M2 Internship proposal, March-Septembre 2020

Thermal radiation at nanoscale for metamaterials and/or low temperature
(French version of this Offer available upon request)

Advisors: P-Olivier Chapuis (Chargé de Recherche CNRS), Olivier Merchiers (Maître de Conférences, INSA de Lyon)
Location: Centre d'Energétique et de Thermique de Lyon (CETHIL), INSA de Lyon, Villeurbanne (Lyon)

Context:
Thermal radiation is one of the main heat transfer mechanism with heat conduction and heat convection, which exists even in absence of matter. At usual macroscopic scale, one can neglect many electromagnetic features of the thermal-radiation carriers (photons) which are considered as particles, but this is not possible at nanoscale, where interference and sub-wavelength effects, including photon tunneling, enter into play. In particular, the heat exchanged between two bodies becomes huge when they are brought very close, in what is known as *near-field thermal radiation* exchange. Predicted 50 years ago, these effects have been demonstrated experimentally in the last ten years in canonical geometries such as parallel semi-infinite media and sphere-plane geometries. While the calculations were initially limited to analytics numerical methods have appeared in the recent years and allow now for computations with arbitrary shapes. However, they are not straightforward to implement and many constraints are still to be dealt with.

The goal of the internship is to compute radiative heat transfer between complex structures by analytical and numerical means (including the SCUFF-EM code developed at MIT), and exchange with various other laboratories at national and international levels who are interested by these results. The structures considered may involve: spherical geometries for medicine applications, low-temperature 2D electron gases, nanowires, micro-electromechanical systems (MEMS) and metasurfaces. The student will learn about nanoscale heat transfer at CETHIL and is not necessarily expected to have a strong knowledge about this domain initially.

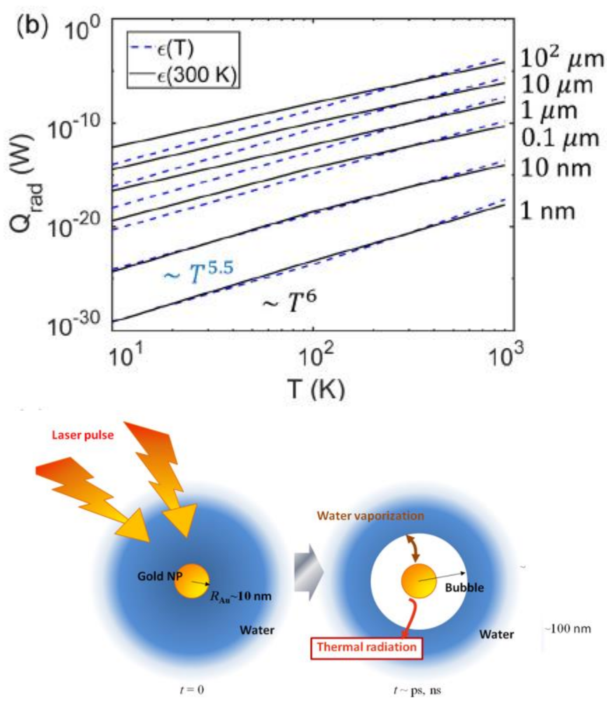

Figure: (a) Example of nanoscale thermal radiation effect: Deviation from the usual $Q \propto \sigma T^4$ law for the power emitted by an object of temperature T. Here the spheres of radii R (indicated at right) are made of aluminium. (b) Example of configuration where near-field thermal radiation is important: radiative exchange around a laser-heated gold nanoparticle (NP) vaporizing water, which induces a nano-bubble.

References :

- *Temperature-dependent and optimized thermal emission by spheres*, K.L. Nguyen, O. Merchiers, and P.-O. Chapuis, Applied Physics Letters 112, 111906 (2018)
- *Harnessing near-field thermal photons with efficient photovoltaic conversion*, C. Lucchesi *et al.*, submitted to high-impact journal and already available online on ArXiV website
- PhD student prize for C. Lucchesi at the French National Days on Solar Energy (JNES) in 2018. See News section in June 2018 on the CETHIL website.

For more information, see website.

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UMR 5008

Work to be performed:

- Understanding of the concept and the numerical codes already available
- Application of the codes on geometrical shapes of interest
- Comparison with previous data and analyze of the results
- Final report

Dates: March-September 2020

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