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

Ultrafast Mid-Infrared Spectroscopy: Revealing Hidden Carrier Dynamics and Defect States in Quantum Materials

ABSTRACT

Two-dimensional transition metal dichalcogenides (TMDCs) have emerged as promising quantum materials for next-generation optoelectronic, photonic, and valleytronic devices because of their strong light–matter interaction, tunable excitonic properties, and atomically thin nature.

However, their performance is critically influenced by defects, many-body interactions, and ultrafast carrier relaxation processes that remain difficult to access using conventional visible or near-infrared spectroscopies. In this talk, I will present our recent work on the development and application of ultrafast visible-pump/mid-infrared-probe spectroscopy to investigate hidden electronic states and carrier relaxation pathways in two-dimensional materials. Using a home-built ultrafast mid-IR transient absorption spectroscopy system, we directly probe intraband and intra-excitonic transitions, providing unique insights into defect-assisted non-radiative recombination in monolayer and few-layer MoS_2. Our studies reveal polarization-dependent carrier relaxation, defect-state saturation, and the influence of sulfur vacancies and vanadium doping on ultrafast carrier dynamics. By resonantly exciting the A and B excitons and probing at 0.31 eV and 0.62 eV, below and above the exciton binding energy, we identify distinct non-radiative relaxation pathways inaccessible to conventional optical techniques. We show that pristine MoS_2 exhibits pronounced fluence-dependent defect-state saturation, whereas vanadium doping introduces additional relaxation channels that suppress this behaviour. We also investigate phonon-assisted spin-flip transitions between excitonic states and demonstrate that mid-IR spectroscopy can quantitatively probe carrier mobility and defect-mediated transport.

More recently, we have extended these studies to MoS_2–$MoSe_2$ heterostructures, revealing the formation and relaxation of interlayer excitons relevant to charge transfer and valleytronic applications.

The talk will also highlight our development of compact ultrafast mid-IR pulse-generation schemes, broadband mid-IR sources, and microscope-integrated transient absorption spectroscopy for micron-scale materials. These advances establish ultrafast mid-IR spectroscopy as a powerful platform for probing hidden defect states and ultrafast carrier dynamics in quantum materials.

Finally, time permitting, I will briefly introduce our complementary research on femtosecond laser direct writing, including tunable plasmonic nanostructures for single-molecule SERS sensing, ultra-black metal surfaces for stray-light suppression, and high-emissivity laser-textured surfaces 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.

HOST FACULTY

Prof. Anjan Barman

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