Optical near-field control of nanoresonators

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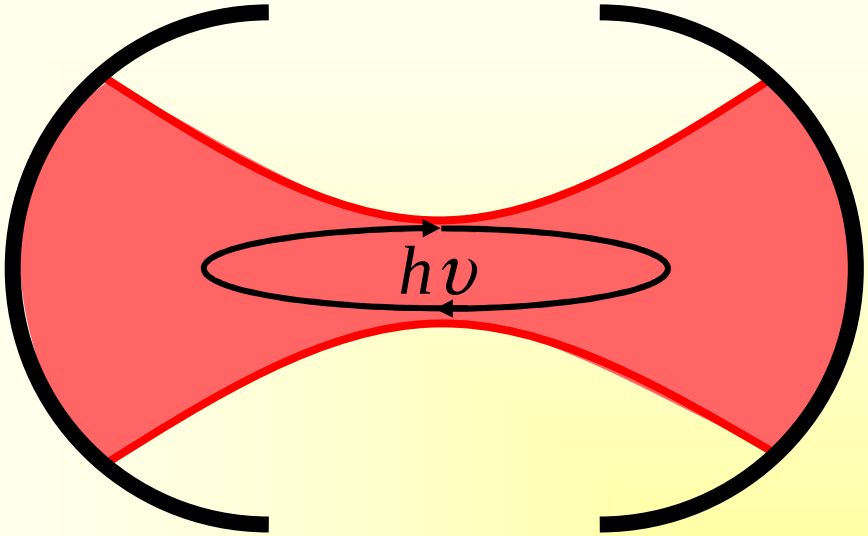
Introduction

Optical resonators



Light confinement inside a volume V with an efficiency Q

For single photon sources, ultra low treshold lasers,
enhanced light matter-interactions.

Figure of merits : **Q/V**

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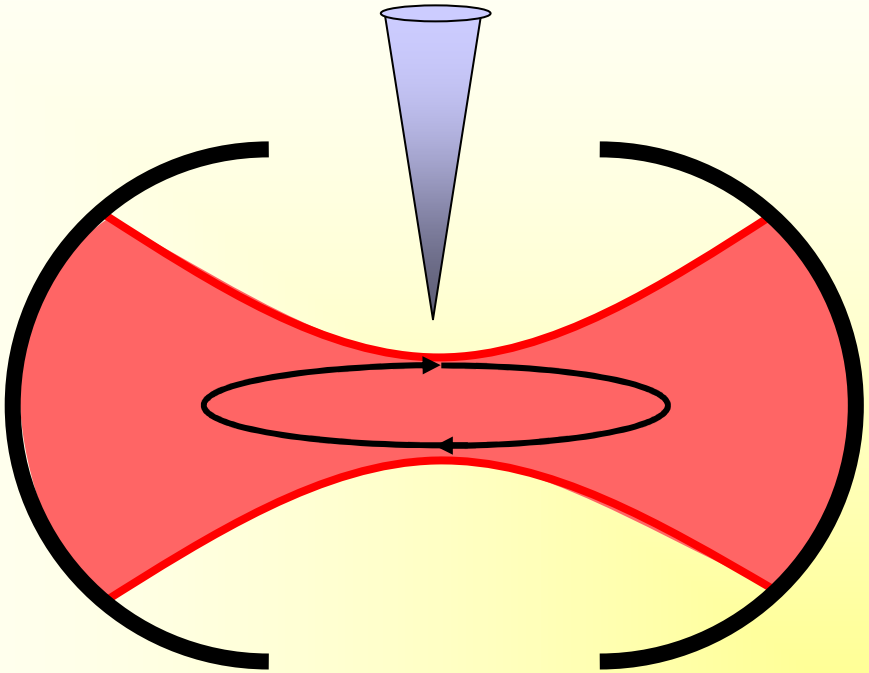
Introduction

Near-Field control of optical resonators



- to probe the electromagnetic field confinement

- to manipulate mechanically the confinement ?

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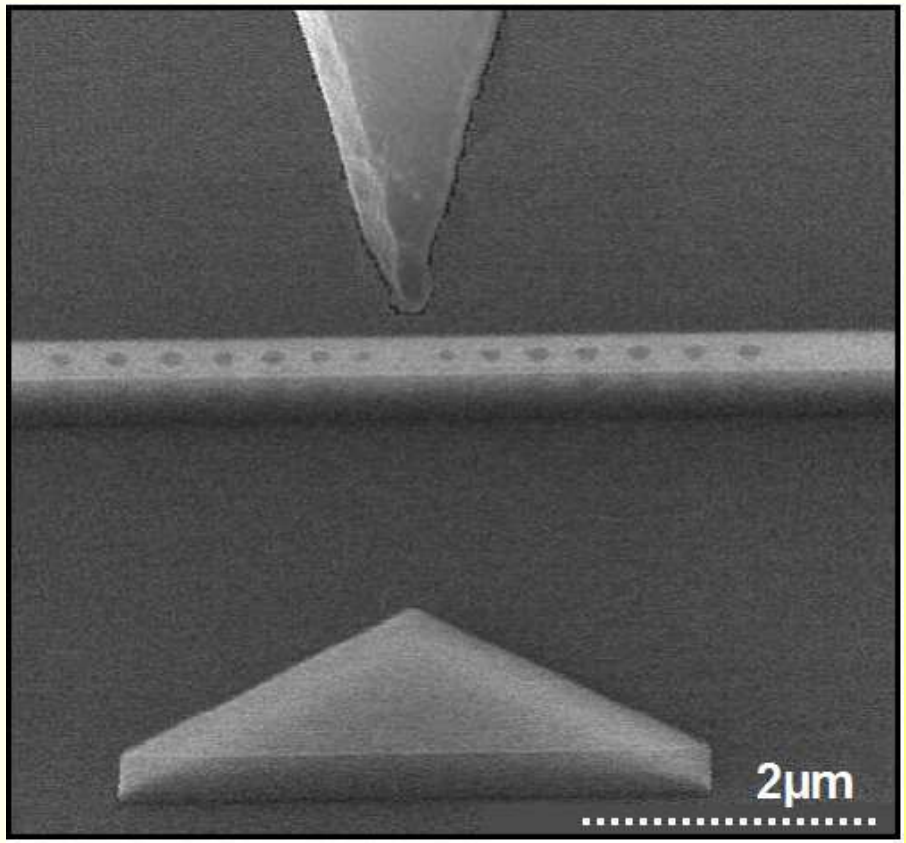
Introduction

