Studying heat transport in 2D materials using ultrafast light

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Understanding heat transport is relevant for applications such as thermal management and thermoelectrics. Our group has been studying transport of heat carried by both electrons and phonons in systems based on 2D materials using newly developed techniques exploiting ultrafast light pulses. We will present two recent results.

The first topic is diffusion of heat carried by the electron system 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 so-called “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.

The second topic we will discuss is a novel technique we have developed to study in-plane heat diffusion in thin films [2]. Most optical techniques for studying thermal transport suffer from relatively complex models that require several known material parameters in order to extract thermal transport properties and the need for relatively strong heating. In contrast, our technique – based on spatiotemporal pump-probe microscopy – does not require any material input parameters and yields the material’s diffusivity from a direct comparison with a simple Fourier diffusion model, under relatively weak heating conditions. We demonstrate the power of this technique by extracting the diffusivity of suspended films of $MoSe_2$ and WSe_2, prototypical transition metal dichalcogenide materials. We expect that this technique will be a valuable tool for studying heat transport in thin films.

REFERENCES

[1] A. Block et al., Arxiv 2008.04189 (2020), *under review*
[2] S. Varghese et al. *in preparation*