

# Sonder les interactions entre boîtes quantiques colloïdales et nano-antennes optiques avec des expériences en température

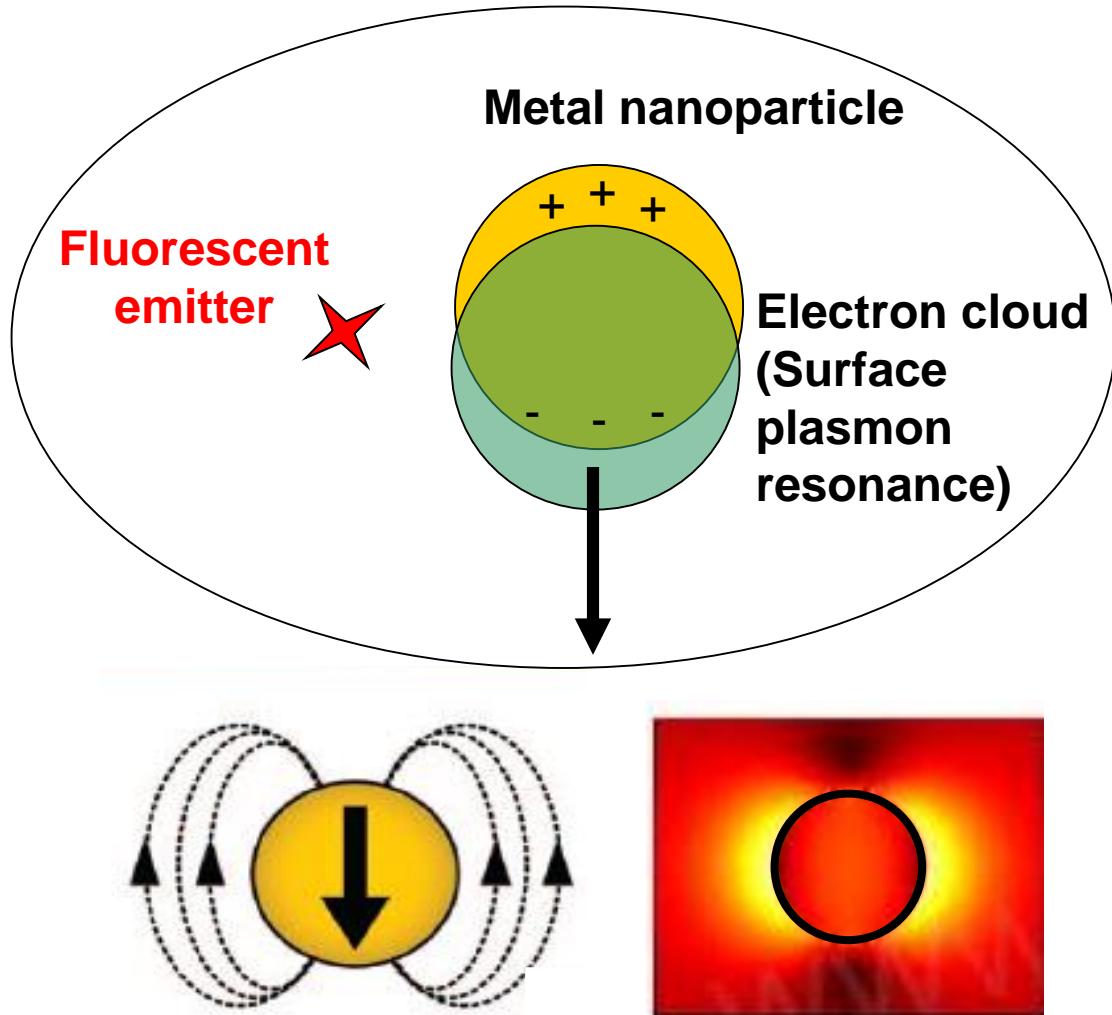
Aloyse Degiron

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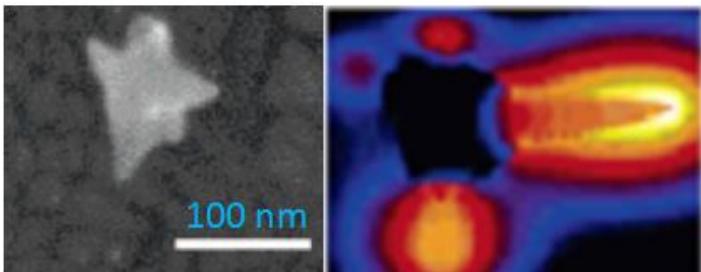
Orsay, France



