



du Minéral au Moléculaire, des Micro- aux Nano-Technologies, de l'Ordre à la Complexité

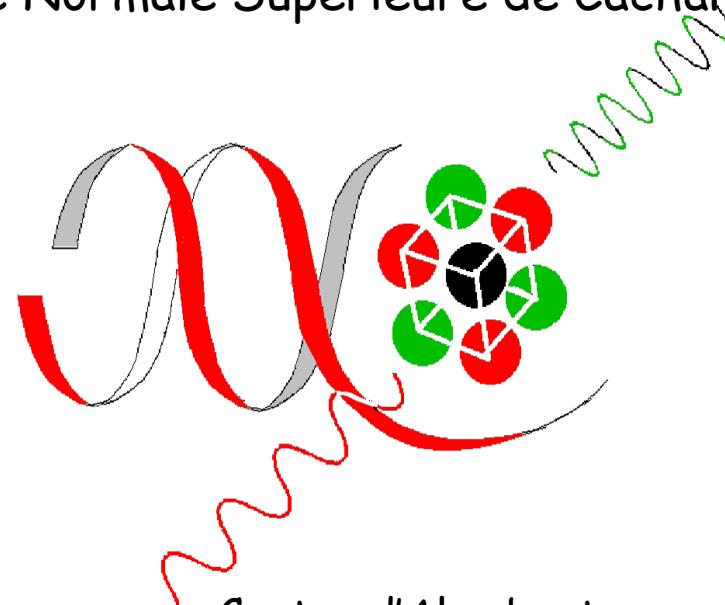


Nouveaux défis au carrefour des Biotechnologies et des sciences de l'information

Joseph Zyss

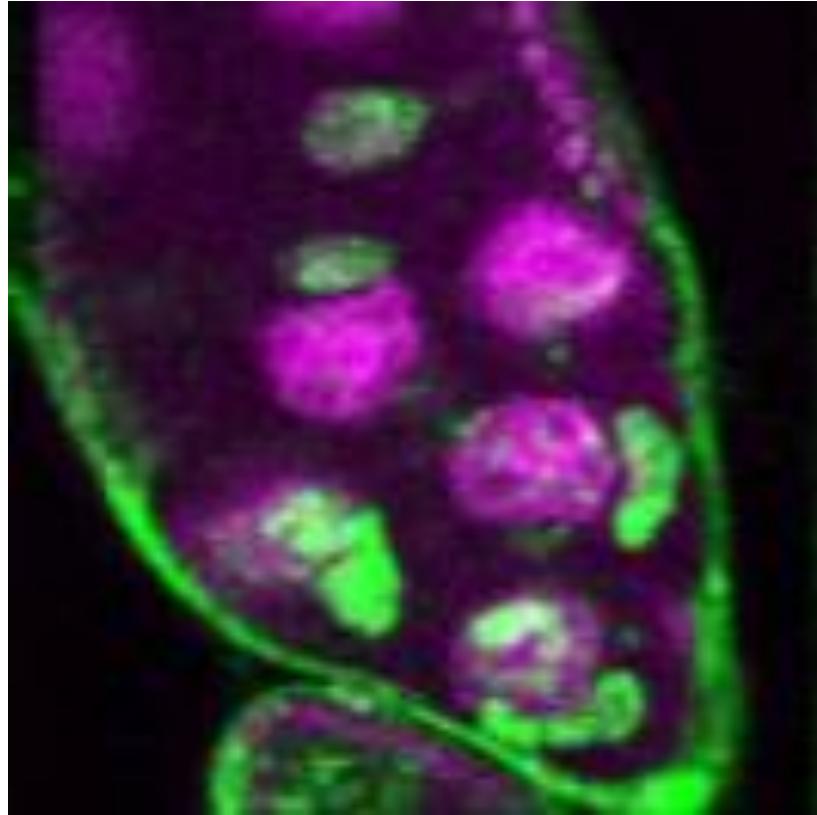
Laboratoire de Photonique Quantique et Moléculaire
Institut d'Alembert

Photonique Moléculaire pour les Biotechnologies et les Télécommunications
Ecole Normale Supérieure de Cachan, France



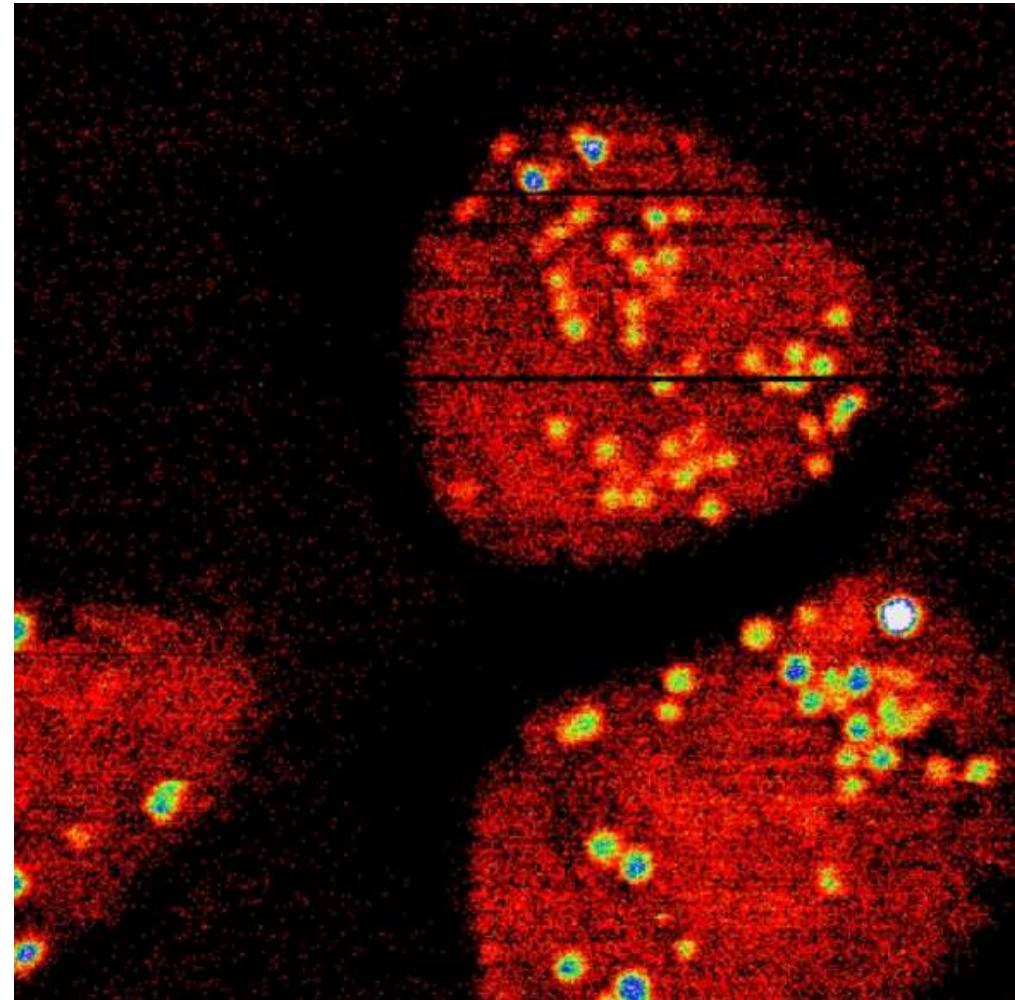
Centre d'Alembert
11 Mai 2005





Second-Harmonic Generation
Third-Harmonic Generation
Drosophila ovary cell labelled by
DAPI dye

CARS Spectroscopy signals from
functional polystyrene nanospheres

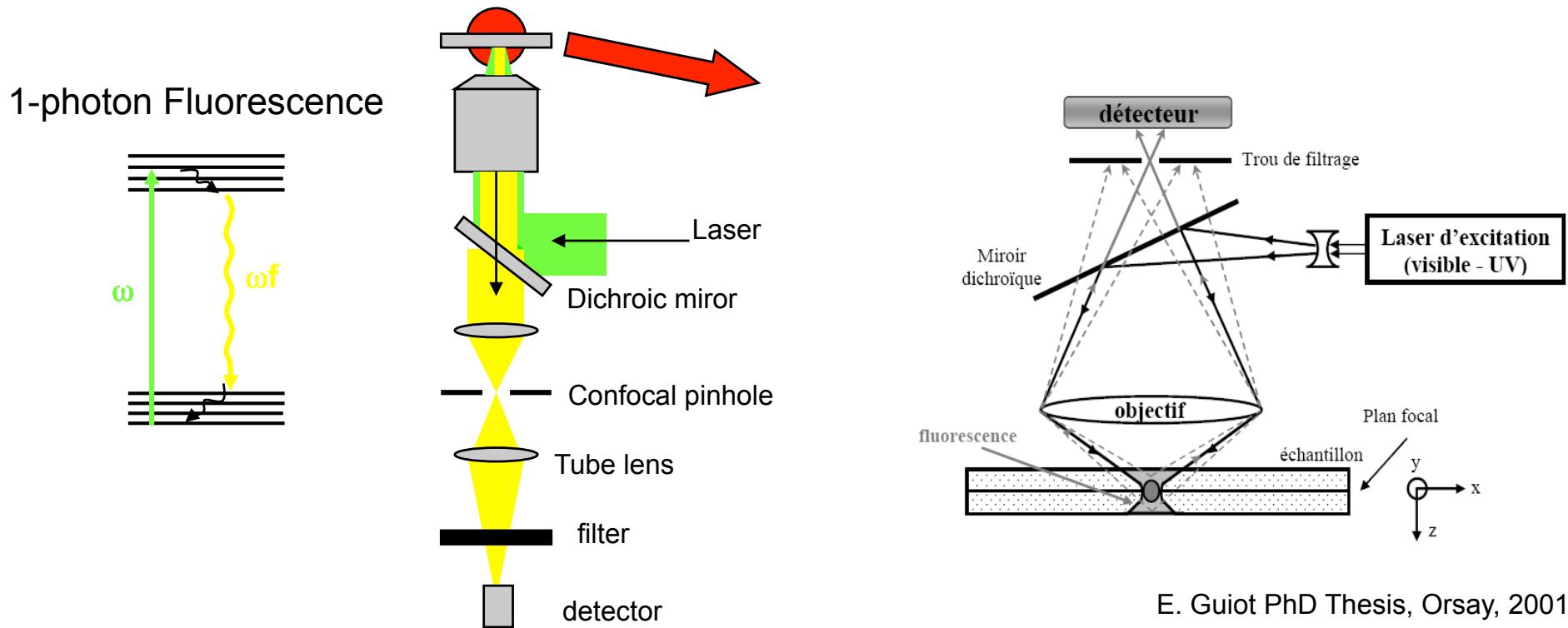


Live HeLa cells ($30 \text{ mm} \times 30 \text{ mm}$) imaged at
 29000 cm^{-1} . Intense signals from mitochondria

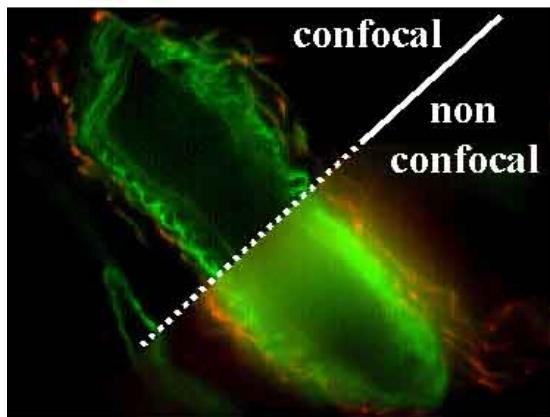
Y. Silberberg et al, Opt. Exp.
5(8), 169(1999)

A. Zumbusch et al, Phys. Rev.
Lett. 82, 4142 (1999)

1-photon confocal fluorescence microscopy



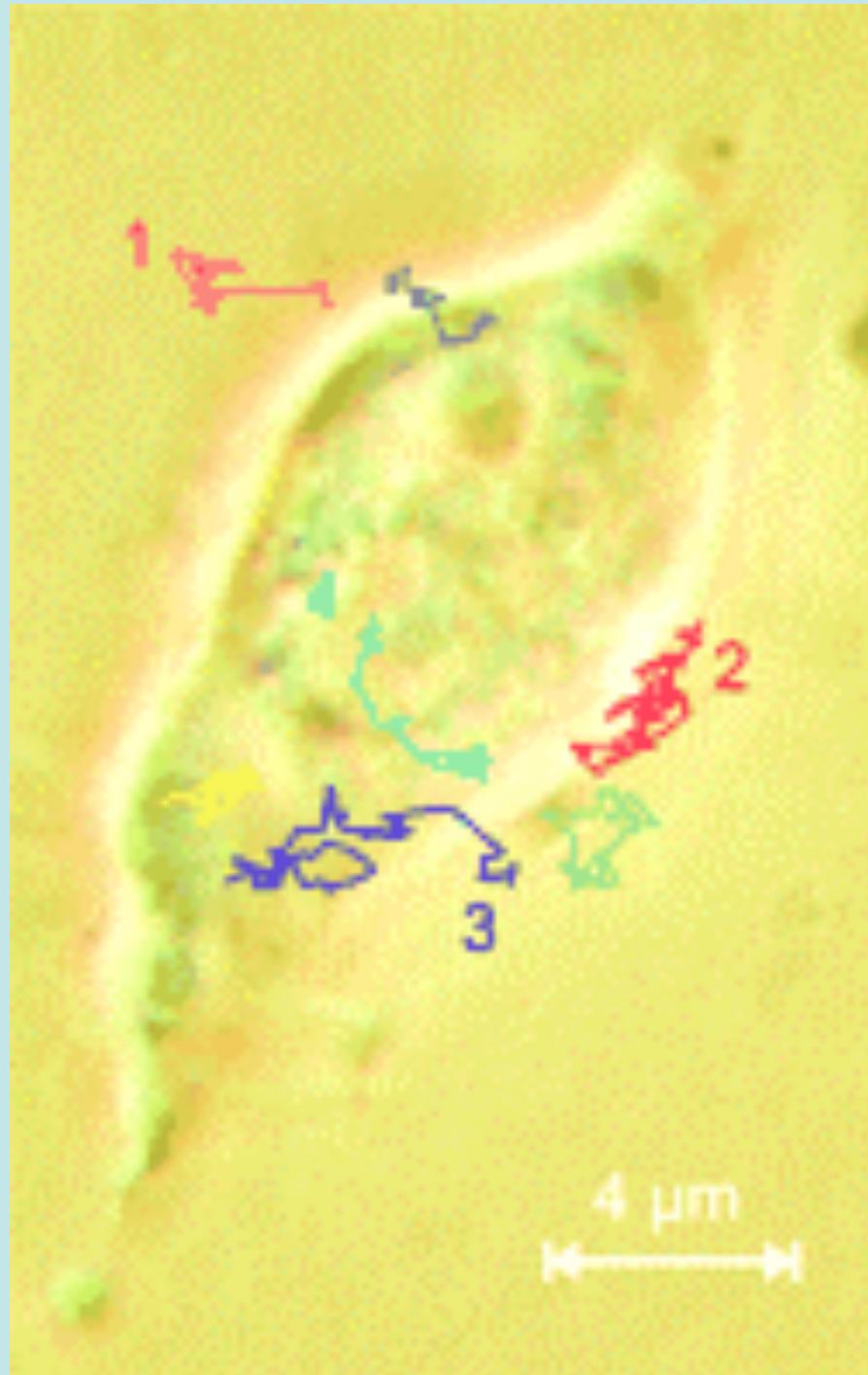
E. Guiot PhD Thesis, Orsay, 2001



$$w_0 = \frac{0.61\lambda}{NA} \quad z_0 = \frac{2n\lambda^2}{NA^2}$$

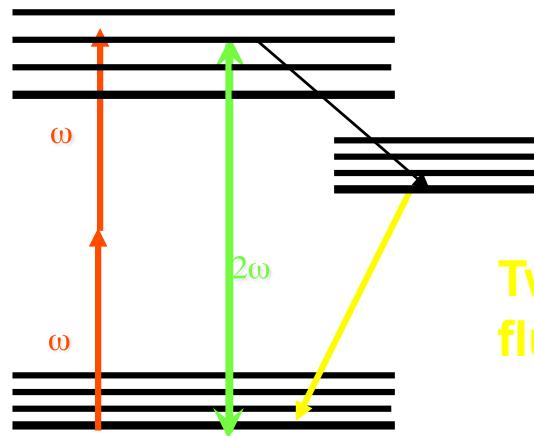
$$V^{1PF} \approx 0.7\pi n \frac{\lambda^3}{NA^3}$$

MONITORING OF SINGLE GENE or PROTEIN CELLULAR TRAFFIC

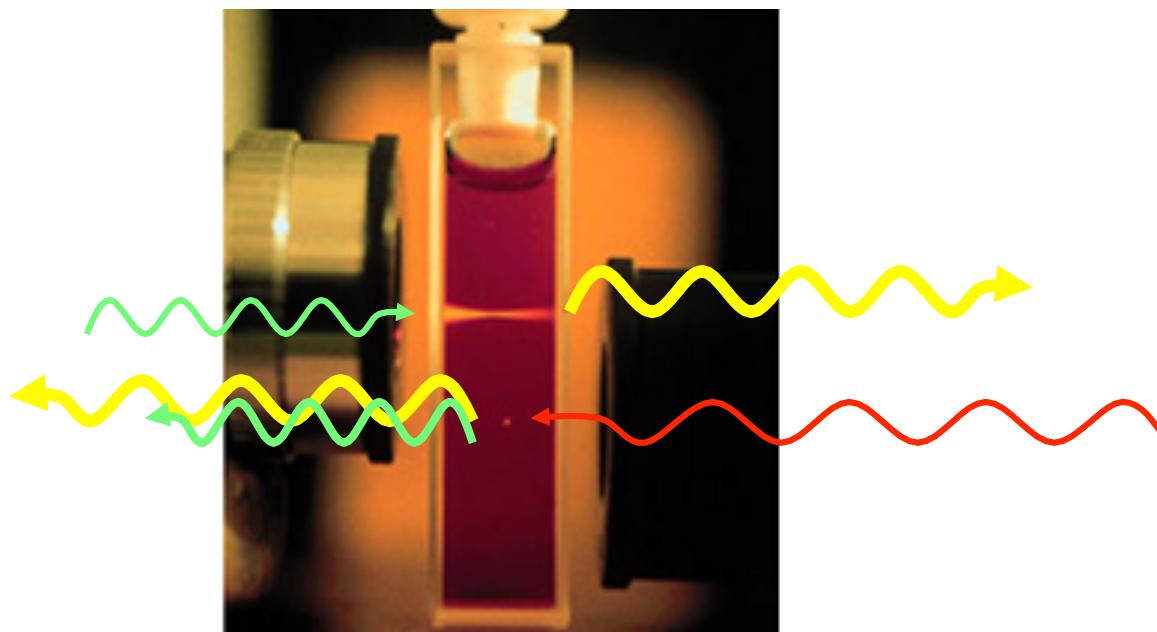


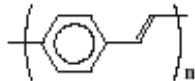
Two-photon absorption

Second-harmonic generation

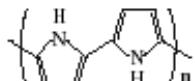


**Two-photon
fluorescence, lasing**

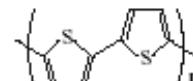




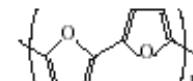
Poly(*para*-phenylenevinylene)



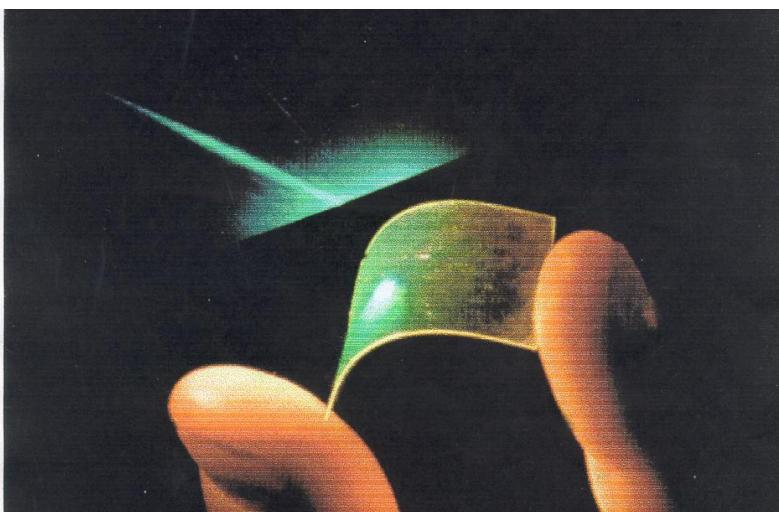
Poly(pyrrole)



Poly(thiophene)



Poly(furane)



40" OLED
screen by Epson

Brent D. Johnson
Senior News Editor

Organic Light Makes the Call

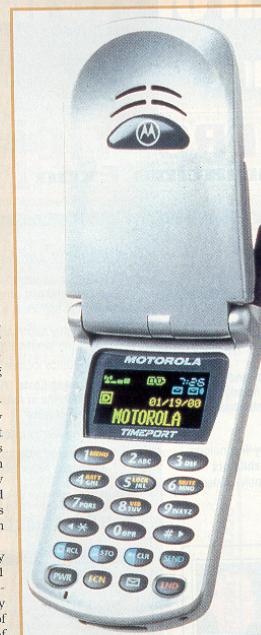
Orgetic light-emitting technologies have been proposed for applications ranging from semiconductors to photovoltaics, but what's really driving the development of these technologies is their benefit to the flat panel display industry.

Motorola Inc. has been using organic electroluminescent technology in cellular telephone displays made by Pioneer Corp. since the middle of last year. The first were the StarTac series of cellular phones, which are available with both liquid crystal and organic electroluminescent displays.

Steve Lalla, senior director at Motorola PCS, said the company wanted to introduce new colors on its Timeport P8767 phone's display. Pioneer easily did this by adding dopants to the electroluminescent material, producing red, green and blue.

He said the biggest enhancement provided by organic display technology is its readability. At 100 cd, the organic display yields 10 times the brightness of an equivalent liquid crystal display (LCD). "It is a very brilliant and dynamic display," Lalla said. "It's a very different experience from LCDs."

The clarity is also significantly better. The contrast ratio is 100:1 because the colors are superimposed on a black background. By comparison, the black lettering of LCDs against a background of



gray/green produces only a 5:1 ratio. In addition, the viewing angle maintains visibility of the organic displays at 170°, whereas the much greater reflectance of LCDs causes lettering on the screen to disappear beyond 100°.

The only drawback to organic electroluminescent displays is that they draw slightly more power than LCDs do. However, Motorola has resolved this issue by integrating the new display in its "clam" form factor, otherwise known as a flip phone. This design opens and closes like a clam; the display shuts off when the phone is closed, conserving more power than devices that have external displays.

The company also is studying the use of the organic display in "candy bar" form factors that would require it to remain illuminated while the phone is on. Lalla said that the battery consumption needs to be managed but that one possible solution is to have the display dim when the phone is not in use. □

Contact: Sue Fredericks, Motorola Inc., Libertyville, Ill.; (847) 523-6555. Dave Wzorek, Pioneer Corp., Aurora, Ill.; (630) 875-9624.

The Motorola Timeport P8767 uses organic electroluminescent display technology to achieve high brightness across a wide viewing angle.

Inching Toward Fiber Alignment

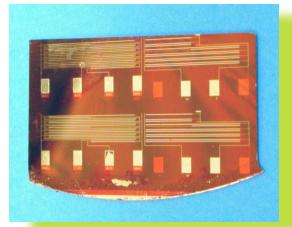
When the growing telecommunications industry faced the challenge of optical broadband data transmission, nanorobots became a practical reality.

Burleigh had been developing inchworm technology since 1974 for

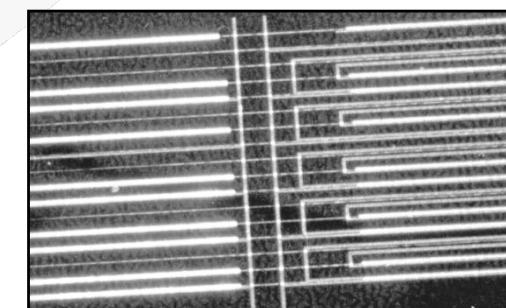
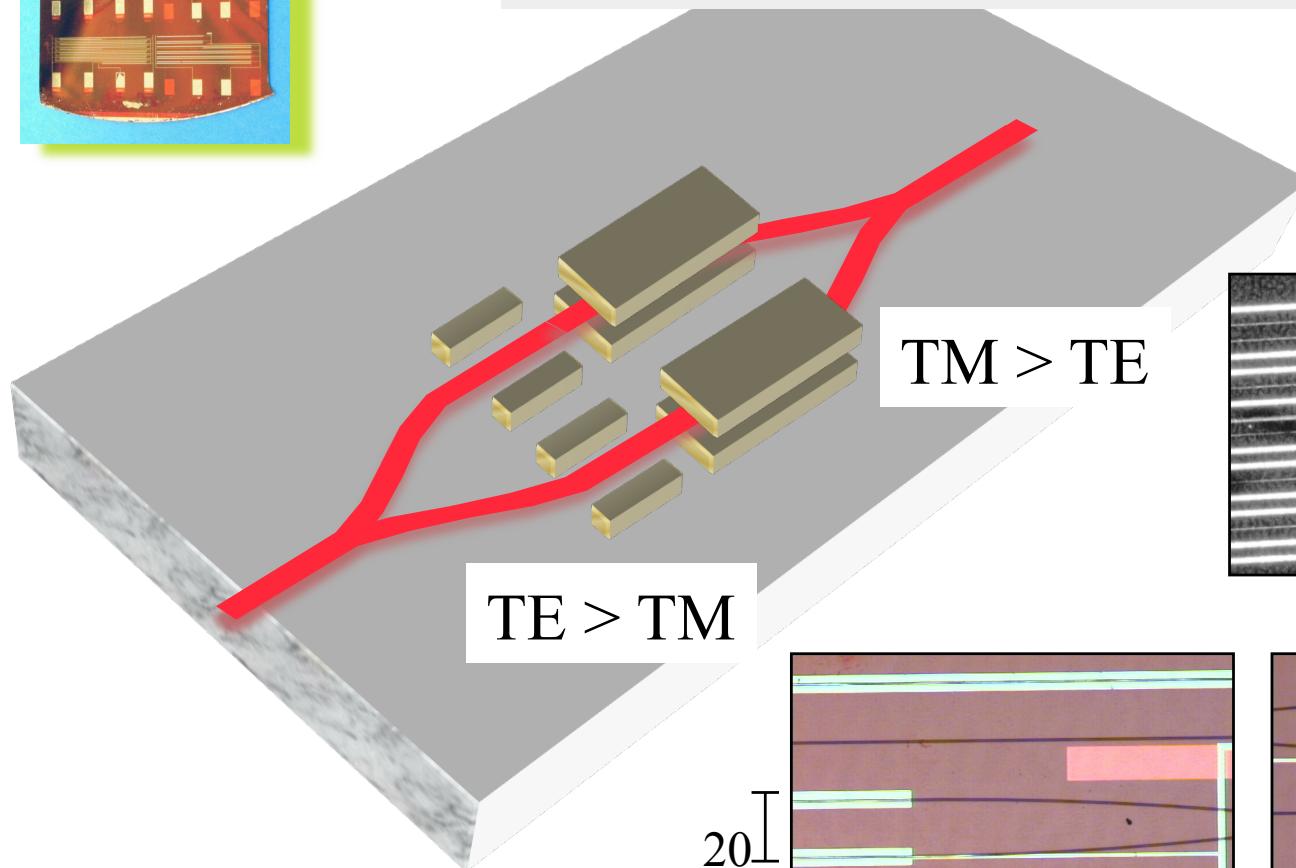
active optics, positioning and alignment. Two years ago, the demand for ultraprecise nanometer alignment combined with multiaxis robots became an imperative for fiber optic communications equipment manufacturers.

