Proposal for a master thesis, 2015

Propagation of electromagnetic waves in dispersive media

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Optical properties of dense matter are subject to the wavelength (or the frequency) of electromagnetic radiation, which results in the unavoidable dispersion phenomenon. For example, in optics, a transparent prism or clouds make the light decomposed into its constituent colours. Number of applications is based on this dispersion phenomenon, for instance the coating of glass surfaces (antireflection, anti UV…) and the transport of information in optical telecommunications, which use filtering properties.
Recently, a major step has been realized with the introduction of metamaterials with their extraordinary effective indices (below unity or negative) and their extremely rich dispersion structures. Potential applications are numerous in the high-tech industry (telecommunications, electronics, defence...), and in the further development of optoelectronics thanks to the reduction of production cost of integrated optical systems (flat lens, filtering, non reciprocity…). Furthermore, metamaterials highlight new situations, denominated in mathematics as "ill-posed" or singular, and where the dispersion is the key to clarify contradictions. These fundamental aspects are addressed in the present master thesis proposal.
Wave propagation in dispersive media is an old question which did not receive significant contributions since the work of L. Brillouin and A. Sommerfeld [1]. The technical difficulty is the presence of a branch cut in the plane of complex frequencies. However, recent advances in knowledge of dispersion and causality principle [2, 3] make it possible to overcome this branch cut, and to make significant progresses in the knowledge of the behaviour of the electromagnetic field in dispersive and absorptive media.
In this proposal, a simple slab made of a homogeneous dispersive material, located in between two parallel plane interfaces, will be analyzed in time domain in both frames of the transient regime and the limiting amplitude principle. The notions of light velocity and electromagnetic energy will be addressed, especially in presence of absorption. This master thesis proposal is a part of a collaboration program which includes the analysis of spatial dispersion and space-time causality, modelling of metamaterials and synthesis of spatial dispersion, numerical modelling of dispersive and absorptive systems.

Keywords: metamaterials, optics, dispersion, causality principle, wave propagation

Additional information :
* Required skills: Fourier analysis, complex analysis, knowledge in wave equations (electromagnetism or acoustics or mechanics or quantum mechanics)
* Miscellaneous: thesis proposal in the frame of a collaboration research program that brings together Institut Fresnel in Marseille, Poems laboratory in Palaiseau, and laboratory Jacques Louis-Lions in Paris 6 university.

References :
[1] L. Brillouin, "Wave propagation and group velocity", Academic Press INC. New York and London (1960).
[2] B. Gralak and D. Maystre, "Negative index materials and time-harmonic electromagnetic field", C. R. Physique **13**, 786 (2012).
[3] M. Cassier, "Etude de deux problèmes de propagation d'ondes transitoires : 1) focalisation spatio-temporelle en acoustique ; 2) transmission entre un diélectrique et un métamatériau", Ecole doctorale de l'Ecole Polytechnique (2014).