WHISPERING GALLERY MODES LASER
with
COLLOIDAL QUANTUM SHELL GAIN

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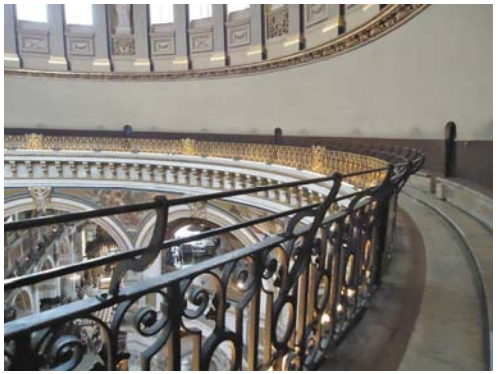
Whispering gallery modes

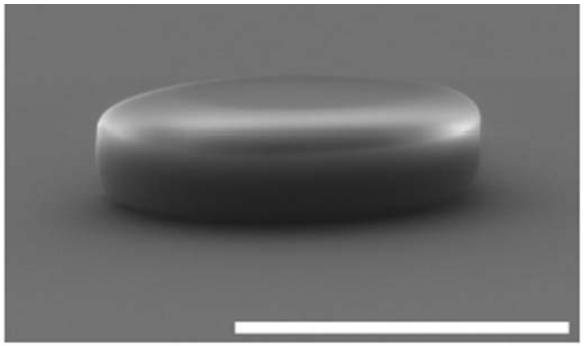
Saint Paul cathedral (London)



Whispering gallery

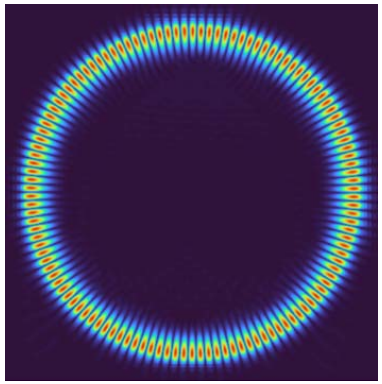
ACOUSTICS

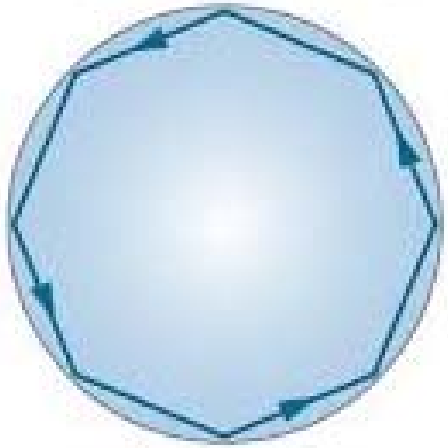
Microcavity



(b) height = 2µm

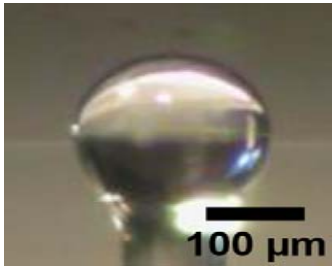
Optical mode
simulation





OPTICS

Whispering gallery modes (WGM) micro-cavities



Spheres

or

disks

High Q factor achievable

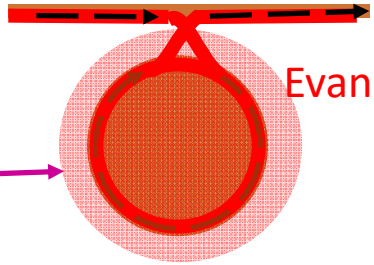
Up to 10^5

$$\frac{1}{Q} = \frac{1}{Q_{bending}} + \frac{1}{Q_{scattering}} + \frac{1}{Q_{absorption}} + \frac{1}{Q_{coupling}}$$

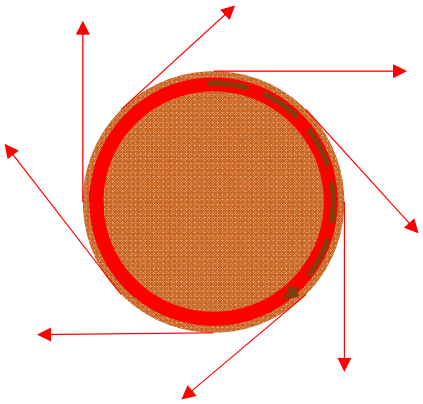
Index
Curvature

rugosity

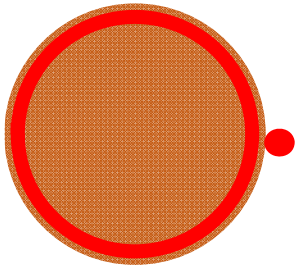
Material



Evanescent wave

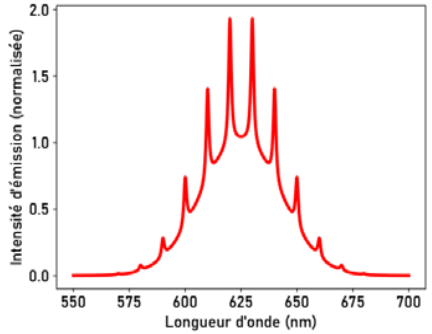


Excitation of WGM by
Quantum dot fluorescence

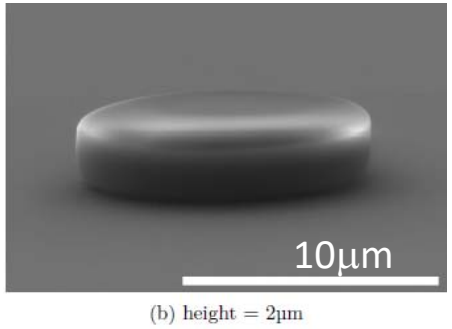


UV laser

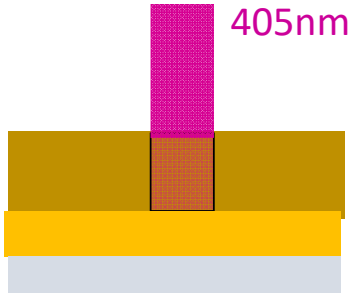
Fluorescence + resonances

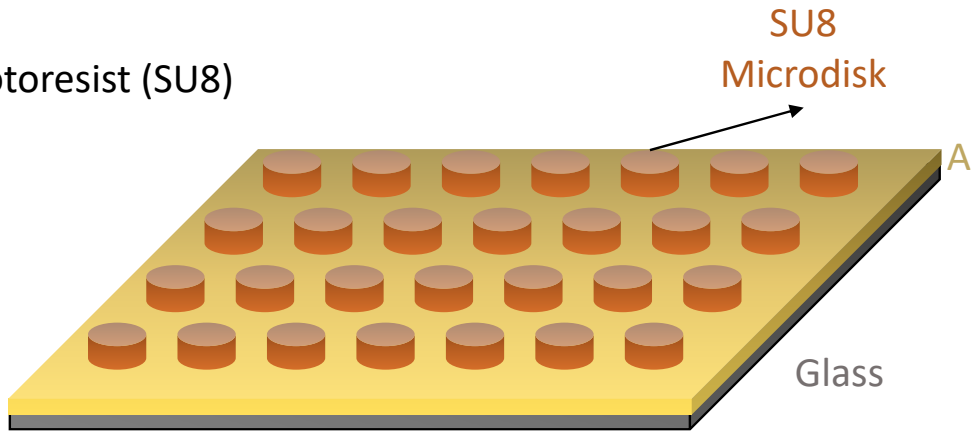


Micro-disk by optical lithography (SU8)



(b) height = 2µm

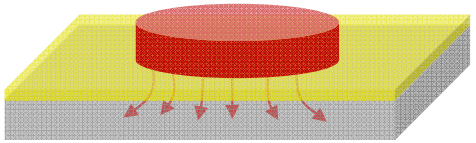




- Controllable size (typical diameter 2-20µm)
- quality factor $Q \geq 6000$

(measure limited by spectrometer resolution 0.1nm)

But losses through interfaces



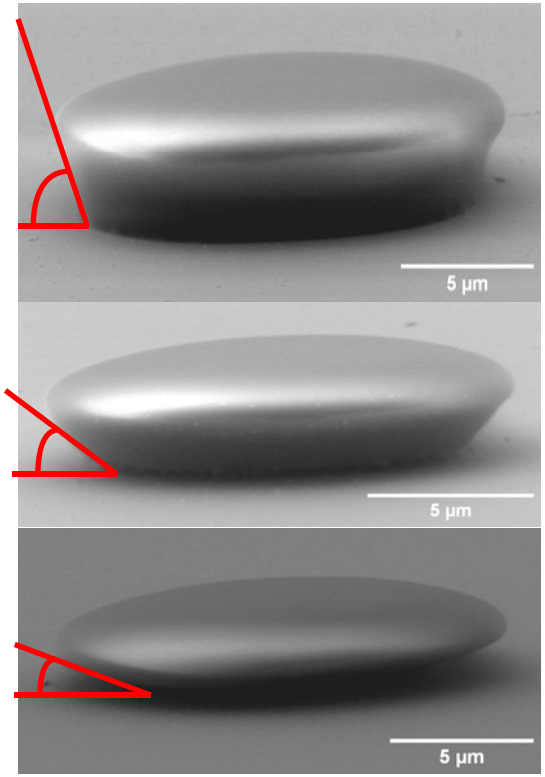
Micro-bowl by optical cavities

θ

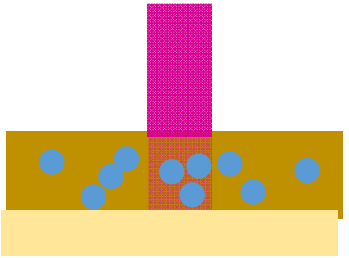
10 mg/ml

20 mg/ml

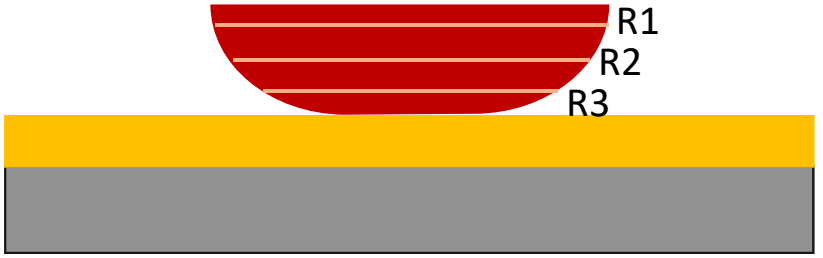
40 mg/ml



Increasing concentration of Tinuvine



SU8+ Non fluorescent UV Absorber (Tinuvine)