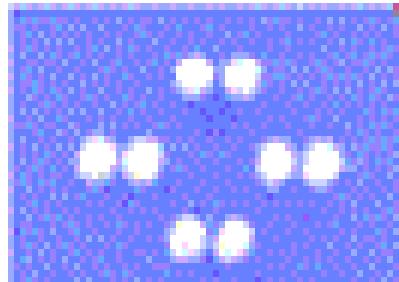
# Optical nano-antennas



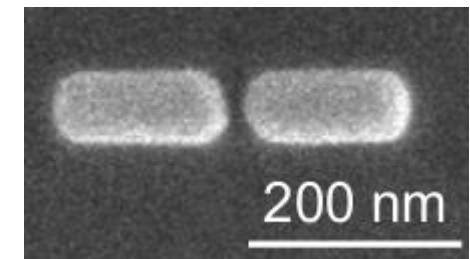
# Some examples of nano-antennas



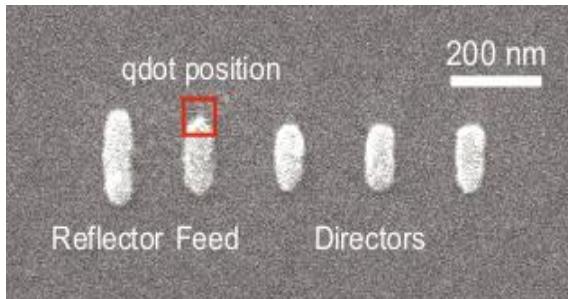
**Nanostar**, F. Hao *et al*,  
Nano Letter **7**, 729 (2007)



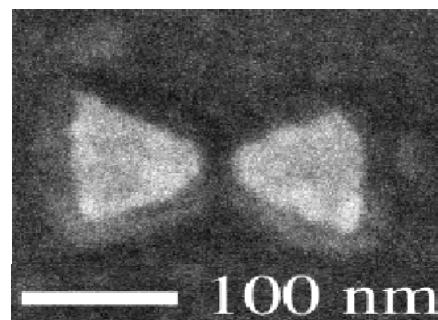
**Dimer**, Muskens, O.L., et al.,  
Nano Letter **7**, 2871(2007)



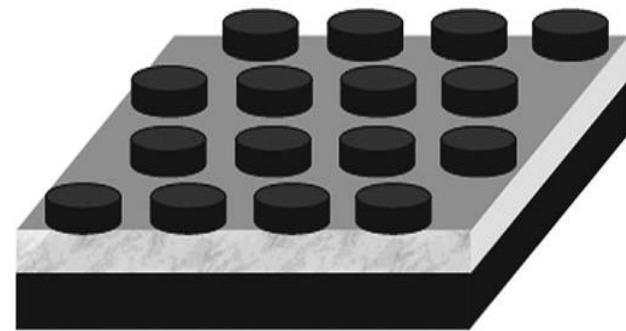
**Dipole**, Huang J-S *et al*,  
Nat Comm **1**, 150 (2010)



