Coherence in semiconductor nanostructures Part II: Photonic enhancement

Jacek Kasprzak

UNIWERSYTET WARSZAWSKI
ZINTEGROWANY PROGRAM ROZWOJU

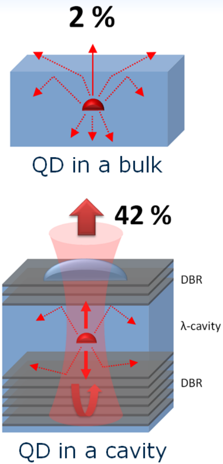
Equipe mixte CEA-CNRS "Nanophysique et semicondcuteurs"
Institut Néel - CNRS
Grenoble France

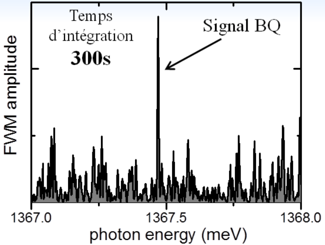
Warsaw University, October-December 2020

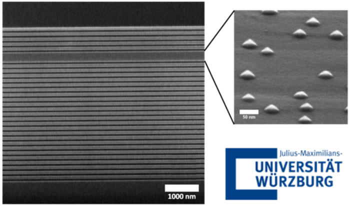
Outline

Outline

How to overcome total internal reflection issue ?

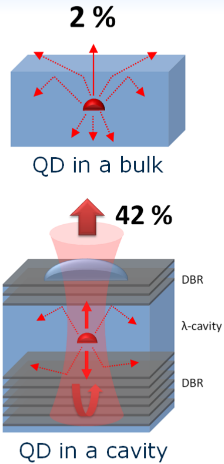


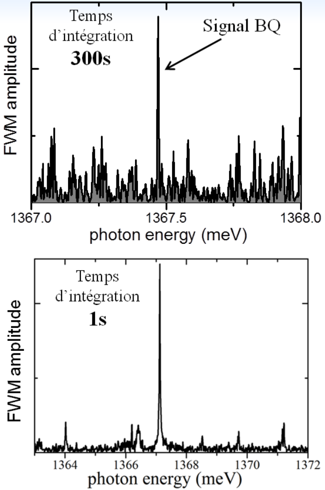




Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

How to overcome total internal reflection issue ?

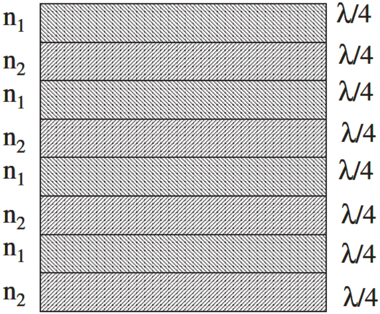


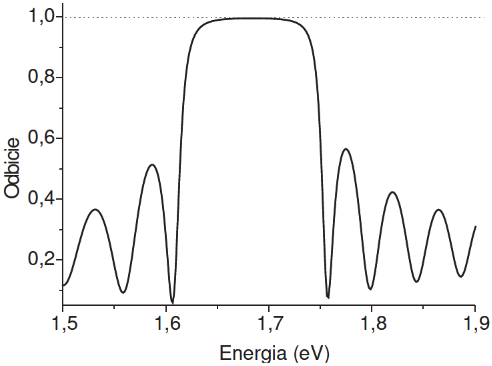


Outline

How to fabricate a microcavity ?

Figure of Merit $\Rightarrow$ Quality factor, $Q = \lambda/\delta\lambda$

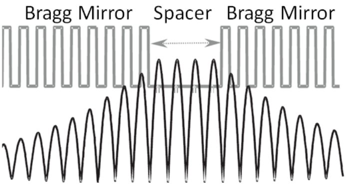


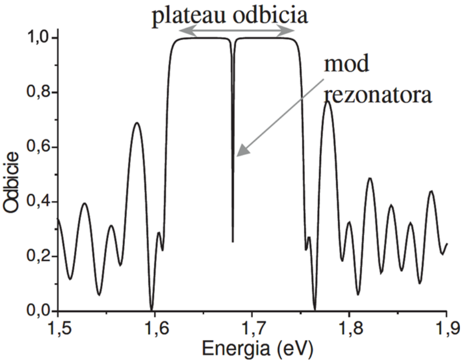


Advantage: intra-cavity field cycling, Drawback: Narrow-band

How to fabricate a microcavity ?