Inchworm motors exploit a property of a material made of ceramic combined with lead zirconate titanate — it changes shape incrementally with voltage. Applying 25 mV produces a movement of 1 Å. This resolution is critical to producing a

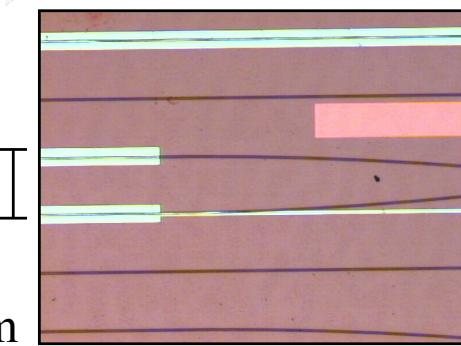
POLARIZATION INSENSITIVE ELECTROOPTIC POLYMER MODULATOR



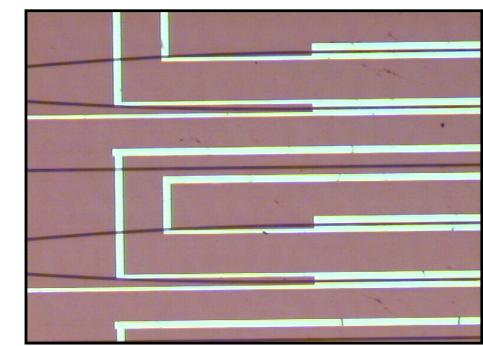
Combination of sandwich and transverse electrodes



T
0.
5
cm



20
0
μm



→ *Same half wave voltage for TE and TM modes*

Invitation à une flânerie mal balisée voire transgressive entre:

- ✓ recherche fondamentale et recherche appliquée
- ✓ physique, chimie, biologie, technologies de l'information et sciences de l'ingénieur
- ✓ monde organique et monde minéral
- ✓ ordre et désordre, statique et dynamique
- ✓ Matière et immatériel

Invitation à une flânerie mal balisée voire transgressive entre:

- ✓ recherche fondamentale et recherche appliquée

Les deux problématiques existent mais forment un continuum

Ex: Horst Störmer le jour à Bell Lab (HEMT) et la nuit à Brookhaven (effet Hall Quantique fractionnaire) sur les mêmes structures !

- ✓ physique, chimie, biologie, technologies de l'information et sciences de l'ingénieur

Un constat nécessaire, mais pas de volontarisme pluridisciplinaire à la mode

Exemple: imagerie nanobiophotonique du noyau de la cellule (rôles des compartiments eu- et hétérochromatiniens)

- ✓ monde organique et monde minéral

Dialectique subtile à arbitrer entre l'ordre et le désordre, souple et rigide:

Jouer l'hybridation multi échelle dans un foisonnement de structures possibles à l'image de la nature: cartilage osseux, émail etc... Fortes connotations psy !

- ✓ ordre et désordre, statique et dynamique

De la rigueur géométrique exemplaire du cristal à la complexité spatio-temporelle des édifices organiques ou biologiques

Sans abandon de rigueur et en jouant les progrès les plus pointus de l'instrumentation

- ✓ Matière et immatériel

Molécules et Photons:

Les phénomènes les plus intéressants se passent sur la « ligne de crête »

De l'interaction (voire même de l'échange des rôles, e.g. BEC et atomes cohérents)

Photonique et Bio-photonique Moléculaires

✓ Transporter et traiter l'information

*bande passante, hauts débits, codage, cryptographie, fibres optiques et composants, mémoires optiques
applications aux télécommunications*

✓ voir/ imager/sonder aux échelles spatio-temporelles ultimes

*nanostructures, molécules uniques, membranes, nouvelles microscopies,
nano-capteurs*

biologie et biotechnologies, optique et télécom quantiques

✓ élaborer

*nouvelles technologies de fabrication de composants
(micro- et nano-structuration)*

composants micro- et nano-photonique, micro-photo-fluidique

✓ fonctionnaliser

*synthèse de nouvelles molécules, marquage de gènes,
édifices supra-moléculaires à finalités télécoms et biologiques
chimie et biochimie, ingénierie moléculaire*

Quelques repères historiques récents....

Fin des années 80: percée de l'étude des molécules uniques

(véritable début de la nanophotonique)

Possibilité d'échantillonner par individus les populations traitées dans leur ensemble par la physique quanto-statistique.

W.E. Moerner (de IBM San Jose à Stanford): absorption par molécules uniques

Michel Orrit (du CPMOH- Bordeaux à Leyden): fluorescence

Observation spectrale indirecte d'objets moléculaires individuels à basse

Température en matrice solide (zéro phonon). Atteinte de largeur de raie homogène caractéristique de l'émission molécules individuelles

Développement foudroyant dans les années 90 des microscopies confocales et à effet tunnel optique, complétant les STM et AFM des années 80

Appropriation ~ instantanée par les biologistes et ouvertures de l'observation intra et péri-cellulaire ex vivo de la transfection et de l'internalisation de gènes, virions, etc...

Développement des nanotechnologies de marquage/labellisation permettant le suivi du « traffic moléculaire »

- greffage de luminophores sur fragments de protéines etc...

- greffages de quantum dots de semiconducteurs émettant dans une

- manipulation code génétique et expression de protéines luminescentes (GFP)

Dans le domaine temporel

Révolution des lasers ultra-brefs depuis le début des années 80

Avec la « banalisation » dans les années 90 du laser Titane Saphir à ampli régénératif et des expériences de stroboscopie femtoseconde (10^{-15}) dites « pompe-onde » (un cycle lumineux visible ~3 à 4 femtosecondes)

➤ Possibilité de résoudre temporellement les échanges photons molécules correspondant à des excitations/désexcitations électroniques (électrons changeant d'orbitales) ou des mouvements atomiques intramoléculaires (fusion-recristallisation du Silicium ou premières étapes de la vision par photo-isomérisation du carotène)

Chuck Shank (Bell Labs, Berkeley) et Ahmed Zewail (Caltech)

Depuis trois à quatre ans, franchissement de la barrière du cycle lumineux

Une nouvelle échelle franchie avec les attosecondes (10^{-18} s); $\dagger \sim 100$ atto

Par interaction de burst X et d'impulsions optiques femtosecondes
(extension du principe de la streak camera)

➤ Possibilité de résoudre temporellement les mouvements électroniques intra-orbitaillaires

Equipe germano-autrichienne de Ferencz Krausz (Vienne et MPI Garching)

Molécules et macromolécules organiques et bio-organiques

Photonique et Bio-photonique

Micro- et nanotechnologies

Modulateurs électro-optiques, commutateurs, filtres
convertisseurs de fréquences...

Neurophysiologie et « patch-clamp » optique

Mémoires optiques cryptées (non-linéaires)

Contrôle du déplacement de molécules uniques
(pinces optiques en milieu cellulaire)

Microcavités et billards optiques (des molécules à la photonique
et de la photonique à la physique fondamentale)

Biocapteurs et biosenseurs

Molécules et macromolécules organiques et bio-organiques



Photonique et Bio-photonique

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Modulateurs électro-optiques, commutateurs, filtres
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Neurophysiologie et « patch-clamp » optique

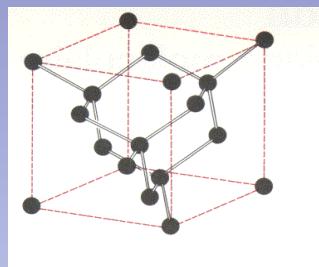
Mémoires optiques cryptées (non-linéaires)

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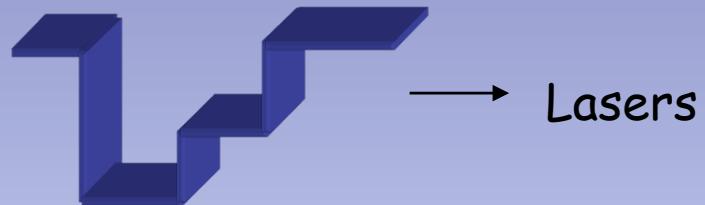
Biocapteurs et biosenseurs

DU MINERAL AU BIOLOGIQUE ...



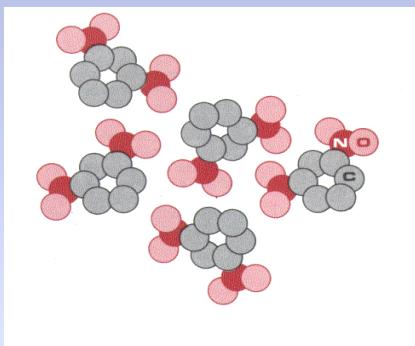
Semiconducteur

Effets
non
linéaires

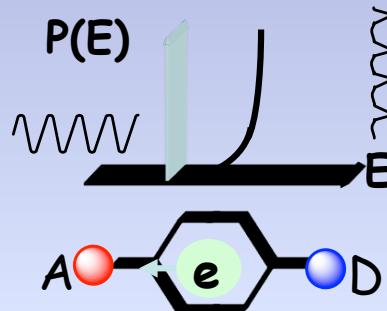


Lasers

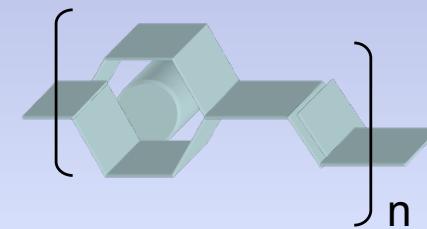
Puits quantiques



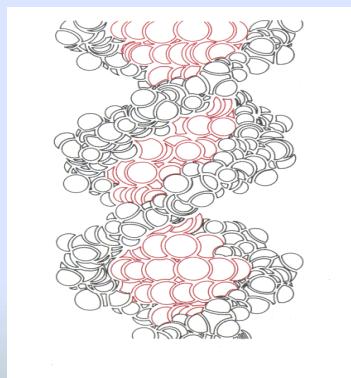
Matériau moléculaire



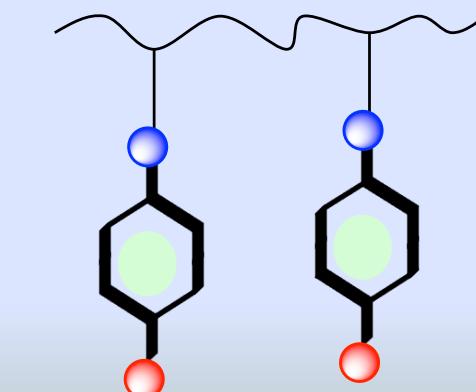
Diode moléculaire



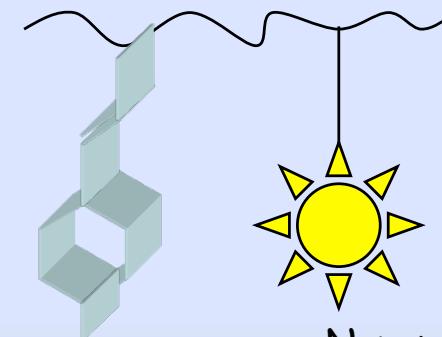
Polymère luminescent



Systèmes biologiques



Senseur de champ local



Nanoparticule

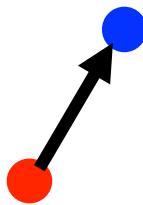
Marquage fluorescent

Material Engineering for Photonics (quadratic NLO)

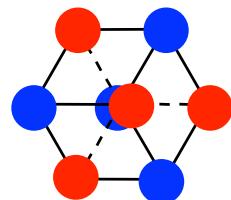
2nd order NLO \longrightarrow Noncentrosymmetric molecules and materials

