Quantum dots in photonic crystal cavities

Stephanie Manz, 18-06-2009

Seminar *Elements of Nanophotonics*

motivation

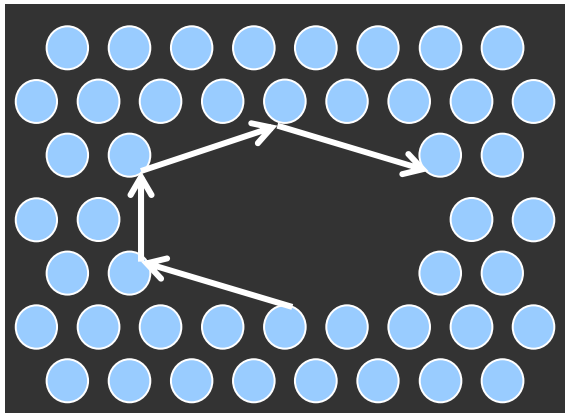
- cQED: interaction between single emitter and cavity

- solid state cavity + quantum dot: small mode volume

→ strong coupling regime ($g_0 \sim V^{-1/2}$)

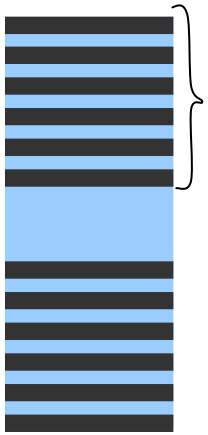
cavities: photonic crystals and micropillars

photonic crystal cavities:



- band gap material
- membrane can consist of layers
- total internal reflection in plane
- cavity modes according to geometry
- typical scale: 200 - 500 nm

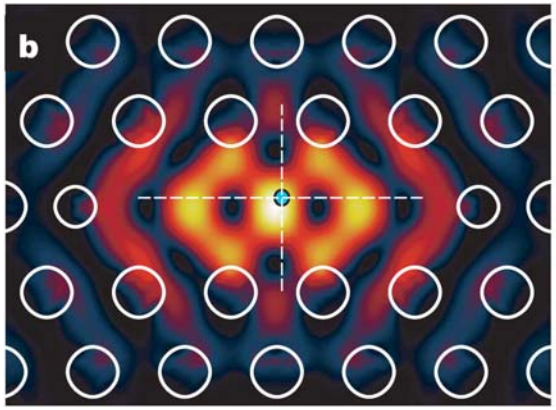
micropillars:



- DBR act as mirrors
- radial confinement by tot. int. Ref
- typical scale: 1µm x n*500nm

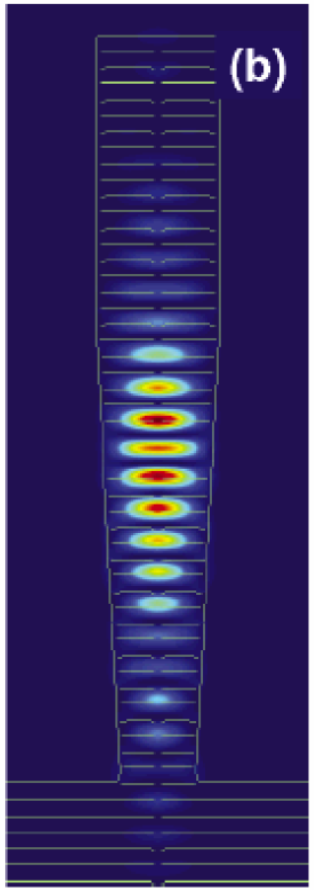
cavities: photonic crystals and micropillars

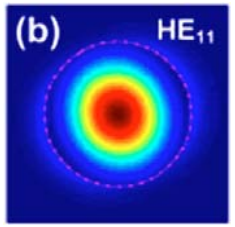
photonic crystals:

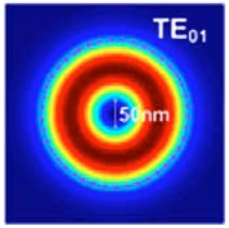


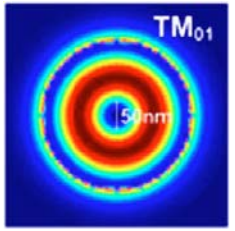
- quantum dot placed in maximum of cavity mode (might be off center)

micropillars:



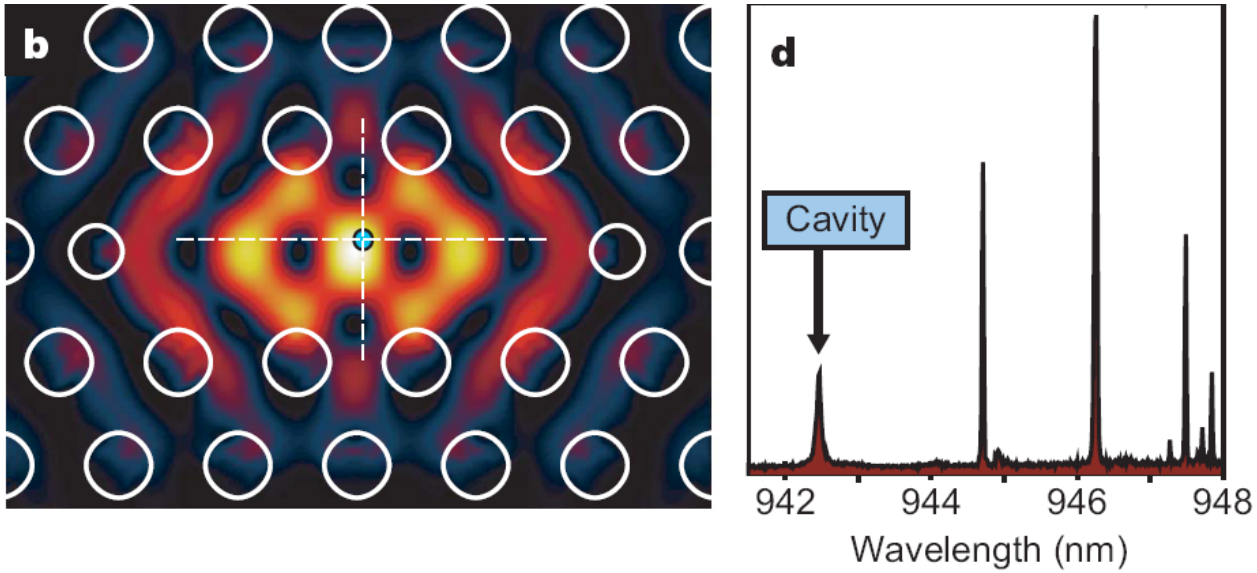






lecture notes;Yinan, Opt. Lett. ,**34** ,7 (2009)

