CentraleSupélec within
LUMIN, UMR9024
LIGHT, MATTER AND INTERFACES LABORATORY

LuMIn
Lumière, Matière et Interfaces

LuMIn is a research laboratory created in 2020 and devoted to light-matter interactions scaling from atoms to materials, devices and living systems at University Paris-Saclay. It aims at proposing novel and original synergies at the frontiers of optical and quantum physics, device technologies, along with the exploration *in vitro* and *in vivo* of fundamental biological processes for a better understanding of cancer and brain disorders pathogenesis.

The core activity of this structure is based on a wide spectrum of competences in optics (lasers, nonlinear optics, quantum physics, plasmonics, optomechanics), with applicative developments to the design and elaboration of micro- and nanophotonic devices (including microfluidic circuits) and to the investigation of biochemical phenomena in cells, tissues and living organisms.

LuMIn operates under the authority of four institutions: CNRS, ENS Paris-Saclay, Université Paris-Saclay and CentraleSupélec. It hosts the Equipex+ eDiamant and shares a common lab. with Thales R&T. It also belongs to the Institut d'Alembert in ENS Paris-Saclay.

Research topics

ULTRAFAST PLASMONICS AND NANOPHOTONICS (IN CENTRALESUPÉLEC SITE)

Metal nano-objects under light irradiation exhibit remarkable optical properties associated with the plasmon resonance phenomenon. We study, by carrying out dedicated experiments and simulations, the interaction of ultrashort light pulses with such plasmonic nanoparticles (NPs). This can lead to the formation of a hot electron gas, whose dynamics is accompanied by interesting phenomena which can be exploited in photonic, chemical or biomedical applications. Further, noble metal NPs are efficient converters of light into heat at small scales when lightened at their plasmon resonance. We study these fundamental mechanisms and exploit them for innovative functional materials and biomedical developments. In addition, we work on optomechanics, which designates the coupling of an electromagnetic wave with the motion or vibration of an object. This interaction is as strong as optical powers are important or as the objects are small. We investigate how optomechanical coupling can be magnified depending on the size of metal NPs and their environment. Besides, while piezoelectric materials change their dimensions when a voltage is applied, a similar effect called photostriction can occur under certain conditions when illuminated by an intense optical beam. We work with the SPMS lab. in CS to investigate this new optomechanical coupling.

DIAMOND-ENABLED MATERIALS AND SENSORS

Our research focuses on applying nitrogen-vacancy (NV) centers in diamond to sensitive magnetic measurements.

LASERS AND OPTICS

Our activities range from very fundamental studies in quantum information to the development of optoelectronic oscillators of high spectral purity, via the physics of lasers and nonlinear optics.

NANOPHOTONICS, MATERIALS AND SPECTROSCOPY

We fabricate and study different kind of nanomaterials and their interaction with light.

STRUCTURATION AND DEVICES

This research theme is focused on the elaboration, physical and technological studies of various kinds of photonic devices, mainly made of molecular and polymeric materials.

NEW OPTICAL METHODS FOR LIFE SCIENCE STUDIES

This theme aims at developing new methods for various applications in life sciences, with a focus on fundamental cellular processes: microscopy setups, optically active nanoprobes, optometry.

BIOPHOTONICS AND PHYSIOPATHOLOGY OF SYNAPSES

We study the synapse biology and circuit physiology in the healthy and diseased brain.

FLUIDIC AND ELECTRIC MICROSYSTEMS FOR LIFE SCIENCE STUDIES

We design and fabricate microfluidic devices for the characterization and treatment of living cells, for medical or environmental applications.

