2,3). Recently, an insightful approach was developed by Reparaz *et al.* (4) and at NEEL for graphene (5), that uses two lasers, one as a heater and one as a non-invasive thermal probe, giving access to spatial mapping of temperature within graphene (4). Furthermore, NEEL has a renowned expertise in thermal bridge measurements of heat conduction thanks to the development of unique thermal platforms at the microscale (6).

Description of the project and facilities:
Within this global objective, the Master 2 internship aims to find out more about how defects and substrate interactions can change thermal properties of 2D materials. The work will be dedicated to the fabrication and thermal characterization in ambient conditions of graphene channels which are asymmetric 1/ due to intentional defect gradient creation (made by lithography and amorphization); or 2/ due to semi-suspension on a substrate (variation of the out-of-plane thermal contact). The student will be in charge of the sample fabrication and their characterization by Raman opto-thermal spectroscopy. She/He will address the challenge of implement graphene onto the thermal bridge platform to realize the first microscale heat transport in this unique configuration and demonstrate innovative heat management. This work is preliminar to a following PhD work on this subject.

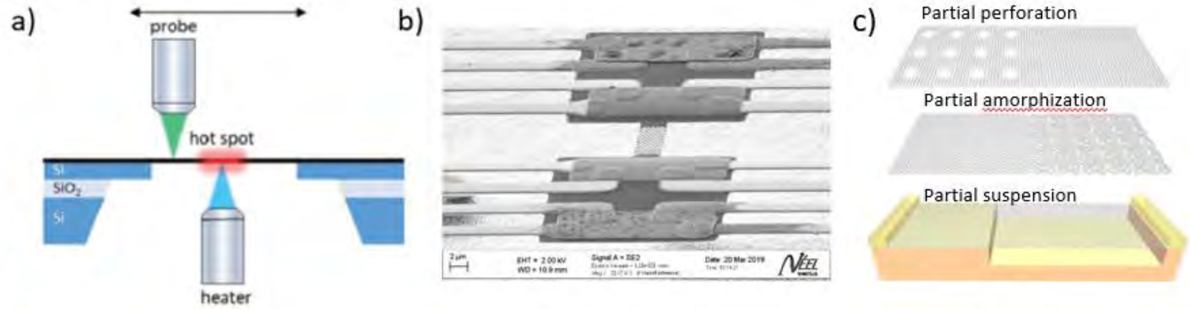


Figure 1: a) Schematics of the two-laser optothermal Raman experiment; b) SEM image of the thermal bridge suspended platforms; c) different sample configurations to be tested.

References :
1) A.A. Balandin, S. Ghosh, W. Bao, I. Calizo, D. Tewelde-brhan, F. Miao, and C.N. Lau, Nano Lett. 8, 902-907 (2008).
2) W. Cai, A.L. Moore, Y. Zhu, X. Li, S. Chen, L. Shi, and R.S. Ruoff , Nano Lett. 10, 1645-1651 (2010).
3) C. Faugeras, B. Faugeras, M. Orlita, M. Potemski, R.R. Nair, and A.K. Geim, ACS Nano 4, 1889-1892 (2010).
4) J.S. Reparaz, et al., Rev. Sci. Instr. 85, 034901 (2014).
5) P. Singh, …, L. Marty, J. Chaste, M. Lazzeri and N. Bendiab, Submitted to PRB.
6) A. Tavakoli, K. Lulla, T. Crozes, E. Collin, and O. Bourgeois, Nat. Commun. ***9****, 4287 (2018)*

Interactions and collaborations :
The student will work in close collaboration between the Quan2m and the TPS teams at Néel Institute. Theoretical support will be provided by collaborators from IMPMC and INSA Lyon.

Required skills :
A M2 in Condensed Matter or Nanosciences is required with motivation for clean room fabrication too.

Start date : February/March 2025
Contact : Nedjma Bendiab (Quan2m), Olivier Bourgeois (TPS)
Institut Néel - CNRS : nedjma.bendiab@neel.cnrs.fr / olivier.bourgeois@neel.cnrs.fr
More information on : Quan2m and TPS teams websites

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Spin-photon interface for individual magnetic atoms in semiconductors

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

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

References: L. Besombes *et al.* Phys. Rev. B. 109, 235302 (2024) ; L. Besombes *et al.*, Phys. Rev. B 107, 235305 (2023); V. Tiwari *et al.*, Phys. Rev. B 106, 045308 (2022); V. Tiwari *et al.*, Phys. Rev. B Letter 104, L041301 (2021).

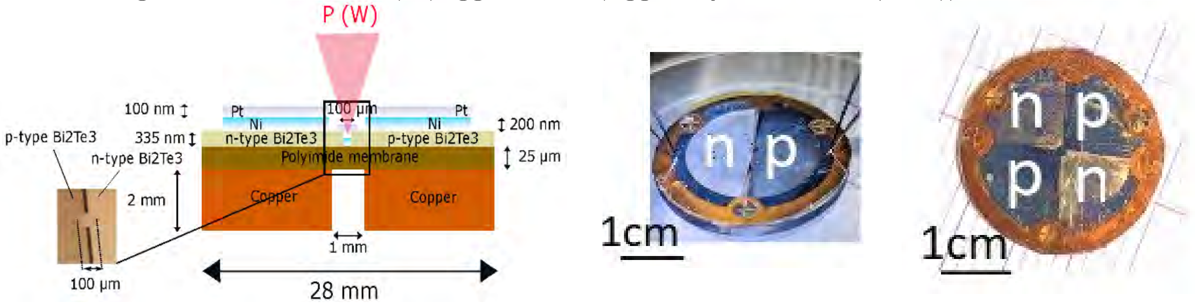
Possible collaboration and networking:
This work will be realized in the NanoPhysique et Semi-Conducteurs group (NPSC, CNRS/Institut Néel & CEA/IRIG) in collaboration with the University of Warsaw and the University of Tsukuba for the growth of some of the samples.
Possible extension as a PhD: Yes
Required skills: Master 2 (or equivalent) with good knowledge in solid state physics (electrical, optical, magnetic properties), quantum mechanics, optics, light matter interaction.
Starting date: March 2025 (flexible)
Contact: L. Besombes, Institut Néel, tel: 0456387158, email : lucien.besombes@neel.cnrs.fr
More information: http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Highly-sensitive infrared thermoelectric detectors

General Scope :
At Institut Néel in Grenoble, we are developing materials for the Energy such as thermoelectric thin films with high performance at ambient temperature. These thin films from the bismuth telluride family form the core of innovative micro-devices such as energy micro-generators or ultra-sensitive thermal detectors. A thin suspended polyimide membrane coupled to thermoelectric thin films with figure of merit ZT~1 ($ZT=S^2T/\rho\kappa$ with ρ electrical resistivity, κ thermal conductivity, S Seebeck coefficient and T temperature) is used to ensure the sensitivity of thermal detectors. To date, single-pixel sensors measuring 1 mm in diameter have been developed and characterized, showing remarkable potential for infrared (IR) applications (Appl. Phys. Lett. **125**, (2024)).



a) b) c)

Thermoelectric detector characteristics : principle of detector in cross section (a) (Scales are not respected) and optical pictures of Bi_2Te_3 detectors constituted of single (b) and dual-junctions (c).

Research topic and facilities available :
The aim of the internship is to develop an array of thermoelectric pixels 150 microns in diameter and to characterize them under IR radiation. One of the objectives of the work will be to determine parameters such as responsivity, noise equivalent power (NEP), thermal constant τ, and specific detectivity, D*, of representative pixels. These measurements will be carried out for a polyimide membrane thickness of 25 microns, then for smaller thicknesses after carrying out an etching process using plasma oxygen technique. A study of the absorption of IR radiation as a function of polyimide thickness will also be carried out.

The trainee will be responsible for :
-carring out a bibliographical review of infrared sensors, in particular thermoelectric sensors
-developing the pixel matrix using clean-room processes at the NANOFAB pole and EpiCM pole facilities
-characterizing the responsivity and detectivity performances under IR radiation.

He (or she) will be integrated into the TPS team (Thermodynamique et Biophysique des Petits Systèmes) in strong collaboration with the 'transfert-cell' for valorization purpose. The trainee will be supported and trained by the technical staff involved in the project.

Possible extension as a PhD : Yes

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

Starting date : February-March 2025

Contacts :
Daniel Bourgault et Jean Luc Garden
Institut Néel - CNRS
Phone: 04 76 88 90 31 / 04 76 88 90 61 ; E-mail :daniel.bourgault@neel.cnrs.fr / jean-luc.garden@neel.cnrs.fr ; More information: http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

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].

