THESIS PROPOSAL in nanophotonics
(cotutelle Institut d'Optique d'Aquitaine – Amsterdam)

Metallo-dielectric nanoresonators

Emission, absorption and refraction of light are favorite probes of matter. Yet, that light is a noninvasive probe signifies that light and matter interact weakly: chances that a photon will repeatedly interact with its source are negligible. Reinforcing this interaction, requires that the interaction be engineered, for instance to reach the "quantum strong coupling" regime, in which repeated coherent interaction of a single photon and its source is achieved [1]. This is conditional on stringent conditions, and requires optical microcavities that confine light to small volumes by resonant recirculation.

So far most researchers aimed for the highest-quality-factor (Q) resonators in lossless 'dielectric' optical materials [2], with mode volumes $\approx\lambda^3$, essentially limited by the diffraction limit. The opposite strategy is to minimize the mode volume to shrink photons well below the diffraction limit with plasmon resonances in metal [3].

Clearly, both strategies lead to radically different extremes situations. In between these two extremes, we believe that a totally new platform of nanocavities (virtually unexplored so far), which relies on the hybridization of photonic microresonators and plasmonic antennas, may enable new paradigms by allowing ultrastrong coupling at **any *practically relevant* Q** ($50 < Q < 1000$) with intermediate V's ($0.01 < V/\lambda^3 < 0.1$) and by removing the drawbacks that microcavities and plasmonics separately present. The purpose of the thesis is to study such hybrid platforms both theoretically and experimentally, and to explore their potential for quantum and classical photonics.

[1] Haroche and Wineland got the Nobel Prize in 2012 for strong-coupling of light with atoms.
[2] K.J. Vahala, "Optical microcavities", Nature **424**, 839-846 (2003).
[3] L. Novotny and N. van Hulst, "Antennas for light", Nat. Photon. **5**, 83-90 (2011).

Practically, it will be a cotutelle thesis (3-4 year long). The experimental part will be performed under the supervision of Femius Koenderink in AMOLF (Amsterdam). The theoretical part will be performed under the supervision of Philippe Lalanne in Institut d'Optique d'Aquitaine (Bordeaux). While the precise time distribution is dependent on the project, it is anticipated that the PhD student will spend 14-18 month in Bordeaux, and the rest of the time in Amsterdam. The financial support is already obtained (thanks to a prestigious fellowship of IDEX Bordeaux and an ERC-like Dutch grant). The net salary on the French side is according to the IDEX thesis fellowship, http://idex.u-bordeaux.fr/News/Excellence-de-la-recherche/Doctorat-international/r887.html . The Dutch net salary is according to the dutch collective labour agreement for research institutes (see www.fom.nl) All extra costs due to the cotutelle bi-location will be covered.

For this cotutelle thesis, we wish to recruit an excellent candidate who will be able to drive the collaboration, with a strong background in physics and optics (electrodynamics, quantum optics, basic photonic knowledge), who is eager to combine state-of-the-art nano-optics experimentation and theory.
Please contact: f.koenderink@amolf.nl and Philippe.lalanne@institutoptique.fr