**Yagi-Uda**, A. G. Curto,  
Science **329**, 930 (2010)

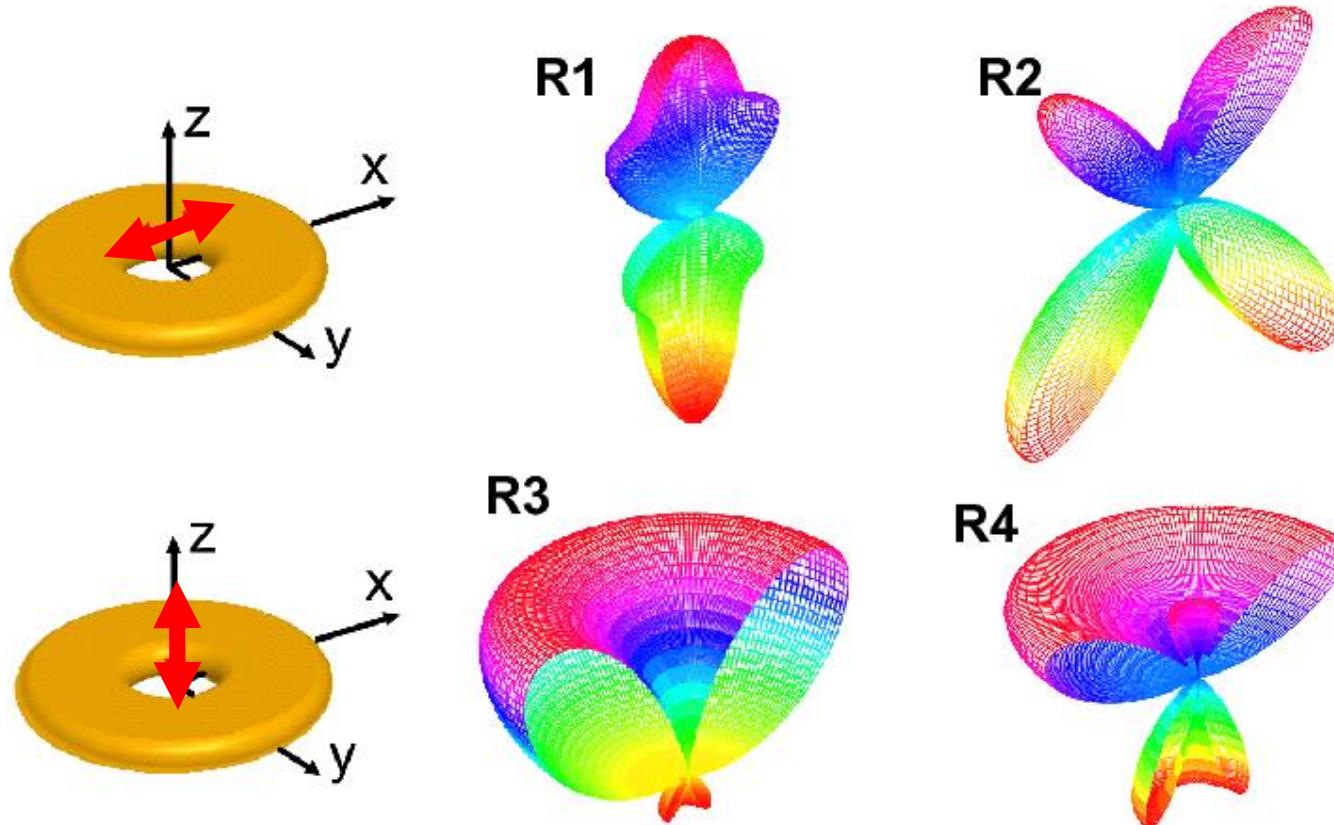


**Bowtie**, Fromm, D.P. et al,  
Nano Letter **4**, 957(2004)



**Patch**, Esteban et al.,  
PRL 2010, Belacel et  
al., Nano Lett. 2013

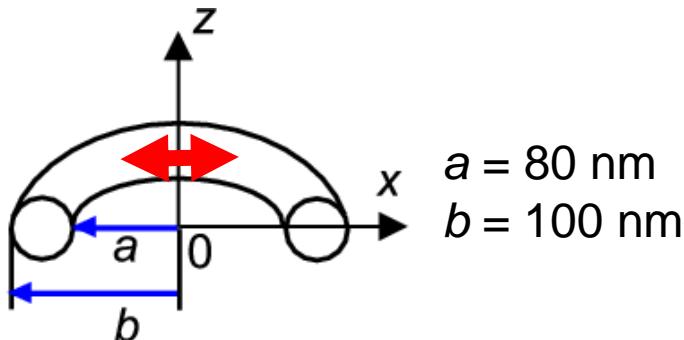
# Particle with size comparable to $\lambda$ : High directivity



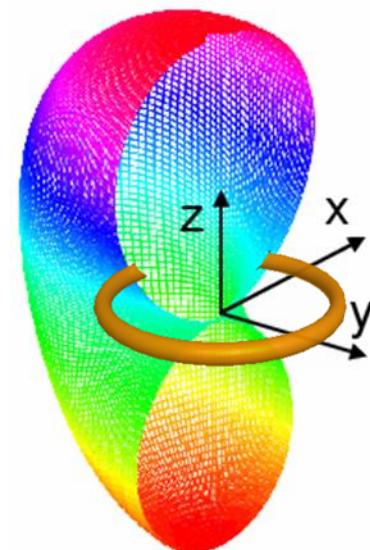
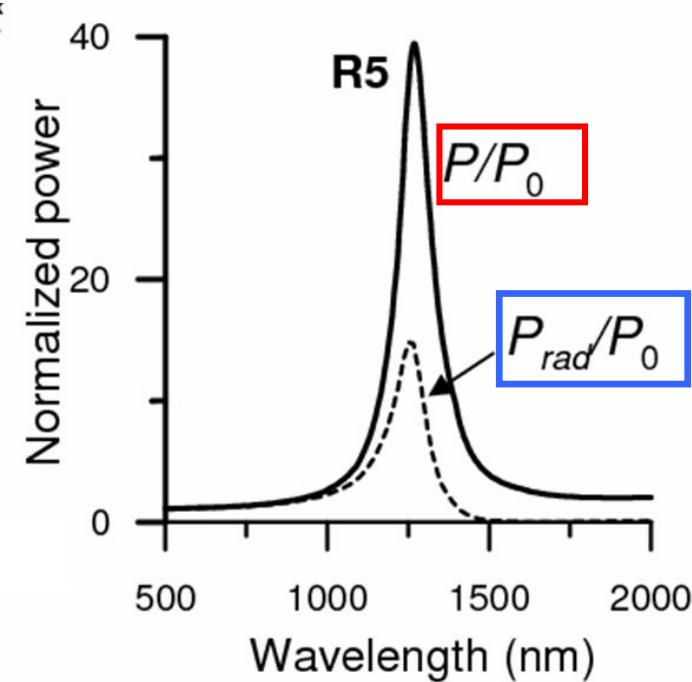
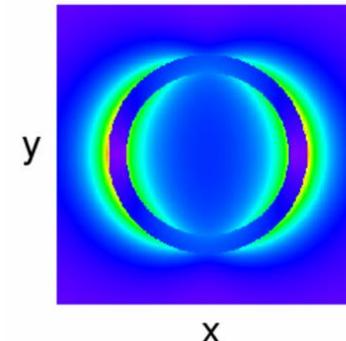
Each pattern corresponds to a distinct plasmonic resonance