APPLICATION DOMAINS

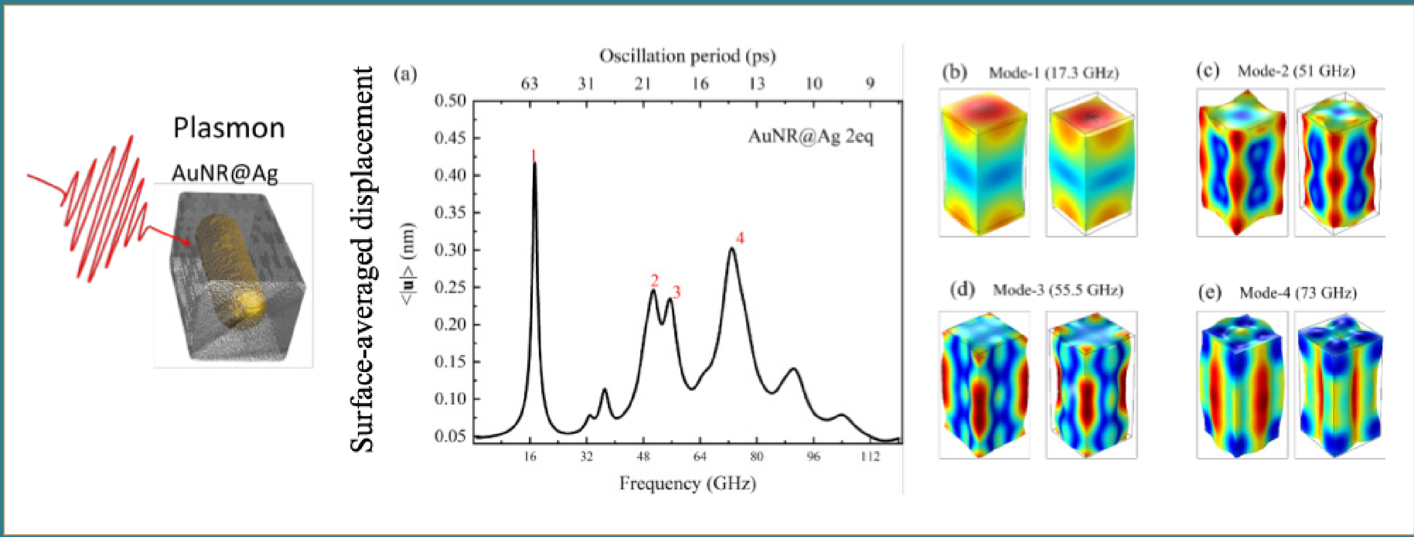
- Optoelectronics,
- Sensors,
- Biomedical imaging,
- Medical diagnosis and targeted therapies,
- Photovoltaics,
- Ultrafast optical processing,
- Quantum information,
- New microscopies,
- Materials for optics, sustainable energies and life science.

HIGHLIGHTS 2023

DECIPHER THE OPTICAL PROPERTIES OF A NEW PLASMONIC MATERIAL: TIN

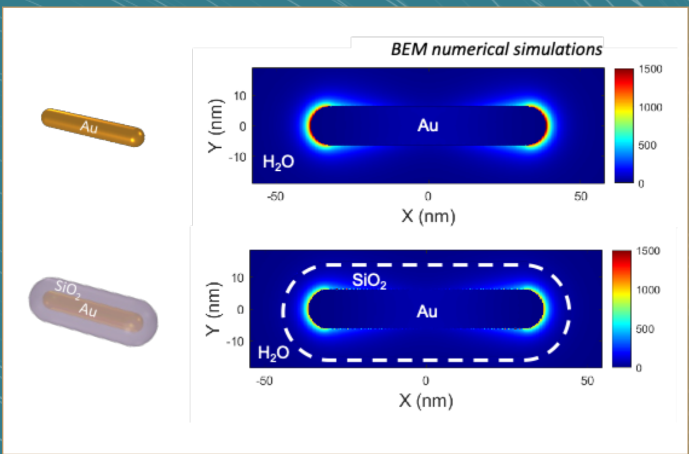
In collaboration with a team of the Physics Department in Politecnico di Milano, Italy, we have investigated the theoretical description of the stationary and ultrafast optical responses of titanium nitride, a material with remarkable plasmonic properties which could replace noble metals for some applications. Our findings have enable to reproduce with accuracy experimental results already published in the literature. They have been presented in several conferences and should be reported in a regular review in 2024.

