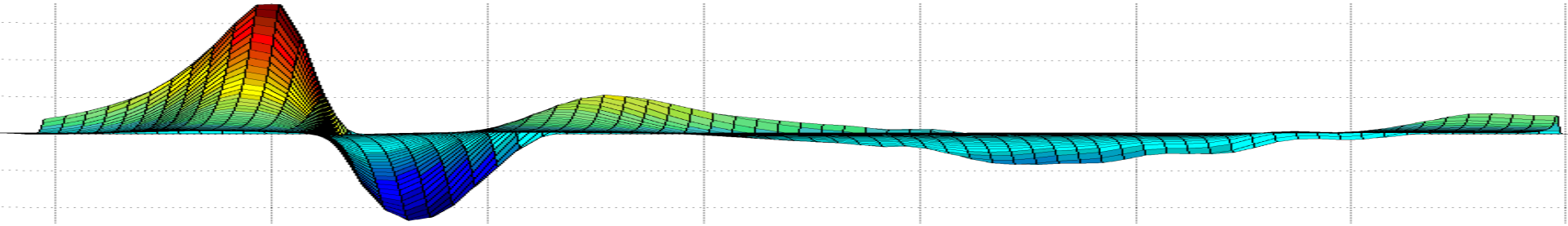


Plasmonique et nanophotonique

Master *Lumière, Matière, Interactions*

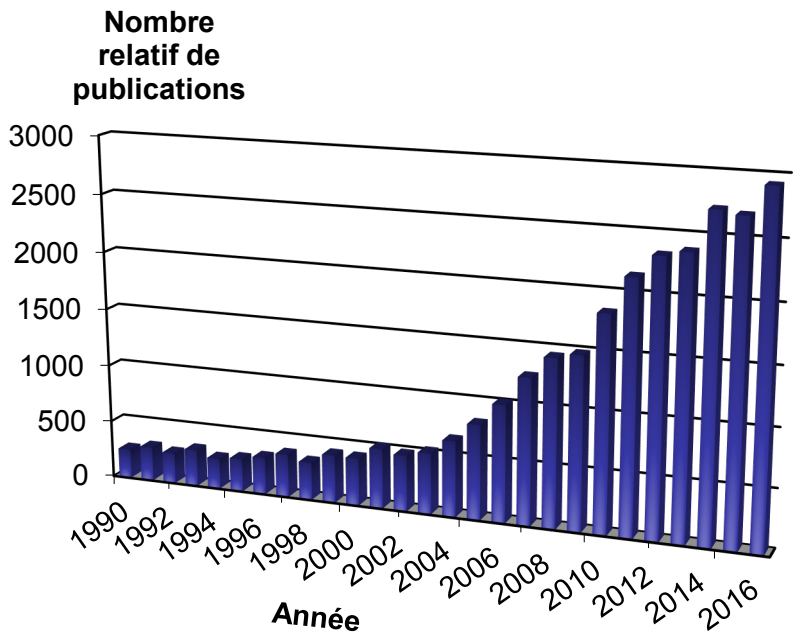
Bruno Palpant
Samuel Grésillon
Richard Hostein
Olivier Pluchery

CentraleSupélec
ENS CACHAN
LPQM laboratoire de photonique quantique et moléculaire
Institut Langevin ondes et images
IMSP Institut des NanoSciences de Paris
UPMC SORBONNE UNIVERSITÉS
cnrs

▸ From confinement…

▶ …to plasmonics

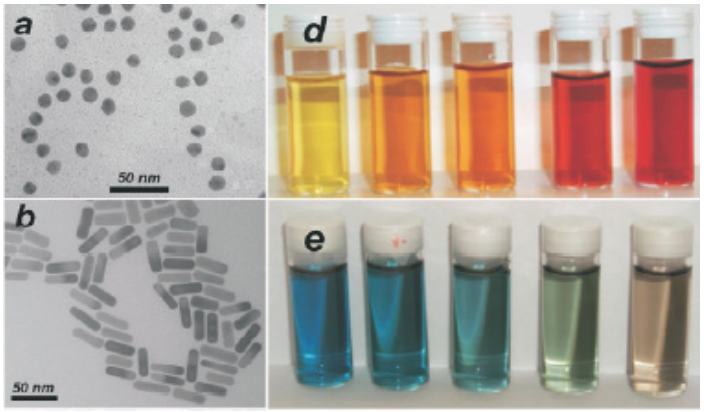
Publications relative to “plasmon” or “plasmonics” since 1990