Degiron and Teperik, Phys. Rev. B 2011

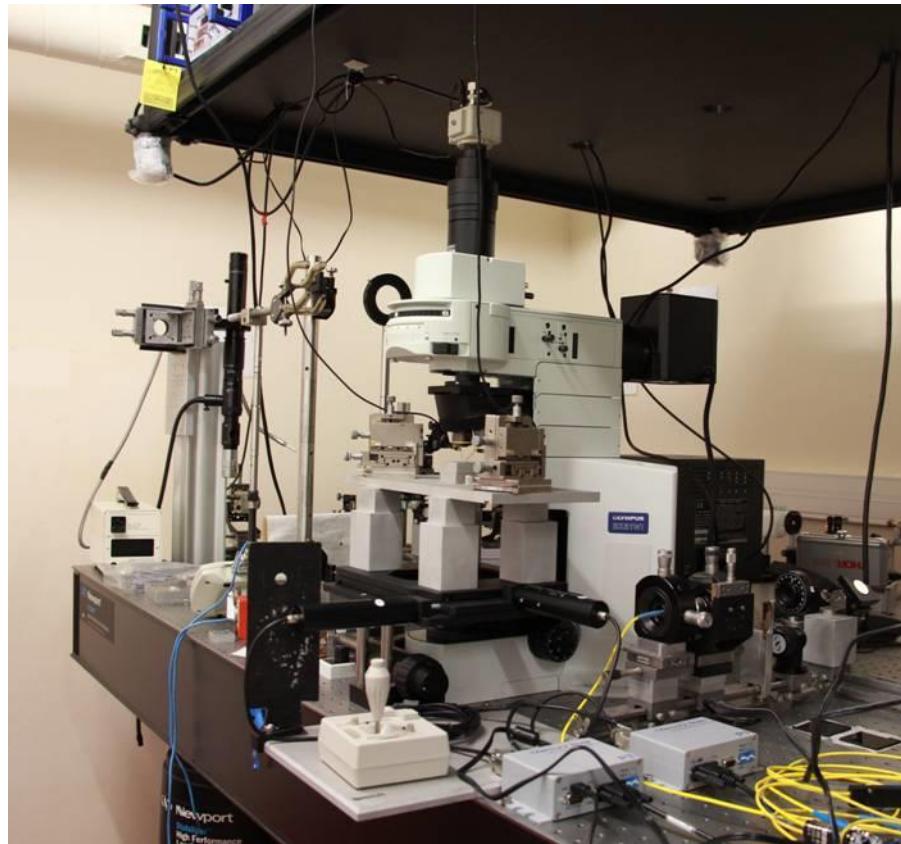
# Particle much smaller than $\lambda$ : dipolar SP resonance



$$a = 80 \text{ nm}$$
$$b = 100 \text{ nm}$$



# Microscope financé par le Labex NanoSaclay



Equipement commun à deux équipes de l'IEF (N. Izard, nanotubes de carbone; A. Degiron, nano-antennes).

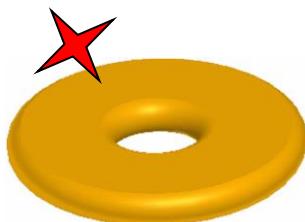
- Manips de photoluminescence et electroluminescence.
- Manips en espace libre et en optique intégré.
- Possibilité d'imagerie en espace de Fourier
- Gamme spectrale 1000-1550 nm.

**NanoSaclay**  
Laboratoire d'Excellence  
en Nanosciences et Nanotechnologies

# Classical formalism for optical antennas



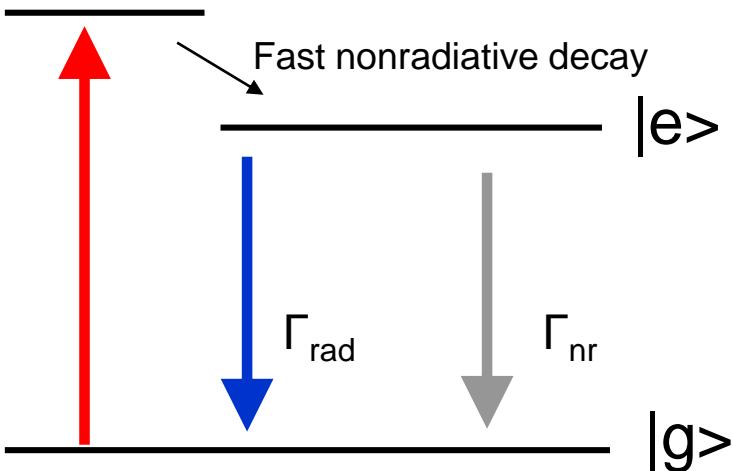
Emitter alone: characterized by a total decay rate  $\Gamma_{Tot}^0$  and a radiative decay rate  $\Gamma_R^0$   
-> has an intrinsic quantum yield  $\eta_i = \frac{\Gamma_R^0}{\Gamma_{Tot}^0}$