at the nanometer scale…



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Outline

1/ Resonators of nanophotonics

2/ Optical near-field microscopy

3/ Near-Field Probing of light confinement

4/ Near-Field Manipulation of light confinement

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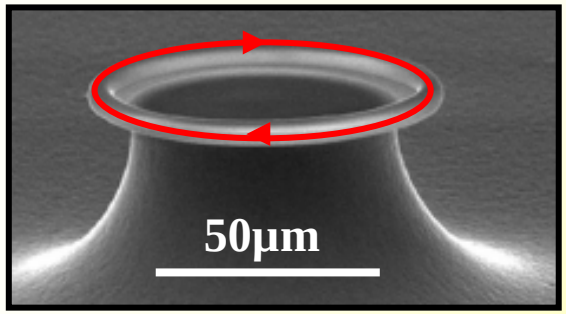
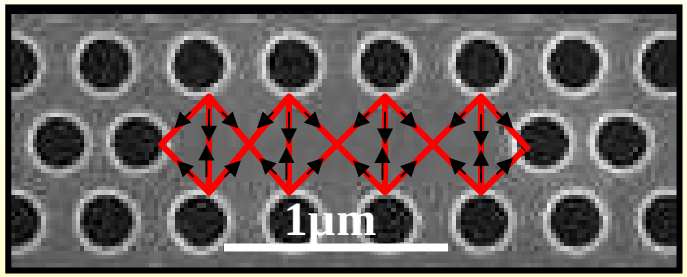
1/ Resonators of Nanophotonics

Spherical/Toroïdal resonators



Kippenberg et al, Nature 421 (2003)

Photonic crystal resonators



Akahane et al, Nature 425 (2003)

Refraction

⇩

*Light confinement with **ultra- high Q***

$Q \sim 10^6\text{-}10^8$ $V \sim 50\mu m^3$

Diffraction

⇩

*Light confinement in **ultra- small V***

$Q \sim 10^4\text{-}10^6$
$V \sim 0.1\mu m^3$

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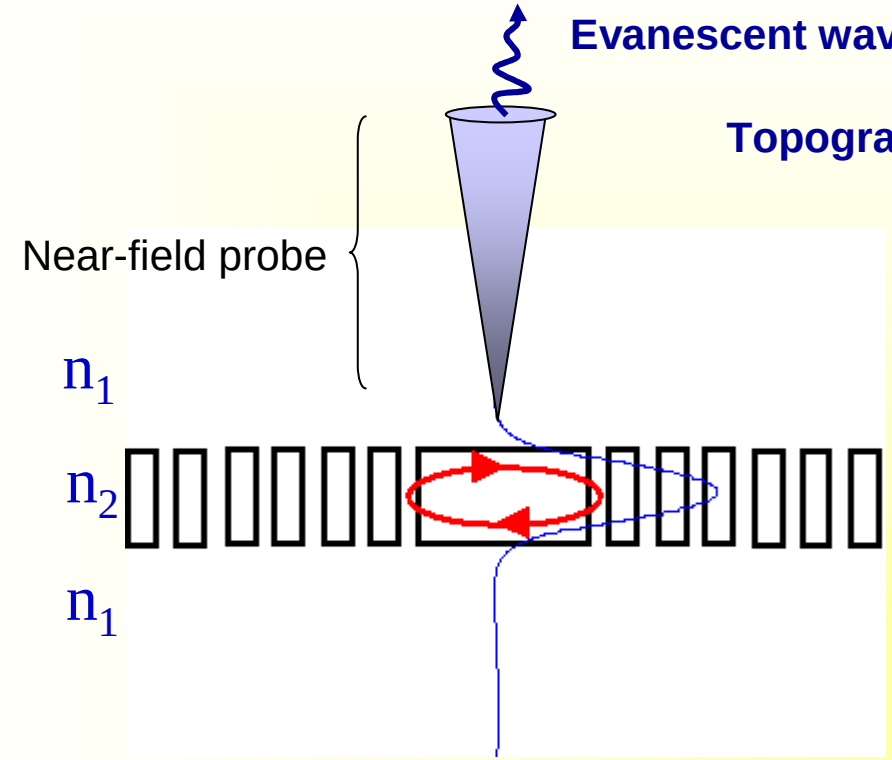
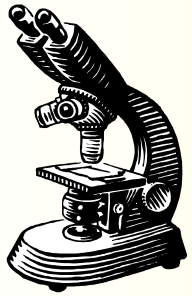
2/ Optical near-field imaging of nanoresonators

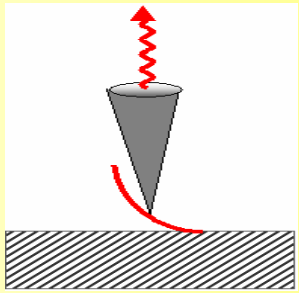
Evanescent wave collection & mapping
+
Topographical pictures



OPTICAL NEAR FIELD



Optical Microscopy :
Propagative waves imaging : Resolution > λ/2 (Rayleigh limit)