We are also studying new superconducting materials (Tantalum and Rhenium) in order to increase the qubit coherence times.

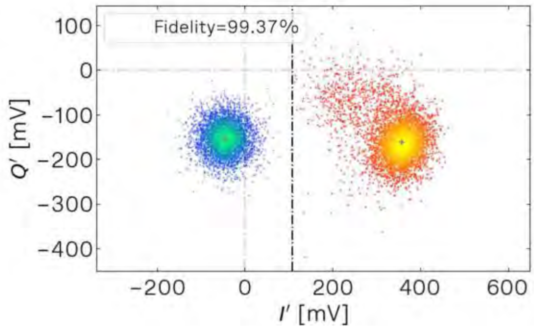


Figure: Histograms of ten thousand single shot QND measurements of the microwave transmitted signal when the qubit is prepared in its ground state |g> (blue points) and excited state |e> (orange points). The two states are very well separated by the measurements leading to a very high readout fidelity.

[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) and Phys. Rev. Applied 20, 044050 (2023).
[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).

PhD grants: available funding through Grenoble PhD calls.

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 2025.

Contact: BUISSON Olivier
Institut Néel- CNRS : phone: +33 4 56 38 71 77 email: olivier.buisson@neel.cnrs.fr
More informations on : http://sqc.cnrs.fr

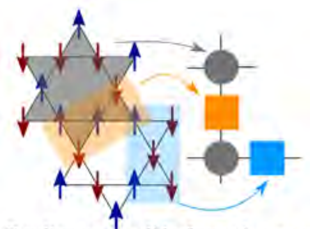
INSTITUT NEEL Grenoble
Proposition de stage Master 2 - Année universitaire 2024-2025

Frustration et physique exotique dans les systèmes à N corps : réseaux de tenseurs

Cadre général :
En physique, comme dans la vie, un peu de frustration rend les choses intéressantes [1]. On s'attend en général à ce qu'à température nulle, les atomes ou les molécules s'ordonnent parfaitement, formant un état fondamental unique du système. Pourtant, dans la glace, mais aussi dans des systèmes magnétiques classiques et quantiques, une compétition entre des interactions irréconciliables (« frustration ») donne lieu de manière inattendue à une entropie résiduelle finie par site – un nombre exponentiel d'états fondamentaux. À température nulle, un certain désordre subsiste dans la position de certains atomes ou dans l'orientation de leurs moments magnétiques, formant un état complexe, analogue à un liquide. Des décennies d'expériences et d'études théoriques sur les oxydes et les systèmes artificiels présentant de telles phases exotiques n'ont cessé d'élargir notre compréhension de ce qui est autorisé par la physique statistique et quantique. Un degré de liberté local peut par exemple appartenir « en même temps » à une phase ordonnée et à un « liquide » collectif fluctuant – un phénomène, la fragmentation, démontrée directement dans l'espace réel par certains d'entre nous [2].
Or, les systèmes fortement corrélés sont particulièrement difficiles à modéliser. Une révolution venant de l'information quantique durant les trois dernières décennies nous a fourni de nouveaux outils pour comprendre et simuler les systèmes quantiques à plusieurs corps : les réseaux de tenseurs. Ces nouvelles méthodes s'avèrent également extrêmement utiles dans l'étude de la physique statistique non conventionnelle. Nous avons à peine commencé à découvrir ce que ces méthodes permettent, notamment en les utilisant pour caractériser des entropies résiduelles étonnamment faibles ou des transitions de phase inattendues à partir d'états fondamentaux partiellement ordonnés [3] .

[1] Paraphrasé de L. Balents, Spin liquids in frustrated magnets, Nature, (2010).
[2] B. Canals et al. Nat. Com. 7, 11446 (2016); E. Lhotel et al., J. Low. Temp. Phys. 201, 710 (2020)
[3] J. Colbois et al. PRB 106, 174403 (2022) et refs. internes; A. Rufino, et al, en préparation.

Sujet exact, moyens disponibles : Le projet se concentre sur des Hamiltoniens où des phases inhabituelles sont attendues, en particulier la fragmentation. Il se déroule à l'Institut Néel, qui possède une expertise de classe mondiale pour l'étude expérimentale de cristaux où la frustration joue un rôle essentiel, ainsi que de systèmes artificiels émulant des Hamiltoniens de spin frustrés à différentes échelles (nanoaimants, billes magnétiques, réseaux moléculaires non magnétiques). Les simulations numériques (réseaux de tenseurs et/ou Monte Carlo) peuvent être réalisées sur les supercalculateurs disponibles localement (Néel/UGA).



Etudier un modèle frustré avec un réseau de tenseurs, c'est comme résoudre un "jeu de dominos" avec des contraintes inhabituelles (en couleur ici).

Interactions et collaborations éventuelles :
L'étudiante ou l'étudiant rejoindra la collaboration entre spécialistes de l'étude théorique et expérimentale des systèmes de spins frustrés à l'Institut Néel. Nous l'encouragerons à interagir et à apprendre de l'ensemble de ces chercheurs et chercheuses.

Ce stage pourrait potentiellement se poursuivre par une thèse.

Formation / Compétences : Solide formation en physique statistique et matière condensée. Curiosité pour la théorie et les expériences, ouverture d'esprit, enthousiasme pour réaliser des calculs analytiques et/ou numériques.
Période envisagée pour le début du stage : Printemps 2025
Contact : J. Colbois (physics.jeannecolbois@gmail.com), B. Canals (benjamin.canals@neel.cnrs.fr)
Institut Néel - CNRS
Plus d'informations sur : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Quantum memory integration of rare-earth doped crystals

General Scope :

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

Research topic and facilities available:

The main objective is to integrate erbium-doped materials into a photonic platform and perform a demonstration of quantum storage using this device. Most of the realizations have so far involved bulk crystals, namely oxide compounds containing yttrium. As compared to glass, silicon, or lithium niobate, rare-earth activated samples are not commercially available as a photonic platform. Based on a recognized consortium, involved in the national quantum initiative on quantum memories (see below), we first propose to fabricate elementary wafers supporting rare-earth doped crystals. After a secondary integration/fabrication step to produce a waveguide, we will benefit from the light confinement to enhance the interaction. We therefore propose to perform a quantum memory demonstration using this unique device.

The internship will focus on the first steps of the project, combining fabrication processes (polishing and surface adhesion), mechanical characterization of the samples at cryogenic temperatures, and elementary spectroscopy of the ions embedded in the structure to evaluate the local strain. To follow-up, a PhD funding is available for a motivated candidate.

Possible collaboration and networking :

- Centre de radiofréquences, optique et micro-nanoélectronique des Alpes (CROMA)
- 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 2025

Contact :

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

NEEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Ultra-cold Nanomechanics

Keywords: quantum mechanics, nano-mechanics, non-linear phenomena, low temperatures, ground-state cooling, stochastic thermodynamics

General Scope:
The project is devoted to fundamental research using nanomechanics cooled down to the lowest possible temperatures. It has two facets: a macroscopic approach concerned with the quantum mechanics behavior of the moving device itself, and a microscopic one concerned with elementary excitations in quantum matter and thermodynamics concepts.

Research topic and facilities available:
The project is based on the « brute force » cooling of nanomechanical devices down to temperatures below 1 mK. For devices resonating around 20 MHz in their first flexure, the collective modes describing the motion are in *their quantum ground states*. Experiments probing mechanical quantum coherence are then possible, on a system which is at equilibrium with the environment. These coherence properties are linked to fundamental aspects of quantum theory, with new developments (e.g. stochastic collapse) and old paradoxes (e.g. Schrödinger cat).
Properties of quantum matter are probed by looking at intrinsic mechanical dissipation mechanisms in the constitutive solids, and more specifically at *their fluctuations*. These are characteristic of the thermodynamic baths connected to the mechanics, and tells us about fundamental aspects of thermodynamics.
These experiments rely on cryogenic capabilities of the group: a unique platform allying demagnetization cooling down to 500 µK with a quantum-limited microwave optomechanical readout (see Figure).

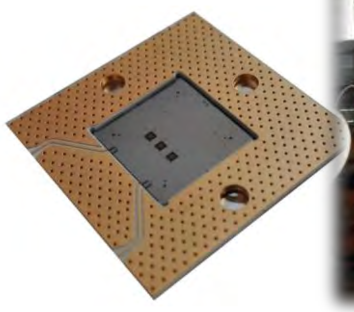


Figure: A PCB board hosting a microwave optomechanics experiment (left) and the nuclear demag. cryostat (right).

