Introduction : ENS de Cachan

ENS CACHAN

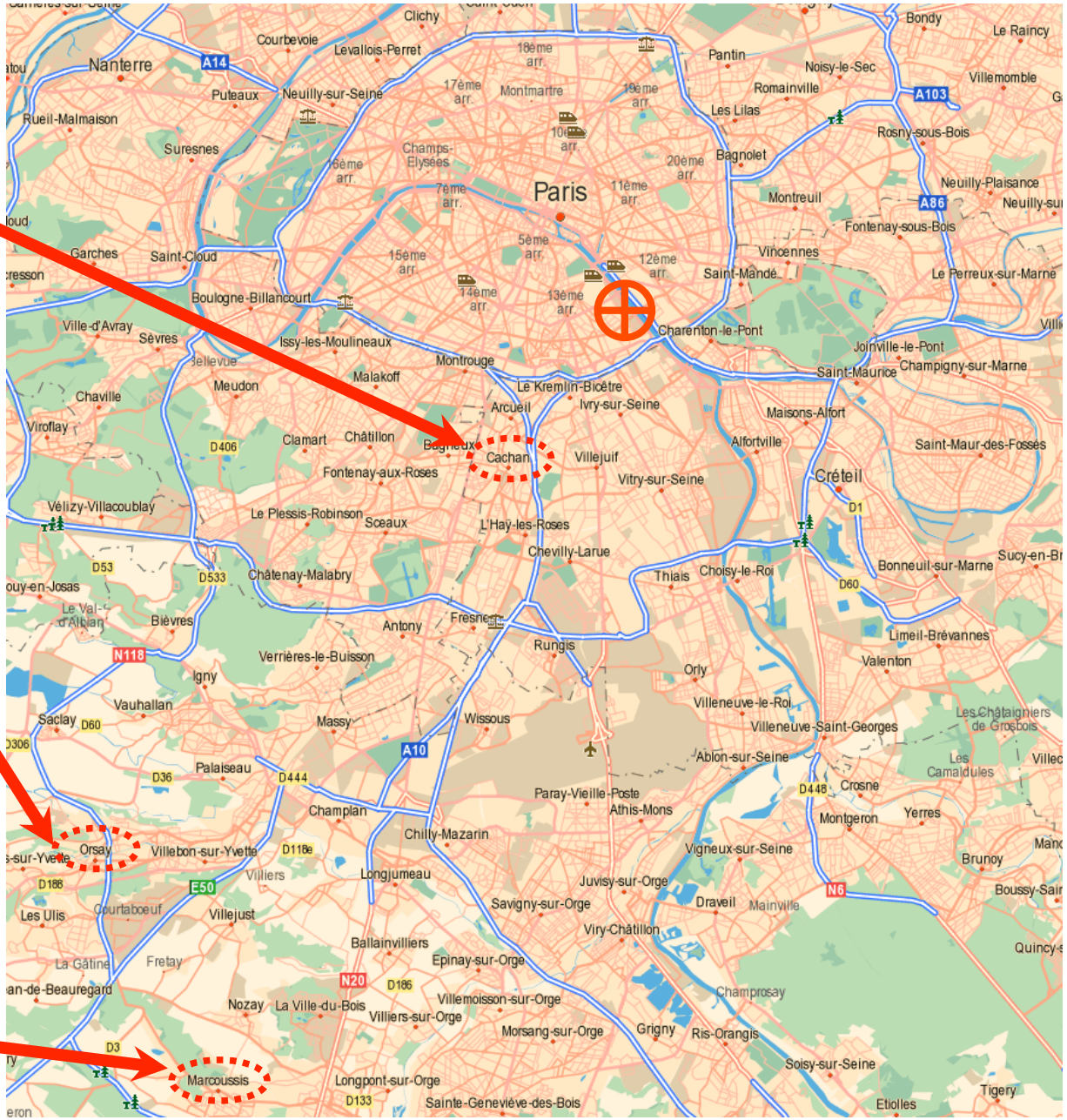
Basic sciences
Social sciences

UNIVERSITÉ PARIS-SUD 11

E. Bogomolny

LABORATOIRE DE PHOTONIQUE ET DE NANOSTRUCTURES

C. Ulysse

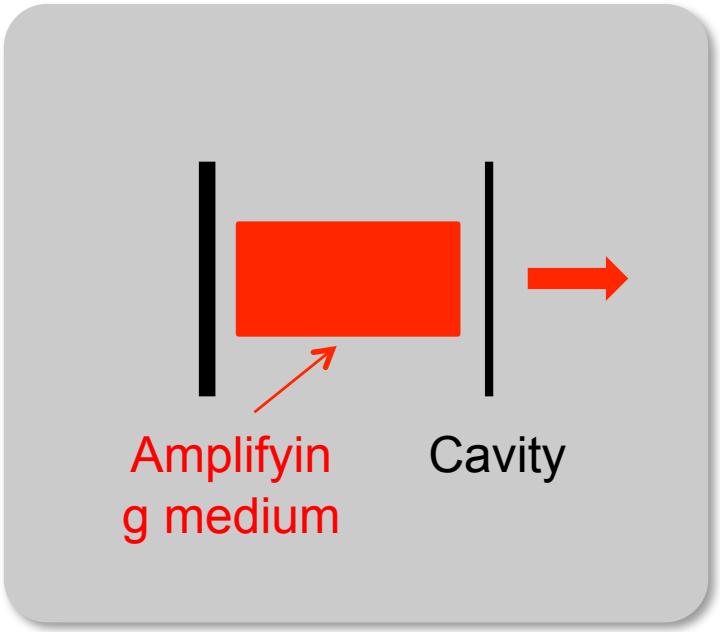


Outline

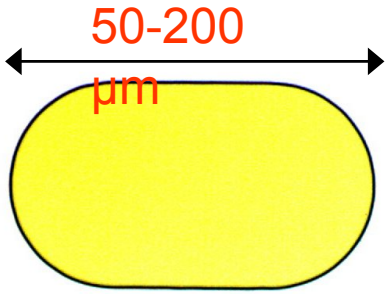
1) Background on organic microlasers
   - Presentation of the devices
   - Optical characterization
   - Applications
   - Lasing studies

2) Recent developments to address diffraction
   - Square shaped cavities
   - Triangle shaped cavities
   - Investigating 3D diffraction

Microlaser = LASER + micro



Laser = cavity + active medium

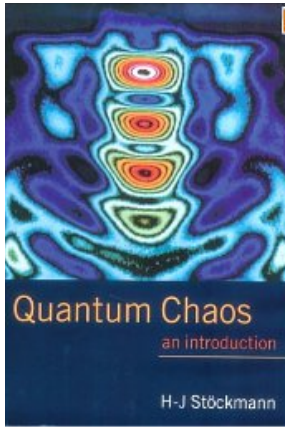


$\lambda = 0.6$ µm

OPEN SYSTEM

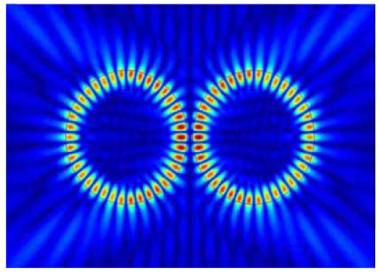
SEMI-CLASSICAL

Optical resonators :



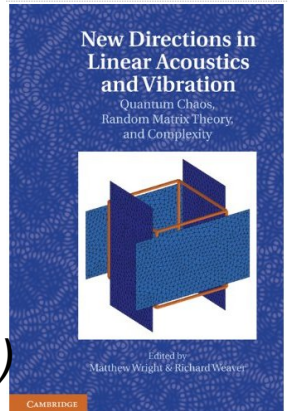
Micro-wave billiards

HJ Stöckmann (2007)



Acoustic resonators

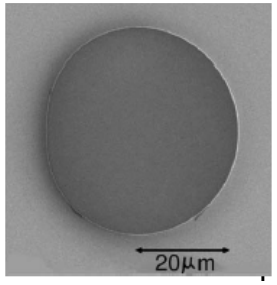
R. Waever (2010)



Tera-Hertz resonators

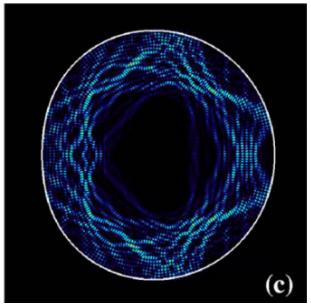
OE 16, 7339 (2010)

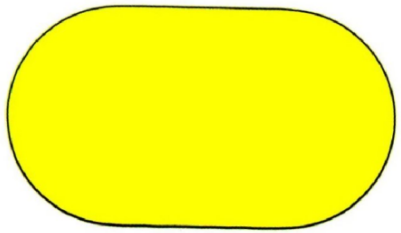
Optical cavities



PRL 108, 253902 (2012)
APL 101, 021116 (2012)

PRL 103, 154101 (2009)

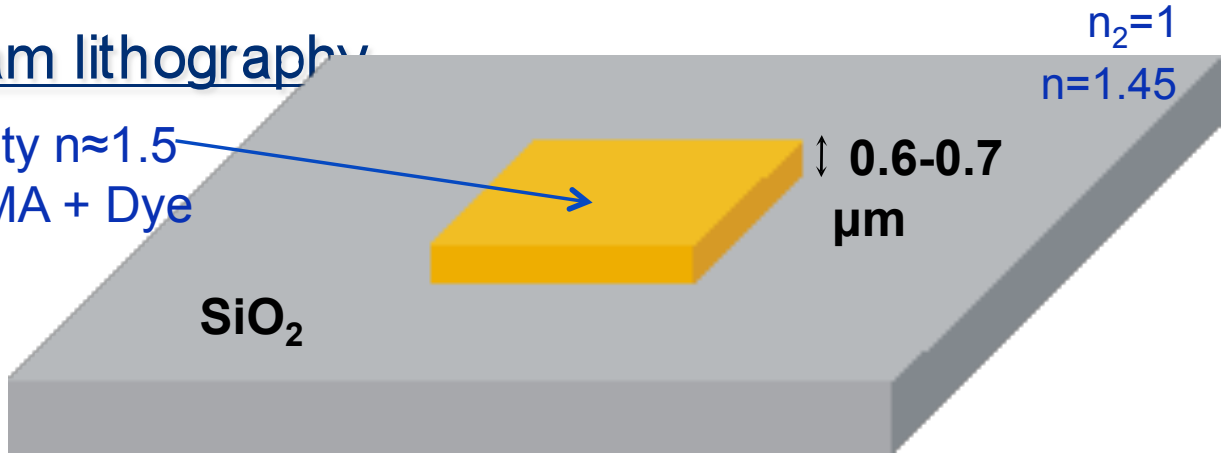




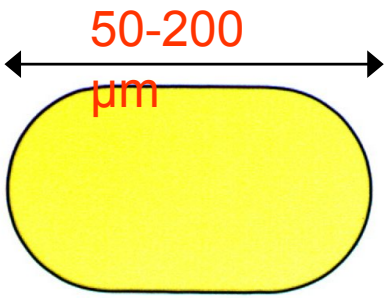
Organic micro-lasers

Organic laser microcavities

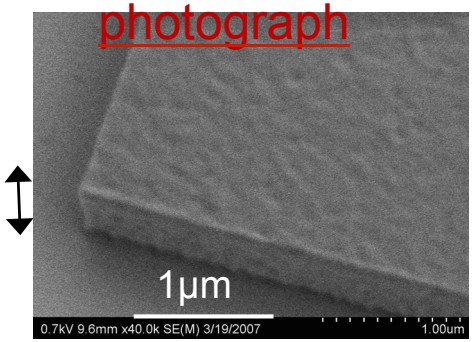
Fabrication : Electron-beam lithography



Microscope photograph



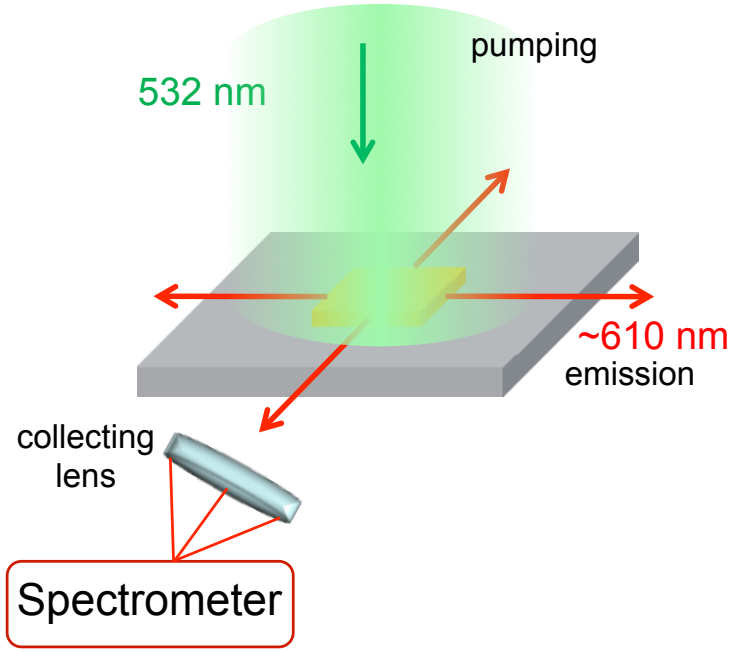
SEM photograph



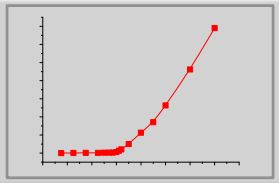
- Different cavity shapes
- Different laser dyes