Figure of Merit $\Rightarrow$ Quality factor, $Q = \lambda/\delta\lambda$

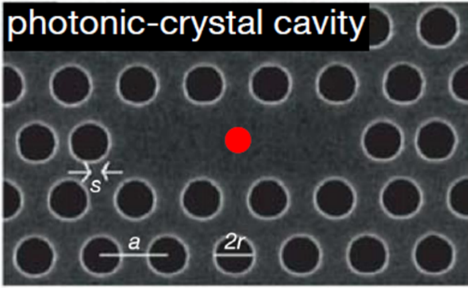




Advantage: intra-cavity field cycling, Drawback: Narrow-band

How to fabricate a microcavity ?

Figure of Merit $\Rightarrow$ Quality factor, $Q = \lambda/\delta\lambda$

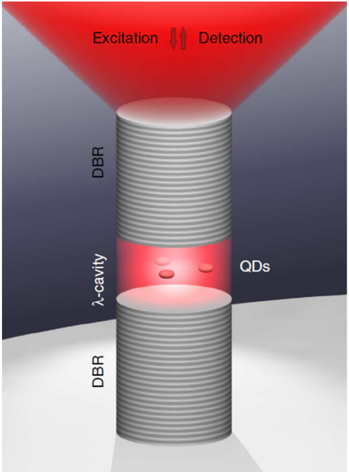


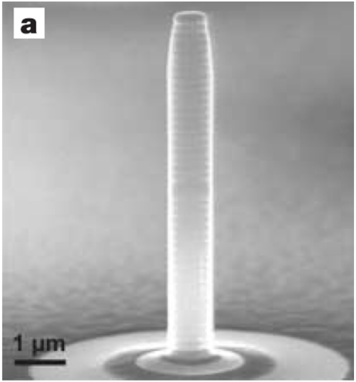
Yoshie *et al.*, Nature **432**, 200 **(2004)**

Advantage: intra-cavity field cycling, Drawback: Narrow-band

Pillar microcavity

Quality factors typically from 10 to 10^5



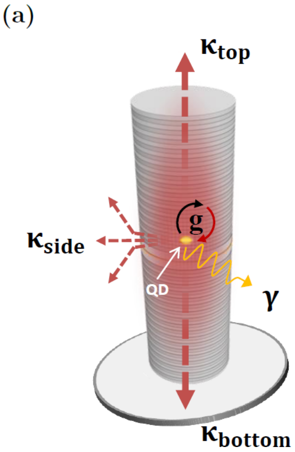


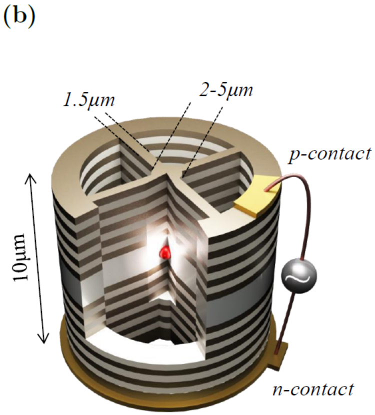
Purcell effect, Cavity QED in solids

Nature 432, 197 (2004)

Pillar microcavity

Quality factors typically from 10 to 10^5





Pillar microcavity

Quality factors typically from 10 to 10^5

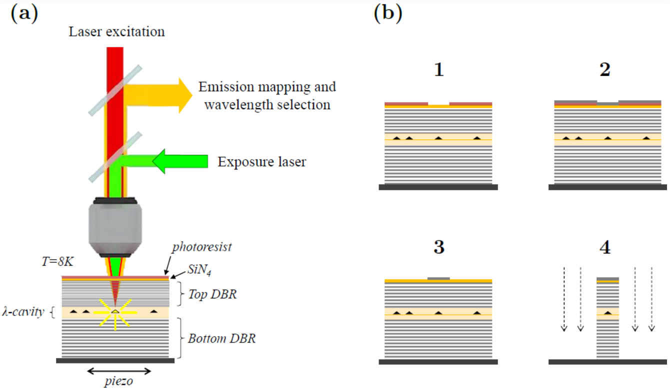


Figure 1.9 – (a) Schematic of the in-situ lithography (see details in the text) (b) Ex-situ etching of the structure defined by the optical lithography. Step 1: development of the positive photoresist. Step 2: deposition of a 40nm layer of Ni and hard mask. Step 3: lift-off of the residual photoresist. Step 4: dry etching of the micropillars, as defined by the Ni layer.