quantum dot – cavity coupling

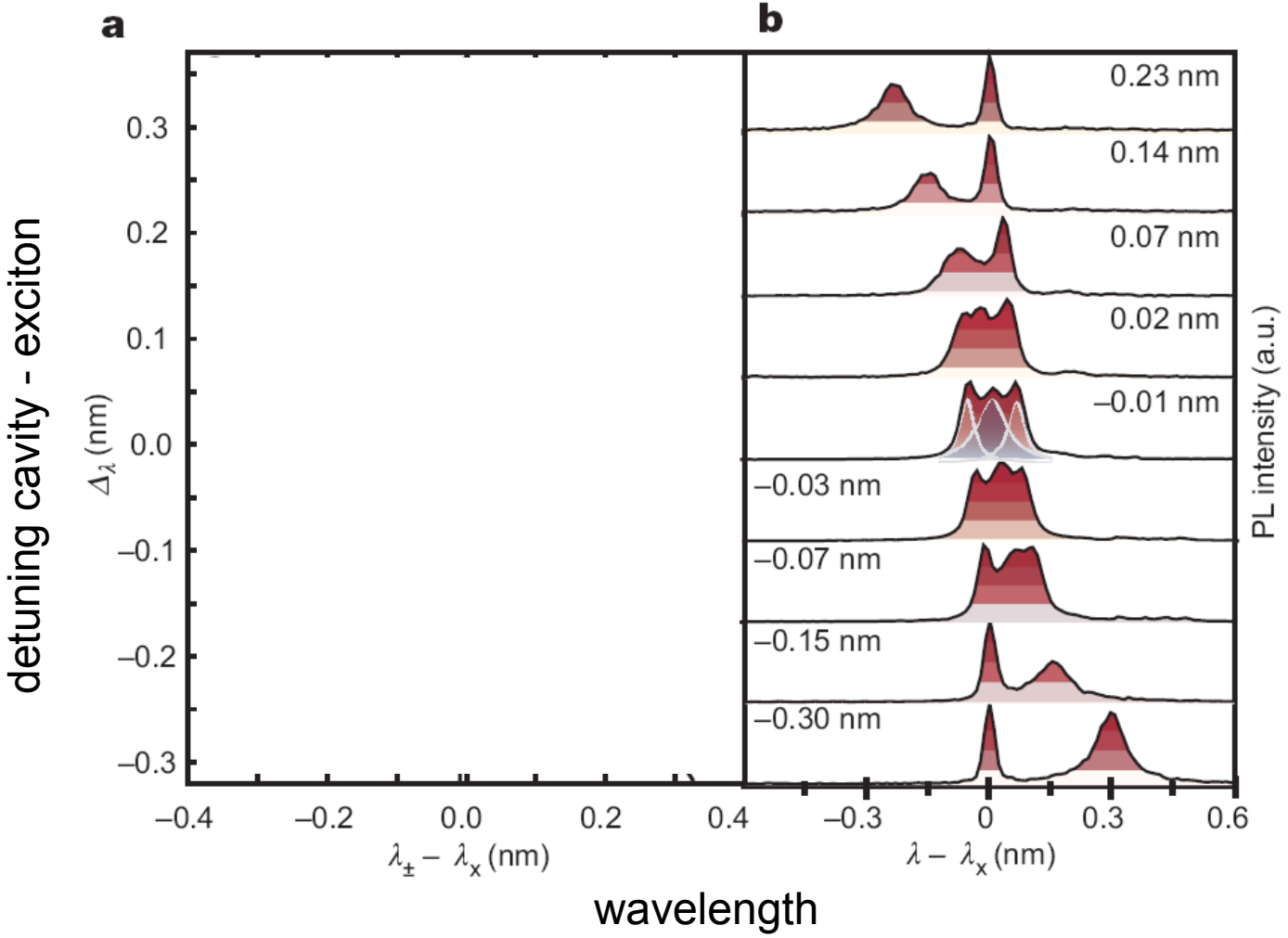


- quantum dot is prepared on substrate (random position)
- cavity is fabricated arround, overlap mode with QD
  → quantum dot emissions, cleary separated
- tune cavity mode further
- proove existence of single emitter by $g^{(2)}(t=0)$ measurment

Quantum nature of a strongly coupled single quantum dot–cavity system
K. Hennessy, …, A. Imamoglu, nature 05586, 1 (2007)

strong coupling: line repulsion and Rabi splitting

line repulsion: Rabi splitting:



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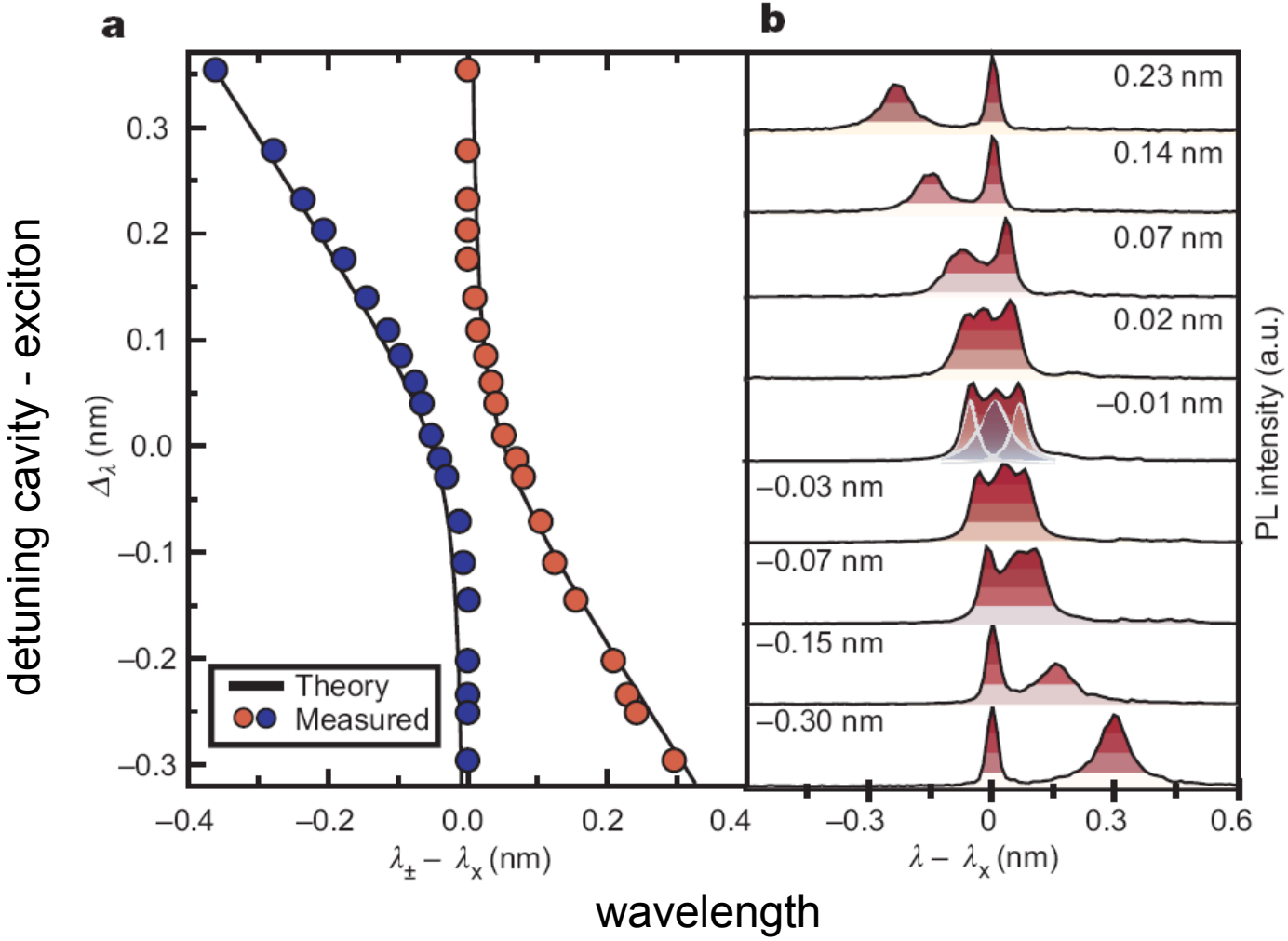

