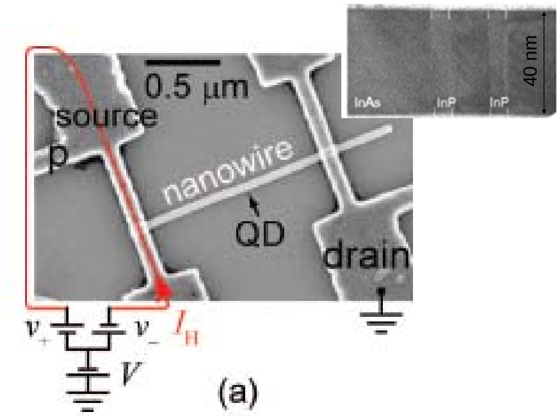
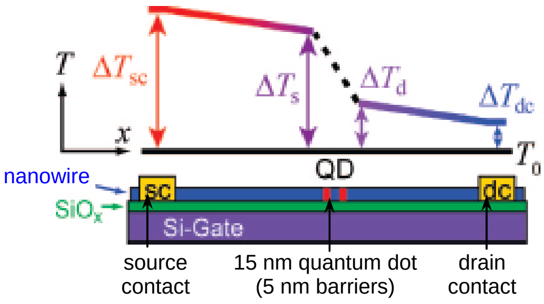
NNI Scientific Accomplishments 2009

Quantum Dot Thermometry

Quantum size effects can modify the thermal (phononic) and electronic transport properties of nanoscale composite materials in novel ways that have significant performance implications for such semiconductor devices as high efficiency thermoelectrics, high-speed transistors, and light emitting diodes. They also involve temperature gradients across very small distances. Measuring these temperature differences to gain a fundamental understanding of these effects has required separate calibration experiments. Distinguishing between electronic and lattice (vibrational) contributions to the thermal transport has been a further complication.

Eric Hoffmann, Heiner Linke, and colleagues at the University of Oregon and Lund University have demonstrated a new measurement technique that overcomes these difficulties. This “quantum-dot thermometry” exploits the dependence of current flow on the distribution of electrons on either side of a single 15 nm quantum dot embedded in a micron-long nanowire.





An SEM image of the InAs nanowire with source and drain contacts. The indicated InP/InAs/InP quantum dot (QD) embedded in the nanowire is shown in the inset. The voltage, V, biases the nanowire electrically, and the heating current, IH, biases the nanowire thermally. The voltage probe (p) assists in tuning the heating voltages, V.	A schematic (not to scale) of the temperature profile along a nanowire with an embedded quantum dot (QD), a heated metallic source contact (sc), and an unheated metallic drain contact (dc). In the source and drain contacts, the electron gas temperature rises by ΔT_{sc} and ΔT_{dc} above the cryostat temperature, T_0, respectively. In the nanowire, the electron gas temperature rises by $\Delta T_{s,d}$ near the source and drain sides of the quantum dot, respectively ($\Delta T_{sc} \geq \Delta T_s \geq \Delta T_d \geq \Delta T_{dc}$).

References: Hoffmann, E. A. *et al*. Measuring temperature gradients over nanometer length scales. *Nano Letters* **2009**, *9*, 779-783; Hoffmann, E.A. *et al*. Quatum-Dot Thermometry, *Appl. Phys. Lett.* **2007**, *91*, 252114.

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