Organic laser microcavities : characterization

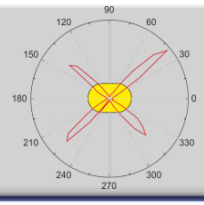
Excitation geometry

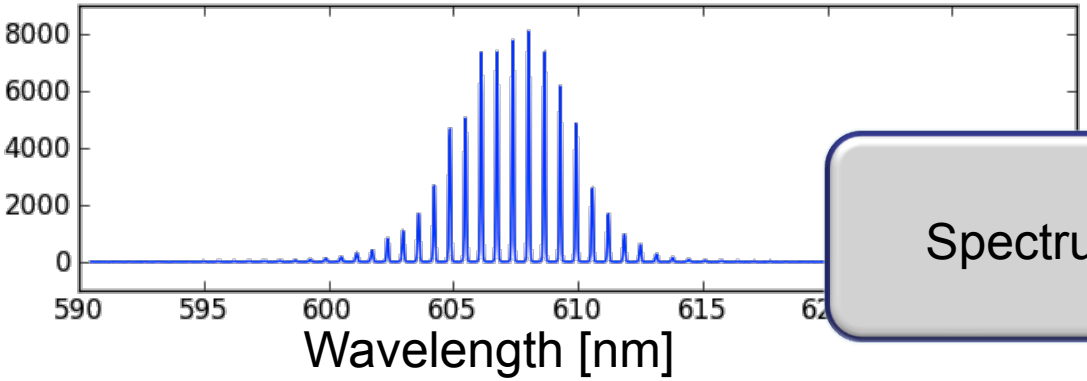


Lasing thresholds



Emission diagrams

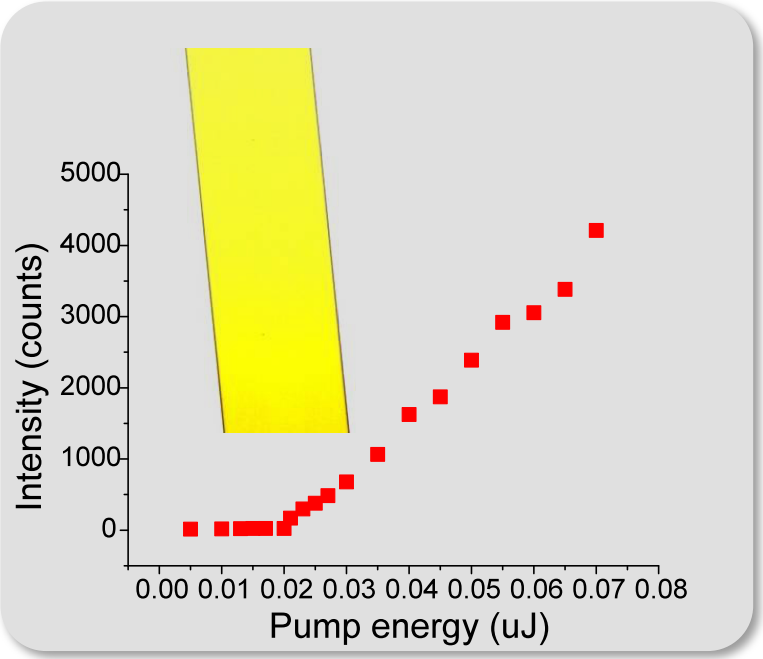




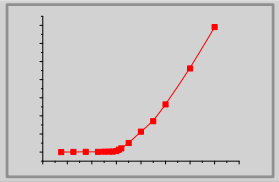
Spectrum

Organic laser microcavities

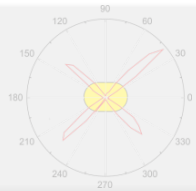
Information, obtained from the experiment

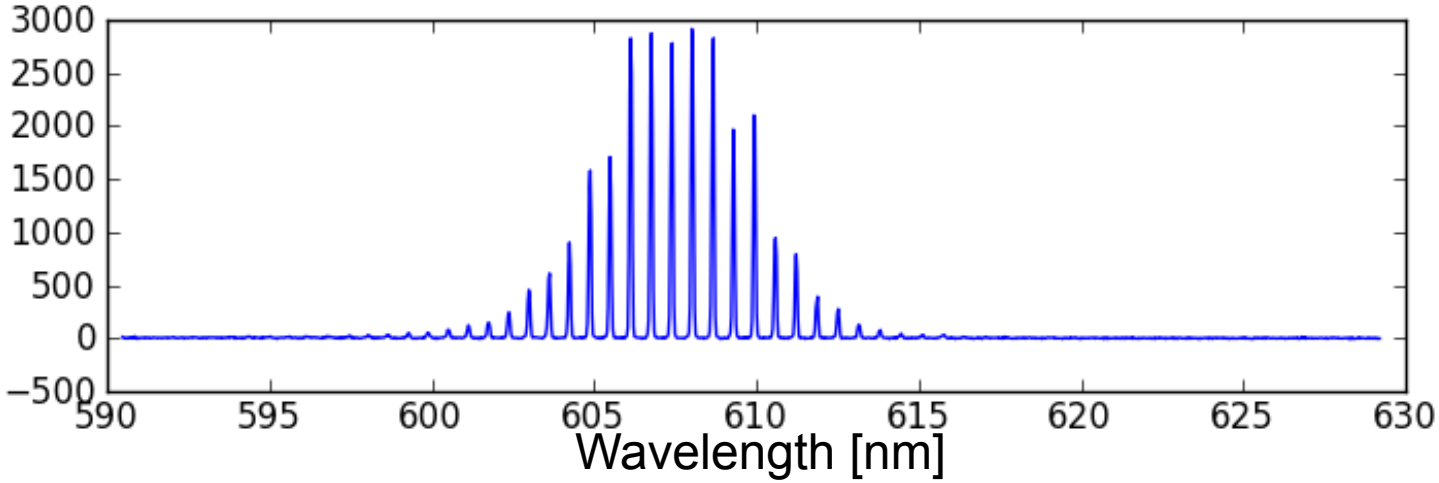


Lasing thresholds



Emission diagrams

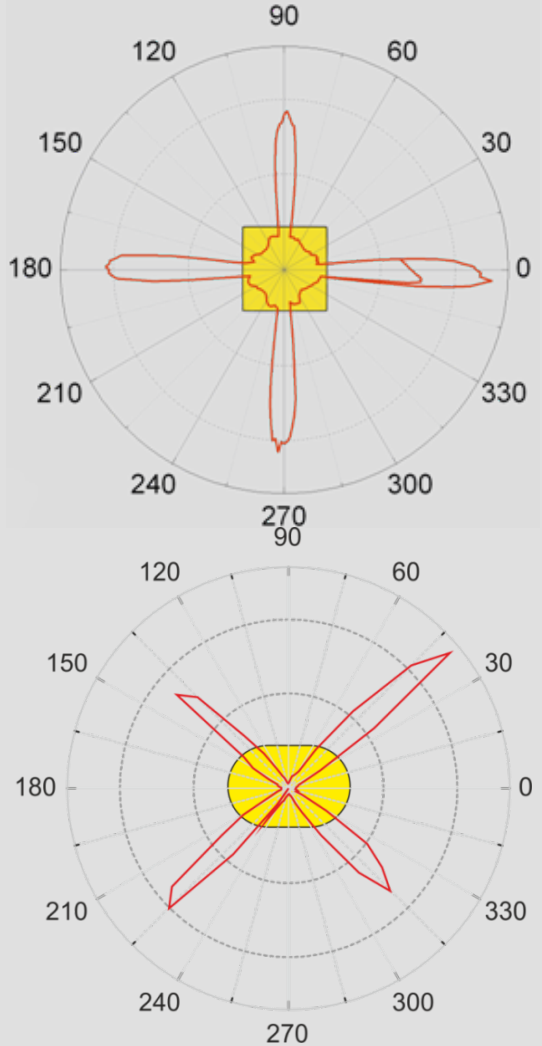




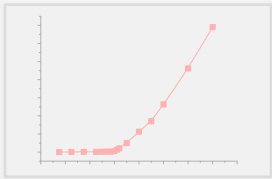
Organic laser microcavities

Information, obtained from the experiment

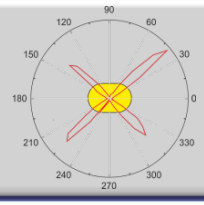
FAR FIELD DETECTION



Lasing thresholds



Emission diagrams

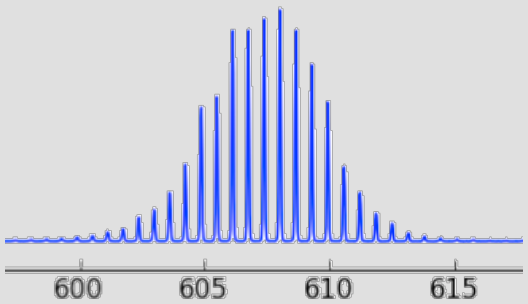


Spectrum

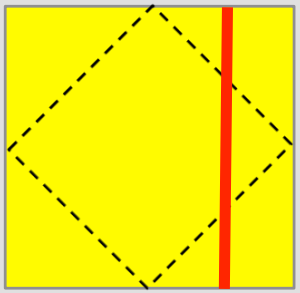
Physical Review A 75, 033806 (2007)

Organic laser microcavities

Information, obtained from the experiment

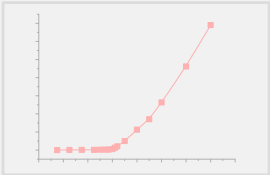


Semi-classical approach

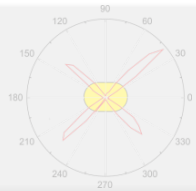


TRACE FORMULA

Lasing thresholds



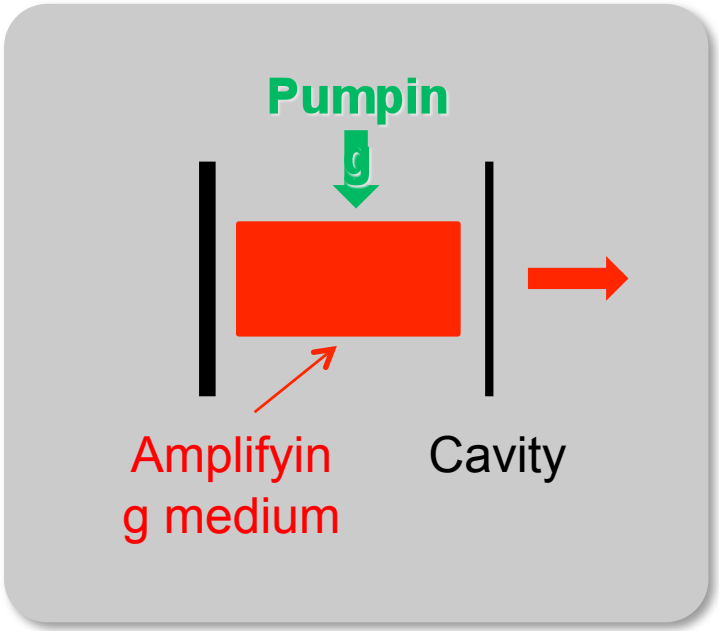
Emission diagrams



Spectrum

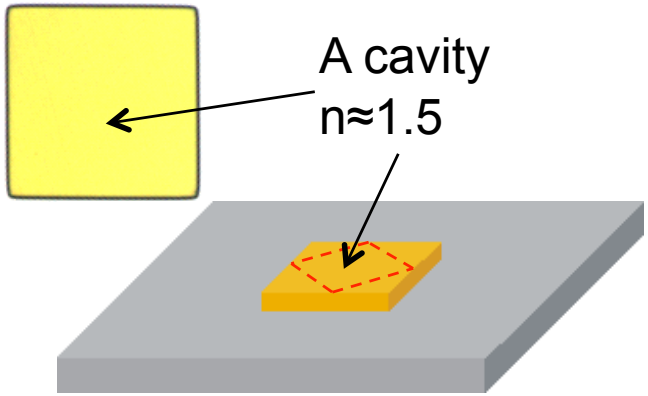
Organic laser microcavities

Conventional laser

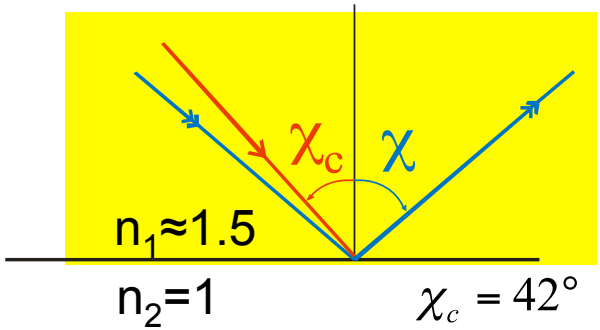


Laser = cavity + active medium

Plastic micro-laser

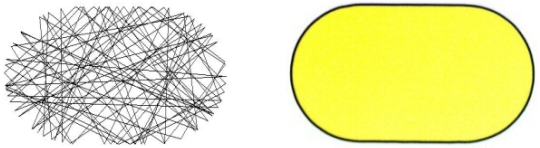


Light confinement by
(total internal) reflection



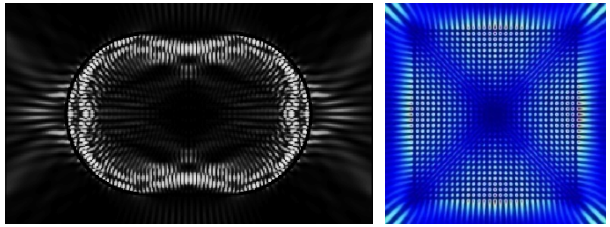
LPQM – micro-laser group

Chaotic cavities



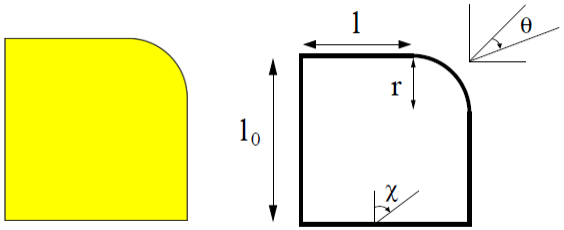
Lebental, APL, 88 031108 (2006)