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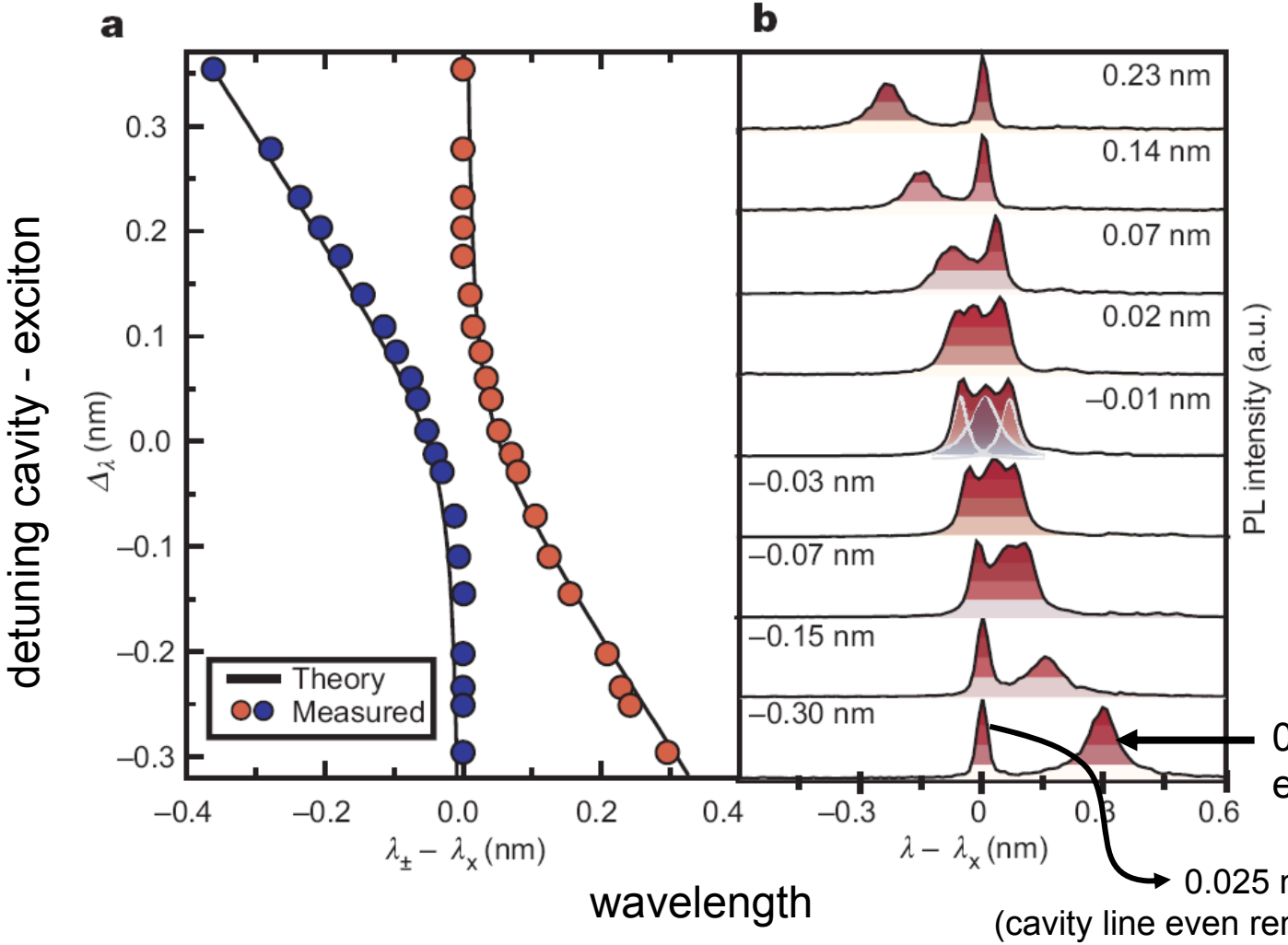