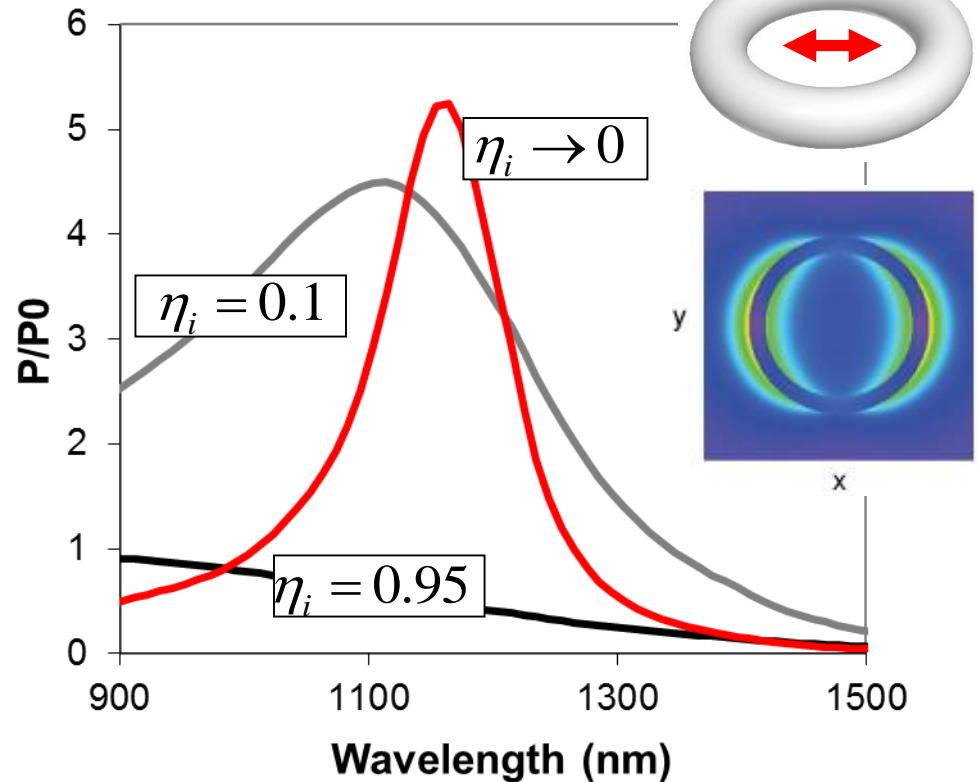
Emitter + antenna: characterized by a total decay rate  $\Gamma_{Tot}$  and a radiative decay rate  $\Gamma_{Rad}$  (Purcell effect)

- The Purcell effect is related to the Local Density of Photonic States (LDOS).
- Independent of the actual emission process.
- The Purcell effect is usually computed for an ideal dipolar lossless emitter.
- In this case, one has  $\frac{\Gamma_{Rad}}{\Gamma_R^0} = \frac{P_{Rad}}{P_R^0}$  and  $\frac{\Gamma_{Tot}}{\Gamma_{Tot}^0} = \frac{P_{Tot}}{P_{Tot}^0}$

# The two-level model



Under weak CW excitation:

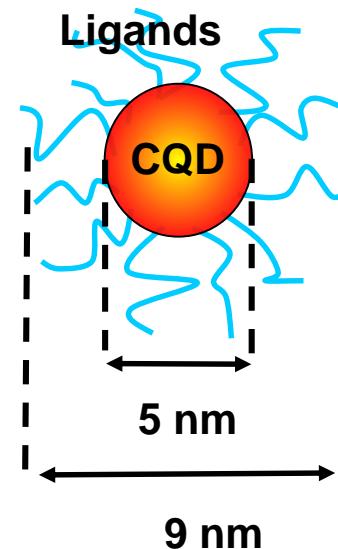


$$\frac{P}{P^0} \propto \frac{1}{\eta_i} \frac{\Gamma_{Rad}/\Gamma_R^0}{\Gamma_{Rad}/\Gamma_R^0 + \Gamma_{Loss}^{Ant}/\Gamma_R^0 + \frac{1-\eta_i}{\eta_i}} |K(\lambda_{abs})|^2.$$

