S N BOSE NATIONAL CENTRE
FOR BASIC SCIENCES
Block JD, Sector III, Salt Lake, Kolkata 700 106

DEPARTMENTAL SEMINAR

Condensed Matter and Materials Physics

31st July 2026 **3.00 PM** **FERMION**

SPEAKER

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TITLE OF THE TALK

Probing Defect-Driven Carrier Dynamics in Two-Dimensional Quantum Materials

ABSTRACT

Two-dimensional transition metal dichalcogenides (TMDCs) are promising materials for next generation optoelectronic and photonic devices owing to their strong light- matter interaction and unique excitonic properties. However, defects and ultrafast non-radiative relaxation processes critically influence their performance and are difficult to investigate using conventional optical techniques. In this talk, I will present our recent work on ultrafast visible-pump/mid-infrared-probe spectroscopy for directly probing hidden carrier relaxation pathways in two-dimensional quantum materials. Using a home-built ultrafast mid-IR transient absorption spectroscopy system, we investigate intraband and intra-excitonic transitions in monolayer and few-layer MoS_2. By resonantly exciting the A and B excitons and probing below and above the exciton binding energy, we reveal defect-assisted non-radiative recombination, polarization-dependent carrier relaxation, and the effects of sulfur vacancies and vanadium doping on ultrafast carrier dynamics. Mid-IR probing further reveals how n-type & p-type doping defects alter excitonic interactions and many-body phenomena across the exciton Mott transition, leading to significant changes in carrier mobility and recombination dynamics. Our recent investigations on MoS_2–$MoSe_2$ heterostructures demonstrate the formation and defect-mediated relaxation of interlayer excitons, providing insights into charge-transfer processes relevant for energy conversion and valleytronic applications.

The talk will further highlight our development of compact ultrafast mid-IR pulse-generation techniques and microscope-integrated transient absorption spectroscopy for micron-scale materials, establishing mid-IR spectroscopy as a powerful tool for investigating hidden electronic states in quantum materials. Also, I will briefly introduce our complementary research on femtosecond laser direct writing, including plasmonic nanostructures for ultrasensitive single molecule SERS sensing, ultra-black metal surfaces for stray-light suppression, and high-emissivity laser-textured surfaces developed for thermal management for ISRO and DRDO applications.

Keywords: Ultrafast spectroscopy; Mid-IR transient absorption; TMDCs; Exciton dynamics; Defect engineering, laser direct applications, Super Black Surfaces, single molecule sensing.

References:

(1) Mid-IR Probing Unveils Vanadium Doping-Induced Unsaturation of Defect States in Monolayer MoS_2, npj 2D Materials and Applications,10,14 (2026).
(2) Anisotropic Nonradiative Recombination of Carriers in Few-Layer MoS_2 Probed by Ultrafast Mid-IR Spectroscopy, The Journal of Physical Chemistry C,127,27,13120, (2023).
(3) Femtosecond Laser-Induced Nanoscale Texturing for Super-Black Stainless-Steel Surfaces, Journal of Physics: Photonics,8,025030, (2026).
(4) Highly Sensitive and Stable Surface-Enhanced Raman Scattering on Ladder-Like Nanostructures, Surface and Interfaces 28,101622, (2023).

HOST FACULTY

Prof. Anjan Barman

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