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Institut Langevin
ONDES ET IMAGES

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

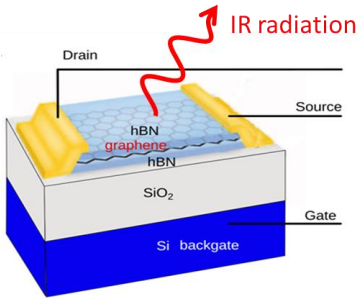
Laboratory name: **Institut Langevin, ESPCI Paris, PSL University, CNRS**
CNRS identification code: UMR7587
Internship director'surname: **Yannick De Wilde**
e-mail: **yannick.dewilde@espci.fr** Phone number: 01 80 96 30 84
Web page: https://www.institut-langevin.espci.fr/home
Internship location: Institut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

Thesis possibility after internship: YES
Funding: YES (ONERA and/or funding source to be adapted depending on student's profile)

Graphene electroluminescence and reconfigurable plasmonic nano-antennas.

The objective of this project is to study and control the electroluminescence of graphene transistors and to design reconfigurable infrared sources based on the thermal emission of plasmonic nano-antennas addressable using visible laser illumination.

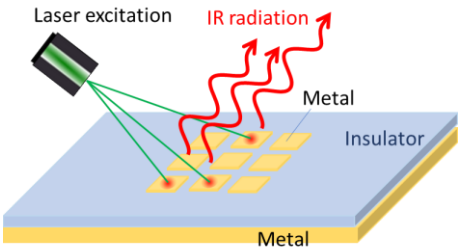
We have recently discovered in close collaboration with École Normale Supérieure (E. Baudin's group at LPENS) that a high mobility graphene transistor encapsulated by boron nitride sheets (ZKFET) under strong bias becomes electroluminescent in the infrared (IR, $\lambda \simeq$ 8-10 µm), thanks to an original carrier injection mechanism specific to 2D semimetals that was first demonstrated by our collaborators in electrical transport measurements: the Zener-Klein (ZK) tunneling conductance [1].



Electroluminescence coincides with abrupt cooling of the graphene electron gas [2], according to a mechanism involving near-field modes known as hyperbolic phonon-polaritons of the hexagonal boron nitride (hBN) encapsulant.

In this part of the project, we will try to better understand the mechanism responsible for the electroluminescence of graphene in the infrared, but also to optimize the scattering of the near-field modes towards the far-field by structuring the devices or by using plasmonic antennas, to create a new type of very efficient infrared light source.

We will also study with our collaborators from ONERA (P. Bouchon and R. Haidar) the infrared thermal emission of metal-insulator-metal (MIM) nano-antennas heated by absorption of spatially modulated visible light. Our team is the only one in the world able to measure the infrared emission of individual MIM antennas [3] or a small number of them [4], both in the near field [5, 6] and in the far field [3, 4].



The second part of the project will focus on the elaboration of MIM antenna arrays that we will heat by absorption of a visible laser beam in order to stimulate their infrared re-emission. The use of a spatial light modulator will allow to modify the spatial configuration of this laser heating on the antenna array. We will thus have a reconfigurable light converter from visible to infrared. This new source could also be modulated at very high rate [7].

The doctoral thesis following the internship will be carried out in collaboration between the Laboratoire de Physique de l'Ecole Normale Supérieure (Emmanuel Baudin), the Laboratoire Charles Fabry - IOGS (Jean-Jacques Greffet), ONERA (Patrick Bouchon), and the Institut Langevin at ESPCI Paris (Yannick De Wilde and Valentina Krachmalnicoff). It will be directed by Yannick De Wilde (Institut Langevin) and Patrick Bouchon (ONERA).

[1] W. Yang et al, Nature Nanotechnol. **47**, 13 (2018).
[2] E. Baudin et al, Adv. Funct. Mater. **30**, 1904783 (2020)
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[5] Y. De Wilde et al, Nature **444**, 740 (2006).
[6] A. Babuty et al, Phys. Rev. Lett. **110**, 146103 (2013).
[7] L. Wojszvzyk et al., Nature communications **12**, 1 (2021).