Thursday, January 9, 2025, 2 pm
RUN auditorium 1st floor

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2D semiconductors: A platform for ultrafast photonics

RUN Colloquium

Layered materials are solids consisting of crystalline sheets with strong in-plane covalent bonds and weak van der Waals out-of-plane interactions. These materials can be easily exfoliated to a single layer, obtaining two-dimensional (2D) materials with radically novel physico-chemical characteristics compared to their bulk counterparts. The field of 2D materials began with graphene and quickly expanded to include semiconducting transition metal dichalcogenides (TMDs). 2D semiconductors exhibit very strong light-matter interaction and exceptionally intense and ultrafast nonlinear optical response, enabling a variety of novel applications in optoelectronics and photonics. Furthermore, stacking 2D materials into heterostructures (HS) offers unlimited possibilities to design new materials tailored for applications. In such HS the electronic structure of the individual layers is well retained because of the weak interlayer van der Waals coupling. Nevertheless, new physical properties and functionalities arise beyond those of their constituent blocks, depending on the type, the stacking sequence and the twist angle of the layers.

This talk will review our recent studies on the ultrafast non-equilibrium optical response of TMDs and their HS. Using high time resolution ultrafast transient absorption (TA) spectroscopy, we monitor the ultrafast onset of exciton formation in TMDs and the dynamics of strongly coupled phonons. Using helicity resolved TA spectroscopy we time-resolve intravalley spin-flip processes. In HS of TMDs we measure ultrafast interlayer hole transfer, interlayer exciton formation and use two-dimensional electronic spectroscopy to dissect interlayer electron and hole transfer processes. We also show that strong exciton nonlinear interactions can lead to a complete quenching of the Rabi splitting in TMD-based microcavities. The demonstrated ultrafast switching between the strong and weak coupling regimes paves the way for the development of TMD based high speed all-optical circuits and neural networks.

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