Near-field Microscopy :
Evanescent waves imaging : **Sub-wavelength resolution**

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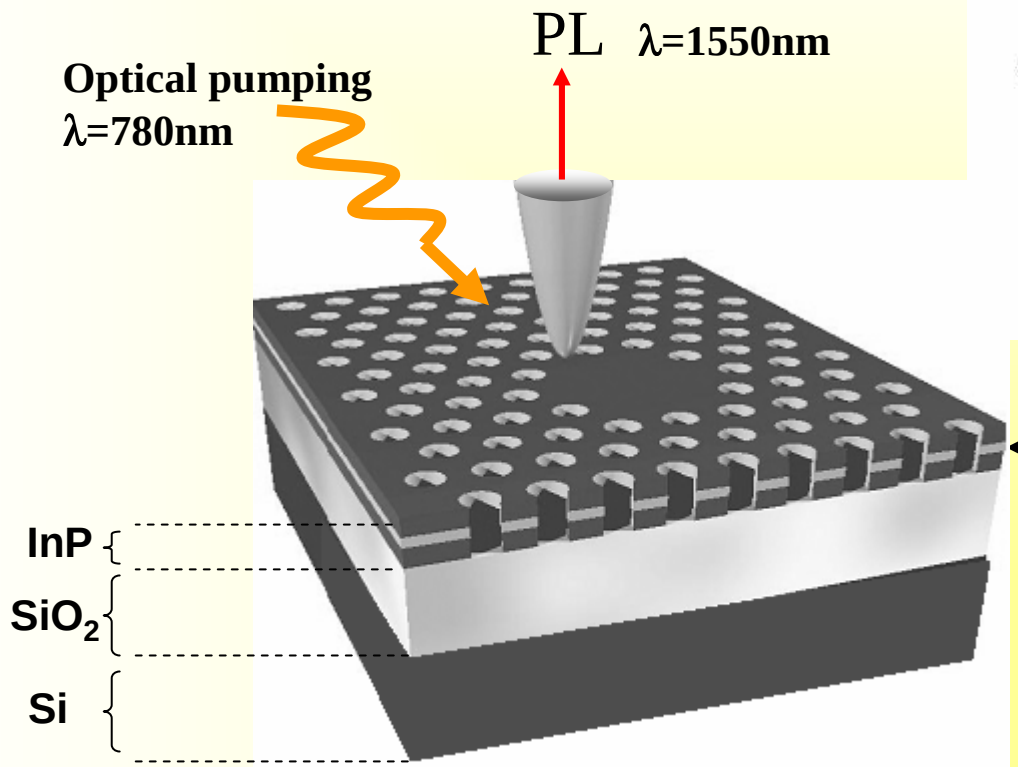
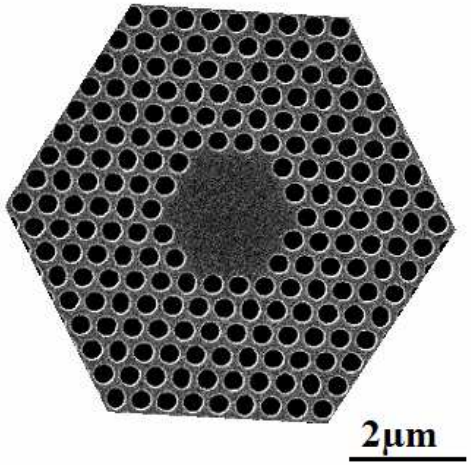
3/ Near-field probing of light confinement

Experimental approach:





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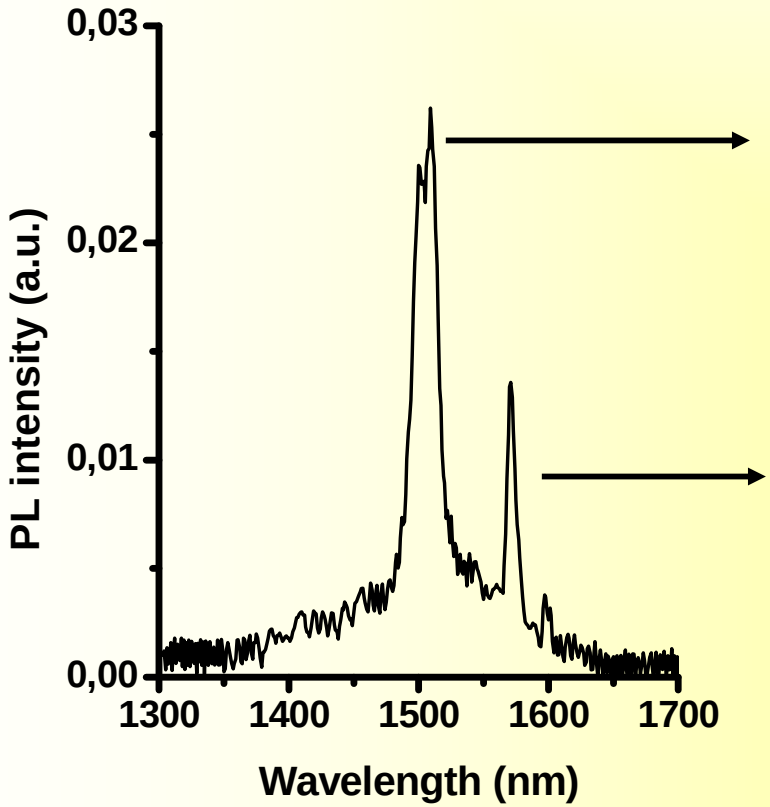
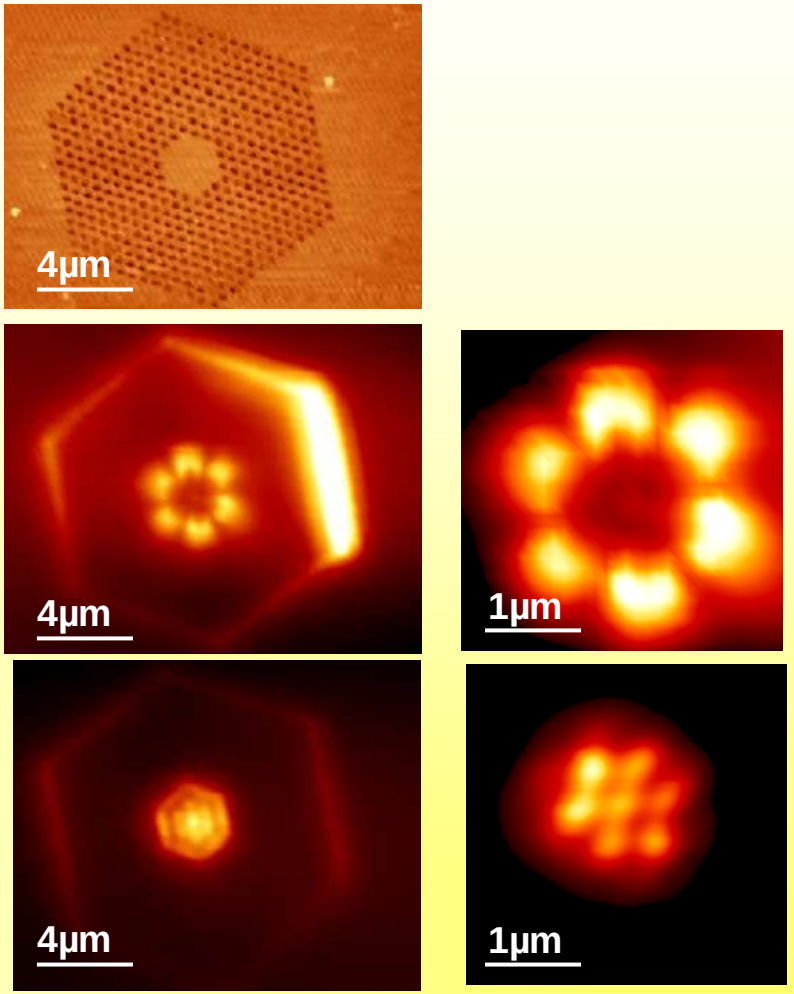
3/ Near-field probing of light confinement

