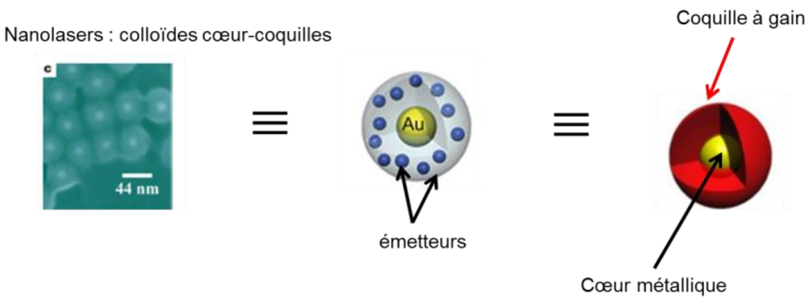
Steady-state and dynamic modeling of plasmonic nanolasers



The nanolaser

Several potential sensing and signal processing applications rely on the use of intense fields, i.e. fields confined into very small volumes. This is because large confinements of the electric field reduce the command power of nonlinear devices and greatly enhance the sensitivity to small perturbations of the index of refraction. Surface Plasmons, which are a coupled oscillation of electromagnetic radiation and surface charge density at a metal/dielectric interface stand out compared to other optical carriers of energy for such applications because of their ability to confine light well below the diffraction limit. However, ohmic losses in metals severely hamper applications and many plasmonic devices or optical metamaterials that incorporate plasmonic resonators. In 2009, the first spaser-based (i.e. surface plasmon amplification by stimulated emission of radiation) nanolaser was built and experimentally tested by Noginov *et al.* [1] and garnered a great deal of interest because it showed that ohmic losses could actually be compensated by coupling a gain dielectric medium to a metal at the nano-resonator scale. The nanolaser consisted in a gold/silica core-shell nanoparticle with fluorophores embedded in the silica shell. Though this nano-device is promising, it still lacks of a firm theoretical understanding and a core-shell holding several embedded emitters is a rich system that needs that may very well exhibit complex and unforeseen responses.

Research at the Centre de Recherche Paul Pascal (CRPP)

The *Metamaterials* team at the Centre de Recherche Paul Pascal has an interest in modeling these nanolasers both to build a solid understanding of the underlying physics of the system as well as predict the actual response of empirical systems made of individual and bulk assemblies of these nanolasers. CRPP and its collaborators are able to synthesize these nanoparticles. Furthermore, CRPP has several self-assembly techniques, which makes it possible to assemble these nanolasers into large volumes of bulk material. This opens a large field of exploration for optical metamaterials, based on a *bottom-up* approach that is radically different to more classical *top-down* approaches that use the micro-electronics fabrication facilities.

Internship work

In the context of this internship, we wish to explore novel approaches in simulating the responses of these nanolasers by incorporating both (i) the steady-state and (ii) the dynamic population equations that govern how fluorophores or quantum dots might emit within the plasmonic core-shell into Maxwell's equations. This work will require modeling of the physical system as well as implementing the nonlinear Maxwell equations into a commercial Finite Element Method software (COMSOL Multiphysics). In the end, we hope to have a robust numerical tool to accurately simulate spaser-based nanolasers. **Softwares used :** Matlab, COMSOL Multiphysics (Finite Element Method). **Key words :** spasers, nanolasers, lasers

Bibliography

[1] M. A. Noginov *et al.*, Nature **460**, p. 1110 (2009)

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