Nano-optical probing of electron wave functions in quantum dot systems

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Semiconductor quantum dots (QDs) are promising candidates as building blocks of future quantum devices due to the ability to maintain and control optical/spin coherence over practical time scale. For optical quantum information processing based on QDs, the real-space coherent optical probing and manipulation of their wave functions will be a key technique. Recent progress in near-field scanning optical microscopy (NSOM) enables us to address single QDs with a spatial resolution on a 10 nm length scale and to map the optical dipole (wave function) in space. We describe near-field photoluminescence PL imaging spectroscopy of GaAs QDs with a spatial resolution of 30 nm to map out the center-of-mass wave function of an exciton [1]. The spatial profile of the exciton emission, which reflects the shape of a monolayer-high island, differs from that of biexciton emission, due to different distributions of the polarization field for the exciton and biexciton recombinations. Furthermore, imaging of specific features of excited-state wave functions is also demonstrated. The novel technique can be extensively applied to wave function engineering in the design and the fabrication of quantum device.

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[1] K. Matsuda, T. Saiki, S. Nomura, M. Mihara, Y. Aoyagi, S. Nair and T. Takagahara, Phys. Rev. Lett. 91, 177401 (2003).

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