PhD's proposal:

Light scattering-based inverse design of complex optical thin-films with deep neural networks

The design of optical interference filters has been intensely studied over the last decades. Today several powerful and reliable methods (e.g., Needle algorithm) are available to synthetize numerous optical functions. Such design issue in photonics has become a major topic which remains under the spotlights because of its impact on many fields [1].

Usually the design of multilayer filters only concerns specular transmittance and reflectance functions. Taking advantage of the rise of artificial intelligence algorithms, many efforts have been undertaken to implement new methods which could provide other solutions than those obtained with conventional design processes with varying degrees of success [2].

In this context, light scattering properties of thin-films have rarely been taken into account in the design process even though it is well-known that it might be critical for some demanding applications such as space optics. Due to the huge number of parameters to manage, the models for light scattering are far more complex than those of specular properties. Although we developed an electromagnetic theory [3] to solve the direct problem of scattering, today the inverse problem remains a critical unresolved issue.

Recent works carried out in our group proposed the implementation of a light scattering based inverse design method of complex thin-film components using deep neural networks [4]. Given fixed number of layers and refractive indices, our method aims to design components with controlled light scattering levels and acceptable specular properties.

This first set of results is encouraging and highlighted the fact that the control of both specular and scattering properties in complex filters is very challenging. To give an order of magnitude, the last developments led to a spectral optimization of the scattering function for a 20 layers coating, while the objective is to reach a global (angular and spectral) optimization for a coating with several hundreds of layers. The strategy of optimization to solve the inverse problem has to be thought again from scratch on the basis of first lessons learned from this preliminary works. This will be the purpose of this PhD's proposal.

Skills required

Due to its interdisciplinarity nature, this PhD will address several disciplins. The applicant must have an interest and the capabilities to work in these fields: Data processing, Deep learning, Informatics, Mathematics, Physics, Optics, electromagnetism.

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References

[1] Optical Coatings Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2022-2027, ID: 5562453 Report March 2022 , 143 Pages, IMARC Group (link)

[2] R. S. Hegde, "Deep learning: a new tool for photonic nanostructure design," Nanoscale Adv., vol.2, no. 3, pp. 1007–1023, 2020, doi: 10.1039/C9NA00656G

[3] Claude Amra, Michel Lequime, Myriam Zerrad. « Electromagnetic Optics of Thin-Film Coatings: Light Scattering, Giant Field Enhancement, and Planar Microcavities", Cambridge University Press, 2020, ISBN 9781108772372.

[4] Marin Fouchier, Myriam Zerrad, Michel Lequime, Claude Amra. Design of multilayer optical thin-films based on light scattering properties and using deep neural networks. Optics Express, Optical Society of America - OSA Publishing, 2021, 29 (20), pp.32627. ⟨10.1364/OE.437789⟩.