IUPAP Commission 17

Quantum Electronics

Working Group on Nanoscience

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Ecole Normale Superieure

Paris, France

April, 2005

Commission Conferences

IQEC (International Quantum Electronics Conference)

- Moscow, Russia 2002
- Tokyo, Japan, 2005

International Symposium "Modern Problems of Laser Physics"

- Novosibirsk, Russia 2004

Session Titles at IQEC 2005

- Quantum Nanostructures, Optics, and Applications
  - A. Forchel, Wuerzburg University

  "Strongly Coupled Single **Quantum Dot**-Microcavity System“
  - D. Awschalom, University of California, Santa Barbara

  "Optoelectronic Control of Electron and Nuclear Spins in Semiconductor **Nanostructures**"

- Cold Atoms, Cold Molecules, Collective Quantum Phenomena and Atom Optics
  - Similar to C15

- New Trends in Chemistry, Biology and Other Fields
  - D. Miller, Stanford University

  "**Nanoresonators** and **Nanophotonics**“
  - S. Fainman, Univ. California, San Diego,

  "Ultra Short Surface Plasmon Polaritons in Photonic Crystal Structures"

Session Titles at IQEC 2005

- Photonic Nanostructures and Devices
  - Y. H. Lee, KAIST
    "Photonic Crystal **Nanolasers** by Optical and Electrical Pump“
  - M. Notomi, NTT Basic Research Laboratories,
    "Nonlinear Switching by Photonic-Crystal **Nanocavities** for All-Optical Digital Processing"
- Near-field Optics and Applications
  - Y. Inoue, Graduate School of Frontier Biosciences
    "Tip-Enhanced Near-Field Raman Spectroscopy for Molecular **Nano-Imaging**“
- THz Emission and Spectroscopy
  - T. Norris, Michigan University
    "**Nanoacoustics**: Propagation and Imaging with THz Coherent Phonons“
  - S. Komiyama, University of Tokyo
    "Photon Counting THz Imaging with **Quantum-Dot** Detectors"

Session Titles at IQEC 2005

- Nonlinear Optics and Materials
  - H. Kamada, NTT Basic Research Laboratories

  "Coherent Nonlinear Effects in a Single **Quantum Dot**“
- Single Photon Emission and Entanglement States for Quantum Information
  - J. Vuckovic, Stanford University

    "Single Photon Source Based on a **Quantum Dot** in Photonic Crystal“
- Dynamics of Photoinduced Phase Transition
  - M. Rini, Lawrence Berkeley National Laboratory