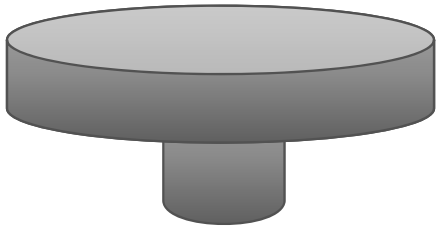
Less losses

Several cavity's radiuses (R)

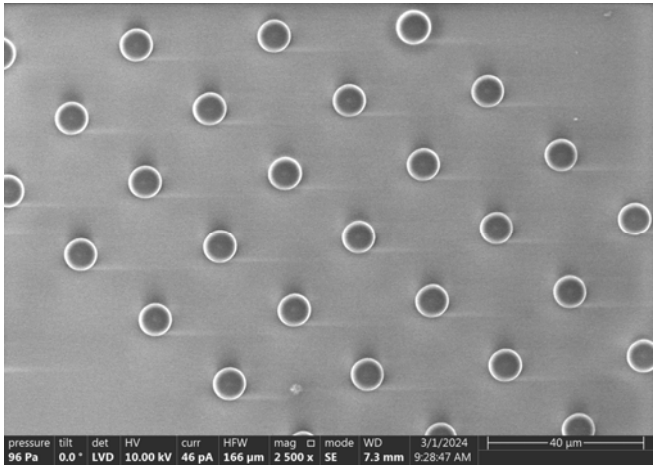
T shaped micro cavities

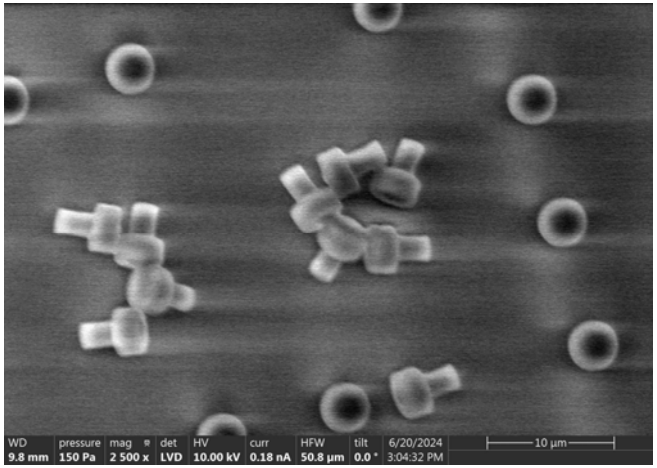
2-photons optical lithography

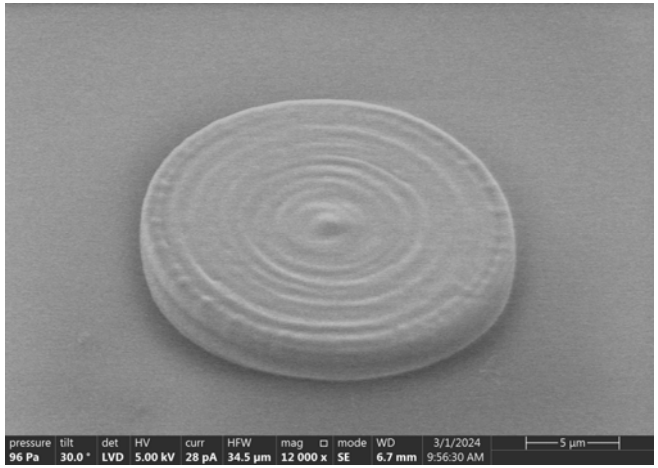
Nanoscribe



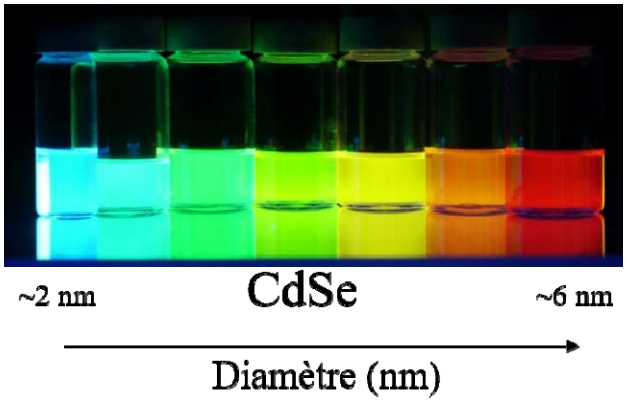
Disk diameter
From 4 to 20 µm





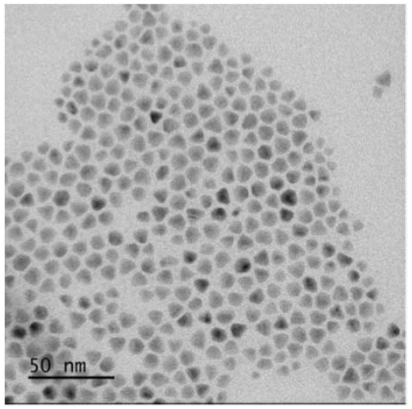


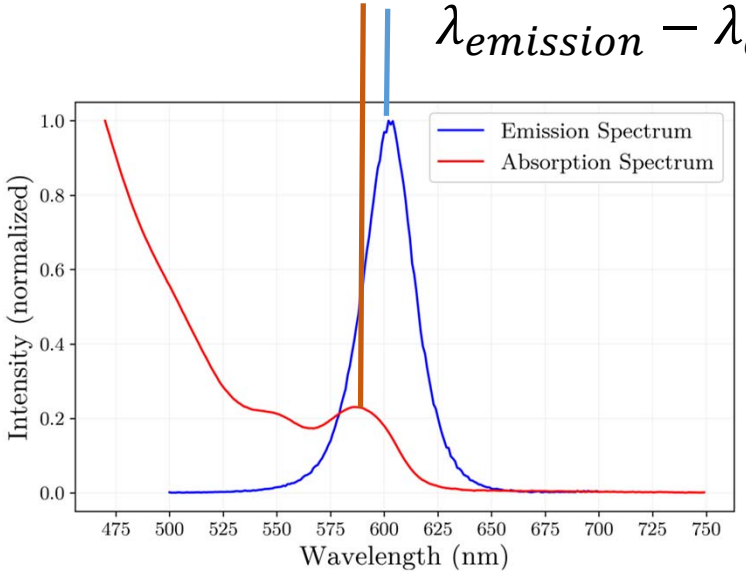
Colloidal quantum dots



+ Room temperature
+ Stability
+ Brigthness

TEM





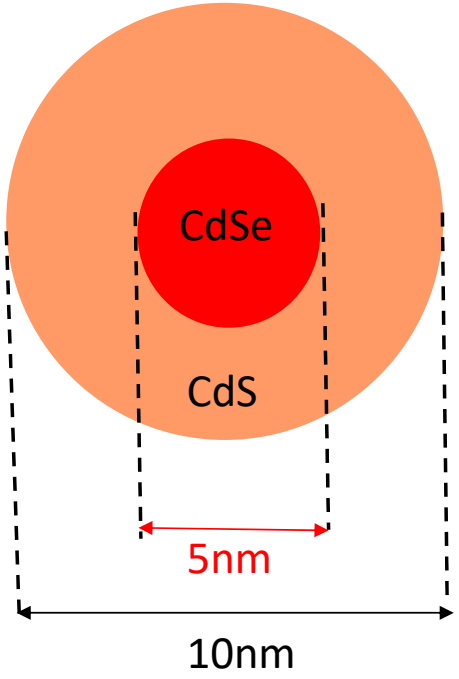
$\lambda_{emission} - \lambda_{absorption}$

Stokes shift:

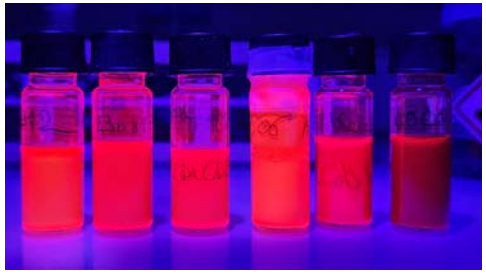
5-10nm

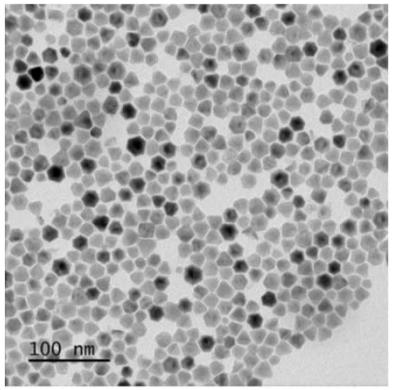
Absorption cross section (@532nm)