Possible collaboration and networking:
This research is carried out at Institut Néel, in collaboration with other researchers from the laboratory. It is performed in the framework of the *European Microkelvin Platform (EMP,* web.emplatform.eu*)*, with contacts to other ultra-low temperature facilities in Europe (UK, Germany, Finland…). Theoretical support is provided by collaborators from Nottingham University, UK.

Possible extension as a PhD: yes

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

Starting date: Flexible

Contact:
Name: Eddy Collin
Institut Néel - CNRS ULT Group
Phone: 04 76 88 78 31 / e-mail: eddy.collin@neel.cnrs.fr
More information: https://neel.cnrs.fr/equipes-poles-et-services/ultra-basses-temperatures-ubt

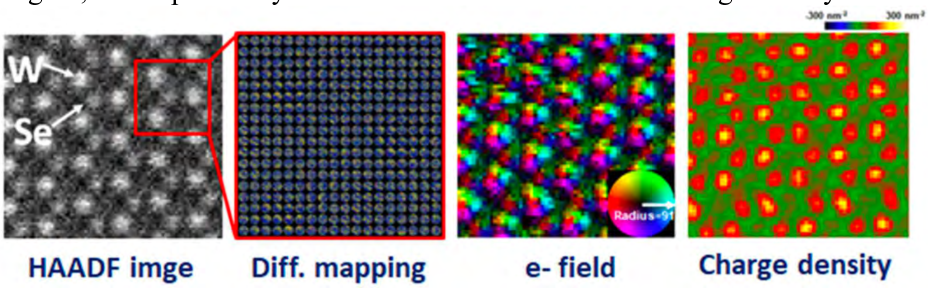
NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Measuring electric fields at nm length scales using 4D scanning transmission electron microscopy

General Scope : Long range electric and magnetic fields are present all around us in devices, where electric fields on atomic length scales are present in all matter. However, it remains challenging to measure the strength of these fields accurately and with high spatial resolution. Several Transmission Electron Microscopy (TEM) based techniques exist, sensitive to internal fields. TEM is of particular interest in this respect, since (i) the electron traverses the sample, and can therefore probe all fields it traverses, and (ii) due to the very high spatial resolution that can be obtained in TEM.

Research topic and available facilities: The aim of this internship is to contribute to the data treatment of so-called four-dimensional scanning transmission electron microscopy (4D STEM) results. In these experiments, a focused electron probe is raster scanned over the sample, and a diffraction pattern is acquired at each probe position. The presence of an (electric) field in the sample results in a deflection of the transmitted beam as well as a phase change. Different methods exist to calculate the phase and amplitude image from such a four-dimensional data-set, and this field is evolving very rapidly. However, this kind of data treatment is not yet available for day to day use on our TEM. The student will integrate an existing project on electron ptychography, either making the ptychographic reconstruction more available to users, or comparing different reconstruction algorithms, on both experimental and simulated diffraction maps, building on our experience in this field. The student will integrate a multi-institute, multi-disciplinary research group, including researchers of both CEA Grenoble and CNRS Institut Neel. The student will assist to the 4D STEM experiments and data acquisition on a state-of-the-art corrected TEM present at Institut Neel, equipped with a new very fast camera. The student will compare approaches using already developed scripts and programming in Python and adapt python scripts to the task. An example of such a 4D data set is shown in the figure, accompanied by the calculated electric field and charge density.



HAADF image of WSe_2 monolayer (2D material), local electric field and charge density maps calculated from deflection of transmitted beam.

Possible collaboration and networking : The internship will be in collaboration with researchers from IRIG.

Possible extension as a PhD : We are open to support applications for a PhD grant.

Required skills : Interest in solid-state physics, transmission electron microscopy, interest in programming and data treatment.

Starting date : jan/feb 2025

Contact : Name : Martien den Hertog
Institut Néel - CNRS
Phone : 0476881045 e-mail : martien.den-hertog@neel.cnrs.fr

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

NÉEL INSTITUTE Grenoble

Topic for PhD – Academic year 2024-2025

Low temperature transport and Transmission Electron Microscopy of silicon aluminum interfaces

General scope:

The combination of superconducting and semiconducting materials at nm length scales is an intensely studied topic as new device functionalities can be realized by combining these material combinations at such small length scales. In particular, these structures are regarded as promising building blocks for quantum computing. More specifically, the Al-Ge and Al-Si material combination has been studied in depth in our groups during the last 10 years, both for its structural aspect by using transmission electron microscopy (TEM) as well as by low temperature transport, in collaboration with researchers at the Technical University of Vienna, Austria. The most intriguing aspect of this material combination is that upon heating an Al contacted semiconductor section, an exchange phenomenon takes place where Al enters the semiconducting material from the contact pads, while the semiconductor material flows through a surface diffusion channel into surfaces and grain boundaries in the Al contact pad. In this way and atomically abrupt interface propagates into the semiconducting region during the annealing, see fig.1. After heating is stopped, a semiconducting region of well-defined length is then created between two crystalline aluminum contacts. Both the interface properties (Josephson effect) as well as quantum size effects due to the size of the semiconducting region (for example Coulomb blockade) can be studied at low temperature.

Research topic and available facilities:

This project aims to fabricate silicon membranes starting from silicon on insulator (SOI) substrates. Our collaborator at TU Vienna (Alois Lugstein and his group) is currently working on the exchange reaction of aluminum with silicon strips defined in SOI. The same fabrication process will be applied to the silicon membranes, to create the same structure compatible with TEM characterization. These Al-Si interfaces will then be studied by low temperature transport. All results will then be correlated by TEM characterization of the identical interface, regarding interface abruptness and shape, as well as crystalline quality. It is then possible to go a step further and combine low temperature transport and TEM directly in the TEM using an in-situ biasing cryogenic TEM sample holder. The aim here is to establish the possibilities, and potentially observe charge related phenomena in the TEM. The student's work will involve:

- Fabrication of silicon membranes (support from supervisor and nanofab cleanroom staff).
- Contributing to the device conception, fabrication will be carried out at TU Vienna.
- Carrying out low temperature transport measurements.
- Carrying out TEM characterization (support from supervisor)
- Data analysis and interpretation

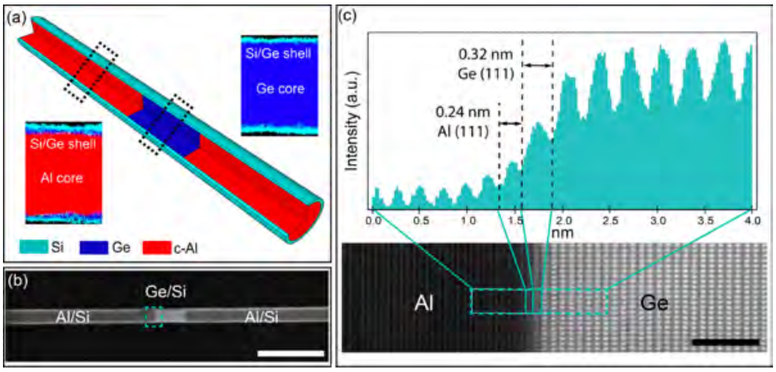


Figure 1. (a) Schematic illustration of an axial Al−Ge−Al NW heterostructure with an ultrathin semiconducting shell wrapped around it. The insets show EDX chemical maps at the respective positions along the heterostructure showing the Al−Ge−Al heterostructure. (b) SEM image of the heterostructure arrangement. Scale bar is 200 nm. (c) High-resolution HAADF STEM obtained at the Al−Ge interface and corresponding intensity profile obtained at the cyan dashed square shown in (b). Scale bar is 2 nm. [ACS Nano 104, 102102 (2019)].

Possible collaboration and networking:.TU Vienna, Neel, CEA Grenoble.

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

Contact: den HERTOG Martien & NAUD Cecile. Institut Néel - CNRS : 0476881045 martien.den-hertog@neel.cnrs.fr & 0456387017 cecile.naud@neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Engineering the Next Generation of Solid-State Electrolytes

General Scope:
Are you interested in working in a large collaborative team to advance the design of next-generation energy storage materials? You will be based at the Institut Néel and the LEPMI laboratory within the GIANT campus of Grenoble. Your role will involve characterizing and performing electrochemical measurements on new electrolytes prepared using the niche technique of Cold Sinter Processing (CSP), a technology poised to revolutionize the autonomy and safety of electric vehicles by enabling the production of new materials and devices at low energy costs.