Molecules

Dipole



Octupole

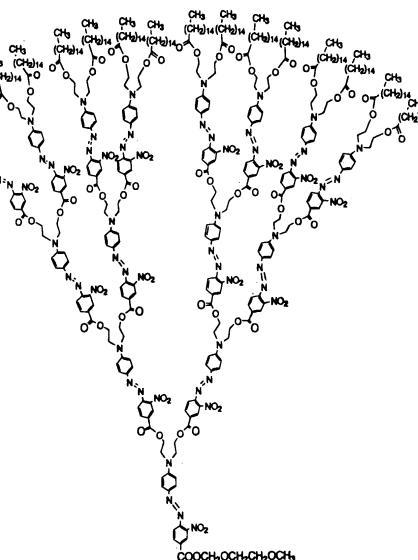


● Electron donor

● Electron acceptor

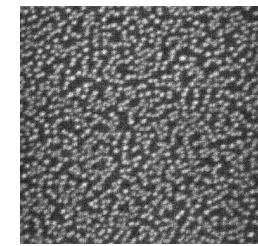
Supramolecules

Dendrimers



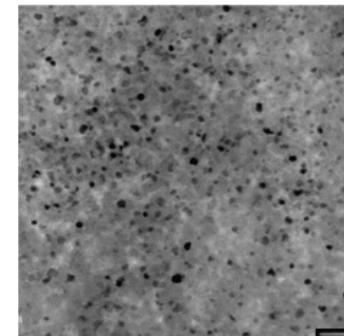
Nanoparticles

Purely Organic crystals



1 μ m

Hybrid structures



50 nm

« Macroscopic » Materials

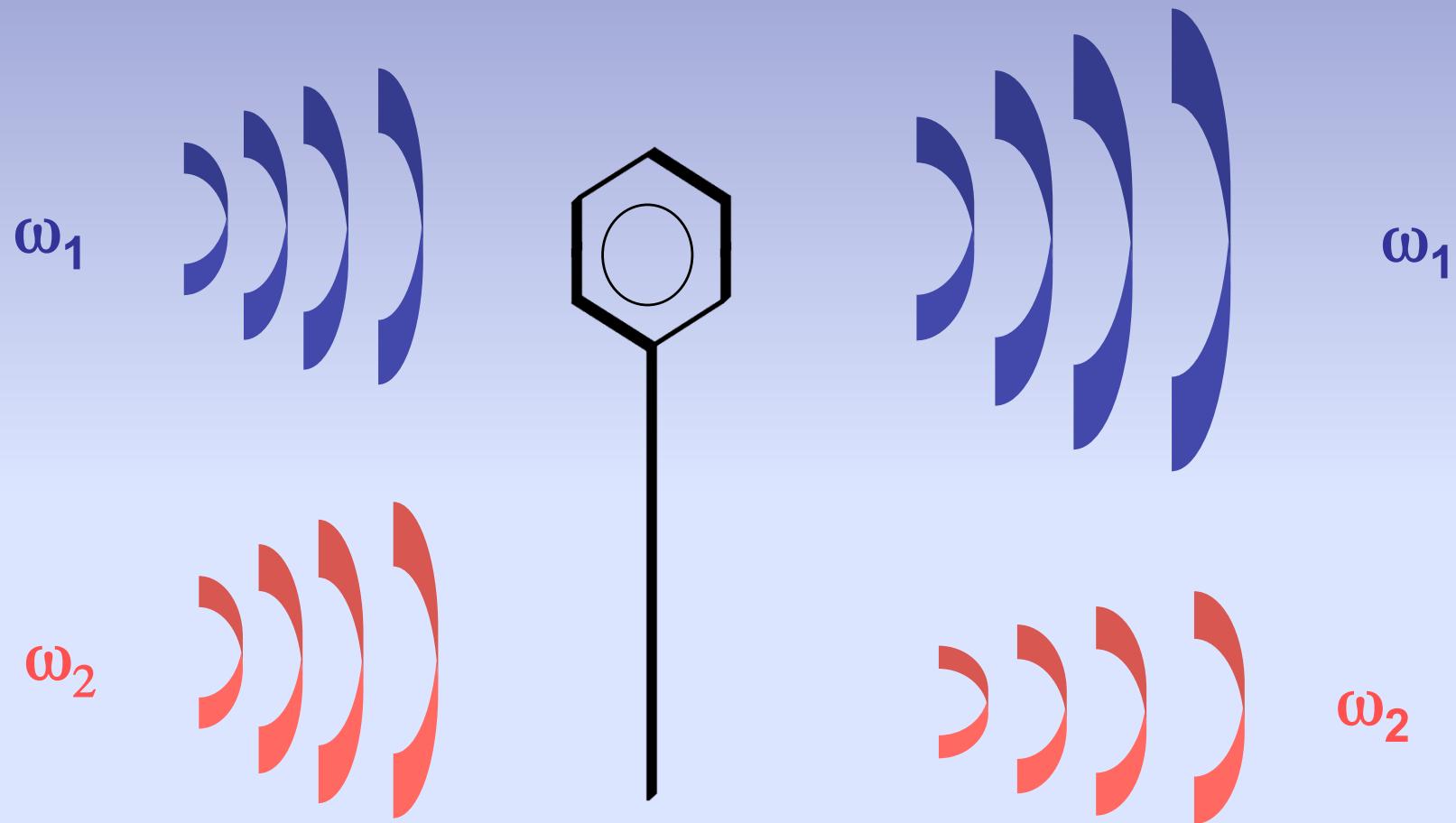
Single crystals



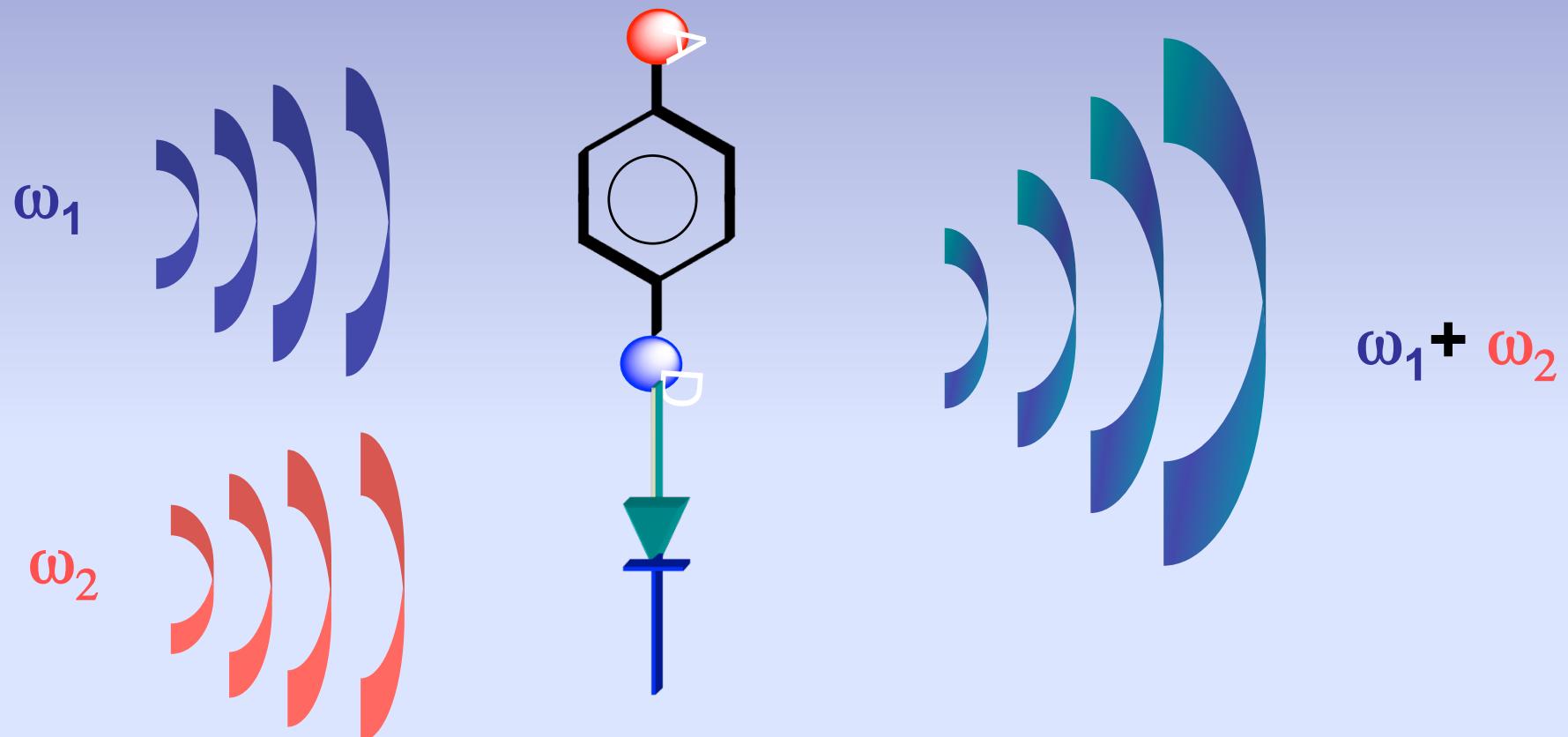
Polymers



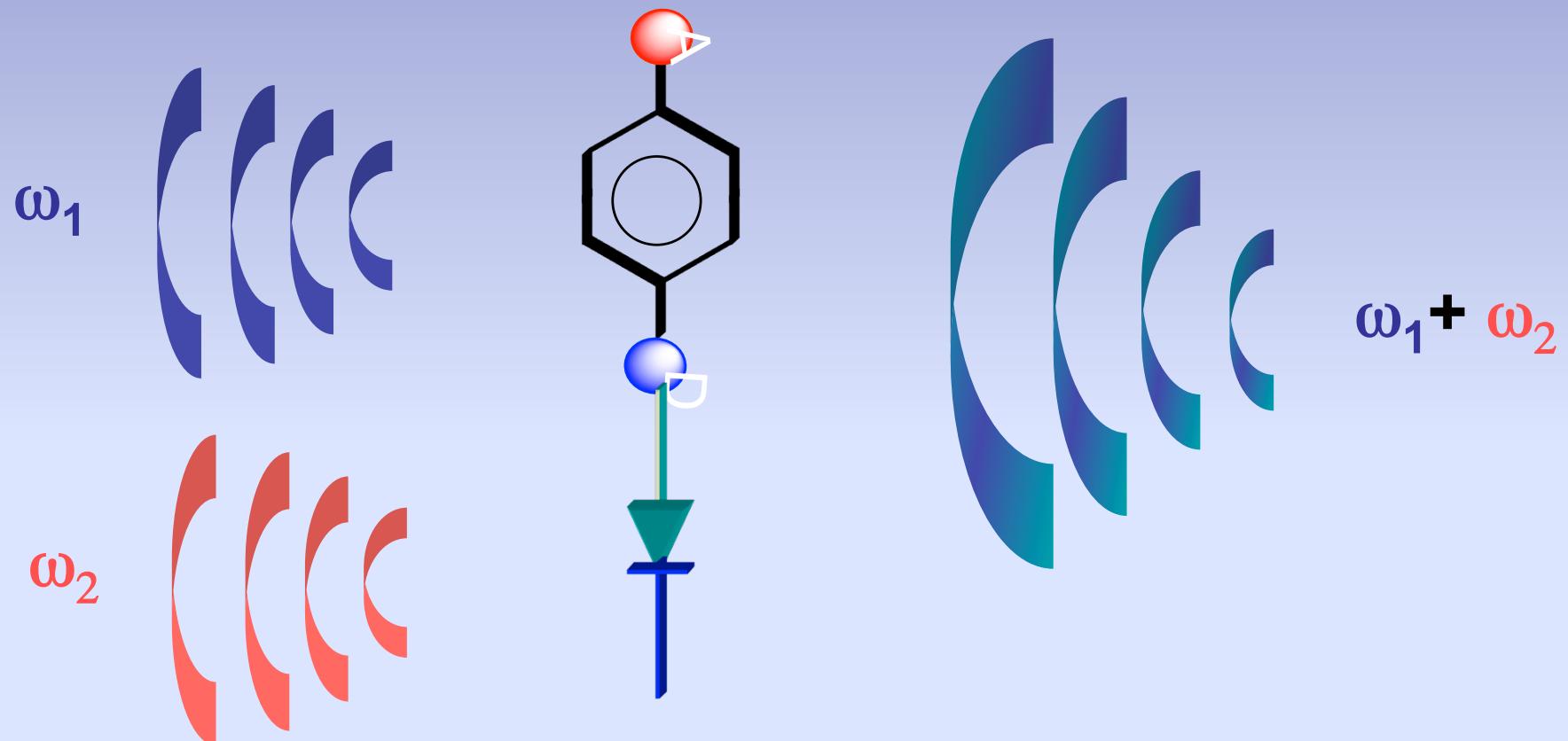
Antenne moléculaire



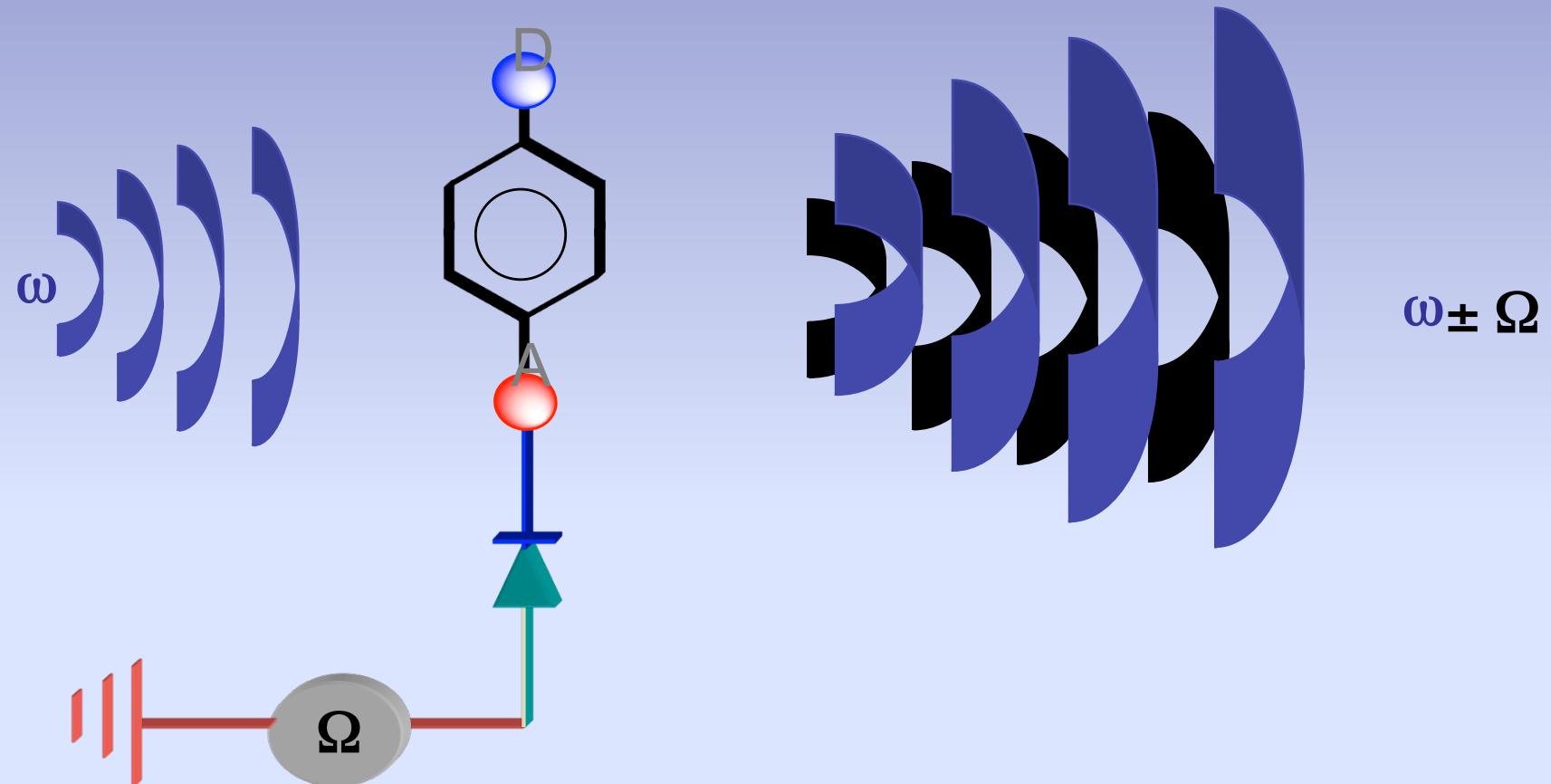
Antenne moléculaire non-linéaire



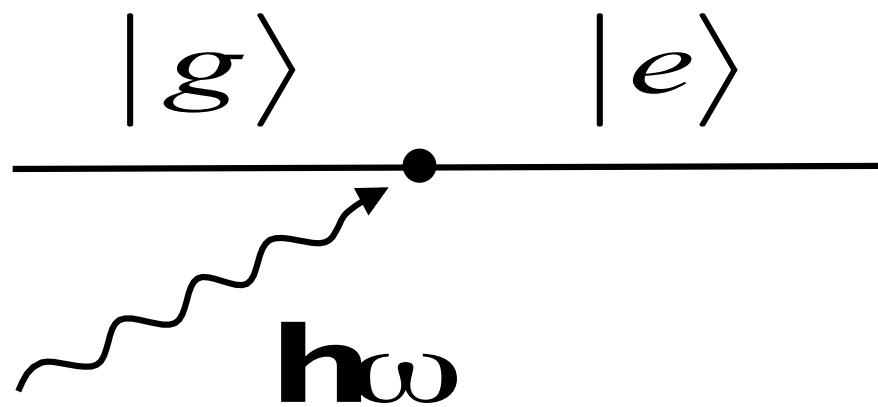
Antenne moléculaire non-linéaire



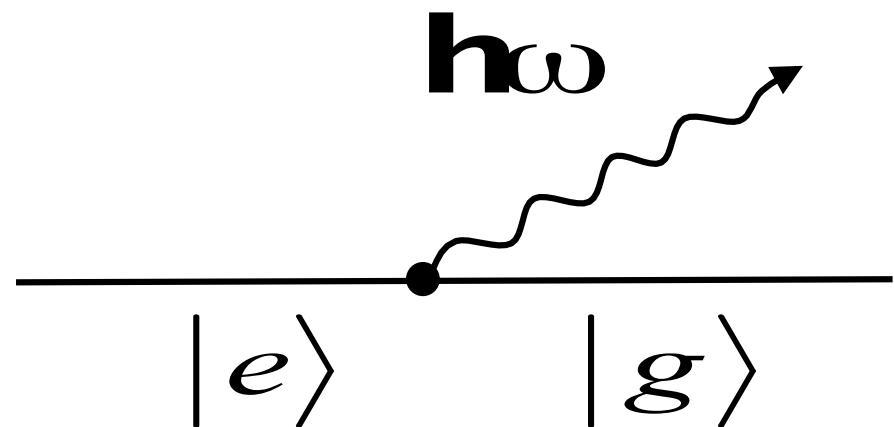
Antenne moléculaire électrooptique



Absorption of a photon

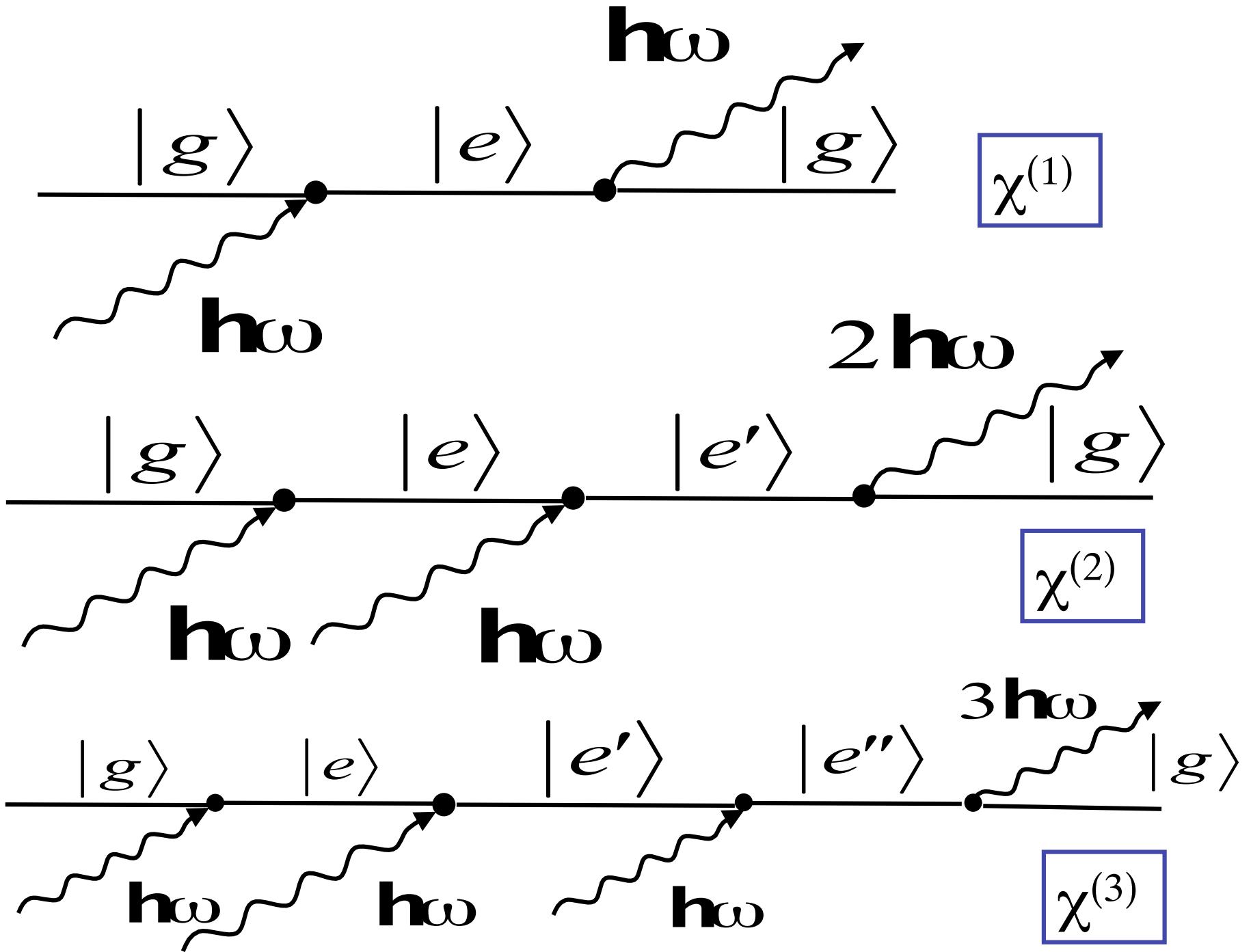


Emission of a photon

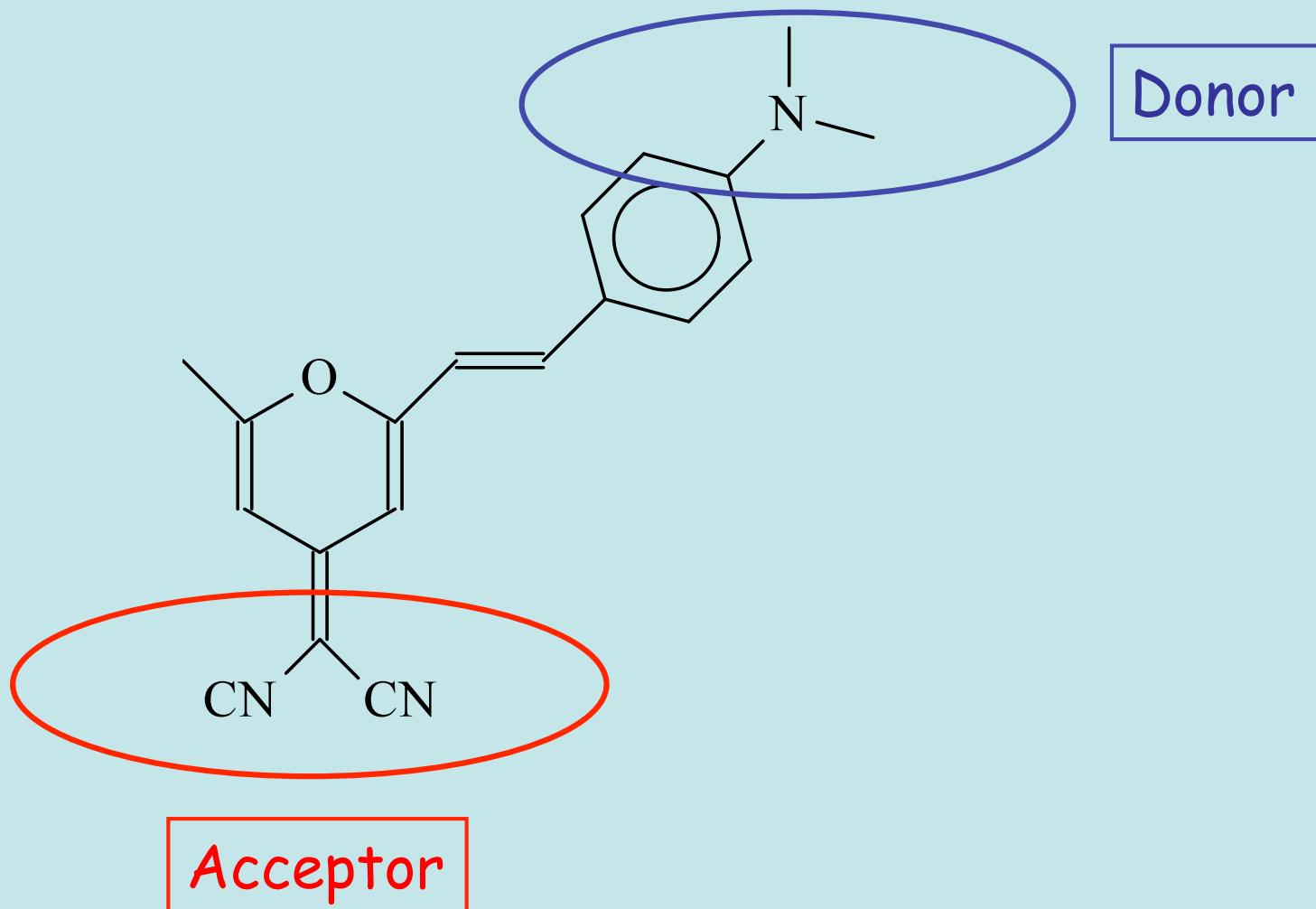


$$\frac{\langle g | \mu | e \rangle}{W_e - W_g - \hbar\omega + i\Gamma_{ge}}$$

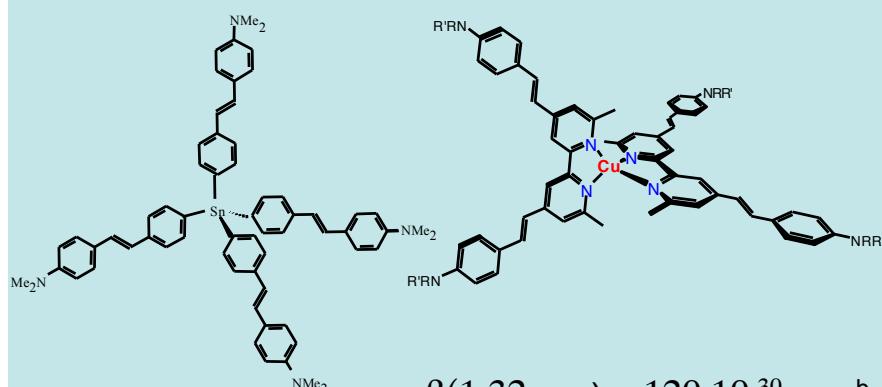
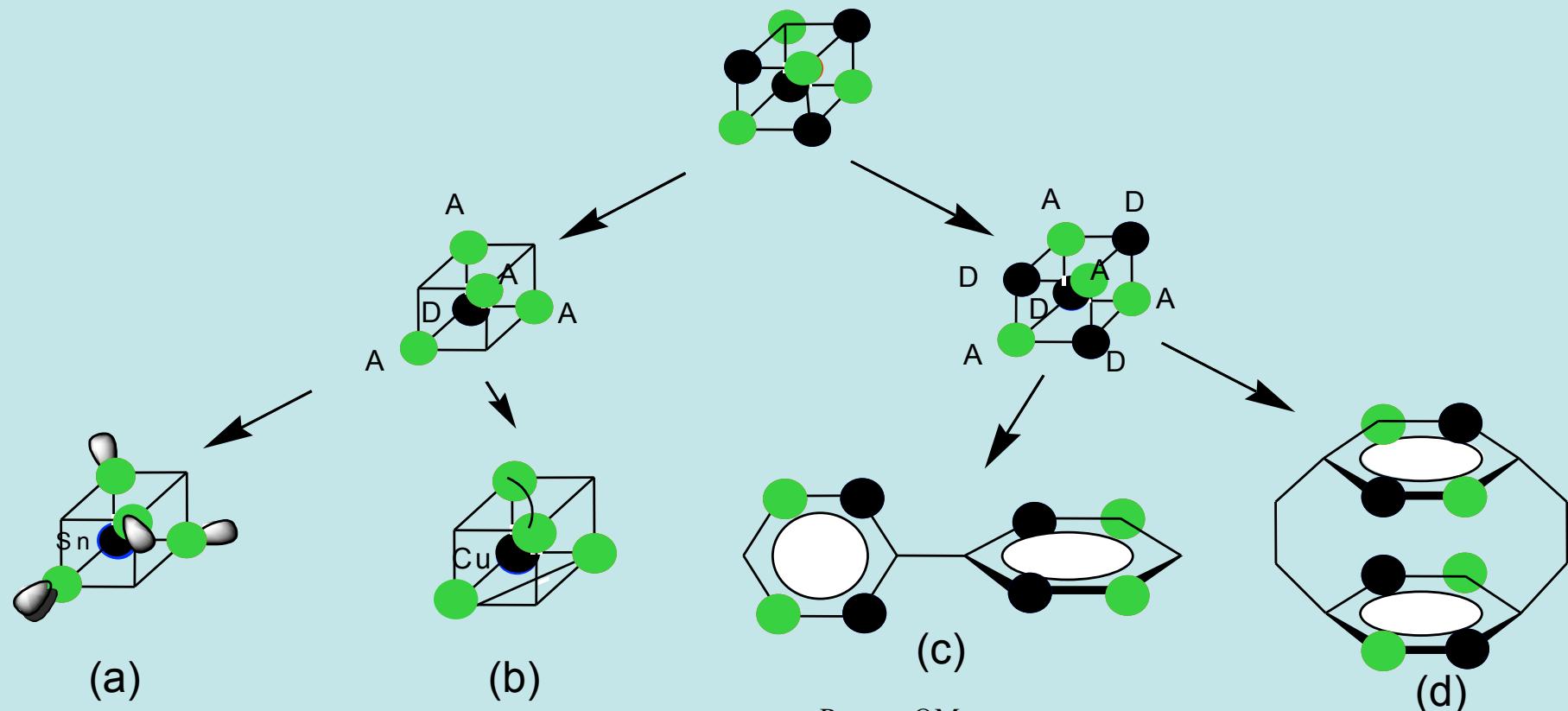
$$\frac{\langle e | \mu | g \rangle}{W_e - W_g - \hbar\omega - i\Gamma_{ge}}$$



FROM LUMINESCENCE to OPTICAL NONLINEARITY



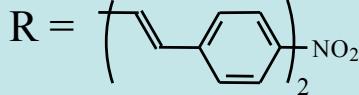
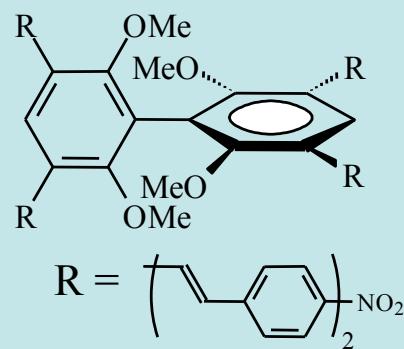
Molécules octupolaires pour la génération de second harmonique



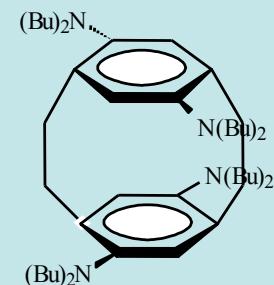
$$\beta(1.32 \mu\text{m}) = 120.10^{-30} \text{ esu}^b$$

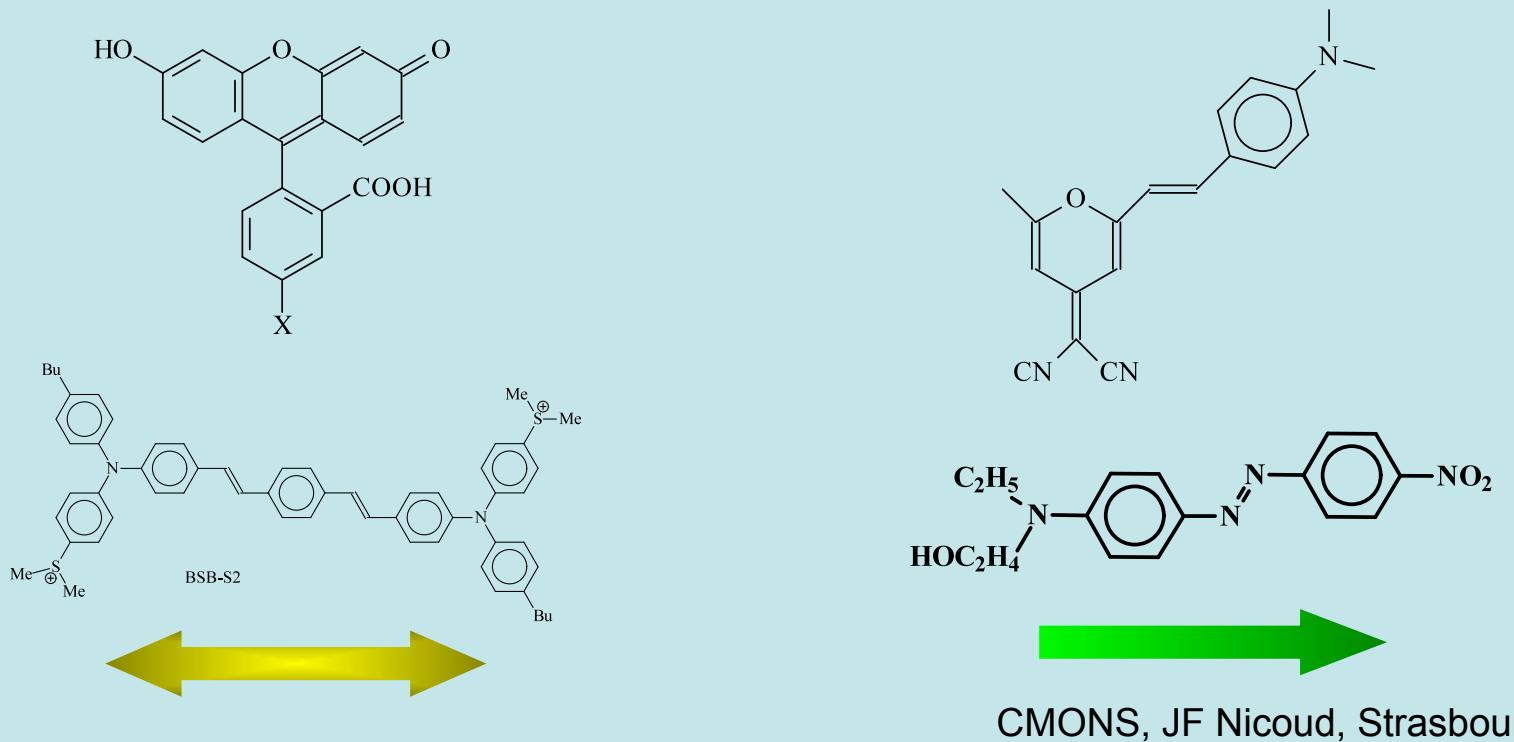
$$\beta(1.06 \mu\text{m}) = 120.10^{-30} \text{ esu}^a$$