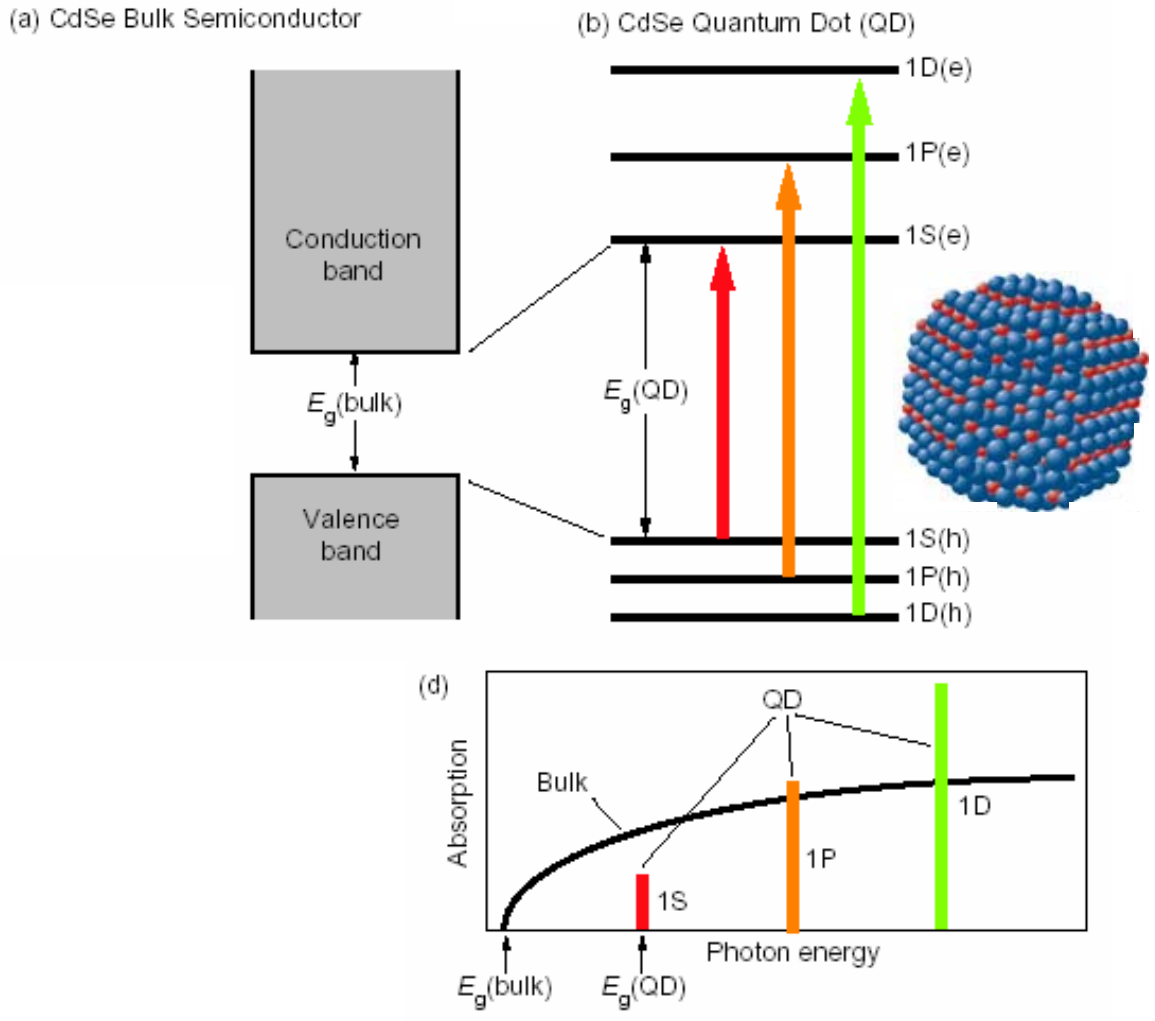
  "On Photo-Induced Phase Transitions in Strongly Correlated **Nanosystems**”
- Plenary Speaker
  - Prof. Zhores Alferov