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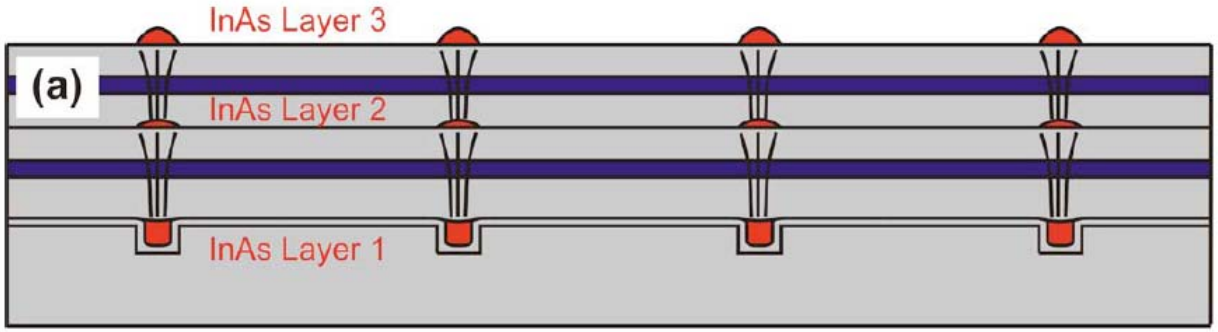
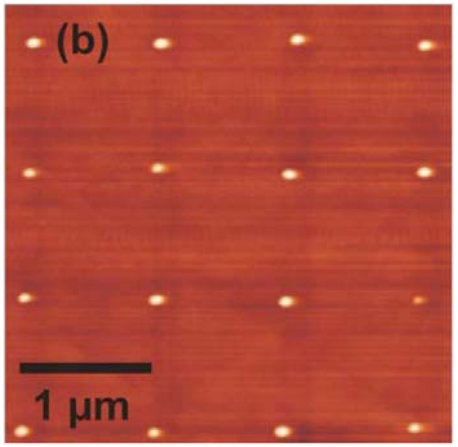
site control in micropillar





fabrication: - bottom part of DBR (AlAs / GaAs)
- bottom half of cavity (GaAs)
- lithography / etching of nano-holes
- overgroth
- grow quantum dot, repeat three times to improve quality

→ quantum dots form at former hole position
→ strain remains after overgroth → quantum dots stacked

Single photon emission from a site-controlled quantum dot – micropillar cavity system
C. Schneider, …, A. Forchel; APL 94, 111111 (2009)

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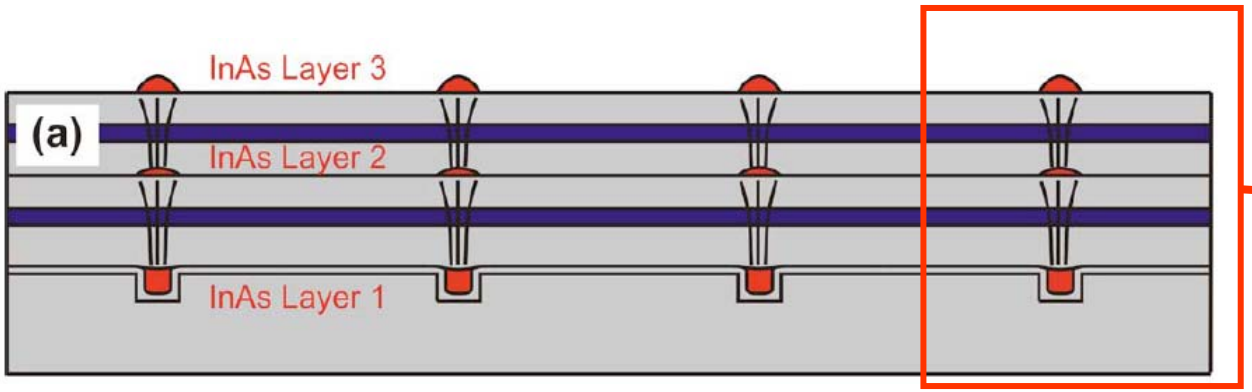