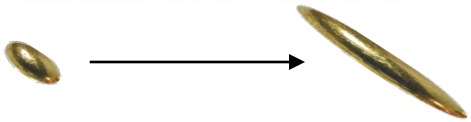
Source : Web of Science

▸ Colour and art

Composition



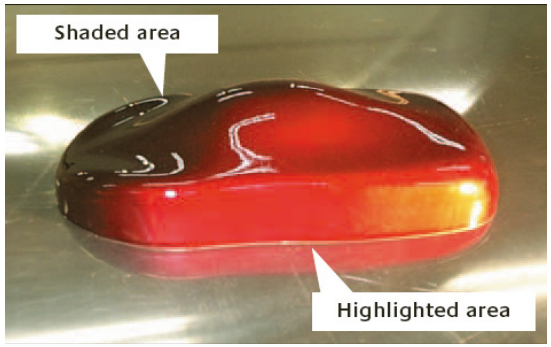
Shape



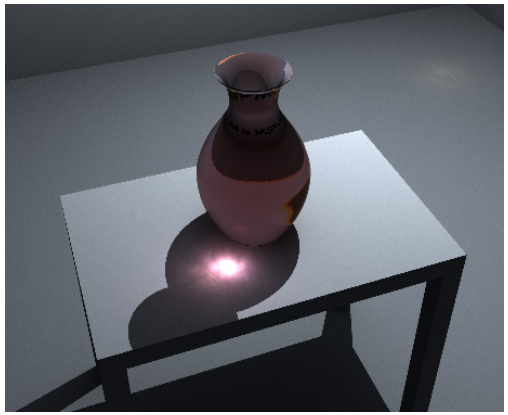
Lycurgus cup 4th century (Rome ?)
British Museum

Reflected light

Transmitted light



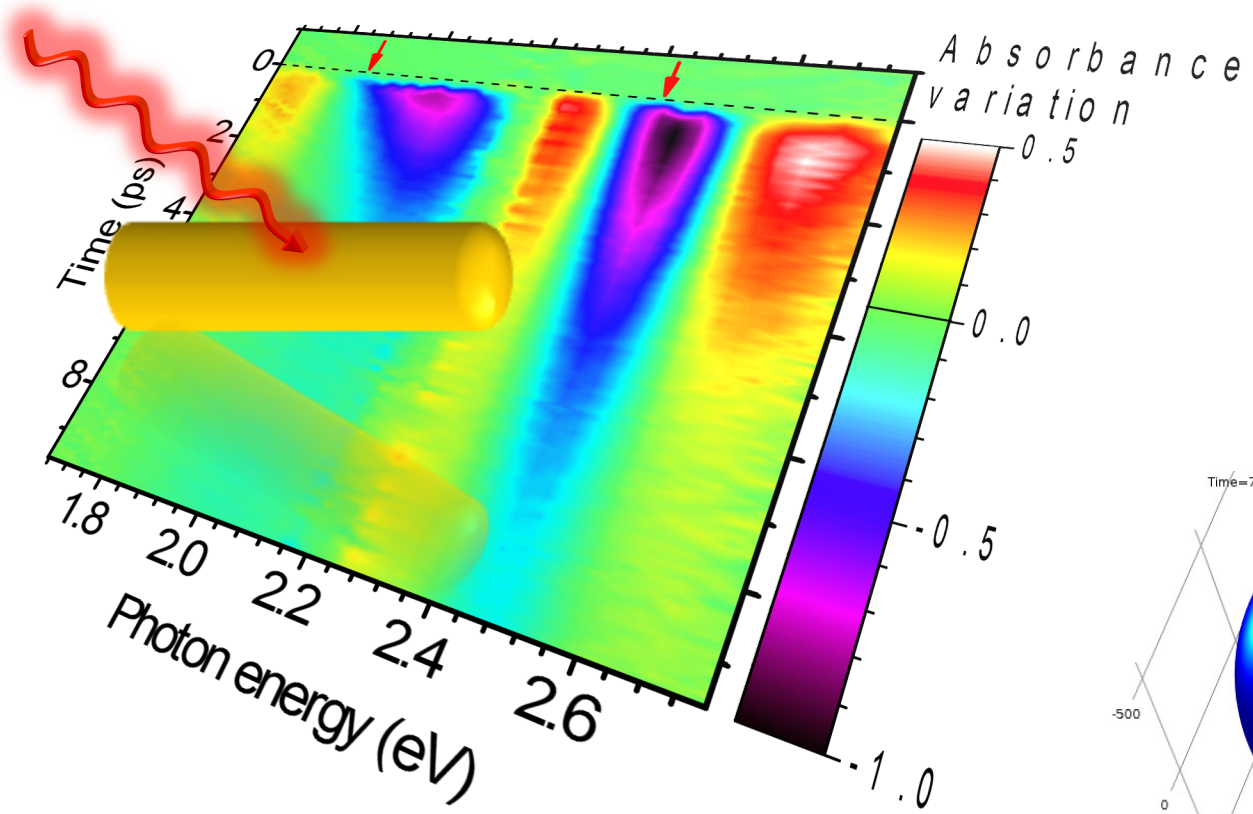
Research and Development, Nippon Paint Co.
Gold Bulletin 2005 • 38/3