    Director, The Ioffe Institute, Russia

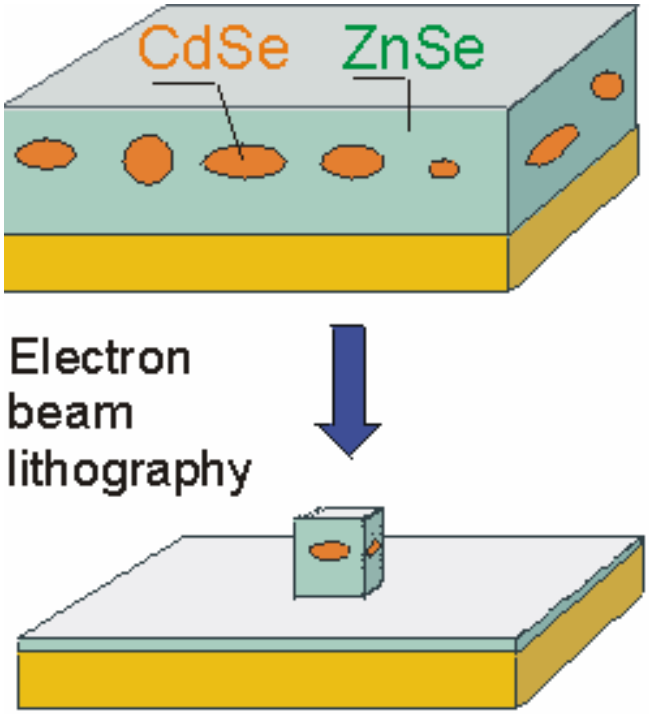
    2000 Nobel Laureate in Physics

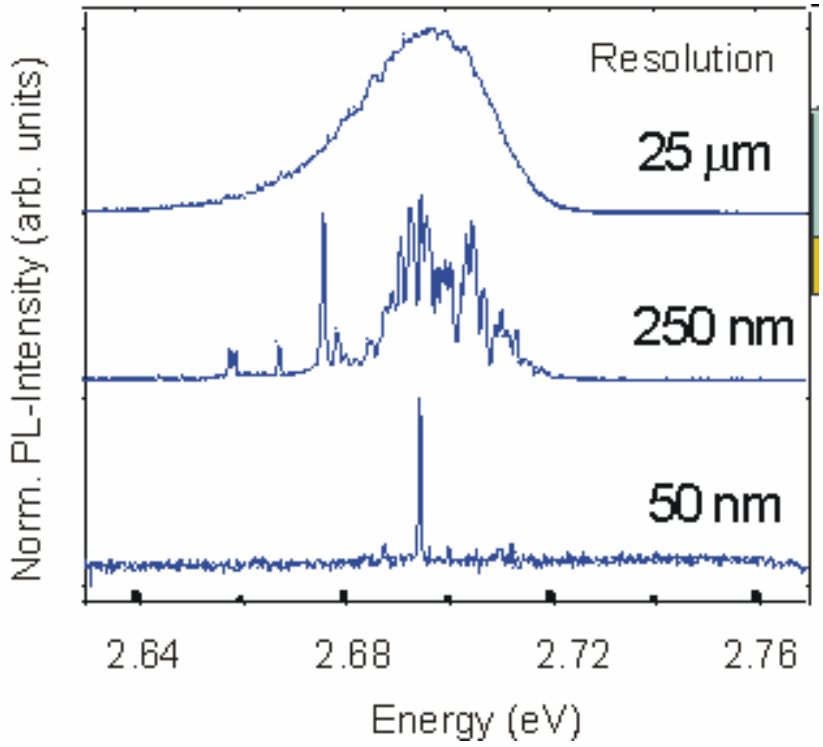
    "Past, Present and Future of Semiconductor Lasers and Related **Nanophotonic** Devices"

Nanocrystal Quantum Dots: Artificial Atoms



Single Quantum Dot Spectra



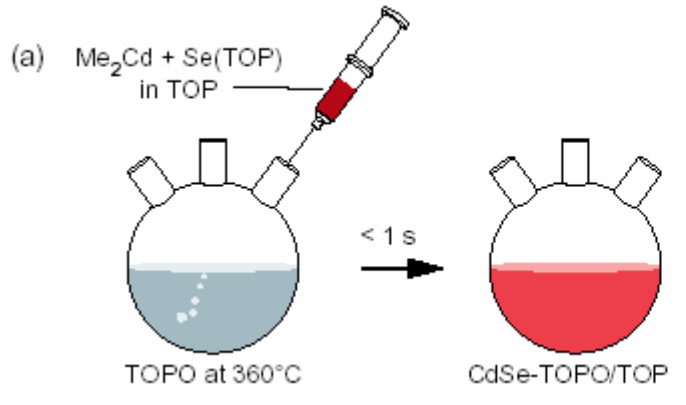


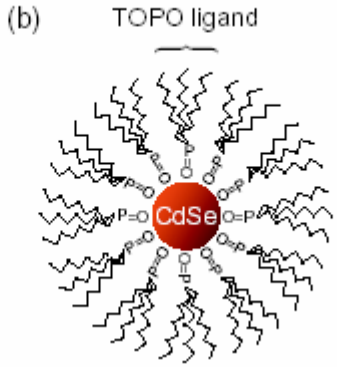
University of Wurzburg
Dr. Lukas Worschech

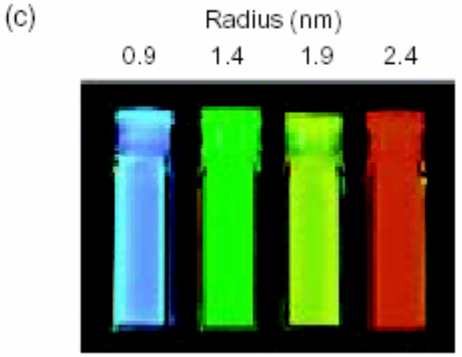
Fabrication of Nanocrystals

Bawendi Group – MIT

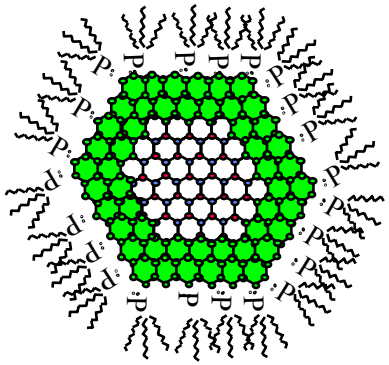
Banin Group – Hebrew Univ.