$$\beta(1.32 \mu\text{m}) = 110.10^{-30} \text{ esu}^c$$

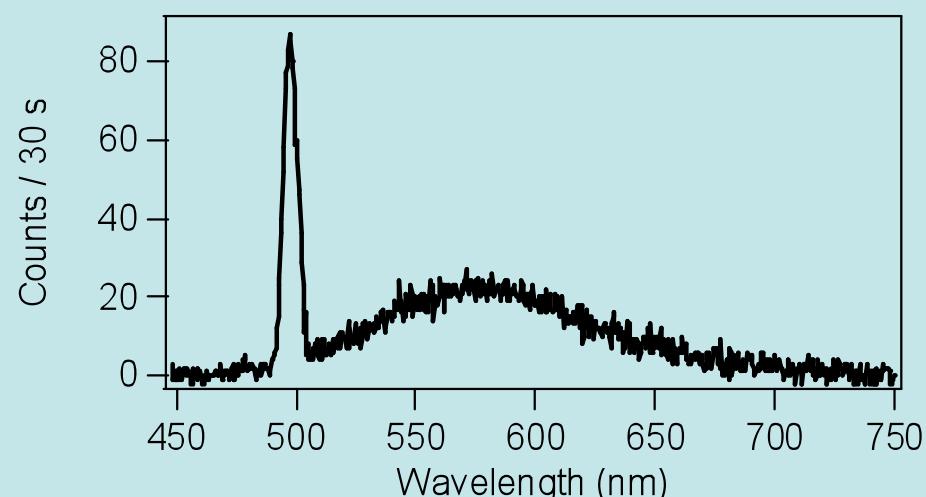


$$\beta(1.32 \mu\text{m}) = 50.10^{-30} \text{ esu}^d$$

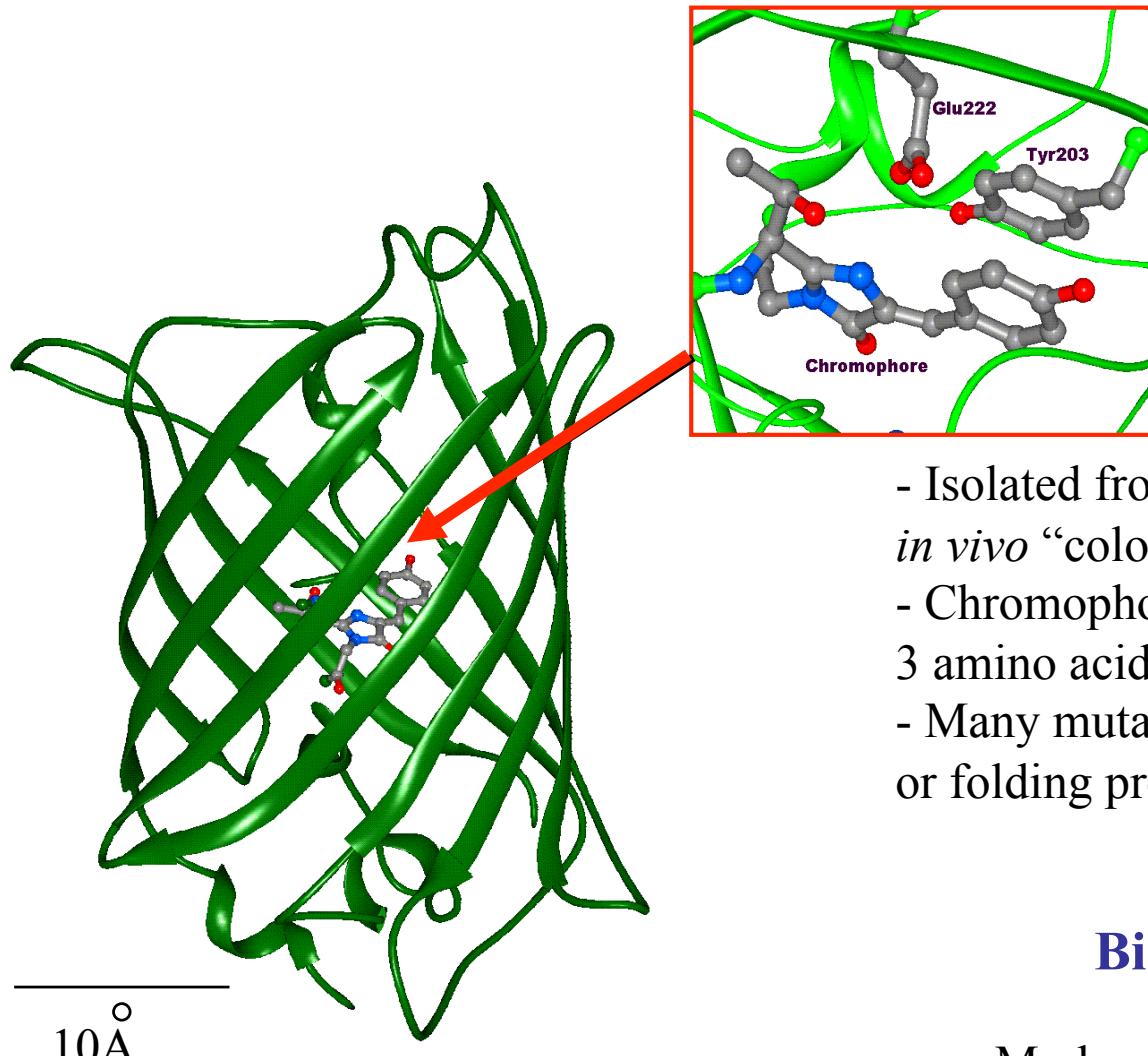




J.Perry, S. Marder, Tucson
M.Blanchard-Desce, Rennes



GENETICALLY ENGINEERED FLUORESCENT PROTEINS



238 amino acids, 27 kD

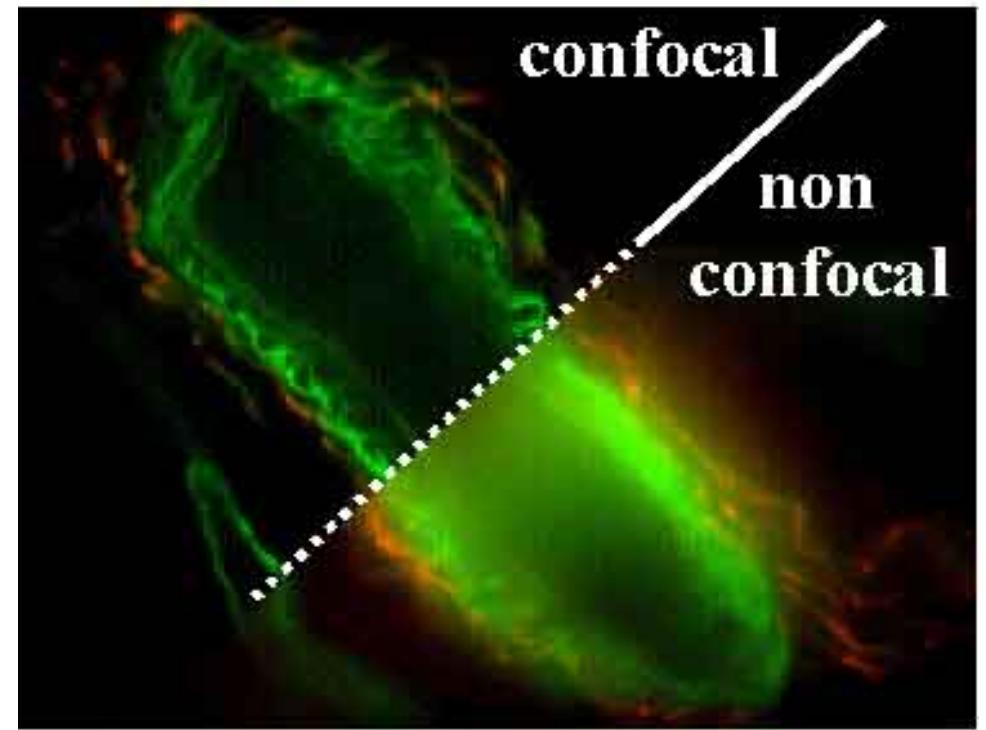
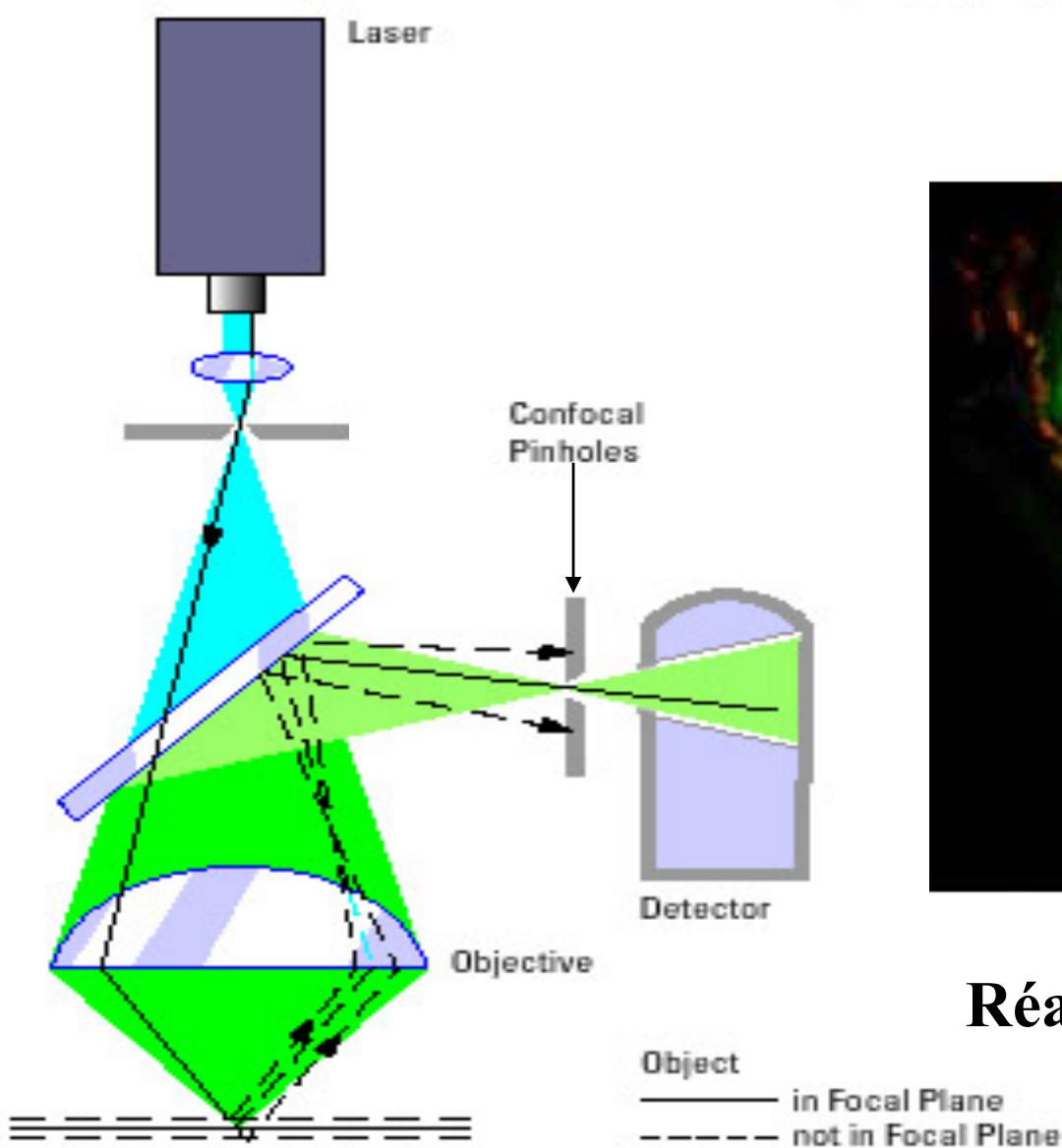
Properties:

- Isolated from jellyfish *Aequoria Victoria* *in vivo* “color converter” for bioluminescence
- Chromophore is spontaneously formed from 3 amino acids: **no cofactor**
- Many mutants with optimized spectral or folding properties

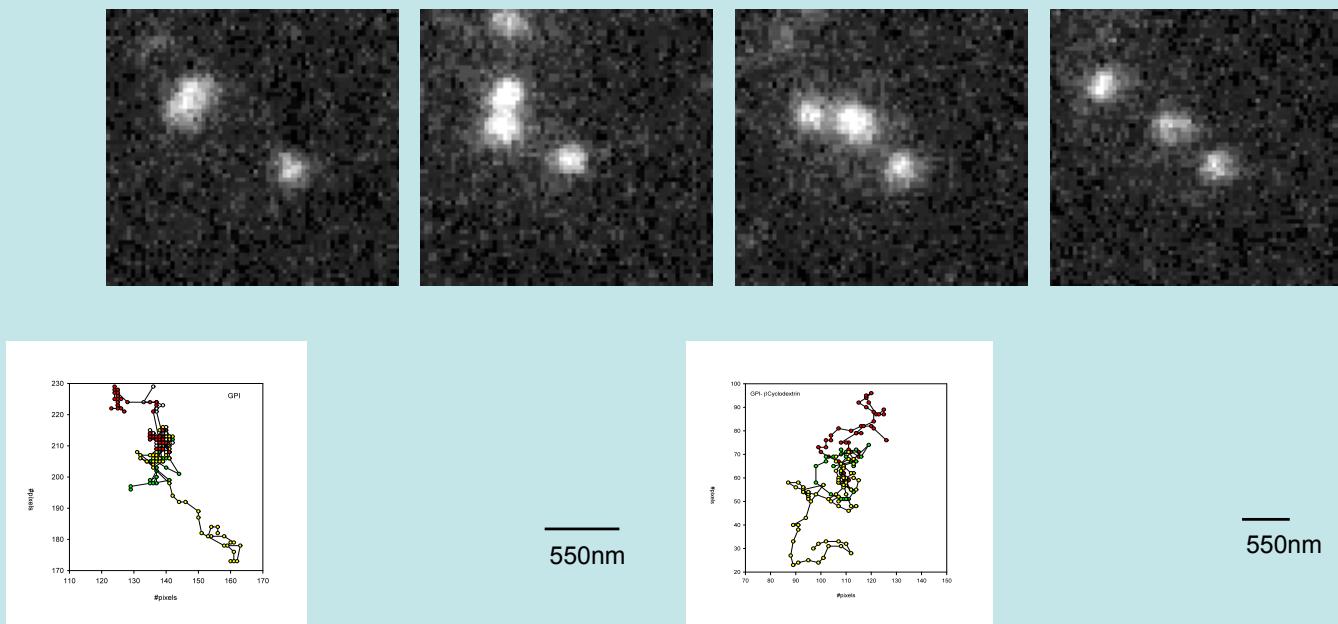
Biological interest:

Marker of expression of genes
Staining of cells for microscopy
pH sensor
 Ca^{2+} sensor

Principe de la détection confocale

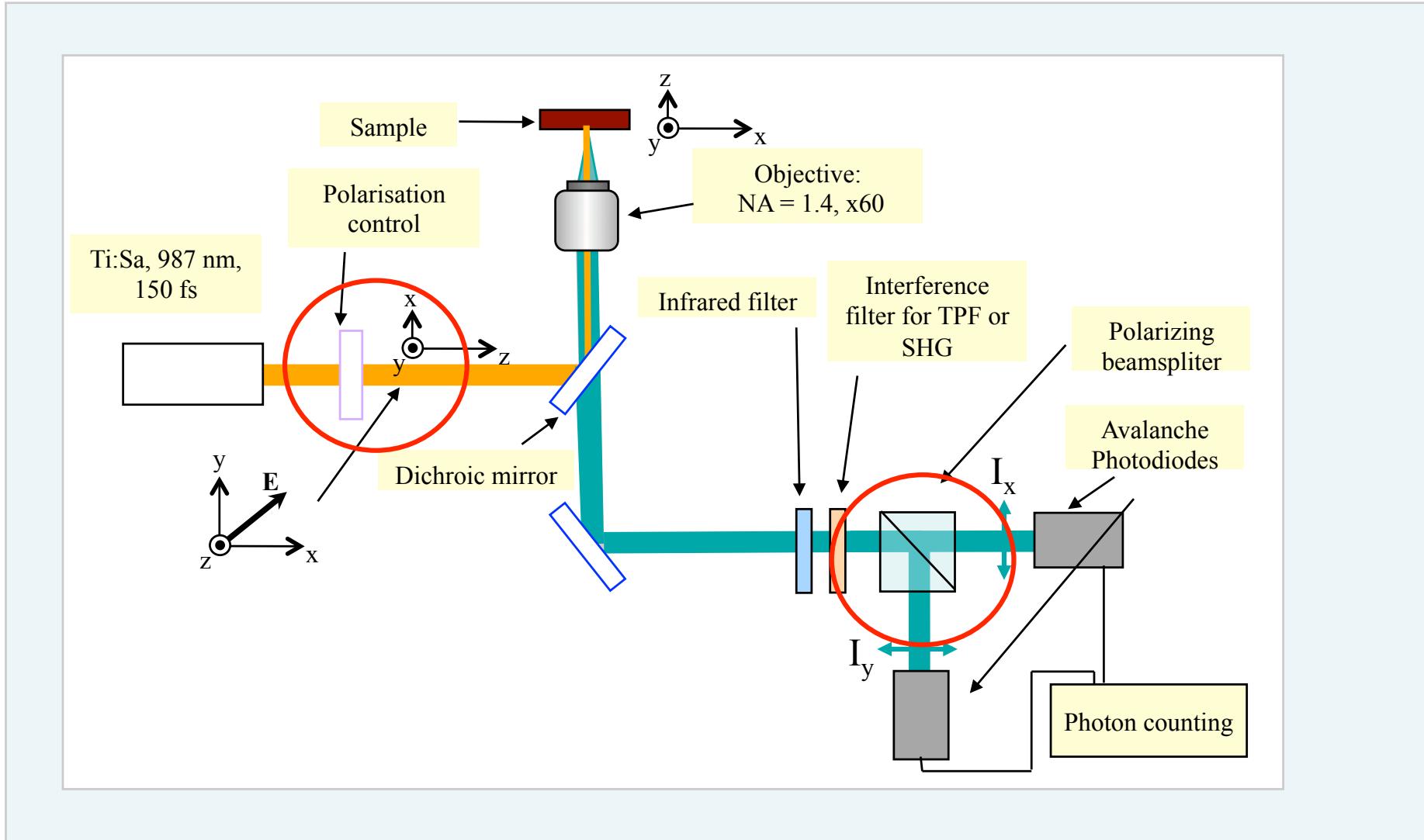


Réalisation de coupes optiques

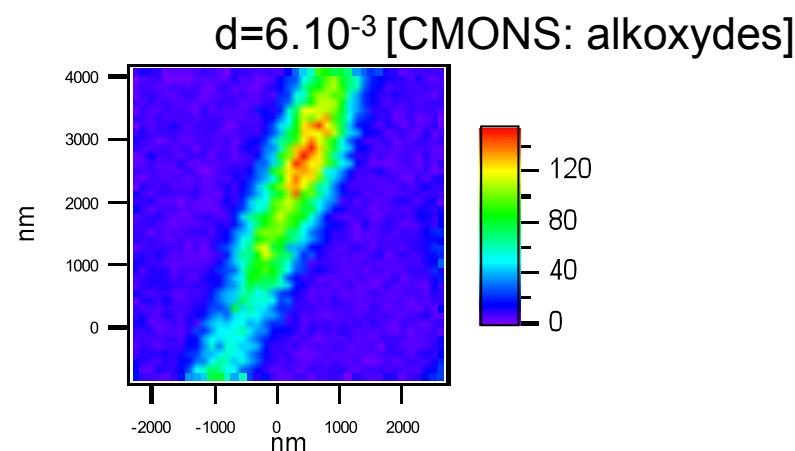


Protein-protein interactions play a role in restricted diffusion in bounded domains

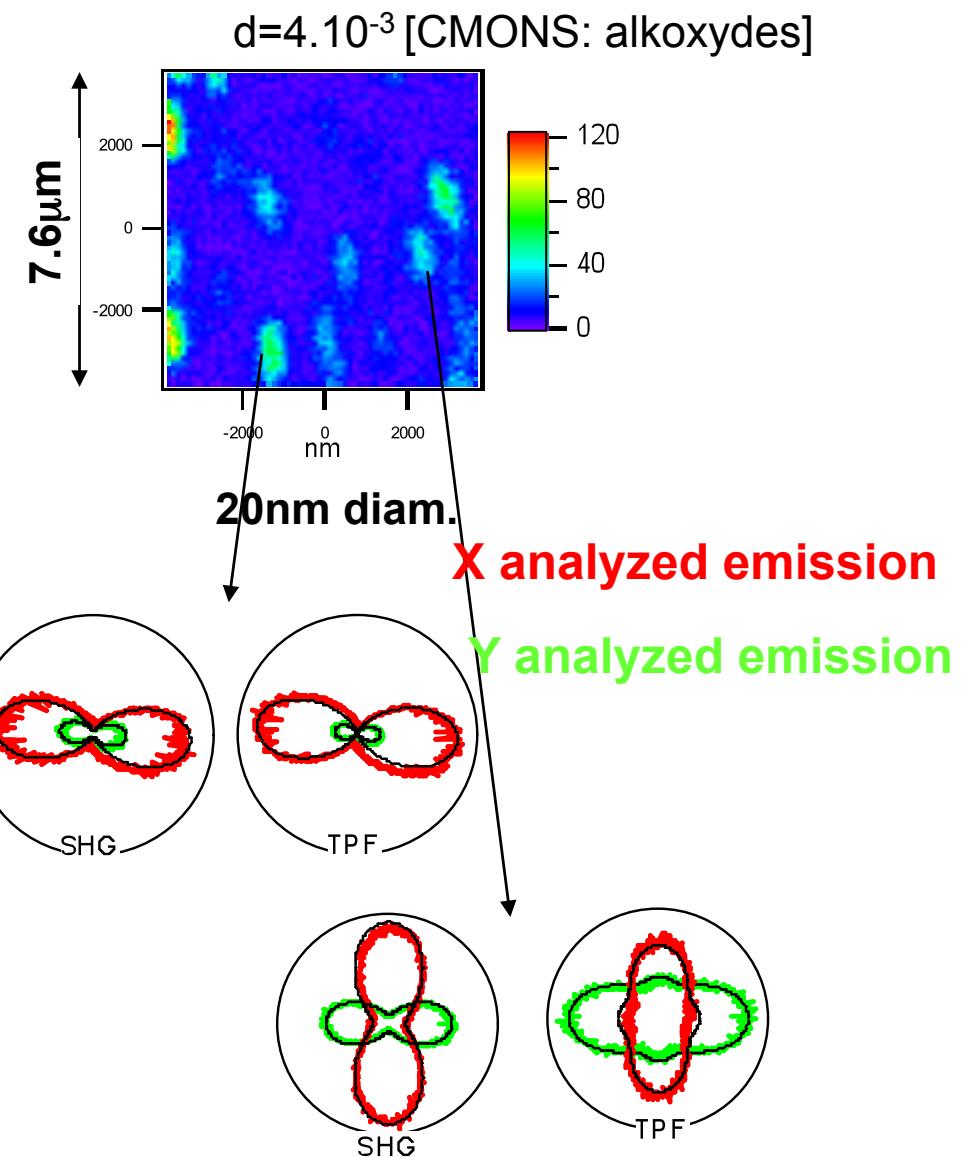
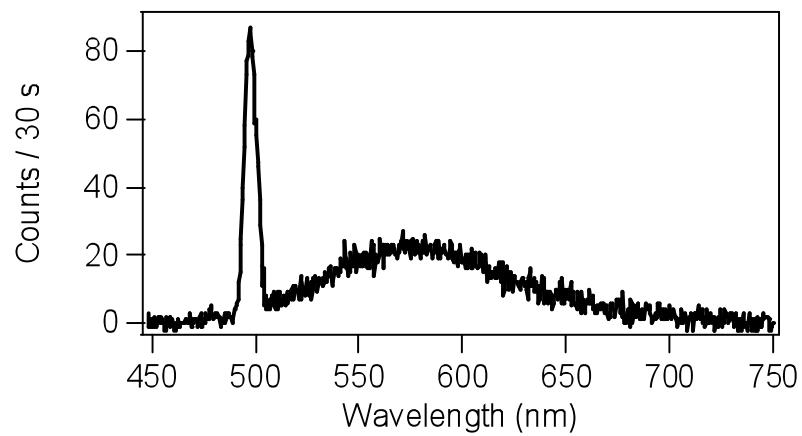
Two photon confocal microscope



SHG signal (ω at 987nm) from isolated nanocrystals



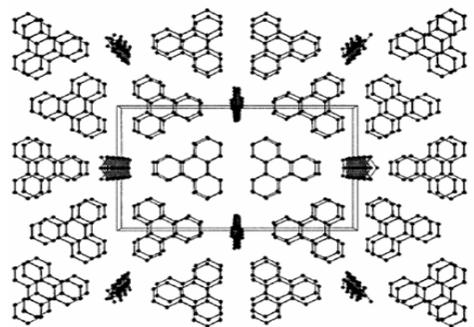
>800nm diam.



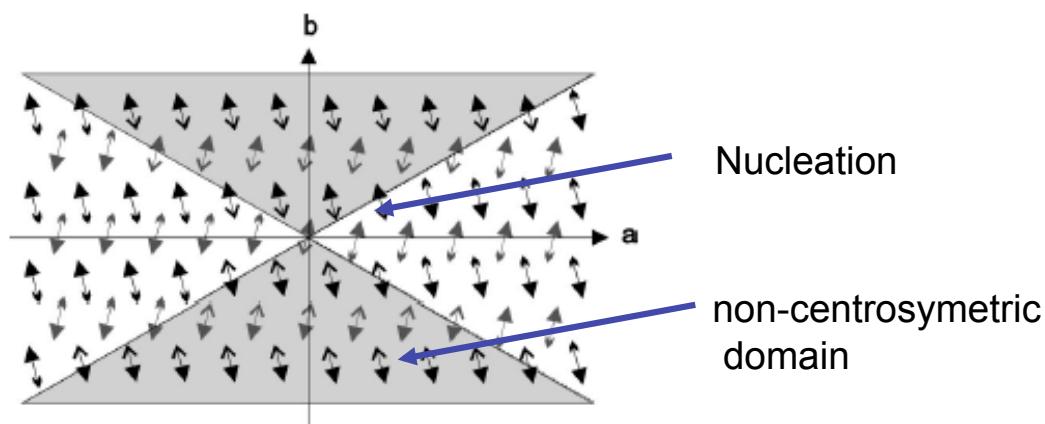
Molecular order in inclusion compounds (PHTP)

Collaboration

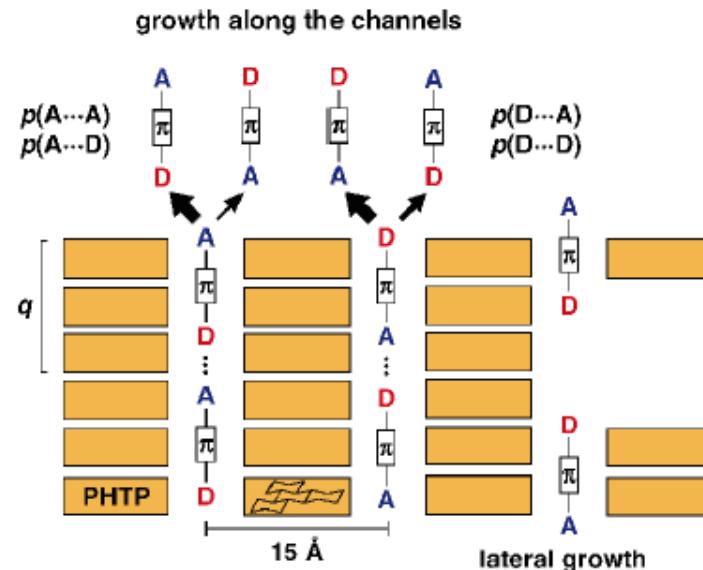
H-J. Egelhaaf, J. Gierschner, L. Poulsen,
M. Hanack, M. Jazdzyk, University of Tübingen (Germany)



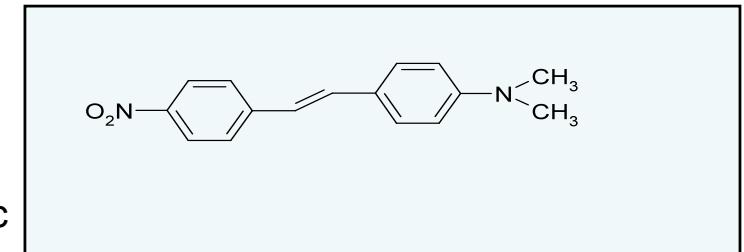
O. König et al., J. Am. Chem. Soc., 119, 44 (1997)



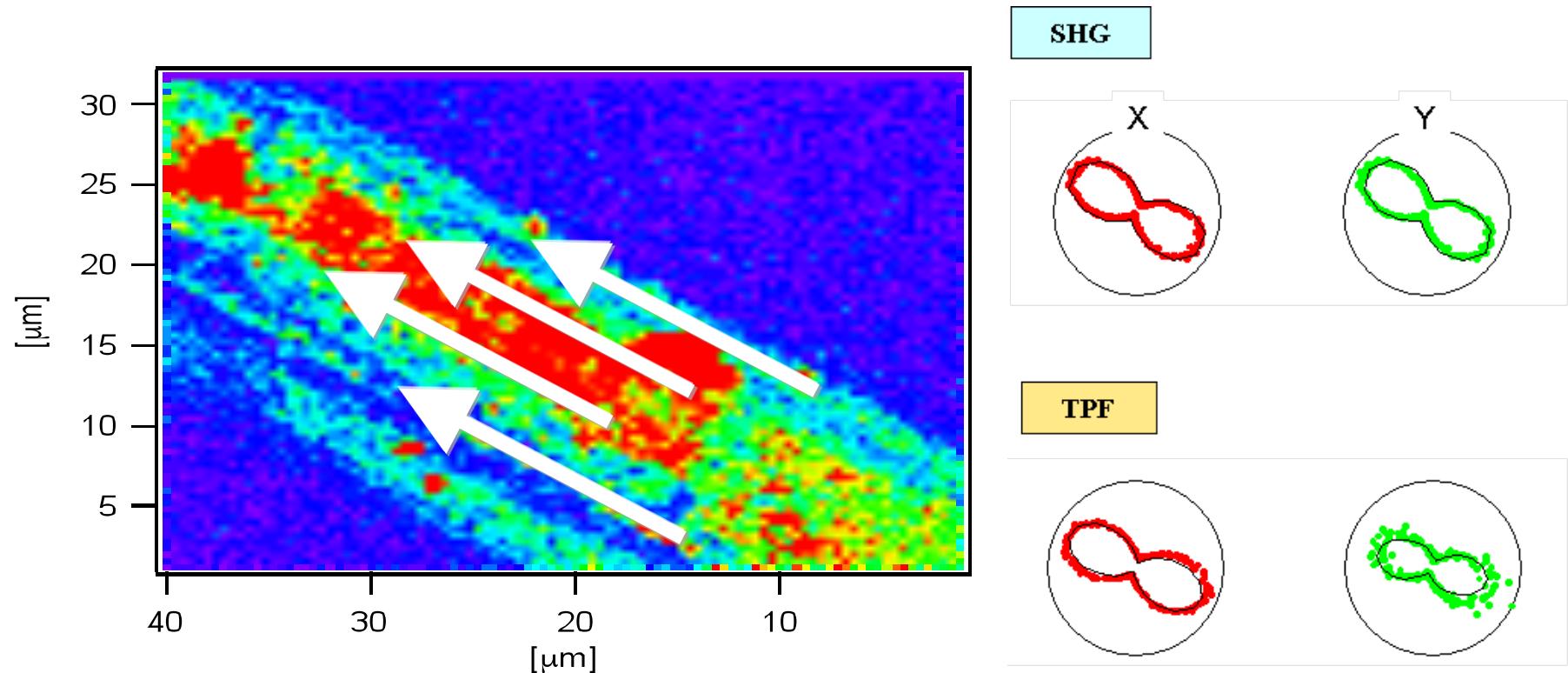
S. Kluge et al., Appl. Phys. Lett. (2002)