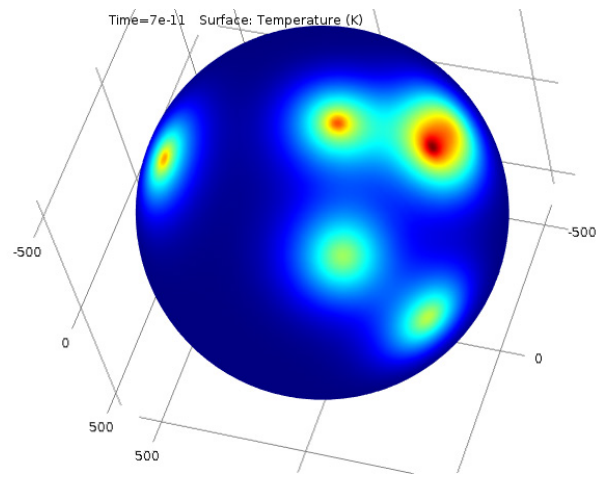


Pièce de musée virtuel
Vase en verre incrusté de nanoparticules d'or (Simulation LPQM/MAS *CentraleSupélec 2015).*

▸ Nanoscale energy exchanges

Ultrafast dynamics of the transient optical and thermal responses





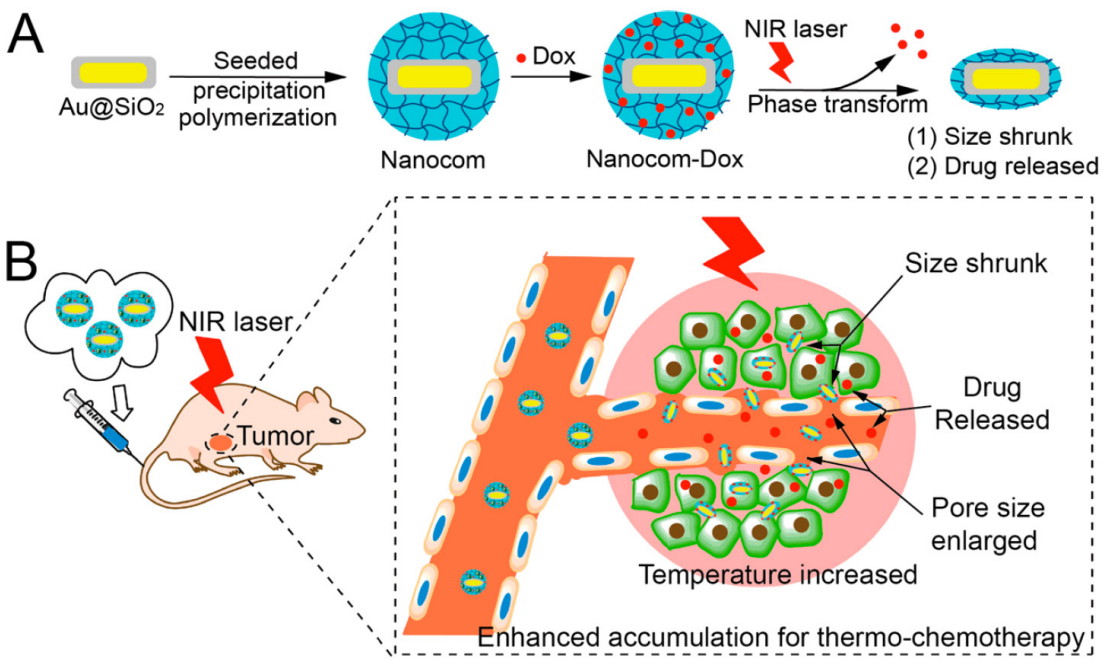
▸ Light-induced nanoscale processes

Applications : new therapies against cancer by nano-hyperthermia

