Universität Münster

Aktuelle Fragen der Nanophysik

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Strain-Engineering Low-Dimensional Excitons: A Building Block for Nanotechnology

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Modern technology relies on powerful, compact devices that can communicate worldwide within seconds. However, the scaling limits of transistors and the advent of quantum computing – which can, in principle, breach our current communication systems – are forcing us to search for alternative solutions to push these boundaries even further. Interestingly, excitons – excited states of matter consisting of an electron and a hole bound by Coulomb interaction – in low-dimensional semiconductors offer a suitable platform for both tasks. Furthermore, leveraging mechanical deformations to tune their optical properties allows us to both explore fundamental phenomena and engineer excitonic behavior.

In this talk, I will discuss my research activity on strain-engineering low-dimensional excitons, focusing on two distinct platforms: monolayer Transition Metal Dichalcogenides (TMDs) and GaAs/AlGaAs quantum dots. By leveraging patterned substrates, hydrogen irradiation, and micromachined piezoelectric actuators, we induced static and dynamic strain fields to investigate and tailor their optical properties for fundamental studies and advanced quantum optics applications.

First, I will present our results on monolayer TMDs, where carrier confinement occurs out of plane. Specifically, we demonstrated that the direct-to-indirect transition in hydrogen-filled, monolayer-thick domes can be dynamically tuned. Furthermore, we showed that a highly anisotropic strain field significantly enhances photoluminescence brightness, enabling the observation of room-temperature linear polarization from valley coherence.

Second, I will focus on GaAs/AlGaAs quantum dots, where carriers are confined in all three dimensions. In this system, we applied triaxial stress to eliminate structural asymmetry and finely tune the emission energy. These tailored features proved pivotal in demonstrating quantum state teleportation—even over an urban link in a metropolitan scenario—and entanglement swapping with remote sources. Ultimately, interfacing such distinct emitters represents a vital step toward future quantum networks capable of sharing entanglement between separate nodes.