Numerical modeling



$$(\Delta_{xy} + n_{eff}^2 k^2)\ \Psi = 0$$

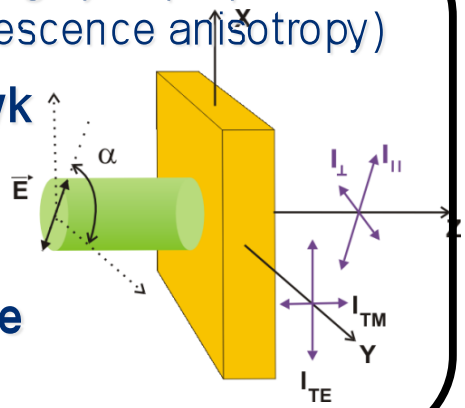
Experimental and theoretical description



N.Djellali, ICTON (2008)

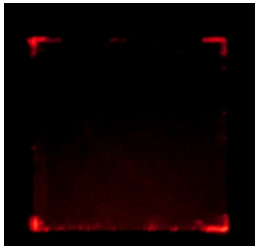
Lasing dyes properties (fluorescence anisotropy)

I. Gozhyk

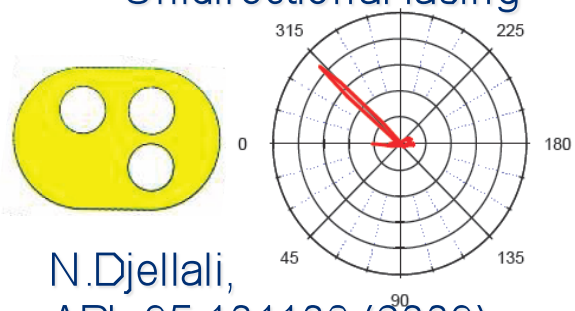


PhD defense 10/16

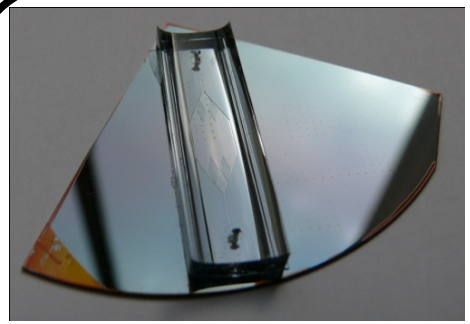
Diffraction



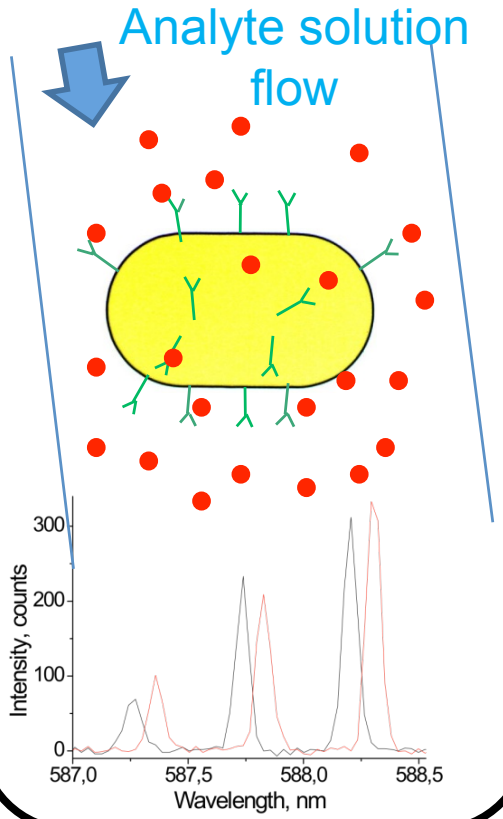
Unidirectional lasing



N.Djellali, APL 95 101108 (2009)

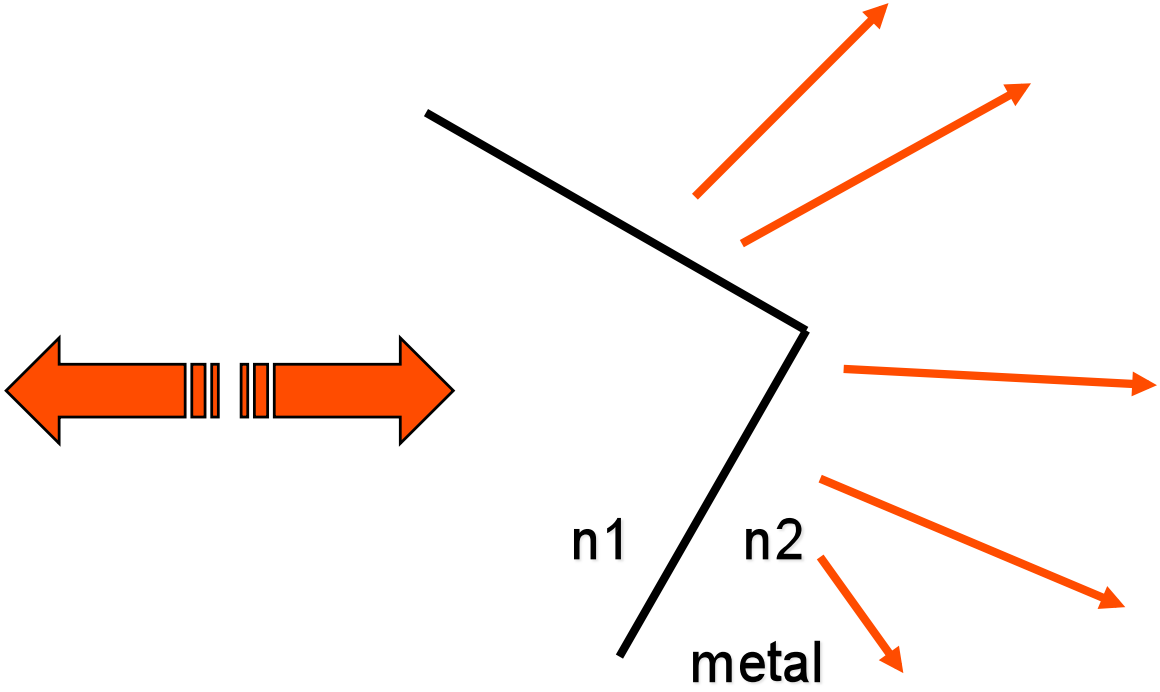


Microfluidics, S.Lozenko



Organic laser microcavities

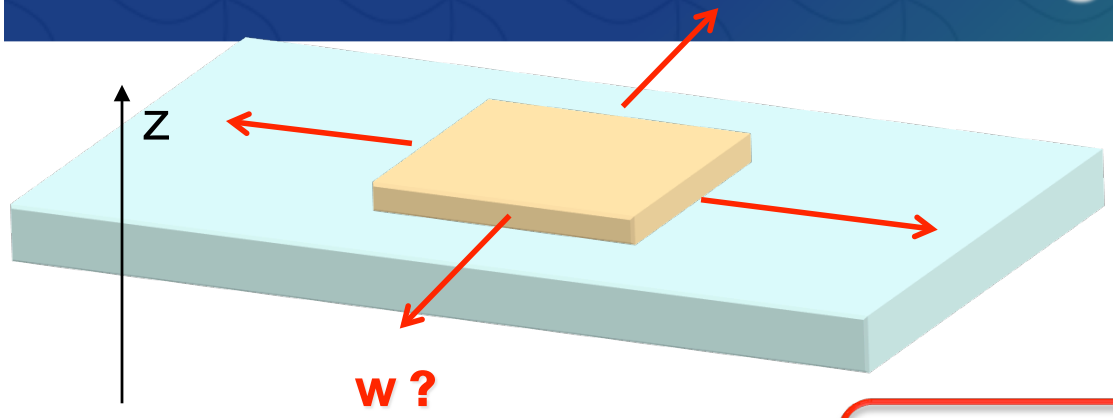
No analytical solution for the diffraction by a dielectric edge



Sommerfeld

A standing wave supported by a dielectric edge could teach us something

Electromagnetism



Passive cavity (no laser) :