Experimental results:





Resolution ~ λ/10 < Rayleigh limit

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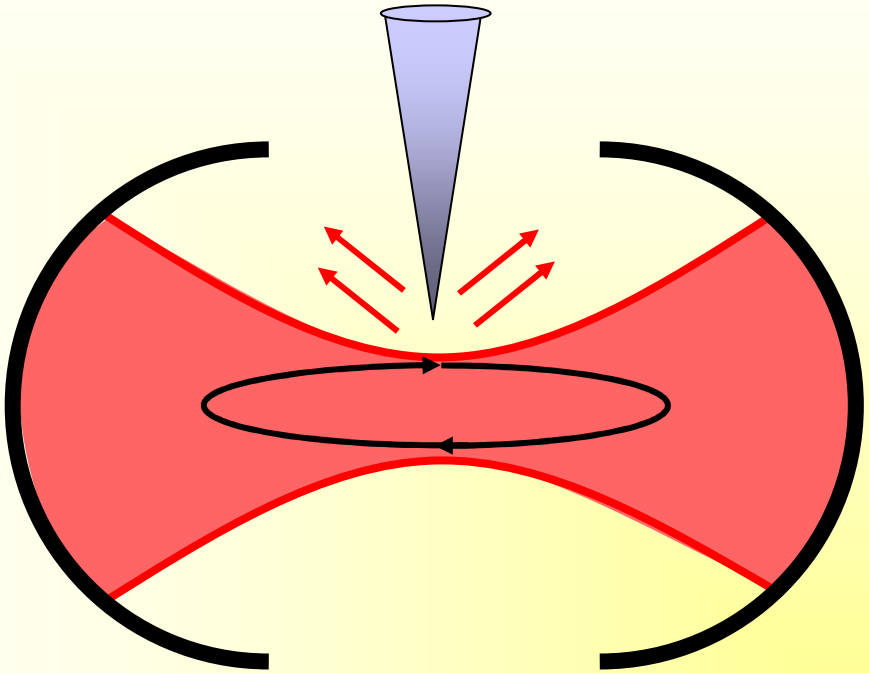
3/ Toward a Near-field control of confined light



What about the effect of the near-field probes ???

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3/ Toward a Near-field control of confined light

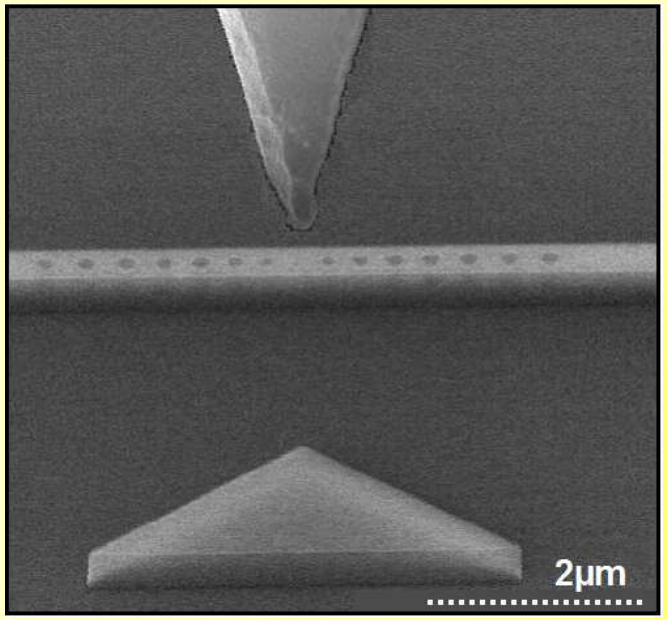
General assumptions:

1- Since the probe volume remains largely lower than the cavity volume

2- The losses introduced by the presence of the probe are lower than the cavity losses

The probe is not a perturbative element of the system

But What happens if



????