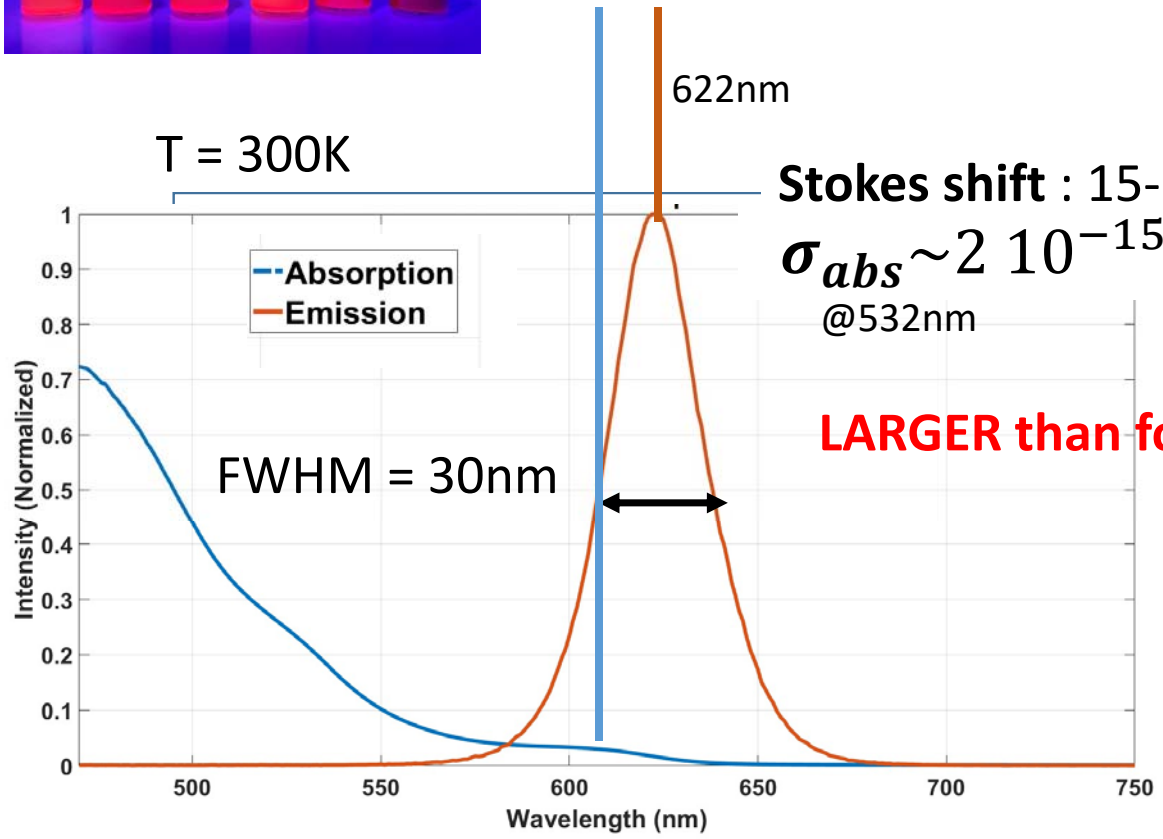
$\sigma_{abs} \sim 5\ 10^{-16} cm^2$



Colloidal Quantum shells



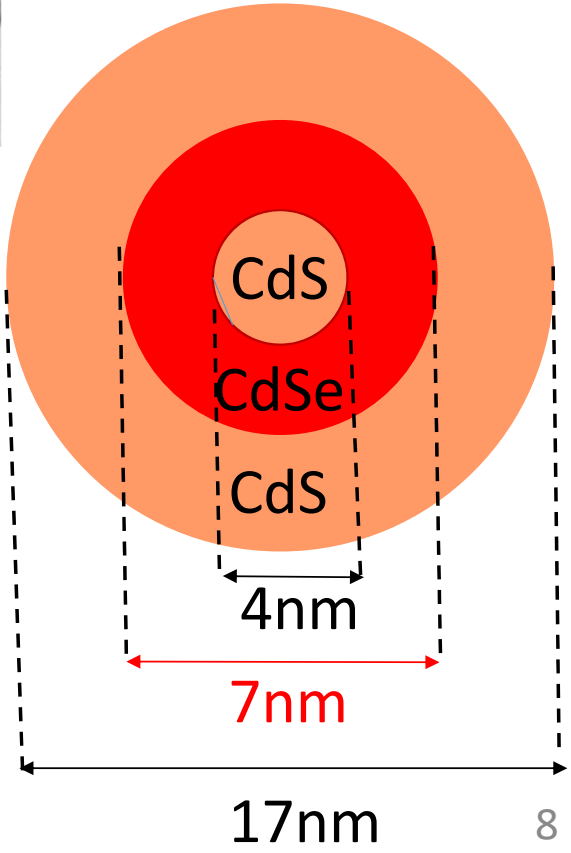




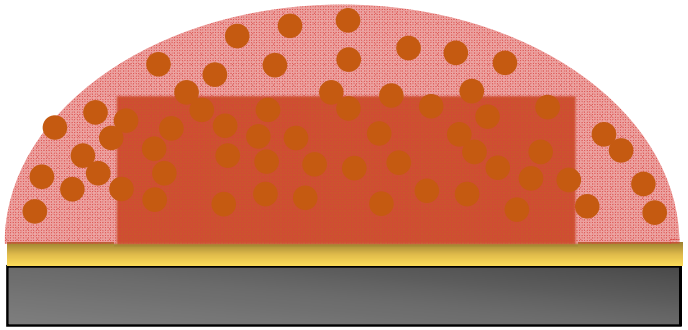
Stokes shift : 15-20nm

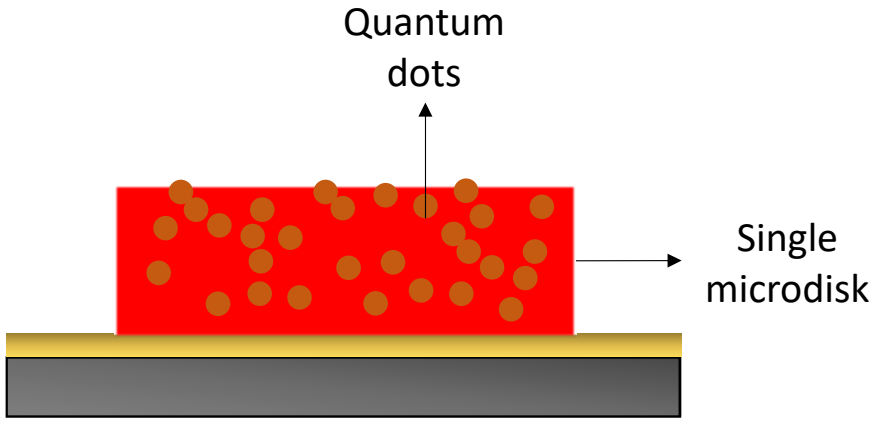
$\sigma_{abs} \sim 2\ 10^{-15} cm^2$ @532nm