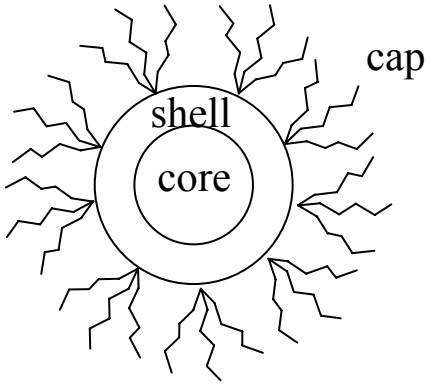






NQD Light Emission





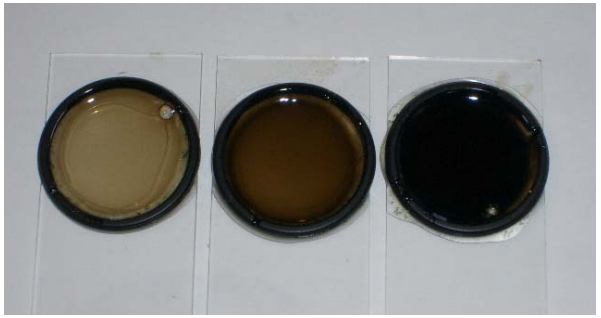
Nanocrystals

CdSe and CdTe -Shell of ZnS
3-6 nm
visible

PbSe - No shell
8 nm
infrared (1.5 micron)

InAs - Shell of CdSe and ZnSe
7-8 nm
infrared (1.5 micron)

Photography by Felice Frankel

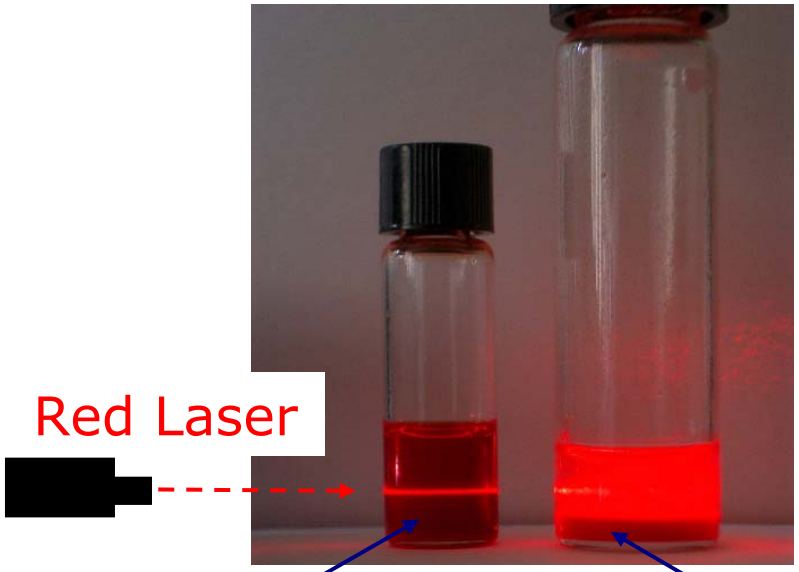


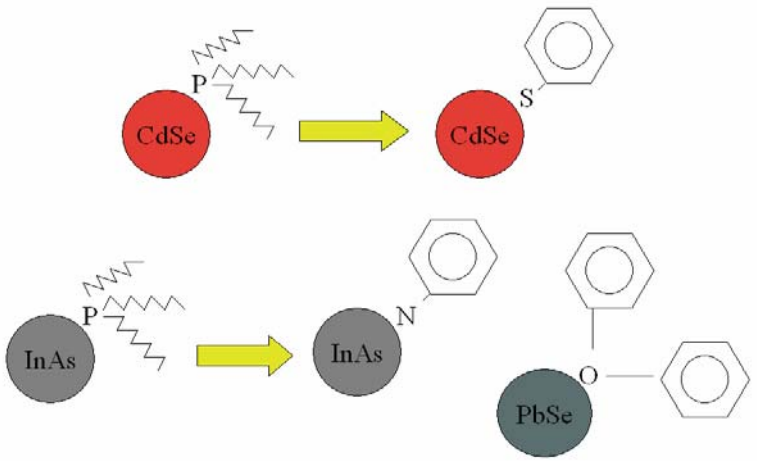
Incorporating the NQDs: Cap Exchange

To incorporate the NQDs into the matrix, the caps needs to be exchanged:

Aromatic polymer ➡

Aliphatic chains exchanged by aromatic groups

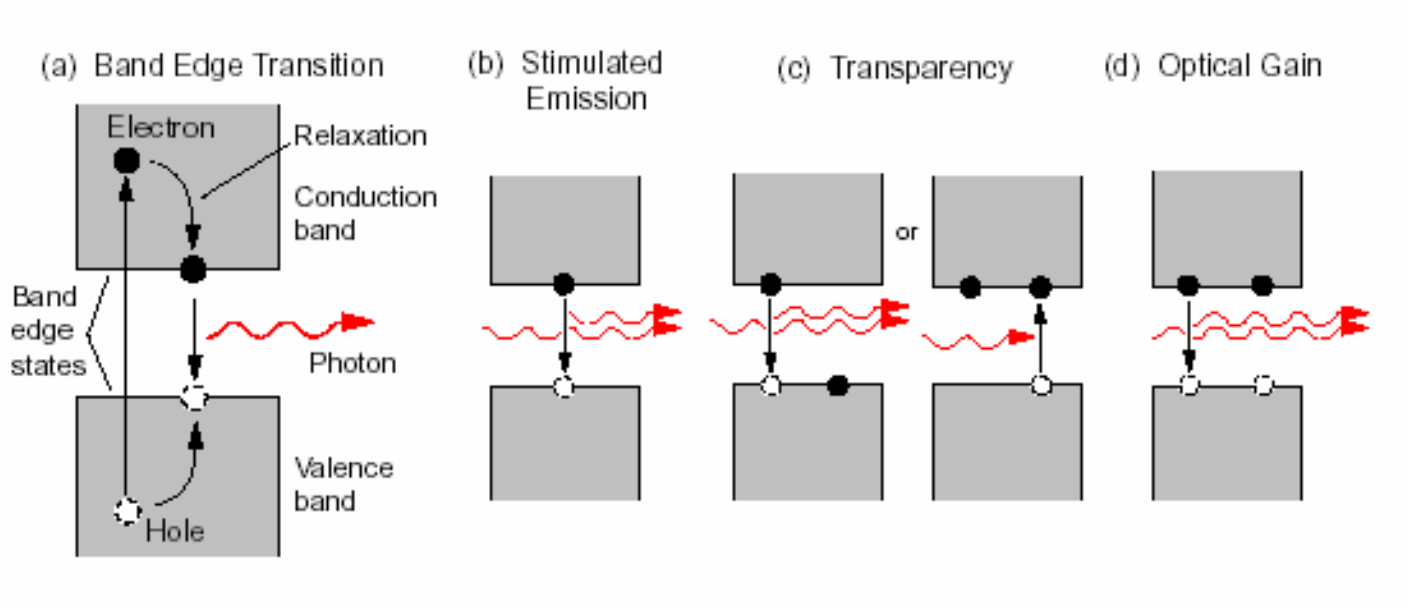




After Cap Exchange
(clear solution)

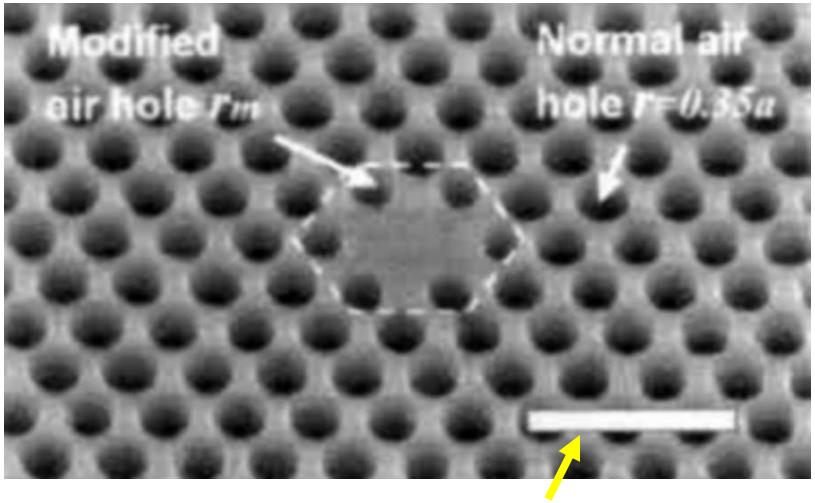
Before Cap Exchange
(NQD sediment, scattering)