Pillar microcavity

Quality factors typically from 10 to 10^5

(a) (b)

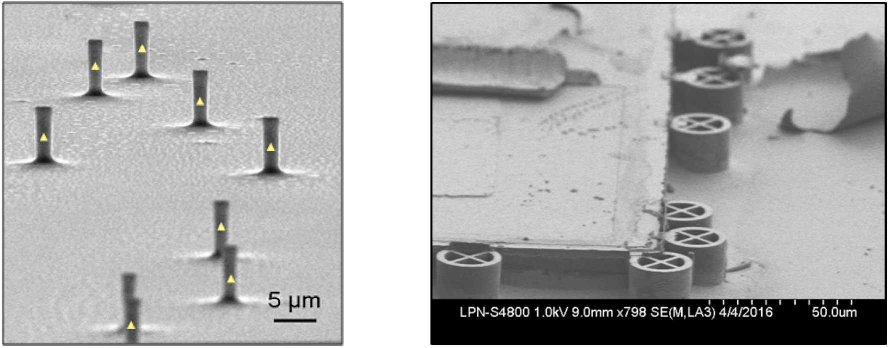
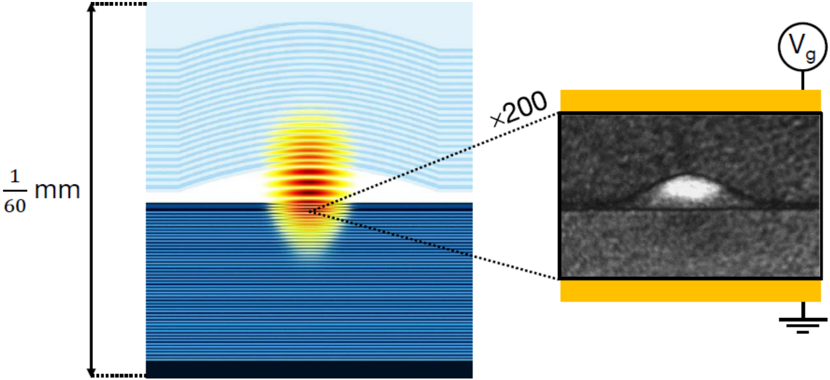


Figure 1.10 – Scanning Electron Microscope images. (a) First generation of deterministically coupled QD-micropillar sample. (b) Second generation of devices, including electrical control.

State of the art: Open Cavity

Q-factor reaching 10^6 + fully tunable in space and frequency
+ charge tunable quantum emitter

Nature 575, 622 (2019)

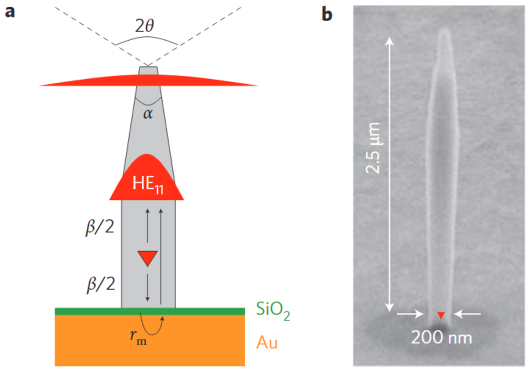


Outline

Signal waveguiding in photonic nanowires

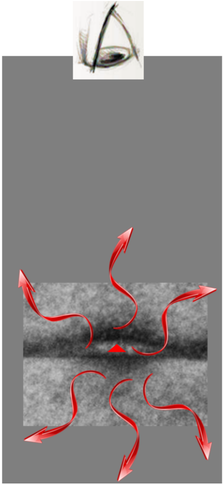
Field enhancement around a QD + 45% extraction, broadband,
Top-Down

