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Revealing Energy Transfer Pathways in Emerging Two-Dimensional Materials with Laser Spectroscopy[1]

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Atomically-thin two-dimensional (2D) layers exhibit unique new properties depending on their thickness and composition and are being explored as functional "building blocks" for a multitude of energy applications, including optoelectronics, hydrogen generation, batteries, fuel cells, and supercapacitors. The 2D layers can be grown or stacked artificially into heterostructures with infinite variability, depending on their exact atomic registry. However, understanding these assemblies and unraveling the energy transfer pathways in these materials require advanced synthesis, assembly, and characterization methods. Laser spectroscopy is one of the most important approaches to understand and characterize unique optical properties of these materials. In this talk I will give an overview of our recent studies on the optical characterization and energy transfer pathways of semiconducting 2D transition metal dichalcogenides (TMDs) and their heterostructures, which are currently the subject of intense interest worldwide. Low-frequency Raman spectroscopy will be described to quickly and remotely understand their atomic-registry stacking patterns. Since TMD monolayers are basically entirely surface their optoelectronic properties are very sensitive to interactions with substrates and the environment, and also to defects. These interactions are revealed through laser spectroscopy and correlated with specific defects characterized by atomic-resolution electron microscopy. Finally, ultrafast pump-probe spectroscopy will be described to understand the generation and dynamics of excitons and trions in 2D layers, and to explore the transfer of charge between 2D layers and quantum dots, and the excitation of plasmons in order to form a brief overview of the many energy transfer pathways being explored utilizing these atomically-thin materials.

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