Observation of controlled orbital coupling in O-band InAs/InGaAs quantum dot molecules

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Epitaxially grown semiconductor quantum dots (QDs) and QD-molecules are a basis for modern photonic quantum technologies. Compared to spin qubits in III-V QDs, singlet-triplet logical qubits in optically active QD-molecules have been recently shown to have enhanced coherence times, due to suppressed coupling to magnetic noise [1].

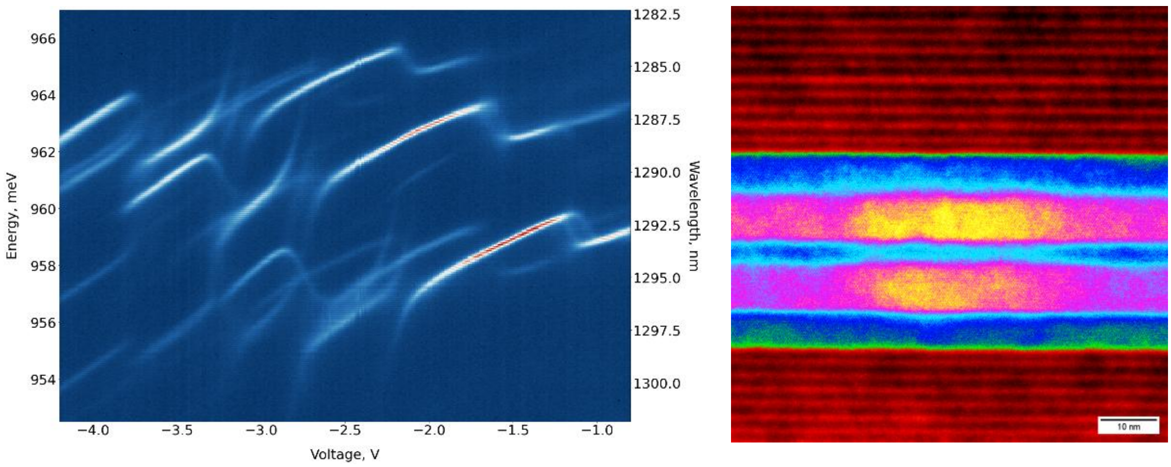

Fig.1 Bias-dependent μPL spectrum of InAs/InGaAs QDM (left) and a false-color cross-sectional HAADF-STEM image of a single InAs/InGaAs QDM with 3 nm GaAs barrier (right).

We present the first direct experimental observation of electrically tunable quantum orbital couplings and spin interaction in individual vertically stacked asymmetric InAs/InGaAs QD-molecules emitting in the O-band (Fig.1). The InAs/InGaAs QD layers, separated by a 3–10 nm GaAs barrier, were symmetrically positioned near the center of the intrinsic region of a p-i-n diode, enabling tunability of excitonic transition energies and orbital couplings. To further enhance wavelength tunability, the QD-molecules were embedded in a GaAs/AlGaAs quantum well [2], enabling the quantum-confined giant Stark effect. By tuning the internal electric field into samples containing InAs/InGaAs QD-molecules, we observed distinct anticrossings [1,3] of different charge-state transitions and the presence of kinetic exchange interaction (Fig.1 left). The correlation of MBE growth parameters with structural properties and optical properties of the developed QD-molecule heterostructures is discussed in detail.

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[2] A.J. Bennett, et al. Appl. Phys. Lett. 97(3), 031104 (2010)
[3] J. Schall, et al., Adv. Quan. Tech. 4(6), 2100002 (2021)