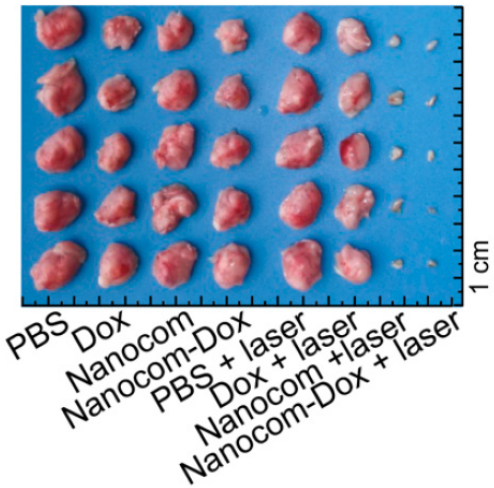
JACS
JOURNAL OF THE AMERICAN CHEMICAL SOCIETY
J. Am. Chem. Soc. 2014, 136, 7317–7326

Near Infrared Laser-Induced Targeted Cancer Therapy Using Thermoresponsive Polymer Encapsulated Gold Nanorods

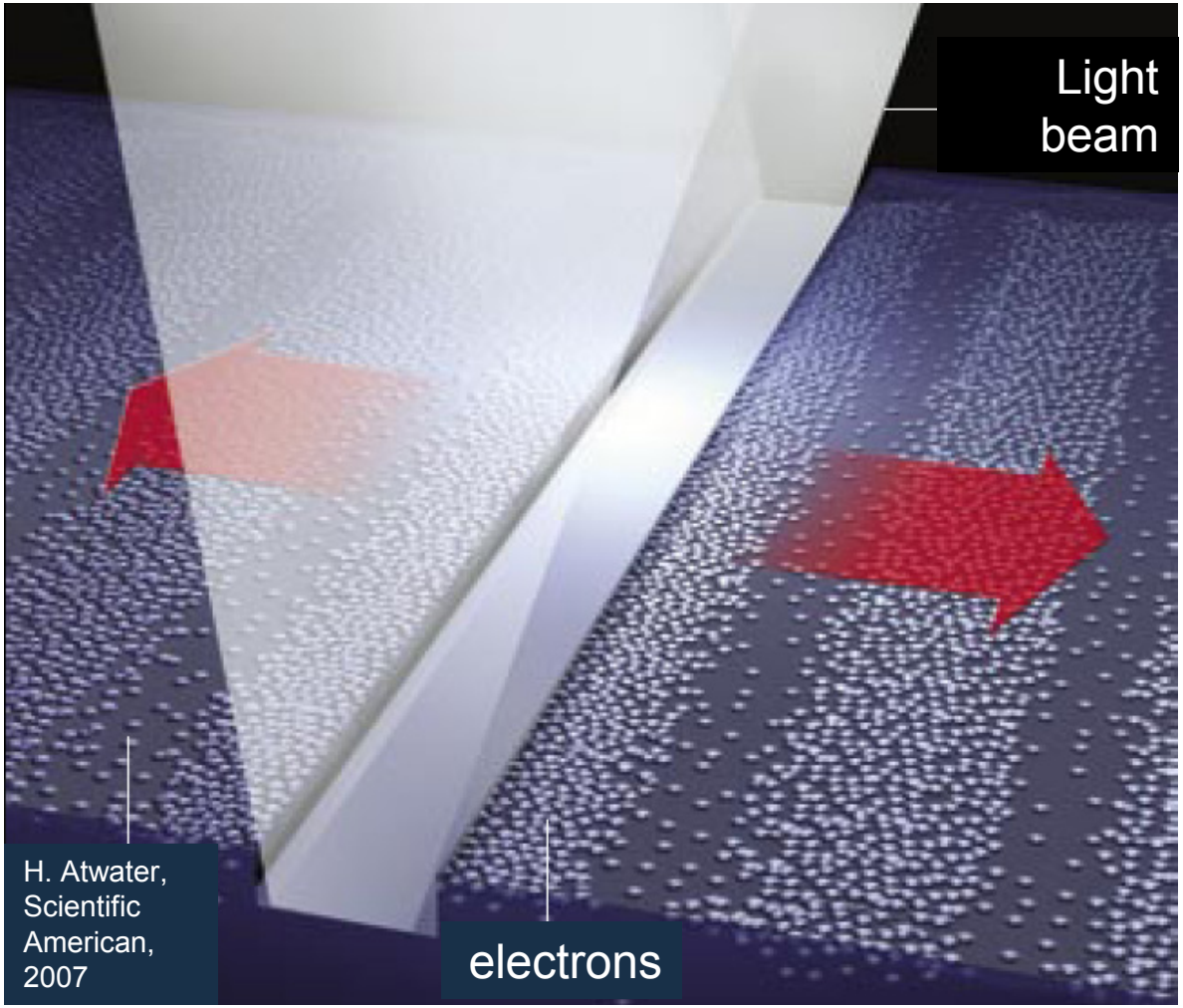
Zhenjiang Zhang,† Jing Wang,† Xin Nie,† Tao Wen, Yinglu Ji, Xiaochun Wu, Yuliang Zhao, and Chunying Chen*



