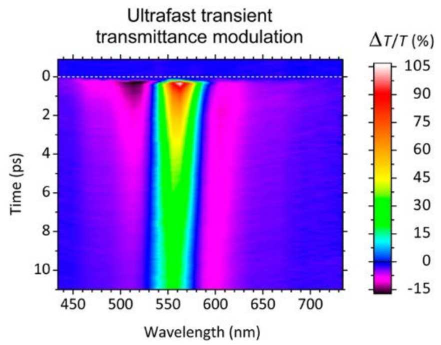
Master thesis proposal

Ultrafast plasmonic near-field modulation in a hybrid microcavity

- **Background, Context**

Thanks to the localized plasmon resonance phenomenon, stemming from the interaction of an electromagnetic wave and the electrons confined in metal nanoparticles (NPs), one can efficiently inject energy in the latter by pulsed light irradiation.[1] From the series of subsequent exchange and relaxation mechanisms the optical properties of the medium where these NPs are spread are modified in a fast transient way.[2] By coupling such effects with a resonant mode of an electromagnetic cavity, one may conceive optically controlled photonic functions. In our team, specialized in ultrafast optical response of plasmonic nanostructures, we have demonstrated a spectacular enhancement of the ultrafast optical response of gold nanoparticles after optimization of the coupling of their plasmon mode with a photonic mode in a 1D cavity.[3] This opens up new opportunities for applications in photonics devices or ultrafast modulation of near-field energy transfer for ultrafast optical sensors, which may be the subject of a further PhD.



Ultrafast photonic modulator. The cavity of a Fabry-Perot device is filled by gold nanoparticles. A short light pulse (200 fs) sent just after time *t*=0 induces a strong (>100%) transient modulation of the signal transmission peak (cavity mode) within the photonic band gap Experiment: Time-resolved fs laser spectroscopy, LPQM).[3]

- **Research subject, work plan**

The objective of the internship is to develop the transient coupling towards an even more powerful anisotropic configuration, using nonspherical nanoparticles and enabling polarization-controlled ultrafast photonic functionalities. Hybrid cavities with single gold nanoparticles in a 1D photonic crystal will be designed and produced by our partners at UTT. Their optical response (near field, transmittance) will be explored in both the stationary and ultrafast transient regimes.

- **Partnership and means**

Hybrid anisotropic cavities will be elaborated and studied in collaboration with our partners from the laboratory *Lumière, nanomatériaux, nanotechnologies* (L2n) at UTT, Troyes.

Models and numerical tools that we have developed will be extended for the design of new structures and the simulation of their properties. The optical response of the devices elaborated will be measured by time-resolved ultrafast laser micro-spectroscopy.

1. *Absorption of ultrashort laser pulses by plasmonic nanoparticles: not necessarily what you might think*, X. Hou, N. Djellali and B. Palpant, *ACS Photonics* **5** (9), 3856–3863 (2018). DOI
2. *Photothermal properties of gold nanoparticles,* B. Palpant, in "Gold nanoparticles for physics, biology and chemistry", pp. 87–130, Eds. C. Louis and O. Pluchery (World Scientific, 2017).
3. *Coupling localised plasmonic and photonic modes tailors and boosts ultrafast light modulation by gold nanoparticles*, X. Wang, R. Moreira, J. Gonzalez and B. Palpant, *Nano Letters* **15**, 2633–2639 (2015). DOI

Laboratories: 1. LuMière, Matière, Interfaces (LuMIn, ex-LPQM, dir. F. Bretenaker) (CentraleSupélec - ENS Paris-Saclay - CNRS). 2. Lumière, nanomatériaux, nanotechnologies (L2n, dir. C. Couteau) (UTT – CNRS)

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