NATURE PHOTONICS DOI: 10.1038/NPHOTON.2009.287



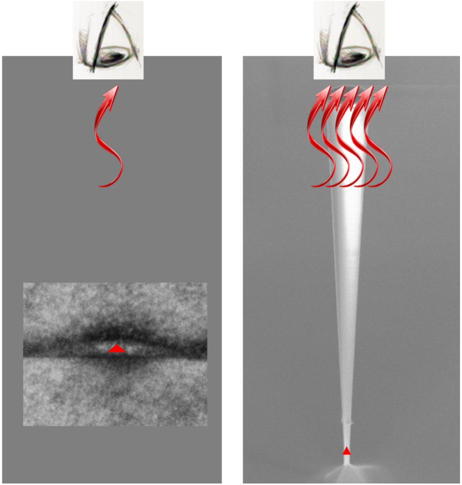
Signal waveguiding in photonic nanowires

Field enhancement around a QD + 45% extraction, broadband, Top-Down



Signal waveguiding in photonic nanowires

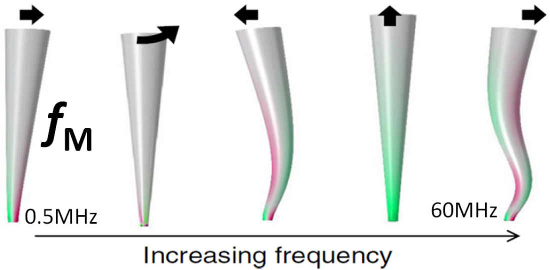
Field enhancement around a QD + 45% extraction, broadband, Top-Down



Photonic waveguide as a mechanical resonator

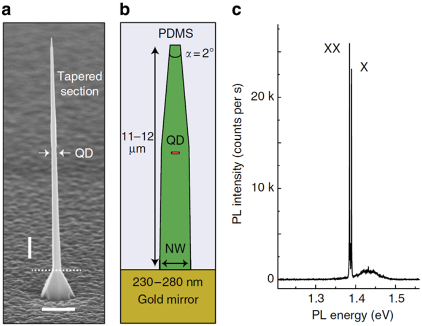
A unique device linking photonics and optomechanics

Nat. Commun. 8, 76 (2017), Nat. Nanotechnol. 9, 106 (2013) (collegues)

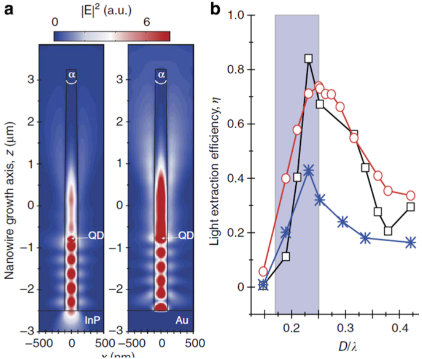


Signal waveguiding in photonic InP nanowires

Bottom-Up, Tailored Antennas



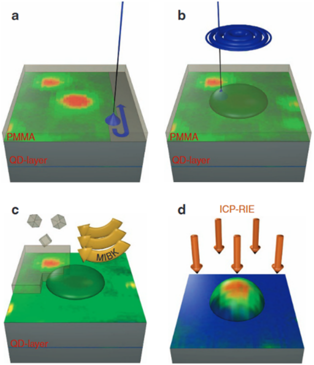
Reimer *et al.* Nat. Com. **3**, 737 (2012)

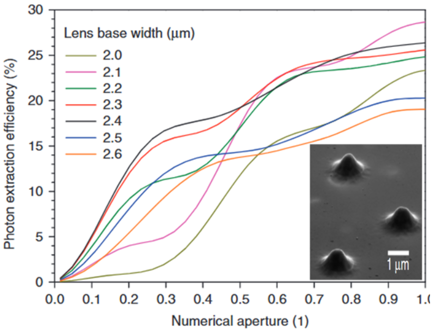


Outline

Deterministic Quantum Dot Microlenses

Enhanced photon-extraction efficiency



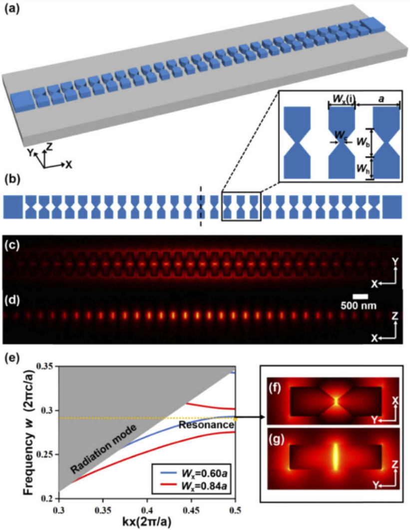


Gschrey *et al. Nat. Com.* (2015)

