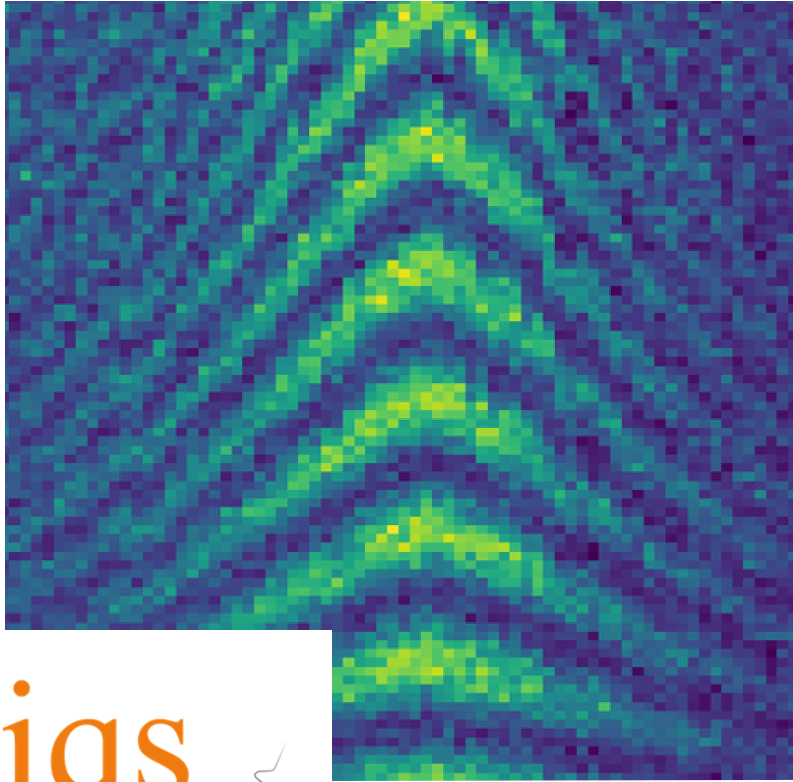
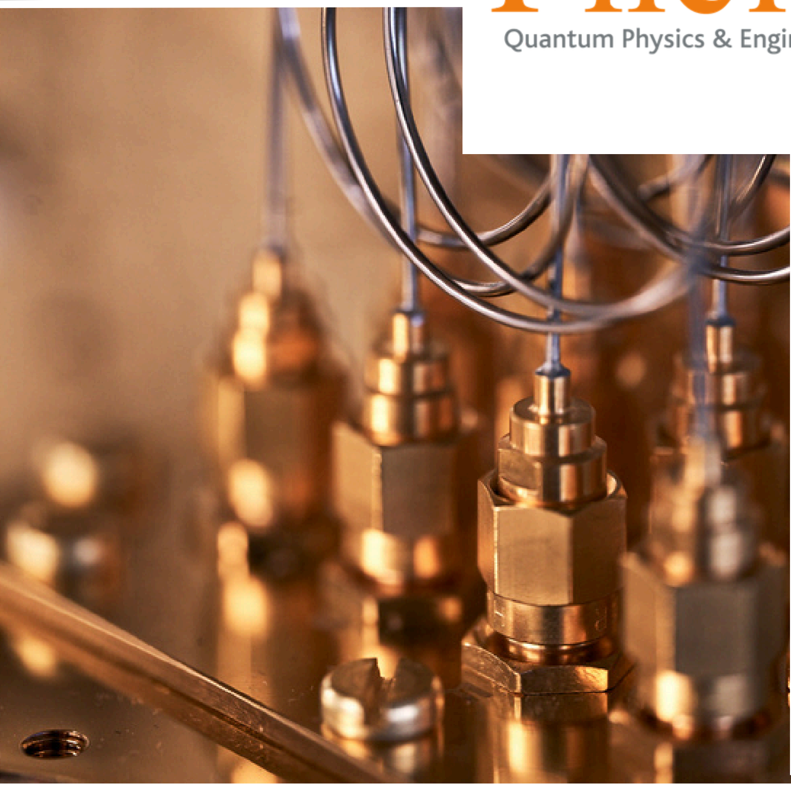


Pheliqs

Quantum Physics & Engineering



Master 2 Internships

Spring - Summer 2027

cea irig

Contents

Presentation of the laboratory

The Laboratory for Quantum Photonics, Electronics, and Engineering (PHELIQS) is a joint research unit of CEA, the Université Grenoble Alpes (UGA), and Grenoble INP Graduate Schools of Engineering and Management, with strong links to neighboring CNRS laboratories. The laboratory comprises five teams with complementary expertise in the fields of quantum physics, nanostructures, and quantum materials. As of September 2026, PHELIQS has a total of 112 people, including 35 researchers and professors, 18 technicians or research engineers, and 2 administrative assistants. In addition, it hosts 38 PhD students and 19 postdoctoral researchers.

PHELIQS conducts fundamental research activities in the fields of nanophysics and condensed matter physics, with potential mid- to long-term applications in information and communication technologies. The laboratory aims to understand and master the unique physical effects that appear in nanoscale solid-state systems and quantum materials, both experimentally and theoretically. To achieve these goals and develop application-oriented systems, PHELIQS maintains strong collaborations with a network of French and international pre-industrial and industrial partners, including CEA-LETI and companies like Alice&Bob and STMicroelectronics.

PHELIQS has solid expertise in instrumentation and methods for the synthesis of innovative bulk materials (mainly crystals) and nanostructures (semiconductor nanowires and quantum dots, monolayers of graphene, high-mobility germanium heterostructures, and other two-dimensional materials). The laboratory also has access to advanced cleanroom technology for device fabrication. PHELIQS has developed customized high-performance instrumentation for physical measurements under extreme conditions (low temperature down to 10 mK, large magnetic field, high pressure) or requiring ultra-high sensitivity (optical studies at the single-photon level, scanning tunneling microscopy and spectroscopy, RF manipulation with arbitrary wave generation, and reflectometry readout at the single-shot level). Additionally, PHELIQS draws on its strong theoretical expertise in condensed matter physics (superconductivity, magnetism, strongly correlated electron systems) as well as in quantum and mesoscopic physics, and is at the forefront of the development of new codes for "computer-assisted" theory in quantum condensed matter physics.

This booklet presents 21 distinct Master 2 projects, most of which are thought as a first step towards a PhD project. We hope they will spark your curiosity, and we look forward to welcoming you in our lab!

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For more information, check our website: https://www.pheliqs.fr
and follow PHELIQS News in LinkedIn: https://www.linkedin.com/company/pheliqs

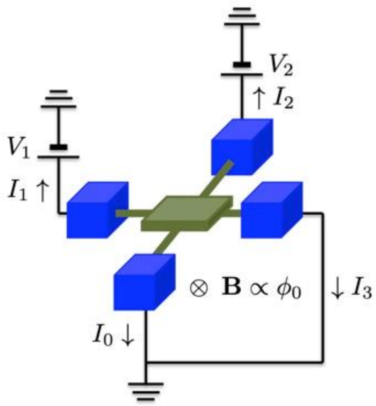
Spring 2027

Master2 internship

Superconducting multiterminal topological qubit

Topological materials attract a lot of attention as they give rise to unusual boundary states that are remarkably robust against local perturbations. This makes them interesting both fundamentally and for potential applications in quantum information. Multiterminal Josephson junctions (MTJJs) have emerged as a versatile platform for emulating topological matter in superconducting hybrid systems [1]. Each superconducting terminal is characterized by its complex order parameter. In particular the phases of these order parameters, which can be tuned with electromagnetic fields, control the formation of localized Andreev bound states at the junction. In an n-terminal junction, there are n-1 independent phase differences. In the resulting n-dimensional phase space, the Andreev bound-state spectrum can develop topological structures, including Weyl points and non-trivial Chern numbers. Multiterminal junctions therefore provide a controllable way to engineer and probe topological phenomena without requiring a complicated bulk material.

In a recent theoretical study, MTJJs have been identified as a pathway towards a qubit that is simultaneously insensitive to charge and flux noises [2]. The goal of the internship is to explore the effect of topological properties of the Andreev spectrum on the robustness of the qubit. The project will be performed mainly by using the analytical tools of condensed matter field theory. Interested candidates should have a good basis in quantum mechanics, statistical physics, and solid-state physics. The internship may be followed by a PhD thesis.



Sketch of a 4-terminal Josephson junctions.
The superconducting phases can be tuned with magnetic fluxes or voltages.

