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Unveiling Magnetic Excitations in Low-Dimensional Mn-Doped II–VI Semiconductors

This presentation explores the quantum spin dynamics and magnetic exchange interactions in Mn-doped II–VI semiconductor nanostructures—specifically $(Cd_{1-x}Mn_xSe)_{13}$ nanoclusters and monolayer $ZnSe(en)_{0.5}$—using both optical and neutron-based techniques. These hybrid materials exhibit rich spin-dependent phenomena, including giant Zeeman splitting, exciton–magnon coupling, and magnetic polaron formation, driven by strong sp–d exchange interactions and spin–orbit coupling (SOC) in reduced dimensions. Time-resolved photoluminescence (PL) and magneto-circular dichroism (MCD) measurements confirm spin-polarized excitonic states and magnetic field-tunable photophysics.

To go beyond surface-level magnetometry, we propose a comprehensive inelastic neutron scattering (INS) study—leveraging instruments such as Pelican, SEQUOIA, and ARCS—to directly probe low-energy spin-wave excitations, resolve momentum-dependent spin dispersion, and extract magnetic exchange constants via linear spin-wave theory. Measurements across doping concentrations (0.5–15%), temperatures (2–300 K), and magnetic fields (up to 3 T) will enable mapping of spin fluctuation spectra and exciton–magnon resonances. The use of polarized neutron analysis will isolate magnetic contributions from nuclear background, offering enhanced sensitivity to weak spin excitations in layered materials.

Complementary structural validation by XRD ensures phase purity, while the observed anomalous Bohr magnetons and ligand-dependent spin responses in nanoclusters underscore the importance of chemical control. Collectively, this research establishes a foundational pathway to engineer spin coherence and quantum photonic functionalities in 2D and 0D semiconductors using neutron spectroscopy.

Topical Area

Hard matter: quantum, electronic, semiconducting materials

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