Outline

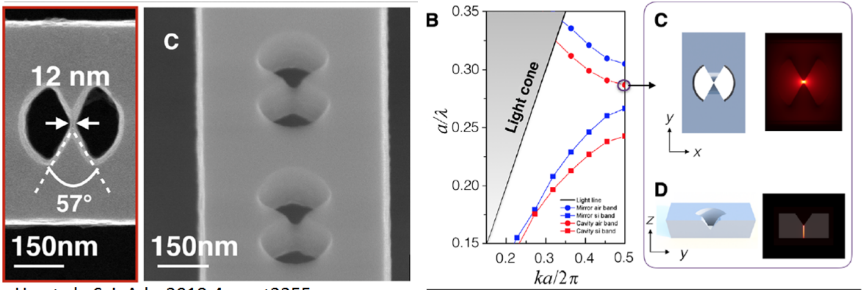
Ultra-low Mode-Volume Plasmonic Cavities

$$V = 7 \times 10^{-3}(\lambda/n)^3,\ Q = 10^5 \Rightarrow Q/V = 1.4 \times 10^7$$



Ultra-low Mode-Volume Plasmonic Cavities

$$V = 7 \times 10^{-3}(\lambda/n)^3,\ Q = 10^5 \Rightarrow Q/V = 1.4 \times 10^7$$

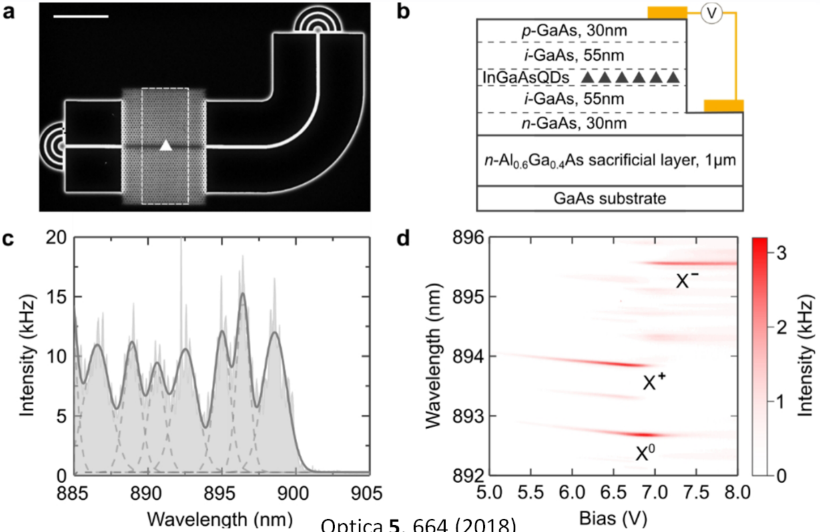


Hu et al., Sci. Adv. 2018;4: eaat2355

Outline

Waveguides: ridges, photonic crystals, nanophotonics

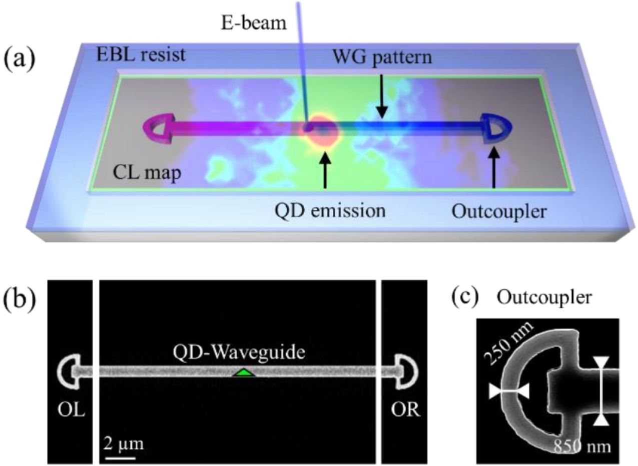
In-plane guiding of light in photonic circuits



Optica **5**, 664 (2018)

Waveguides: ridges, photonic crystals, nanophotonics

In-plane guiding of light in photonic circuits



Waveguides: ridges, photonic crystals, nanophotonics

In-plane guiding of light in photonic circuits