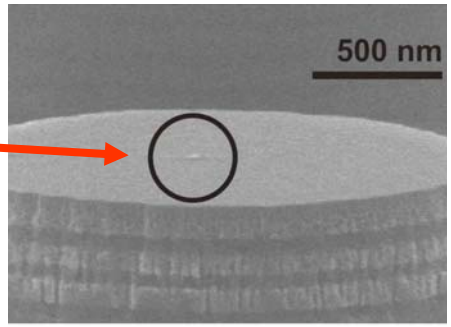

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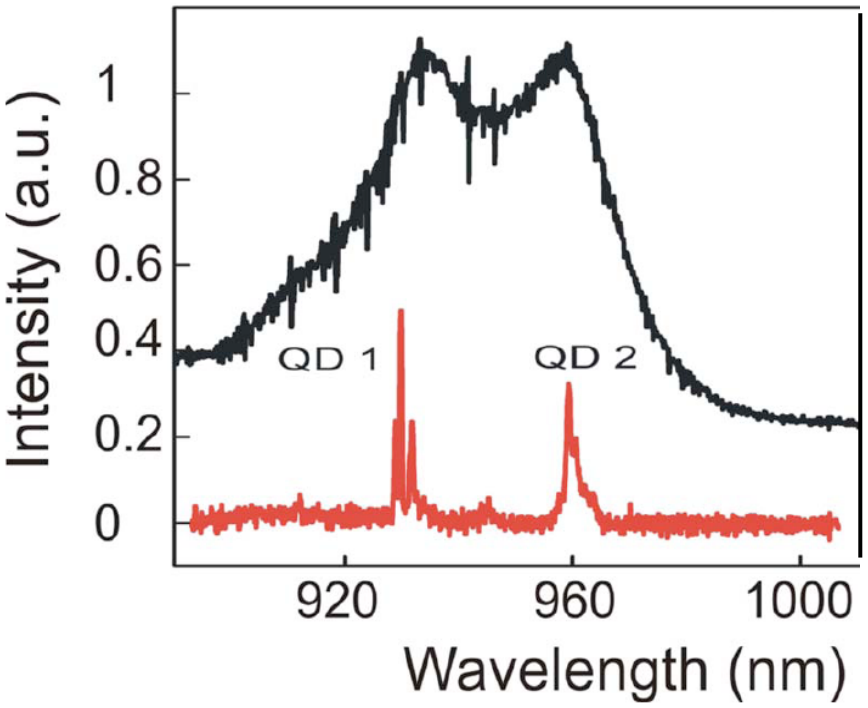
characterization



black:

quantum dot emission without cavity
(top DBR layer has been removed)

→ 2 peaks according to second / third layer

red:

QD emission inside cavity:

→ lines from different QD separated

spectrum can be resolved

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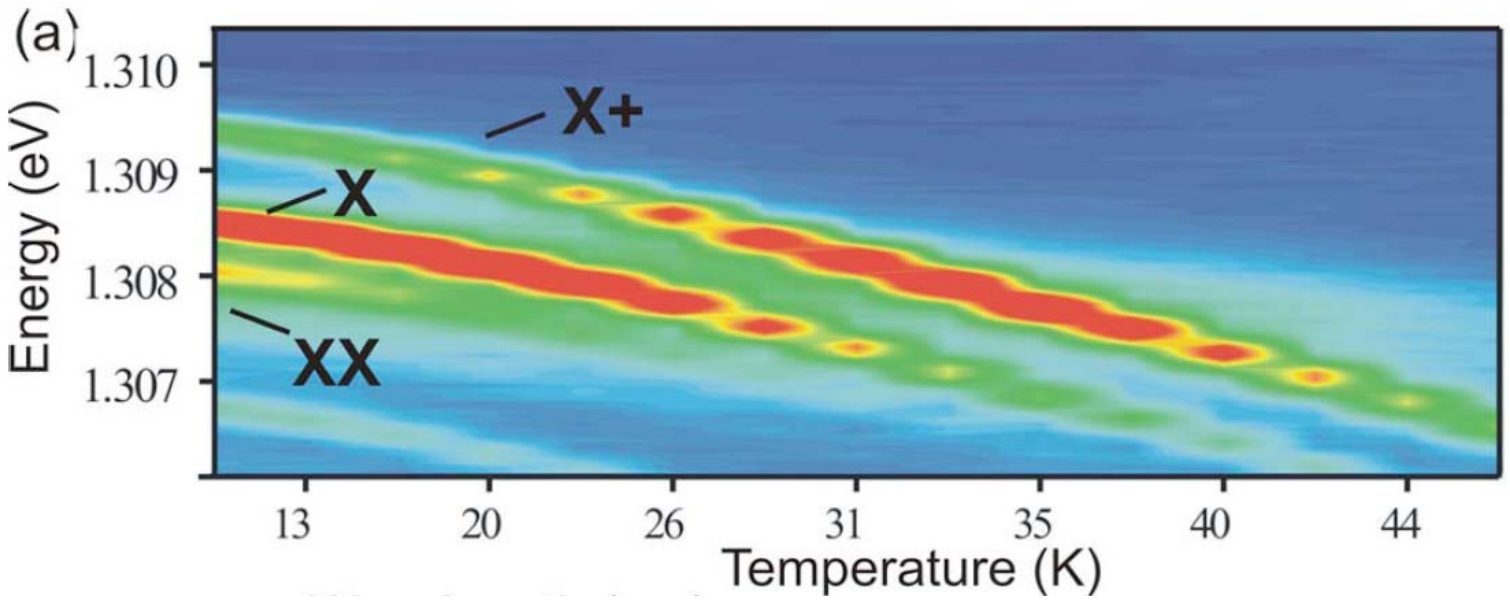
spectroscopy and tuning



