WPI

Department of Physics

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PhD Candidate

Physics

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Rm 4911

50 Prescott Street

PhD Dissertation Defense

Title: Ultrafast spectroscopy of 2D MXenes and 1D TiO_2 nanofilaments

Abstract: Nanomaterials have at least one dimension measuring less than 100 nm, such as one dimensional (1D) nanotubes and nanowires or two dimensional (2D) layered van der Waals materials. Their electronic, chemical, and optical properties differ from those of their bulk counterparts due to combinations of factors such as quantum confinement of charge carriers, enhanced electromagnetic interactions, or large surface to volume ratio. In this work, we focus our attention on two classes of nanomaterials, 2D MXenes and 1D lepidocrocite titania nanofilaments (1DL NFs) and use ultrafast spectroscopy to study their optical and electronic properties.

Discovered in 2011, 2D MXenes demonstrate high conductivity and capacitance, efficient light-to-heat conversion, as well as high laser damage threshold. Although a variety of electronic and photonic applications of MXenes have been proposed, such as electromagnetic interference shielding and energy storage, the electronic and optical properties of this family have not yet been fully understood. Here, we use pump-probe spectroscopy techniques in the visible and THz ranges to study the dynamics of photoexcitations in three different MXenes, $Ti_3C_2T_z$, $Mo_2Ti_2C_3T_z$, and Nb_2CT_z. We uncover pronounced plasmonic effects in the visible and near-IR in all three MXenes and demonstrate that the observed kinetics of plasmon bleach recovery following optical excitation provide a means to monitor lattice cooling and carrier-phonon interactions.

1DL titania-based NFs, first discovered in 2022, have sub-nanometer cross-section and the highest band gap energy, 4 eV, reported for titania materials. Despite the high energy gap, they exhibit significant defects and surface state-related optical absorption across the visible range. Using transient optical absorption, we reveal long lifetimes of sub-gap photoexcitations that raise the prospects of applications in photocatalysis and optoelectronics.

Approved for Public Release (PR2024-866)