Nanocrystal Quantum Dots as Lasing Media



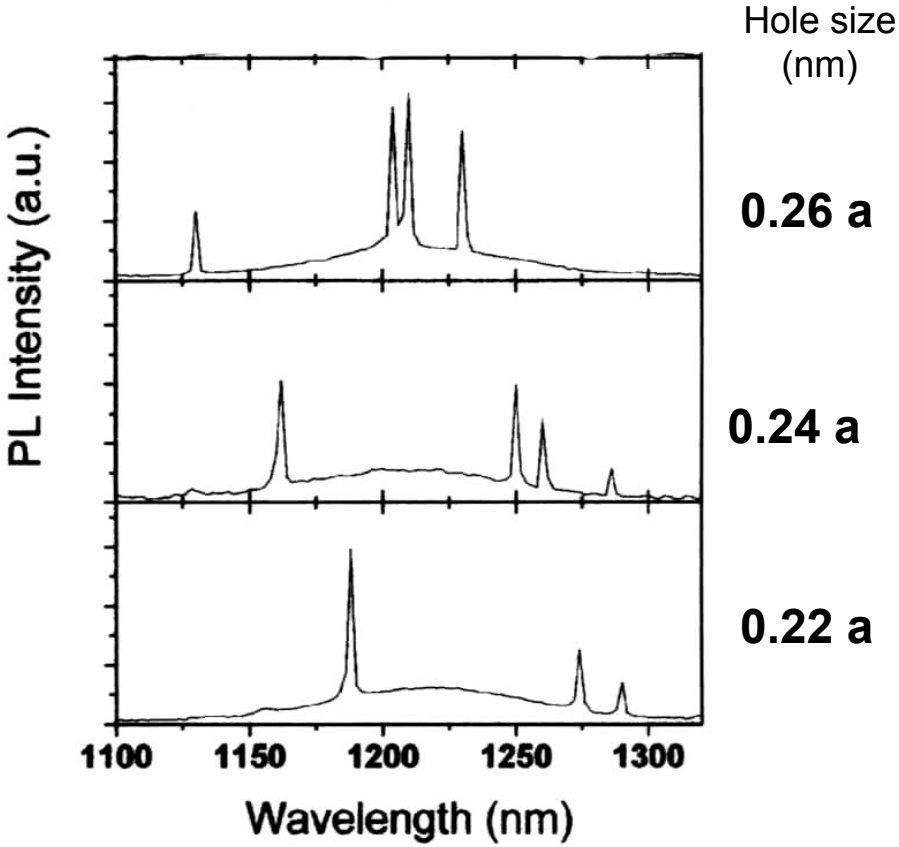
- Lower threshold than 3D and 2D lasers
- Wavelength (size) tunability
- Thermal gain stability

