ABSTRACT

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Ultrafast energy dynamics of two dimensional semiconducting and topological materials

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The search for faster computing and better electronic devices has led to the opening up of several promising routes, which include spintronics, valleytronics, quantum computing and exotic two-dimensional (2D) material based systems, to name a few. Each field has seen a vast amount of research effort in the past decade. Broadly, this thesis explores some of the fundamental aspects of 2D semiconducting and topological materials, via a femtosecond spectroscopy approach.

Two-dimensional (2D) materials offer a platform to explore new physics at the nanoscale. Several common properties such as electrical and thermal conductivity, mechanical strength, chemical reactivity etc. are enhanced in many 2D materials. Furthermore, it is possible to use them in a wide range of devices such as batteries, sensors, heat sinks and transistors. They are also being tested as possible candidates for beyond-silicon technologies, to meet the ever increasing demand for computation. Our research focuses on studying low-bandgap 2D semiconductors, which hold potential for mid-infrared photodetectors, transistors and spin-logic devices. Femtosecond laser spectroscopy is performed with the aim of understanding electron-lattice interaction, electron-hole recombination, spin dynamics and other related effects. Carrier dynamics in black phosphorus, elemental tellurium and topological insulator Bi2Te2Se are explored. The wavelength dependent studies on black phosphorus will elucidate the carrier generation, thermalization, cooling and recombination mechanisms following excitation by an ultrafast laser pulse. Estimates of mobility are deduced from the obtained data. Experiments on air-stable tellurium flakes show radiative and surface recombination characteristics. The recombination coefficients are calculated with a transient diffusion-recombination equation. Lastly, to explore the alternate path to computation, namely spintronics, momentum resolved studies on the topological insulator Bi2Te2Se are performed. The measurements reveal long spin diffusion lengths on the surface, which are comparable to graphene and hold promise for spin FETs and topological quantum computing.