Tumor regression under treatment

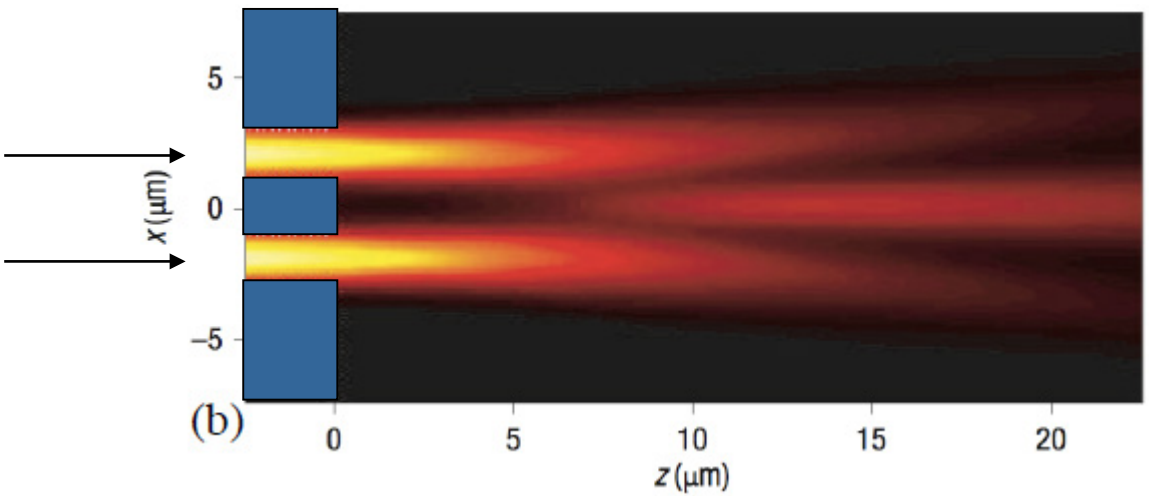


▸ Propagation…



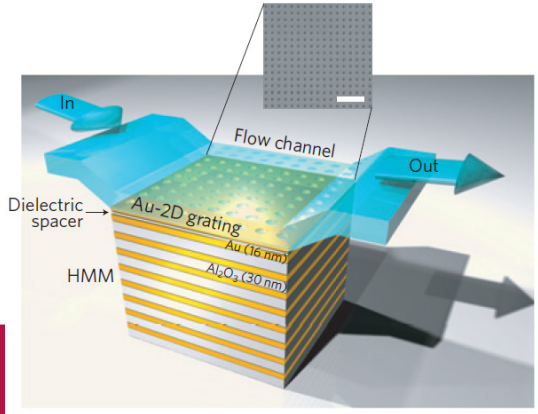
▸ Wave-like behaviour

Interferences as Young slits with surface plasmon polaritons (exp.)