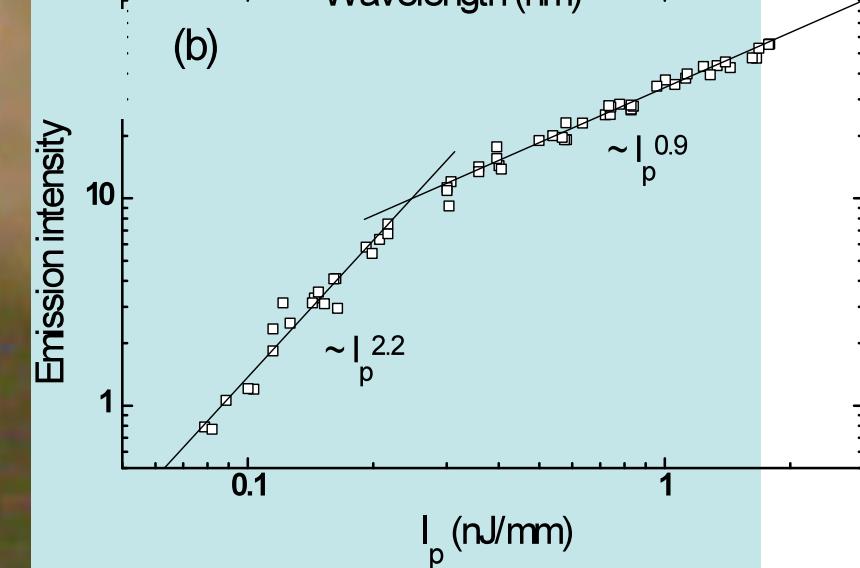
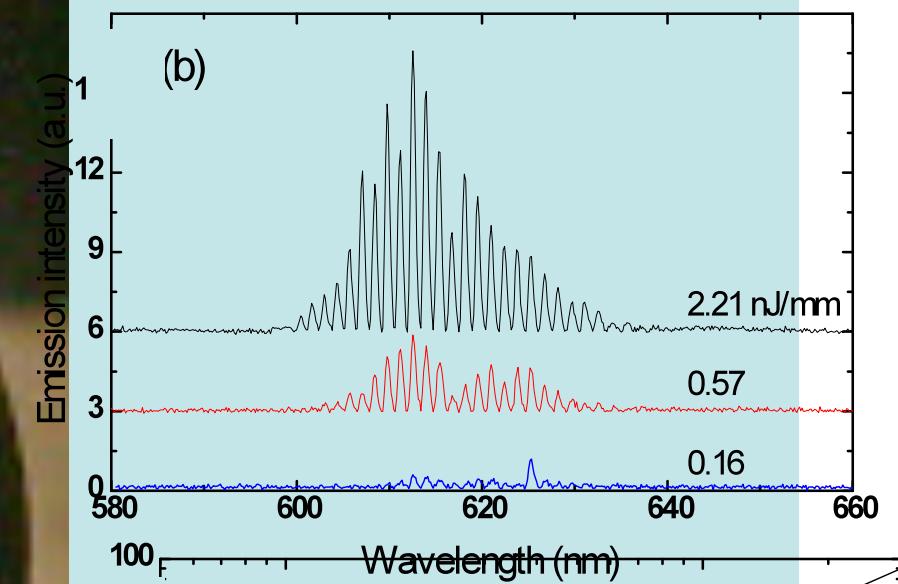
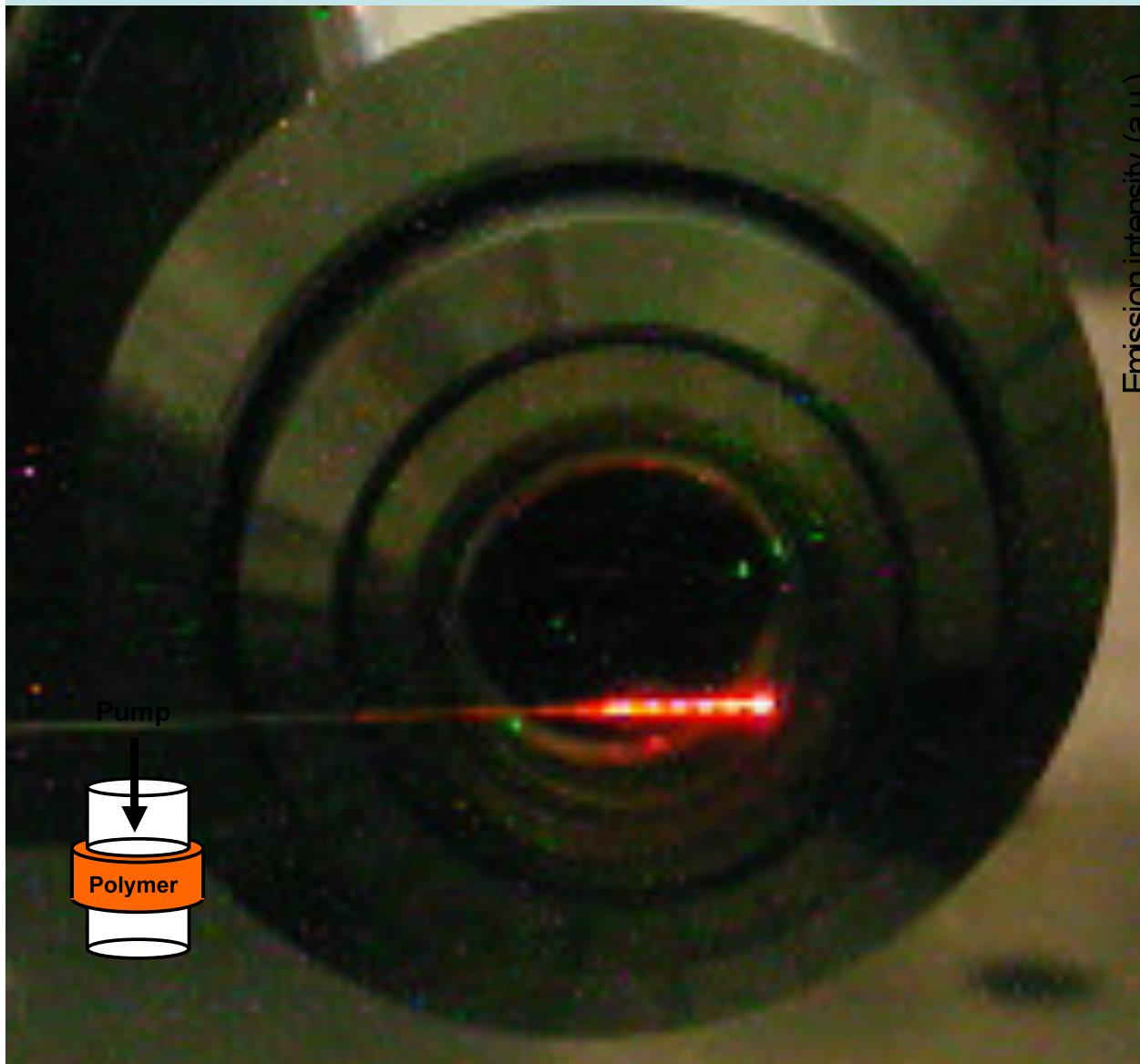
W. Roth et al., Adv. Mater. (1998)



SHG and TPF intensities I_x and I_y emitted by DANS - PHTP

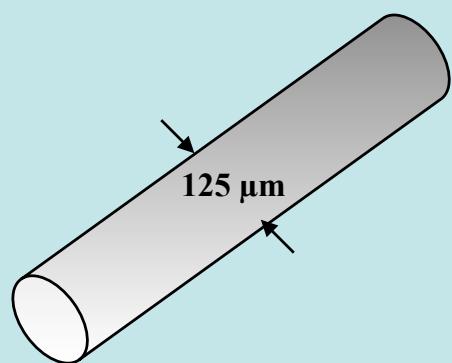


Emission from μ -ring lasers

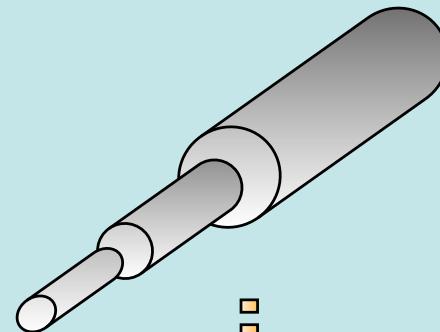


S. X. Dou, E. Toussaere, T. Ben Messaoud, A. Potter, D. Josse, G. Kranzelbinder and J. Zyss, "Polymer microring lasers with longitudinal optical pumping", Appl. Phys. Lett., Vol. 80, no. 2, pp. 165-167, (2002).

μ -ring Lasers on Fibers



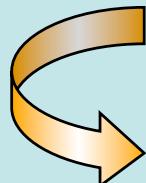
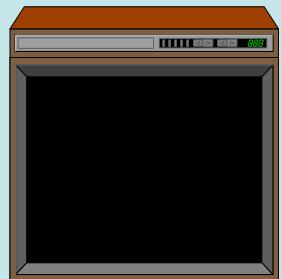
Etching with HF



Dipping
PMMA : DCM



Oven annealing





CLEAN ROOM FACILITIES FOR POLYMER DEVICES

cnrs
cachan

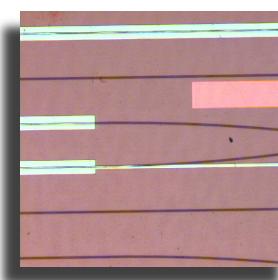
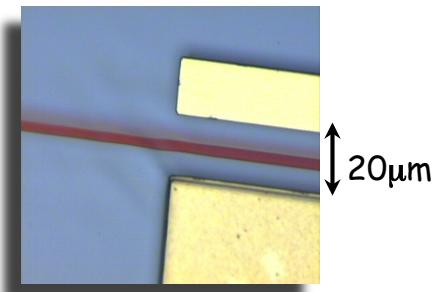
Spin-coating



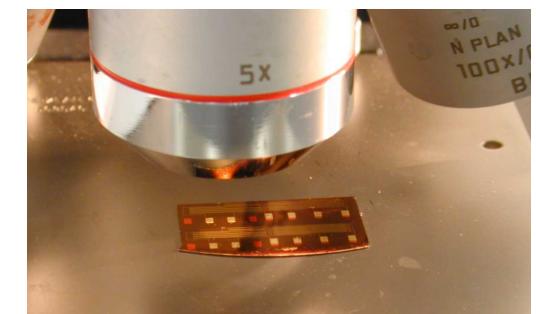
Profilometry



RIE : reactive-ion etching

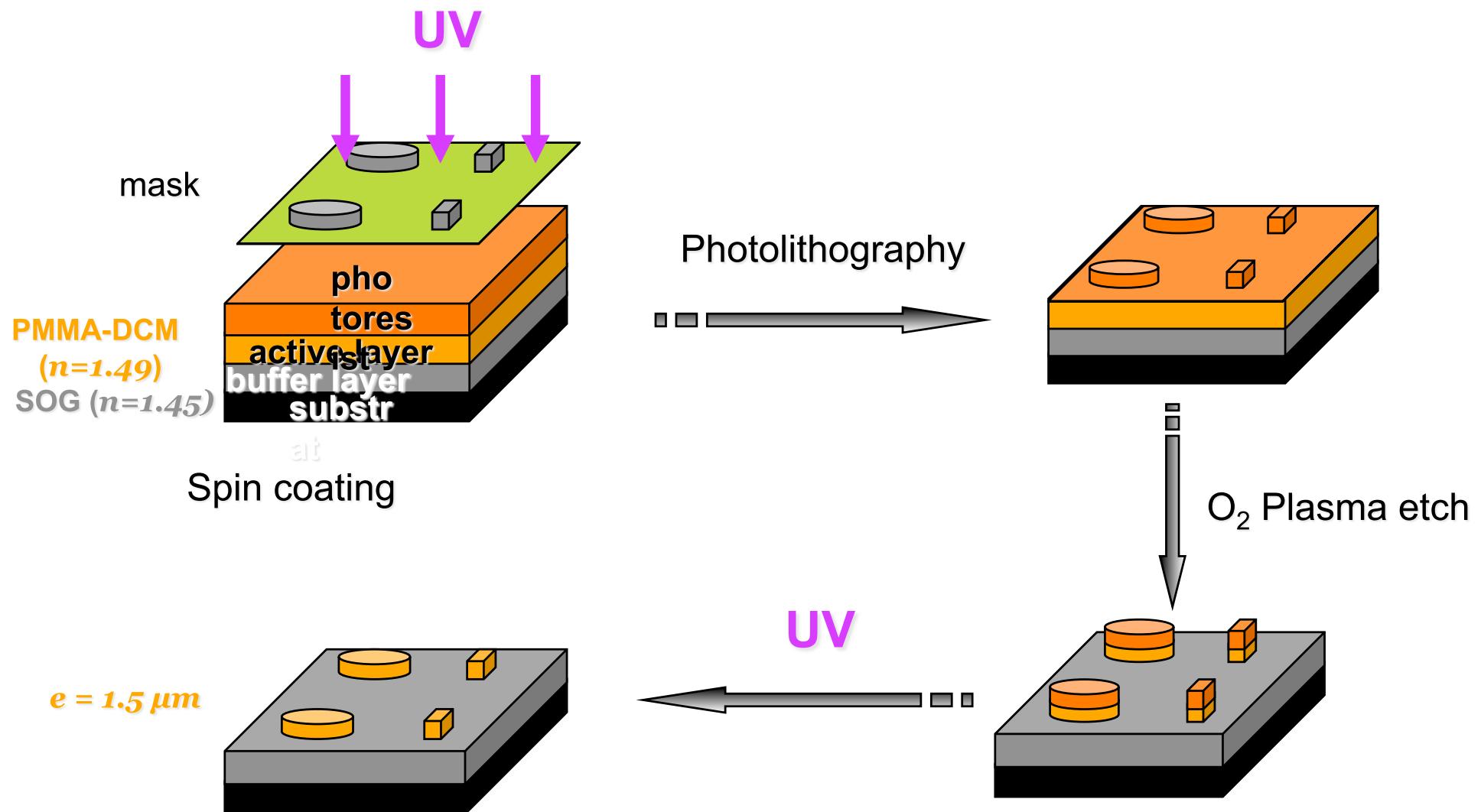


Microscopy



Gold sputtering

μ -cavity fabrication process



Flexible low-voltage electro-optic polymer modulators

Hyun-Chae Song,^{a)} Min-Cheol Oh,^{b)} Seh-Won Ahn,^{c)} and William H. Steier
*Department of Electrical Engineering, University of Southern California, Los Angeles,
 California 90089-0483*

Harold R. Fetterman
Department of Electrical Engineering, University of California, Los Angeles, California 90095

Cheng Zhang
Pacific Wave Industries, Los Angeles, California 90024

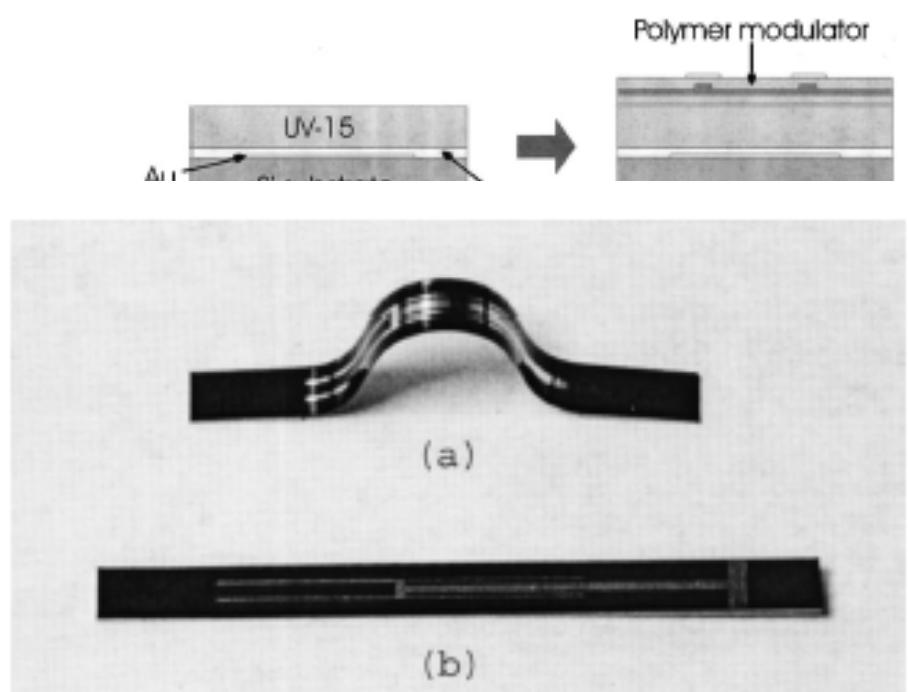


FIG. 2. Photograph of the EO polymer devices on the flexible substrate. (a) Flexed EO polymer device on the flexible substrate. (b) Straight EO polymer device on the flexible substrate.

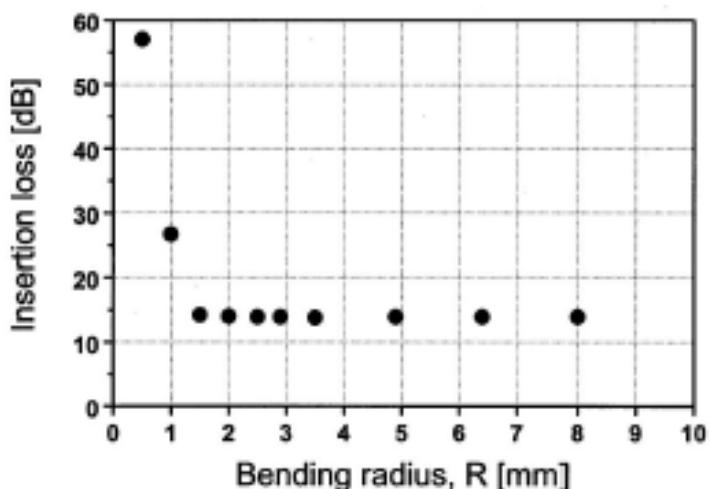
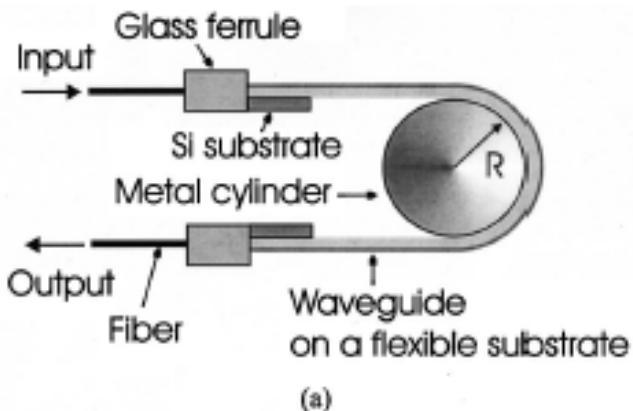
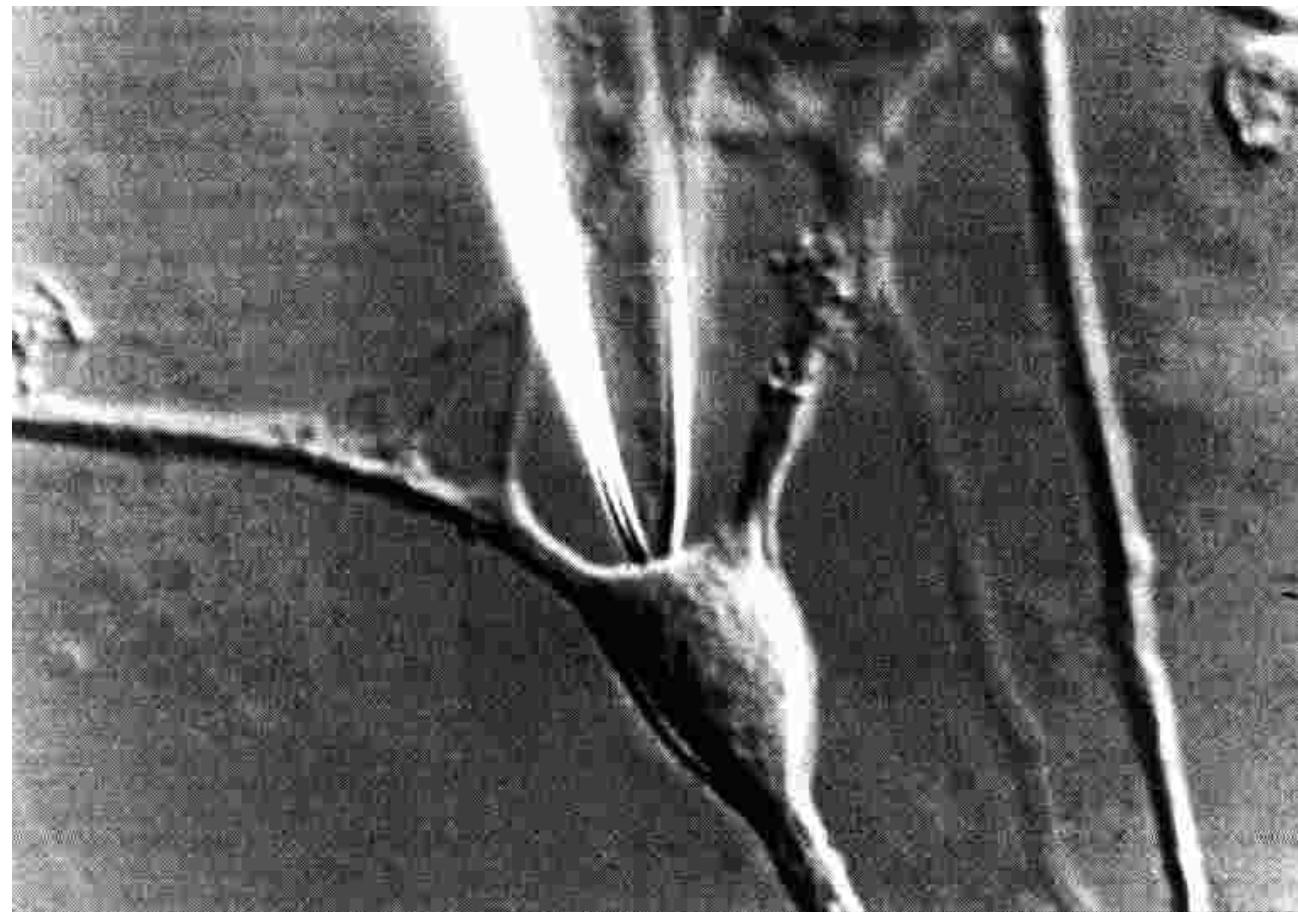


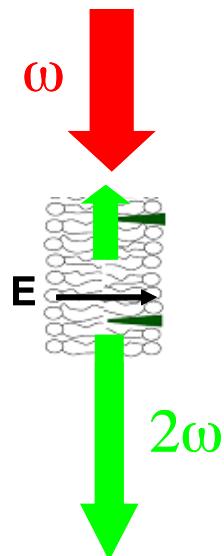
FIG. 4. Insertion loss measurement of the EO polymer device on the flexible substrate. (a) Measurement method. (b) Insertion loss change depending on the bending radius. The insertion loss remains unchanged with a bending radius of 1.5 mm.

Probing transmembranar potential by nonlinear microscopy



Electro-optic microscopy as a probe for neuronal potentials

Second Harmonic Generation (SHG):

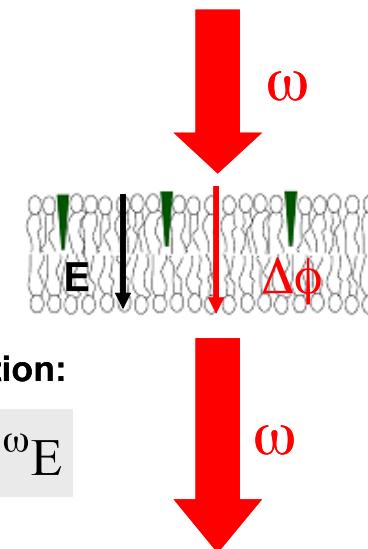


Second order contribution:

$$\chi^{(2)}(2\omega; \omega, \omega): E^\omega E^\omega$$

Measured: $I^{2\omega} \propto \left(\chi^{(2)} I^\omega \right)^2$

Electro-optic microscopy (EOM):



Phase shift contribution:

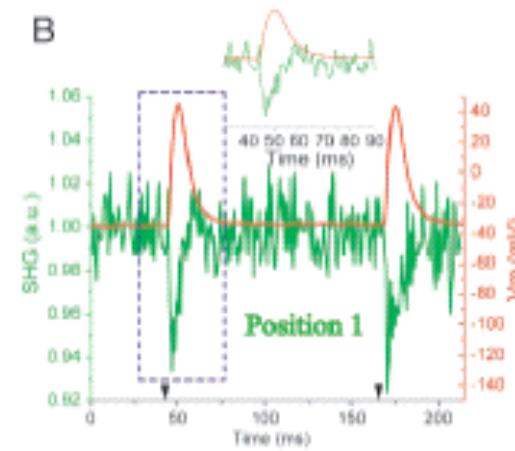
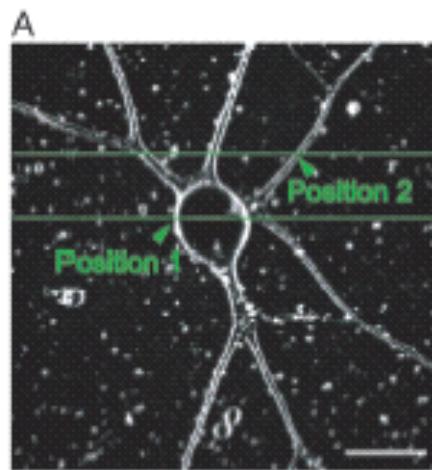
$$\chi^{(2)}(-\omega; \omega, 0): E^\omega E^0$$

Measured: $\Delta\phi \propto \frac{2\pi}{\lambda} n^3 \chi^{(2)} V$

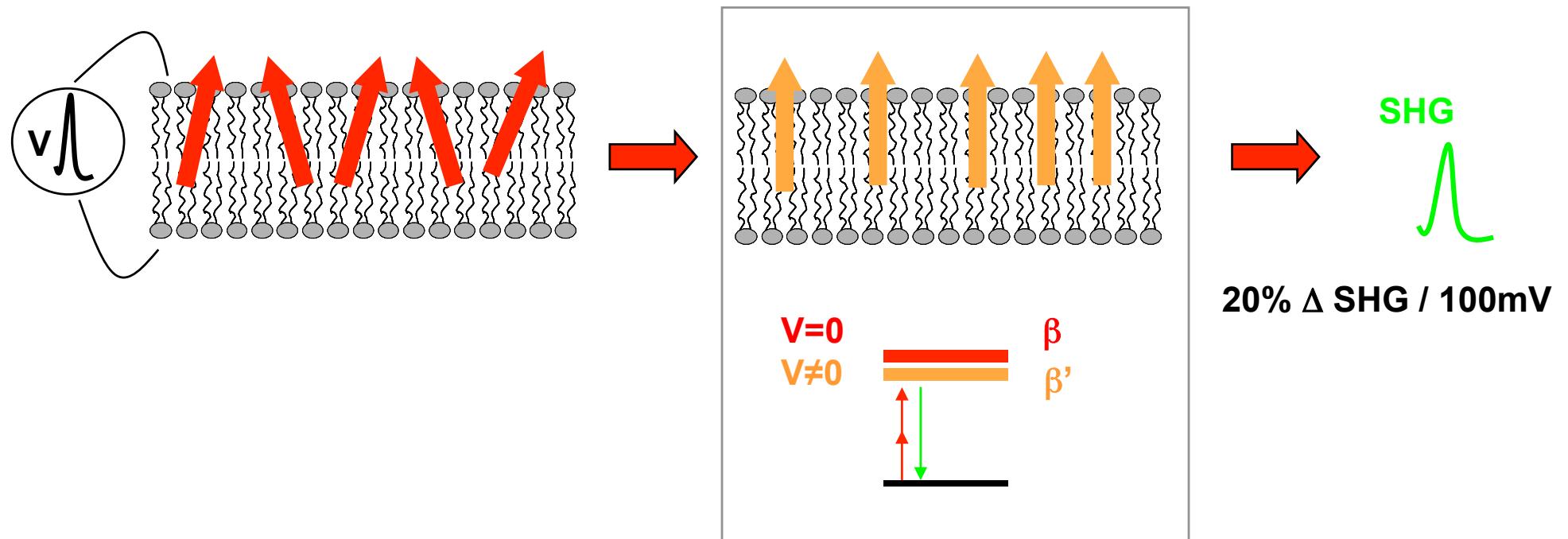
Patents

J. Zyss, T. Toury, 22 août 2003
T. Toury, J. Zyss, 22 août 2003

Imaging membrane potential by SHG in Neurons



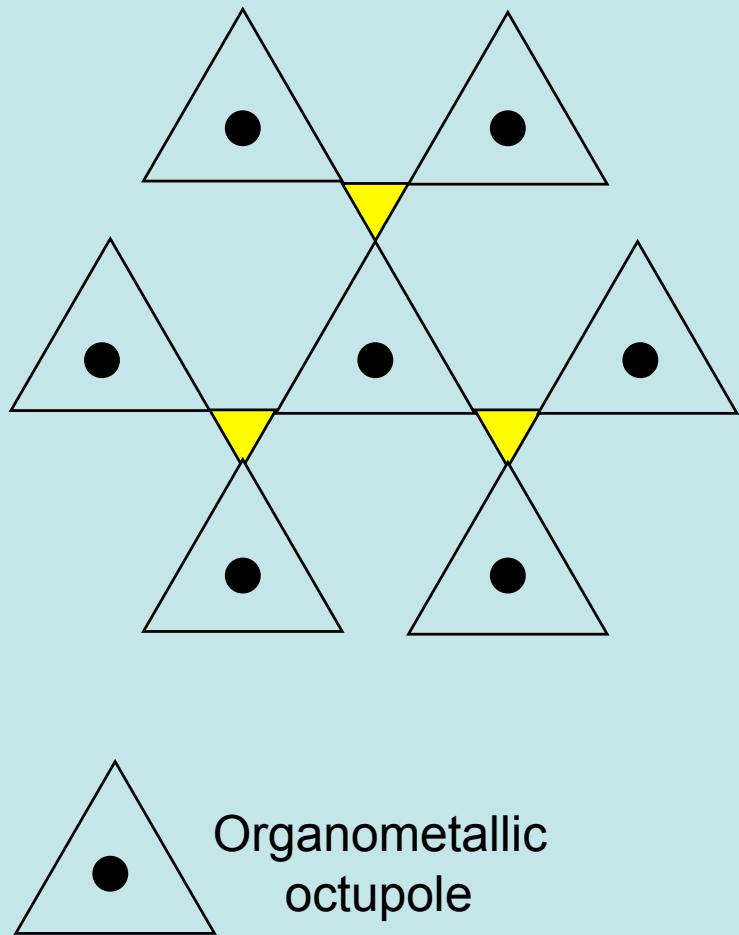
W. Webb et al. J.
Neurosciences (2004)