Research Topic and Facilities Available:
Currently, All Solid-State Lithium Battery (ASSLB) technology is limited by the high impedance at solid-solid interfaces, which hinders the effective transport of lithium ions. We have identified the potential of reactive CSP to expand the available phase space and enhance the properties of solid electrolyte materials, with the potential to overcome current limitations and reshape the future of ASSLB technology. The reduction in processing times and temperatures of ceramics in CSP (by up to an order of magnitude) results in a significant decrease in processing costs. Coupled with the streamlined single reaction and sintering step, the potential for scalability makes reactive CSP a promising avenue for ASSLB fabrication.
You will fabricate new electrolyte materials using CSP at the Institut Néel. You will characterize the (micro)structure of these new materials using X-ray diffraction and Scanning Electron Microscopy. Their performance in ASSLBs will be investigated through electrochemical methods under the supervision of experts at the LEPMI laboratory (Patrice Rannou and Renaud Bouchet).
You will interact with a multidisciplinary team, and the outcomes of your research will motivate further studies and grant applications by the team, including a PhD studentship.

Possible Collaboration and Networking:
Easy access to a wide range of structural characterization techniques at the Institut Néel will inform and expedite the synthesis work. You will establish an interdisciplinary network that brings together research activities at Néel and LEPMI, creating opportunities for pioneering science in a burgeoning field of research.

Possible Extension as a PhD:
An extension to a PhD is conceivable, contingent upon the student demonstrating outstanding performance and funding availability.

Required Skills:

- This project is suitable for students pursuing degrees in chemistry, chemical engineering, materials chemistry, and materials engineering.
- Candidates with practical experience in a chemistry laboratory will be better suited for the project.
- A hands-on attitude and good organizational skills are essential.
- Interest in researching new materials and energy storage.
- Knowledge of relevant topics (solid-state chemistry, electrochemistry) is a plus.
- Experience working in a multidisciplinary team.

Starting Date: Flexible, beginning 15th September 2024, or later, based on the student's availability and upon discussion.

Contact:
Name : Maria Diaz-Lopez
Institut Néel - CNRS
Phone : e-mail :maria.diaz-lopez@neel.cnrs.fr
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Ultra-Coherent Nanomechanical Resonators

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

Further reading: M. Raba *et al.*, *Physical Review Applied* **22**, 024027 (2024) http://dx.doi.org/10.1103/PhysRevApplied.22.024027, D. Cattiaux *et al.*, *Nature Communications*, **12**, 6182 (2021) https://doi.org/10.1038/s41467-021-26457-8

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

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

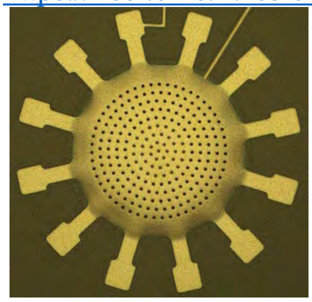
Possible extension as a PhD : Yes

Required skills: Enthusiasm for carrying out challenging experiments at ultra-low temperatures.

Starting date : Negotiable

Contact :

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



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

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Investigation of living bacteria using optical fiber tweezers

General Scope: Over the last years, optical tweezers became an essential non-invasive observation, characterization and manipulation tool in microbiology, chemistry and solid state physics. In particular, optical tweezers permit to get deeper insight into biological species such as cells, viruses, or bacteria.
In this context, we have developed an original optical tweezers approach based on nanostructured optical fibers. In this technique, the trapping light beam is emitted by an optical fiber close to the trapped species, thus limiting optical aberrations and other problems when working in crowded media. Recently we applied this fibered optical tweezers for investigating *P. aeruginosa* bacteria. This species is of particular intersest because it harbours an efficient unique flagellum and diverse extracellular appendages including Type 4 pili also involed in motility. We could demonstrate efficient optical trapping and observed interesting features of bacteria swimming behavior. The main object of this internship is to go further into the characterization of trapped and swimming bacteria, e.g. to observe the division of trapped bacteria, or to investigate the relation between the bacteria speed and its flagellum rotation frequency.

Research topic and facilities available:
Working with *P. aeruginosa* bacteria requires to operate in a biological safety cabinet inside a P2 laboratory. Such a facility is not available at Institut Néel (IN) and will be provided by E. Faudry at Institut de Biologie Structurale (IBS), just 500 m north of IN. He will also train the student working with biological specimen and supply the bacteria. The actual measurement phase will be preceded by a training phase at IN allowing the student to get familiar with optical trapping and the experimental set-up. For the measurement, the tweezers will be moved to IBS. The third and final part of the internship consists in exploiting the acquired data.

Possible collaboration and networking: This research project is based on a close collaboration with Eric Faudry from IBS in Grenoble, who will also supervise all the biological aspects of the internship.

Possible extension as a PhD: YES

Required skills: This internship is thematically situated at the interface of photonics and microbiology. Students should have good knowledge in one of these domains and strong interest in the other one. In general, the student should have good experimental skills and should be motivated by interdisciplinary work.

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

Contact :
Name : Jochen Fick
Institut Néel - CNRS
Phone : 04 76 88 10 86 e-mail : jochen.fick@neel.cnrs.fr

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

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Nanowire betavoltaics

General Scope: The internship will part of a collaborative research project that aim at developing advanced betavoltaic (BV) energy sources, addressing the growing demand for long-lasting, autonomous power generation in challenging environments. The principle of these BV generators is rather simple: they convert the kinetic energy of β-particles (electrons or positrons) into electrical energy in a semiconductor, similar to the photovoltaic effect. The energy output of these devices persists for a period of time on the order of the radioisotope source's half-life, making BV sources durable and insensitive to environmental conditions. Thus, BV source is offering a promising alternative to traditional batteries due to its higher energy density and extended lifespan.

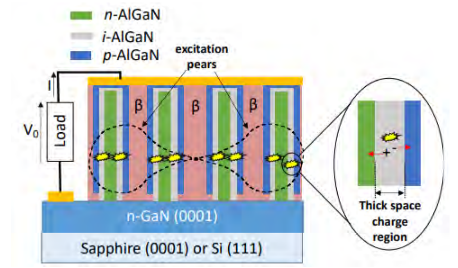


Figure 1 - BV generator proposed within the framework of the master internship

The project aims to overcome the limitations of current commercial BV devices by exploring innovative semiconductor structures. While existing solutions use planar designs with limited efficiency, this research proposes using core-shell nanowire p-i-n junctions, particularly with (Al)GaN semiconductors. This novel approach seeks to optimize the conversion of β-radiation to electron-hole pairs by decoupling particle absorption and charge carrier collection directions.

Research topic and facilities available: In this context, the aim of this internship is twofold:

(1) Firstly, the student will be in charge of making such betavoltaic cells from core-shell nanowires epitaxied by our partner at CEA-IRIG. To reach this objective, the intern will have access to all the necessary clean-room equipment (resin deposition, lithography, metal deposition, etc.).

(2) Once the device has been realized, the intern will be in charge for characterising the device. Firstly, he/she will carry out standard electrical characterisation (I(V), C(V), etc.). Finally, in order to quantify the efficiency of the BV cell, the student will carry out electron beam induced current (EBIC) measurements in which the beta emitter will be simulated by the electron gun of a scanning electron microscope.

Possible collaboration and networking: This work will involve strong collaborations with researchers from CEA (Bruno Daudin & Christophe Durand) as it is part of a collaborative research project.

Possible extension as a PhD: It will be possible to pursue as a PhD on the same subject with funding already secured (ANR Funding). The thesis will be shared between CEA-IRIG and Institut Néel. The student would be in charge of growing the core-shell nanowires at the CEA and would produce and characterise the BV cells at the Néel Institute. He will also have the opportunity to collaborate with other laboratories: LTM in Grenoble, CRHEA in Nice and McMaster University in Canada.

