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

Deadline for applications: 12 May 2020

**Laboratory:** [Institut Fresnel](#), Joint laboratory of the CNRS, Centrale Marseille, and [Aix-Marseille University](#)**PhD supervisors:** Prof. Frédéric Zolla, Prof. Gilles Renversez, [ATHENA](#) research teamEmails: [gilles.renversez@fresnel.fr](mailto:gilles.renversez@fresnel.fr), [frederic.zolla@fresnel.fr](mailto:frederic.zolla@fresnel.fr)**Address:** Campus de St Jérôme, Av. Escadrille Normandie-Niémen, 13397 Marseille, France**Co-advisor:** Dr. Guillaume Demésy**Titre:** Modelization of the electromagnetic waves in nonlinear, dispersive, anitropic media–Application to the redefinition of effective parameters of nanostructures taking into account the imaginary part of physical parameters.**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 gometries (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 ( $\chi_1$ ,  $\chi_2$ , ...) 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 eigenvalue problem 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 developed 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].

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 attributed in a competitive process consequently only an highly skilled student will be selected.**PhD funding:** 3 years starting in September or October 2020, 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](mailto:gilles.renversez@fresnel.fr) no later than the 12<sup>th</sup> of May 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.
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- [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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