Photonic Crystals Nanoresonators



1000 nm

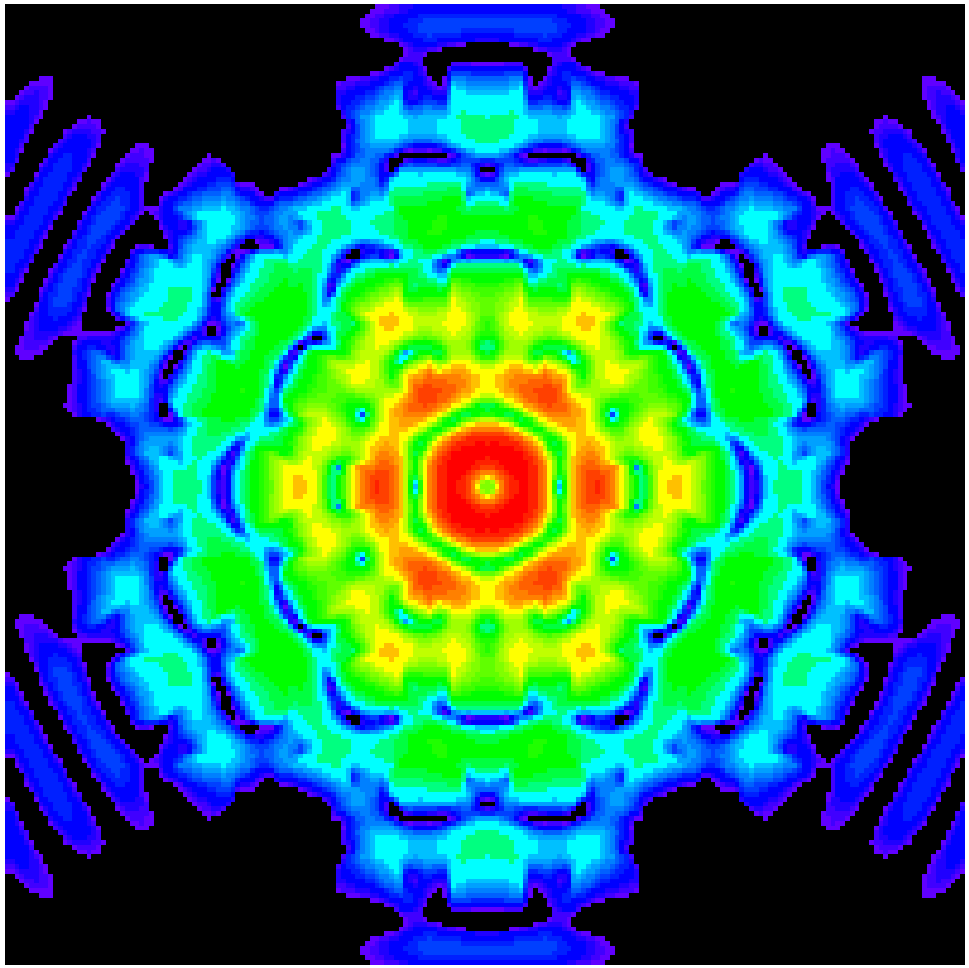
Lattice constant = a
Resonator Q ~ 2000



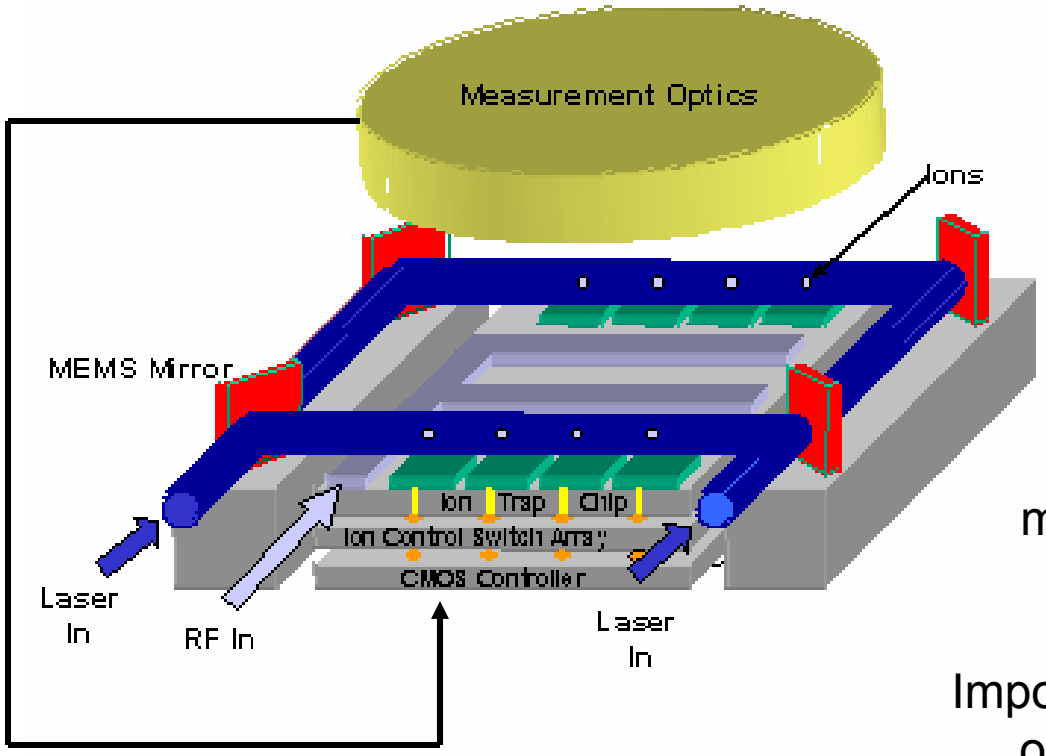
Tuning resonator with
Nearest hole size

Y. H. Lee, J. Vac. Sci. Tech. B **23**,252(2005)

Nanoresonator Mode



Quantum Information Processing multiplexed ion traps



System of trapped ions and MEMS controlled laser beams for quantum information processing