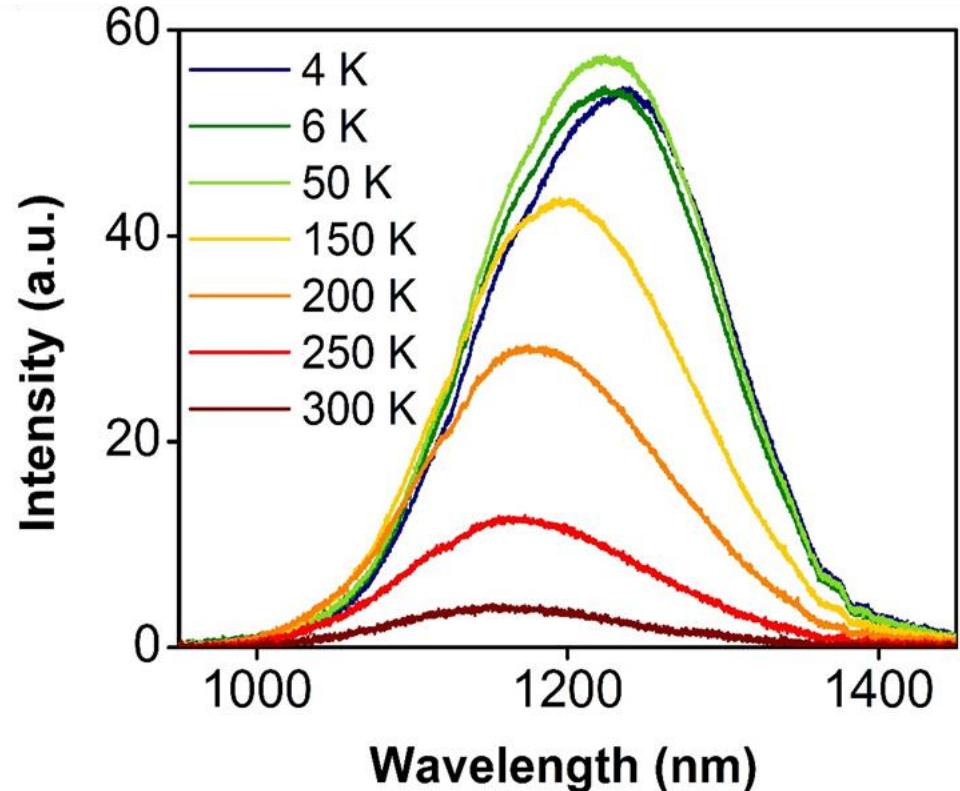
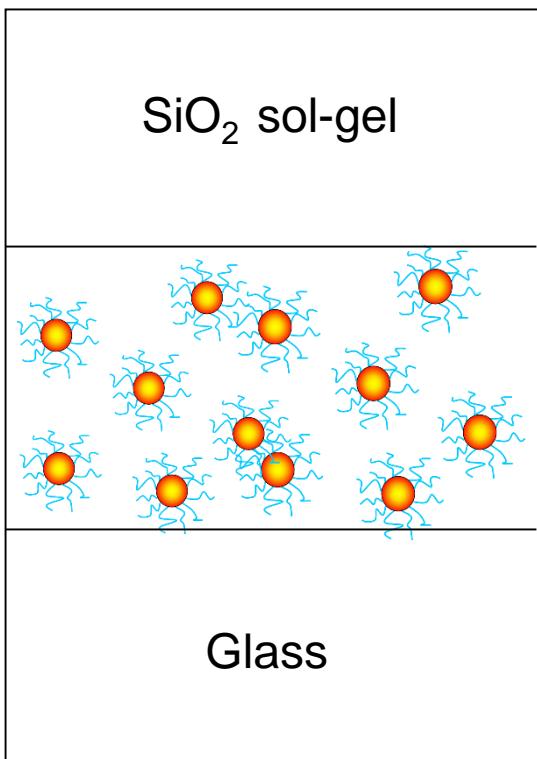
# Testing the two-level model with PbS colloidal quantum dots (CQDs)