Zia and Brongersma, *Nature Nanotechnology* **2**, 426 (2007)

▶ Ultrasensitive sensors



nature materials

PUBLISHED ONLINE: 28 MARCH 2016 | DOI: 10.1038/NMAT4609

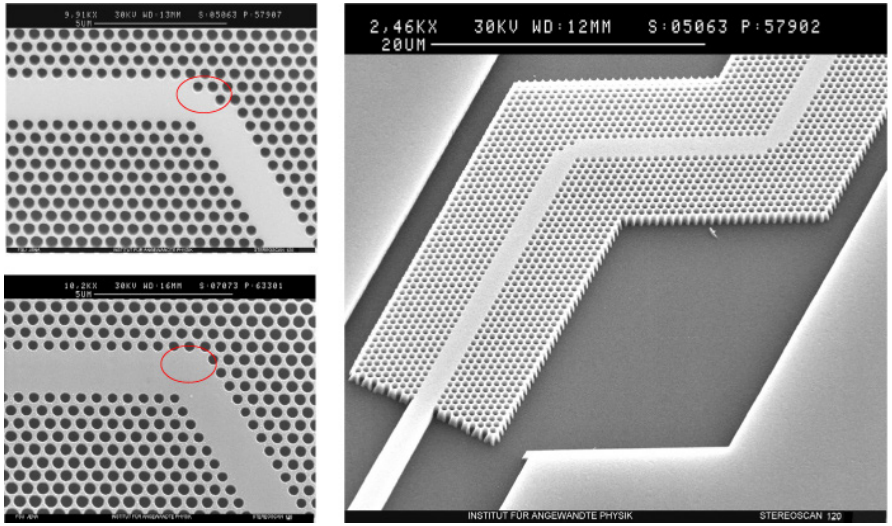
Extreme sensitivity biosensing platform based on hyperbolic metamaterials

Kandammathe Valiyaveedu Sreekanth[1]*, Yunus Alapan[2], Mohamed ElKabbash[1], Efe Ilker[1], Michael Hinczewski[1], Umut A. Gurkan[2,3,4,5], Antonio De Luca[6] and Giuseppe Strangi[1,6]*

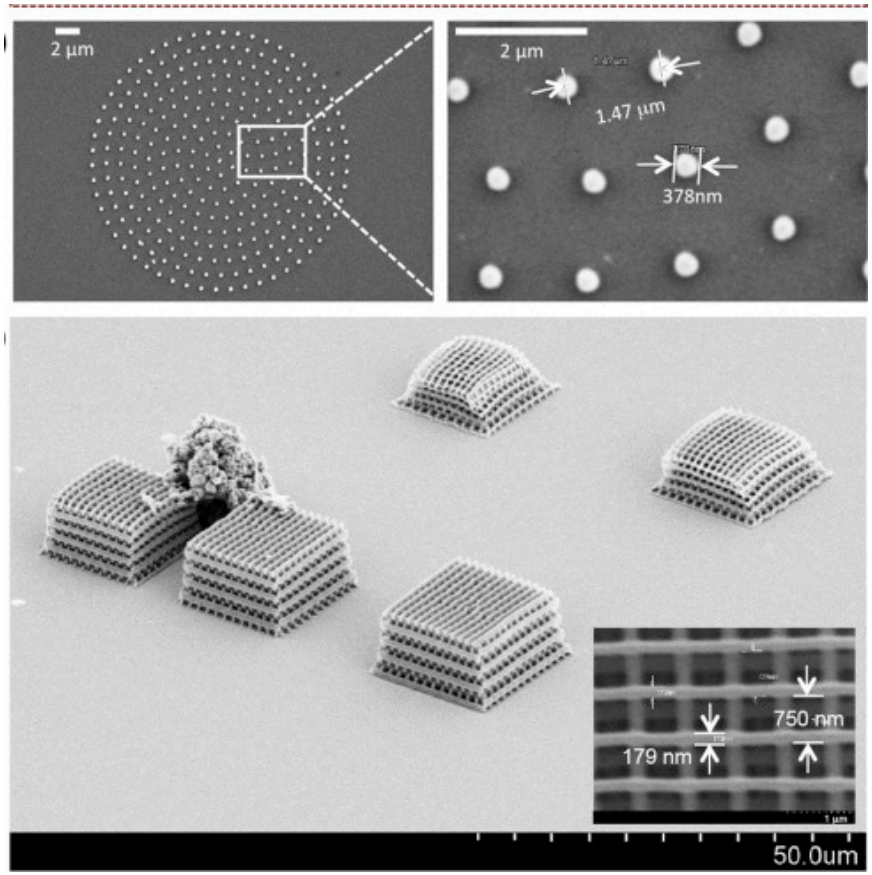
Optical sensor technology offers significant opportunities in the field of medical research and clinical diagnostics, particularly for the detection of small numbers of molecules in highly diluted solutions. Several methods have been developed for this purpose, including label-free plasmonic biosensors based on metamaterials. However, the detection of lower-molecular-weight (<500 Da) biomolecules in highly diluted solutions is still a challenging issue owing to their lower polarizability. In this context, we have developed a miniaturized plasmonic biosensor platform based on a hyperbolic metamaterial that can support highly confined bulk plasmon guided modes over a broad wavelength range from visible to near infrared. By exciting these modes using a grating-coupling technique, we achieved different extreme sensitivity modes with a maximum of 30,000 nm per refractive index unit (RIU) and a record figure of merit (FOM) of 590. We report the ability of the metamaterial platform to detect ultralow-molecular-weight (244 Da) biomolecules at picomolar concentrations using a standard affinity model streptavidin–biotin.

