Master 2: ***INTERNSHIP PROPOSAL (2021-2022)***

Laboratory name: **Institut Langevin, ESPCI Paris, PSL University, CNRS**
CNRS identification code: UMR7587
Internship director'surname: **Yannick De Wilde**
e-mail: **yannick.dewilde@espci.fr** Phone number: 01 80 96 30 84
Web page: https://www.institut-langevin.espci.fr/home
Internship location: Institut Langevin, 1 rue Jussieu, 75005 Paris, France
Thesis possibility after internship: YES (Funding available)

Many-body near-field radiative heat transfer: towards a transistor for thermal photons

Two solid bodies at different temperatures which are separated by vacuum exchange heat in the form of thermal photons. This exchange of energy is limited in the far field by Stefan-Boltzmann's law which is a direct consequence of Planck's law. On the other hand, in the near field (when the separation distance is smaller than the thermal wavelength) the flux can overcome this limit by several orders of magnitude due to tunneling of photons making this transfer prominent at nanoscale. Until recently, only the radiative exchange between two objects has been considered in this non-planckian near-field regime, first theoretically [1] and then experimentally [2-7].

In this project, we propose to develop the very first setup to experimentally investigate the near-field radiative heat exchanges by thermal photons in many-body systems. We will specifically address the case of micrometer-size objects for which the appropriate multipolar theoretical formalism will be developed by our collaborators (P. Ben-Abdallah and R. Messina, Labo. Charles Fabry – IOGS), to go beyond the dipole approximation suited for objects much smaller than the thermal radiation wavelength. To this end we will:

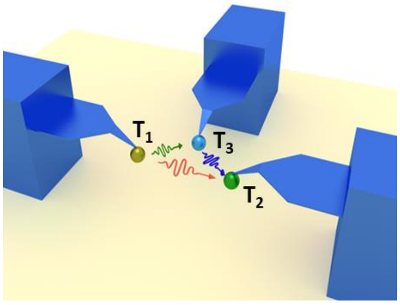

Figure 1: Sketch of of a near-field transistor for thermal photons.

- **Create ultrasensitive sensors capable of measuring the near-field heat transfers between micrometer-size objects.** Based on our expertise in nanosystems [8], a platform allowing the measurement of near-field radiative heat transfers between up to three or four micrometer sized bodies in high vacuum will be developed at Institut Langevin, in collaboration with the Laboratoire National de Métrologie et d'Essai (W. Poirier) which will provide its expertise in ultrasensitive measurements in quantum metrology [9].
- Measure the near-field heat exchanges in simple many-body systems by means of multiple interacting SThM probes supplemented by infrared thermal radiation studies. **A sketch of the configuration which we envision to study energy transfers between three spherical bodies to create the first near-field transistor for thermal photons is shown in figure 1.**
- In parallel, a general formalism based on the multipolar expansion of the electromagnetic field will be developed at LCF-IOGS to study at arbitrary separation distance the mutual radiative heat exchanges in many-body systems made of micrometer-size objects [10].

[1] K. Joulain, J.-P. Mulet, F. Marquier, R. Carminati, and J.-J. Greffet, Surf. Sci. Rep. **57**, 59 (2005).
[2] A. Kittel, W.Muller-Hirsch, J. Parisi, SA. Biehs, D. Reddig, M. Holthaus, Phys. Rev. Lett. **95**, 224301 (2005).
[3] Y. De Wilde et al, Nature **444**, 740 (2006).
[4] A. Narayanaswamy, S. Shen, and G. Chen, Phys. Rev. B **78**, 115303 (2008).
[5] E. Rousseau et al. , Nature Phot. **3**, 514 (2009).
[6] A. Babuty et al, Phys. Rev. Lett. **110**, 146103 (2013).
[7] C Lucchesi, D. Cakiroglu, J. -P Perez, T. Taliercio, E. Tournié, P. -O Chapuis, Rodolphe Vaillon, Nano Lett. **21**, 4524 (2021).
[8] J. Doumouro et al., Phys. Rev. Applied **15**, 014063 (2021).
[9] J. Brun-Picard et al., Phys. Rev. X 6, 041051 (2016).
[10] P. Ben-Abdallah, Phys. Rev. Lett. **123**, 264301 (2019).