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Post-doctoral position at Institut Langevin

Nanoscale imaging and spectroscopy of infrared electroluminescence of graphene and optical control of thermal radiation of plasmonic antennas.

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We recently demonstrated in collaboration with the LPENS (Emmanuel Baudin's team) that when graphene-based transistors encapsulated in boron nitride (hBN) are subjected to a large bias voltage, electroluminescent radiation is produced in the mid-infrared spectral range. The phenomenon of non-incandescent infrared emission is accompanied by efficient evacuation of the electrical power applied to the devices mediated by the excitation of hyperbolic polariton phonons in hBN [arXiv:2310.08351; arXiv:2306.05351, paper just accepted in NATURE (2024)] The measurements we have carried out to date to investigate this phenomenon are far-field measurements involving an infrared microscope coupled to a Fourier transform infrared spectrometer, using a method called infrared spatial modulation spectroscopy [doi.org/10.1103/PhysRevLett.121.243901 ; doi/abs/10.1021/acsphotonics.2c00273].

As part of this post-doctoral fellowship, we wish to extend our knowledge of the phenomenon by carrying out super-resolved near-field measurements in the infrared using a local scanning probe called TRSTM (thermal radiation scanning tunnelling microscope). The instrument developed by our team is similar to an infrared scanning near-field optical microscope (SNOM), which detects the electromagnetic fields produced by the sample itself through thermal fluctuations or other processes, rather than using external illumination. It uses a tungsten tip as a local scatterer of the infrared radiation emitted at the sample surface [doi.org/10.1038/nature05265]. The scattered electromagnetic field is then collected and guided in free space towards a mid-infrared detector coupled to a commercial Fourier transform infrared spectrometer (FTIR).

Since graphene-based transistors have a typical width of 10 – 30 µm and nanostructured electrodes, the spatial resolution of far-field measurements is insufficient to observe the exact location of the infrared electroluminescent signal they produce. The aim of the near-field TRSTM measurements is then to obtain super-resolved images and spectra of the infrared radiation emitted by the graphene-based device in operation, with a spatial resolution of 100 nm. A similar approach was successfully used in our team to investigate non-Planckian near-field thermal radiation [doi.org/10.1103/PhysRevLett.110.146103].

In addition, the post-doctoral research will also aim to use intense laser illumination to excite thermally some specific electromagnetic modes of infrared plasmonic nano-antennas [doi.org/10.1103/PhysRevLett.132.043801] **in order to produce optically programmable infrared sources.** Such optically programmable devices could be of use in the future for free space infrared telecommunications.

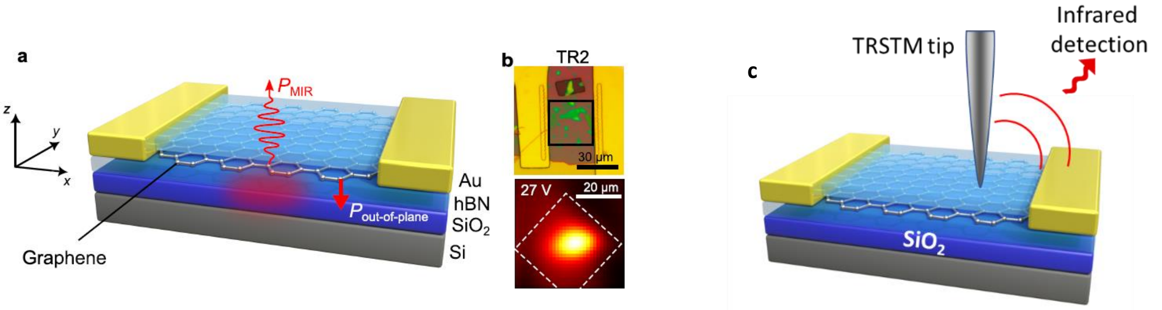

Figure: *(a) Transistor based on a graphene sheet encapsulated in hBN ; (b) Optical microscopy image of the device and far-field mapping of the mid-infrared electroluminescent signal ; (c) TRSTM measurements to be developed during the post-doc to obtain super-resolved images and spectra of the infrared electroluminescent signal produced by the devices in operation.*

This post-doctorate is part of the ELuSeM project funded by the French National Research Agency. The post-doc will be carried out at Institut Langevin (Yannick De Wilde's team) in collaboration with the Physics Laboratory of the Ecole Normale Supérieure (LPENS) in Paris, the Laboratoire Charles Fabry-IOGS, the ONERA, among others. The graphene devices are produced and characterized electrically by the team of Emmanuel Baudin at ENS (PI of the project), while the optical measurements are performed at Institut Langevin. The infrared plasmonic antenna devices are produced at ONERA by the team of Patrick Bouchon. Theoretical modeling is performed at Lab. Charles Fabry by the team of Jean-Jacques Greffet.

ACTIVITIES:

Main tasks in experimental physics:
- Ultra-sensitive infrared measurements
- TRSTM measurements (infrared SNOM without external source) - SNOM
- FTIR spectroscopy; IR SMS (spatially-modulated infrared spectroscopy)
- Setting up laser heating of plasmonic antennas on measurement bench
- Electromagnetic modeling

Secondary tasks:
- Design of plasmonic antenna samples for lithography
- Contribution to other experimental studies

Required skills:

- Mastery of near-field microscopy techniques. Desirable experience: manipulation with infrared SNOM; manipulation with RHK control electronics; FTIR spectroscopy.
- FTIR spectroscopy; infrared nano-spectroscopy
- Electromagnetic modeling

Host laboratory and team:

Located in the heart of Paris, the Institut Langevin is a world-renowned research unit of ESPCI Paris, PSL University and CNRS, dedicated to wave physics and its applications. The spectrum of waves involved is very broad: mechanical waves (acoustic, elastic and seismic waves, waves), electromagnetic waves (radiofrequencies, microwaves, Terahertz) and optical waves (infrared and visible).

Yannick De Wilde is both Director of the Institut Langevin and head of a team of experimental physicists whose activities are mainly focused on nano-optics and plasmonics in the infrared, micro- and nano-thermics, near-field microscopies, super-resolved imaging and spectroscopy, ….

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