Required skills: The candidate should have a master 2 in Nanosciences or equivalent, with a marked interest in experimental physics, material growth and characterization

Starting date: The internship could start from January to April 2025

Contact:

Name : Gwénolé JACOPIN
Institut Néel - CNRS
Phone : 04 76 88 11 83 e-mail : gwenole.jacopin@neel.cnrs.fr

Contacts of CEA collaborators (Christophe Durand (christophe.durand@cea.fr) et Bruno Daudin (Bruno.Daudin@cea.fr))

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

NÉEL institut

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Attempt to nano-engineer flat bands to increase critical superconducting temperatures

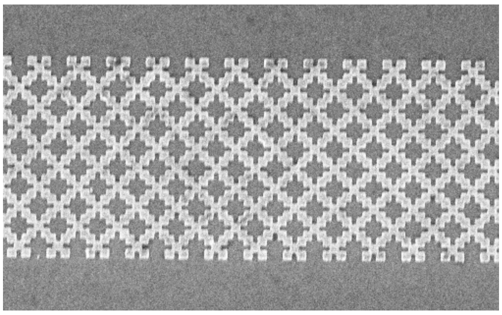
General Scope :

Superconductivity is a fascinating state of matter corresponding to zero electrical resistance and magnetic field expulsion occurring in some materials cooled down below a critical temperature. Microscopically it corresponds to a condensate of electron pairs. Such a condensate of fermions can occurred only because electron paired up to form Cooper pairs. In conventional superconductors, the glue binding the electron pairs is the exchange of lattice vibrations: the phonons. In conventional superconductors the critical temperature is expected to scale with the pairing interaction g as $Tc \sim \exp(-1/g)$.

In flat-band systems, i.e. when the Fermi velocity is zero, theories predict that the superconducting critical temperature Tc depends linearly on the pairing interaction g, $Tc \sim g$. As a result, critical temperatures much higher than those of conventional superconductors can be envisaged (without changing the nature of the pairing interaction).

Research topic and facilities available :

This project aims to explore experimentally structures in which superconductivity could be enhanced by the emergence of flat bands. The idea is to control the emergence of flat bands via the geometry of the nano-patterning. To this end, we plan to produce flat band superconducting structures using nano-lithography techniques and measure the evolution of the critical temperature and the Fermi velocity via magneto-transport measurements. The final objective is to study wether the critical temperature correlates with the Fermi velocity for different nano-patterning of the very same material as suggested by recent theoretical predictions. For this projet the student will be trained in nano lithography and low-temperature resistance measurement techniques.



MEB image of nano-pattern wire.
Grey: silicon substrate. White: superconducting material. This is a second-order fractal pattern. The wire is connected to four pads (not shown) for resistivity measurements.

Possible collaboration and networking :

The project is part of the Institut Néel's collaboration with the theoretician George Bouzerar.

Required skills:

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

Starting date : January-April 2025

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

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Spectrometers based on Kinetic Inductance Detectors (KID)

General Scope :

Millimeter and sub-millimeter astrophysics is nowadays among the most important pillars supporting our common cosmological model. In particular, the Cosmic Microwave Background, the most primordial electro-magnetic radiation that is observable, is peaking at millimeter wavelengths.

Kinetic Inductance Detectors are state-of-the-art detectors for millimeter wave observations in astrophysics. They are LC resonators made out of superconducting materials. The detection principle is based on the monitoring of the resonator frequency variation $f_0 = 1/(2\pi\sqrt{LC})$. Incident photons break down Cooper pairs, modifying the inductance L and thus the resonance frequency. The superconducting gap Δ sets in the photon detector cutoff frequency to $\nu > \Delta/h$.

Research topic and facilities available:

In this project, we aim to develop a new technology for on-chip spectroscopy using Kinetic Inductance Detectors and a magnetic field (the H-KID projet). The spectral response of the Kinetic Inductance Detectors will be modified by reducing the superconducting gap using the magnetic field. The aim of the project is to design, nanofabricate and test at low temperature a spectrometer based on Kinetic Inductance Detectors.

The student will ensure all the steps of the study from the fabrication up to the measurements. She/he will design and nano-lithography the detectors. Test of the detectors will be realized in an optical dilution fridge refrigerator at 100 mK.

Photo of a Kinetic Inductance Detector.
Grey: silicon substrate. White: superconducting material. The resonator consists of a second order Hilbert shape fractal inductor and an interdigital capacitor. The resonator is capacitively coupled to the transmission line : top straight line.

Possible collaboration and networking :

The project is part of the Institut Néel's collaboration with Alessandro Monfardini, Martino Calvo and Usasi Chowdhury.

Required skills:

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

Starting date : January-April 2025

Contact : Institut Néel - CNRS
Florence Lévy-Bertrand, 04 76 88 12 14, florence.levy-bertrand@neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Quasi-ballistic charge transport in ultra-pure diamond

General Scope :

Diamond is a very promising material for various applications in the fields of power electronics, detectors and quantum information. Understanding its fundamental properties is essential for the development of future devices. In this context, Institut Néel has developed, as part of a thesis in collaboration with the LPSC (M.L. Gallin Martel's team), an original Time of Flight Electron Beam Induced Current (ToF-EBIC) technique. This technique enabled a world first to be achieved, namely, to measure the mobility of free carriers by ToF-EBIC in ultra-pure diamond at low temperature. The principle of the experiment is that a 1 ns pulsed electron beam (from a scanning electron microscope) impacts the diamond semiconductor, inducing the creation, and then the displacement, of charge carriers through a solid diamond more than 500 µm thick to which a bias electric field is applied. The resulting signal is analysed using the current transient technique. Electron and hole velocities were evaluated as a function of temperature from 13 to 300 K and as a function of electric field with values ranging from 1.5 to 9200 $V.cm^{-1}$. We measured a low-field mobility value of more than 10^6 $cm^2.V^{-1}.s^{-1}$ for holes at 13 K, demonstrating that diamond is a suitable material for transporting charge carriers in a ballistic regime on a scale of 10 µm [1]. This mobility is the highest value ever achieved for holes in a bulk semiconductor. At the same time, we succeeded in reproducing for the first time the measurements of generation, transport and detection of valley-polarized electrons in diamond first reported by the group at Uppsala University in Sweden [2]. These two major results demonstrated the power of the technique for measuring charge transport properties in ultra-pure diamond.

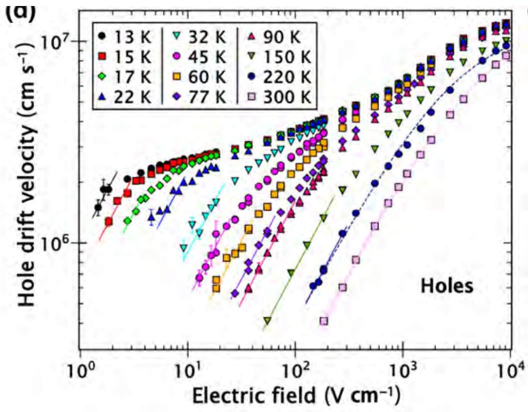


Figure : The velocity of the holes is measured as a function of the electric field and at different temperatures in order to determine the mobility of the carriers in ultra-pure diamond (slope at very low electric field).

[1] Portier, A., Donatini, F., Dauvergne, D., Gallin-Martel, M.-L., Pernot, J., 2023. Carrier Mobility up to 10^6 cm^2 $V^{-1}.s^{-1}$ Measured in Single-Crystal Diamond by the Time-of-Flight Electron-Beam-Induced-Current Technique. Phys. Rev. Appl. 20, 024037. https://doi.org/10.1103/PhysRevApplied.20.024037

[2] Isberg, J., Gabrysch, M., Hammersberg, J., Majdi, S., Kovi, K.K., Twitchen, D.J., 2013. Generation, transport and detection of valley-polarized electrons in diamond. Nature Materials 12, 760–764. https://doi.org/10.1038/nmat3694

Research topic and facilities available :

As part of our proposed internship, we want to take our techniques and methods even further to measure electronic properties that have never been explored before in this field. By developing cryogenic RF amplification as close as possible to the sample holder, we hope to achieve lower temperatures (of the order of 5 K). By optimising the injection of electrons, we expect to be able to minimise the internal shielding of the charge carrier drift at very low applied electric fields. This should make it possible to approach a hole mobility measurement of 10^7 $cm^2.V^{-1}.s^{-1}$ to 10^8 $cm^2.V^{-1}.s^{-1}$. The aim of this work is to apply this technique to other samples, to achieve ballistic or quasi-ballistic transport between two electrodes.

In the longer term, as part of a thesis, we could design and even demonstrate the possibility of : 1) ballistic, and therefore coherent, transport of holes between two NV centres (nitrogen-carbon monochromatic centre in diamond) separated by hundreds of micrometres, 2) manufacture of electronic components using the 'valleytronics' principle thanks to the valley polarisation of electrons in diamond. The two objectives of this thesis would be world firsts, paving the way for new applications in the field of electronics.