[1] R.-P. Riwar, M. Houzet, J.S. Meyer, and Yu.V. Nazarov, *Multi-terminal Josephson junctions as topological matter*, Nat. Commun. **7**, 11167 (2016)

[2] F.J. Matute-Cañadas, L. Tosi, and A. Levy Yeyati, *Quantum Circuits with Multiterminal Josephson-Andreev Junctions*, PRX Quantum **5**, 020340 (2024)

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contact Julia Meyer (julia.meyer@univ-grenoble-alpes.fr) or Manuel Houzet (manuel.houzet@cea.fr)

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Spring
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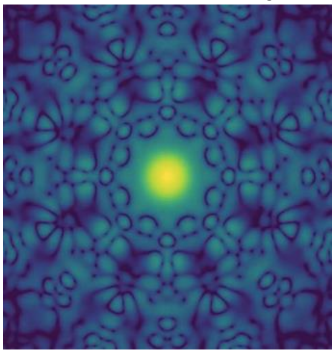
Master2
internship

Quantum algorithms meet Quantum inspired algorithms

Hybrid quantum and quantum inspired algorithms

Quantum computers are, in essence, machines that can instanciate any quantum many-body problem with absolute control: an ideal quantum computer would allow one to prepare a correlated state, evolve it under known dynamics and measure any observable of interest. It is therefore no wonder that one of the key application that has been foreseen for these machines is the simulation of quantum matter or chemistry, i.e. use them as a quantum many-body solver. An emblematic example put forward worldwide is the catalysis of the dissociation of nydrogen performed by the nytrogenase. Progress in the understanding of this problem would have huge societal impact including in energy consumption and nutrition. Yet, the mathematical problem that we need to solve are not directly expressed in a way suitable to a quantum computer and there are in fact very few algorithms that have been proposed for these machines. On the other hand, it is being increasingly understood that a large fraction (but not all) of what those machines could do can be performed classically using the mathematics that have been developped to understand quantum computers and the quantum many-body problem. These mathematics, known generically as quantum inspired algorithms (here we will focus on tensor networks, one of the most important component), are therefore the perfect glue that can transform a mathematical problem into a form suitable to a quantum computer. An introduction to this subject can be found in [1].



Snapshot of a simulation of a non-linear partial differential equation performed with a quantum inspired algorithm. Adapted from [2].

This Master/PhD project lies at the intersection between theoretical quantum many-body physics, quantum information and applied mathematics. The goal will be to develop and apply hybrid algorithms that use tensor networks to construct states that could be created on a quantum computer. A long term application would be to benefit from the capacity of quantum computers to handle dynamics (a difficult target for tensor networks due to the entanglement growth). A short term one will be a better understanding of the frontier where quantum computers can bring a genuine advantage. The practical problem we will focus on is a many-body quantum formulation of the classical Boltzmann equation. Such an equation is rarely considered computationally because it lives in six dimensions and is therefore plagued by the ``curse of dimensionality''. Quantum computers are, however, immune to this problem – this is the very reason they are being developped – and the Boltzmann equation have other advantages over its more popular counterpart used in computational fluid dynamics (Navier-Stokes). We will study how trading non-linearity against an increased dimensionality might be favourable to the quantum approach.

[1] https://scipost.org/10.21468/SciPostPhysLectNotes.133
[2] https://journals.aps.org/prresearch/abstract/10.1103/zwn1-f981

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Spring 2027

Master2 internship

High pressure investigation of 2D Cr_2Te_3

We propose an M2 internship to carry out an exploratory investigation of the use of high pressure on a 2D quantum material. The project is a collaboration between two laboratories within IRIG: SPINTEC, experts in the fabrication of 2D devices, and IMAPEC for low-temperature, high-field measurements under pressure.

Pressure is a very powerful and much used tool to study bulk quantum materials. Applying pressure changes the interatomic distances and the microscopic interactions providing a convenient way to tune the macroscopic physical properties of the material and reach different states, such as unconventional superconductivity or magnetic order.

2D materials are now at the forefront of research in quantum matter. Tuning the properties of these systems is an important aspect. Up to now tuning is done by applying a voltage to a gate, or creating strain through changing growth conditions. Pressure would have large potentiality to study these systems: By continuously modifying interatomic distances and orbital overlap. It could provide a predictive tool for identifying optimal electronic regimes before stabilizing them through growth engineering. However, to date pressure has hardly been used, mainly due to experimental complications.

In this internship we will make a first exploratory study of the use of pressure on the 2D system Cr_2Te_3. This is a ferromagnetic semimetal with a layered structure that exhibits a complex anomalous Hall effect attributed to modifications of the Berry curvature. By modifying the out-of-plane lattice parameter *c* and the interlayer coupling, we expect that pressure could provide a direct means of tuning these anticrossings.

Epitaxial Cr_2Te_3 thin films will be synthesized with controlled stoichiometry and thickness. Hall-bar devices will be prepared by the SPINTEC group before the internship. The target of the internship will be first to characterise these at ambient pressure. Then we will tackle the task to integrate the devices into a piston–cylinder pressure cell compatible with multipoint measurements at low temperature and under magnetic field. Then we will map out the longitudinal and transverse (Hall) resistivities, Rxx and Rxy, versus temperature, field and pressure.

The target will be to identify a possible reversal of the intrinsic Hall signal, corresponding to an inversion of the Berry curvature. More generally this internship will demonstrate the feasibility of such measurements under pressure establish a methodology that can be generalized to other 2D materials for future studies

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Spring
2027

Master2
internship

Topological Superconductivity and Thermal Hall Effect

General Scope: Chiral superconductivity is a topological state breaking time reversal symmetry. Hence, its main signature is the appearance of a "spontaneous" magnetic field when cooling below the superconducting temperature (quite the opposite of the Meissner effect!). Very sensitive microscopic probes like muons spectroscopy can be used to detect this very small field, but often lead to controversial results. More recently, thermal Hall effect has been put forward as a more accessible probe to reveal such a symmetry breaking.

Subject: In Pheliqs, we have very recently performed such thermal Hall effect measurements on the ferromagnetic superconductor UCoGe, which is spin-triplet and chiral, detecting indeed an anomalous signal below the superconducting transition. For the internship, we will perform these measurements for the first time on a crystal of the same system cut by focused ion beam, which should greatly enhance the sensitivity, and open novel perspectives for this technique. Moreover, if it arrives in time, we will install a new noise thermometer allowing to get more reliable measurements between 20 and 50mK.

Environment and collaborations: The team at Pheliqs is very active and well recognized in this field of spin-triplet superconductivity, and is supported by strong interactions with the theory group of the laboratory and tight collaborations with groups in Japan. It also owns a unique facility for growing the required crystals. This thermal Hall and thermal conductivity experiment will also be performed in the future at higher fields on spin triplet superconductors like UTe_2.

Required skills: A strong interest for quantum materials and for challenging (very low temperatures) experiments!

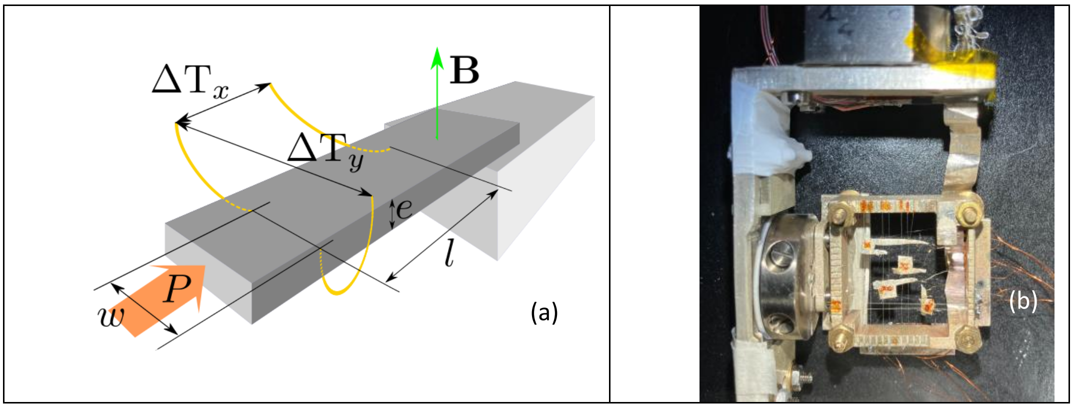

Figure: (a) Scheme of the thermal Hall effect experimental set-up.
(b) Real set-up, mounted on a piezo rotator and goniometers.