resonances

Boundary conditions

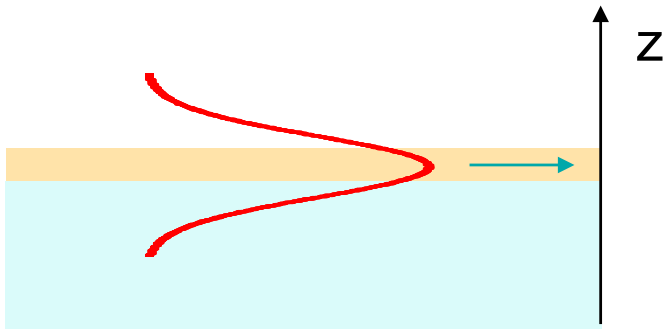
Inside

$$(\Delta_{xy} + n_{eff}^2 k^2)\ \Psi = 0$$

Outside

$$(\Delta_{xy} + k^2)\ \Psi = 0$$

Effective index approximation



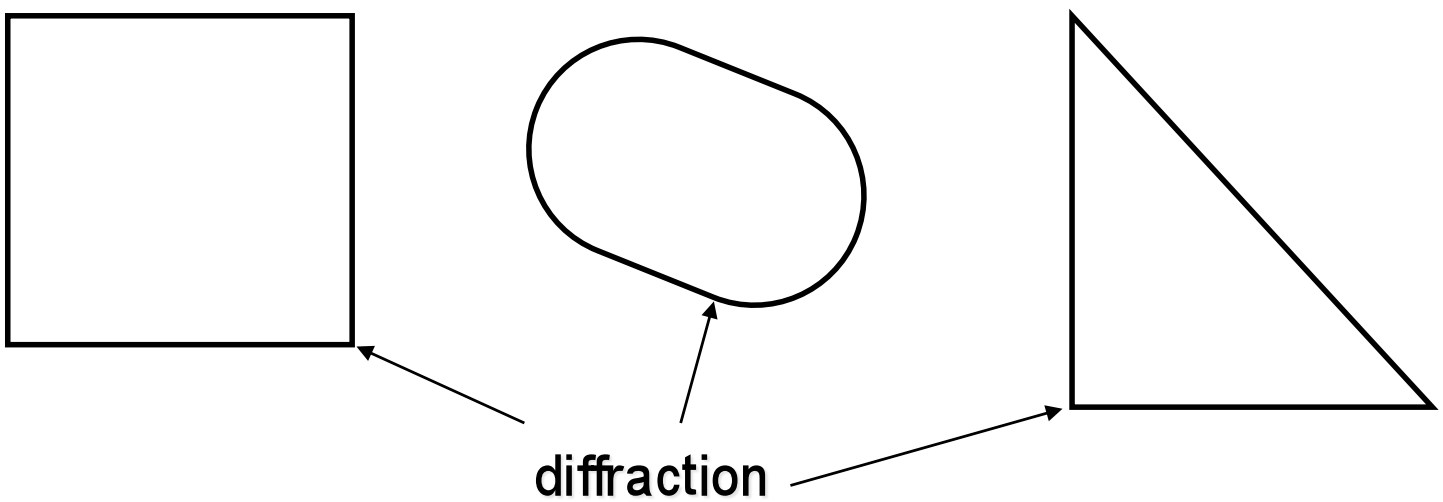
From electromagnetism to wave chaos

2D problem

$$(\Delta_{xy} + n_{eff}^2 k^2)\ \Psi = 0$$

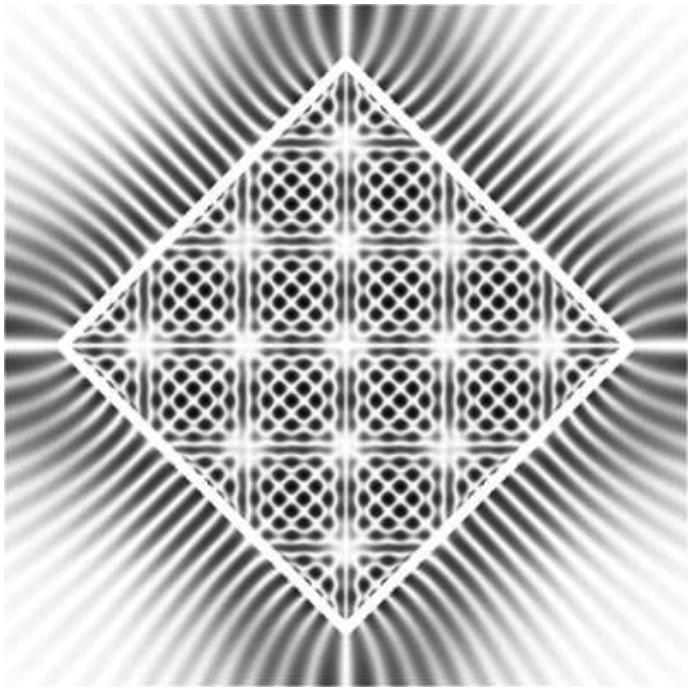
$$(\Delta_{xy} + k^2)\ \Psi = 0$$

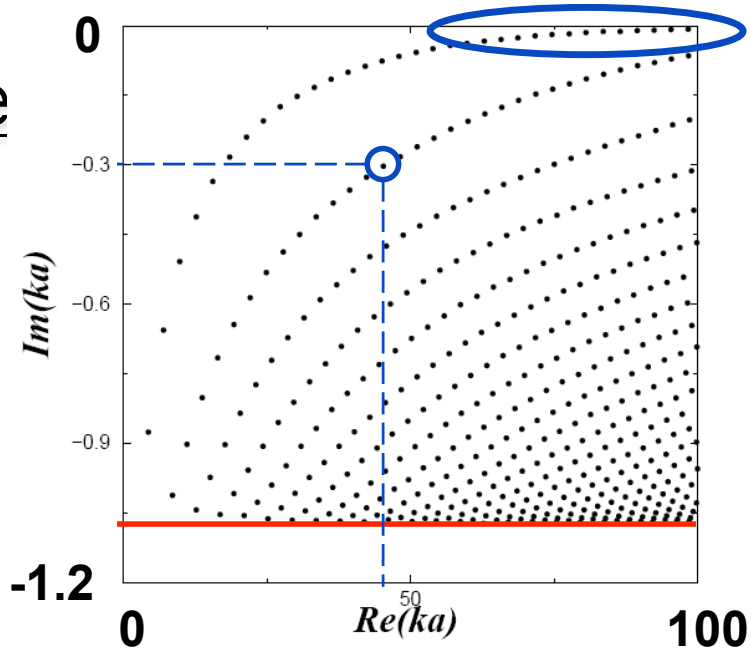
Boundary conditions

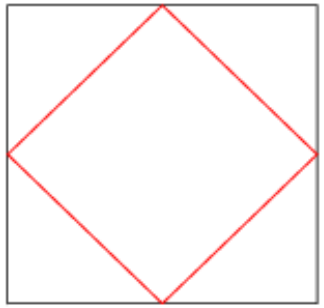


Resonance computation

Square: not integrable



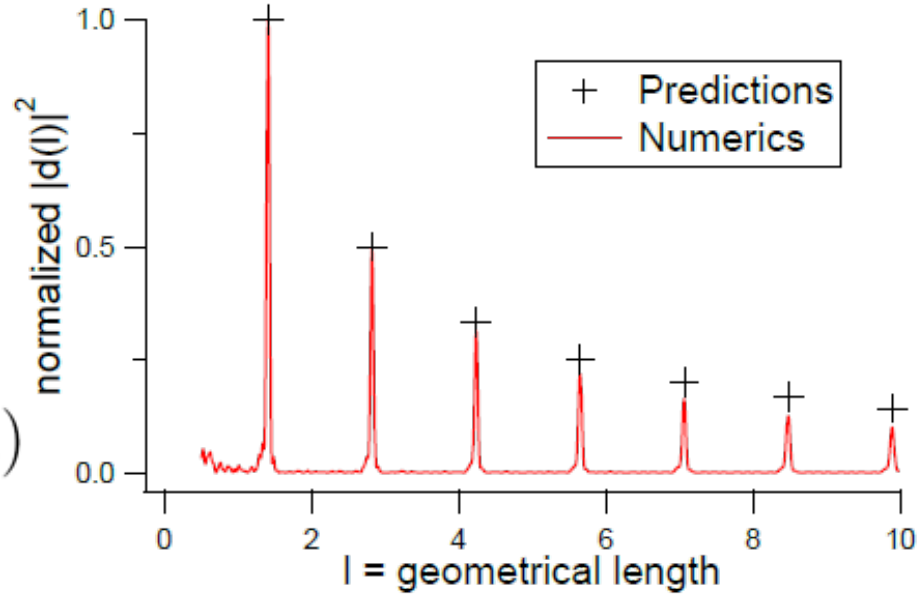




Diamond

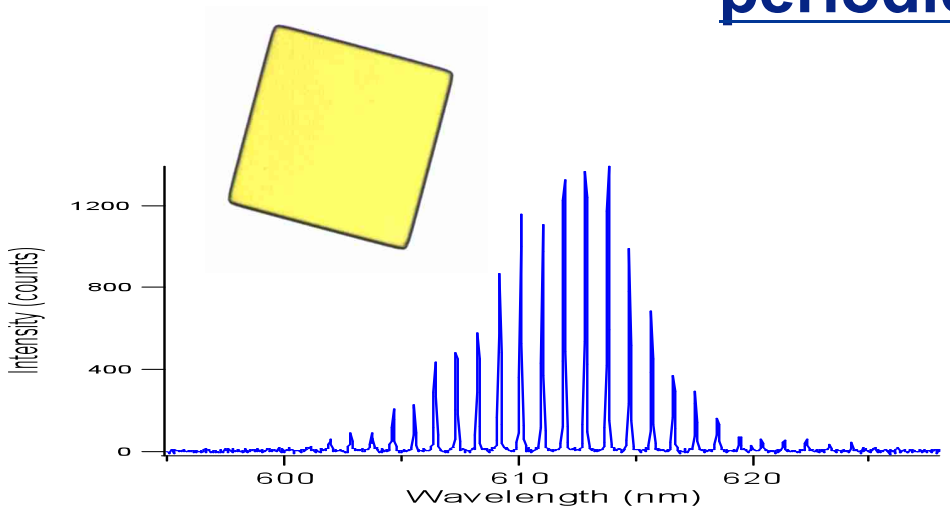
Charles Schmit, Eugène Bogomolny
Phys. Rev. E 83, 036208 (2011)

$$d(k) \propto \sum_p \mathrm{r_p} C_p \cos(\mathrm{n} k L_p + \varphi_p)$$

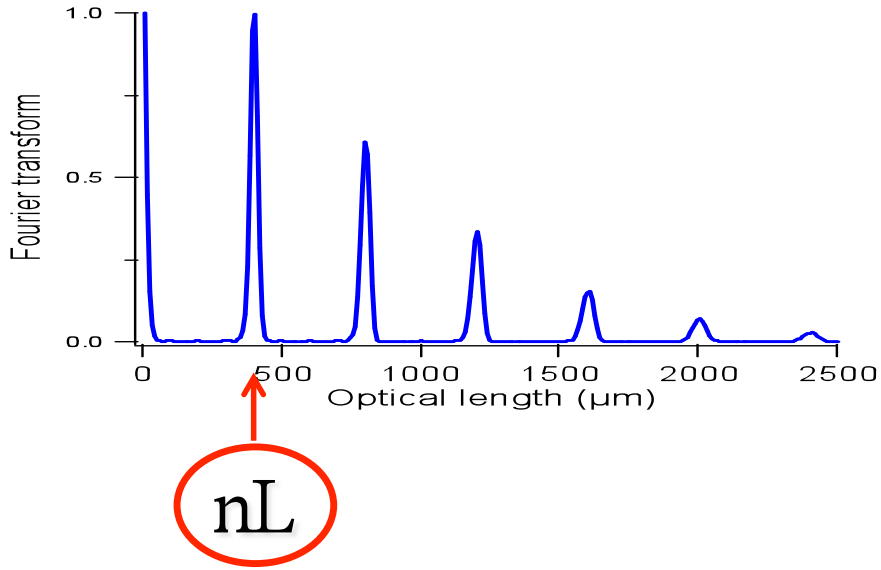


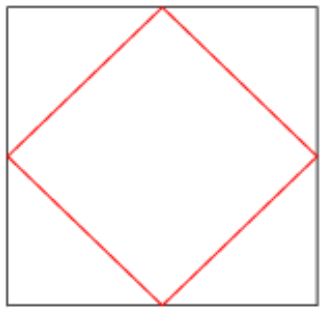
Semi-Classical point of view

Information in the spectrum : Length *L* of the periodic orbit



Fourier transform





Fresnel coefficients:
r (45°) = 1
r (0°) = 0.2

Diamond

Phys. Rev. A, **76**, 023830 (2007)

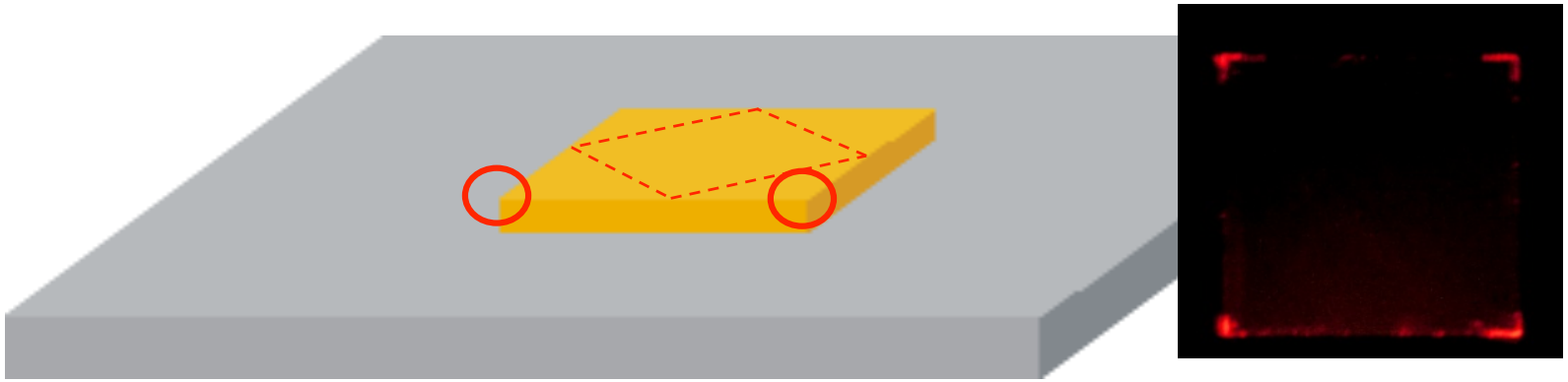
Outline

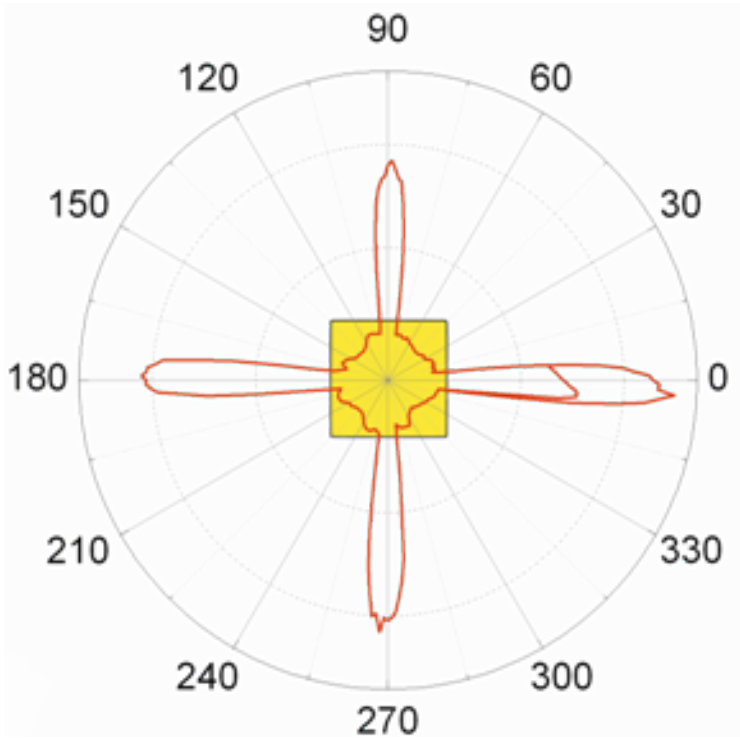
1) Background on organic microlasers
   - Presentation of the devices
   - Optical characterization
   - Applications
   - Lasing studies

