Near-field radiative heat transfer of hBN-encapsulated Graphene Field Effect Transistors

Rémi Bretel[1]
Loubnan Abou-Hamdan[2], Aurélien Schmitt[1], Sylvio Rossetti[2], Takashi Taniguchi[3], Kenji Watanabe[3], Michael Rosticher[1], Gwendal Feve[1], Jean-Marc Berroir[1], Christophe Voisin1, Bernard Plaçais[1], Patrick Bouchon[2], Yannick De Wilde[2], and Emmanuel Baudin[1]
[1]*Laboratoire de Physique de l'ENS, Paris, France*
[2]*Institut Langevin, ESPCI, Paris, France*
[3]*National Institute for Materials Science, Tsukuba, Japan*
remi.bretel@phys.ens.fr

Heat management is critical for the performance of most modern electronic devices. The case of Van der Waals materials is no exception, but thanks to their anisotropic layered structure, most of them host collective bulk excitations, called hyperbolic phonon polaritons (HPhP), which are efficient radiative heat carriers. [1,2]

In this talk, I will present a direct observation of the out-of-plane heat transfer in a vertical SiO_2-hBN-graphene-hBN heterostructure. The out-of-plane heat transfer is deduced from the steady-state temperature of the hot 285nm-thin SiO_2 layer in contact with the bottom hexagonal Boron Nitride, when the graphene transistor is operated under a large bias. This temperature is deduced from the characteristic incandescent peaked emission of SiO_2 in the middle-infrared. Using this technique, we show that out-of-plane heat transfer through hBN is triggered by interband tunnelling in graphene at large bias [2], and we quantify the amplitude of this effect. [3]

References

[1] S. Biehs, et al, Phys. Rev. Lett. 109, 104301 (2012)
[2] W. Yang, et al, Nat. Nanotech. 13, 47 (2018)
[3] L. Abou-Hamdan et al, in preparation (2023)

Figures

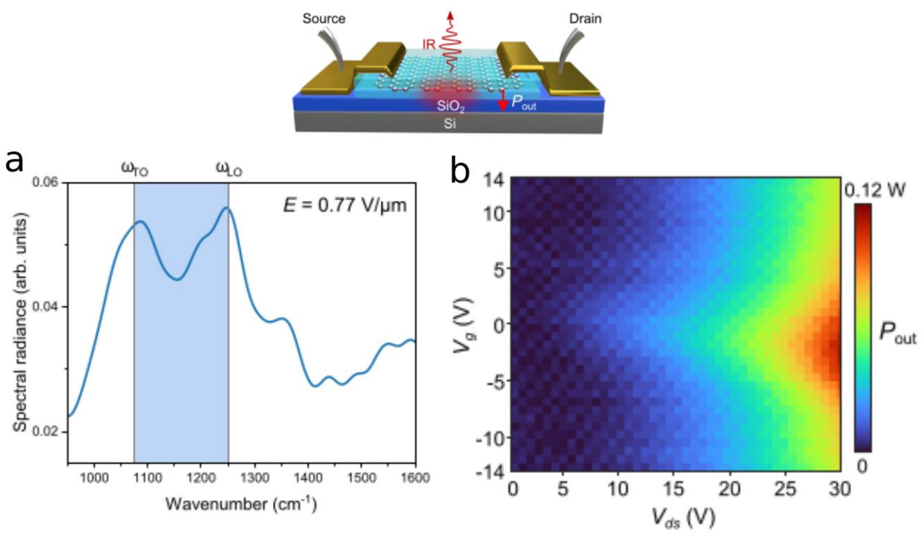

Figure 1: Depiction of the out-of-plane heat transfer in a high-mobility graphene field-effect transistor with an SiO_2 back-gate. The subsequent mid-IR emission is represented by a red wavy arrow. a) MIR spectral radiance of the transistor for an applied electric field E = 0.77 V/µm (Vg = 0 V), the blue-shaded region encloses the Reststrahlen band of SiO_2. b) Out-of-plane dissipated power as a function of electrical bias and gating, deduced from the SiO_2-temperature increase.