Colloidal PbS QDs

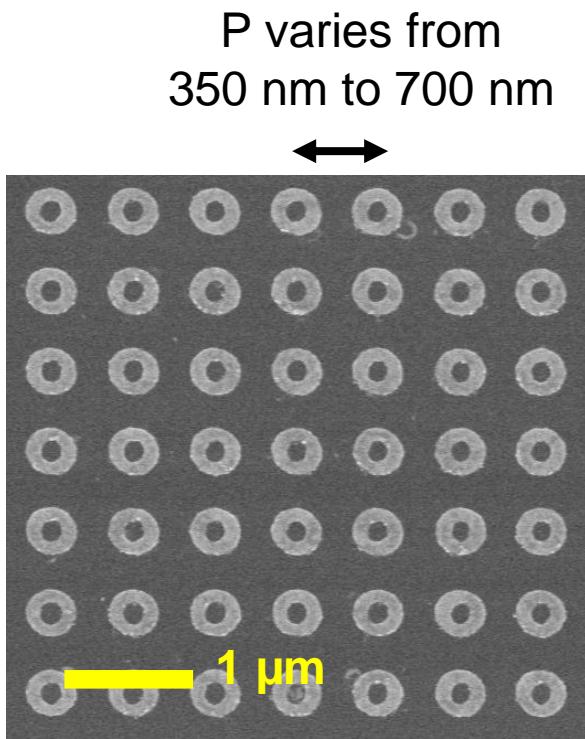


# $\eta_i$ vs temperature

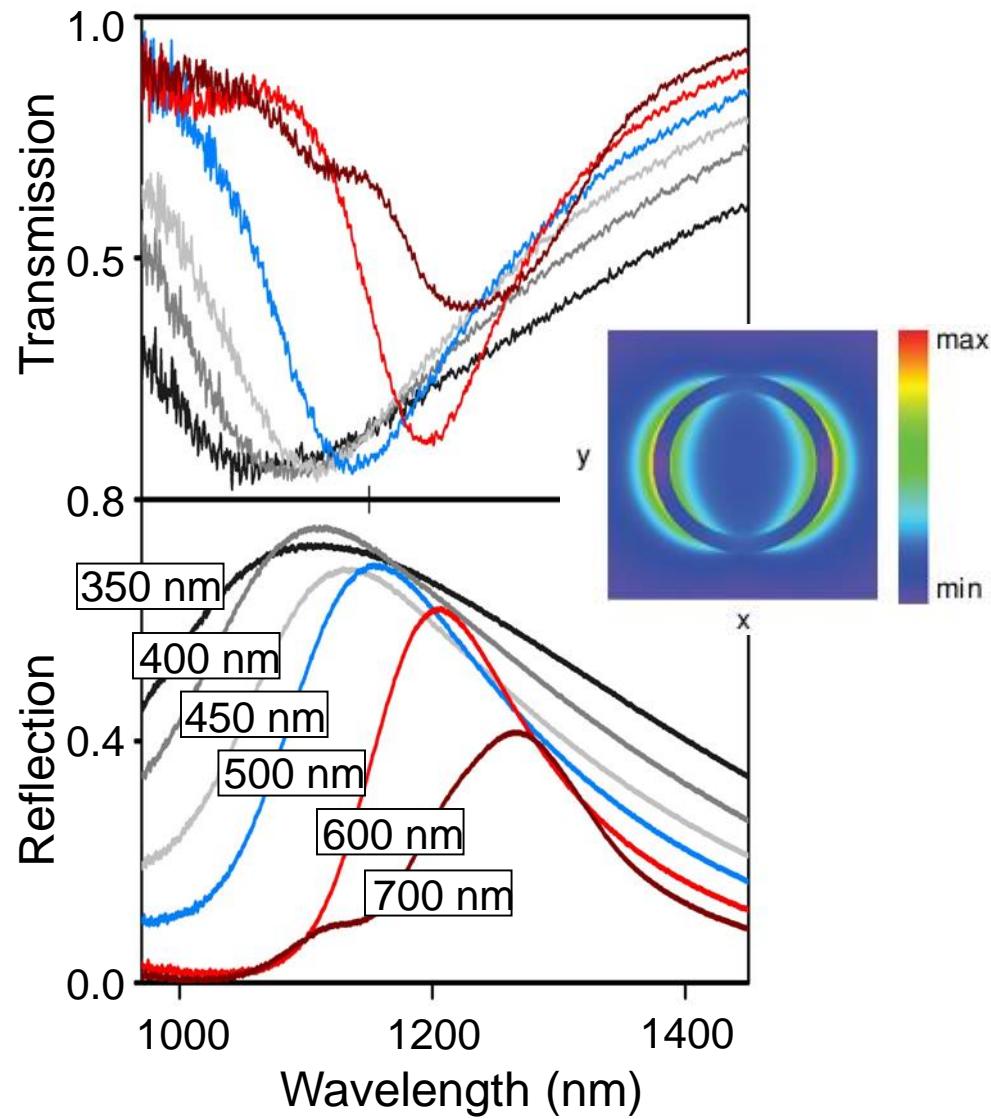


$\eta_i$  varies from ~0.1 to ~1  
as T decreases from 300K to 4K

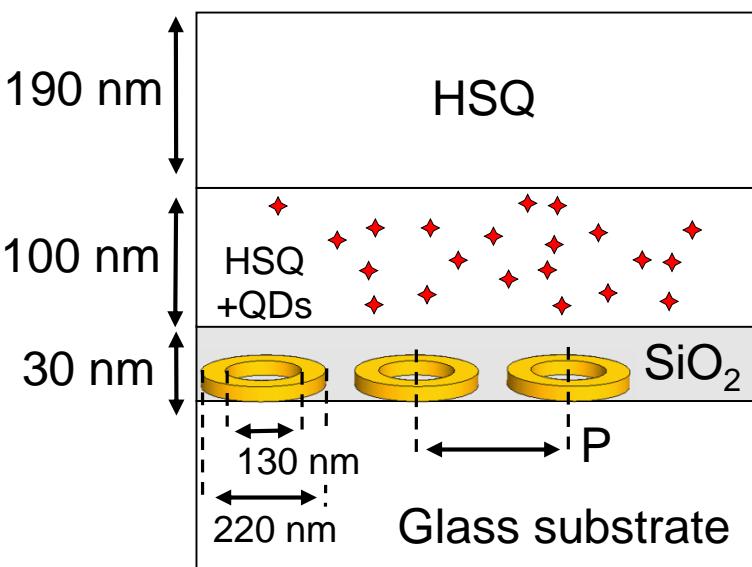
# PbS QDs coupled with Au ring arrays



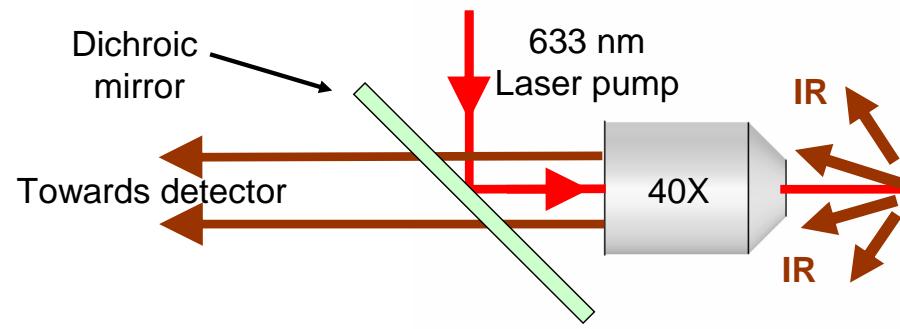
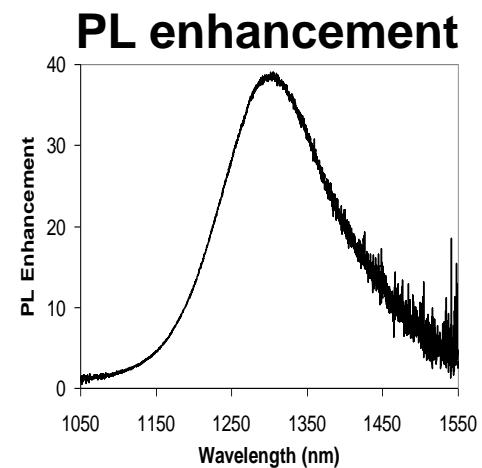
The rings of all structures have the same dimensions