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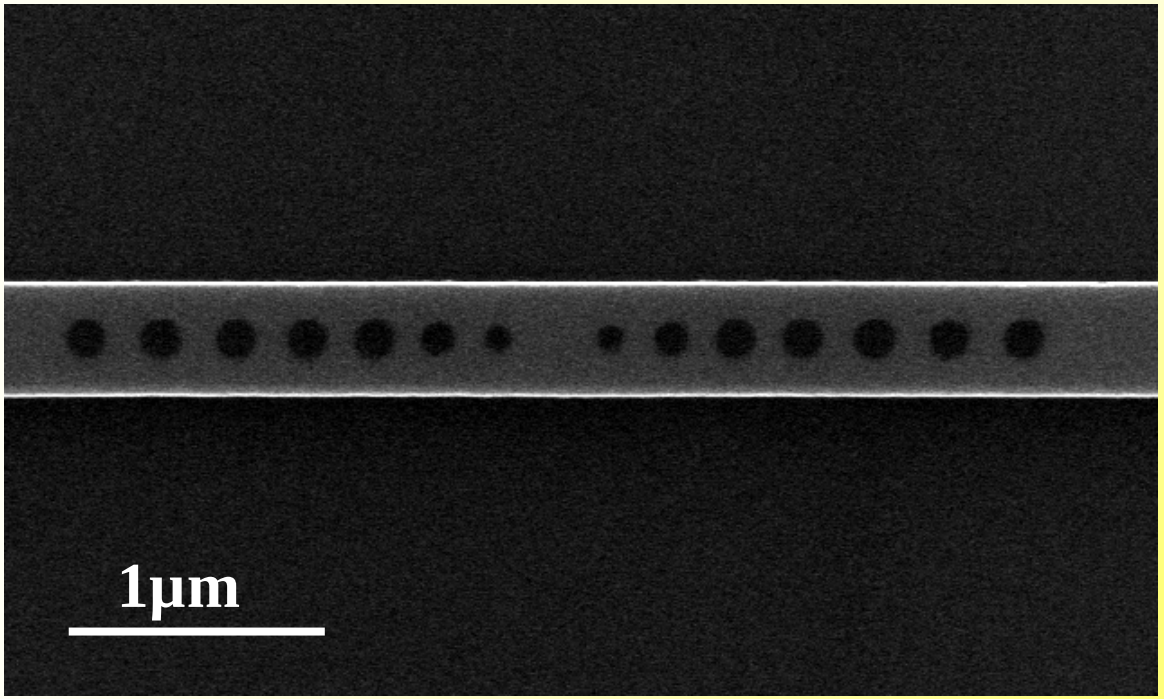
3/ Toward a Near-field control of the confined light

Let consider a state of the art nanocavity with:

An ultra low-volume : $V=(\lambda/n)^3$

A high Q-factor: $Q\sim10^4\text{-}10^5$



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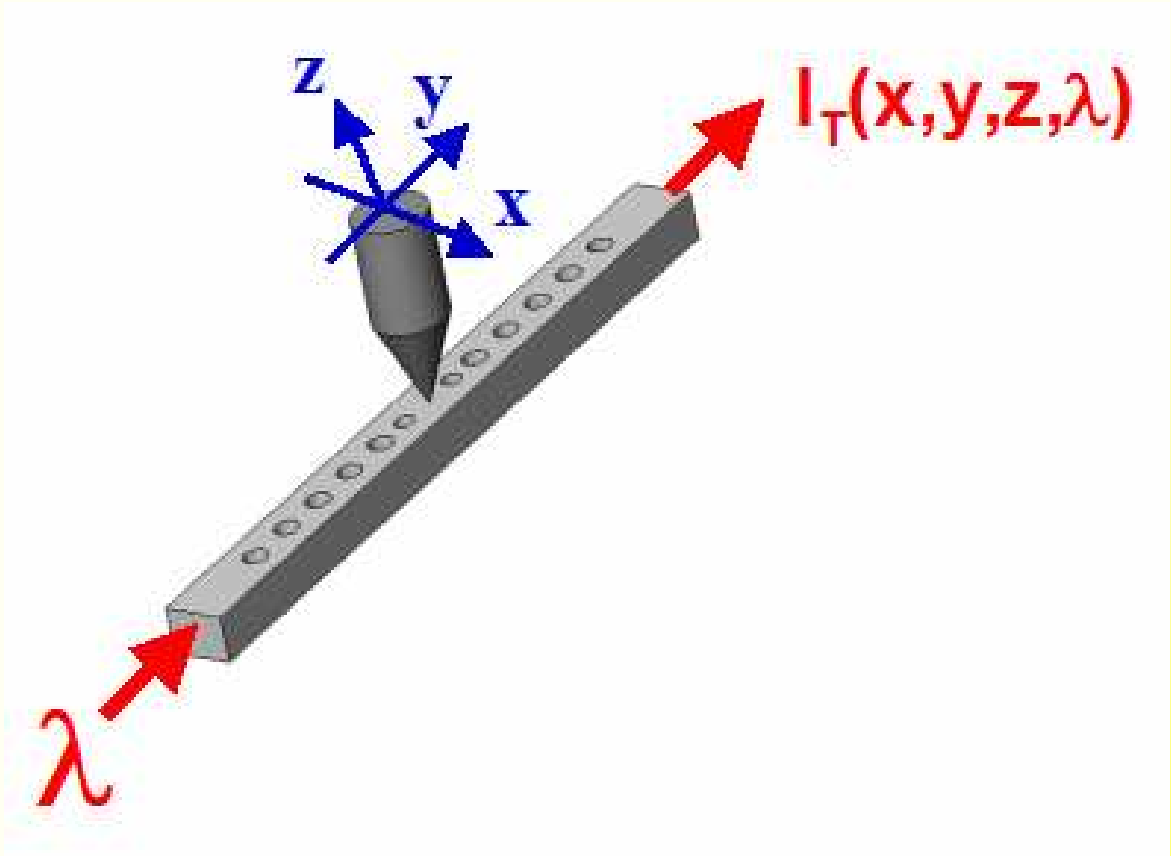
3/ Toward a Near-field control of the confined light