Although experimental development is envisaged during this thesis, the measurement bench already exists, and developments will be limited to RF and cryogenics aspects.

Possible collaboration and networking :
Collaboration with the LPSC will continue. The samples envisaged come from a number of sources: commercial substrates from Element 6 identical to Ref [1], ultra-pure and thick self-supported epitaxial layers in collaboration with Dr Teraji (NIMS, Tsukuba, Japan) as part of the international J-FAST laboratory (Grenoble-Tsukuba) or diamond substrate from Prof Achard of the LSPM (Univ Paris), or the Diamfab company.

Possible extension as a PhD : Yes see above

Required skills : Semiconductor physics, solid state physics and condensed matter physics.

Starting date : February 2025

Contact : Julien Pernot– co-encadrants: Fabrice Donatini (Institut Néel) et Christophe Hoarau (LPSC)
Institut Néel - CNRS : 04.56.38.70.83,
e-mail : julien.pernot@neel.cnrs.fr
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Protected superconducting qubit with a graphene Josephson junction

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. 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 new functionalities.

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 a qubit with a new property: a gate tunable energy. In the team we have already demonstrated the fabrication of such graphene based Josephson junctions and their use in quantum circuits[1,2]. The next step, is to use the specificities of such junction to build a qubit protected from decoherence, which is the characteristic that makes a qubit usable for future quantum computing.
A one atom-thick sheet of graphene will 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, coherence, gate fidelity...

[1] G. Butseraen et al *Nature Nanotechnology* 17, 1153 (2022); arXiv:2204.02175
[2] S. Messelot et al *Phys. Rev. Lett*, in press (2024); arXiv:2405.13642

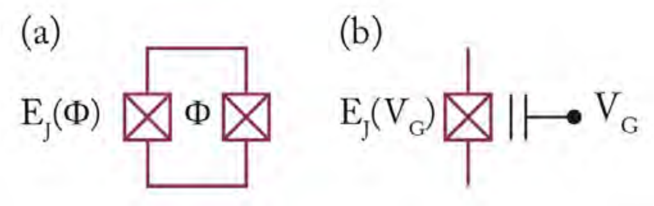


Figure 1: tunability of the Josephson energy E_J in standard Josephson junctions necessitates a loop geometry and a magnetic flux Φ (a). The introduction of a semiconductor allows simple electrical gating with a gate voltage V_G (b). In addition such junction presents original properties that can be used to build a protected qubit

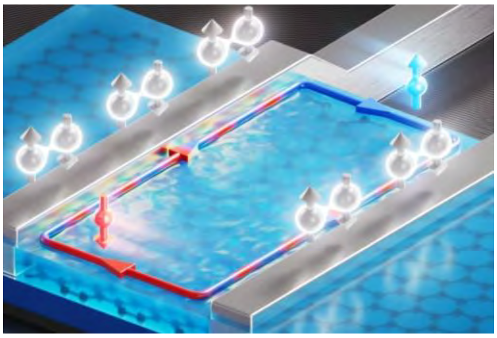
Possible collaboration and networking :
The student will be part of the Quan2m team, which has a multidisciplinary expertise (growth, nanofabrication, electronic transport, spectroscopy...). The team has also several external collaborations worldwide (France, US, Canada).
Possible extension as a PhD : Yes
Required skills : The internship (and the PhD thesis) will require a solid background in solid state/condensed matter physics. The work will be mainly experimental. The candidate is expected to be strongly motivated to learn the associated techniques (nanofabrication in clean room, radiofrequency electronics, cryogenics...) and engage in a hands-on experimental work.
Starting date : March 2025 (flexible)
Contact :
Name: Julien Renard Institut Néel - CNRS
Phone: 0456387176 e-mail: julien.renard@neel.cnrs.fr http://perso.neel.cnrs.fr/julien.renard/
https://sqc.cnrs.fr/
More information : http://neel.cnrs.fr

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Hybridizing superconductivity and quantum Hall physics

Hybridizing superconductivity with the quantum Hall (QH) effect has notable potential for designing circuits capable of inducing and manipulating non-Abelian states for topological quantum computation. A variety of QH states exhibits remarkable properties, as full spin polarization, helical phases with spin-momentum locking[1], fractionalization of charges into anyons quasiparticles, or a non-local nature and non-commutative braiding properties for non-Abelian anyons.



Figure| Graphene quantum Hall Josephson junction. The supercurrent that is a mixture of electrons (blue) and holes (red) is carried non-locally by the quantum Hall edge channel.

Last year, our group demonstrated the first Josephson junction made with graphene operating in the quantum Hall regime[2] up to a record magnetic field of 8T. We showed that the supercurrent in this regime is carried by the QH edge states, which are one dimensional channel propagating unidirectionally at the edges of the sample (see Figure), resulting in an unusual chiral supercurrent[2].
The project builds on this breakthrough to explore more exotic regimes of the QH effect, where coupling with superconductivity is expected to proximity-induce non-conventional superconducting states, such as p-wave superconductivity and topological Andreev bound states with non-Abelian properties.

The M2 internship will consist of realizing state-of-the-art high mobility graphene van der Waals heterostructures, in which suitably designed Josephson junctions will be fabricated and equipped with gate electrodes for tuning the quantum Hall states and controlling the trajectories of the edge channels. Quantum transport measurements will be performed in our highly-filtered dilution refrigerator, at a temperature of 10 mK and up to 14 T.

This internship aims to be integral to a PhD project that will extend to the coupling of such junctions with superconducting resonators, for performing circuit quantum electrodynamics and unveiling the Andreev bound states of the junctions.

Possible extension as a PhD: YES
Funding: YES (ERC grant)
Starting date: Flexible
Required skills: We are looking for highly motivated students with a strong background in condensed matter physics or quantum physics who can work collaboratively. Notice that lab visits are highly encouraged.

Contact: Benjamin SACEPE (benjamin.sacepe@neel.cnrs.fr), Hermann SELLIER (Hermann.sellier@neel.cnrs.fr)
Website: http://sacepe-quest.neel.cnrs.fr/

[1] *Helical quantum Hall phase in graphene on $StrTiO_3$*, L. Veyrat et al. Science 367, 781 (2020) arxiv:1907:02299

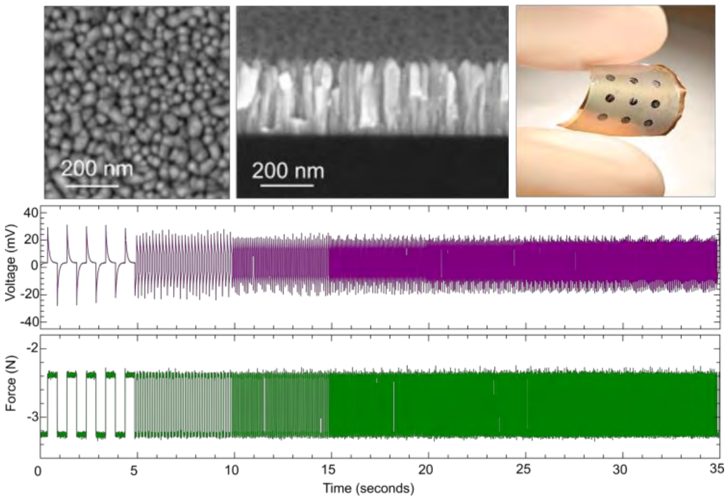
[2] *Evidence for chiral supercurrent in quantum Hall Josephson junctions*, H. Vignaud et al. Nature 624, 545 (2023) arxiv:2305.01766

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Title: Sputtering growth of ZnO for flexible piezoelectric energy harvesters

General Scope:



In recent decades, there has been significant progress in biomedical devices that can be implanted in the human body for diagnostic and treatment purposes. The miniaturization of these devices is critical to reduce their impact on human activities. However, these devices mostly rely on batteries which presents a challenge in reducing their size while prolonging their operational lifespan. Recent advancements in piezoelectric energy harvesters (PEHs) offer a solution for creating energy-autonomous devices by converting mechanical energy from human movements into electricity. Yet, traditional bulky-type energy conversion systems are not suitable for this application due to incompatible contact with soft tissue and curved surfaces. Therefore, thin, flexible, and lightweight PEHs are essential.

In the meantime, numerous research teams have focused on developing nanomaterial-based flexible PEHs. These devices not only generate electric power from tiny mechanical vibrations and irregular deformation but also can function as self-power sensors capable of detecting mechanical bio-movements. The challenge lies in selecting materials with high piezoelectric coefficients, with good flexibility and mechanical stability, for fabricating a fully flexible structure.

