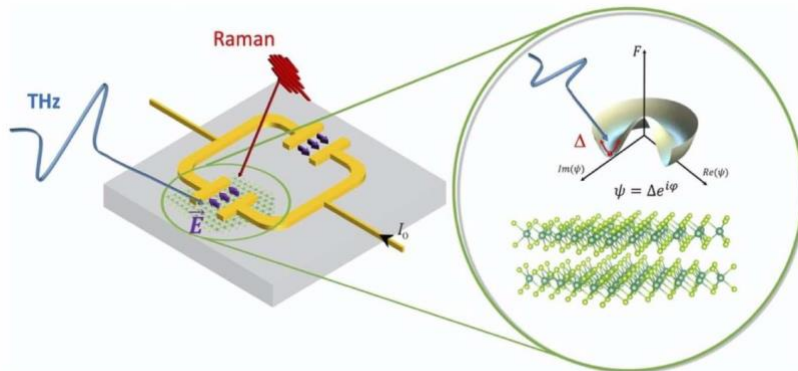


Master 2: *International Centre for Fundamental Physics*
INTERNSHIP PROPOSAL

Laboratory name: Matériaux et Phénomènes Quantiques
CNRS identification code: UMR 7162
Internship director's surname: Yann Gallais
e-mail: yann.gallais@u-paris.fr Phone number: 01 57 17 69 89
Web page: <https://mpq.u-paris.fr/?-Spectroscopie-de-QUAsi-Particules-SQUAP->
Internship location: Batiment Condorcet, Université Paris Cité, 75013 Paris
Thesis possibility after internship: YES
Funding: YES/N If YES, which type of funding: ANR

Cavity Higgs polaritons in 2D superconducting materials

Thanks to strong light-matter interactions in cavity-coupled systems, new important vacuum phenomena are emerging in condensed matter physics. In analogy with exciton- and phonon-polaritons that are now routinely observed in semiconductors an exciting perspective is to tune or even enhance the properties of a superconductor (SC) at equilibrium by dressing it with vacuum photons. Strong light-matter interactions offer unprecedented control opportunities of SC states since they can be shaped by modifying the spatial geometry and spectrum of the cavity electromagnetic modes. Beyond static properties such as enhancing the SC transition temperature, of particular interest is the possibility to directly couple the SC Higgs mode, a superconducting analogue of the Higgs boson well-known from high-energy physics, to a THz cavity mode. In this setting a new hybrid light-matter excitation coined the Higgs polariton is formed. To date none of the effects described above has been observed.



2D TMD embedded in a THz split ring cavity (left) The resulting coupled light-SC matter state is probed by Raman and THz spectroscopy. The SC Higgs mode is a collective oscillation of the SC condensate (right) that can couple to cavity photon to form cavity-Higgs polariton

2D SC transition metal dichalcogenides (TMDs) like NbSe₂, and NbS₂ are extremely attractive platforms to demonstrate these effects. Their 2D nature make them particularly suitable for integrating into deep sub-wavelength THz cavities based on split-ring resonators which have been used successfully to produce strong light-matter polariton state in semiconductor heterostructures. During this internship, the fabrication of TMD-based van der Waals heterostructure will be carried out and integrated into THz split resonant cavities. An originality of the project will be to go beyond static properties like T_c and explore the effect of strong light matter coupling on the SC excitation spectrum and search for spectroscopic fingerprints of the Higgs polariton via Raman and THz spectroscopic techniques. The work will be performed in close collaboration with THz cavity experts at the LSI lab of Ecole Polytechnique.

References :

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- F. Garcia Vidal et al. Science 373, eabd0336 (2021)*
- R. Grasset et al. npj Quantum Materials 7, 4 (2022)*
- K. Katsumi et al. Phys. Rev. Lett. 120, 117001 (2018)*

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	NO