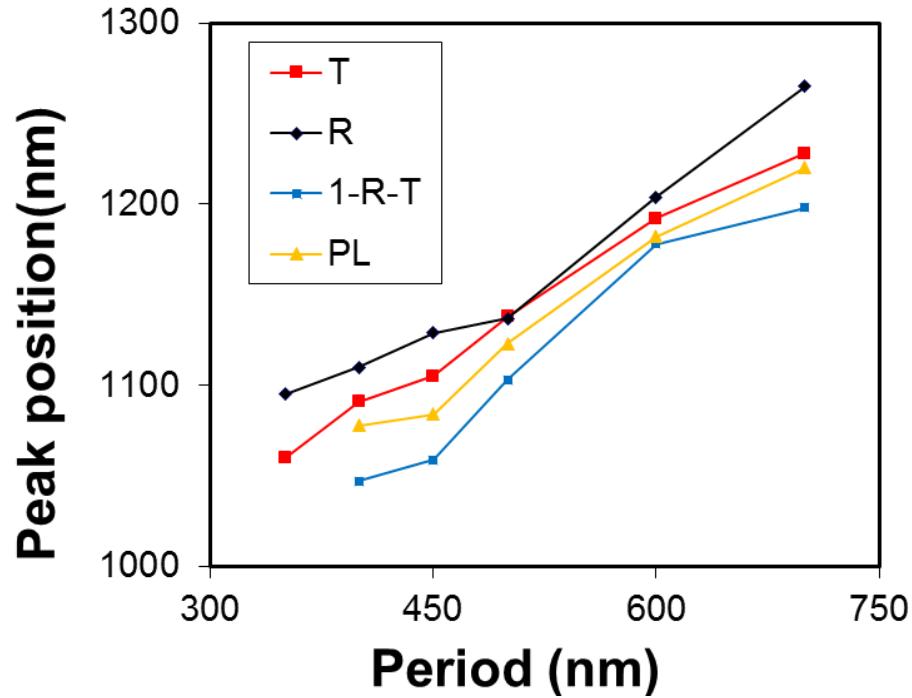
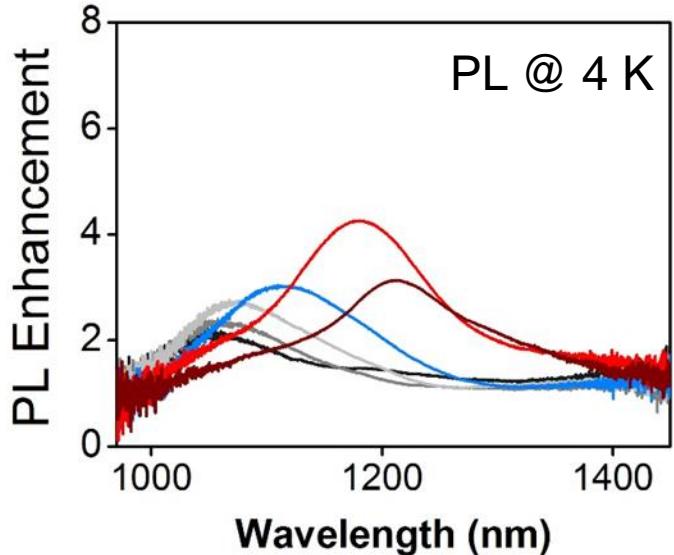
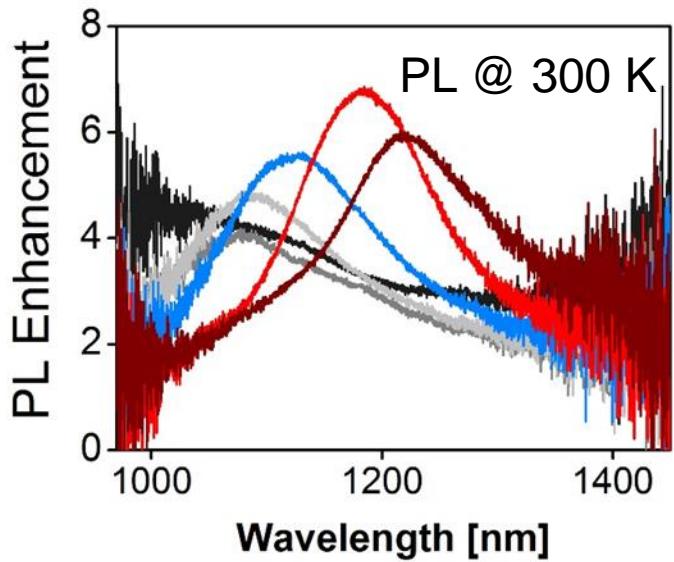
# PL measurements



PL  
above rings  
=  
PL above  
substrate



# PL measurements



# Acknowledgments

@ IEF: Quynh Le Van, Tatiana V. Teperik, Xavier Leroux,  
Nicolas Izard

Group of Jean-Jacques Greffet, Institut d'Optique



## Funding:

Labex NanoSaclay



RTRA Triangle de la Physique

Université Paris-Sud