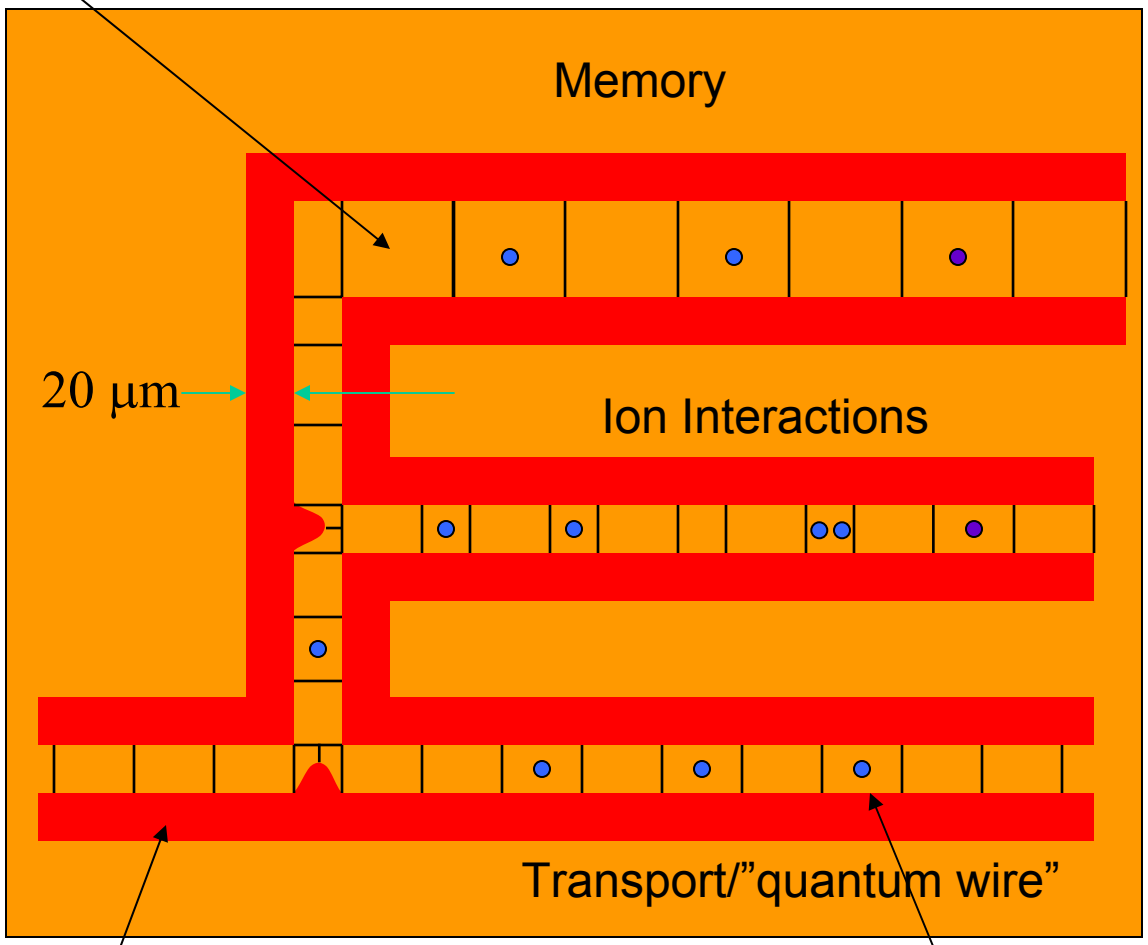
>1000 ions/cm^2

Quantum error correction requires many classical optical measurements fed back to ion controls

Important example of interfacing nano-scale objects (trapped ions) to macroscopic measurements and readout.

Quantum states are nuclear hyperfine levels of ions

Multiplexed ion traps and quantum wires



Area/trap complex ~ 1x1 mm^2

~ 50 vias/trap complex

~10 ions/complex
- ~ 4 computing ion
- ~ 4 memory ions
- ~2 cooling ions

~ 2000 traps/cm^2

Summary

- Nanoscale quantum electronics
  - Quantum dots
  - Photonic crystals
  - Nanolasers
  - Nano-optical probes (e.g. single molecule Raman)
  - Nonlinear photonic crystals
- Links to broader nanoscience
  - Molecular biophysics
  - Collective dynamics in condensed matter
  - Quantum information
  - AMO