▸ Light control

Guiding, trapping, slowing down, enhancing or inhibiting light



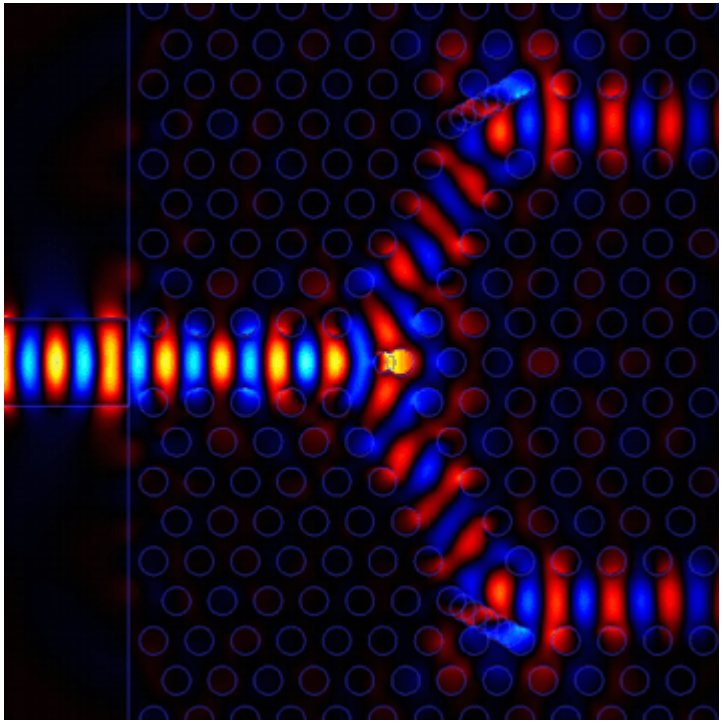
M. Augustin *et al.*, *Optics Express* **11**, 2003



D. T. T. Nguyen *et al.*, *J. Sci. Adv. Mater. Devices* **1**, 2016

▸ Calculation methods

FDTD: solving Maxwell's equations

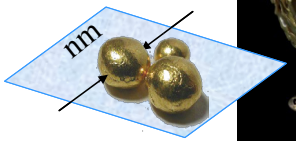


Omnisim software, Photon Design®

▸ Organisation de l'option

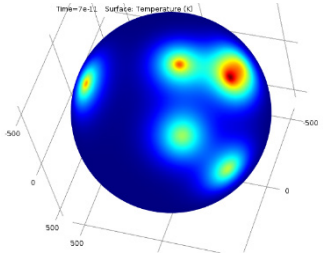
Examen : TP (25%) + projet numérique (25%) + oral (50%)

Cours (24 heures) :



