

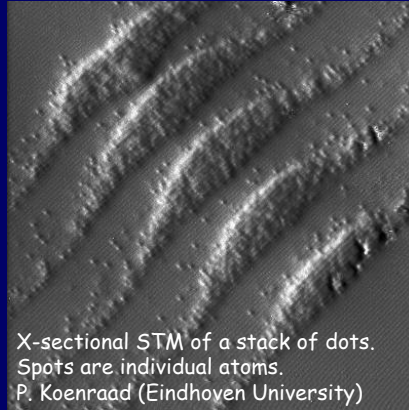
Self Assembled Quantum Dots

Quantum Dot

- An 'artificial atom', a man-made structure in which electrons can be confined in all 3 dimensions. By changing the structure of the dot we can create systems with electronic properties not seen in nature.

STM imaging

- Scanning tunnelling microscopes (STMs) are used to image structures to an atomic level of detail.



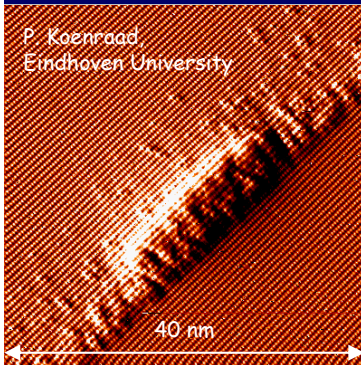
X-sectional STM of a stack of dots. Spots are individual atoms. P. Koenraad (Eindhoven University)

Nanoscale engineering

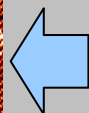
- The dots self assemble when two semiconductors of different lattice spacing are grown on top of each other.

- The quantum dot length is roughly 1/100,000x that of a pin head.

- Self assembled dots have many uses as nanoscale device components. For example: in opto-electronics, as single electron devices, as solid state lasers and in quantum computing.

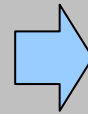


P. Koenraad, Eindhoven University

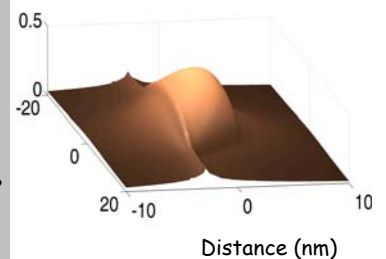


We can determine the dot shape, size and composition with detailed STM imaging. The image shows a X-sectional view of a truncated pyramidal $\text{In}_x\text{Ga}_{1-x}\text{As}$ dot in a GaAs matrix. The Indium fraction, x is higher at the top of the dot.

The dots are under tremendous strain (100x the strain in the blades of a jet engine). We deduce the strain from the distance the dot bulges out of the surface when it is cleaved.



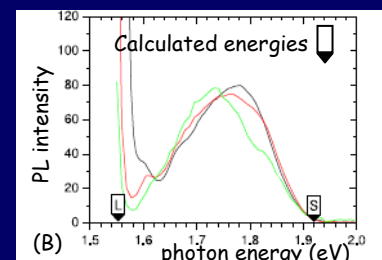
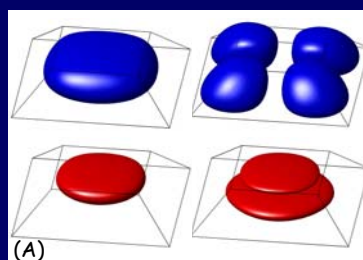
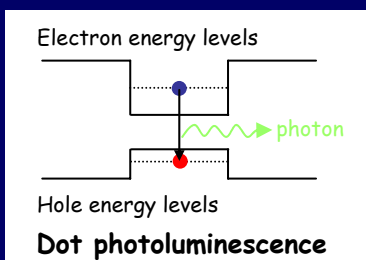
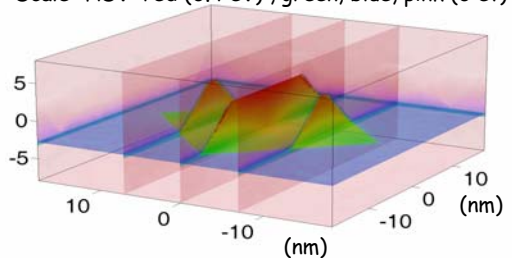
Calculated dot deformation



The quantum states and dot photoluminescence

- To model quantum dot devices accurately we must first understand the electronic structure of the dot.
- Self assembled dots are unique: they can confine both electrons and holes (an absence of an electron from the valence band). It is this property which makes self-assembled dots ideal for opto-electronic applications.
- Electrons and holes are trapped in the dot due to the difference in band gap of the two semiconductor materials: the confinement potential (right) is strongly dependent on the physical structure and strain in the dot.

Electron confinement potential
Scale- HSV: red (0.4 eV) , green, blue, pink (0 eV)



Light is created when an electron recombines with a hole. This is the basis for the quantum dot laser. We can change the colour of light by modifying the dot structure to alter the energy levels.

We have recently investigated photoluminescence in a new system: InAs quantum dots in AlAs. (A) shows the 1st and 4th electron (blue) and hole (red) densities. (B) shows the measured photoluminescence (Eindhoven) from an ensemble of InAs/AlAs dots of different sizes and the calculated spread of energies (Leicester). Smaller dots produce higher energy photons (right arrow).