Funded PhD in theoretical/numerical photonics: wave propagation in complex structures

Deadline for applications: 30 April 2021

Laboratory: Institut Fresnel, Joint laboratory of the CNRS, Centrale Marseille, and Aix-Marseille University

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Titre: Photonic of non-linear media : Application to the redefinition of the non-linear susceptiblities of highly dispersive and anisotropic nanostructures.

Topic: The recent developments in the fabrication of photonic nano-structures allow to obtain strongly confined electromagnetic field in highly nonlinear and dispersive materials, including in structures with complex geometries. Thanks to recent modelling tools, it is now possible to study light propagation in nano-structures with a fairly good accuracy even for relatively special geometries (3D, unbounded structures, anisotropic materials, . . .). Nevertheless, not all available structures or investigated ones can be modelled in a satisfactory way.

At least two barriers can be identified: on one hand, the non-linear behaviour for high field values, including or not spatial effects, and on the other hand the treatment of initially Hermitian problems [1] when the imaginary part of the different susceptibilities (χ_1, χ_2, . . .) can no longer be neglected. These two aspects have important consequences on the definitions and consequently on the values of the effective parameters describing these new photonic structures. We have already demonstrated this result for 2D nonlinear waveguides in reference [2]. The improved treatment of the nonlinearities requires to quit the monochromatic regime (except possibly in the simple case of the optical Kerr effect) to take into account harmonic generations. Two approaches are then possible: one transient approach with time stepping and a multiharmonic approach where several harmonic are coupled together. Each of these approaches can be meaningfull depending on the context and can also be used together for cross-checkings. For the multi-harmonic case, the finite element method seems to be the most natural in order to compute the solutions, knowing that we have been able to realize key progress in the rigorous resolution of the nonlinear eigen-value problen in this framework [3]. For transient regimes the Finite-Difference Time-Domain method is certainly the most appropriate.

The PhD student will have to build dedicated models and to implement them using the tools we have already developped in our research team. We have already obtained numerous results in the modelling of these complex nanostructures that could be used as building blocks or as validation tools for special cases [2, 4, 5, 6, 7]. Using these tools and a new method built for this purpose, we have also been able to propose, to design, and to analyze the first experiment demonstrating self-confined nonlinear waves in plasmonic structures [8].
We collaborate with other European research teams working in modelling including in Belgium and more recently in Germany. We also collaborate with several French teams for the fabrication and characterization of the studied structures.

Qualifications: The candidate must have a European master in Physics, or Modelling or Photonics. Candidates from French Grandes Ecoles can also apply. The candidate must have good level in electrodynamics, modelling and numerical simulations. French or English are mandatory. Only candidates with very good grades from bachelor to master studies will be considered. The PhD grant will be granted in a competive process. Therefore only a highly skilled student will be selected.

PhD funding: 3 years starting in September or October 2021, 1420 euros net/month before income taxes.

How to apply: Applications must contain a full CV together with copies of diploma (BSc or Licence, Master) and grade transcripts, a specific motivation letter, and 2 recommendation letters. All the documents must be sent in PDF in a single zipped archive file to gilles.renversez@fresnel.fr no later than the 30th of April 2020.

References

[1] P. Lalanne, W. Yan, K. Vynck, C. Sauvan, and J.-P. Hugonin. Light interaction with photonic and plasmonic resonances. *Laser & Photonics Reviews*, 12(5):1700113, 2018.

[2] M. M. R. Elsawy and G. Renversez. Exact calculation of the nonlinear characteristics of 2D isotropic and anisotropic waveguides. *Opt. Lett.*, 43(11):2446–2449, 2018.

[3] F. Zolla, A. Nicolet, and G. Demésy. Photonics in highly dispersive media: the exact modal expansion. *Opt. Lett.*, 43(23):5813–5816, 2018.

[4] F. Drouart, G. Renversez, A. Nicolet, and C. Geuzaine. Spatial Kerr solitons in optical fibres of finite size cross section: beyond the Townes soliton. *J. Opt. A: Pure Appl. Opt.*, 10:125101, 2008.

[5] F. Zolla, P. Godard, and A. Nicolet. Virtual antenna method as applied to the study of the scattering by 2-dimensional non-linear metamaterials. Progress in Electromagnetics Research Symposium, pages 1204–1207. PIERS, 2009.

[6] W. Walasik and G. Renversez. Plasmon-soliton waves in planar slot waveguides. I. Modeling. *Phys. Rev. A*, 93:013825, 2016.

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[8] T. Kuriakose, G. Renversez, V. Nazabal, M. M. R. Elsawy, N. Coulon, P. Nemec, and M. Chauvet. Nonlinear self-confined plasmonic beams: Experimental proof. *ACS Photonics*, 7(9):2562–2570, 2020.