LARGER than for quantum dots



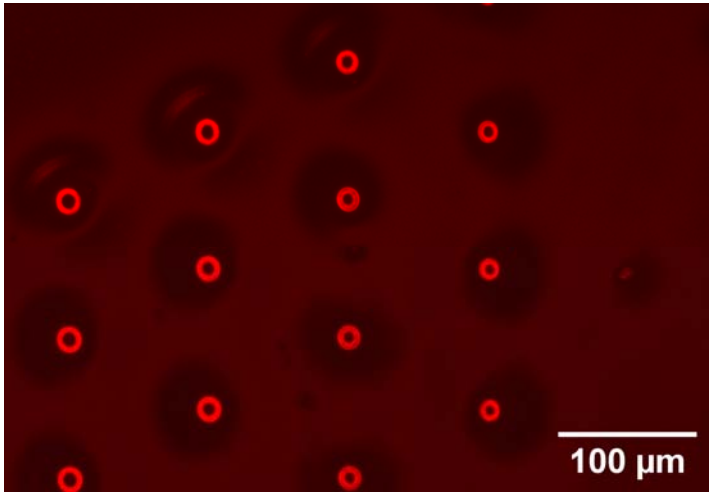
Microdisk infusion with quantum shells

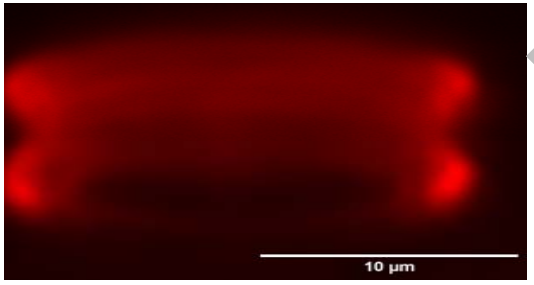


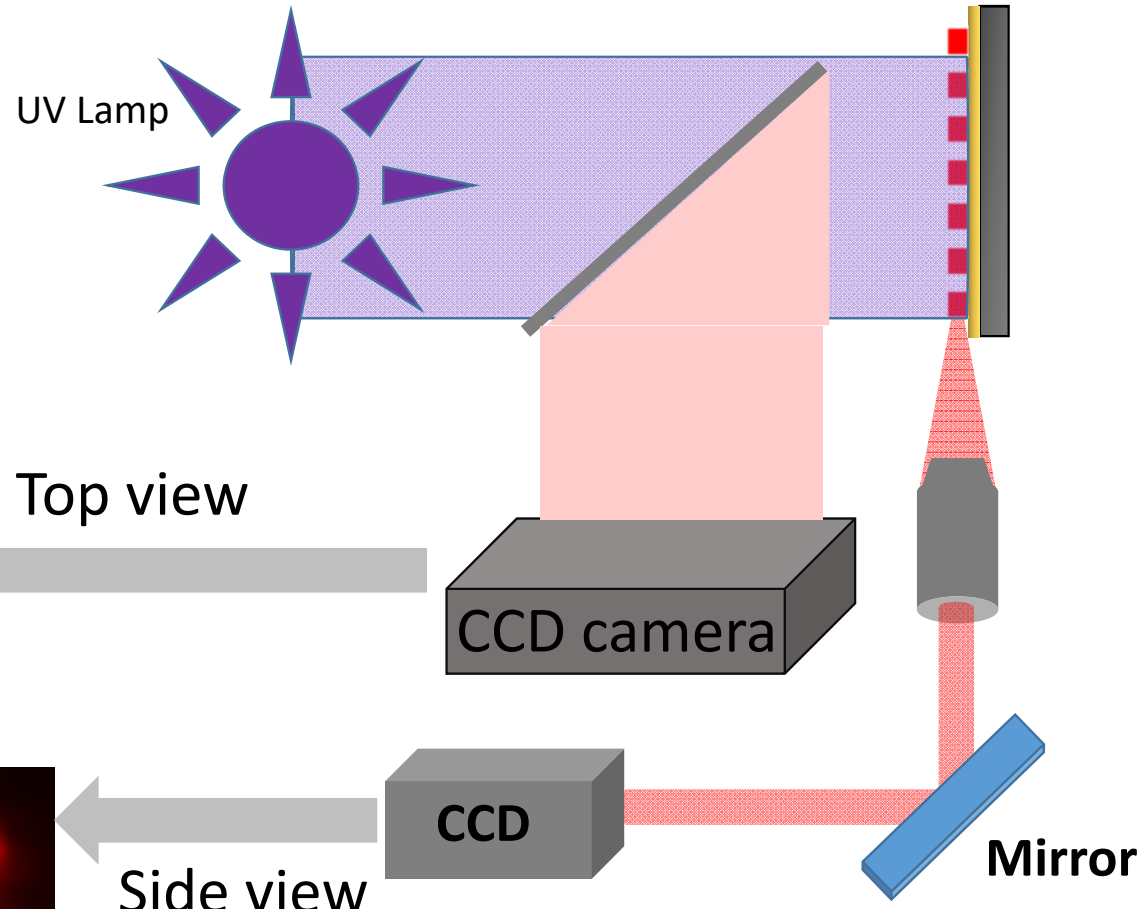


- **Low** concentration: **fluorescence** and whispering gallery modes
- **High** concentration: **lasing**

