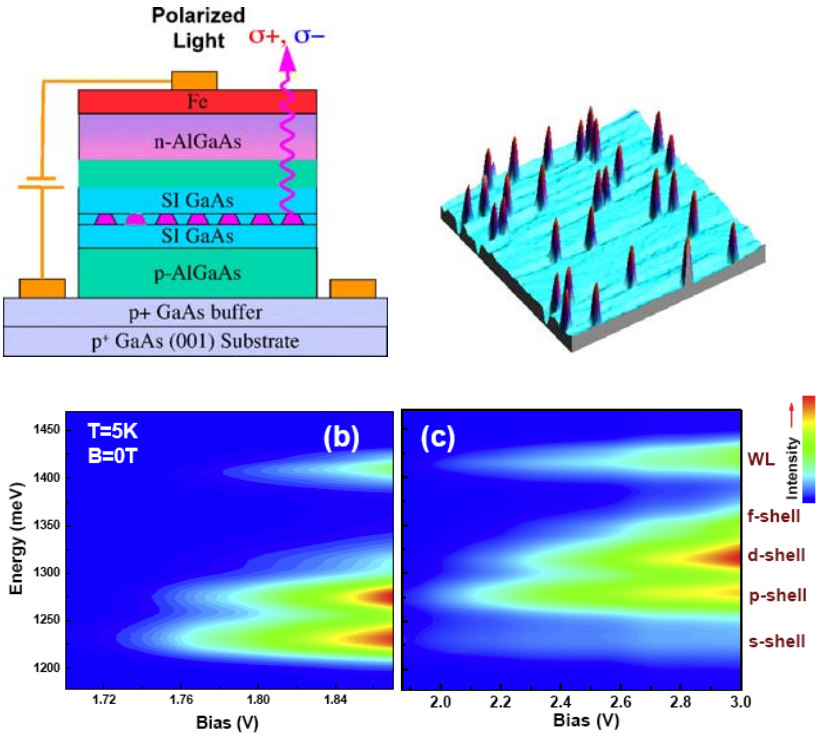
Intershell Exchange in Spin-Polarized Semiconductor Quantum Dots

Semiconductor Quantum Dots (QDs) are nanoscale circular disks of one semiconducting material, typically 3 nm high by 30 nm in diameter, embedded within layers of a second material. They are attractive for a variety of quantum information processing, electronic and spintronic applications. In the latter, the electron's *spin* rather than charge is used to store and process information. The *International Technology Roadmap for Semiconductors* has identified the electron's spin as a new state variable which should be explored as an alternative to the electron's charge for use beyond CMOS. The QD electronic structure exhibits the *s,p,d,f* shells characteristic of single atoms, so they are often referred to as "artificial atoms."

NRL scientists from Code 6361 lead by Dr. Berend Jonker have recently demonstrated the ability to control the spin population of the individual quantum shell states of self-assembled indium arsenide (InAs) QDs using a spin-polarized bias current from an iron (Fe) thin film contact, and determined the strength of the interaction between spin-polarized electrons in the *s*, *p* and *d* shells. They monitor the shell population and spin polarization by measuring the polarized electroluminescence (EL) as a function of the bias current from the Fe contact.
An analysis of the EL spectra provides the first experimental measure of the exchange energies between electrons in the *s*- and *p*-shells, and between electrons in the *p*- and *d*-shells. These energies describe the degree of interaction between these quantum levels. These results are significant for our ability to utilize QDs in active devices or for information processing.



InAs QDs embedded in an AlGaAs/GaAs structure, with an atomic force microscope image of the uncovered QDs to the right. As the bias current is increased, the shell states fill, and the electroluminescence (EL) from the QDs exhibits peaks characteristic of the s,p,d,f shell energies and the initial wetting layer (WL), as labeled in the figure.

G. Kioseoglou *et al*, "Intershell exchange and sequential electrically injected spin populations of InAs quantum dot shell states," *Physical Review Le*tters 101, 227203 (2008).

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