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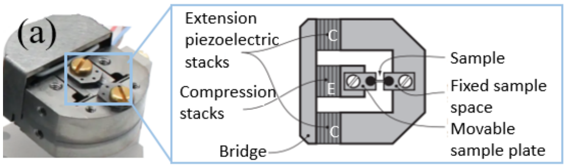
Spring 2027

Master2 internship

Tuning quantum materials by uniaxial stress

General Scope: Quantum materials are a class of systems whose electronic or magnetic properties are governed by quantum effects, manifesting up to the macroscopic scale, not just at the atomic level. Prominent examples are superconductivity, magnetic spin liquids, or materials where topological properties of the band structure trigger the emergence of novel ground states. In this project we want to use a uniaxial stress as tuning parameter to change purposely, interactions in such materials. Uniaxial stress is a very

Subject: In this master thesis project, we will probe quantum materials with uniaxial strain measurements. We will use a commercial uniaxial strain device (Razorbill CS 100) that allows in-situ tensile and compressive strain tuning. It will be installed on a standard Quantum Design PPMS, which allows measurements at temperatures down to 1.8 K and magnetic fields up to 9 T. The newly developed probe will be set up for electrical magneto-transport and hall measurements. To perform stress measurements, a major task is to prepare well-polished thin bar shaped crystals of appropriate dimensions (the typical sample dimensions are 2mm x 0.2mm x 0.1mm), and to fix the sample on the device. First test measurements will be performed on cerium-based heavy fermion superconductors or antiferromagnets ($CeCoIn_5$ and $CeRhIn_5$) where large single crystals are available in the lab. In a future step we want to use this technique to study uranium-based spin triplet superconductors.



Environment and collaborations: At the IMAPEC team of Pheliqs in CEA, we study different quantum materials under extreme conditions: low temperature, high magnetic fields and high hydrostatic pressure. Research on topological superconductivity in strongly correlated uranium compounds is the central research activity of our team with recently a strong focus on UTe_2, which is a spin-triplet superconductor with multiple superconducting phases. IMAPEC has strong interactions with the high magnetic field laboratory LNCMI Grenoble, and this novel technique of uniaxial stress will open new perspectives for high-field measurements in future.

The candidate will further profit from strong theoretical support from the theory group of Pheliqs, and have the possibility to interact with groups in Japan where tight collaborations are well established.

Required skills: The candidate should have sound knowledge in solid state physics, good practical skills and strong interest in the development of instrumentation. The subject can be continued by a PhD thesis.

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Master2
internship

Topological magnetic phases in quantum materials

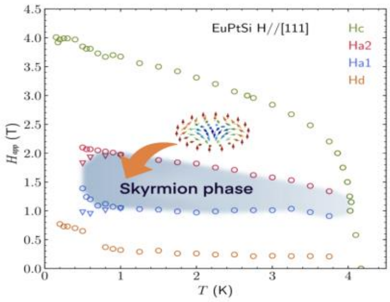

FIG. 1: Phase diagram of the chiral antiferromagnet EuPtSi exhibiting a skyrmion phase at low temperature, inside an antiferromagnetic phase.

General Scope: Topological spin textures are a source of unusual physical phenomena owing to the interplay between magnetism and topology. A most prominent example is the magnetic skyrmion (see inset Fig. 1), a nanosized noncollinear spin structure with particle-like topological states which can move with a low depinning current density, enabling to develop novel spintronics. Hence, magnetic skyrmions are regarded as small and energy-efficient information cells having the potential to develop high-density, low-power, and multi-functional devices for memory and logic applications. This drives a line of research concentrating on controllable and efficient ways to create, delete, manipulate, and excite magnetic skyrmions. One approach to manipulate spin textures is to use temperature gradients.

Subject: We propose an experimental and fundamental research project which will explore different types of magnetic materials (EuPtSi, $GdRu_2Si_2$, Gd_2PdSi_3, MnP, CrAs) with exotic magnetic states (skyrmion and helimagnet states). The goal is to use mainly thermoelectric effects under extreme conditions (low temperature, high magnetic field and high pressure), to characterize these exotic spin textures, understand the different competing orders present in these magnetic materials and ultimately displace these spin texture with the application of a thermal gradient. We have recently revealed a metastable behavior of the skyrmion phase in the cubic chiral antiferromagnet EuPtSi, see Fig.1, underlying the complexity of the stability of the skyrmion phase.

Experimental environment: The candidate will benefit from a unique scientific environment: a dedicated dilution refrigerator (50mK-16T), a large range of experimental probes (resistivity, Hall effect, specific heat, thermal conductivity and thermoelectric effects…), the possibility to grow and characterize his own material in the laboratory, a strong interplay with local theoreticians.

Possible collaboration and networking: The internship proposal is based on a long-term collaboration with the high magnetic field facility (LNCMI) in Grenoble and with close collaborators in Japan.

Required skills: Master or Engineering degree. Skills on solid state physics or nanophysics will be appreciated. Motivation for experimental studies is needed.

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Spring 2027

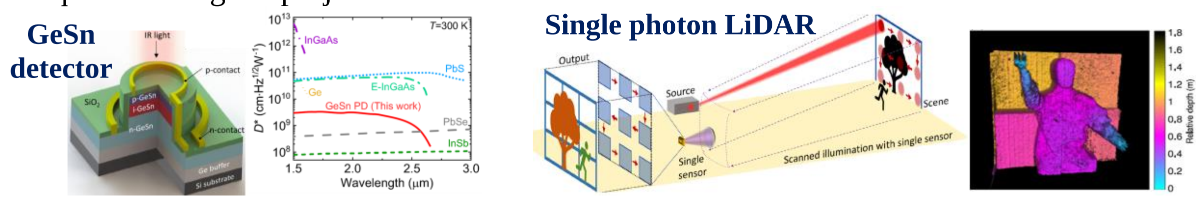
Master2 internship

Infrared imaging down to the single photon level

Direct band gap GeSn semiconductors enabled the monolithic integration of infrared light emitters and detectors on a Si photonics chip.[1] Over the past decade, GeSn photodetectors, lasers, and LEDs operating from short-wave infrared (SWIR: 1.5-3 µm) to mid-wave infrared (MWIR: 3-8 µm) have been demonstrated,[2-4] and their use in practical technological applications at room temperature is now being explored. Developing GeSn classical and quantum photonics devices and their mass-scale integration in quantum sensing, industrial inspection, safety and security, environmental imaging, and automotive applications will be the primary technology roadmap for GeSn over the next decade.

The goal of this internship is to integrate the SWIR/MWIR GeSn photodetectors developed at PHELIQS[4] into imaging and quantum sensing technologies. The envisioned application is the detection of infrared single photons and the demonstration of a benchtop LiDAR system.[5] To this end, the single pixel GeSn detector is mounted on a remote-controlled X-Y stage to scan the scene and thus acquire the infrared image of an object. The student will design the electronic interface between the GeSn photodetector and the computer to acquire the 2D intensity map of the photocurrent signal and explore the data collection down to the single photon level. Post-processing image optimization using machine learning algorithm will be developed to improve image quality and combine multispectral datasets (*e.g.*, 2-3-4 µm sub-bands) into a single, enhanced hyperspectral image.

The student will have access to the optoelectronic lab at PHELIQS/SINAPS that is equipped with multiple FTIR setups for infrared absorption, photoluminescence, photocurrent, and imaging. With the support of a lab technician, the student could also utilize to the 3D printing and machining lab for the fabrication of custom plastic/metallic components that may be required during the project.



References (available on demand):
[1] O. Moutanabbir *et al.*, Applied Physics Letters 118, 110502 (2021). [2] M.R.M. Atalla *et al.*, ACS Photonics 11 (2024). [3] M.-H. Chou *et al.*, Advanced Photonics Research 2400155 (2024). [4]. T. Willoquet *et al.*, ACS Photonics 12 (2026). [5] R. Hadfield *et al.*, Optica 10 (2019).

Possible collaborations and networking. CEA-Leti, Polytechnique Montréal (Canada).
Possible extension as a PhD. Yes.
Required skills. Performing collaborative experiments, background in solid-state physics, optics, and electronics, Python programming language.
Starting date. Winter 2026/Spring 2027. **Supervisor.** Simone Assali (PHELIQS/SINAPS).