« pump – probe » experiments with a near-field tip



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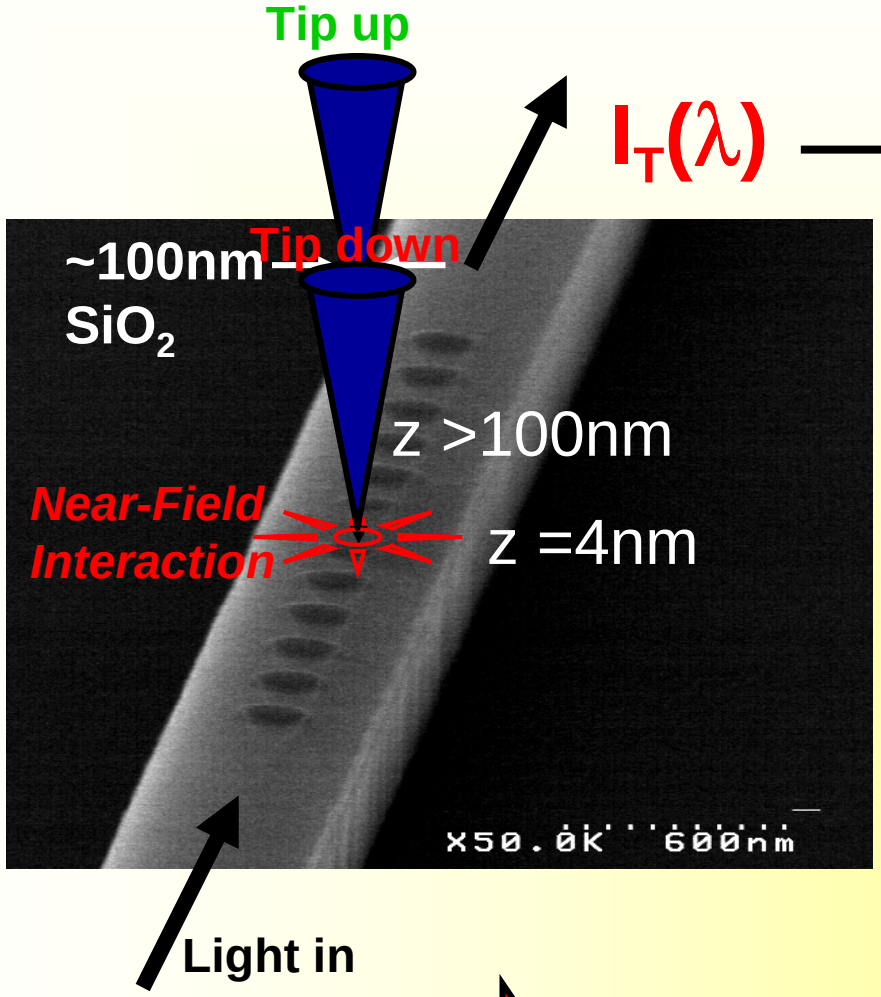
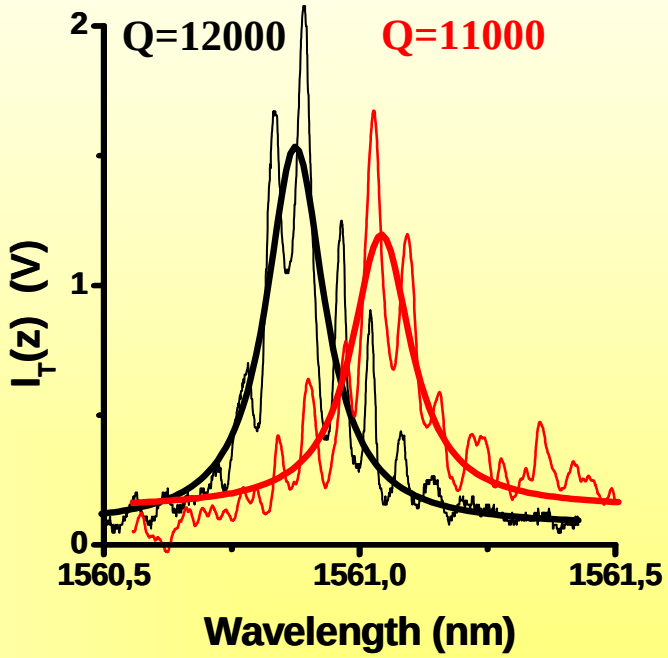
3/ Basics of Optical Near-Field interactions