2) Recent developments to address diffraction
   - Square shaped cavities
   - Triangle shaped cavities
   - Investigating 3D diffraction

Diffraction is 3D

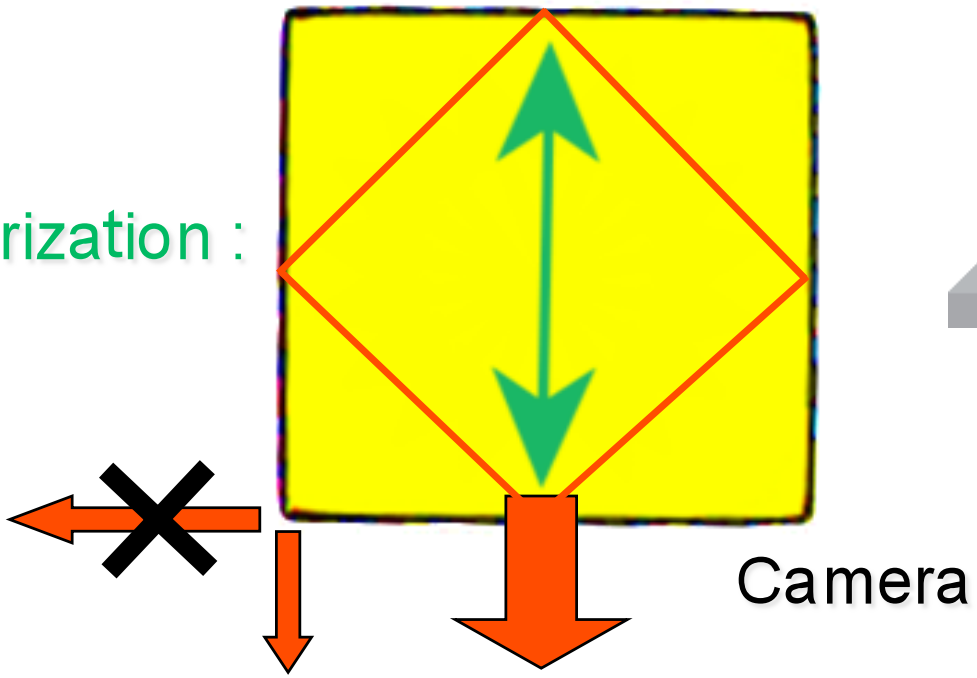
Diamond orbit is not totally confined !

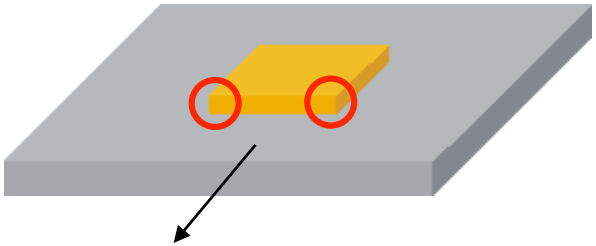




3D – Polarization selection

Pump polarization :





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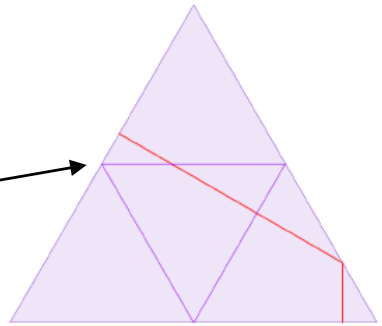
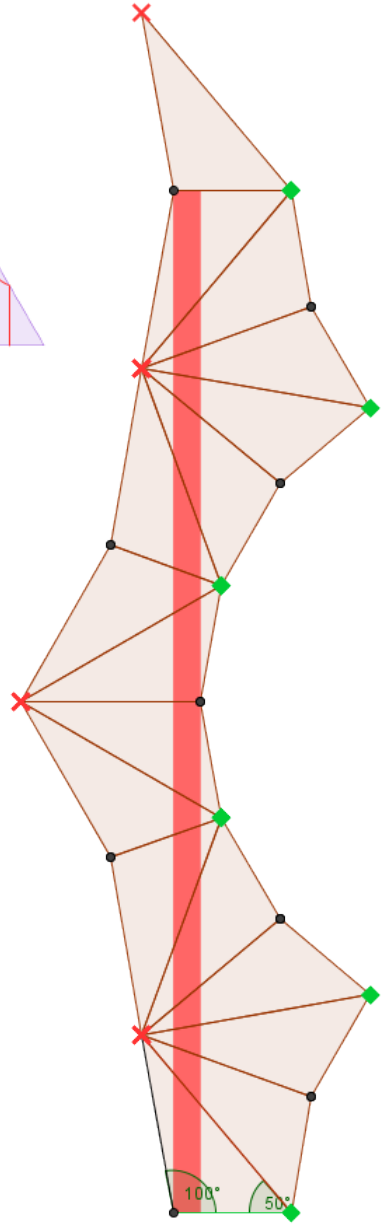
Does a periodic orbit in a triangle exist ?

Alain Grigis, University Paris XIII

- Acute triangles feet of the altitudes

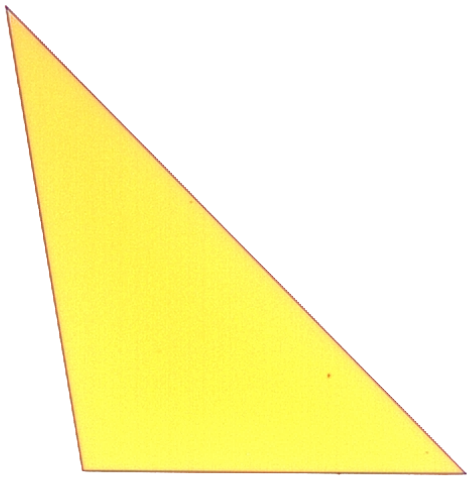


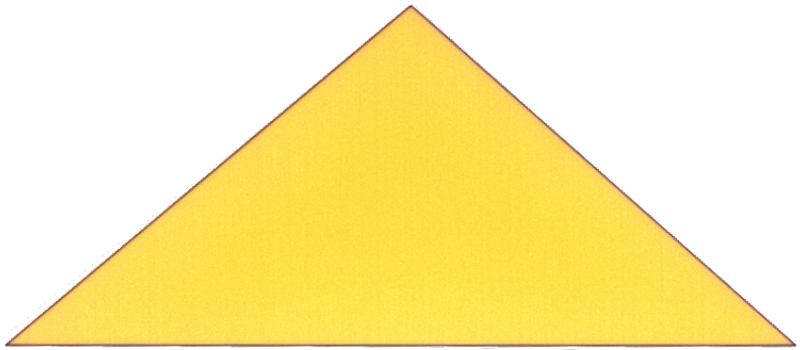
- Less than 100° triangles:
  Journal of Experimental Mathematics, 18, p. 137 (2008)



