The electroluminescence of graphene

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Electroluminescence is the emission of light by a material submitted to a strong electric field. It is ubiquitous in our modern life because it is much more efficient than incandescence which is the process of light emission by a hot material. Therefore it has been the subject of thorough research in material science.

Known electroluminescent materials have one thing in common : they are all insulators. Metals in contrast are just incandescent. The reason for this difference lies in the existence of a bandgap which allows partial insulation of band electrons with respect to each other : this allows reaching far nonthermal electronic distribution in insulators whereas in metals, electrons relax to a hot thermal state systematically.

In the recent years, we have predicted and observed that this was not always true and that a metal – albeit a very strange one :graphene – can become electroluminescent. In our devices this occurs in ambient conditions (room temperature, ambient pressure), with reasonable voltage (~10V). In 2022, we launched an ambitious ANR project with a consortium gathering the best partners in France to try to understand the mechanisms at stake which involve transport, quantum mechanics, photonics and thermodynamics. We are looking for a PhD student who will be at the core of this project to discover this whole new physics of far out-of-equilibrium Dirac fermions in graphene. [1-4]

To permit this exploration, the Phd will realize state-of-the-art graphene heterostructures and optoelectronic experiments involving radiofrequency, Raman, and middle-infrared spectroscopy. The core apparatus will be a Cascade microwave cryogenic probe station (see probe head in Figure 1b) equipped with low-noise amplifiers for electronic thermometry (1-10GHz) and optical accesses. Graphene-hBN based heterostructures under test will be designed and fabricated in the LPENS clean room on the newly designed transfer station.

The candidate will have bases in physics of condensed matter, a real taste for nano-fabrication, and rf electronics, and an open mind for surprises. The PhD grant and the project are funded by the ANR project EluSeM started in February 2022, and the European Graphene Flagship.

Illustration and bibliography are on the next page.

Bibliography:

[1] A. Betz et al., Nature Physics 9, 109 (2013).
[2] W. Yang et al., Nature Nanotech. 13, 47 (2018).
[3] E. Baudin et al., Adv. Funct. Materials 30, 1904783 (2020).
[4] A. Schmitt et al, (2022) *In preparation*.
See also : https://www.mpsd.mpg.de/events/30822/2736

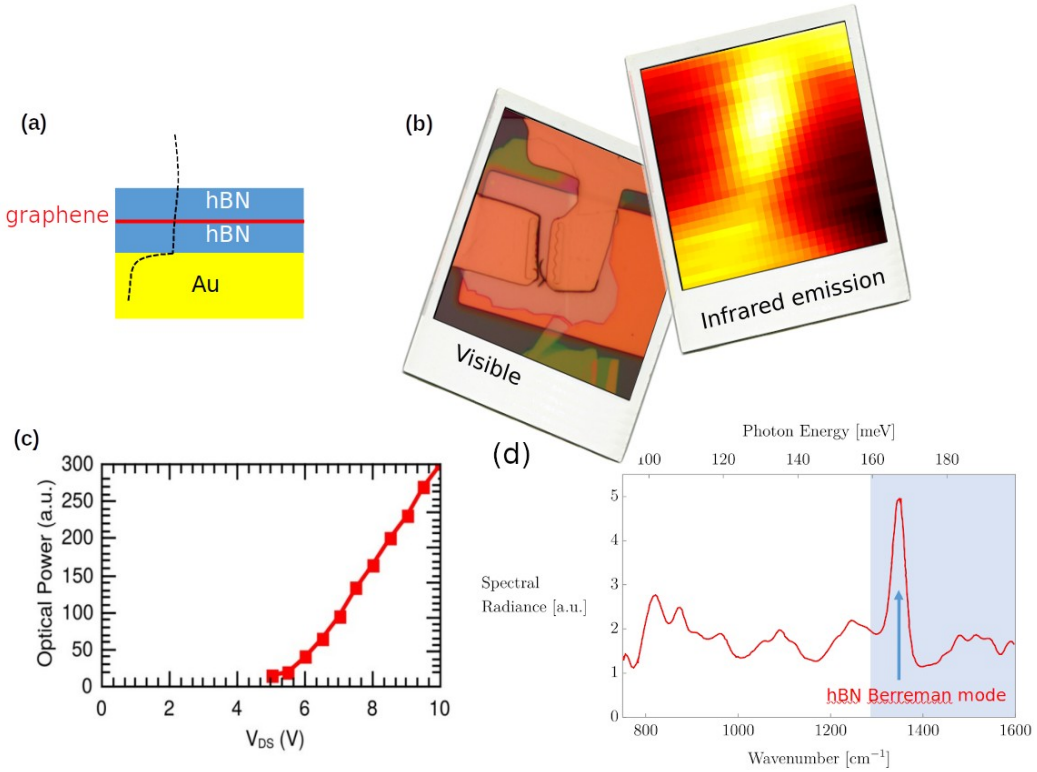

Figure : (a) Transverse view of the graphene field effect transistor encapsulated in hexagonal Boron Nitride on top of a gold backgate. The heterostructure thickness is 250nm. (b) Visible miscoscope photography of the Graphene FET and comparison to its infrared emission in the LWIR band. A clear signal escapes from the channel. (c) Optical power emitted in the LWIR function of bias. The charge injection threshold characteristic of electroluminescent devices is observed at 5V. (d) LWIR emission spectrum. The peak at 170 meV is electroluminescence within the Berreman resonance mode of the structure.