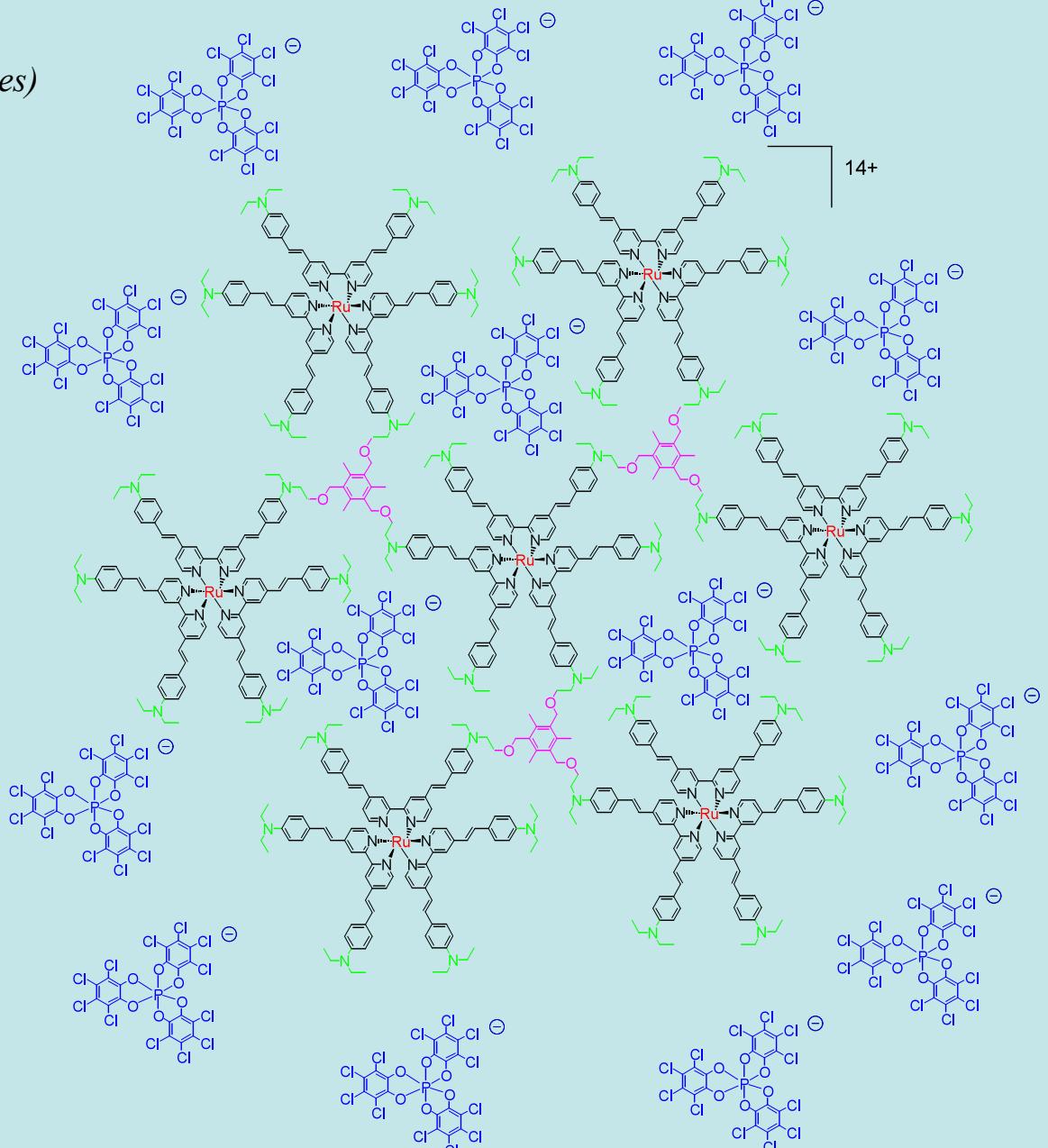
SUPRAMOLECULAR ORGANIZATION: FROM FUNCTIONAL MOLECULES TO FUNCTIONAL MATERIALS

SUPRAMOLECULAR OCTUPOLAR ENGINEERING

Coll. H. Le Bozec, University of Rennes)



▼ Trigonal binding moiety



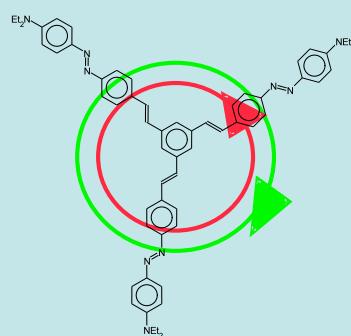
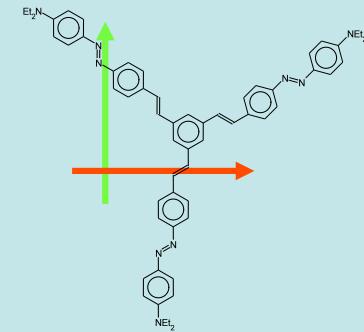
Ledoux, Le Bozec, Maurin, Zyss et al.
Adv. Mat. 2001

Tensorial data encryption by all-optical poling of nonlinear holograms (polarization sensitive coherent control)

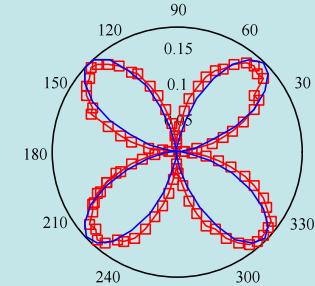
$$I_{\text{SHG},2\omega}^Y(\varphi) \propto I_{\text{SHG},2\omega}^X(\varphi) \cos \varphi$$

$$I_{\epsilon}^{\text{SHG}}(\phi) \propto \left| \sum_{J,m,m'} \frac{1}{(2J+1)} \beta_m^J f_{m'm}^J F_{\epsilon}^{\text{SHG}}(\phi) \right|^2$$

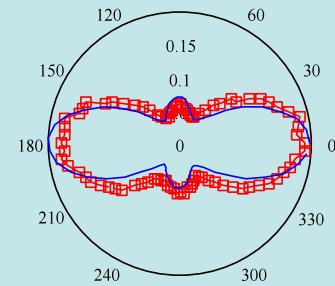
→ J=1 or 3



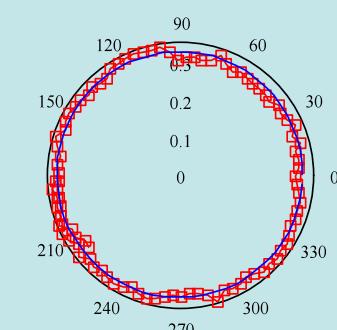
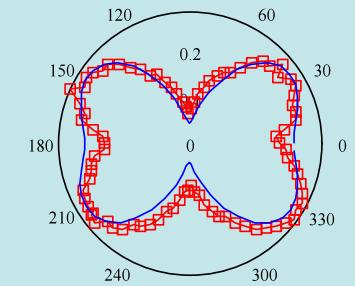
$$I_{\text{SHG},2\omega}^X(\varphi)$$



$$I_{\text{SHG},2\omega}^Y(\varphi)$$



$$I_{\text{SHG},2\omega}(\varphi)$$



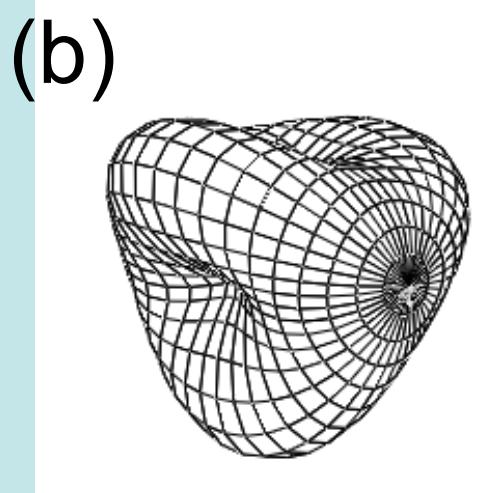
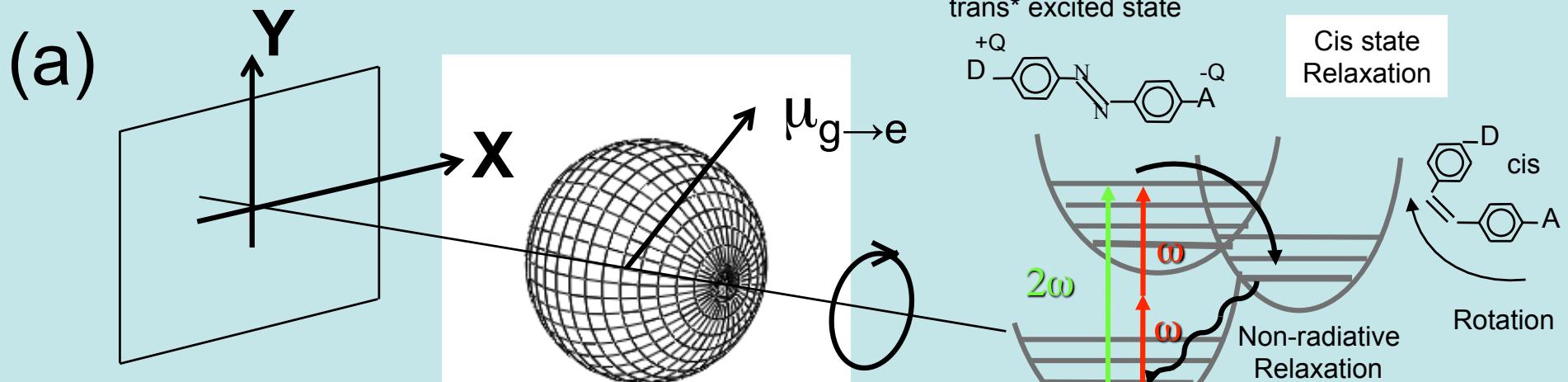
SHG anisotropy :
→ molecular symmetry

$$\beta^{J=3}/\beta^{J=1} \approx 2.5$$

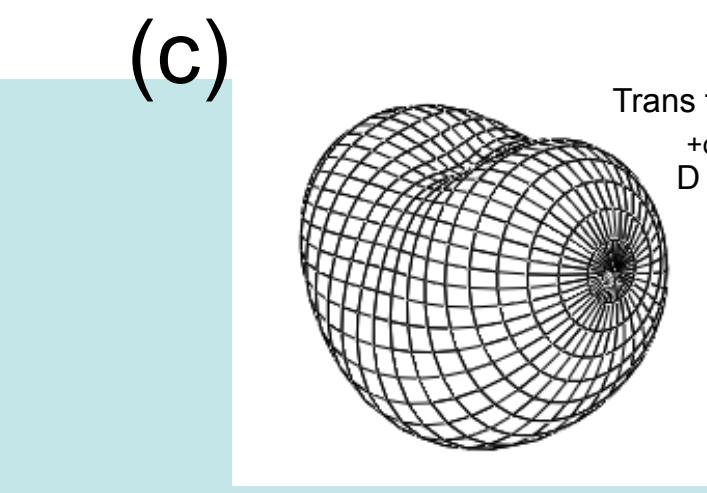
Optically poled 2-D octupole "octopus" in a PMMA polymer guest-host film

Rozenn Piron et al.
JOSAB June 05

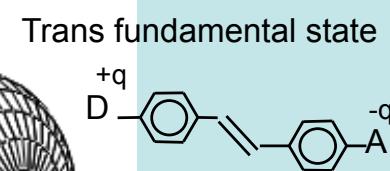




ω 2ω



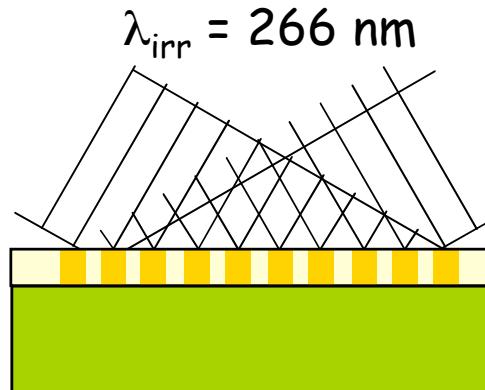
ω 2ω



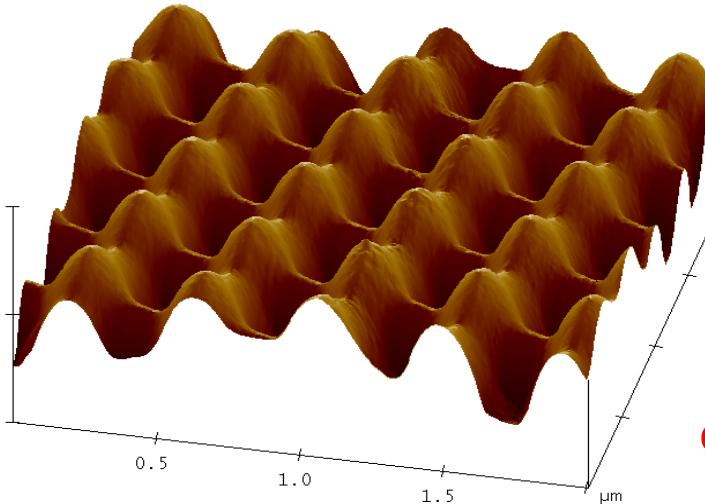
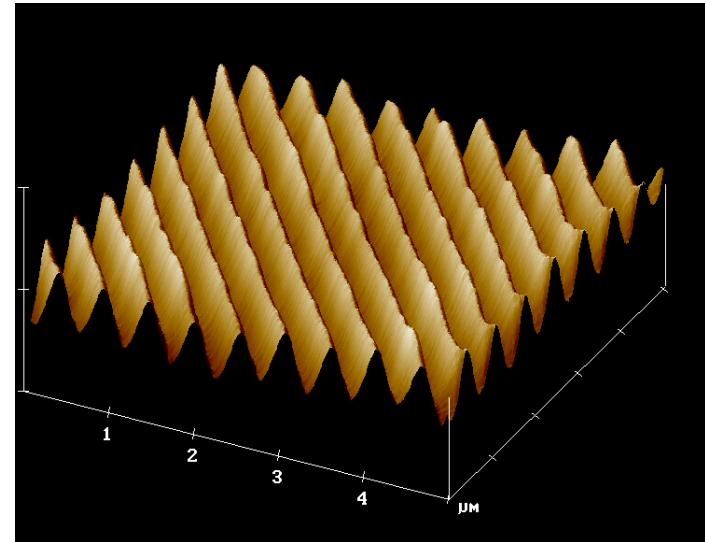
Multiplexed Refractive Index Patterns

Collab. TU Graz, W. Kern et al.

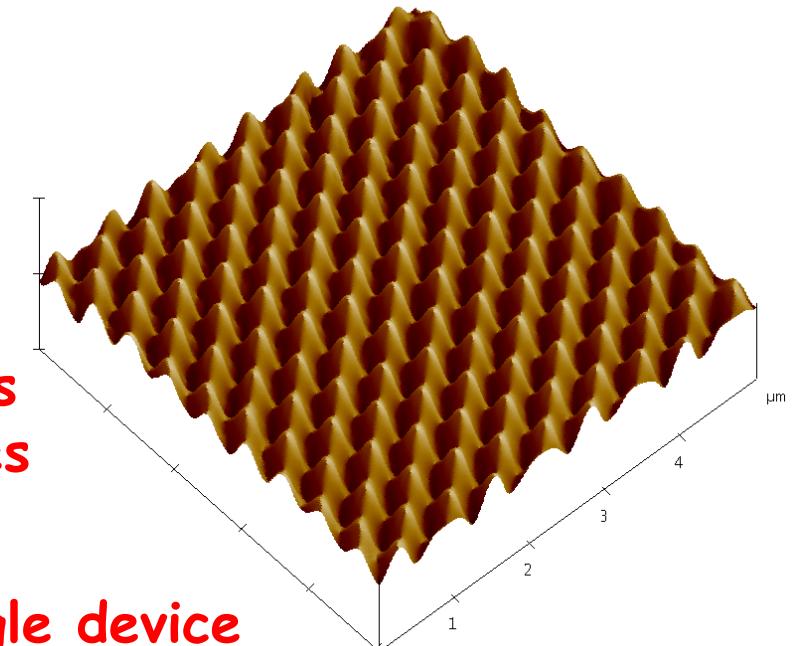
4th harmonic of NdYAG-Laser:



$$\Lambda = \frac{\lambda}{2 \sin \theta}$$



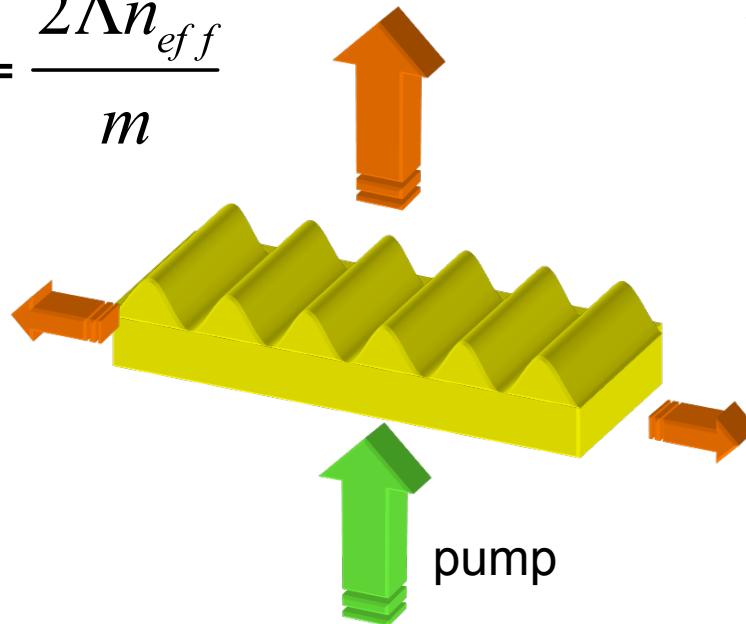
Double and triple grating structures from multiple exposures at different angles



- Several output wavelengths from a single device

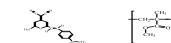
Organic DFB Laser Samples

$$\lambda_L = \frac{2\Lambda n_{eff}}{m}$$

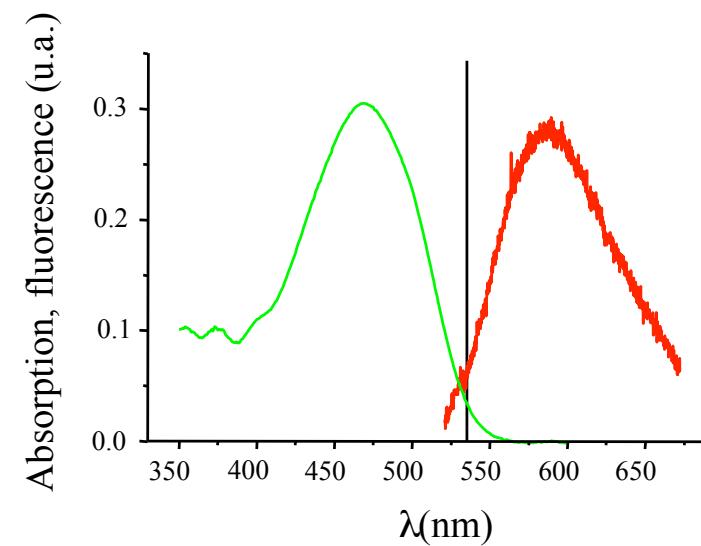


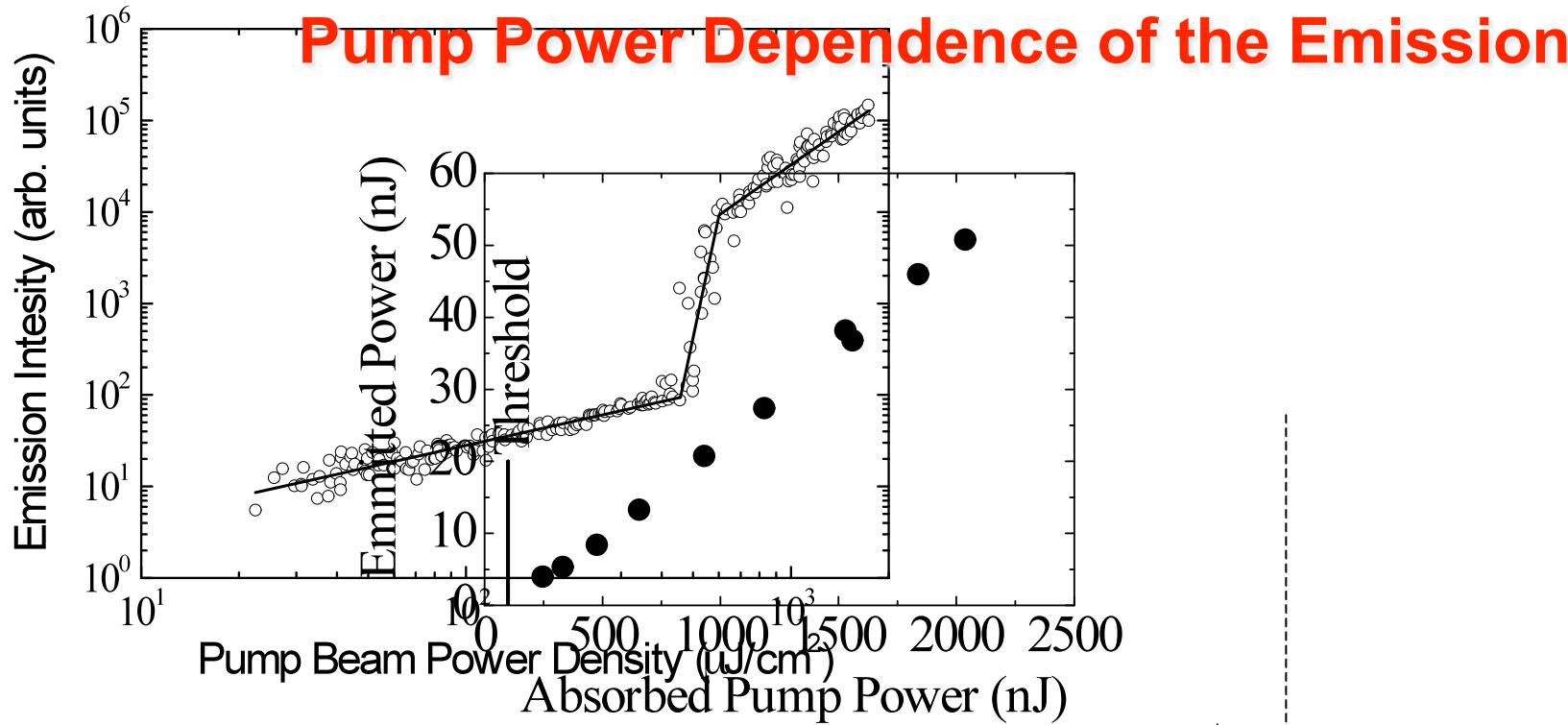
Thickness and index modulation: propagation in guided modes (TE, n_{eff}) superposed with laser feedback modulation

Strong index modulation or thickness modulation → surface emission: laser guided mode coupled out by second order diffraction