- Rational triangles : **angles = $p\pi/m$, unfolding theory**

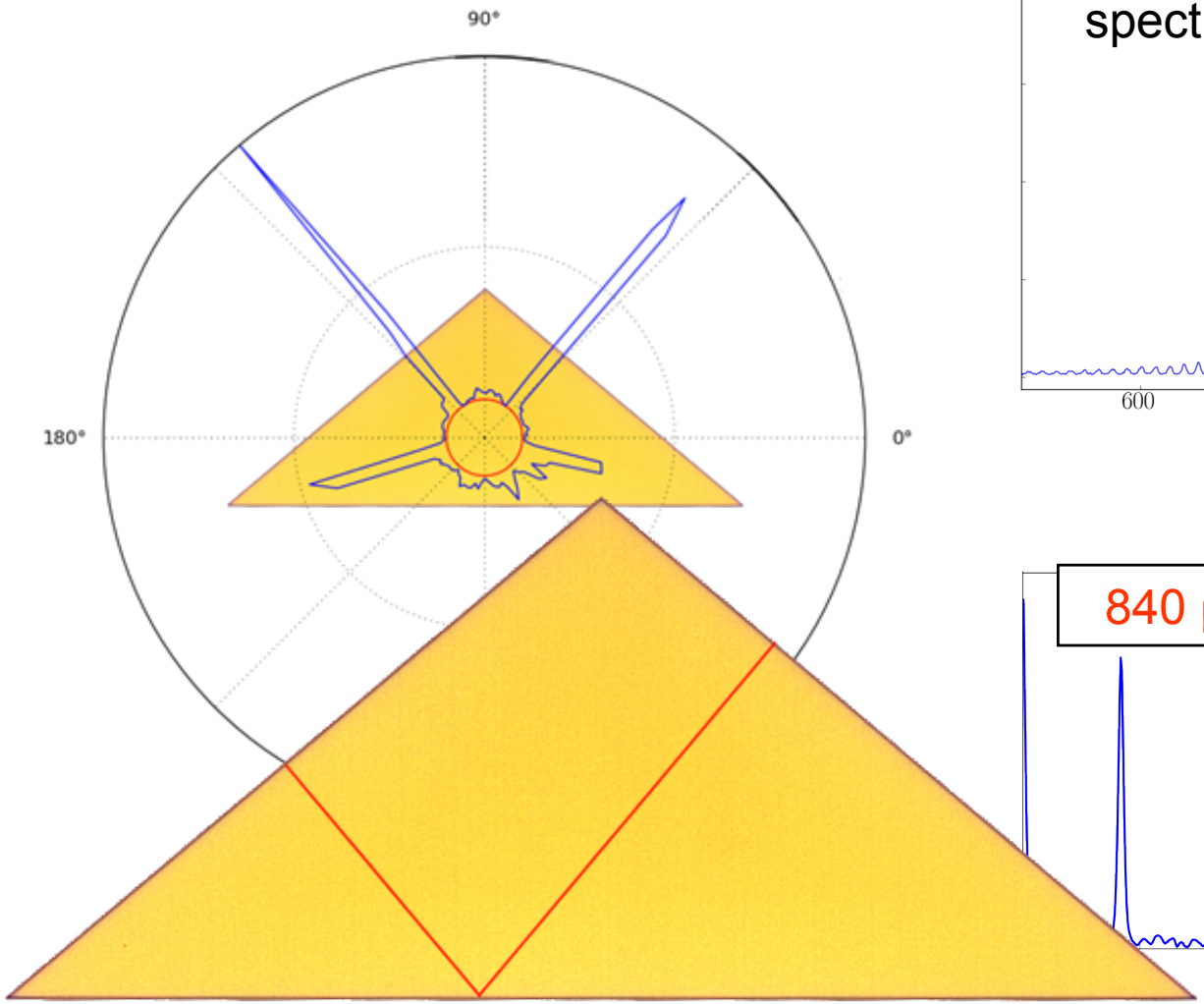
- Others …

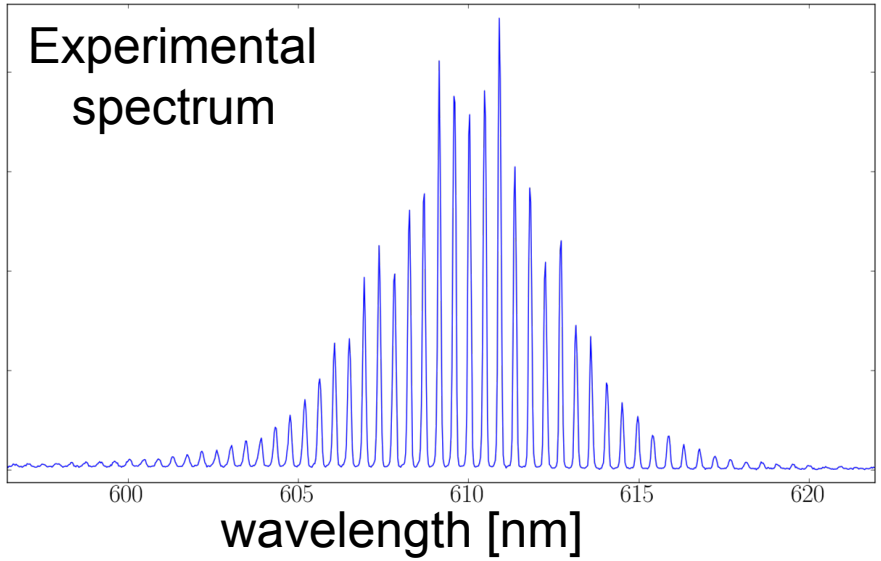


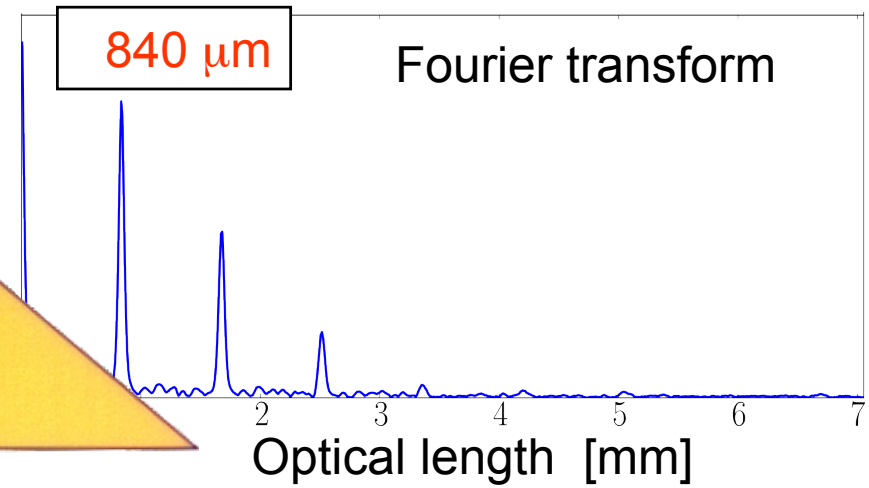


Spectra & trace formula : triangles

Triangle Isosceles



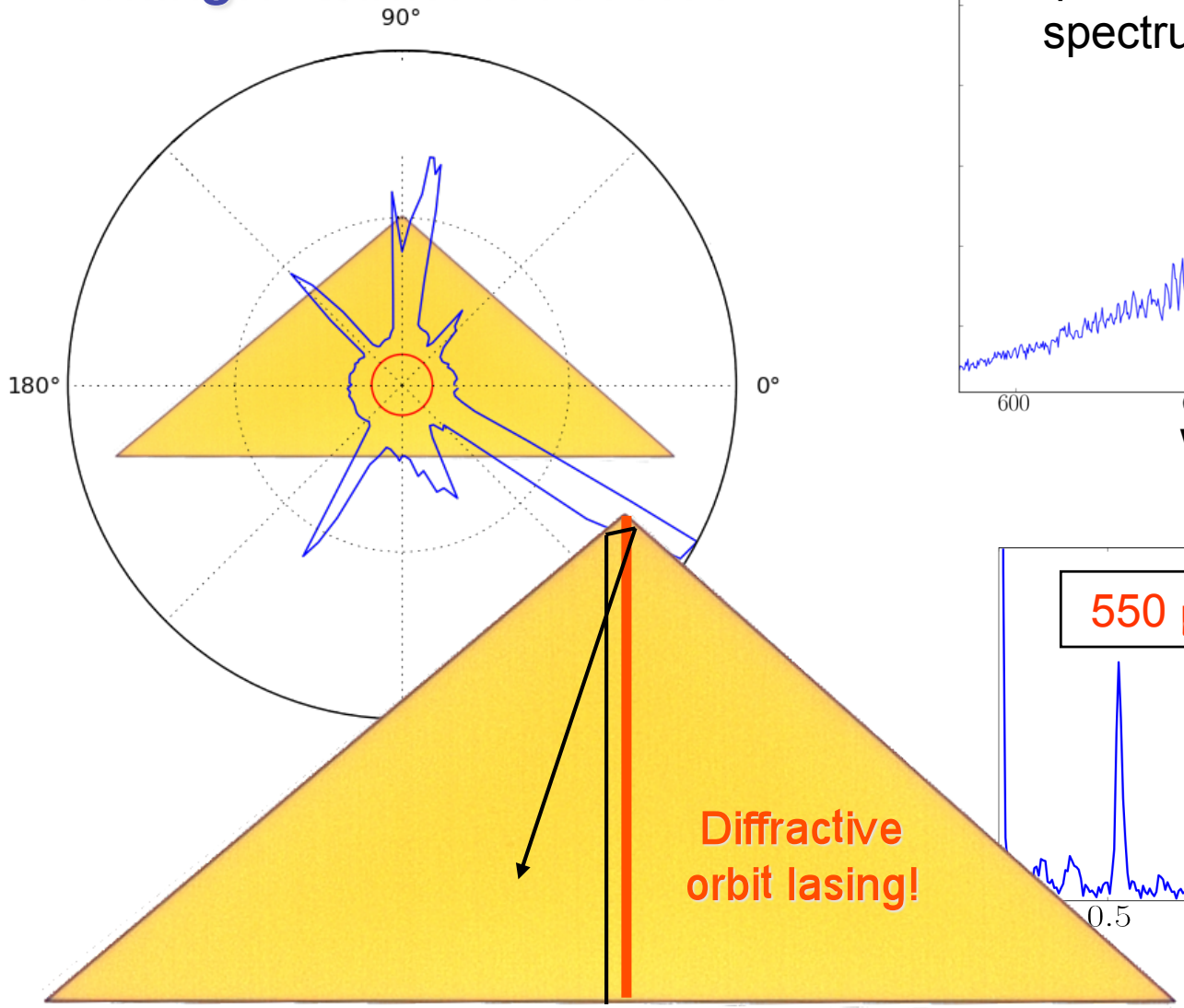


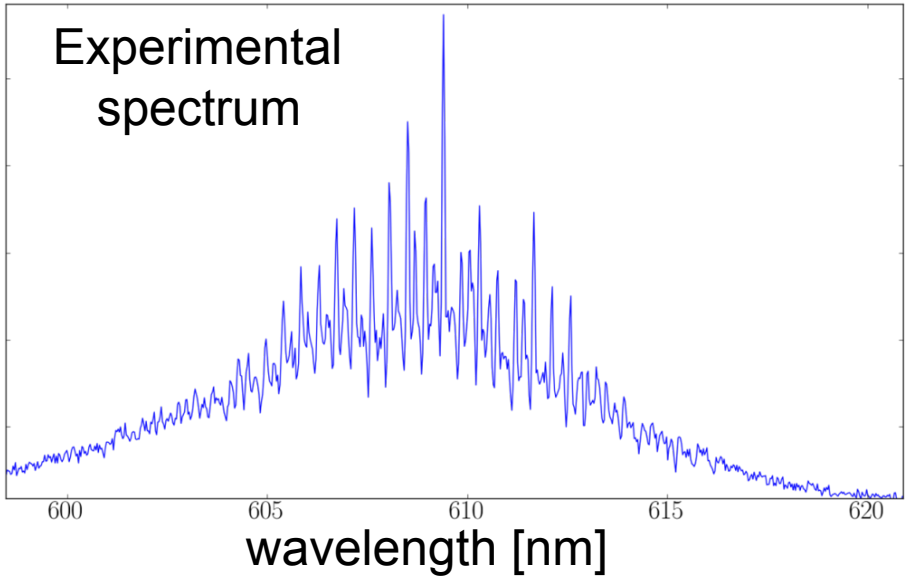


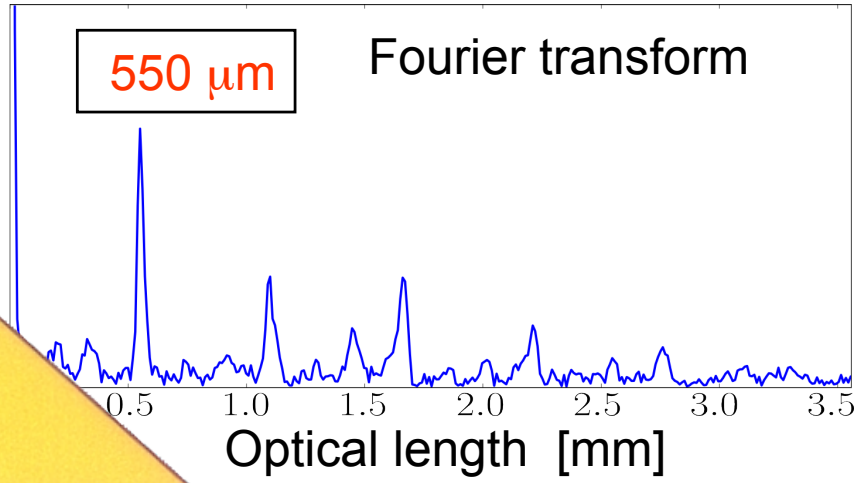
L_{opt}=840 ± 20 μm

Spectra & trace formula : triangles

Triangle Quasi-Isosceles







L_{opt} = 547 ± 20 μm

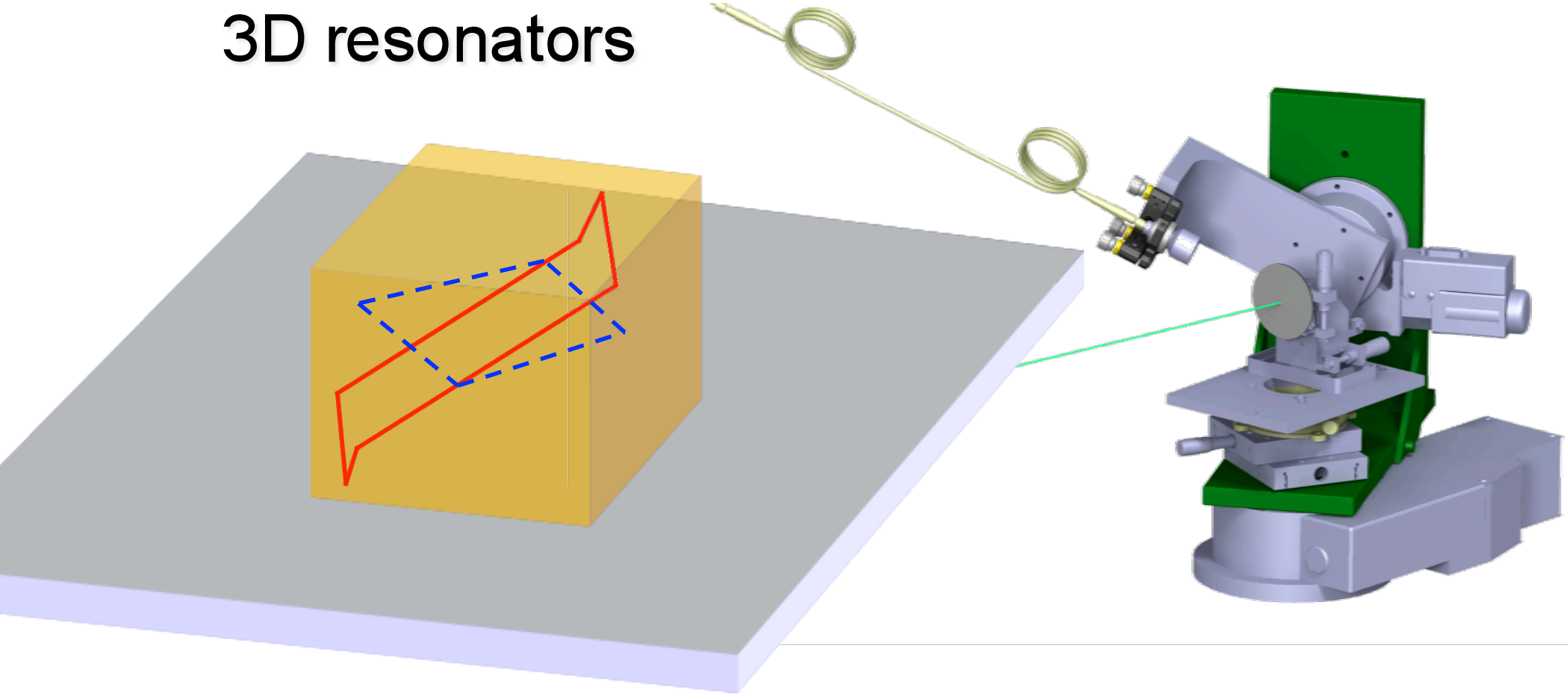
Outline

1) Background on organic microlasers
   - Presentation of the devices
   - Optical characterization
   - Applications
   - Lasing studies

2) Recent developments to address diffraction
   - Square shaped cavities
   - Triangle shaped cavities
   - Investigating 3D diffraction