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Master2 internship

A source of indistinguishable single photons in silicon

Applications of quantum photonics to quantum simulation and computing require a scalable, compact and low-cost technology for future widespread deployment. The silicon-on-insulator (SOI) platform is a highly attractive in this context, offering the possibility to implement a large panel of integrated devices for the coherent manipulation, encoding and detection of single photons. However, sources being able to deliver on demand indistinguishable single photons in silicon are not yet available. This lack increases the complexity of quantum photonic chips and limits both their performances and their potential for scalability.

In this context, PHELIQS researchers and their partners have recently unveiled the interest of point defects acting as color centers in silicon [1]. Photon antibunching, i.e. the ability to emit photons one by one, has been demonstrated for a broad variety of implantation defects, and noticeably for the W center (obtained through implantation of Si ions). PHELIQS has also played a pioneering role for the integration of color centers in optical cavities, that are used to enhance the emission of the color centers thanks to the Purcell effect [2]. Very recently, we have presented a bright and pure source of single photons, obtained by positioning a single W center at the core of an optical cavity [3]. However, the coherence of the single photons and their indistinguishability remain to be demonstrated.

During his project, the student will perform microphotoluminescence (µPL) experiments on single W centers in optical cavities. He will evaluate the magnitude of the Purcell effect from time-resolved PL, and will estimate the brightness and purity of these single photon sources. The best performing sources will be selected in view of realizing a Hong-Ou-Mandel (HOM) photon coalescence experiment, and measure the degree of indistinguishability of the emitted photons.

The project could be extended, in the framework of a PhD, into the development of waveguide-coupled sources of indistinguishable single photons, using a novel geometry for the optical cavity. In the mid-term, we target the cointegration of such sources and single-photon detectors, to perform fully-integrated quantum optics experiments on a SOI photonic chip.

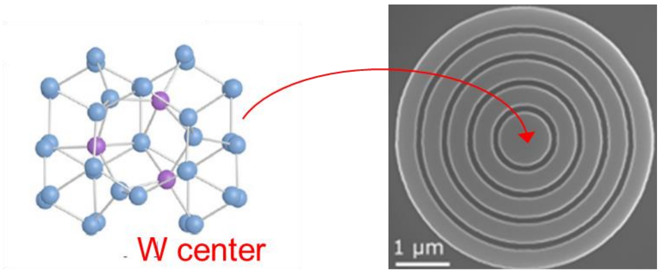

Fig: View of the cavity, formed by a circular Bragg grating, that is used to tailor the emission of a single W center, placed at its core.

References

[1] W. Redjem et al, Nature Electron. 3, 738 (2020), A. Durand et al, Phys. Rev. Lett. 126, 083602 (2021)

[2] B. Lefaucher et al, ACS Photonics 11, 24 (2024)

[3] B. Lefaucher et al, to appear in Nature Commun. (2026)

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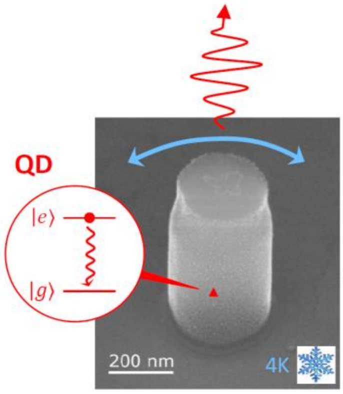
Master2 internship

Single-photon emission from a quantum dot embedded in a vibrating nanopost



Background. This M2 research project lies at the crossroads of quantum optics and nanomechanics, using a semiconductor device. It focuses on a quantum dot (QD) integrated into a nanopost. A QD is a nanostructure that behaves as an artificial atom with remarkable optical properties. In particular, it is an excellent single-photon emitter. The nanopost is a photonic structure that enhances the QD emission and shapes it into a directive output beam. It also supports high-frequency mechanical resonances (first flexural mode around 500 MHz).

Project. The goal of this M2 project is to explore how the mechanical vibration of the nanopost — driven by thermal fluctuations at 4 K — affects the spectral coherence of the emitted photons. Specifically, we will measure the mutual coherence of photons separated by a variable delay in a Hong–Ou–Mandel (HOM) setup. On the optical side, the experiment will provide valuable insight for improving photon indistinguishability, a crucial metric for future quantum applications. On the mechanical side, HOM measurements offer an original route to characterizing high-frequency mechanical modes.

Host team and experimental means. You will join a lively team bringing together researchers from CEA-Pheliqs and CNRS-Néel. The device is already fabricated, and the host team operates a state-of-the-art cryogenic micro-photoluminescence setup for quantum-optics correlation measurements.

Applicant profile. This project sits at the crossroads of semiconductor physics, quantum optics and nanomechanics. We are looking for a highly motivated candidate with a strong taste for experimental work (optical measurements).

This M2 internship can be extended into a PhD thesis, with funding already secured (Marie Curie PhD grant). Eligibility criterion: at the PhD start date, the candidate must have spent less than 12 months in France over the last 3 years.

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Spring 2027

Master2 internship

Analysis of InAs/GaAs nanowire heterostructures growing inside a transmission electron microscope

Context: Understanding how the interface forms between two materials with very different lattice parameters (InAs/GaAs, ~7% mismatch) remains a key open question in axial nanowire heterostructures [1,2]. This is directly relevant to single-photon emitters based on InAs/GaAs quantum dots, where the compositional abruptness and structural quality of the interface strongly affect the optical properties of the resulting quantum dot. High-resolution video data acquired on an environmental transmission electron microscope capture the growth of gold-catalyzed InAs/GaAs nanowires in real time, offering a way to directly observe how the catalyst droplet and growth front behave during the material switch. The internship will take place in the NPSC team at Institut Néel and IRIG/Pheliqs, and the analysis work will be complemented by participation in molecular beam epitaxy growth campaigns of InAs quantum dot/GaAs nanowires, carried out by the NPSC team.

Objectives: The student will analyse growth movies frame by frame, tracking the gold droplet and the nanowire dimensions. These quantities will be used to understand the growth dynamics and how the interface forms without forming dislocations despite the lattice mismatch between the two materials.

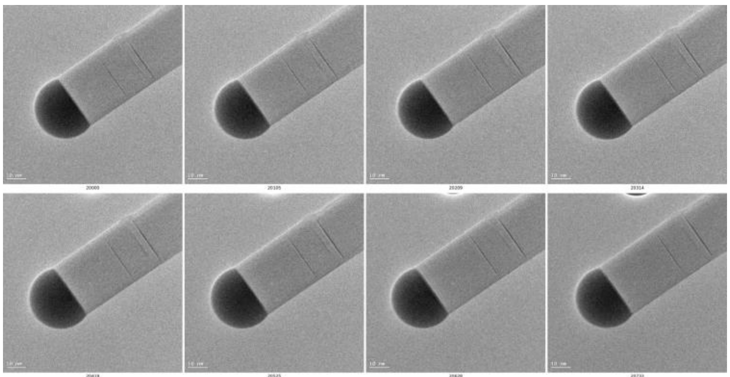

Figure: Sequence of TEM frames extracted from an in situ growth movie, showing the elongation of an InAs segment on top of a GaAs nanowire.

Refs: [1] Beznasyuk, D.V. *et al.* (2020). Full characterization and modeling of graded interfaces in a high lattice-mismatch axial nanowire heterostructure. *Physical Review Materials*.

[2] Beznasyuk, D.V. *et al.* (2017). Dislocation - free axial InAs-on-GaAs nanowires on silicon. *Nanotechnology*.

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Master2 internship

From InN Nanowires on Silicon to SWIR Photodetectors

Context: Short-wave infrared (SWIR) imaging is an emerging technology that can reveal information invisible to conventional cameras, enabling applications such as night and low-light vision, food and material inspection, chemical identification and spectroscopy, environmental sensing, and semiconductor quality control. Current SWIR photodetectors are mainly based on III–V compounds such as InGaAs, which offer excellent performance but are difficult and costly to integrate monolithically with silicon. Indium nitride (InN) nanowires offer an exciting alternative. InN combines a narrow direct bandgap with a very high optical absorption coefficient in the SWIR range. Moreover, its relatively low growth temperature and the ability of nanowires to accommodate large lattice mismatch make InN particularly attractive for direct integration on silicon.

At PHELIQS, we have recently demonstrated the catalyst-free growth of vertically aligned InN nanowires by molecular beam epitaxy (MBE) on technologically relevant Si⟨100⟩ substrates, with good morphological homogeneity and reduced tapering. Our work now focuses on improving their electrical properties and developing the first photodetector prototypes.

