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Super-Diffusion of Excited Carriers in Semiconductors MARCO BERNARDI, EBRAHIM NAJAFI, VSEVOLOD IVANOV, AHMED ZEWAIL, Caltech — We characterize the spatiotemporal dynamics of excited carriers in silicon using scanning ultrafast electron microscopy (SUEM), a technique that combines the nanometer spatial resolution of electron microscopy and the femtosecond time resolution of ultrafast lasers. Following excitation with a short laser pulse, our experiments show direct evidence of a transient super-diffusive regime in which electrons and holes exhibit a diffusivity up to 1,000 times higher than the room temperature diffusivity, $D_0 \approx 30$ cm^2/s. The diffusivity then decreases rapidly for delay times longer than 200 ps, reaching a steady-state value of D_0 roughly 500 ps after the excitation pulse. We attribute the transient super-diffusive behavior to the rapid expansion of the hot carrier gas generated by the laser pulse, which decays to equilibrium with a time scale of 100−150 ps. This interpretation is supported by numerical solution of the diffusion equation with an exponentially decaying diffusivity, as well as ab initio calculations of the initial temperature of the hot carrier gas. Our findings open new avenues for investigating the ultrafast spatial dynamics of excited carriers in materials.

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