Ultrafast Pump-Probe Microscopy of Photocarrier Transport in 2D Materials and Heterostructures

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Optical pump-probe microscopy is a powerful tool to study carrier transport in semiconductors. Its high spatiotemporal resolution allows access to various types of transport phenomena. In this talk, recent progress on using this technique to study carrier transport in 2D materials and their heterostructures will be discussed. Four examples will be used to illustrate the capability of such measurements, including in-plane carrier diffusion, nanoscale ballistic transport, charge transfer in lateral heterostructures, and interlayer charge transfer. At first, diffusion of photocarriers in monolayer semiconductors is monitored by scanning pump-probe microscopy. Exciton diffusion coefficients in various materials are deduced. Secondly, charge transfer across an in-plane junction between MoS_2 and $MoSe_2$ monolayers in a lateral heterostructure is time-resolved by imaging carrier distribution near the junction area. Thirdly, nanoscale ballistic transport of charge carriers is time-resolved by combining pump-probe microscopy with a quantum interference and control technique. Sub-nanometer ballistic transport of charge carriers is observed in ReS_2. At last, multi-beam pump-probe microscopy with tightly focused spots is performed van der Waals heterostructures to reveal the interlayer charge transfer dynamics. These examples show that ultrafast pump-probe microscopy and its variations provide a powerful platform to study various photocarrier transport phenomena.