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The quantum dot molecule from an optical point of view

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For over ten years the techniques of single quantum dot optical spectroscopy has enabled rapid progress in the fundamental understanding of quantum dots and in the application of quantum information concepts [1]. We now apply these ever improving optical techniques to two self-assembled InAs/GaAs quantum dots that are coherently coupled through tunneling that is, a quantum dot molecule [2]. The optical spectrum of a quantum dot molecule is much richer than that of a single quantum dot. As one might expect, there is both new physics and enhanced opportunity for quantum information applications. We find that the optical spectrum of single QD molecules charged with 0, 1, or 2 electrons or holes show intriguing and unique patterns of anti-crossings and spin exchange splittings that are readily understood in terms of a few simple concepts. Closer inspection is revealing new information and opportunity, however. For example, on the fundamental side, we have recently discovered evidence that the ground state of the molecule can be an anti- bonding state when it is the hole that tunnels between the dots a new effect not found in atoms. On the quantum information side, we have engineered a quantum dot molecule in which we can simultaneously control and nondestructively measure the spin of a single electron. This solves a serious limitation in the optical control of single quantum dots. These studies are laying the groundwork necessary to enable optically controlled entanglement of two spins. Here I give an overview of our current understanding of this system from an optical point of view.

[1] "Optical Studies of Single Quantum Dots" D. Gammon and D.G. Steel, Physics Today 55, 36 (2002).
[2] "Optically Mapping the Electronic Structure of Coupled Quantum Dots," M. Scheibner et al. Nature Physics 4, 291 (2008).