Fluorescence: full field

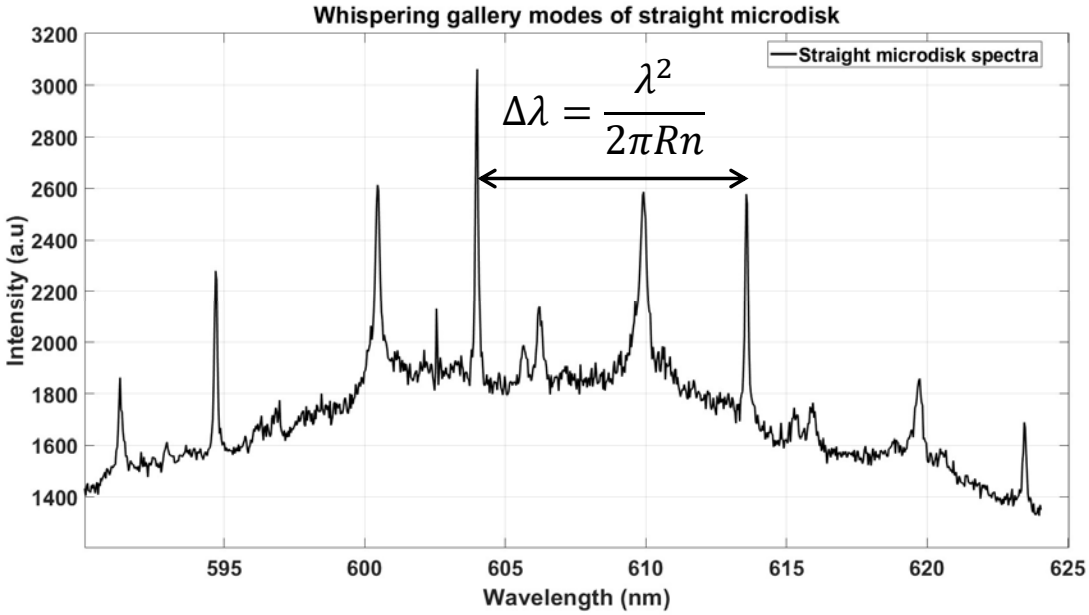


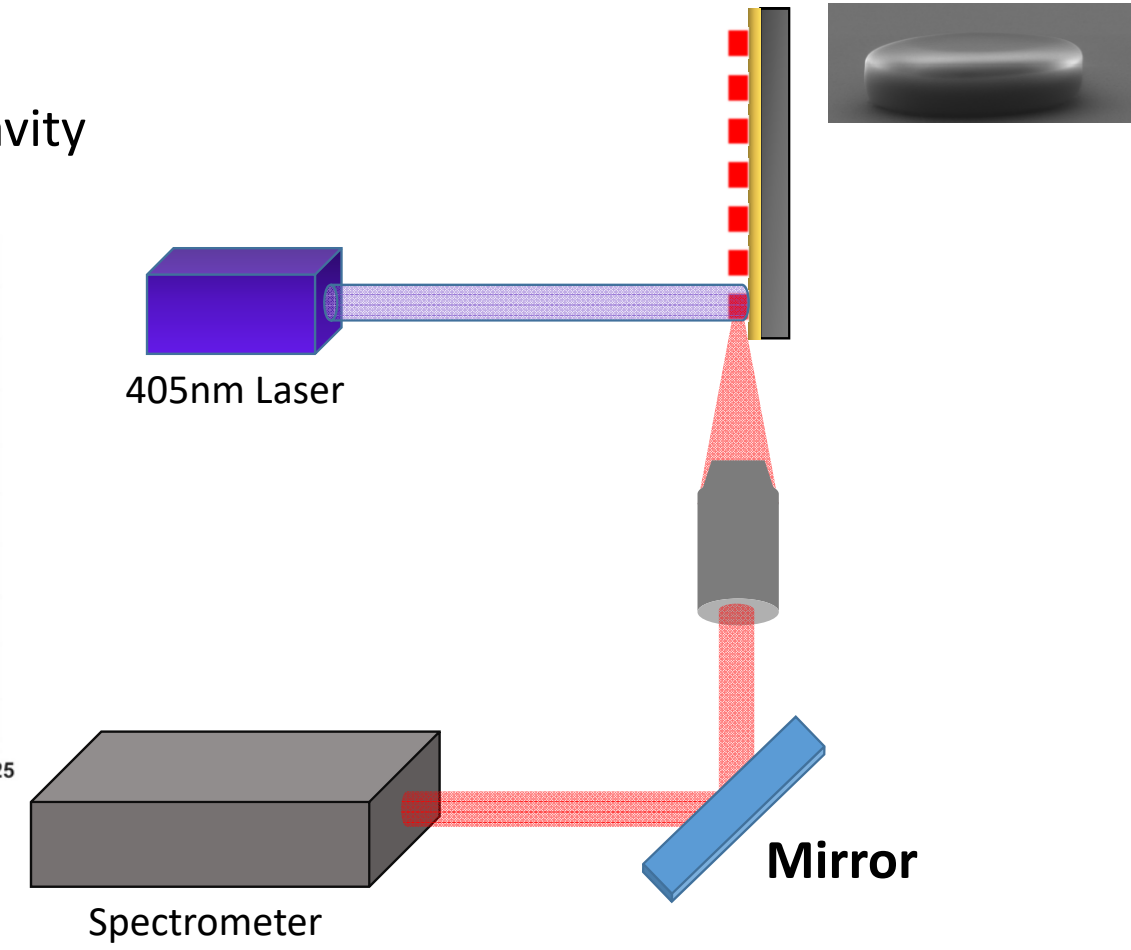




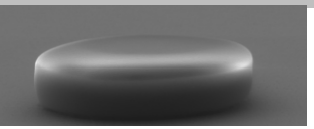
Fluorescence spectra

$\Delta\lambda \equiv$ free spectral range of the microcavity



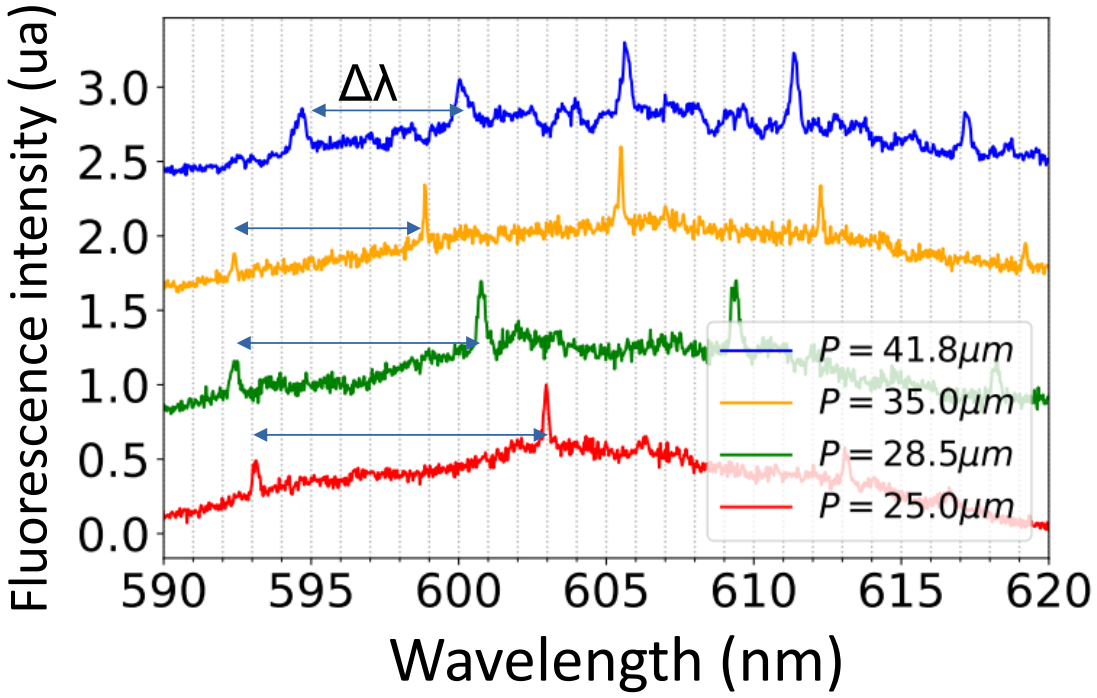


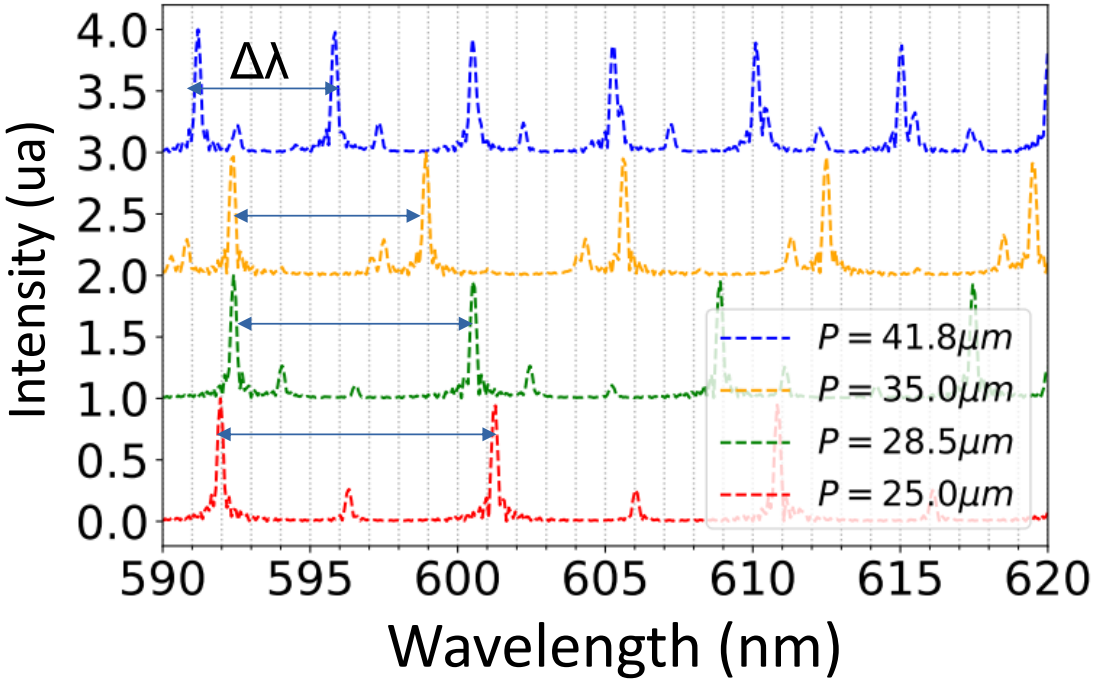
Whispering gallery modes



Cavity radius from 4 µm to 7 µm

Fluorescence: experiments *In accordance* **Simulations**





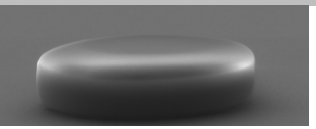
P= perimeter of the cavity
R= radius of the cavity

« free spectral range » $\Delta\lambda = \frac{\lambda^2}{2\pi R n}$

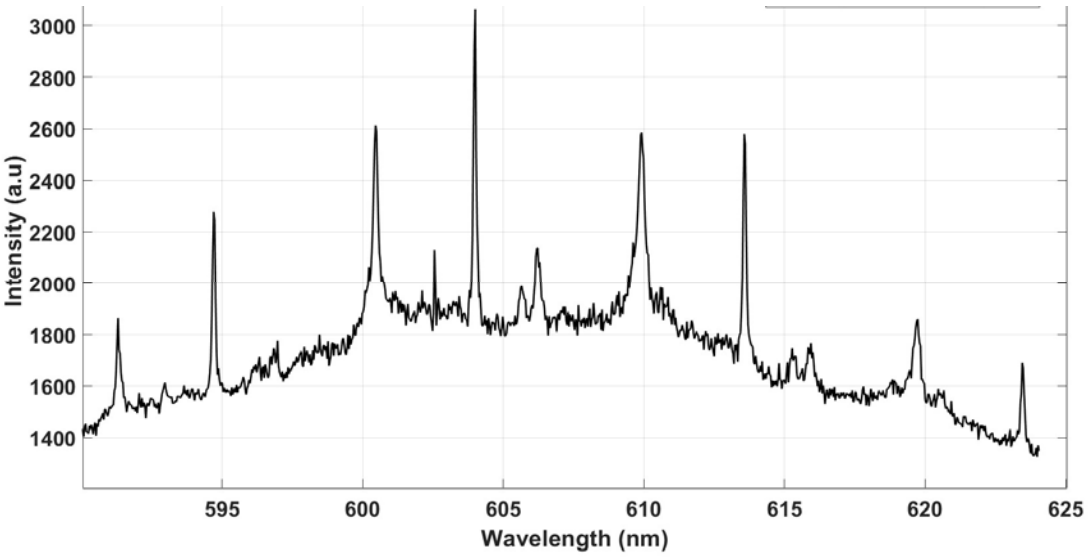
$\Delta\lambda$ ↗ when **R** ↘

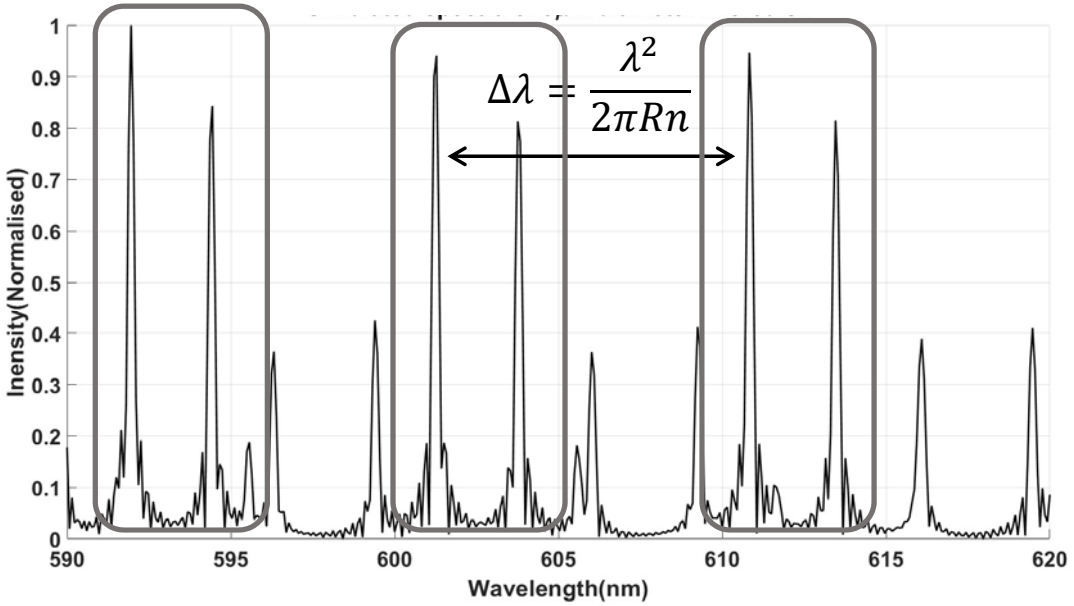
Kersuzan, ACS Photonics 11, 4, 1715 (2024)

