LP2N Laboratoire Photonique Numérique & Nanosciences

INSTITUT d'OPTIQUE GRADUATE SCHOOL ParisTech

université de BORDEAUX

Proposition de stage et de thèse à l'Institut d'Optique (financement acquis)

Production of new striking visual appearance with disordered metasurfaces composed of random arrays of resonant nanoparticles

Optical metasurfaces are currently considered for a broad variety of applications, from quantum studies to imaging and holography. In relation with the present proposal, they are currently investigated to supply printings with vivid-colour palettes, using Mie or localized plasmon resonances have been shown. See Appl. Phys. Rev. **6**, 041308 (2019) for a recent review.

The present project goes a step forward: it proposes to control the appearance, rather than the colour. Colour is very important, but it is only one attribute of appearance. Haze, gloss, and the change of colour with viewing angle or illumination direction, considerably alter our perception and impact our aesthetic judgement. We have recently developed a numerical platform, which mixes nanoscale electrodynamics, mesoscale multiple scattering and macroscale rendering (as used in computer graphics). The platform allows us to model the scattering properties of random monolayers composed of resonant nanoparticles and to deliver true-to-life synthetic images of arbitrary objects (cell phones, cars, rings) covered by random metasurfaces. This platform constitutes a *new tool in nanophotonics*. Results clearly indicate the high potential of random metasurfaces to produce unusual visual effects. We have also achieved the very first experimental validations with samples fabricated in different groups, with colloidal chemistry and top-down electron-beam patterning. Our first publication on the topic is under review.

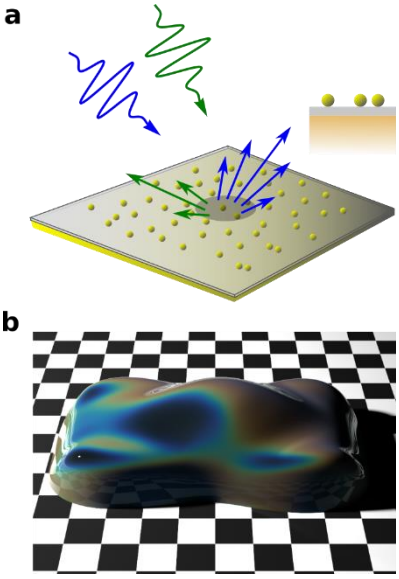

Figure 1. *Prediction of the visual appearance of macroscopic nanostructured objects.* ***a.*** *Complex nanostructured surface, consisting of a disordered ensemble of nanoparticles deposited on a thin-film stack.* ***b.*** *Rendering of a macroscopic object covered by such a nanostructure. The appearance of the object stunningly changes when moving around the object or changing the light source position.*

We have several collaborations with nanoscientists to fabricate the metasurfaces. We are characterizing and modelling the metasurfaces in the group.

The PhD student will participate actively to the ongoing development of the numerical tools to design metasurfaces, interact with our partners (Glenna Drisko-ICMCB, Giuseppe Léo-LPQM and Mark Brongersma-Stanford) to fabricate the metasurfaces through short-period visits, and develop optical characterization setups to experimentally demonstrate new appearances. The PhD student will acquire advanced skills that are of strong interest to many academics and industries (metasurfaces and structural colors are receiving considerable attention).

Qualifications: The PhD student needs to have a solid background in optics, nanophotonics, electromagnetism, statistical optics as well as a strong interest in both numerical modelling and experimental physics. The PhD student will work in the very stimulating environment provided by the group "Light in Complex Nanostructures" and collaborators. Please refer to Google Scholar for a rapid scan of our present collaborations.

How to apply: Please contact Philippe Lalanne (philippe.lalanne@institutoptique.fr) with the following required documents:

- Current curriculum vitae
- Research statement for the master thesis (max. 2-page single-spaced)
- Letters of recommendation are welcome.
- Master internship possible and beneficial.

References in relation with the subject (the first one is deeply related):

Kevin Vynck, Romain Pacanowski, Adrian Agreda, Arthur Dufay, Xavier Granier, and Philippe Lalanne, "Stunning visual appearances of disordered optical metasurfaces", under review in Nat. Materials. See the article on Arxiv.

C. Gigli, Q. Li, P. Chavel, G. Leo, M. Brongersma, P. Lalanne, "Fundamental limitations of Huygens' metasurfaces for optical beam shaping", Laser Photonics Rev. **15**, 2000448 (2021).

Q. Li, T. Wu, J. van de Groep, P. Lalanne, and M. L. Brongersma, "Structural color from a coupled nanowire pair beyond the bonding and antibonding model", Optica **8**, 464-470 (2021).

P. Lalanne and P. Chavel, "Metalenses at visible wavelengths: past, present, perspectives", Laser Photonics Rev. **11**, 1600295 (2017).

LP2N laboratory at Institut d'Optique d'Aquitaine, 1 rue François Mitterrand, 33400 Talence, France.