ZnO, a wurtzite piezoelectric semiconductor, is of high interest for this application as it is bio-compatible, and its relative ease of forming nanostructures on various substrates through standard, industrial-compatible growth techniques. Although hydrothermal growth is a simple and cost-effective technique for synthesizing ZnO nanostructures, it often results in impurities that degrade piezoelectric performance. Magnetron sputtering, the widely used deposition technique with reasonable running costs and feasibility of mass production, should offer higher quality ZnO material quality due to its high vacuum deposition conditions.

Research topic and facilities available:

In this work, we will focus on developing the sputtering growth and device processing to fabricate flexible ZnO PEHs. The student will explore the sputtering of ZnO on various substrates i.e. Si and copper foil by using the radio frequency sputtering technique. The objective is to synthesize high-quality ZnO in a controlled morphology and desired crystal orientations. The optimal growth conditions necessary to achieve ZnO nanocolumns and films with high piezoelectric coefficients will be determined. The student will investigate the structural, electrical, optical, and electromechanical properties of the ZnO films as a function of the deposition parameters. The comprehensive film characterization such as surface roughness, crystallography, piezoelectricity, and electrical resistivity will be performed with various techniques (SEM, AFM, PFM, electrical, etc) available at Néel Institute. In addition, the student will be involved in the development of flexible ZnO/polymer composite films through encapsulation and transfer processes. Together with the team, the student will participate in the large-scale characterization of electrical and electromechanical properties. The piezoelectric properties of ZnO will be studied and correlated with the electrical and electromechanical properties of large-scale piezo harvesters.

Possible collaboration and networking: Néel (NPSC, Optima, EpiCM) and CEA/Grenoble
Possible extension as a PhD: No funding is available, but we support the PhD grant applications.
Required skills: Material science, Semiconductors, Nanomaterials, Solid State Physics
Starting date: Feb./March 2024 (4-5 months), please apply 2 months before the starting date.
Contact : Name : Rudeesun Songmuang, Institut Néel, e-mail : rudeesun.songmuang@neel.cnrs.fr
More information: https://neel.cnrs.fr/les-chercheurs-et-techniciens/rudeesun-songmuang

INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2024-2025

Magnétisme non-conventionnel dans des matériaux en nid d'abeille

Cadre général :
La frustration magnétique, résultant d'une compétition entre interactions qui ne peuvent être toutes satisfaites à la fois, engendre souvent des états de spins non-conventionnels tels que des ordres magnétiques complexes, voir des états liquides (absence d'ordre à longue portée) [1-2]. Ces états magnétiques non-conventionnels résultent donc d'un compromis, mais ne correspondent pas toujours à un état de plus basse énergie. Le fait de perturber le système magnétique permet donc d'accéder à de possibles ordres cachés et donc de révéler les mécanismes microscopiques complexes sous-jacents.

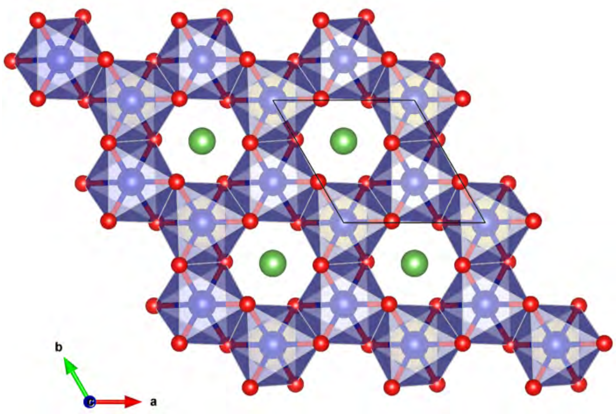


Fig.1 : Le réseau en nid d'abeille formé par les ions magnétiques représentés en bleu (composé $BaCo_2(AsO_4)_2$).

Sujet exact, moyens disponibles :
Le composé $BaCo_2(AsO_4)_2$ (dont la structure cristallographique est présentée en figure 1) présente un ordre magnétique très original : l'ordre magnétique est intrinsèquement désordonné, bien que la structure cristallographique soit très ordonnée. Cet « ordre » magnétique est la conséquence d'une forte compétition entre plusieurs interactions.
L'objectif de ce stage est l'étude de ce composé, dans lequel certains ions (cobalt d'une part et arsenic d'autre part) sont remplacés par d'autres ions (nickel, fer, vanadium) dans le but de perturber l'ordre magnétique établi et possiblement révéler d'autres états magnétiques exotiques.
Pour cela, l'étudiant.e réalisera des mesures physiques (aimantation, chaleur spécifique) sur les équipements disponibles à l'Institut Néel, ainsi que des mesures complémentaires de diffraction des neutrons afin d'étudier les structures magnétiques. Cette partie se fera sur grand instrument, à l'Institut Laue Langevin, situé à côté du laboratoire.

Interactions et collaborations éventuelles :
L'étudiant.e sera amené.e à interagir avec les différents pôles techniques de l'Institut Néel (synthèse des cristaux, magnétométrie, diffraction des rayons-X) ainsi qu'avec les chercheurs du groupe MagSup. Il/Elle aura aussi l'occasion d'assister à des séminaires scientifiques organisés régulièrement au sein du laboratoire. De plus, ce sujet étant une collaboration avec l'ILL, l'étudiant.e sera en forte interaction avec les scientifiques responsables des instruments et pourra se familiariser avec la diffusion neutronique.

Ce stage pourra se poursuivre par une thèse : oui sous condition de financement.

Formation / Compétences : de solides connaissances en physique du solide et en magnétisme

Période envisagée pour le début du stage : printemps 2025

Contact :
Manila SONGVILAY / Lucile MANGIN-THRO / Virginie SIMONET
Institut Néel - CNRS : manila.songvilay@neel.cnrs.fr, virginie.simonet@neel.cnrs.fr
Institut Laue Langevin : mangin-throl@ill.fr
Plus d'informations sur : http://neel.cnrs.fr

[1] « Spin liquids in frustrated magnets », L. Balents, Nature, vol. 464, 11 (2010)
[2] « Un nouveau liquide de spins quantique », Pour la Science (2021)

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

High T_c superconductivity in layered $Ln_{n+1}Ni_nO_{3n+1}$ nickelates

General Scope:
The search of high T_c superconductivity in other analogous materials than cuprates has started more than 35 years. For Ni, the discovery of unconventional superconductivity in thin film of hole-doped infinite-layer nickelate $Nd_{1-x}Sr_xNiO_2$ (with square planar coordinated Ni^+ in d^9 configuration for x = 0) below T_c = 15 K (for x~0.2) by the group of H.Y. Hwang (Stanford) mid-2019 has suddenly intensified the research in this field. So far, no superconducting bulk nickelates were discovered until the recent report of superconductivity near 80 K in $La_3Ni_2O_{7-\delta}$ (La-327) under high pressure (HP) by M. Wang et al. (China). On the contrary of previous nickelates this bilayer compound shows a mixed valency state $Ni^{2.5+}$ (i.e. d^7/d^8) and several theoretical scenarios have been proposed to understand the related high T_c superconductivity mechanism but the question is not yet resolved. Like cuprates, La-327 shows a $3d_{x^2-y^2}$-based Fermi surface but also an additional pocket involving $3d_{z^2}$ orbitals which is potentially crucial. In fact, superconductivity occurs just above a structural phase transition at P* ~ 10-14 GPa, where the $Ni\text{-}O_{apical}\text{-}Ni$ angle, closely related to oxygen 2p/nickel $3d_{z^2}$ orbitals hybridization, changes from 168° to 180° [Fig. 1]. In addition, superconductivity has also been detected in the trilayer $La_4Ni_3O_{10-\delta}$ nickelate, with a lower maximal T_c, around 30 K at 69 GPa and also with a similar phase transition around 15 GPa involving apical oxygens by Y. Zhu et al.