Whispering gallery modes

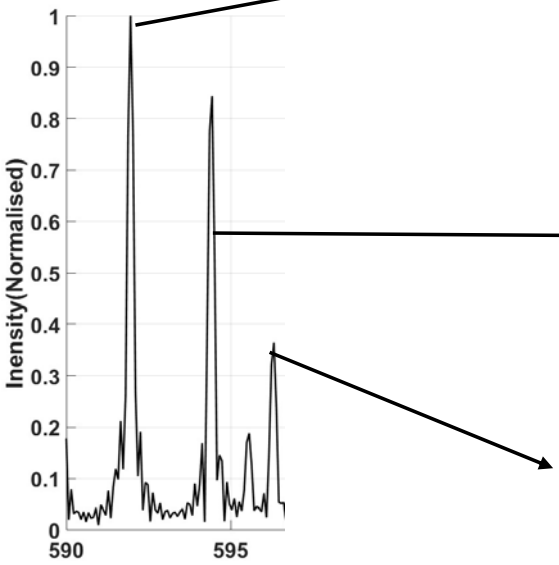


Straight, R=4μm

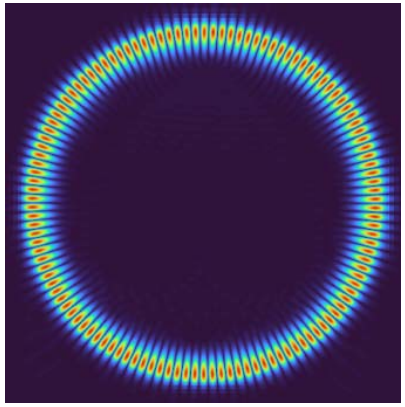




Transverse and polarisation modes

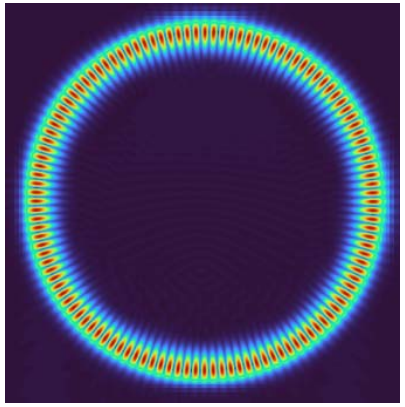


$TE(H_x, H_y, E_z)$

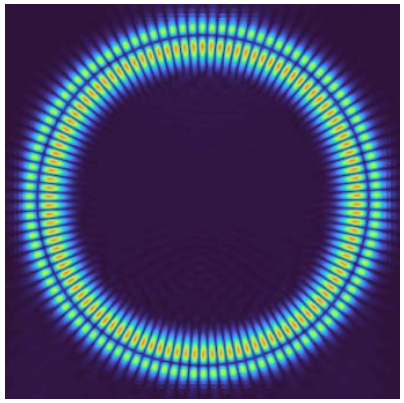


$\ell = 1$

Bessel modes



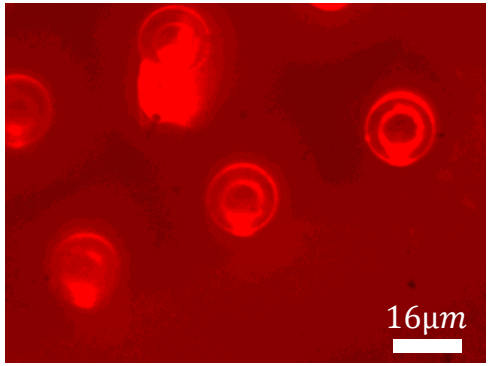
$TM(E_x, E_y, H_z)$

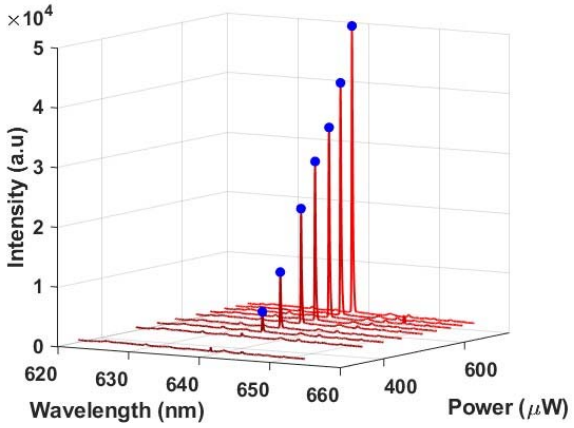


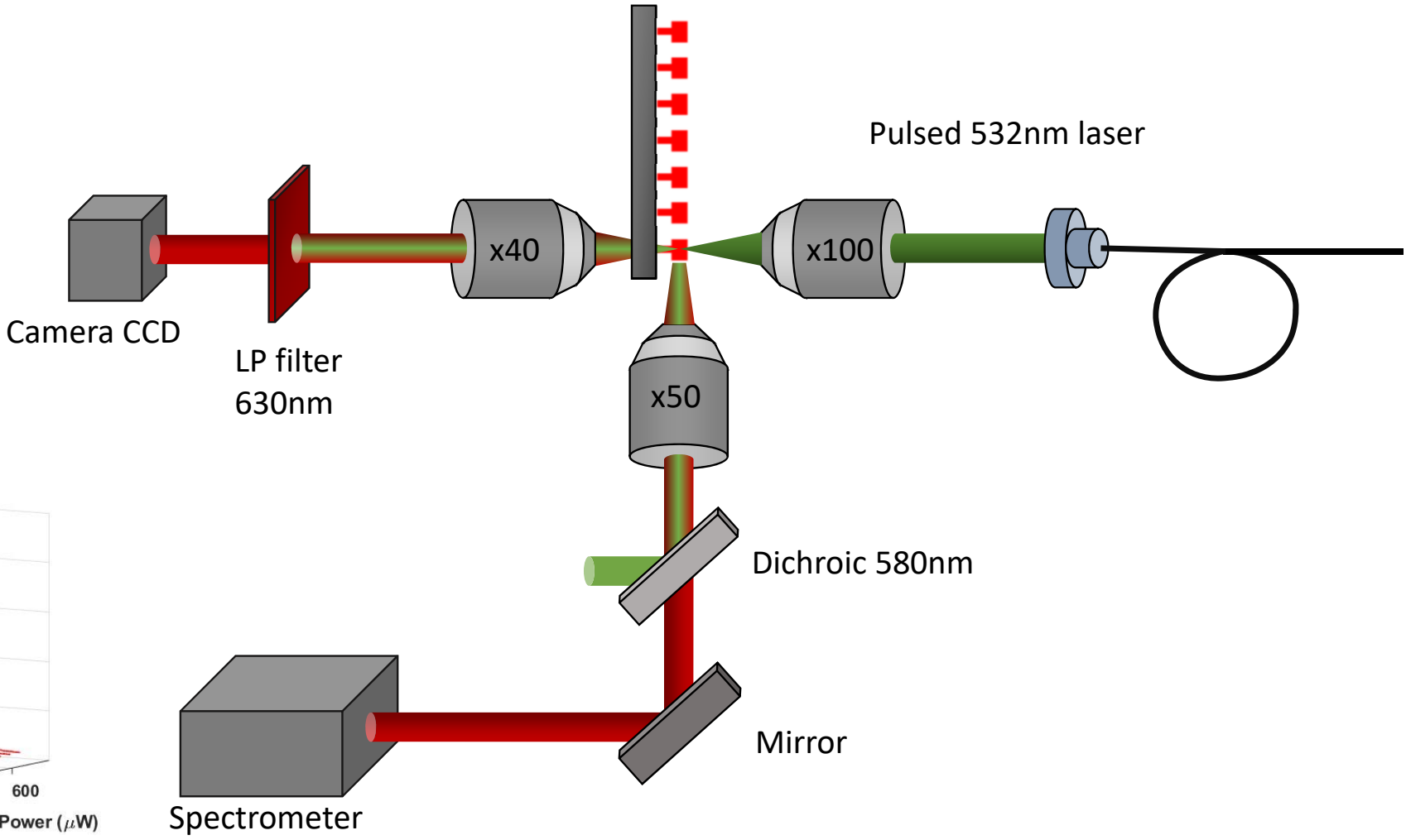
$TE(H_x, H_y, E_z)$

$\ell = 2$

Setup for observing lasers (T shaped)

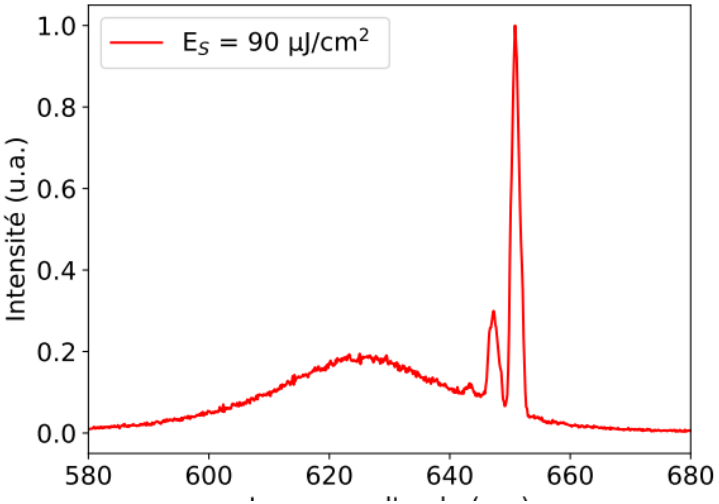


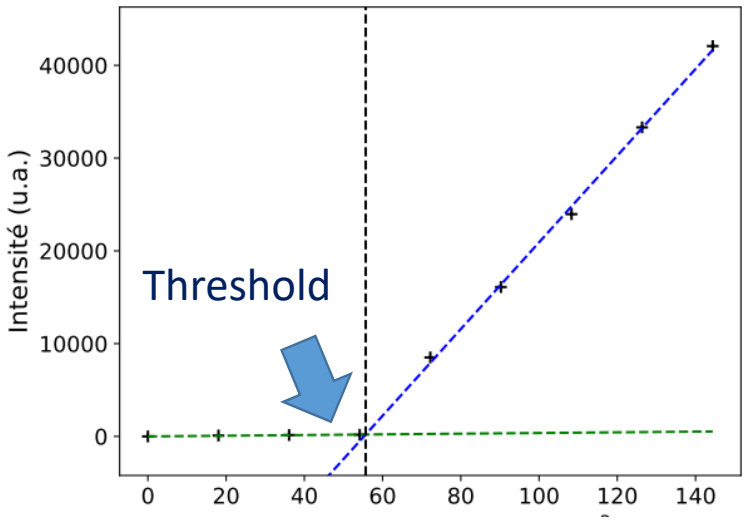




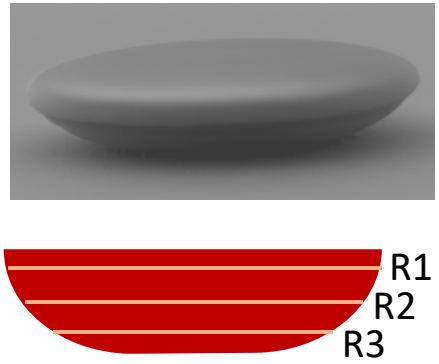
High concentration of quantum shells: Laser