DCM
Laser Dye





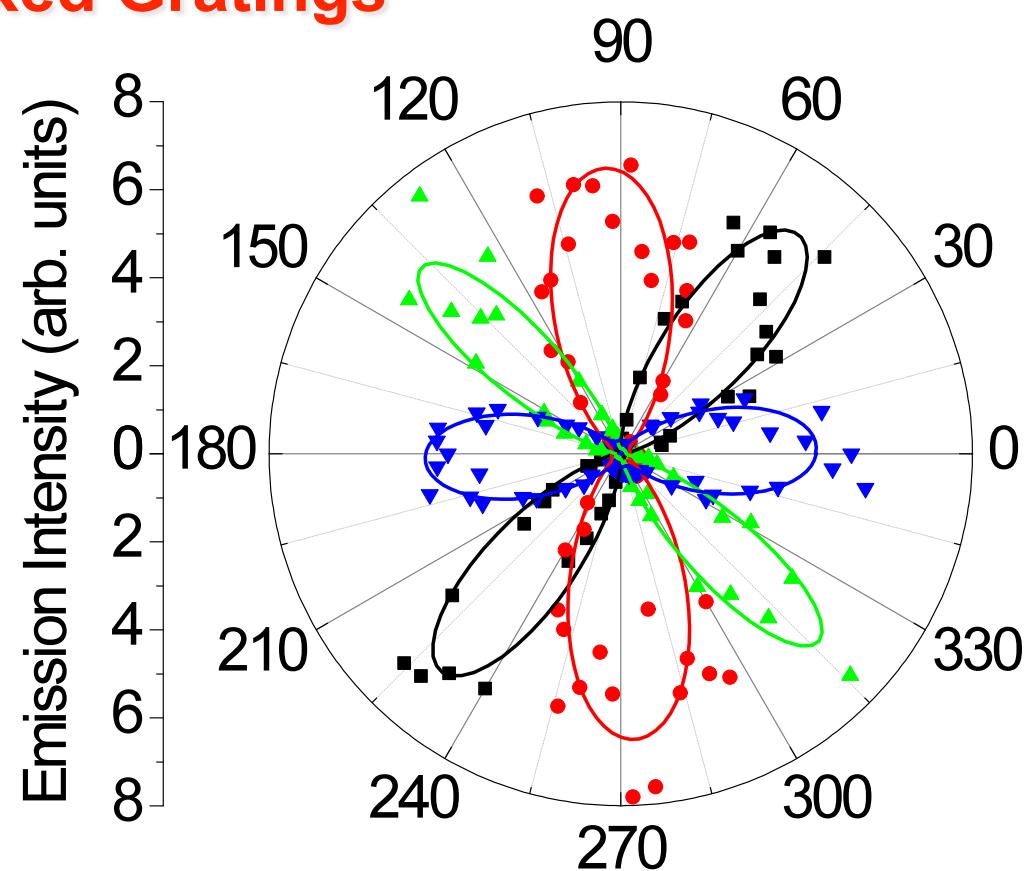
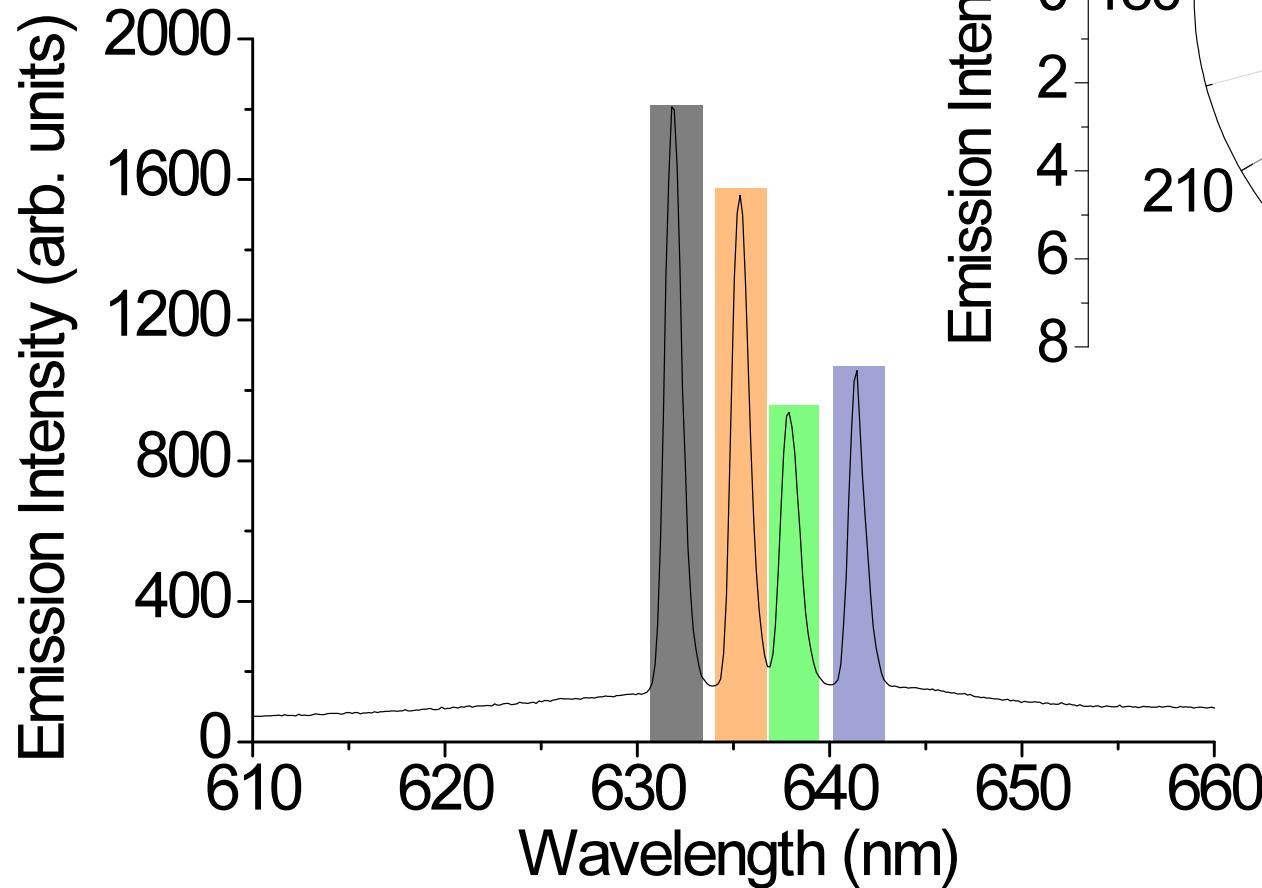
I_{th}

I_{sat}

- Clear fluorescence, transition and saturation, regimes
- Laser conversion efficiency ~2%

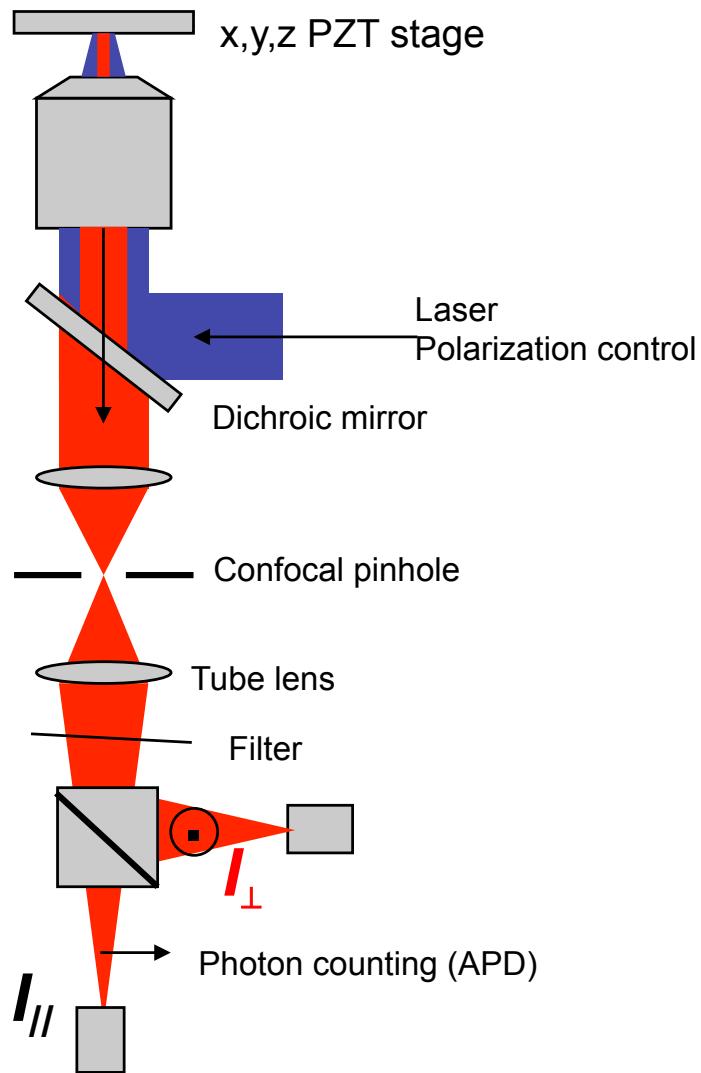
Multiplexed Gratings

- Tuning demonstrated with 2, 3 and 4 multiplexed DFB lasers having different periods

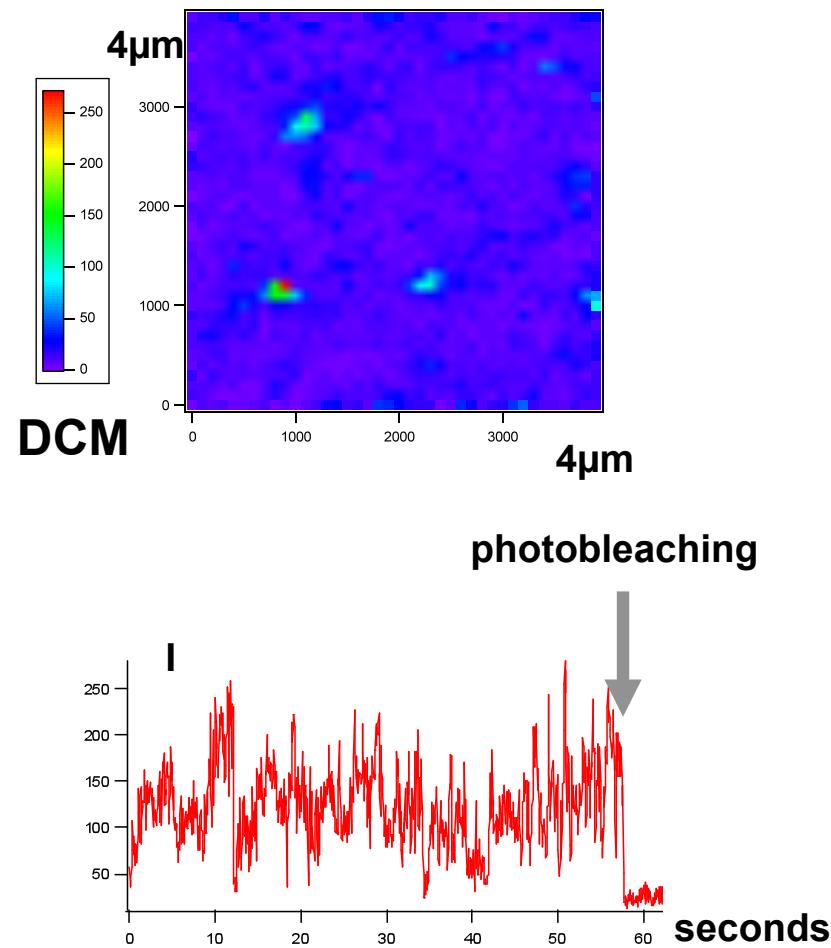


- Lobe shape defined by the input/output characteristics of each laser

Single Molecule Experimental Set-up



- Constant Nitrogen flow on the sample
- Acid pre-treatment (coverslips)
- UV pre-treatment (polymer solutions)

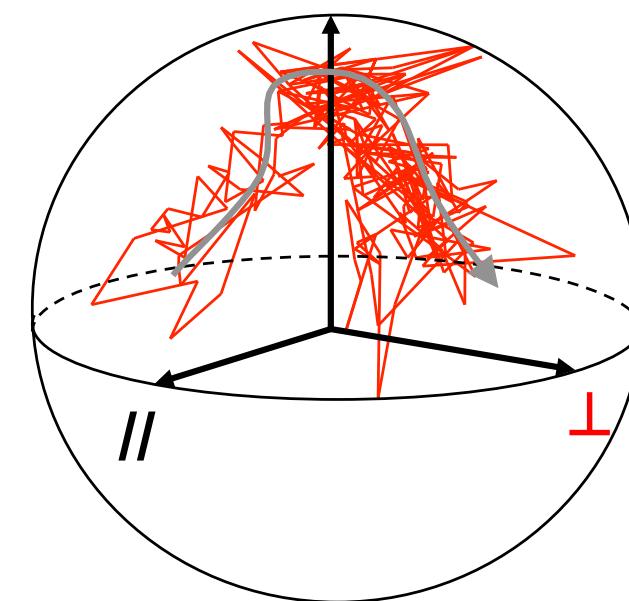
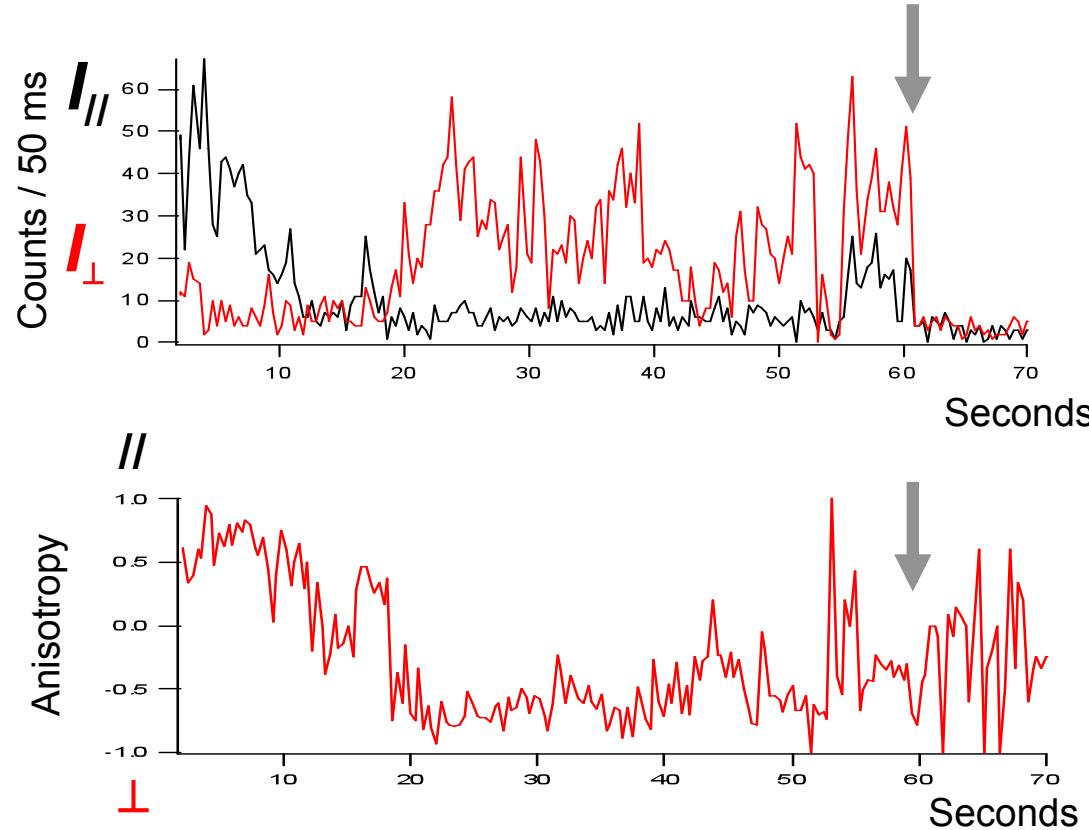


Dynamics of the photoinduced Rotation in PMA

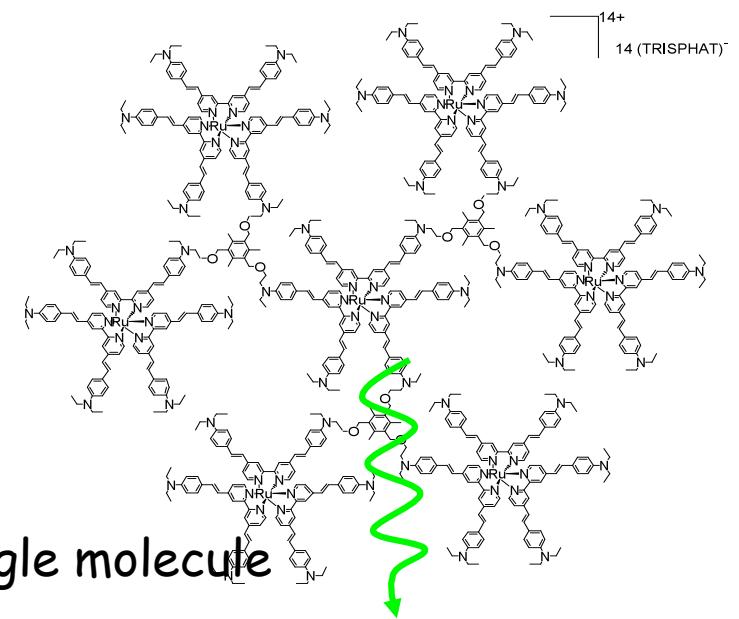
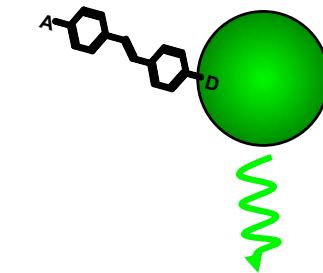
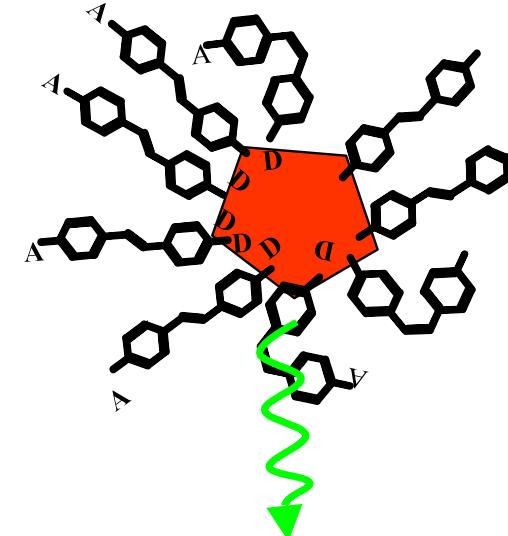
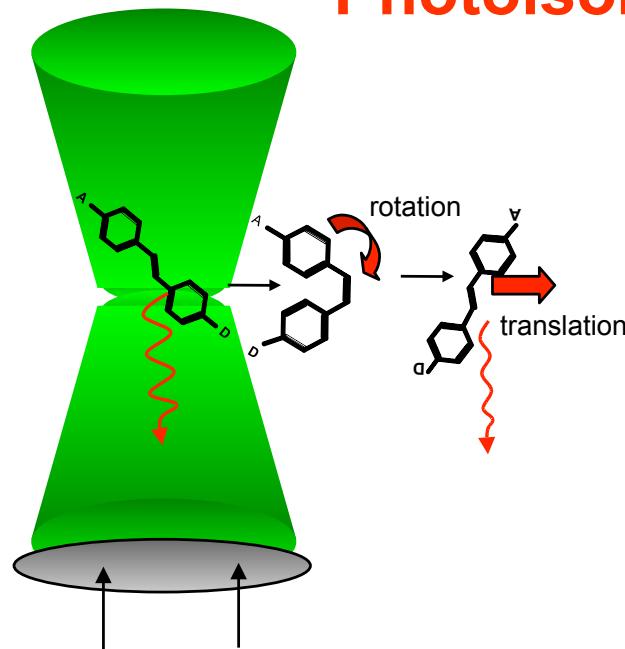
$$T_1 = 300\text{ms} \quad T_2 = 50\text{ms}$$

Pump
↔

Probe
○



Towards Molecular Tensorial Tweezers and new Photoisomerisable Nonlinear Labels

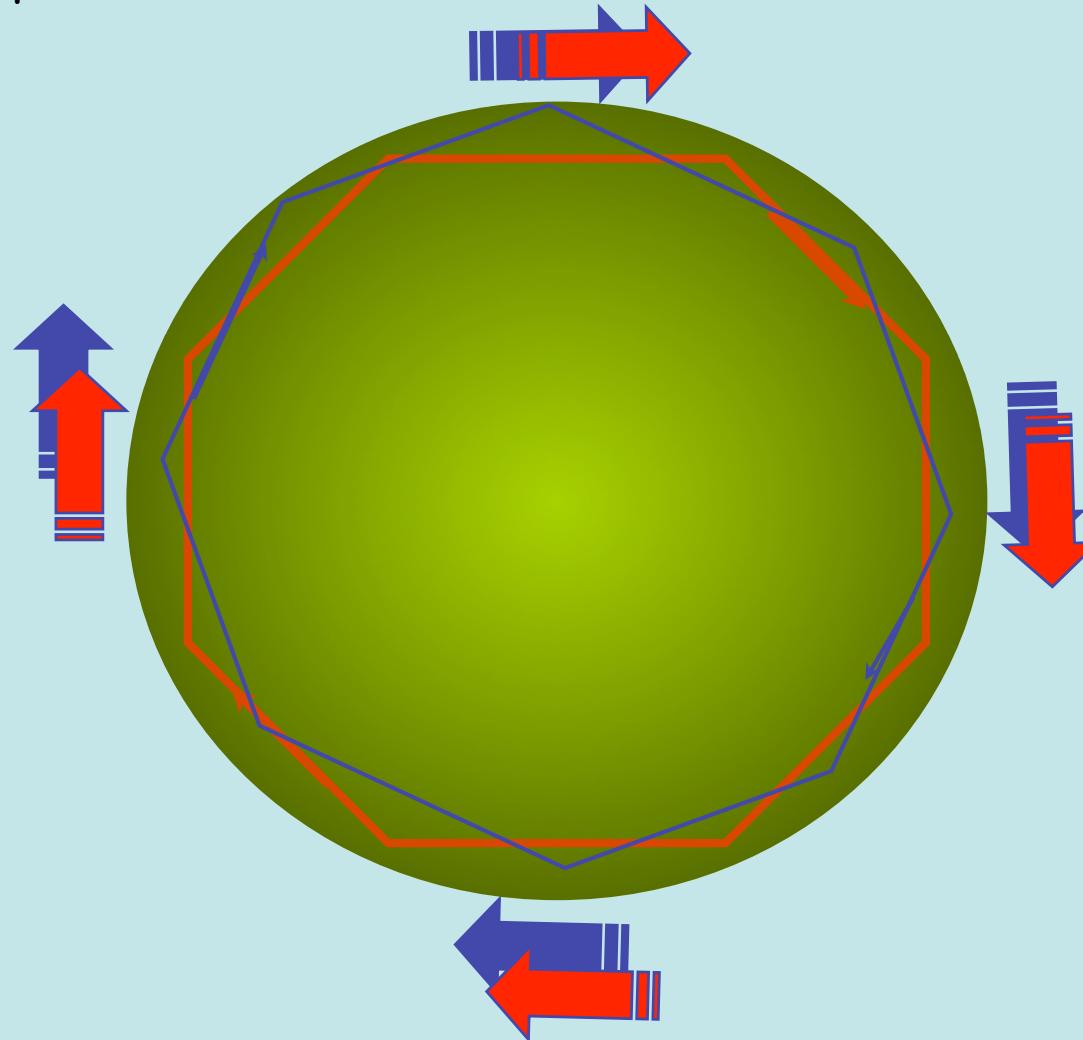


Main Goals:

- steering translational and rotational motions of single molecule via NLO coherent control techniques.
- Tracking of molecular motion by fluorescence anisotropy of single emitter
- controlled molecular displacements in cellular environments e.g. through membranes etc...

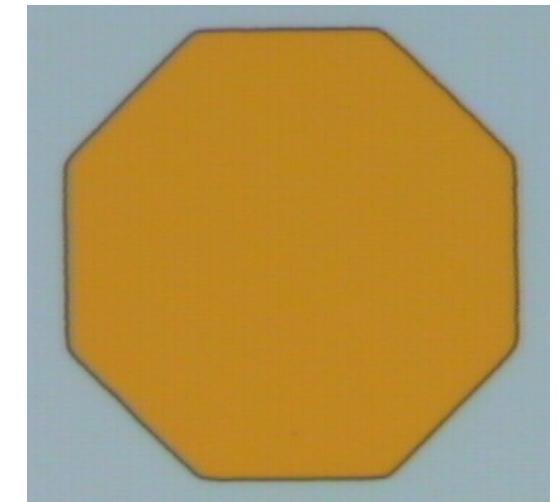
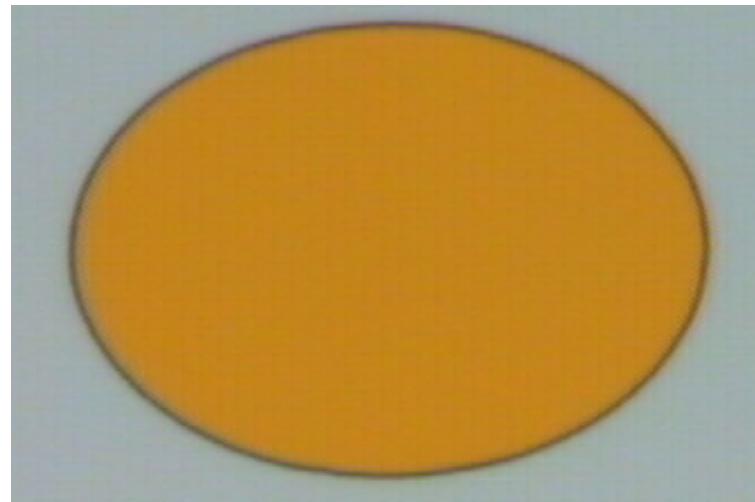
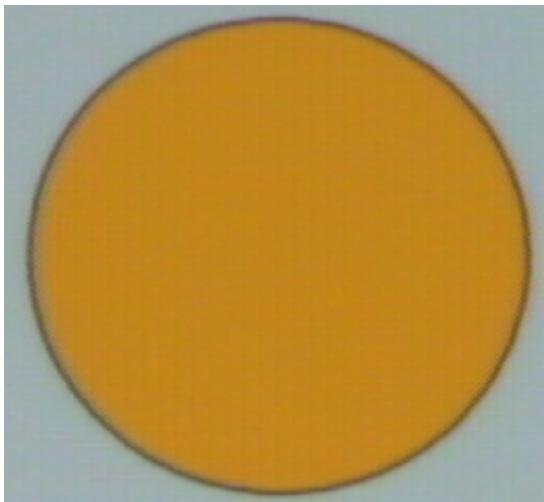
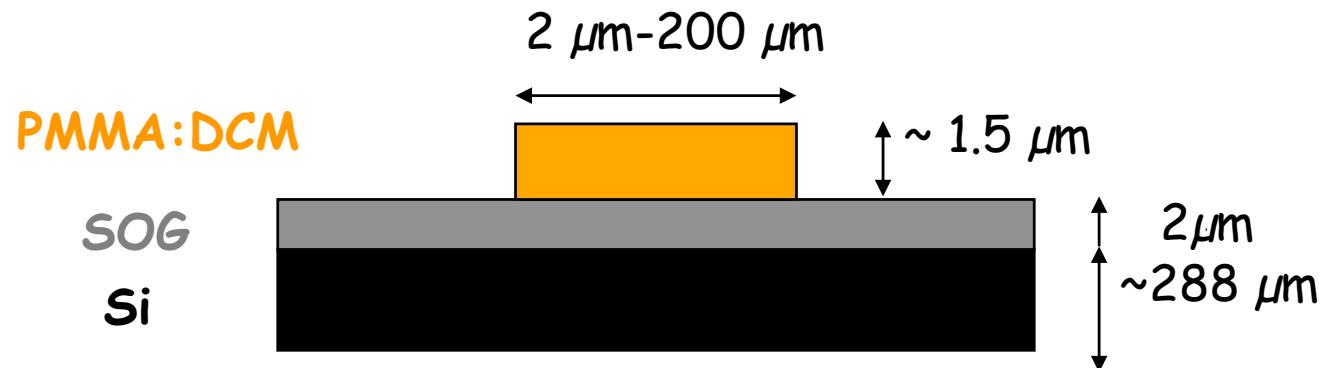
Whispering Gallery Modes Optical Billiard

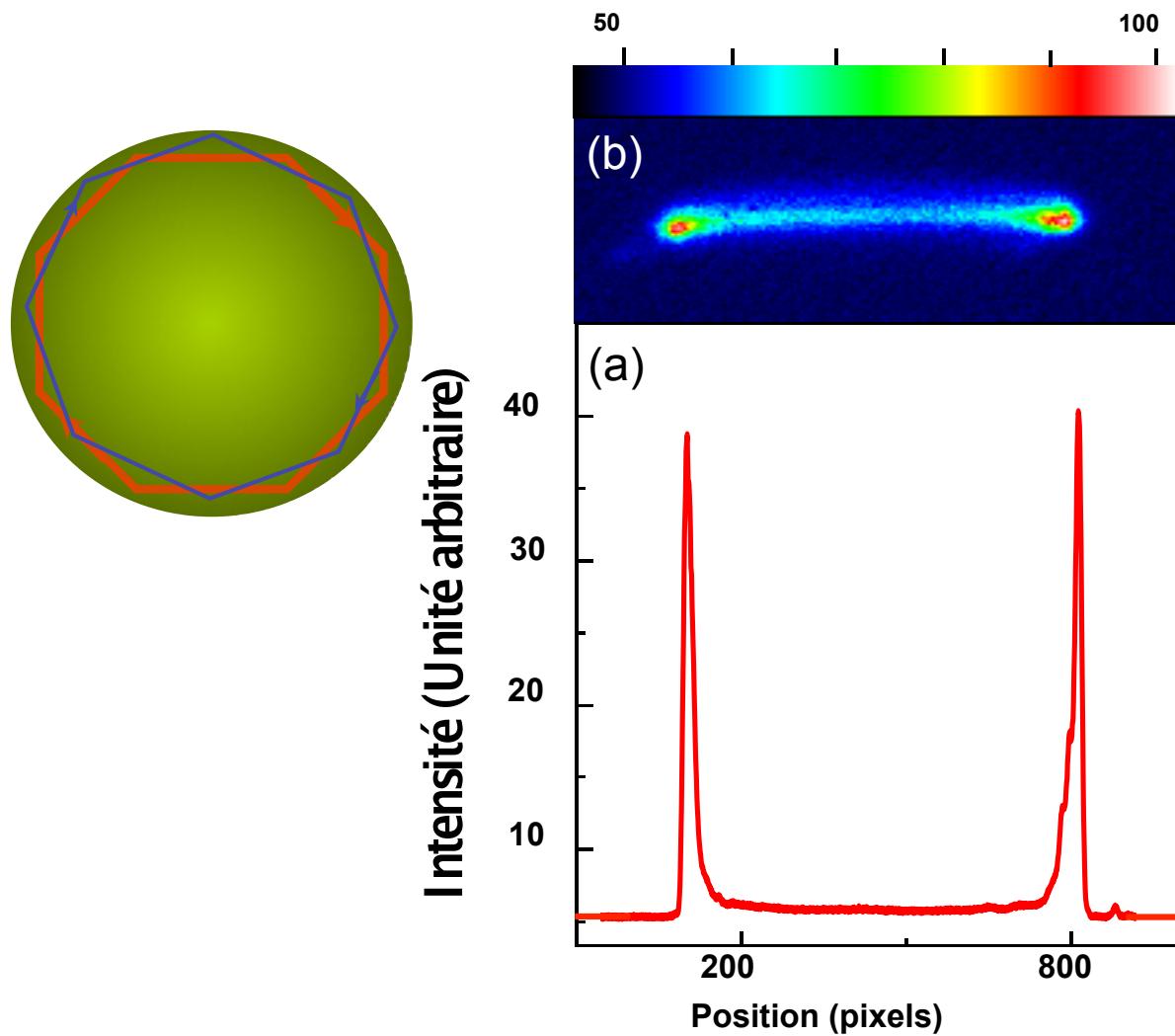
1877 : First interpretation in the dome of the St Paul cathedral by Lord Rayleigh



