Dirac fluid with giant room temperature thermal diffusivity

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Graphene conducts heat even better than diamond, with a phonon thermal conductivity above 4000 W/mK [1]. The electronic contribution to thermal transport is typically thought to be considerably smaller. This is indeed the case in the regime of diffusive transport, where the Wiedemann-Franz law, which connects electronic charge transport with electronic heat transport, is valid. However, strong interaction between electrons can lead to a non-diffusive transport regime with viscous, fluid-like behavior. We experimentally find that in this hydrodynamic regime the electronic contribution to the thermal conductivity can instead become dominant [2].

Recently, the hydrodynamic regime was reached in ultraclean graphene systems [3-9], as evidenced via electrical [3-5] and scanning probe [6,7] measurements. A more elusive manifestation of hydrodynamic behavior – the quantum-critical Dirac-fluid – was observed as a violation of the Wiedemann-Franz law [6] and as a contribution to Drude scattering [9]. In our recent work [2], we directly track the spreading of electronic heat in space and time using a split-gate graphene device at room temperature, controlling whether the system is in the Dirac-fluid regime or not. We use the novel technique of ultrafast thermoelectric microscopy, which allows for quantifying heat transport on the femtosecond and nanometer scale. We observe a giant thermal diffusivity of the Dirac fluid that is more than two orders of magnitude larger compared to the diffusive regime, in agreement with transport calculations.

We believe this efficient, faster-than-phononic thermal transport, as well as the possibility of switching the effect on and off, will lead to important technological advances, such as superior thermal management in high-performance electrical devices.

References

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