EXAMPLES OF STUDIES



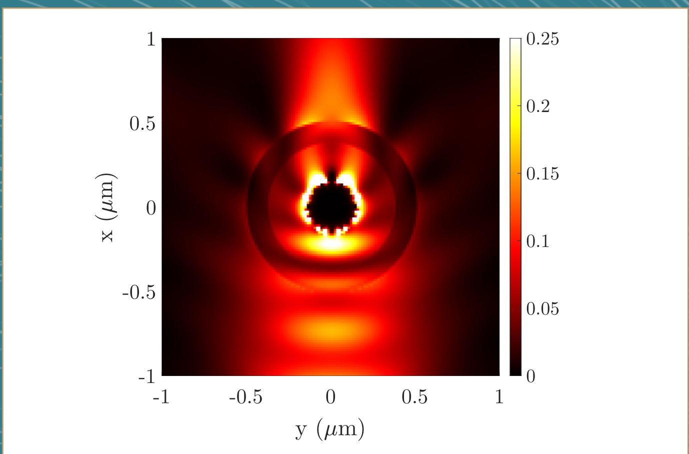
The vibrational landscape of nano-objects revealed by their ultrafast optical response

Bimetallic gold-silver core-shell nanoparticles: under pulsed laser illumination tuned to the plasmon resonance mode wavelength (left Fig.), the vibration properties of the nanoparticles can be analyzed by ultrafast transient optical absorption and modeling thanks to opto-mechanical coupling. The vibrational spectrum (middle) reveals different peaks in the sub-THz range, which correspond to specifc vibration modes. The main ones are labelled and their origin revealed by acousto-plasmonic modeling (right; colors denote the relative induced displacement).
These results can be exploited for nano-sensing as both the optical and vibrational responses of the nanoparticles are very sensitive to their close environment. Collaboration: LPS, Orsay; ISM-CNR, Rome; IMMM, Le Mans. Published in: T. O. Otomalo et al., Chemosensors 10 (5), 193 (2022). DOI : https://doi.org/10.3390/chemosensors10050193.



Hindering the production of reactive oxygen species in biomedical applications of gold nanoparticles

Gold nanorods are extensively used for biomedical applications thanks to their tunable and effective optical properties. Under ultrashort laser pulses, they can generate reactive oxygen species (ROS) which, while useful for some targeted therapies, must be avoided in other developments like localized gene delivery. We have recently demonstrated that coating such nanoparticles with a thin layer of dense silica (SiO_2) enables us to hinder the production of ROS. This mainly stems from the confnement in the oxide layer of the electromagnetic near-feld enhancement occurring at the nanoparticle tips, as illustrated on the fgure (color levels: near-feld intensity). Collaboration: NIMBE/CEA Saclay. Published in S. Mitiche et al., Journal of Materials Chemistry B 10, 589 - 597 (2022). DOI: https://doi.org/10.1039/D1TB02207E.



Mechanical properties of light at the nanoscale

Optomechanics refers to the coupling of electromagnetic radiation with one or more mechanical degrees of freedom. Indeed, although mass less, photons carry a mechanical momentum. It is intrinsically weak : the typical resulting force is 1nN for a 1W beam. Consequently these phenomena are negligible at the macroscopic scale, but at the nanometric scale objects are much lighter, and therefore much more sensitive to small forces. In addition, at such scales, surface effects are non-negligible since the surface to volume ration increases as the characteristic dimension decreases. In particular evanescent waves have a major contribution to the optical behavior and amplify the mechanical features of photons.

Industrial Partners

- Attocube R&D,
- Christex,
- Essilor,
- IMSTAR,
- Institut Photovoltaique d'Île-de-France,
- Orsay Physics,
- Photonscore GmbH,
- Thales TRT,
- United Visual Researchers.

Academic Partners

In France: Mascot (AP-HP, INSERM, U. Sorbonne Paris Nord); Ecole Polytechnique: Chaire Art & Science; LRS (Sorbonne U., CNRS); UTT: L2n (UTT, CNRS), LBPA (ENS-PS, CNRS), LPS (U. Paris-Saclay, CNRS).

In Europe: Politecnico di Milano (Italy).

Outside Europe: INRS, Montréal (Canada).

Key figures*

• Professors, Associate Professors & Researchers	2
• Engineers & Administrative staff	2
• PhD Student	1
• Post-doc	1
• Publication of the year (WoS)	1

*CentraleSupélec only

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