$I_T(\lambda)$



Losses introduced by the probe << Cavity Losses

The probe acts as an optical path length modulator

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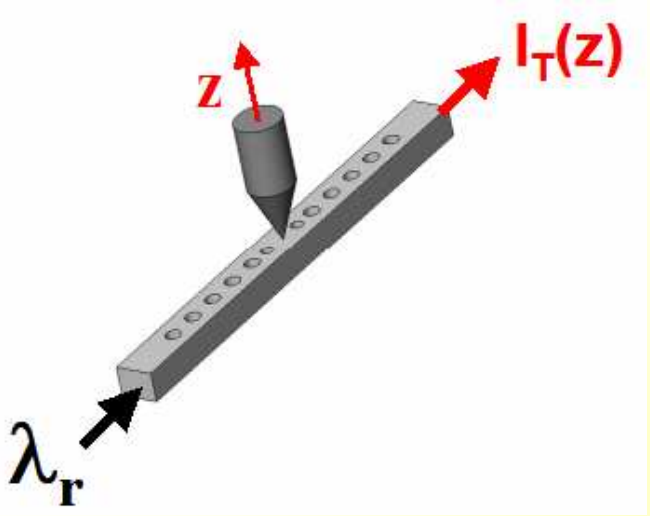
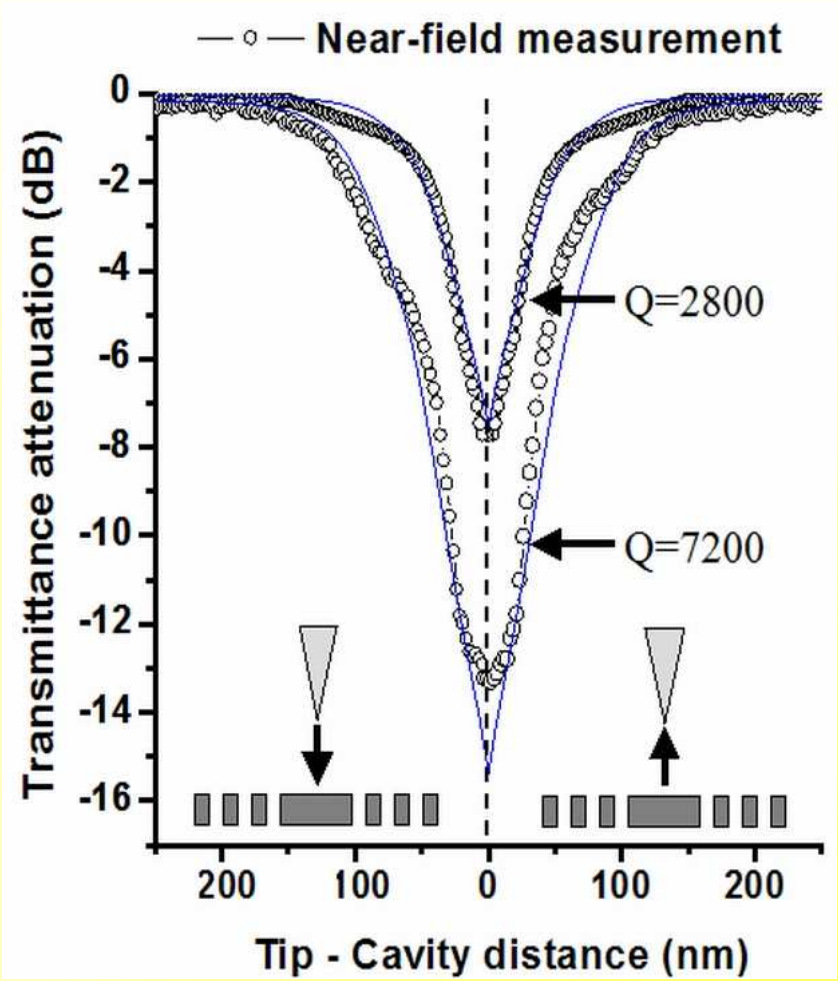
3/ Basics of Optical Near-Field interactions



Evanescent interaction between probe and cavity



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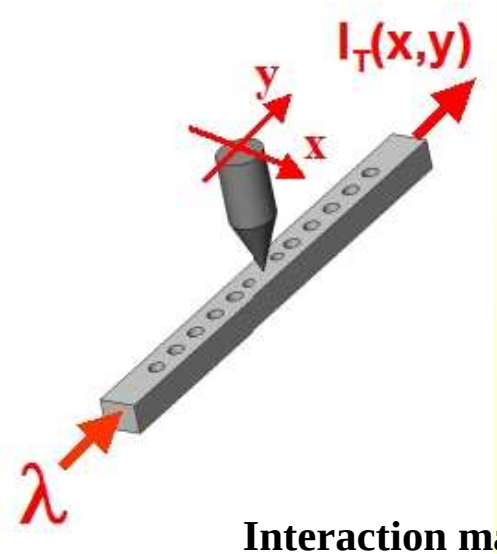
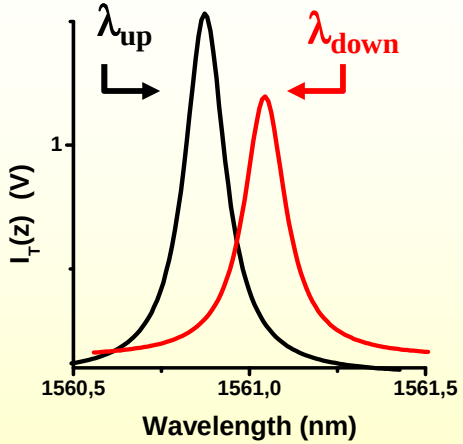
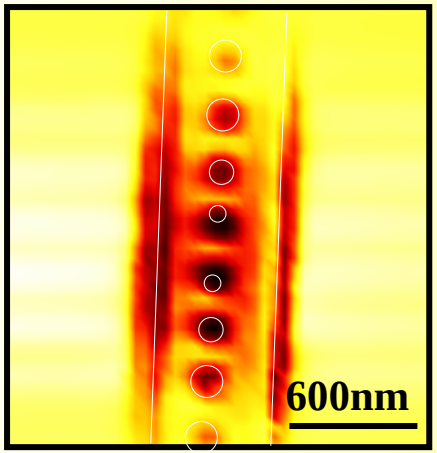
3/ Optical Near-Field interactions mapping

