Graphene electrons for highly efficient thermal transport and nonlinear terahertz photonics

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Graphene has been suggested as a game-changer material for many types of applications. Here, we highlight two such applications that we identified recently.

In the first part of this talk, we will discuss diffusion of electronic heat in graphene, which we have studied using a novel spatiotemporal thermoelectric microscopy technique with femtosecond temporal and sub-100 nm spatial control [1]. With this technique we follow electronic heat flow in space and time at room temperature, and observe electronic heat flow consistent with charge flow in the "normal" diffusive regime. In the hydrodynamic time window before momentum relaxation occurs, and under Dirac-fluid conditions, we observe much more significant heat spreading. Importantly, we show that heat spreading is so efficient that the thermal conductivity of the electron system can be larger than the already record-high thermal conductivity of the phonon system of graphene. This result is relevant for thermal management applications where heat needs to be extracted as fast as possible from sub-micron-sized local hot spots.

In the second part of this talk, we will discuss the highly efficient generation of terahertz (THz) harmonics, facilitated by hot carriers in graphene. This effect was first observed in 2018 [2], and recently we combined graphene with a metallic grating in order to make this process even more efficient [3]. We will show that this grating-graphene metamaterial gives third-harmonic generation with a power that is enhanced by more than 3 orders of magnitude compared to graphene without metallic grating, has a harmonic field conversion efficiency of 1%, as well as gives rise to generation of higher harmonics (up to the ninth). These results are promising for the development of on-chip THz nonlinear photonic applications.

REFERENCES

[1] A. Block et al., Arxiv 2008.04189 (2020), *under review*
[2] H. Hafez et al. Nature, 561 (2018) 507
[3] J.C. Deinert et al., ACS Nano, 15 (2021) 1145

FIGURES

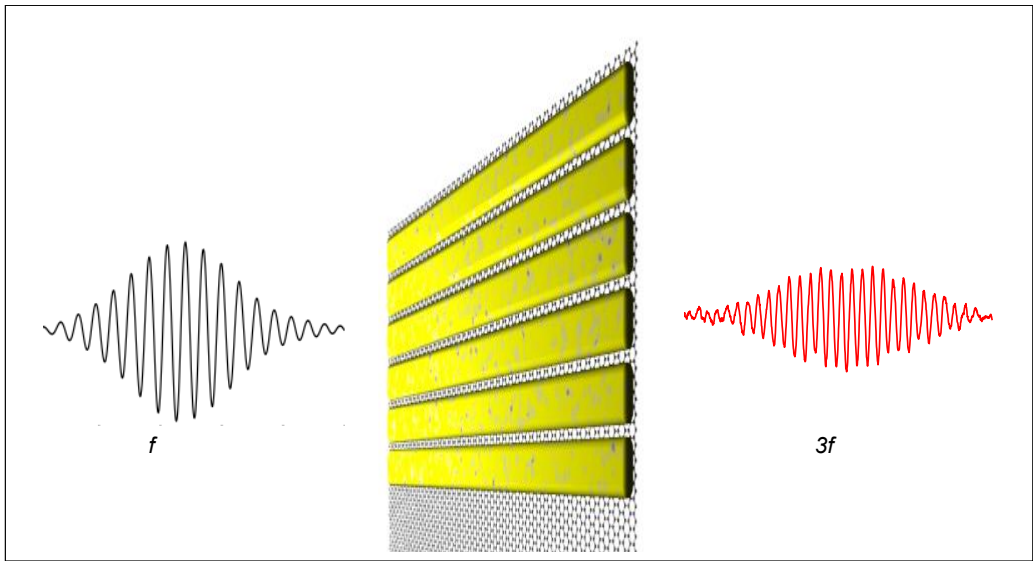

Figure 1: Terahertz third-harmonic generation using a grating-graphene metamaterial [3].