Laser spectrum



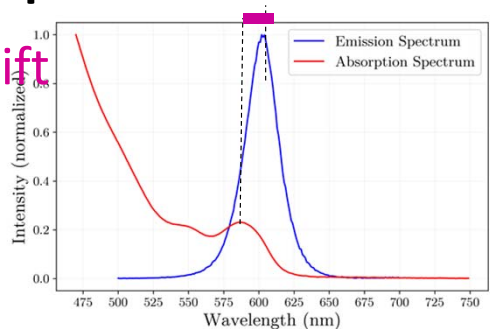


BOWL (R=6-9µm)



Lasing in the red part of the fluorescence

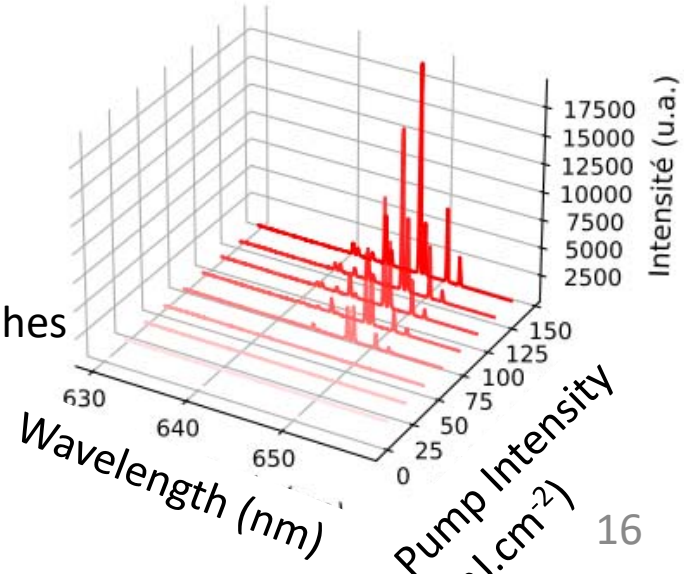
Due to stokes shift



Less absorption on the red part

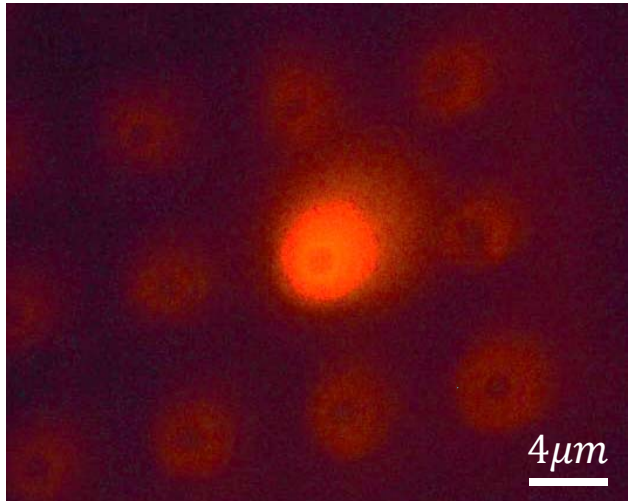
Multimode

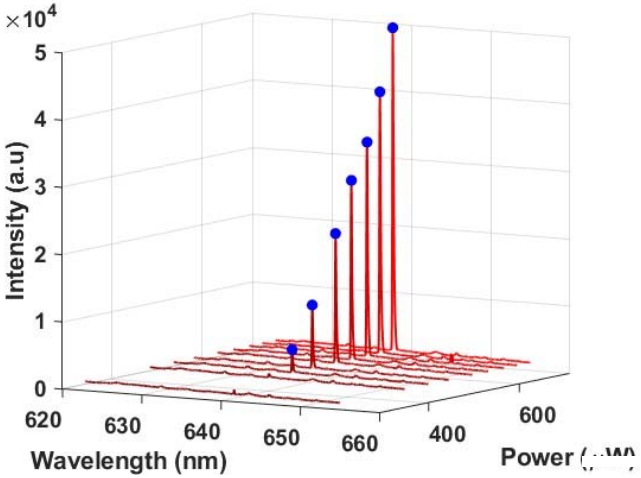
Different cavity lengthes



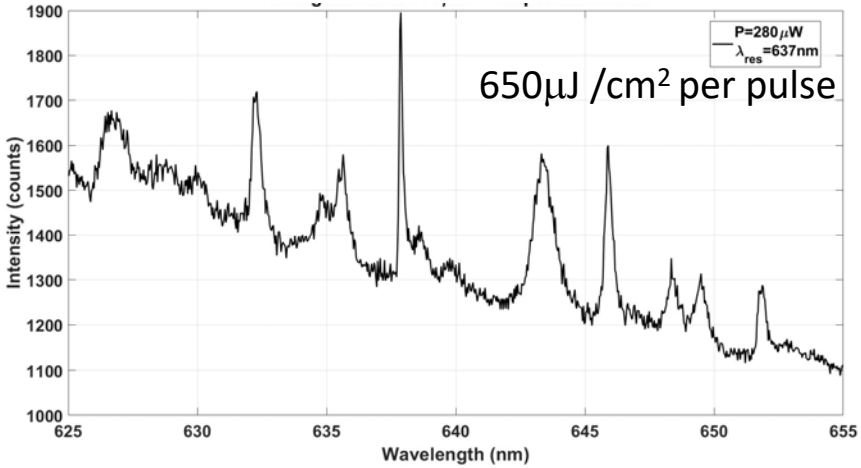
Kersuzan, submitted

Single mode emission for small size disk

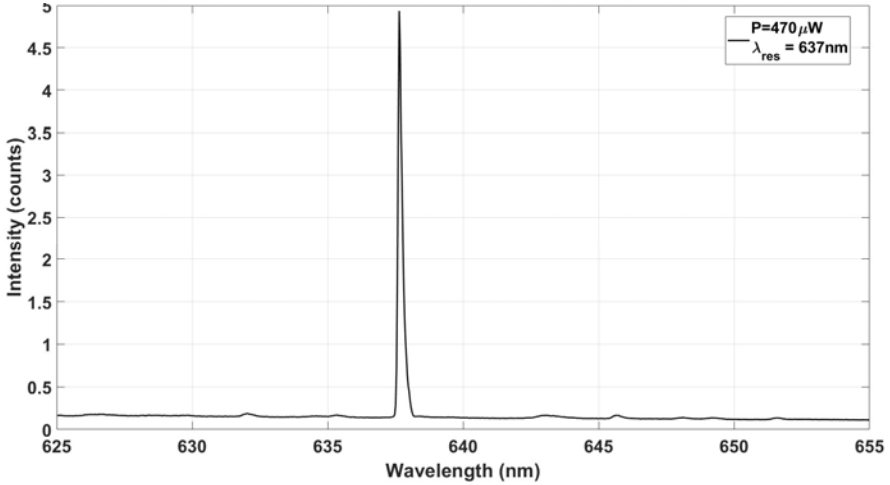


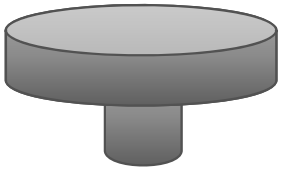


At threshold



Above threshold





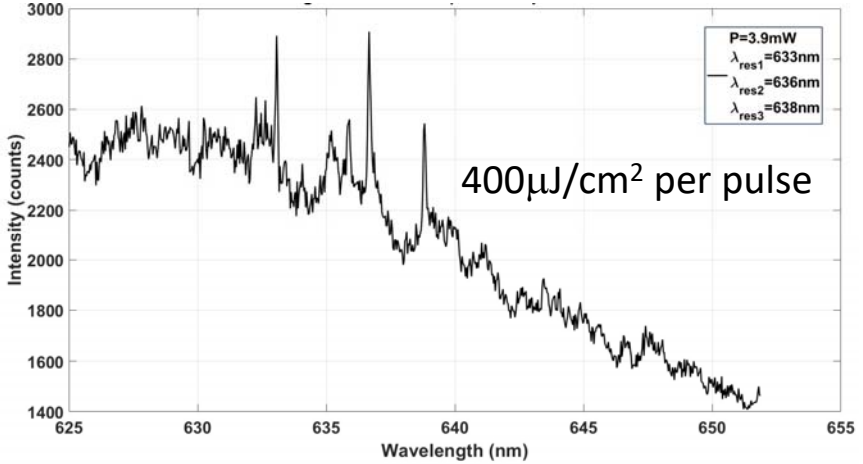
$R = 2\mu m$

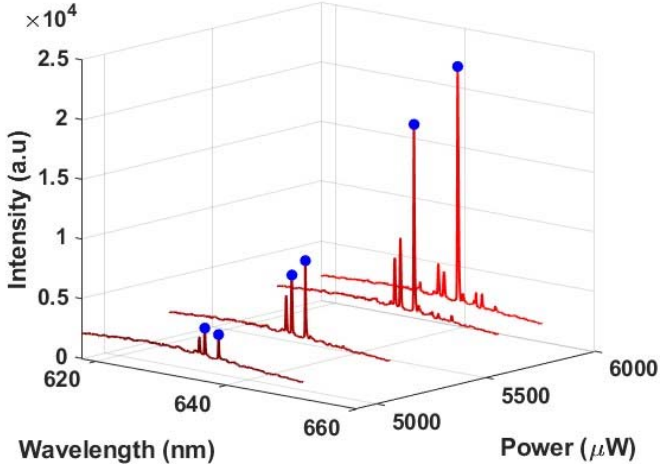
multimode emission for large size disk

Smaller free spectral range

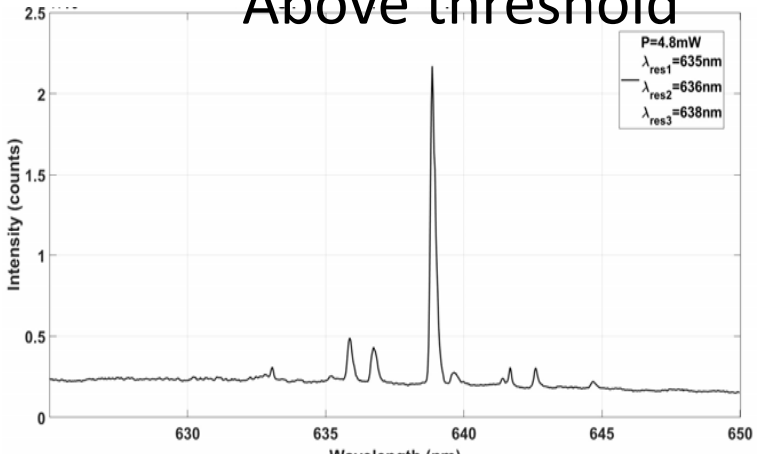
$R = 10\mu m$

At threshold

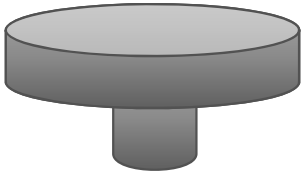




