Experimental observation of giant thermal diffusivity of Dirac fluid

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The transport of heat and charge in solids is typically described in terms of diffusive and ballistic motion of point particles. However, for strongly interacting electrons under certain circumstances a viscous, fluid-like behaviour has been predicted. Only recently, with the advance of ultraclean 2D electron systems such as graphene, it has become feasible to experimentally access this hard-to-reach regime of electron hydrodynamics [1-11]. To date, hydrodynamic viscous transport has been observed via electrical device measurements [2-7] and scanning probe microscopy [8, 9]. An even more elusive manifestation of hydrodynamic behavior exists: the quantum-critical Dirac-fluid regime with enhanced thermal transport. This regime has been accessed at cryogenic temperatures, where it manifested in a violation of the Wiedemann-Franz law [10] and as a contribution to the Drude scattering rate [11].

Here, we present direct experimental signatures of electron hydrodynamics, including the Dirac-fluid regime, at room temperature in standard quality graphene [12]. We directly track the motion of optically excited electronic heat pulses in the temporal domain using a split-gate device via ultrafast thermoelectric microscopy. This novel technique allows us to quantify heat transport on the femtosecond-nanometer scale and at room temperature. We are able to tune in and out of the Dirac-fluid regime of electron motion using carrier temperature and carrier density as control knobs. We observe a thermal diffusivity of the Dirac fluid that is more than two orders of magnitude larger compared to the non-interacting, diffusive regime. The effect persists at room temperature and shows agreement with transport calculations.

Besides the fundamental breakthrough, we believe that the surprisingly large thermal transport, together with the possibility of switching the effect on and off, could lead to important technological applications, such as nanoscale thermal management.

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