Photophysics of 2D Nanosystems: Raman and Ultrafast Pump-Probe Spectroscopy

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My talk will focus on the rich photophysics of graphene, graphene nanoribbons, single and a few layer MoS_2, single layer black phosphorous (Phosphorene) and MoT_2/graphene hetrostructure, probed using electrical transport along with Raman and ultrafast spectroscopies in the visible as well as in the terahertz range. Insitu Raman spectroscopy of electrochemically top-gated field effect transistors made of graphene[1] and phosphorene[2] will be presented to understand the phonon renormalization due to electron-phonon and electron-electron interactions in these systems. We show that phonons with A_g symmetry depend much more strongly and concentration of electrons than that of holes, whereas phonons with B_g symmetry are insensitive to doping.

Optoelectronic applications of two-dimensional systems require an in-depth understanding of the photoexcited carriers. The dynamics of the electrons, holes and excitons created by the pump laser in the visible range has been explored in our studies by probe lasers in the visible as well as in terahertz range. We show[3,4] that optical pump induced photo-conductivity of graphene in the terahertz range can be either positive or negative depending on the Fermi energy and the carrier momentum relaxation time. The dominant processes contributing to the photo-conductivity are intraband scattering and secondary hot carrier generation due to Coulomb interaction of photo-excited carriers with the existing carriers in the Dirac cone. The cooling of photo-excited carriers is explained in terms of super-collision model. We will present our very recent results on a few layer MoS_2[5]. The dynamics is shown to be governed by the Auger processes as expected due to the unscreened Coulomb interactions in 2D systems.

The last part of my talk with present recent results[6] on enhanced photoresponsibility 20mA/W) using $MoTe_2$-graphene vertical hetrostructures as compared to that of few layer $MoTe_2$ (< 1mA/W).

[1] Biswanath Chakraborty and A.K. Sood, Doping dependence of D-mode dispersion: Signatures of electron-electron interactions (2016)
[2] Biswanath Chakraborty, Satyendra Nath Gupta, Anjali Singh, Manabendra Kuiri, Chandan Kumar, D V S Muthu, Anindya Das, U V Waghmare and A.K. Sood**,** Electron-hole asymmetry in the electron-phonon coupling in top-gated phosphorene transistor, **2D Materials 3, 015008** (2016).
[3] Srabani Kar, D.R. Mohapatra, Eric Freysz and A.K. Sood, Tuning photoinduced terahertz conductivity in monolayer graphene: Optical pump terahertz probe spectroscopy, **Phys. Rev. B 90,** 165420 (2014).
[4] Srabani Kar, Jayanthi Swetha, Eric Freysz and A.K. Sood, Time-resolved spectroscopy of low frequency electronic resonances and optical pump induced terahertz photoconductivity in reduced graphene oxide membrane, **Carbon 80,** 762 (2014).
[5] S. Kar, Yang Su, Rahul Nair, A.K.Sood, Probing photoexcited carriers in MoS_2 laminate by time resolved optical pump terahertz probe spectroscopy. **ACS Nano 9,** 12004 (2015)
[6] Manabendra Kuiri, Biswanath Chakraborty, Arup Paul, Subhadip Das, A.K. Sood and Anindya Das, Enhancing photoresponsivity using $MoTe_2$-graphene vertical heterostructures, **Applied Physics Letters 108, 063506** (2016)