Master internship (M2, or long-duration M1) offer

Thermal radiation of nanoscale objects and their spectroscopy
(traduction française possible sur demande)

Advisors: P-Olivier Chapuis (Directeur de recherche CNRS), Olivier MERCHIERS (Assistant Professor INSA)
Centre for Energy and Thermal Sciences of Lyon (CETHIL), INSA Lyon

Context: Thermal radiation is ubiquitous around us, since any body at a given temeprature emits radiation. Classical laws like the Stefan-Boltzmann one (flux proportional to T^4) and Planck's one (spectral equivalent) are well established and used widely for determining the flux transfer between opaque surfaces. A well-known issue, already mentioned by Planck, is that this intensity-based theory works only for object sizes, distances and curvature radii larger than the wavelength (around 10 µm at ambient temperature). When the wavelength is comparable to such lengths, phenomena such as interferences, diffraction and photon tunneling should be accounted for in addition. This can be done in a broader framework involving electromagnetism and statistical physics (termed 'fluctuational electrodynamics'). Due to miniaturization many objects and systems possess now lengthscales of the order of the micrometer and below, and if one wants to estimate correctly how they radiate (for instance for material analysis, telecom information transport, stellar signal detection, stealth, device tagging similar to RFID, waste heat harvesting with thermophotovoltaics, etc.), it is key to clearly determine the thermal-radiation characteristics at subwavelength scale. Following our work dealing with distances between objects [1] and current work [2], we aim at systematically investigating objects with thermal-emission patterns in the nano to micrometre scale.

References:

[1] *Temperature dependence of near-field radiative heat transfer above room temperature*, C. Lucchesi et al., Materials Today Physics 21, 100562 (2021). See also the press release from CNRS:
https://www.insis.cnrs.fr/fr/cnrsinfo/la-loi-de-stefan-boltzmann-nest-pas-valable-lechelle-nanometrique

[2] Kyriaki KONTOU, PhD thesis at INSA Lyon, in progress

Goal of the project: This master internship, which is essentially experimental, will consist in refining an experimental setup involving an infrared spectrometer coupled to an optical microscope, which allows to measure the spectrum of the thermally-emitted flux of small objects. The setup further includes a system to heat the radiating object, a positioning system and a spatial-modulation device, which is required in order to be able to subtract the large background thermal radiation in order to single out the small signal of interest associated with the thermal emission of the small object. The goal is to check spectral signatures of small objects and determine their temperature dependence (power proportional T^n, with n to be determined), which deviates from Stefan-Boltzmann's $n = 4$. The work will built on previous steps [2].

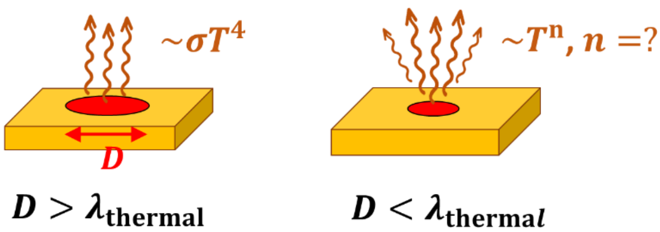

Figure 1. *Modification of the power emitter by a hot disc when its diametre decreases [2]*

Work to be performed:

- Understanding the project goals; bibliography
- Improvement of the experimental setup based on elements already available
- Experimental measurements of sub-wavelength objects
- Analysis of the data and comparison with in-house numerical codes
- Final report/oral defense

Framework: ANR project STORE with the Nanotechnology Institute of Lyon (INL) and colleagues at CETHIL working on thermal radiation at larger scale.

Required background: Thermal physics, electromagnetism, solid-state physics and electronics will also be applied. English is mandatory.

Possibility of PhD thesis after the internship: Yes. Application to a 'Contrat Doctoral' of INSA Lyon in June 2026 is possible. Note that it is a selective process.

Contact: olivier.chapuis@insa-lyon.fr (webpage, office in Carnot building third floor: 304A)
olivier.merchiers@insa-lyon.fr (webpage, office in Carnot huilding second floor: 210)