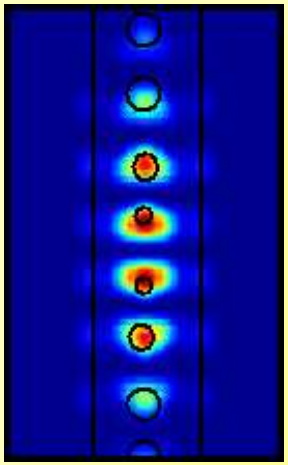




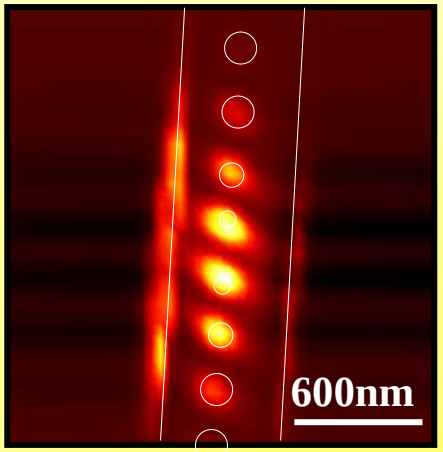
Interaction map @ λ_{up}



$\|E\|^2$



Interaction map @ λ_{down}



Dielectric pertubation of the Electric field

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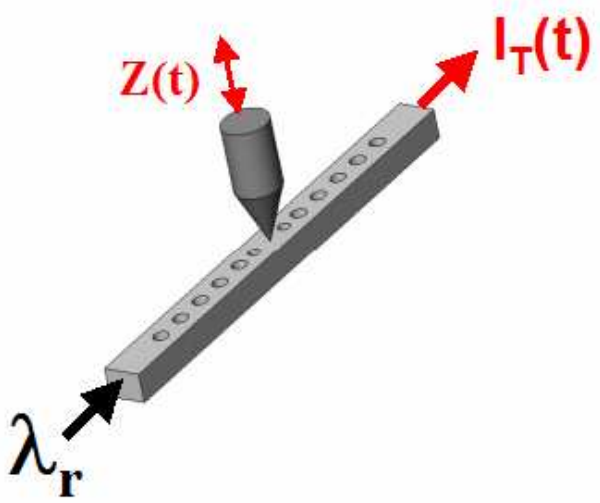
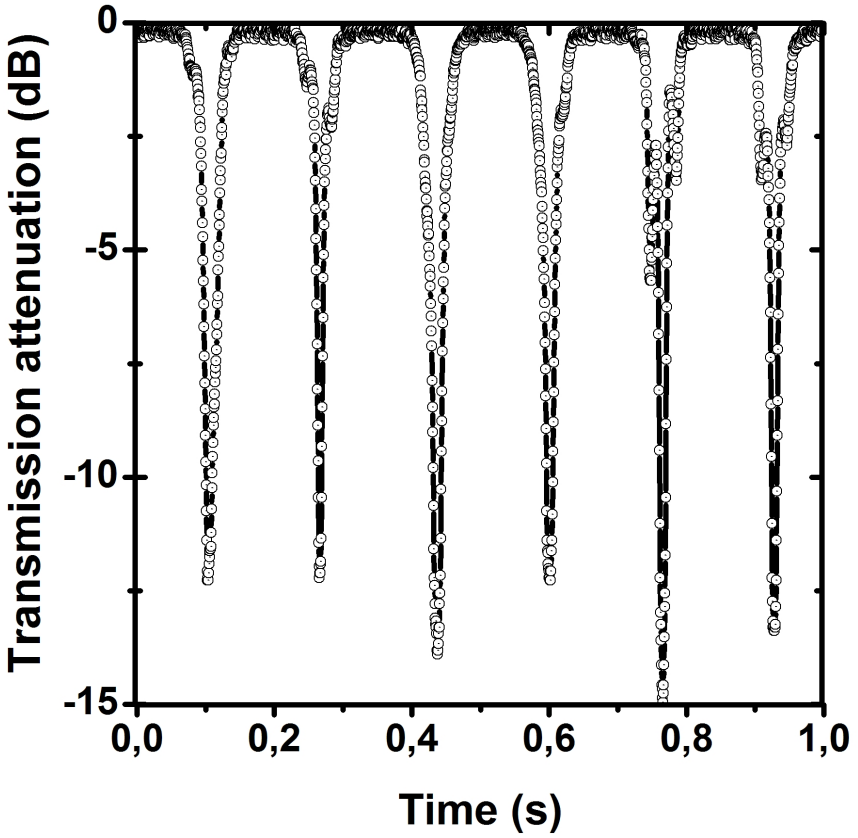
3/ Optical Near-Field interactions control





Time scale for switching limited by mechanical resonance

=>could excess the MHz range with the integration of cantilevers

Near-Field Switch

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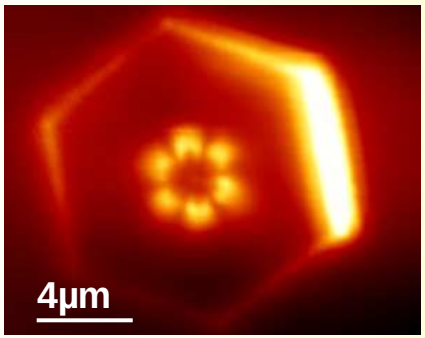
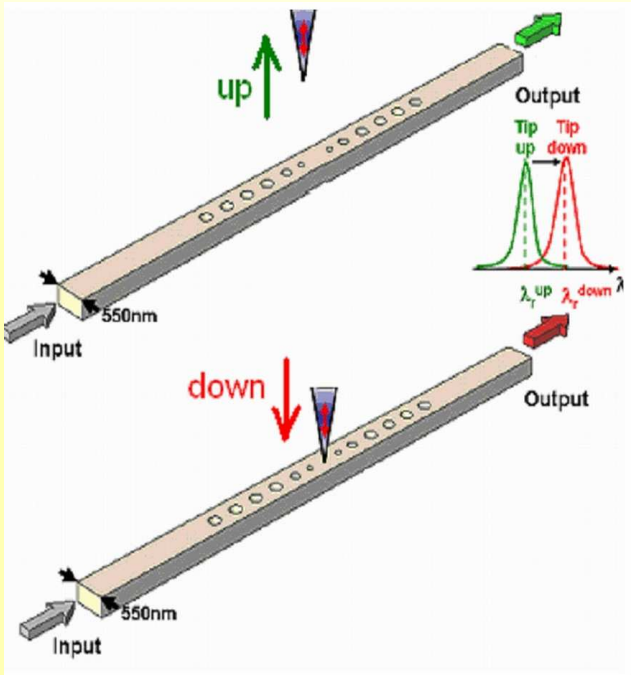
Conclusion

From Passive to Active Near Field Optics

Sub-λ probing of the light confinement in nanoresonators



Sub-λ manipulation of the light confinement in nanoresonators



Publications:

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Cluzel et al, **App. Phys. Lett. 88**, 2006

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