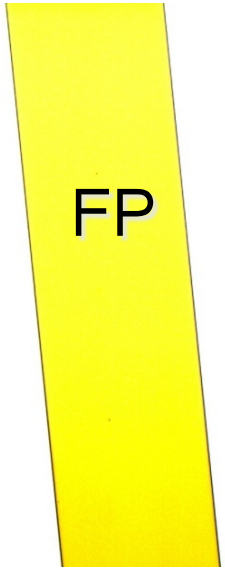
3D - Perspectives

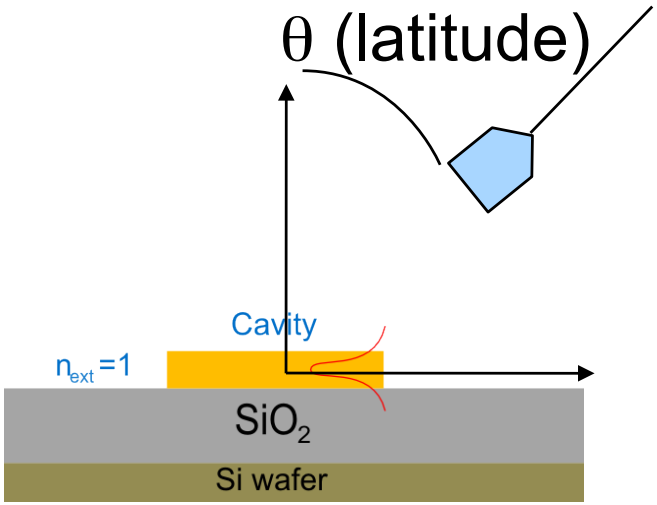
3D resonators



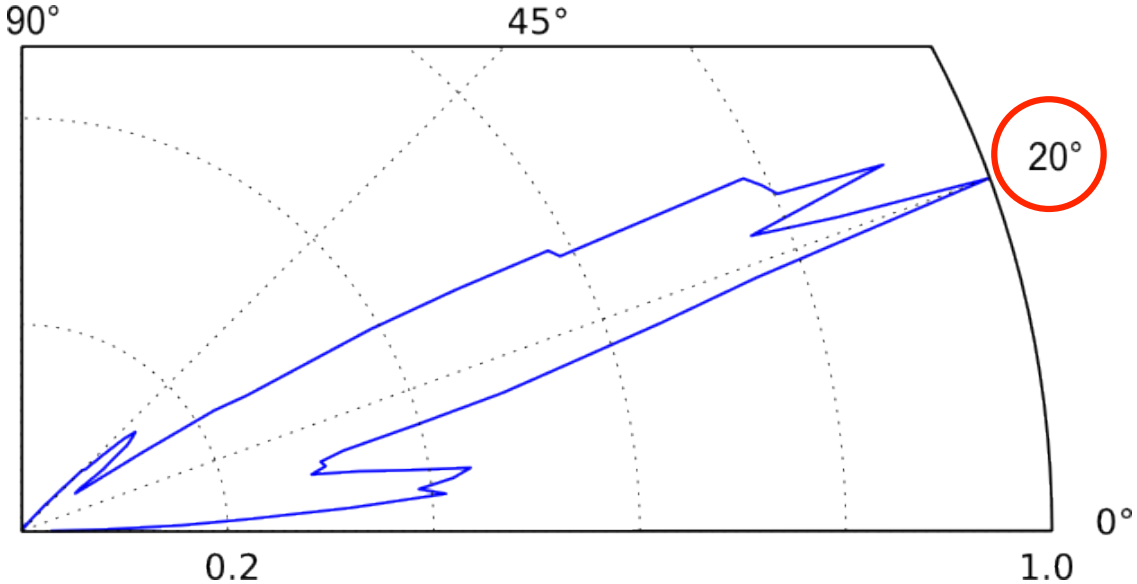
- **How to fabricate ?**
- **Where to put the detector ?**

3D - latitude diagrams

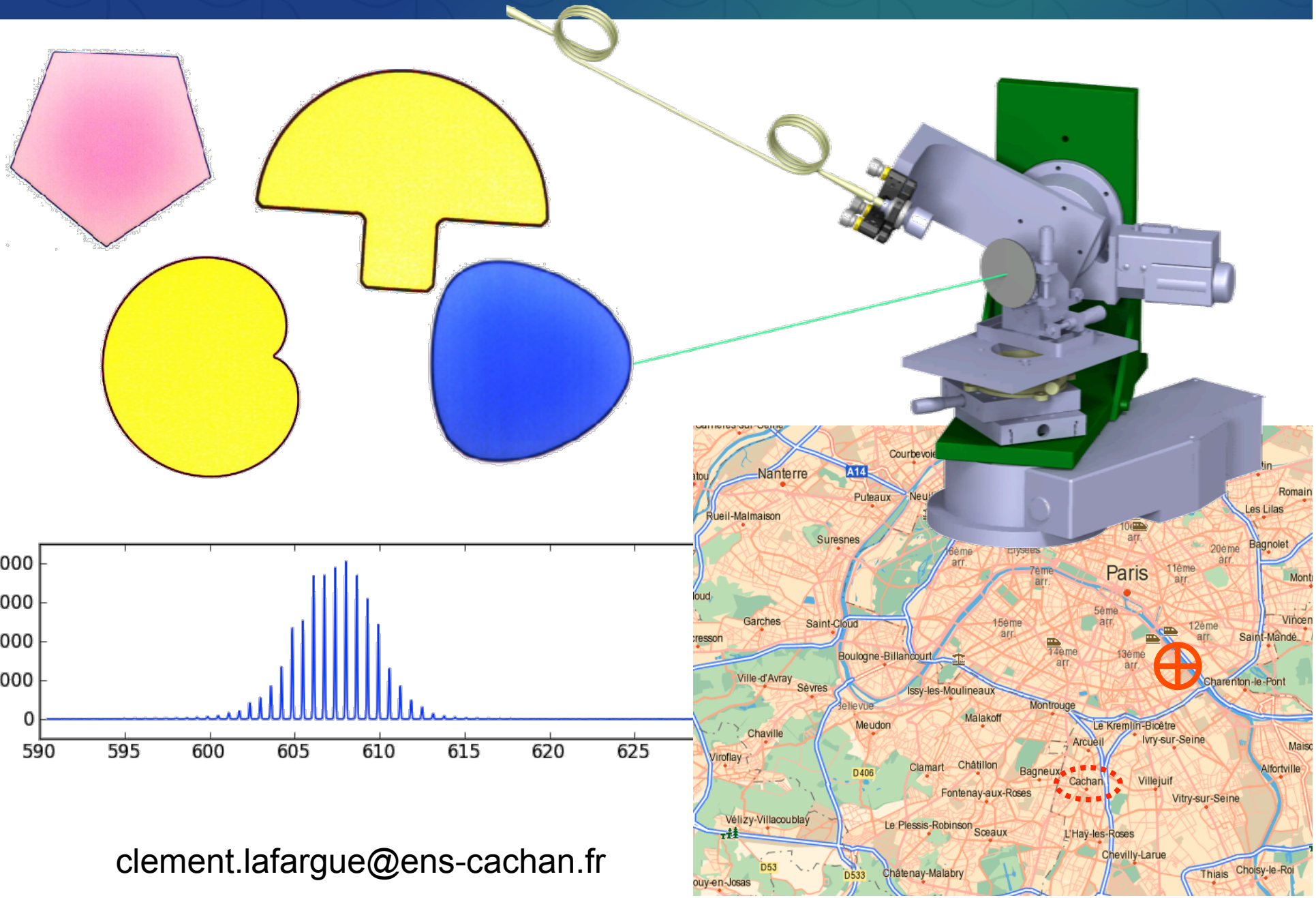




Measurement :

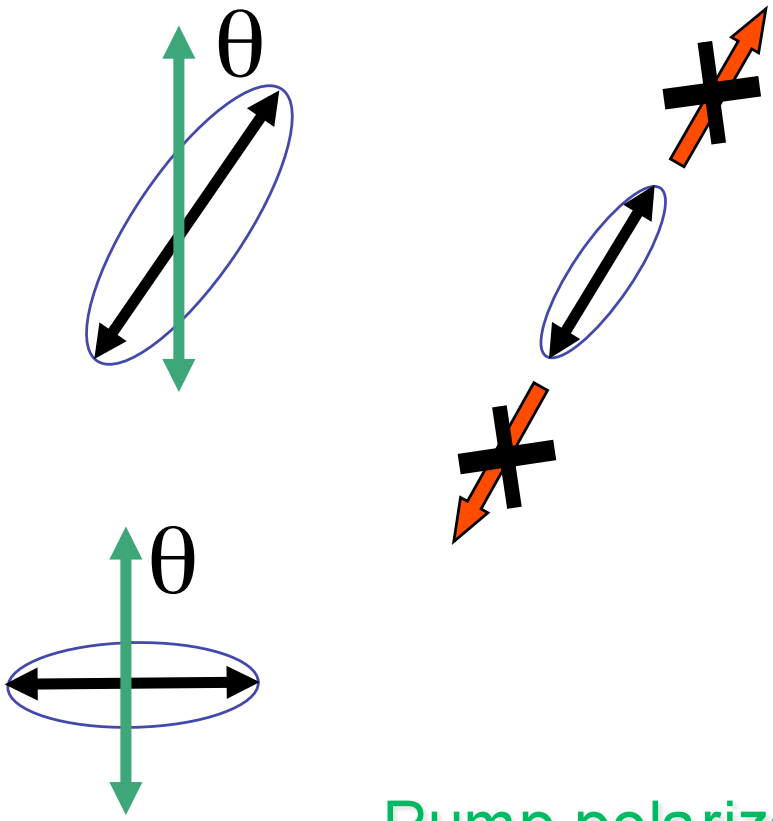


Thank you for your attention

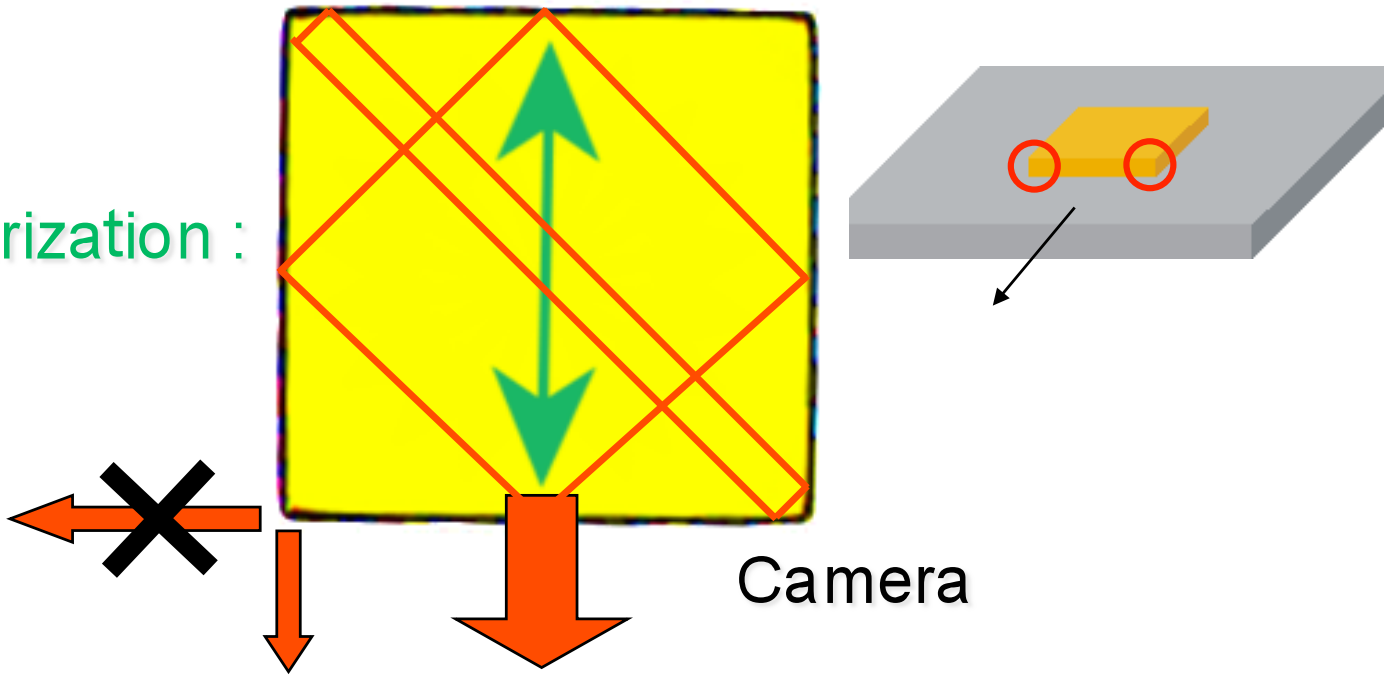


clement.lafargue@ens-cachan.fr

3D – Polarization selection



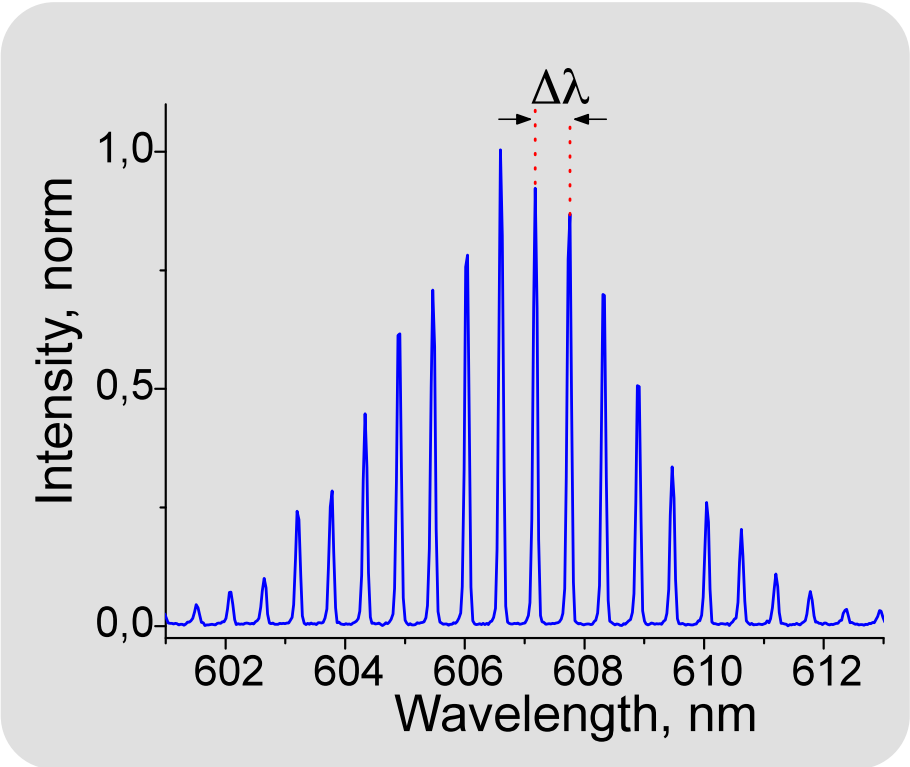
Pump polarization :