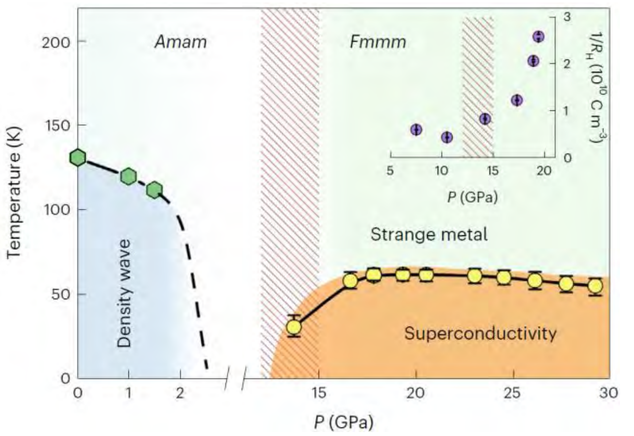


Fig. 1 P,T phase diagram of La-327 [Sun et al., Nature 621, 493 (2023) ; Zhang et al. Nat. Phys. 20, 1269 (2024)].

Research topic and facilities available:
In fact, P* is closely related to hydrostaticity conditions and/or oxygen vacancies content (δ). In early studies a transition from *Amam* to *Fmmm* space groups (both orthorhombic) was reported. Since 2019, at Néel Institute we are working on related infinite-layer Ni oxides. In MRS group, we have also synthesized several $Ln_{n+1}Ni_nO_{3n+1}$ compounds, in particular the n = 2 and 3 members. Thanks to x-ray diffraction (XRD) experiments under high high pressure (HP) conducted on different synchrotrons x-ray sources (ESRF, SOLEIL and Elettra) we have shown that in good hydrostatic conditions (with helium as pressure medium) P* is ~ 6.5-8 GPa for La-327 and is related to an orthorhombic – tetragonal transition (towards *I4/mmm*). During this internship we will complement these results by studying other properties, like the magnetic ones, via the development of magnetization/HP. We will also focus our studies on samples with lower defects levels ($La_2PrNi_2O_{7-\delta}$). A last objective will be to try to stabilize superconductivity in these layered nickelates at (nearly) ambient pressure thanks to adequate chemical substitution and/or the use of new synthesis techniques. Possibly another XRD/HP study at SOLEIL will be planned during the internship and resistivity or Raman spectroscopy measurements under (/HP) measurements in collaboration with MagSup team.

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

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

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

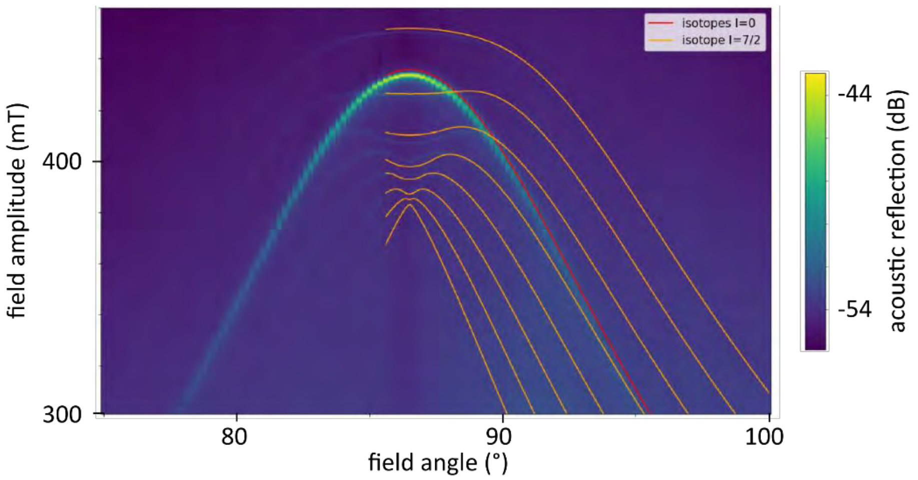
Starting date: Spring 2025

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

NÉEL INSTITUTE Grenoble
Topic for Master 2 internship – Academic year 2024-2025

Controlling and detecting spins with an engineered acoustic interface

General Scope : Most solid-state spins are coupled to their environment via spin-phonon interactions. Instead of considering these spin-phonon interactions as detrimental, we aim to use them as a resource for spin-based quantum technologies.
For this purpose, we engineer acoustic systems in which the phononic excitations are well controlled, and we use them to drive and detect electron spins. In our group, we have developed a technique to couple acoustic wave resonators (bulk modes) to microwave circuits at low temperature via piezoelectric components. We use these acoustic modes to detect the spin of dopants via intrinsic spin-phonon interactions (see figure). On the long term, this idea could be used to couple single spins with superconducting microwave circuits or to mediate controlled interactions between distant spins.



Acoustic resonance spectroscopy of Erbium spins at ≈5 GHz. Colorscale data is measured at 50 mK, lines is theory from the known Hamiltonian or Erbium isotopes.

Research topic and facilities available: On the short term, we will use this technique to measure the coherence and the anisotropy of spin-phonon interactions for relevant dopant spins (rare earth, diamond vacancy centers). The project will then move on, either to the control of spin ensembles for quantum functionalities, or to the development of acoustic nanostructures for the coupling to single spins.

The student will start with learning how to design, fabricate and operate bulk acoustic wave resonators at microwave frequencies (several GHz) and cryogenic temperatures (tens of mK). The fabrication takes place in the clean room of the Néel institute using state-of-the-art techniques. The cryogenic microwave measurements are performed in a dedicated dilution refrigerator.

Possible collaboration and networking: We collaborate with colleagues (in Paris and Grenoble) who provide us with samples containing dopant spins.
Possible extension as a PhD: Yes
Required skills: We are looking for a student motivated to learn a wide variety of skills in experimental physics, willing to be part of a project involving both fundamental and technical challenges.
Starting date: Flexible

Contact: Jeremie Viennot, Institut Néel – CNRS
Phone: +33 4 76 88 79 05 e-mail: jeremie.viennot@neel.cnrs.fr
Web: https://www.sqc.cnrs.fr/

NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Quantum microwave-to-optics interface

General Scope: This project aims at developing a microwave-optical quantum interface to be used as a key element in future quantum technologies. Such an interface will for example permit long-distance transfer of microwave quantum information, which is not possible without conversion in the optical domain. The realization of this project will also make possible the optically-mediated entanglement of distant microwave qubits (superconducting qubits or spin qubits). This will support the scalability and the connectivity of quantum-computing architectures by opening an interface between microwave qubits and silicon photonics.

Research topic and facilities available: We aim to realize a device capable to convert signals between microwave and optical domains, but also to generate entanglement between microwave and optical fields. This device consists of three main elements: a microwave superconducting circuit, a GHz-frequency mechanical mode (see Figure 1) and a near-infrared optical cavity on a single chip. The interactions between these elements (optomechanical and electromechanical) will be designed and optimized to provide the best performances for the full device.

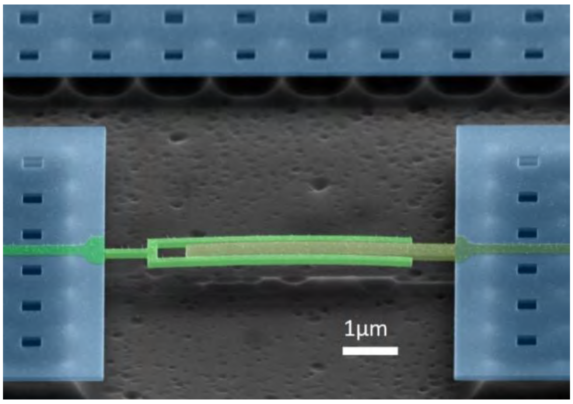


Figure 1: electron micrograph of a suspended mechanical resonator integrated with a superconducting circuit (green)

The student will start with learning how to design, fabricate and operate microwave superconducting electromechanical devices (several GHz) and optomechanical devices (hundreds of THz) at cryogenic temperatures (tens of mK). We will then combine these techniques to develop the full microwave-to-optics converter and characterize it, in terms of quantum efficiency and added noise.

The fabrication will take place in the clean room of the Néel institute using state-of-the-art techniques such as electron beam lithography. The cryogenic microwave measurements will be performed in a dedicated dilution refrigerator.

Possible collaboration and networking: This project is part of the french Quantum plan and we will work in close collaboration with partners with an expertise that complements ours: Matériaux et Phénomènes Quantiques (MPQ) in Paris is recognized for breakthroughs in quantum optomechanics and CEA Leti is a major Research Technological Organization in Europe.

Possible extension as a PhD: Yes

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

Starting date: Flexible

Contact: Julien Renard & Jeremie Viennot, Institut Néel – CNRS
e-mail: Julien.renard@neel.cnrs.fr & jeremie.viennot@neel.cnrs.fr
web: https://www.sqc.cnrs.fr/