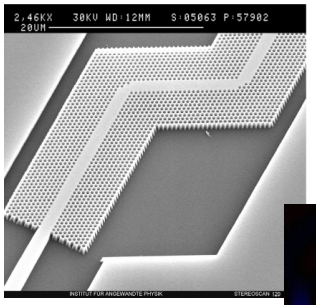
1. Plasmon localisé (8h)

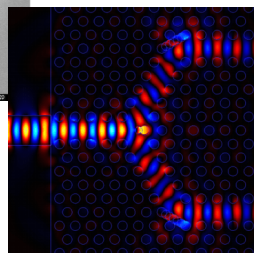
- Principe et propriétés
- Influence de paramètres morphologiques
- Applications de l'exaltation de champ proche, couleur
- Echanges énergétiques photo-induits
- Dynamique électronique
- Conversion photo-thermique



2. Nanophotonique (8h)

- Modes de Bloch et structure de bandes
- Propriétés de propagation, notion de bande interdite
- Cavités, modes de défaut, illustrations à 1D
- Cristaux photoniques 2D, guidage, modes TE et TM
- Fabrication et outils numériques
- Applications : diodes laser, VCSEL, couplage aux atomes froids

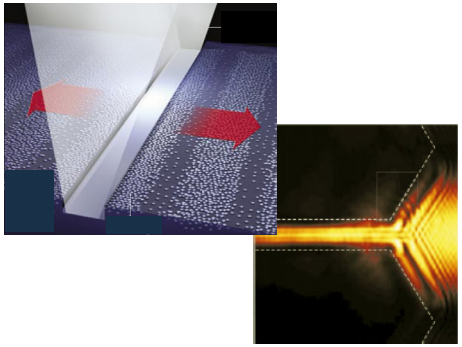




▶ Organisation de l'option

3. Plasmon propagatif et métamatériaux (8h)

- Plasmon propagatif : principe et applications du plasmon-polariton de surface
- Spaser
- Métamatériaux, métasurfaces
- Nano-antennes



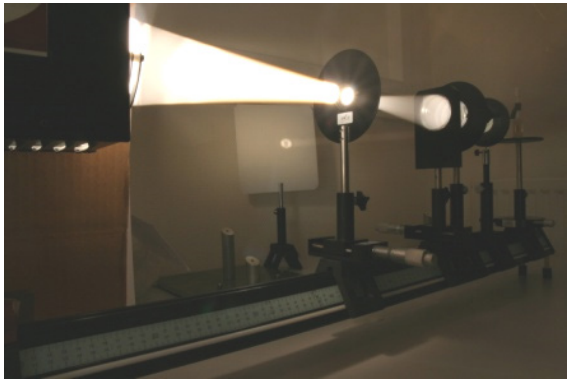
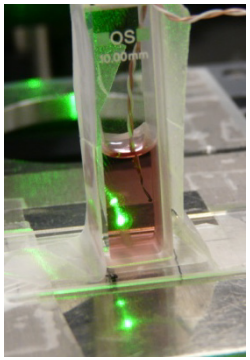
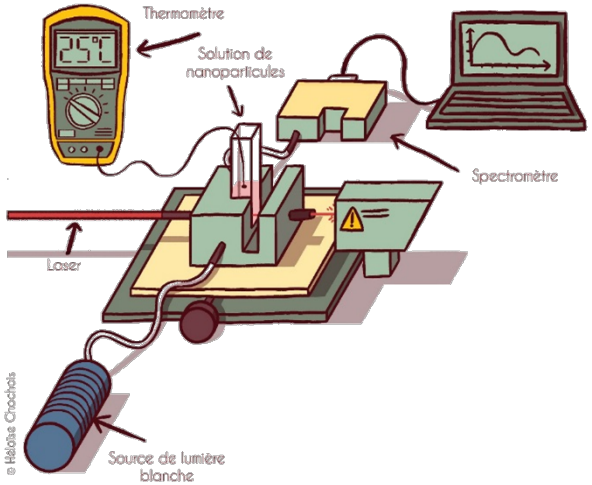
+ Conférences de chercheurs (2)

+ Ateliers en groupes

- Projets expérimentaux (2×4h)
- Projets numériques : champ proche plasmonique, FDTD

Projets expérimentaux

- **Principle of an ultrasensitive plasmonic chemical sensor**



- **Plasmonic photothermal conversion**