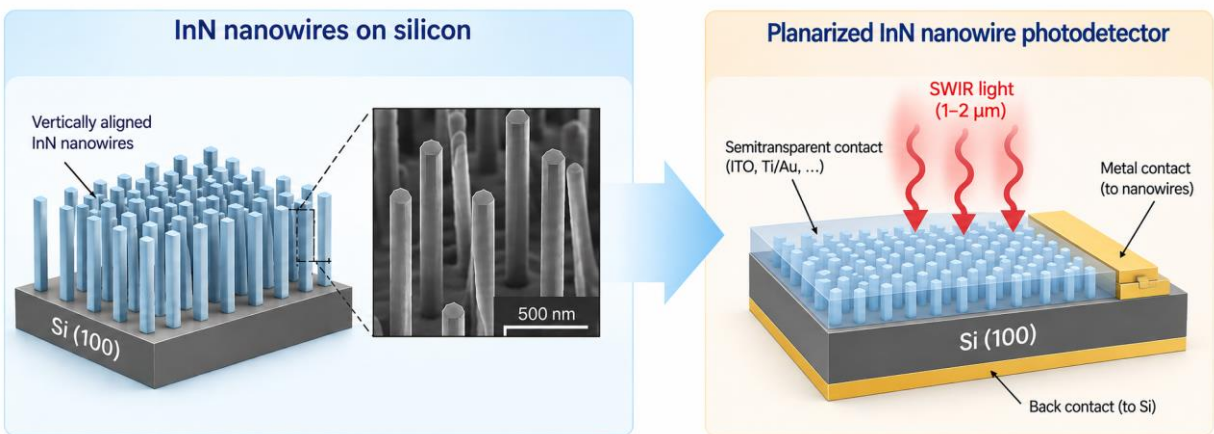
Targets and strategy: The objective of this internship is to investigate the optical and electronic properties of InN nanowires and identify the key parameters controlling their performance in SWIR photodetectors. In collaboration with a PhD student, the master intern will participate in various steps of the development, from nanowire growth to device characterization. InN nanowires will be synthesized by MBE and characterized using scanning electron microscopy (SEM), infrared spectroscopy (FTIR) and cathodoluminescence (CL). Particular attention will be paid to the influence of surface states and surface passivation on carrier transport and optical response. The project will also explore nanowire integration into silicon-based photodetector architectures, followed by electrical and optoelectronic characterization of the resulting devices.

The internship offers hands-on experience at the interface between semiconductor physics, nanotechnology and infrared optoelectronics, combining state-of-the-art epitaxy, spectroscopy and device characterization.

Required skills: Motivated Master student in physics, materials science, nanoscience or semiconductor engineering, with an interest in semiconductor physics and optoelectronics, a strong taste for experimental work, and willingness to use complementary experimental techniques.

Starting date: Jan/Feb/Mar 2027

Supervisor: Eva Monroy



To apply for this position, contact Eva MONROY (eva.monroy@cea.fr)

French Commission for Atomic Energy and Alternative Energies
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Spring
2027

Master2
internship

Ultra-Wide-Bandgap Oxides for Solar-Blind UV Photodetectors

Context: Solar-blind ultraviolet (UV) photodetectors allow the detection of weak UV radiation to be identified without interference from the solar background. This is particularly attractive for applications such as flame and electrical-discharge detection, plasma diagnostics, space observation and instrumentation in radiation-intensive environments. Ultra-wide-bandgap oxide semiconductors offer exciting opportunities for a new generation of UV detectors. In particular, Ga_2O_3 has a bandgap of about 4.6-4.9 eV, naturally providing sensitivity in the solar-blind spectral region. Alloying Ga_2O_3 with Al to form $(Al,Ga)_2O_3$ (AlGaO) further increases the bandgap, potentially allowing the detection cutoff to be tuned from approximately 260 nm down to 200 nm.

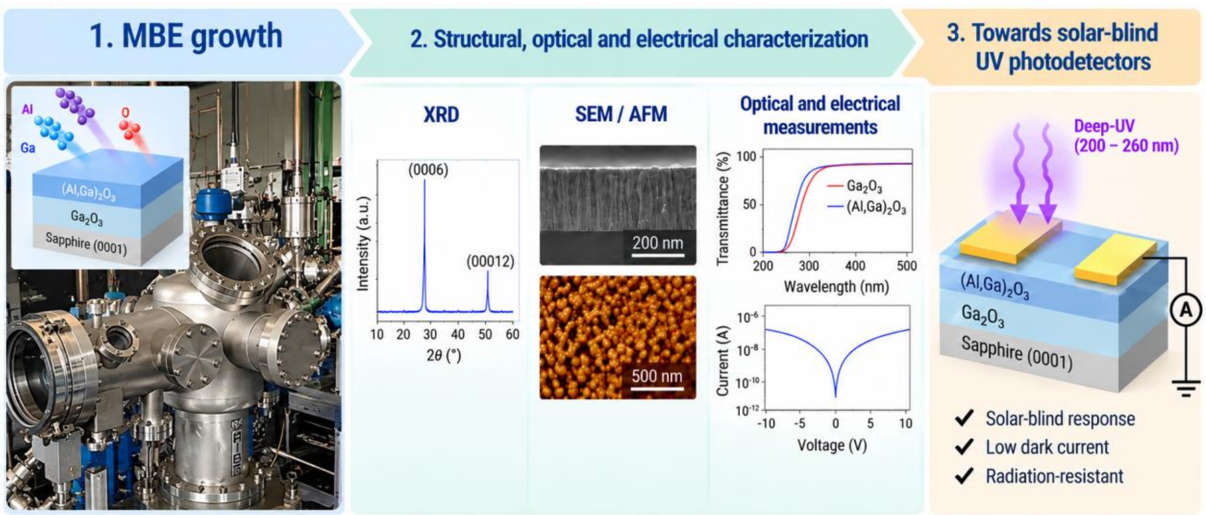
At PHELIQS, we have developed the molecular beam epitaxy (MBE) of Ga_2O_3 and want now to extend this expertise towards AlGaO. MBE provides precise control of composition, doping and interfaces, making it particularly powerful for understanding how the material properties determine the optical and electronic behavior of these emerging materials.

Targets and strategy: The objective of this internship is to develop the MBE growth of Ga_2O_3 and $(Al,Ga)_2O_3$ thin films and establish the relationships between growth conditions, composition, crystalline quality and optical and electrical properties. N-type doping using Si or Ge may also be explored. The grown layers will be investigated using complementary structural and morphological characterization techniques, including X-ray diffraction (XRD), scanning electron microscopy (SEM), and atomic force microscopy (AFM). Their optical and electrical properties will be assessed through optical transmittance and resistivity measurements. Electrical contacts will then be deposited to fabricate and test the first photodetector prototypes. The results will lay the basis for the subsequent development of solar-blind UV photodetectors within the framework of a national research program.

Required skills: Motivated Master student in physics, materials science, nanoscience or semiconductor engineering, with an interest in semiconductor materials and solid-state physics, a strong taste for experimental work, and willingness to work with complementary growth and characterization techniques.