Evanescence wave out-coupling at every bounce

WGM μ -cavity lasers

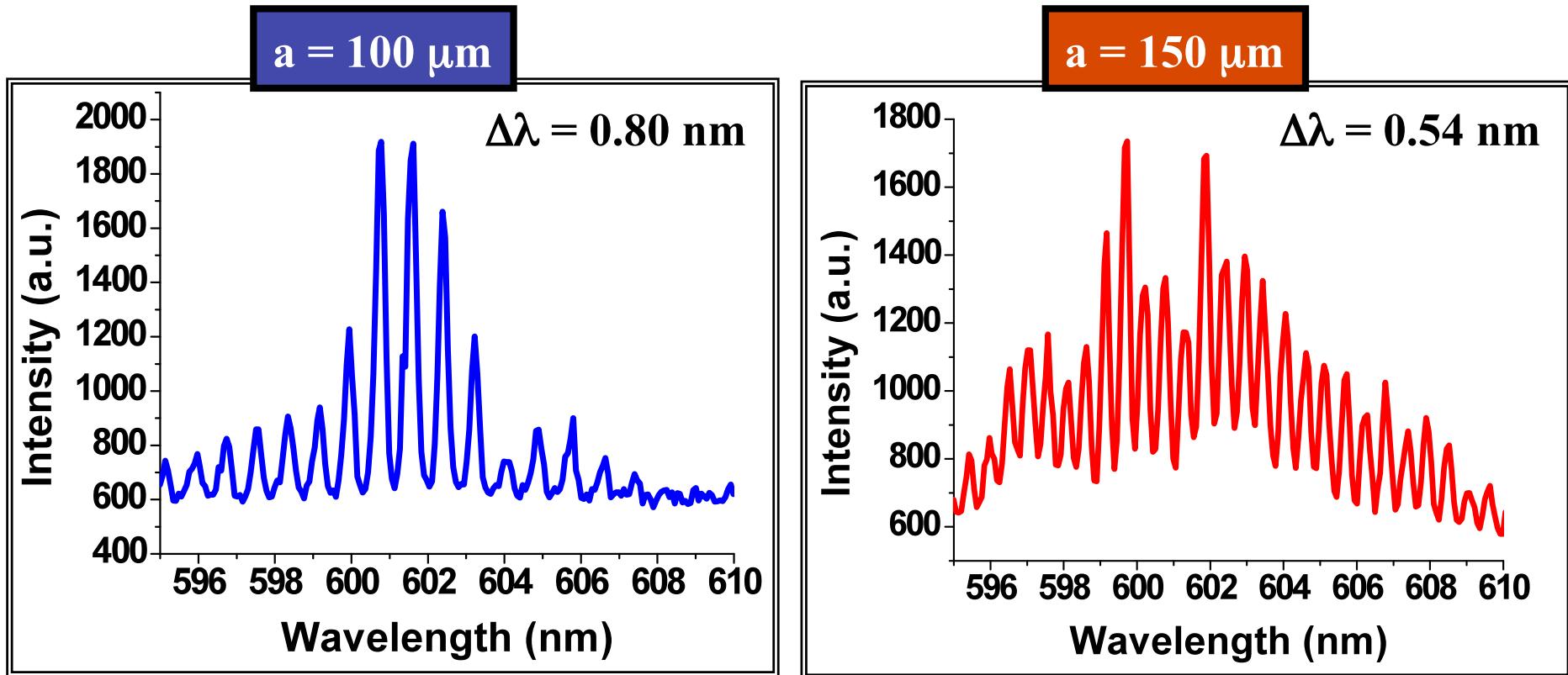




**(a) ICCD evanescent wave profile from a circular *PMMA-DCM* micro-cavity
 $D_c = 318 \mu m$ and $e = 1.5 \mu m$.**
Profile independant of observation angle θ
(a) Inferred from (b) by integration on ICCD pixels for arbitrary θ

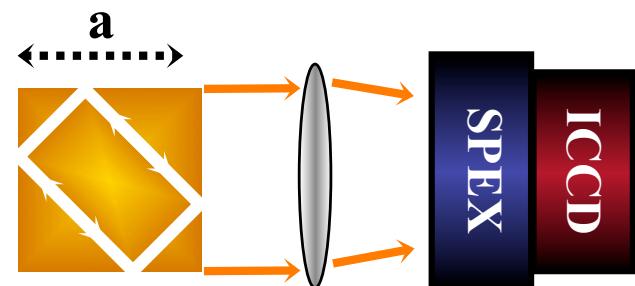


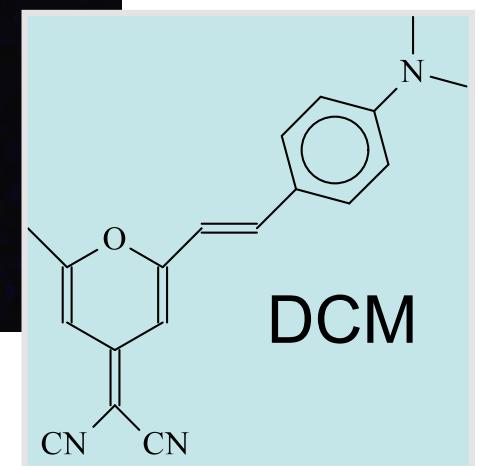
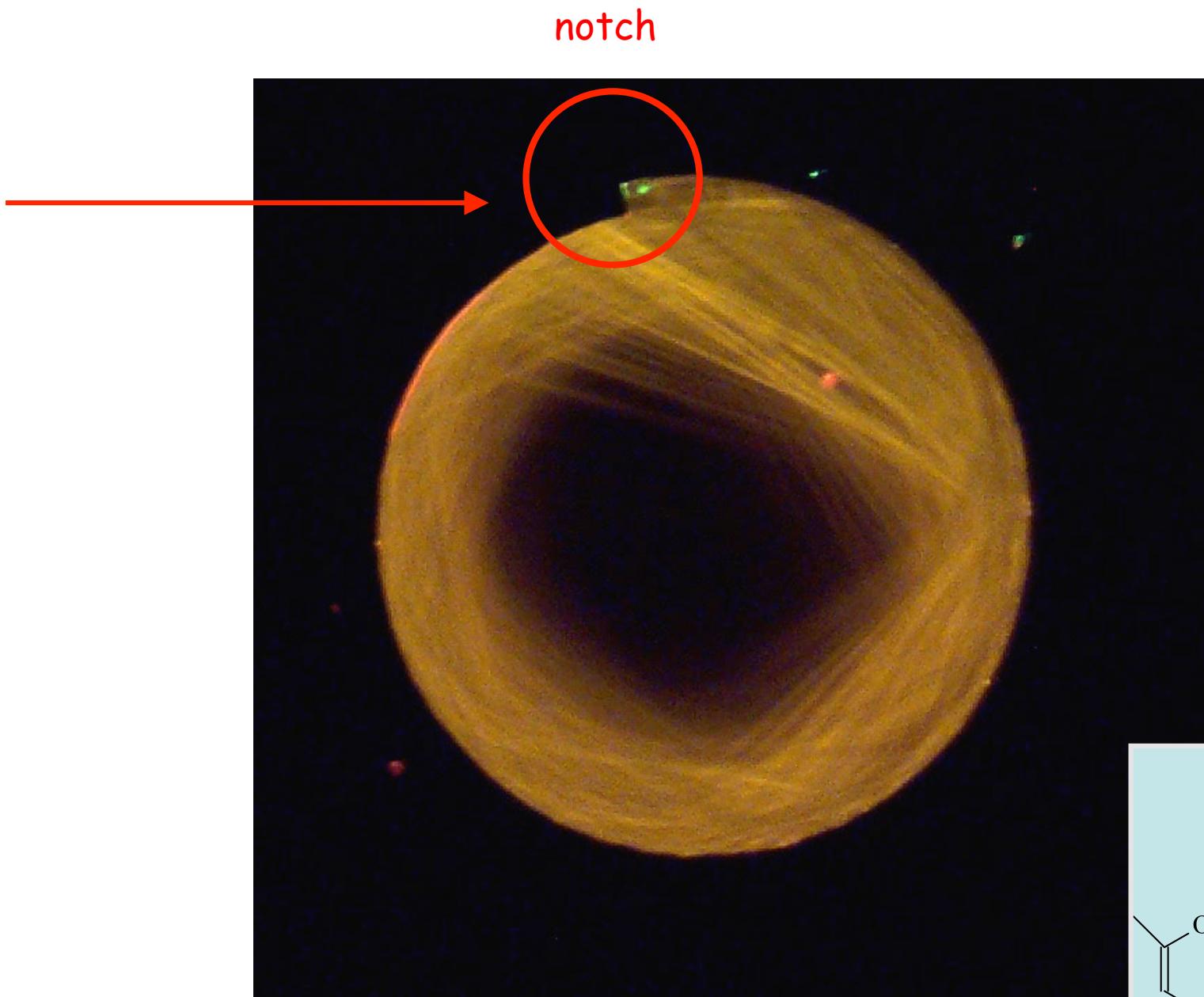
Spectrum from diffractive emission at corners

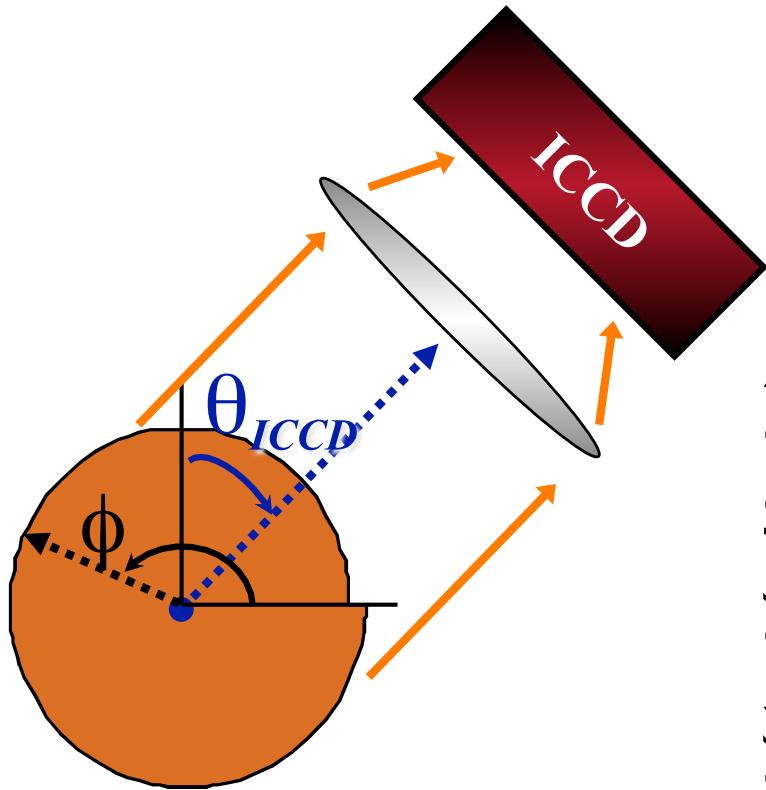


- Measured mode spacing $\Delta\lambda$ agrees with “Diamond” trajectories:

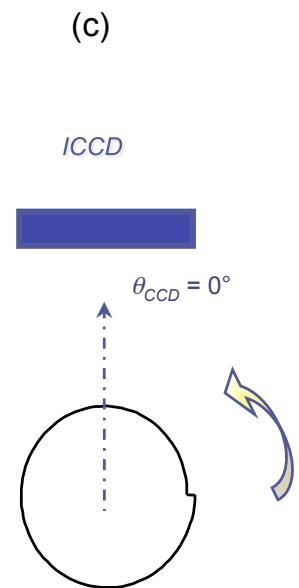
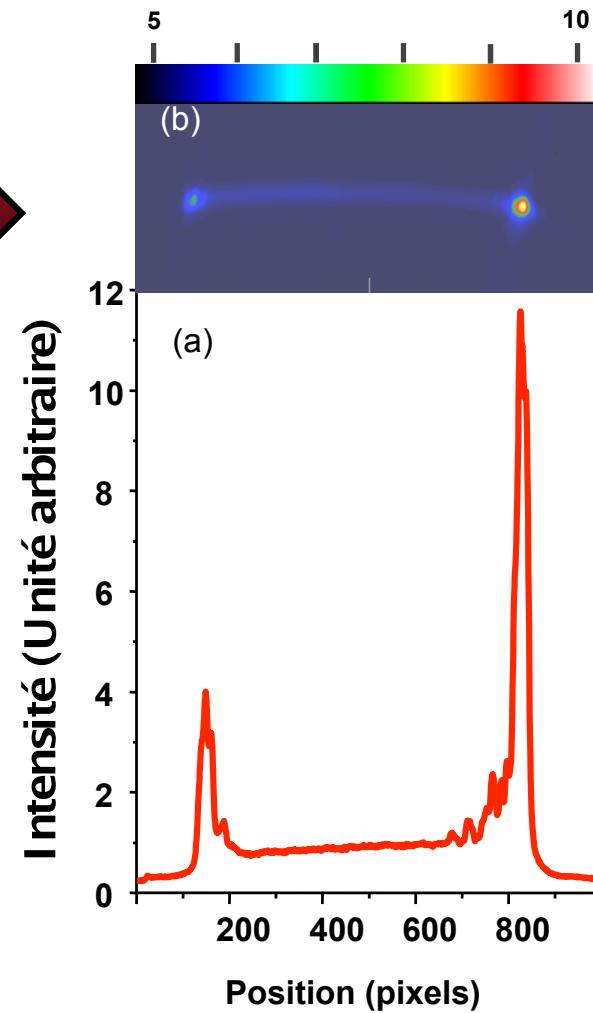
$$\Delta\lambda = \lambda^2 / n^{2^{3/2}} a$$







Spiral: $r(\phi) = r_0 (1 + \varepsilon\phi)$
 Discontinuity @ $\phi=2\pi$



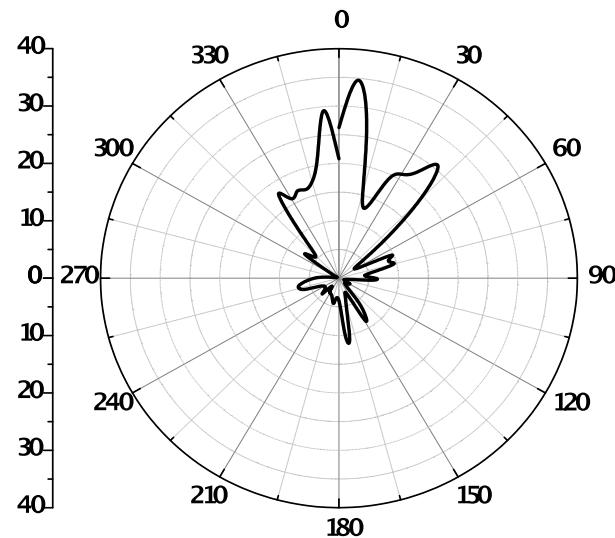
Profile for $\theta_{CCD} = 0^\circ$ for a spirale polymer cavity
 $\varepsilon = 0.1$, major axis $D_s = 318 \mu m$; thickness $e = 1.4 \mu m$.

Spiral laser ($D_s = 318 \mu\text{m}$) pumped by ring shaped beam

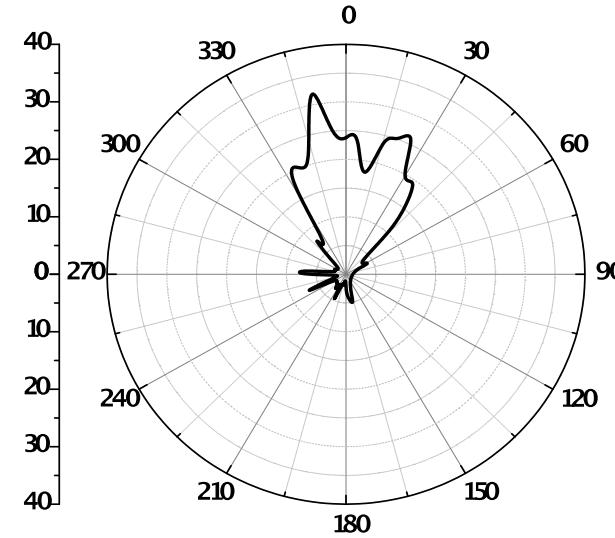
(a) diameter $320 \mu\text{m}$, width $w = 35 \mu\text{m}$

(b) diameter $350 \mu\text{m}$, width $w = 50 \mu\text{m}$.

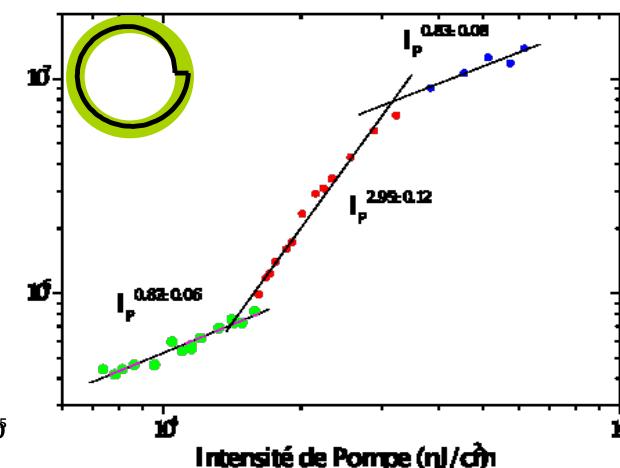
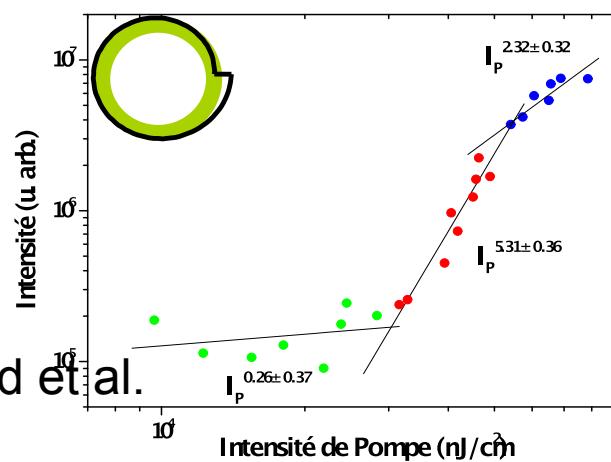
(a)



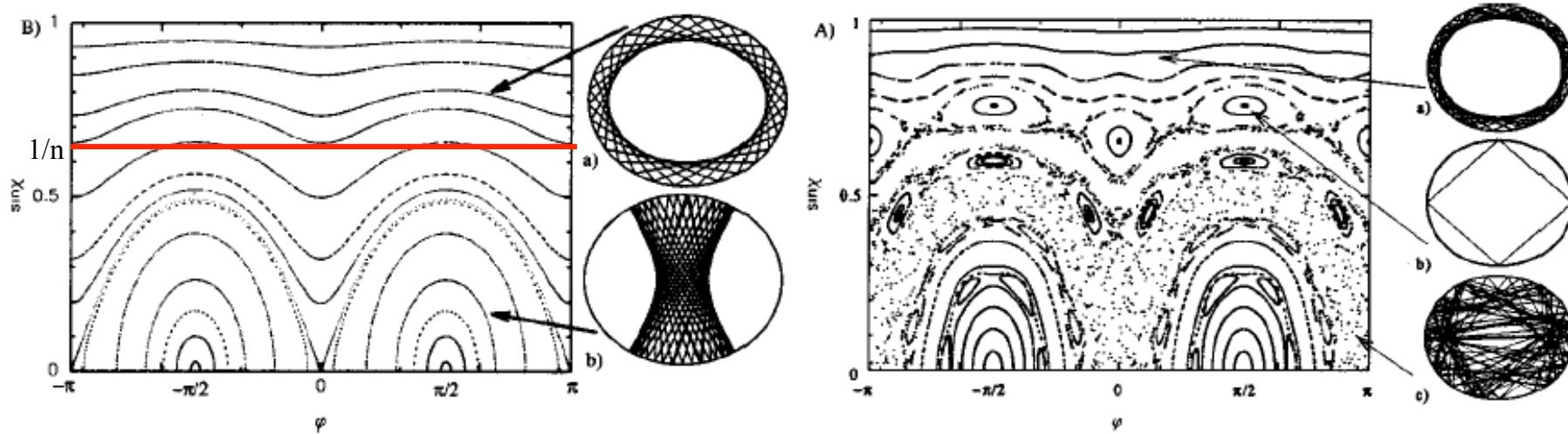
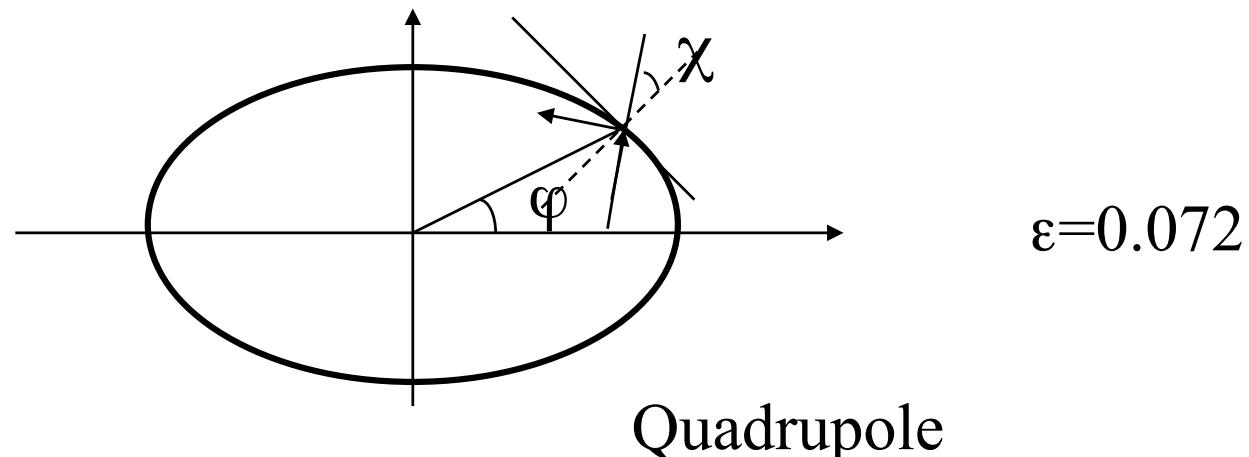
(b)



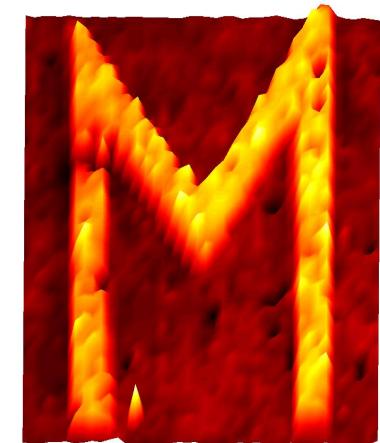
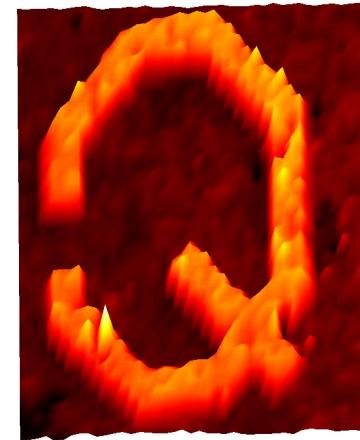
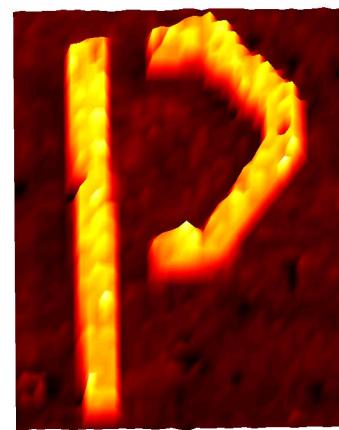
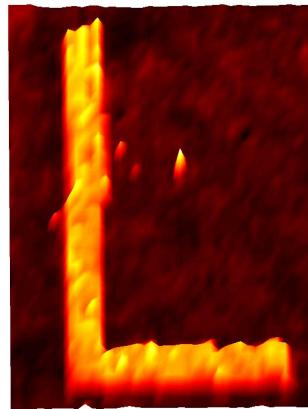
(d)



Poincaré Section



Laboratoire de Photonique Quantique et Moléculaire



Submicron-scale SHG read-out of an optically encoded
polar distribution of nonlinear molecules

- Molecular engineering for Photonics (NLO and luminescence)
- Nano-scale photonics and quantum effects
- Coherent control by and for NLO
- Microphotonics for electrooptic and lasers

Located 15' by RER fast metro from the heart of Paris
(Luxembourg garden)



➤ Main External Collaborations

Physics and Technology

- Yale (Dept. of Applied Physics): Richard Chang and group
- Weizmann Institute (Physics): A.Friesem et al.
- Mesa Institute Twente: A.Driesssen et al.
- Trinity Dublin: W.Blau
- Lyon I: J.P.Wolf
 - Synthetic and (nano-)Material Chemistry
- Université Rennes I: M.Blanchard-Desce, H.Le Bozec, O.Maury
- Université Louis Pasteur/IPCMS: J.F.Nicoud
- ENS Lyon: C.Andraud et al.
- CNRS Grenoble: A.Ibanez
- Univ. Versailles: C.Larpent
- Univ. Montpellier: R.Corriu
- ENSC Montpellier: A.Rousseau et al.
- T.U. Graz: W.Kern et al.
- Jena: H.Hörhold
- UC Santa Barbara: G.Bazan
- Un. Torino: G.Viscardi

Theoretical Chemistry

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- MIT: R.Silbey et al.
- Rochester: S.Mukamel
- Carnegie Mellon: David Yaron