Institut Langevin
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Postdoctoral fellowship at Institut Langevin
(1 rue Jussieu, 75005 Paris, France)

Radiative transfer of ultrasonic waves in heterogeneous media

Project managers: Arnaud DERODE (PR Université Paris Diderot - Paris 7, arnaud.derode@espci.fr)
Romain PIERRAT (Scientist CNRS, romain.pierrat@espci.fr)

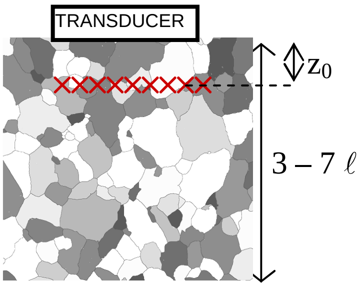
Deadline for applications: December 17th 2012.

Duration : 18 months, starting between February and May 2013

Funding : Agence Nationale de la Recherche, research project DiAMAN (2011-2015)

Scientific context and objectives :

This project deals with the **physics of waves in complex media**. The subject of this study is oriented towards the **physical modelling of the propagation of waves.** The long-term applications of this project are linked to non-destructive evaluation of heterogeneous structures by ultrasound.



An example of the physical problem is depicted on the left. A coherent ultrasonic source, such as a piezo-electric transducer with finite dimensions (yet greater than the wavelength) is put in contact with a heterogeneous medium which is essentially characterized by its mean-free path ℓ. Classically, the transmitted or reflected intensity is determined from transport theory, based on a Radiative Transfer Equation (RTE) or a simple Diffusion Equation (DE) [1,2]. In these approaches, the source is supposed to be intrinsically “incoherent”, and waves are treated as classical particles undergoing a random walk. Assuming that the wavefield becomes diffuse beyond a depth z_0, equivalent incoherent sources (red crosses) can be placed below the surface following the same geometry as the transducer. The DE or RTE can then be resolved, with the appropriate boundary conditions.

Yet in some cases, this simple approach fails. Unlike an actual source (here, the transducer) the proper source term in the RTE is not necessarily localised in time and space. In fact, as the wave is scattered, it progressively transitions from a coherent regime to a fully diffusive one. The first objective of this work is to examine thoroughly, from a theoretical point of view, the passage from the heterogeneous wave equation to a transport-like equation. It should allow **determining the appropriate source term of an acoustic RTE**. To that end, only scalar waves will be considered in a first step and previous works in optics [3] will be adapted to acoustics. The second objective will be to implement a numerical resolution of this acoustic transport equation, in a slab geometry, based on existing numerical codes for optical wave transport. This will allow us to study the early-time evolution of the average acoustic intensity transmitted or backscattered by heterogeneous media with intermediate thicknesses (a few ℓ). The results will be compared to experimental data or numerical simulations of the acoustic wave equation, using a software developed at the Institut Langevin.

The project has a fundamental tone, but has potential applications in the field of non-destructive evaluation of heterogeneous materials by ultrasound. For instance, the spatio-temporal properties of the « structural noise » (i.e., the ultrasonic signals backscattered by structural heterogeneities of a complex medium such as concrete or coarse-grain steel) are not well predicted outside the two opposite regimes $z \ll \ell$ (single scattering) and $z \gg \ell$ (fully diffuse regime). The project will focus on the intermediate regime.

Keywords : waves in complex media, radiative transfer, transport, Wigner transform.

Requirements : knowledge of modelling in wave physics ; motivation and autonomy ; specific numerical or experimental skills in acoustics are welcome.

Short bibliography :

[1] J.H. Page et al , Phys. Rev. E, 52(3), 3106 (1995) ; Z.Q. Zhang et al, Phys. Rev. E, 60(4), 4843 (1999).

[2] G. Ghoshal, J.A. Turner and R.L. Weaver, J. Acoust Soc. Am, 122, 4, (2007); L. Margerin, *Introduction to radiative transfer of seismic waves*, Geophysical Monograph Series,157, chap. 14, AGU (2005).

[3] R. Pierrat, *Propagation et émission du rayonnement diffusant: application à l’imagerie des milieux complexes*, Thèse de doctorat, Ecole Centrale (2007) ; C. Henkel, *Radiative transfer and atom transport*, http://arxiv.org/abs/physics/0505023v1.