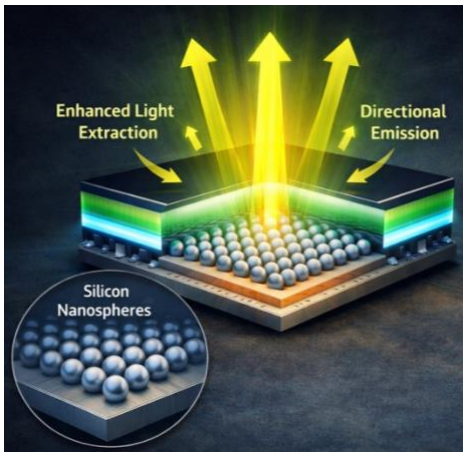
PHD PROPOSAL

METALED

Metasurfaces are two-dimensional (or quasi-2D) structures made up of nanometric elements (“meta-atoms”) that enable the controlled manipulation of electromagnetic waves (phase, amplitude, polarization) [1]. Compared to plasmonic metasurfaces, whose constituent elements are made of metal, metasurfaces based on dielectric materials have the advantage of very low optical losses. Silicon is a particularly good candidate because it has a high index (~3-4 in the visible/NIR range), mature manufacturing techniques (CMOS/industry), and relatively low absorption [2]. In addition, Mie resonances (electric dipole, magnetic dipole, higher multipoles) can be excited in silicon nanoparticles [3]. When creating silicon metasurfaces based on periodic or quasi-periodic arrays of high-index nanoparticles, it is possible to couple the resonances supported by each nanoparticle via diffraction effects, such as Rayleigh anomalies [4]. The existence of a range of Mie resonances therefore makes it possible to expand the number of functions that a high-index metasurface can have. By modulating the geometry (size, shape, spacing, arrangement) of the nanoparticles, it is possible to control the spectral position of the Mie resonances, the quality (Q-factor), the local electromagnetic field, and also the directionality of the scattering [5]. Interference between the light scattered by the nanoantennas and the wave reflected by the substrate can then lead to near-zero reflection or increased absorption. The goal of this project is to use these properties to modulate and direct light emission in OLED devices. The main advantages are:

- A metasurface below or above the OLED emitter could increase its efficiency by improving the extraction, direction, and conversion rate of the light generated.
- Better extraction would allow the OLED to operate at lower current for the same brightness—reducing heating, degradation, and potentially extending lifetime.
- For lighting devices: the use of metasurfaces could enable superior performance (brighter, more directional, better efficiency) for the same or less power.
- In very bright environments, strengthening the light directed toward the observer and optimizing the emission angle could partially compensate for OLED's limitations in brightness.



The METALED project will follow the methodology described below:

1. Before any experiments are conducted, numerical simulations will be performed using Comsol®, software based on the finite element method (at UTT), or Lumerical®, software based on the FDTD method (at Hull). In both cases, the use of the Roméo2025 regional supercomputer and the University of Hull High Performance Computing cluster (Viper) will be a significant asset when it comes to simulating the optical properties of nanoparticle networks. Silicon-based metasurfaces will be studied, but more exotic structures, such as metal-dielectric multilayers with unusual optical properties, will also be considered.
2. The metasurfaces will be manufactured at UTT using the electron lithography method on silicon substrates. Reactive ion etching will then be used to etch the substrate in order to draw the final patterns. A second, less expensive solution will be to use interferential laser lithography (ILL) to avoid the use of an electron microscope to create the patterns.

3. The deposition of fluorescent organic molecules and optical characterization will be carried out by the Nano3 research group at the University of Hull (UK). Specifically, existing spectroscopy, fluorescence lifetime measurement, and Fourier plane imaging devices will be used for this project.
4. The insertion of the metasurface into the OLED device will be considered in collaboration with colleagues from L2n based in Reims (formerly LRN), who are working on these organic dielectric layers. Surface-enhanced Raman spectroscopy (SERS) measurements will be carried out there to determine the influence of the insertion of the metasurface on the degradation of the device's organic semiconductors.

Bibliography:

[1] A. Li, S. Singh and D. Sievenpiper. "Metasurfaces and their applications" Nanophotonics, vol. 7, no. 6, 2018, pp. 989-1011. https://doi.org/10.1515/nanoph-2017-0120
[2] E. Tiguntseva, A. Chebykin, A. Ishteev, et al., "Resonant silicon nanoparticles for enhancement of light absorption and photoluminescence from hybrid perovskite films and metasurfaces", Nanoscale, 2017,9, 12486-12493. https://doi.org/10.1039/C7NR01631J
[3] C. F. Bohren and D. R. Huffman, "Absorption and scattering of light by small particles", 1998, John Wiley & Sons, Hoboken, NJ. Print ISBN:9780471293408 |Online ISBN:9783527618156 |DOI:10.1002/9783527618156
[4] V. G. Kravets, et al., "Extremely Narrow Plasmon Resonances Based on Diffraction Coupling of Localized Plasmons in Arrays of Metallic Nanoparticles", Phys. Rev. Lett. 101, 087403 (2008) https://doi.org/10.1103/PhysRevLett.101.087403
[5] Y. Kivshar, "All-dielectric meta-optics and non-linear nanophotonics", National Science Review, Volume 5, Issue 2, March 2018, Pages 144–158, https://doi.org/10.1093/nsr/nwy017

How to apply?

The applicant must hold a master's degree in physics, or in a field related to Electromagnetism and/or Photonics. An aptitude for experimental work is necessary for the success of this project. An experience of work in a clean room environment and skills in numerical simulation will be highly appreciated.
Please send a CV, your Master grades, and a motivation letter to Anne-Laure BAUDRION (anne_laure.baudrion@utt.fr) and Jean-Sebastien BOUILLARD (J.Bouillard@hull.ac.uk).
A recommendation letter, directly sent to the above-mentioned supervisors will be highly appreciated.

Useful links

UTT: https://www.utt.fr
L2n laboratory: https://recherche.utt.fr/light-nanomaterials-nanotechnologies-l2n
Nano'Mat platform: https://www.nanomat.eu
J.-S. Bouillard's webpage: https://www.hull.ac.uk/staff-directory/jean-sebastien-bouillard