Above threshold



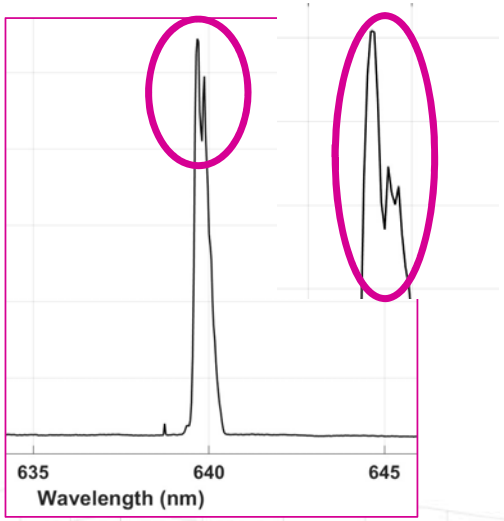
Open questions at high excitation

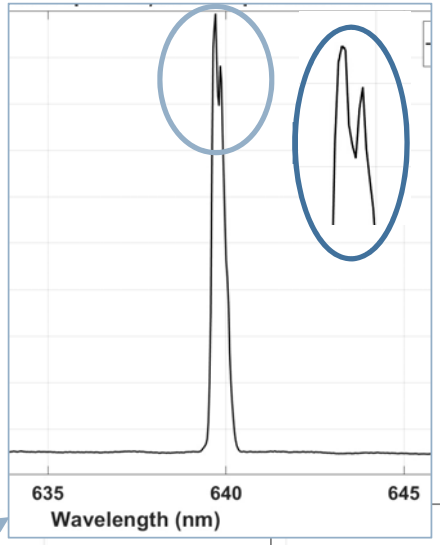


R=4μm

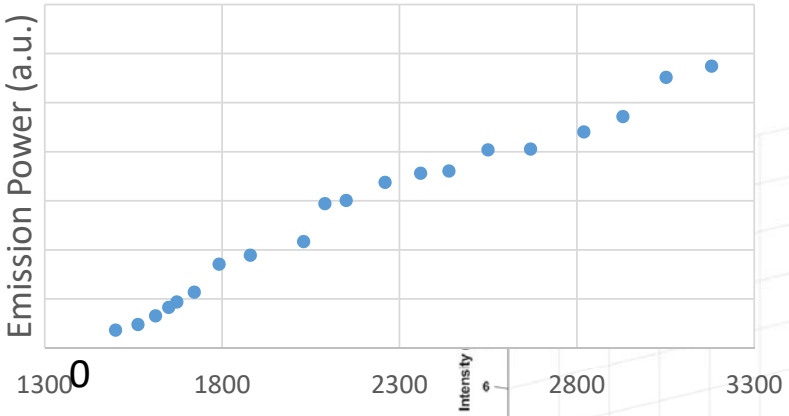
3 peaks
0.2nm total split

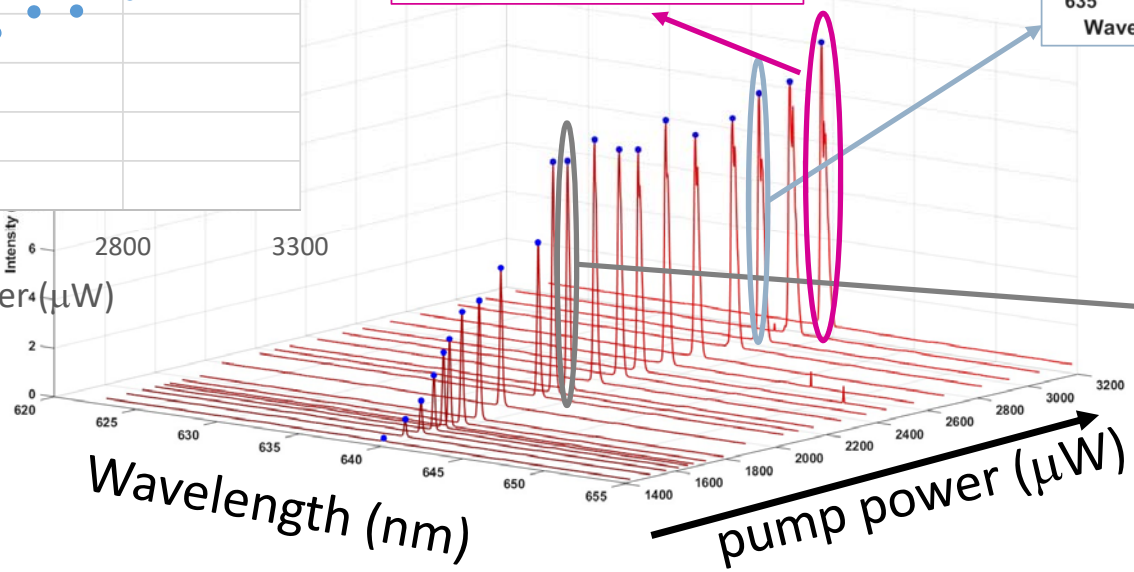
Spectrometer resolution
0.1nm

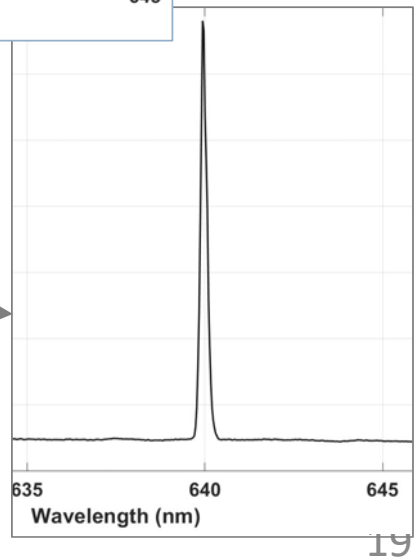




2 peaks
0.1nm split

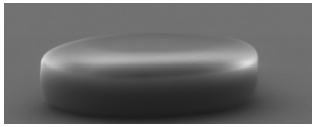


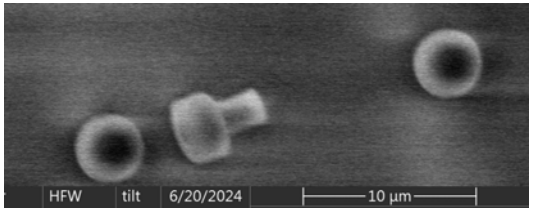


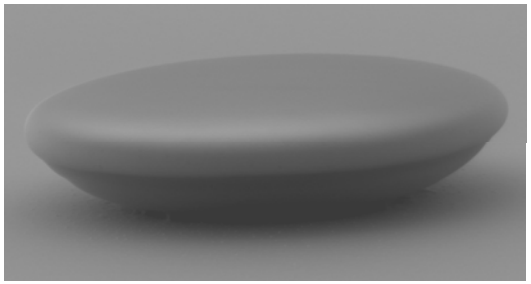


Conclusion

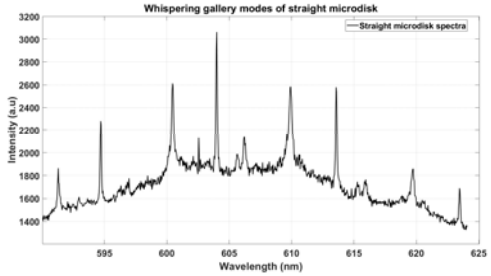
✓ Microdisks by photolithography

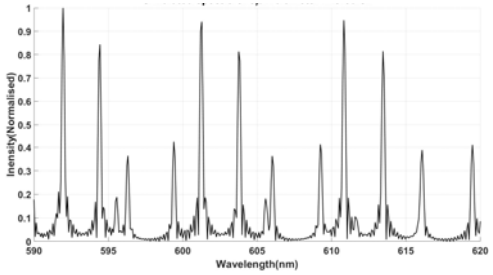


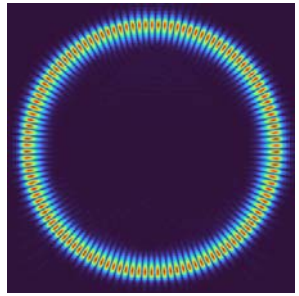




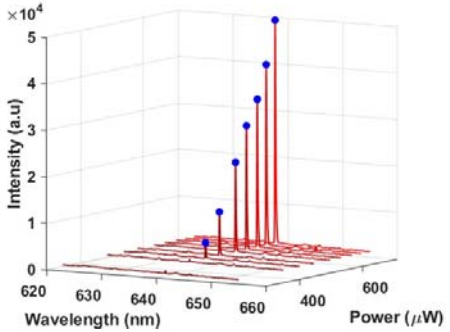
✓Whispering gallery modes







✓ Single mode whispering gallery mode laser



Thanks

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