Hyperbolic cooling of graphene Zener-Klein transistors

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Engineering of cooling mechanisms is a bottleneck in nanoelectroniscs. In graphene/hBN transistors, Wiedemann-Frantz cooling[1] and supercollision-cooling[2] prevails, and the latter is suppressed in high mobility graphene/hBN samples and substituted by the super-Planckian radiation[3]of hyperbolic phonon-polaritons (HPPs) in the hBN substrate. Using electrical Joule heating and sensitive noise thermometry in several GHz range we report on prevailing HPP cooling in the upper Reststrahlen-band of hBN at high bias. We predict and observe its activation threshold, along with interband Zener-Klein tunneling. HPP cooling is able to evacuate at least several GW/m2 to the bottom gate, resulting in an unusual clipping of electronic temperature. As a scattering counterpart, HPPs of the lower Reststrahlen-band control current saturation at high doping. The combination of both mechanisms promotes graphene/hBN as a valuable nanotechnology for applications in the high power devices and radio frequency electronics.

References

[1] A.C. Betz, *et al.* PRL. 109(2012), 056805.
[2] A.C. Betz, *et al.* Nat.Phys. 9(2013), 109.
[3] A. Kumar, et al. Nano lett. 15(2015), 3172

Figures

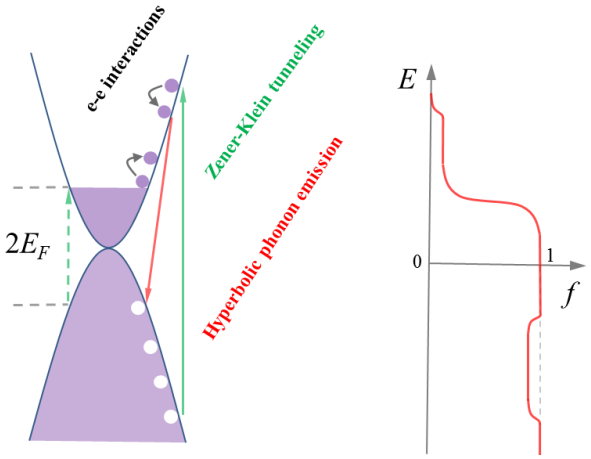

Figure 1: Schematic of energy relaxation

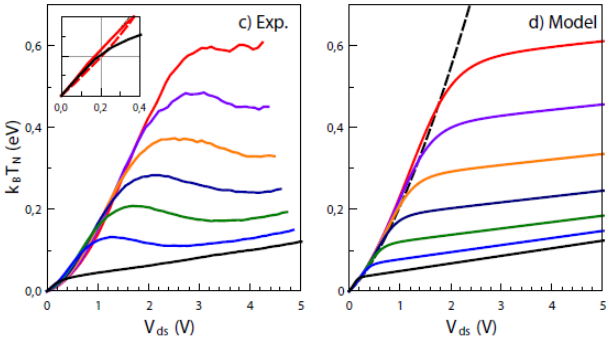

Figure 2: Measured electron temperature and simulation.