

MASTER 2 AND DOCOTORAL THESIS PROPOSAL (Academic year 2026 - 2027)

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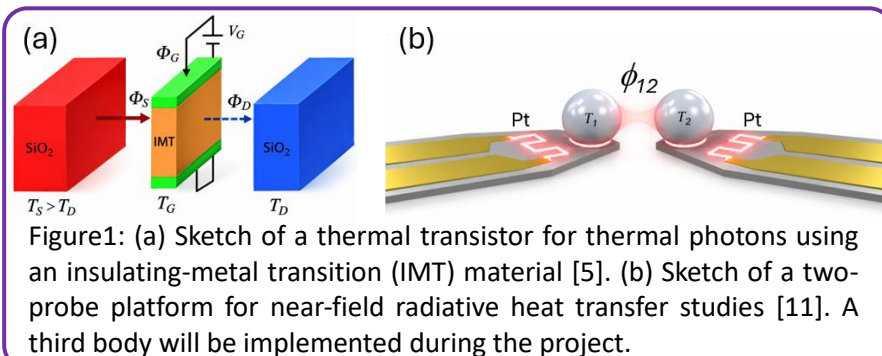
Internship location: Institut Langevin, ESPCI Paris, 1 rue Jussieu, 75005 PARIS

Collaboration with Laboratoire Charles Fabry – IOGS (Philippe Ben-Abdallah and Riccardo Messina).

Thesis possibility after internship: YES

ENGINEERING THERMAL RADIATION BEYOND PLANCK'S LAW FOR ACTIVE CONTROL OF NEAR-FIELD RADIATIVE HEAT TRANSFER: TOWARDS RADIATIVE THERMOTRONICS

INGENIERIE DU RAYONNEMENT THERMIQUE AU-DELA DE LA LOI DE PLANCK POUR LE CONTROLE ACTIF DES TRANSFERTS RADIATIFS EN CHAMP PROCHE : VERS LA THERMOTRONIQUE



Keywords: Thermal radiation management, Near-field radiative heat transfer, Many Body Physics, Phase change materials, Near-field optics, Surface waves, Nanosciences, Thermotronics

Description of the work: Experiments and simulations

Summary: The ability to control electric currents in solids laid the foundations of the modern electronics revolution, which has transformed our daily lives since the second half of the 20th century. Surprisingly, no comparable technology has yet emerged for the active control of heat flows [1]. This project aims to develop the first building blocks of radiative thermotronics, enabling active control of radiative heat transfer. Building on a recently developed experimental platform designed to investigate many-body radiative heat transfer, we will exploit the metal-insulator phase transition of vanadium dioxide (VO_2) to actively modulate heat exchange between bodies interacting in the near field.

Controlling radiative heat flow at the nanoscale represents a fundamental and technological challenge for nanoscience, thermal management and energy conversion. At subwavelength separation distances, heat exchange can exceed the blackbody limit set by Planck's law by several orders of magnitude through photon tunneling mediated by evanescent electromagnetic modes. Near-field thermal radiation [1-3] offers the possibility of controlling not only the magnitude and spectrum of heat transfer, but also its spatial distribution and direction. Building on these possibilities, **radiative thermotronics** has emerged as a theoretical framework for manipulating thermal photons to achieve functionalities analogous to those of electronic components. In particular, thermal diodes, transistors, memories, and Boolean logic gates have been theoretically proposed by our collaborators, Dr. Philippe Ben-Abdallah and Dr. Riccardo Messina, at the Laboratoire Charles Fabry (LCF-IOGS) [4–9].

On the experimental side, near-field radiative heat transfer has been investigated using scanning thermal microscopy (SThM) [2,3]. More recently, our team at Institut Langevin, in collaboration with the Laboratoire National de Métrologie et d'Essais (LNE) and the Laboratoire Charles Fabry, has demonstrated the modification—or *dressing*—of thermal emission by its near-field electromagnetic environment [10]. While most experiments performed to date have involved a single probe interacting with a passive substrate [3,10], our consortium has recently achieved a major breakthrough with the development of a **novel experimental platform featuring two independently operated SThM probes under vacuum**. This instrument enables high-precision measurements of near-field radiative heat transfer with sub-millikelvin temperature resolution and nanowatt-level heat-flow sensitivity, opening new avenues for investigating many-body effects in radiative heat transfer at the nanoscale [11].

The objective of this project is to exploit this unique experimental platform to demonstrate active control of near-field radiative heat transfer within a many-body configuration comprising two SThM probes and a substrate. Rather than developing three independent devices, we aim to establish, in close collaboration with our theoretical partners, that a single reconfigurable radiative platform can provide three key thermotronic functionalities: controlling the

direction of heat flow (thermal pumping), modulating heat transfer and achieving thermal amplification (thermal transistor), and implementing Boolean operations using thermal signals (thermal logic gates).

To achieve these objectives, we will exploit the remarkable properties of vanadium dioxide (VO_2), a phase-change material that undergoes a reversible insulator-to-metal transition near 68 °C. This transition induces dramatic changes in its optical and thermal radiative properties, both in the far field and in the near field, over a narrow temperature range of only a few degrees. By incorporating VO_2 into configurations involving two or three bodies maintained at different temperatures, we will investigate how its phase transition can be harnessed to dynamically control radiative heat exchange and realize the targeted thermotronic functionalities.

Ultimately, this project aims to establish the experimental foundations of active radiative thermotronics, paving the way towards nanoscale thermal circuits capable of manipulating heat flows in a manner analogous to the control of electric currents in conventional electronics.

References:

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