substructure of quantum dot spectrum:

X: excitonic emission (electron-hole pair)
X+: positively charged emission (trion / charged electron-hole pair)
XX: biexcitonic emission („bound“ electron-hole pairs)

cavity can be tuned in resonance with each line by temperature control

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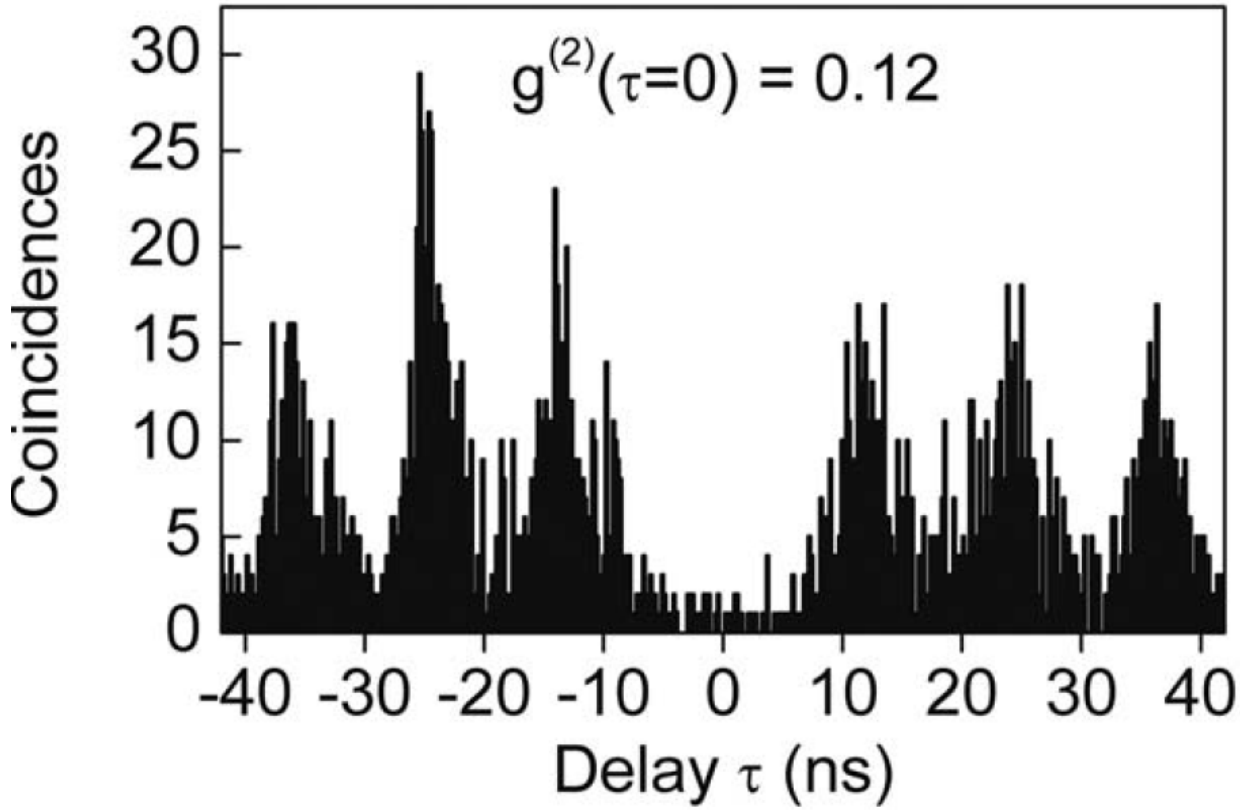
single photon emission

cavity tuned to the X+ transition:



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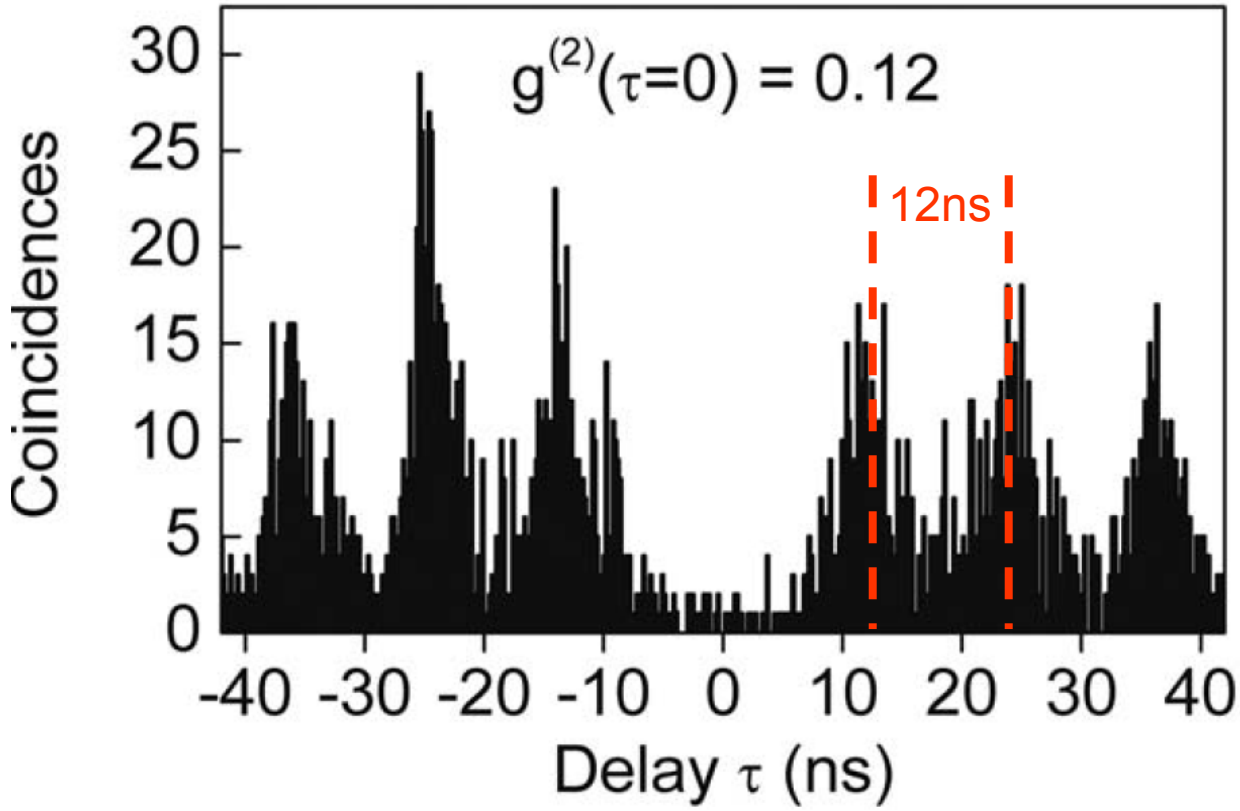

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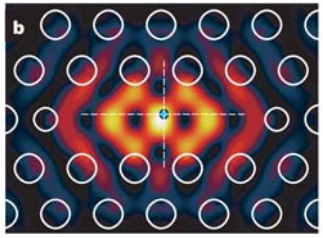
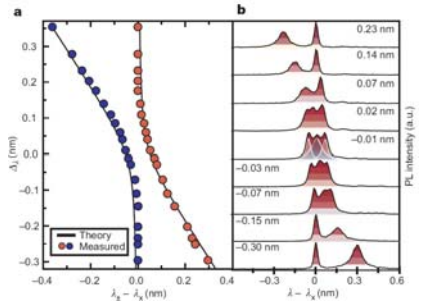
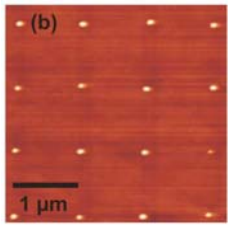
summary



couple quantum dots to cavity modes



strong coupling regime possible



position control of quantum dots