Starting date: Jan/Feb/Mar 2027

Supervisors: Anna Sacchi and Eva Monroy



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Spring 2027

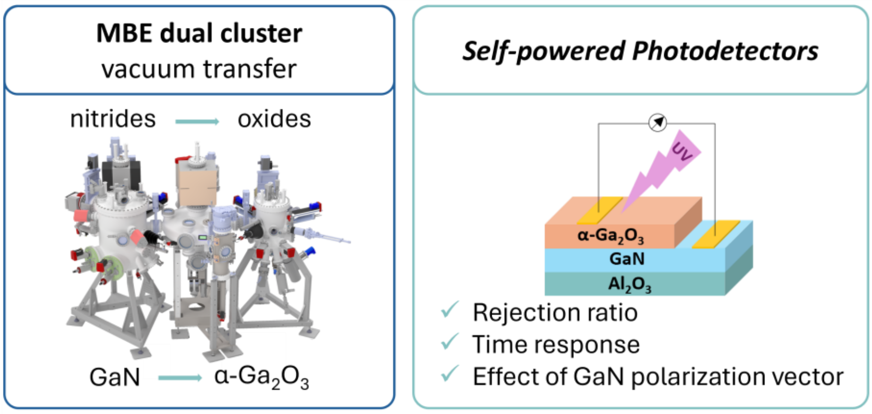
Master2 internship

MBE growth of α-Ga_2O_3/GaN heterostructures for self-powered UV photodetectors

Context: UV photodetectors based on wide- and ultra-wide-bandgap semiconductors are attractive for solar-blind detection, flame sensing and secure optical. Self-powered Ga_2O_3/GaN heterojunctions combine *n*-type Ga_2O_3 with *p*-type GaN to generate an internal field that separates photocarriers at zero bias. Among Ga_2O_3 polymorphs, corundum α-Ga_2O_3 is particularly appealing because it is structurally compatible with both sapphire and GaN, enabling an integrated oxide/nitride stack. However, α-Ga_2O_3 transforms irreversibly to β-Ga_2O_3 above ~600–650 °C, making conventional sequential growth challenging. GaN polarity provides an additional means to control the junction. On sapphire, Ga-polar or N-polar GaN can be obtained through different nucleation strategies. Since GaN polarization determines the sign of interface charge, it can modify band alignment, band bending and the built-in field in Ga_2O_3/GaN heterojunctions. Yet, the effect of GaN polarity has not been experimentally explored in Ga_2O_3/GaN photodetectors.
Targets and strategy: The objective of this internship is to grow α-Ga_2O_3/GaN heterostructures on c-plane sapphire using a dual-chamber nitride/oxide MBE system, and to determine how GaN polarity affects the electrical and optoelectronic properties of self-powered UV photodetectors. Since GaN growth (~700–800 °C) exceeds the α-to-β Ga_2O_3 transition temperature, GaN will be grown first, followed by α-Ga_2O_3 at a lower temperature, with vacuum transfer between chambers to preserve the interface. The student will (i) develop Ga- and N-polar GaN growth on nominally on-axis c-plane sapphire; (ii) grow α-Ga_2O_3 on each GaN polarity while optimizing the α-phase growth window and monitoring interfacial chemistry by XPS; and (iii) fabricate and compare Ga- and N-polar α- Ga_2O_3/GaN photodetectors in terms of rejection ratio, responsivity and time-rsponse, testing whether polarization-dependent band alignment produces a measurable device effect. Depending on the progress, the project may be extended to other sapphire orientations to suppress GaN polarization and address the fundamental question of how crystal polarity influences photodetector performance.
Required skills: Motivated master student in physics, materials science, nanoscience or semiconductor engineering, with an interest in materials engineering, a strong taste for experimental work, and willingness to combine thin-film growth with materials and device characterization.

Starting date: Jan/Feb/Mar 2027

Supervisor: Anna Sacchi



To apply for this position, contact Eva MONROY (eva.monroy@cea.fr)

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Spring 2027

Master2 internship

MBE growth of *p*-type spinel gallate for improved Ga_2O_3 *pn* heterojunctions

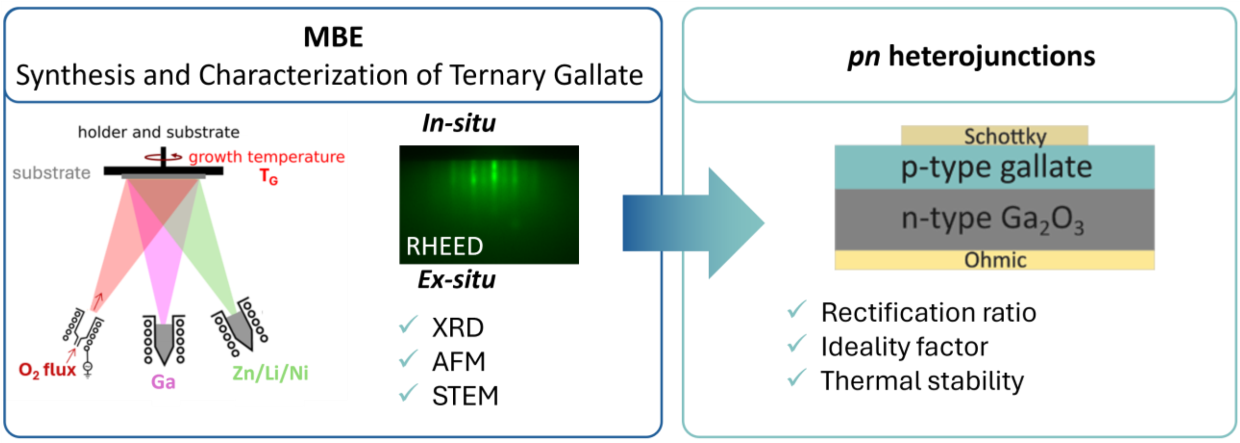
Context: Ga_2O_3 is an ultra-wide-bandgap semiconductor (bandgap ≈ 4.8–4.9 eV) with an exceptionally high critical electric field, making it promising for next-generation power electronics, solar-blind UV photodetectors and harsh-environment devices. A major limitation is the lack of *p*-type conductivity in this material system, making it necessary to design bipolar devices based on heterojunctions. NiO/Ga_2O_3 is the most mature example, but recent studies revealed spontaneous formation of a thin $NiGa_2O_4$ spinel interlayer, particularly at elevated temperatures, which significantly affects device performance. However, intentional $NiGa_2O_4$ interlayers enabled more reliable *pn* heterojunctions. More recently, other spinel gallates have emerged as *p*-type ultra-wide-bandgap oxides: $ZnGa_2O_4$ exhibits self-doped *p*-type conductivity with a bandgap above 4.4 eV, while defect-spinel $LiGa_2O_4$ has been demonstrated as a robust, dopable *p*-type semiconductor. To date, these spinel/Ga_2O_3 heterostructures have been fabricated by PLD, sputtering or chemical-vapor methods. Molecular beam epitaxy (MBE), offering precise control of stoichiometry, cation ordering and interface abruptness, can improve epilayers quality so then devices performances.

Targets and strategy: The objective of this internship is to develop, by MBE, *p*-type spinel-gallate epilayers on Ga_2O_3 and to evaluate their impact on the electrical performance of Ga_2O_3-based *pn* heterojunctions. The student will (i) grow spinel gallate thin films by oxide MBE on Ga_2O_3 substrates/epilayers, exploring growth window stability according to cation flux ratio, temperature, oxygen flow; (ii) assess structural and morphological quality by RHEED, XRD and AFM/SEM; (iii) fabricate stacked heterojunction diodes and characterize their rectification behavior, turn-on voltage and, where possible, breakdown voltage and thermal stability, benchmarking them against the published PLD-grown references. Depending on progress, the project may extend to the influence of substrate orientation and post-growth annealing on interlayer properties.

Required skills: Motivated master student in physics, materials science, nanoscience or semiconductor engineering, with an interest in material synthesis and power electronics, a strong taste for experimental work, and willingness to combine thin-film growth with materials and device characterization.

Starting date: Jan/Feb/Mar 2027

Supervisor: Anna Sacchi



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Spring
2027

Master2
internship

Thermal readout of a transmon qubit

Superconducting qubits are among the most advanced platform for quantum computation nowadays. To read out the state of the qubit, low-power microwave signals have to be amplified at ultra-low temperature, a task currently performed with Josephson parametric amplifiers. An alternative route has however recently been demonstrated, using a microwave bolometer [1].
In a bolometer, a small absorber heats up under photon absorption. Monitoring the absorber temperature in real time was shown to allow measuring extremely small microwave powers, offering an appealing alternative to parametric amplifiers, with the potential to overcome the current limitation of these. We developed in the team a novel type of microwave bolometers, based on a two-dimensional hole gas in a germanium heterostructure, offering high sensitivity owing to its very small specific heat and fast thermal response [2].
In this thesis, we propose to benchmark these novel micro-bolometers to read the state of a transmon qubit [3]. The candidate will adapt an existing dilution refrigerator, including shielding design and proper microwave filtering, for state-of-the-art transmon readout using a conventional readout. In the next step, the candidate will replace the standard amplification measurement setup by a germanium bolometer, and benchmark the performances obtained with this thermal readout.

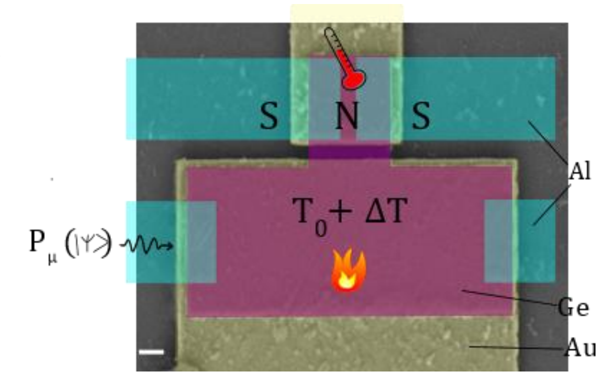

Fig.: False-color scanning electron micrograph (SEM) image of a germanium bolometer. An absorber (bottom part) heats up under an incident microwave radiation whose power depends on the transmon state. A Josephson junction (top part) allows to measure the temperature of the absorber and deduce the qubit state.

