Master internship (M2) offer

Experimental study of near-field thermophotovoltaic and thermophotonic conversion - Etude expérimentale de la conversion thermophotovoltaïque et thermophotonique en champ proche (traduction française possible sur demande)

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Context: The recovery of waste heat and its conversion into electrical energy is a means of limiting greenhouse gas emissions. Different possibilities allow this conversion, depending on the temperature of the hot source and the dimensions of the planned installations. Photovoltaics, i.e. radiative energy harvesting from the Sun – a heat source with its surface at about 5500°C – is well known. Another option is thermophotovoltaic (TPV) conversion, where thermal energy is also harvested by photovoltaics, but with dedicated cells in the *infrared* instead of the visible. While infrared thermal emission is ubiquitous (all bodies emit) and therefore attractive for energy harvesting, Carnot efficiency ($\eta = 1 - T_{cold}/T_{hot}$) limits unfortunately the power that can be harvested at heat-source temperatures close to ambient. In contrast, high-temperature sources (>1000°C), found e.g. in industrial processes, are well suited to TPV. The Micro and Nanoscale Heat Transfer (MiNT) group at CETHIL has shown theoretically and has experimentally demonstrated that the performance of TPV devices is greatly improved when the distance d between the radiative source and the TPV cell is reduced to reach the so-called "near field" regime ($d < \lambda$, where λ is the infrared wavelength). One of the key points is to match the spectrum of thermal radiation emitted by the source to that which can be converted by the TPV cell. As a result, the temperature of the emitter can be reduced to $\sim$500°C. Lower-temperature emitters are also expected for thermal-energy harvesting, this can be done in a thermophotonic configuration, which involves a hot light-emitting diode (LED) close to TPV cell.

Figure (1)

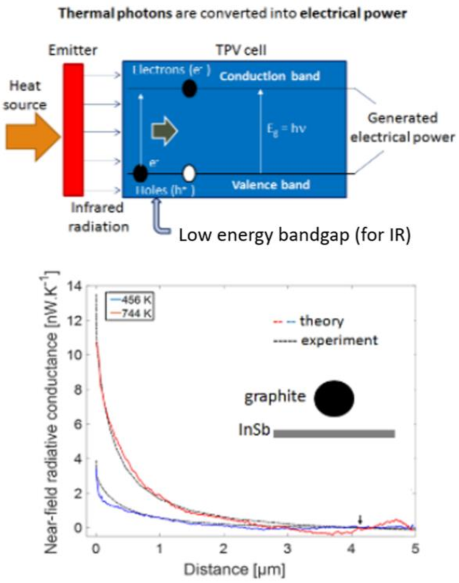

Figure **1.** (a) Principle of a thermophotovoltaic energy-harvesting device (b) Large power increase when a hot body (here a graphite sphere) is brought close to a cold body (here an InSb plate).

References :

- *Harnessing near-field thermal photons with efficient photovoltaic conversion*, C. Lucchesi *et al.*, Nano Letters 21 (11), 4524-4529, 2021.
  Also https://arxiv.org/abs/1912.09394
- *Indium antimonide photovoltaic cells for near-field*

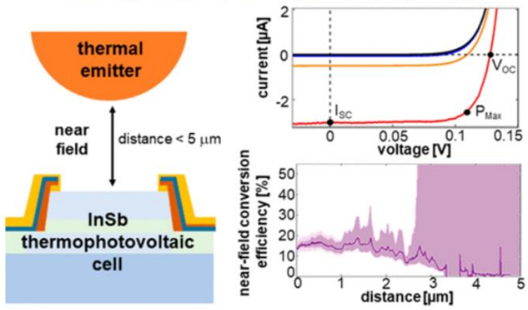

Figure (2)

Figure **2.** (a) Schematic of the experiment, where a hot emitter is brought closer to the TPV cell. (b) IV characteristics. (c) Efficiency vs distance

Goal of the project: This master internship, which is essentially experimental, will consist in using two experiments developed at CETHIL, based on AFM microscopy, to perform local near-field energy conversion experiments. In the frame of the European project TPX-Power and OPTAGON, light-emitting diodes (LEDs) and photovoltaic (PV) cells are to be characterized. In another project, thermophovoltaic (TPV) cells should also be characterized. In both case, we aim at determining the efficiency of the energy-harvesting devices and the power output.

Work to be performed:

- Understanding the project goals; bibliography
- Experimental measurements of near-field TPV conversion with the setup of samples
- Analysis of the implementation of thermophotonic experiments
- Final report/oral defense

Framework: Collaboration with other laboratorie, especially those experts in cells, is usual. In the frame of the TPX-Power and OPTAGON EU projects, colleagues at Aalto Univ and VTT Technical Research Centre of Finland, both in Helsinki area, Finland; Raadboud Univ. and tf2 devices, both in Nijmegen, Netherlands is expected. Collaboration with IES Montpellier and LAAS Toulouse in the frame of the project-team TREE devoted to TPV conversion is also possible.

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 2025 is possible.

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