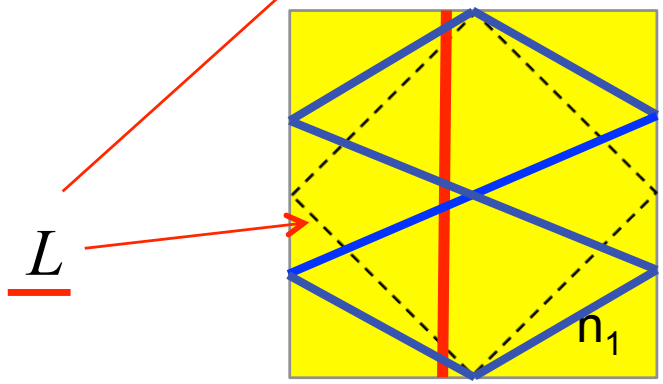
Semi-Classical point of view

Information in the laser spectrum : Length *L* of the periodic orbit

Lasing $r^2 \; e^{iknL} = 1 \quad \Rightarrow \quad k = \dfrac{2\pi}{nL} m \quad \Rightarrow \quad \Delta k = \dfrac{2\pi}{nL}$



$$\Rightarrow \quad \boxed{\Delta\lambda = \frac{\lambda^2}{nL}}$$



Periodic orbits & trace formula

Density of states

$$d(k) = \sum_m \delta(k - k_m)$$

Wave physics

Semi-classical limit $k \to \infty$

$$d(k) \propto \sum_p \mathbf{r_p} C_p \cos(\mathbf{n} k L_p + \varphi_p)$$

Classical physics

PRE 83, 036208 (2011)

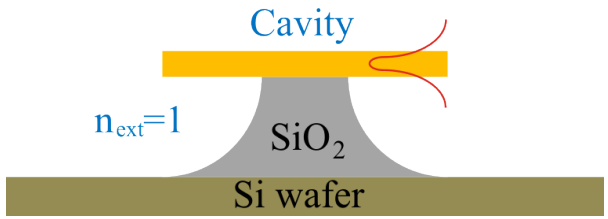
Sum on periodic orbits

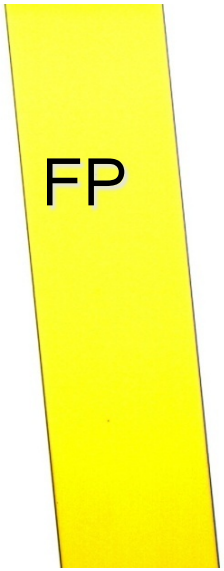
Fresnel reflexion coefficients

Coeff depending only on classical quantities

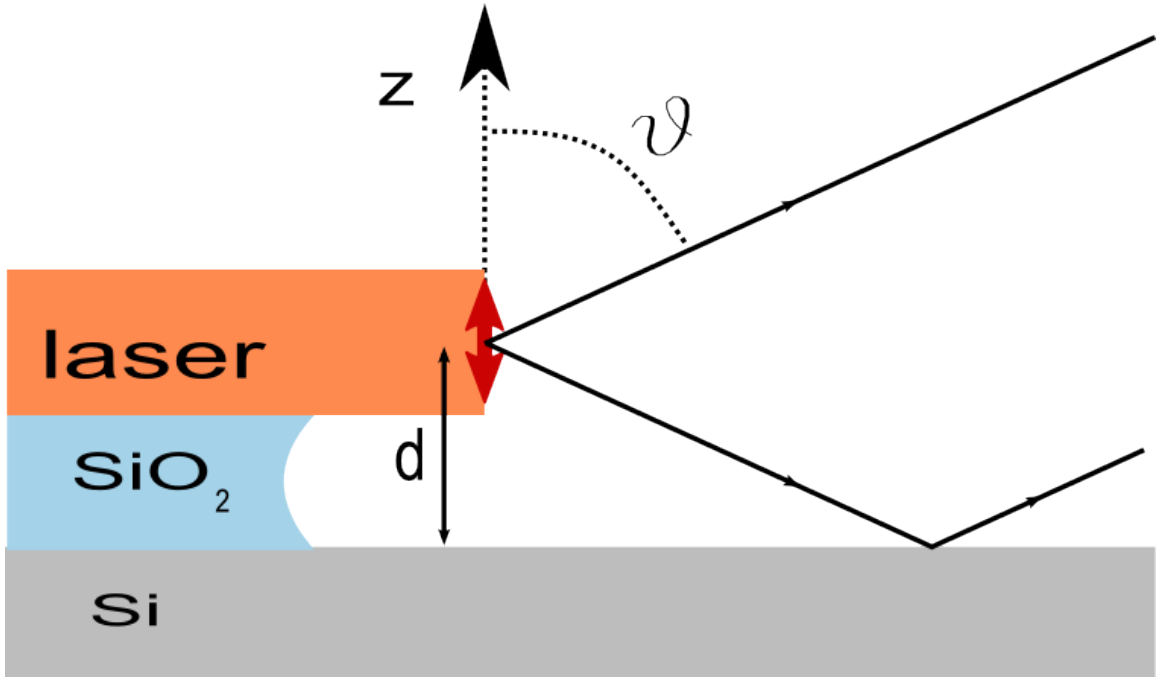
Length of the orbits

3D - latitude diagrams

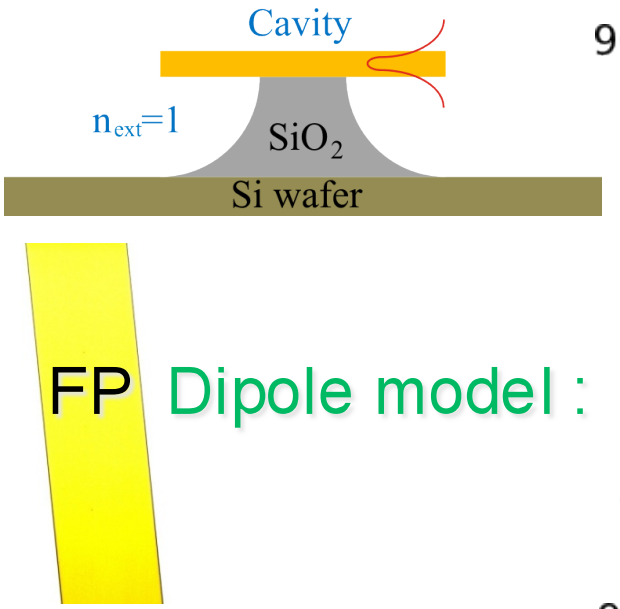




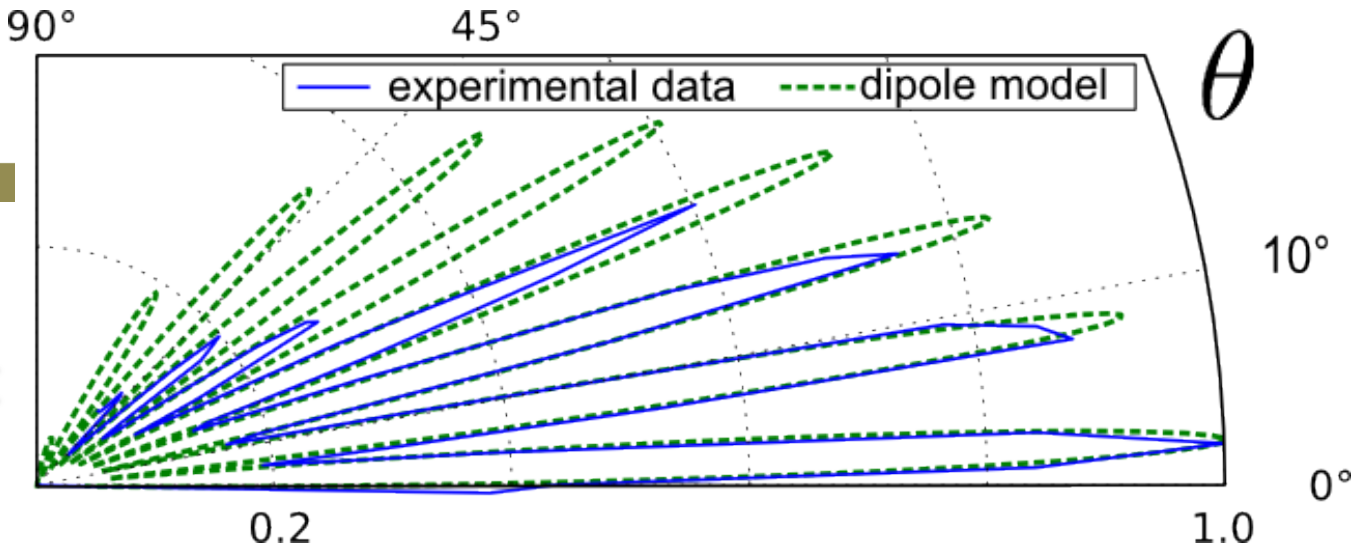
Dipole model :



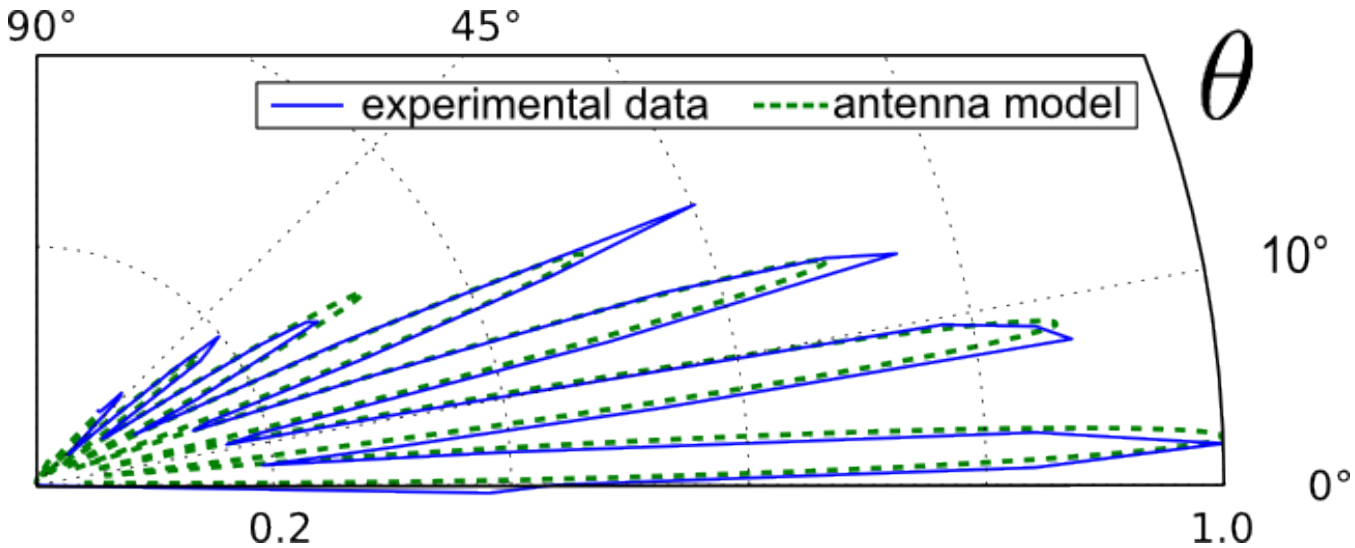
3D - latitude diagrams



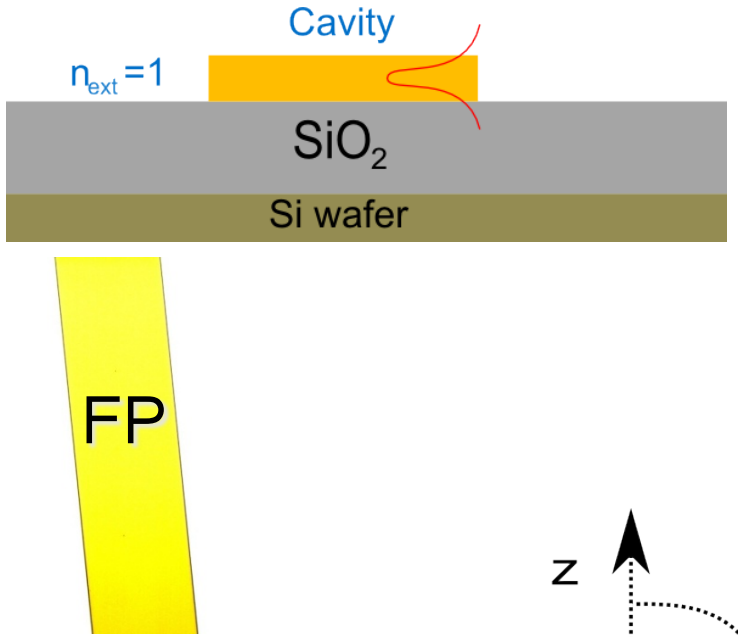
Dipole model :



antenna model :



3D - latitude diagrams



Measurement :