References:
[1] Gunyho *et al.*, *Nature electronics* (2024)
[2] Werner *et al.*, in preparation (2026)
[3] Blais *et al.*, Rev. Mod. Phys. (2020)

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Spring 2027

Master2 internship

Correlated physics in artificial 2D moiré systems

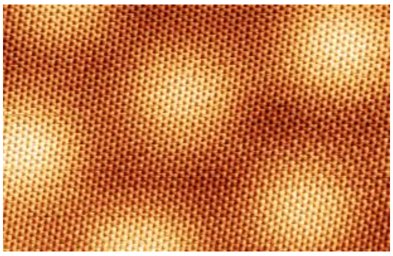

Fig1: Atomically resolved image of a moiré from twisted bilayers of graphene. The large periodicity is the moiré and the small one is the atomic lattice

When two van der Waals crystals are placed on top of each other, lattice mismatch, twist and strain lead to the formation of a moiré pattern (see Fig: 1). This moiré strongly affects the electronic properties of the layers and in particular flattens the bands, quenching the Fermi velocity so that Coulomb energy dominates the system. Carefully designed moiré systems are therefore arising as an incredibly promising platform to investigate correlated phases: In a single device, one can measure for example superconductivity, correlated insulating phases (Mott, Wigner, Chern), strange metal, anomalous Hall effects. This has been shown in twisted graphene layers but also in other 2D systems, such as transition metal dichalcogenides. [1,2]

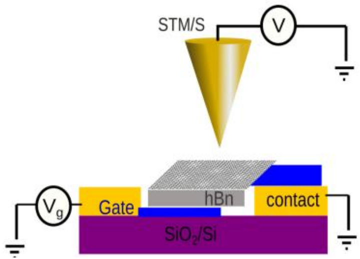

Fig2: sketch of the STM/S setup. Quantum tunneling current is measured between the tip and the sample. The gate (blue) is separated by a thin hBn layer (grey), allowing to tune the doping of the system in-situ.

The goal of this project is to access and investigate the correlated phases in moiré systems by scanning tunneling microscopy (STM), for example in twisted bilayers of graphene, and using a backgate to dope the system into the strongly correlated regime. With this technique, we will focus on measuring the superconducting properties with scanning tunneling spectroscopy (STS), and measure the spatial distribution of electronic density down to atomic resolution, in order to elucidate the fundamental properties of these states.

This work involves fabricating STM-compatible devices in our facilities, measuring these samples using a milliKelvin setup and analysing the data. It is part of the team's effort to measure carefully designed stacks that are well suited for STM with the perspective of measuring these systems using new techniques : either using quasiparticles intereferences around defects or by Josephson spectroscopy.

We are looking for a motivated candidate with interest in experimental physics and a strong background in condensed matter physics who will be involved in all aspects of the research from the fabrication of samples to their measurements with state-of-the-art equipment.

[1] BA Bernevig et al. Physics Today 77 (4), 38 (2024)

[2] Xia, Y., Han, Z., Watanabe, K. et al. Nature 637, 833–838 (2025)

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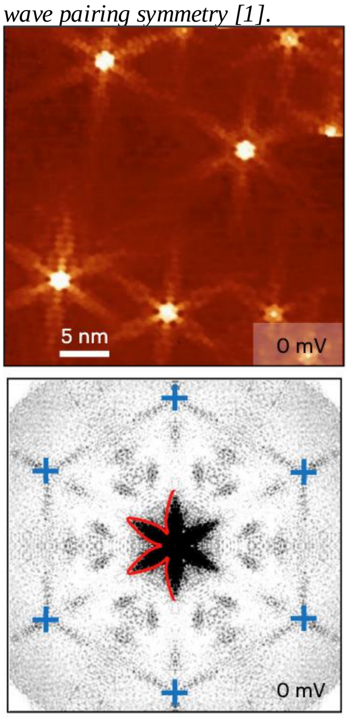
Spring 2027

Master2 internship

Exploring unconventional superconductivity by scanning tunneling microscopy

Figure 1: (top) STM image revealing quasiparticle interferences near surface defects in monolayer Sn on doped Si. (bottom) Fourier transform of the image. The central flower-like feature is related to super-conductivity and points to a chiral d-wave pairing symmetry [1].



Superconductivity is among the most fascinating manifestations of many-body quantum physics in condensed matter. Conventional superconductivity is well understood and integrated into modern quantum technologies. Unconventional superconductivity conversely manifests as an anisotropic gap function $\Delta(\mathbf{k})$ in reciprocal space, which can have for instance the spherical harmonic *p*-, or *d*- or more complicated wave symmetries and triplet spin states of the Cooper pairs. Measuring and understanding unconventional superconducting states can be a highly non-trivial task. In this context, the interference between electronic surface waves and their reflections by a defect, known as quasi-particle interferences (QPI), provides useful information.

QPIs can be measured by scanning tunneling micro-scopy/spectroscopy (STM) (Fig. 1). Their Fourier analysis can reveal the precise symmetries of the superconducting state [1] and even topological properties [2]. A complementary technique to go beyond standard tunneling spectroscopies involves measuring the Josephson supercurrent between a superconducting tip and the sample under investigation [3], which probes directly the superconducting condensate.

This experimental research project aims at applying these techniques to several candidate non-conventional superconductors, such single-layer $NbSe_2$, the Kagomé superconductors AV_3Sb_5 (with A=Cs, Rb, K), and the superconducting surface state of the Weyl semi-metal γ-$PtBi_2$, to elucidate the nature of their superconducting state. The experiment involves molecular-beam epitaxy (MBE) growth on the *Spintech 2D cluster*, and bases on a unique STM facility at PHELIQS, operating in ultra-high vacuum, magnetic field and 50 mK temperature.

We are looking for a motivated candidate with a strong background in condensed matter physics, interested in superconductivity and low-temperature scanning tunneling microscopy.

[1] F. Ming *et al.*, Nat. Phys. **19**, 500 (2023). [2] C. Dutreix *et al.*, Nature **574**, 219 (2019). [3] M. Trahms *et al.*, Nature **615**, 628 (2023).

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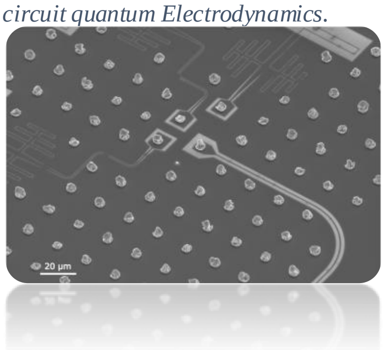
Research Training 2026/2024 + Spring 2027 Master2 internship

Multi-photon sideband transitions in hybrid spin circuit quantum electrodynamics devices

High-quality microwave circuit for spin circuit quantum Electrodynamics.



Light-matter interaction in the form of cavity or circuit quantum electrodynamics (cQED) enable precise control and manipulation of quantum states for spectroscopy, entanglement and quantum measurement. Among others, sideband transitions are playing a key role as they can be leverage for entanglement, quantum state initialization, quantum cooling and the preparation of non-classical states of light.

Here we propose an experimental Research Training (RT) + M2 Internship to explore multi-photon sideband transitions in a special cQED environment consisting in a single spin strongly coupled to microwave photons developed in our laboratory. The exploration of such spin cQED device requires a highly noise-filtered cryogenic environment at T=10mK. The RT+M2 project is envision with two phases.

During the Research Training you will contribute to the improvement of the experimental setup by developing a dedicated highly filtered sample holder for spin cQED. The research work will consist first in understanding the complex physics behind spin cQED and its coupling to noise sources (low frequency noise, microwave radiation, infrared radiation, magnetic noise…). This will allow you to devise the best filtering strategies to be implemented. Then you will design and simulate the filtered sample holder based on PCBs, copper enclosure and more… this task will allow you to strongly interact with our cryo-engineer and our mechanical workshop.

During the M2 internship you will install the developed sample holder in our cryogenic setup to perform quantum measurement on a spin cQED device already available. You will learn how to perform microwave spectroscopy, real-time spin quantum control to characterize the noises acting on the spin and the microwave circuit. Eventually, you will characterize blue and red multi-photon sideband transitions in the quiet environment you will have developed. This will allow a quantitative comparison to theory which will be developed in parallel by our collaborators in Madrid. The research project may continue as a PhD to leverage multi-photon transition for spin cooling and spin-spin entanglement.

[1] Nature Nanotechnology, 18, 741, **2023**
[2] Nature Physics, 22, 917, **2026**
[3] Rev. Mod. Phys. 93, 025005, **2021**

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Spring 2027

Master2 internship

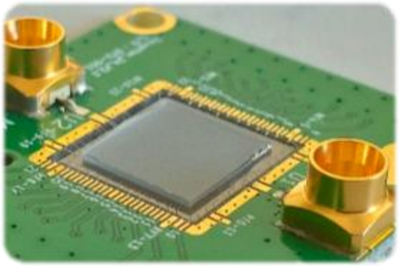
Defect-free germanium materials for spin qubits and spin-cQED experiments

Semiconductor spin qubits are a promising platform for quantum computing and simulation [1]. Nowadays, strained silicon- and germanium-based quantum well heterostructures have enabled the most advanced gate-defined spin-qubit quantum processors with arrays containing up to 56 quantum dots. However, strained quantum wells are deposited on defective metamorphic SiGe substrates, which negatively impact spin qubit performance and scaling through wafer inhomogeneities, dislocations and dielectric losses.

To overcome this inherent challenge, we propose to explore a novel platform for spin qubits, consisting in a heterojunction between unstrained Ge and a coherently strained SiGe barrier, all lattice matched to a Ge substrate. The buried unstrained germanium spin qubit platform, recently proposed experimentally by collaborators in Delft [2] and by in-house theorists [3] is perfectly suited for coherent spin-photon interfaces that form the basis of spin-cQED experiments.

During the M2 internship you will contribute to the design and nano-fabrication of quantum dot structures and superconducting microwave resonators that will be combined in a flip-chip process to form a hybrid 3D-architecture [4]. You will learn how to perform microwave spectroscopy and real-time spin control at cryogenic temperatures to characterize the properties of the hole spins in unstrained germanium, a completely unexplored material system for the moment. This will allow a quantitative comparison to theory developed by collaborators in-house. The research project may continue as a PhD to leverage unstrained germanium as a new and versatile material platform for spin-cQED experiments (e.g. spin-spin entanglement through microwave photons, rapid single-shot spin readout).

Homemade PCB with a flip-chip sample bonded in its center for microwave measurements at cryogenic temperatures.



[1] Rev. Mod. Phys. 95, 025003, **2023**

[2] Advanced Science, 13, 40, **2026**

[3] npj Quantum Information, 11, 167, **2025**

[4] arXiv: 2604.25871, **2026**

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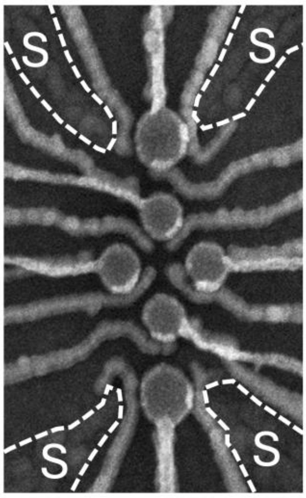
Spring 2027

Master2 internship

Hybrid Quantum Dots

Strained Ge/SiGe heterostructures have become an outstanding platform for hole spin qubits, combining strong, electrically tunable spin-orbit coupling with low disorder and long coherence times, and record single- and two-qubit gate fidelities.

A particularly exciting direction is to couple Ge/SiGe quantum dots to superconducting electrodes to build hybrid devices. Such hybridization can enable novel ans so-far barely explored functionalities, such as mediating long-range qubit coupling between distant spin qubits via crossed Andreev reflection, or enabling new fast readout schemes. Strongly coupled dot-superconductor systems can also host Andreev spin qubits or novel types of gate-tunable superconducting qubits, which combine the fast electrical control and protection from eenvironmental noise. Our group is well positioned and strongly motivated to explore these opportunities in the coming years.



Example of multi quantum dot device with Al-based superconducting (S) contacts. This device was fabricated by PhD student O. Gallego-Lacey.

In this M2 project, lying at the intersection between quantum information processing and mesoscopic/superconducting physics, the student will focus on electrical characterization of existing hybrid quantum-dot devices. While no new fabrication is required, an introduction to cleanroom fabrication process, e-beam lithography, and Ar-milling steps can be envisioned. The student will carry out low-temperature measurements in different cryogenic setups (10mK – 4 K). The goal is to study how superconductivity affects the electronic properties of the semiconductor nanostructure, e.g. through the emergence of Yu-Shiba-Rusinov-like states. The project is susceptible to evolve into a PhD thesis.

Related publications:

[1] De Franceschi et al., Nat. Nanotech. **5**, 703 (2010).
[2] Kiyooka PRX Quantum **7**, 033043 (2026).
[2] Leblanc et al., Nat. Comm. **16**, 1010 (2025),
[3] Leblanc et al. Phys. Rev. Research **6**, 033281 (2024).

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Spring
2027

Master2
internship

Hybrid superconductor-semiconductor for Parity protected qubit

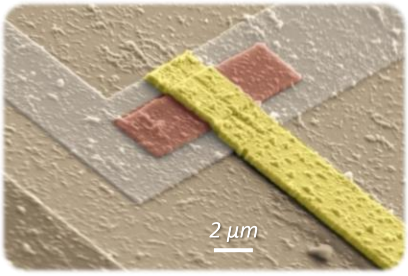

Fig. 1: Colorized SEM micrograph of a S-Sm nanostructure. Light gray shows superconducting Al, yellow normal metal Ti/Au gates and red semiconducting Ge.

Hybrid Superconductor – Semiconductor (S-Sm) nanostructures are nano-circuits which combine superconducting and semiconducting materials. Such devices take advantage, first from the superconductivity that is a macroscopic quantum effect and can be viewed here as a quantum coherence provider –needed ingredient to create a quantum bit or qubit. Second, from the semiconducting properties that allow changing the amount of carriers using an electrostatic gate – like in a field effect transistor (FET).

Our research focuses on hybrids made from aluminum-germanium nanostructure that we fabricate in our academic cleanroom, see Fig. 1. In a nutshell, our samples consist of a loop interupted by two hybrids nanostructures. By studying the multi-harmonicity of their current response to an applied magnetic field, we observed that only the transport of an even number of Cooper pair is allowed [1,2]. Such property is the building block to a type of protected qubit, the parity protected qubit [3].

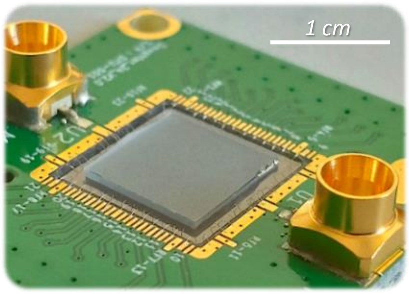

Fig. 2: Home-made PCB with a flip-chip sample micro-bonded in its center for microwave and DC measurement at cryogenic temperature.

The aim of this project is to incorporate our hybrid nanostructure in a circuit Quantum ElectroDynamics (cQED) architecture, a well-known and heavily used architecture in superconducting quantum information, to explore its properties as a qubit[4]. For this integration, we leverage our long-term collaboration with the CEA - LETI and use advanced flip-chip integration, where two quantum chips of different nature are coupled together, see Fig. 2.

The final sample will be probed at cryogenics temperature in state-of-the-art DC and microwave measurement setup.

During the master project, you will collaborate on a daily basis with our entire team (www.lateqs.fr) with 30 people including 15 Ph.D. You will participate to the development of new samples that includes design, theory and nano-fabrication performed in our cleanroom facility. You will also learn to cool down samples to reach cryogenic temperatures and you will perform measurements using state-of-the-art DC and RF techniques.

This master project may continue as a PhD thesis.

[1] A. Leblanc et al. Phys. Rev. Research **6**, 033281, 2024
[2] A. Leblanc et al., Nat Commun **16**, 1010 (2025)
[3] S. Messelot et al., To appear in Phys. Rev. Applied (2026) https://arxiv.org/abs/2601.10209v1)
[2] E. Kiyooka et al., Nano Lett., **25**, 1, 562 (2025)

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