Laboratoire d'Acoustique
Le Mans Université · CNRS · UMR 6613

Institut d'Acoustique Graduate School
Le Mans Université

M2 internship

Feb. - July 2025

(open PhD position, Fall 2025)

Wavefront shaping in periodic and disordered waveguides

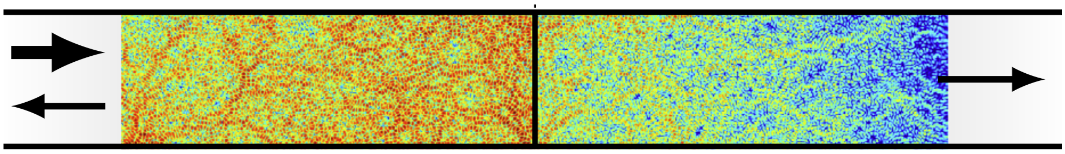

Figure 1: Transmission through a disordered waveguide. Source: [1]

Context and Objectives: Controlling the wave propagation in complex media has long been a major challenge for imaging natural or artificial materials in which disorder induces a strong and complex scattering of the waves. The last 15 years, however, have seen a major change with the development of wavefront shaping techniques, enabling a fine control of the transport through complex media, with experimental evidences of optimal transmission through opaque media, controled focusing of the transmitted field or inside the material, etc. Wavefront shaping techniques are based on control of the incident wavefront and have been extensively studied in optics [2]. Although the problems of imaging and information transport in complex environments are also of great interest in the field of audible acoustics, such wavefront manipulation techniques are not yet well developed.
As an answer, the proposed internship aims at investigating wavefront shaping for controlling the wave transport through complex, periodic or disordered, acoustic waveguides. Such research work will be made possible using the *MAINE Flow* experimental facility developed at LAUM. It consists in a rectangular duct facility instrumented with two sets of 90 acoustics sources and 60 microphones, allowing both a fine control of the multimodal field generated in the duct and the measurement of the scattering matrix of a waveguide element with up to 25 cut-on modes [3]. Being able to both control the wave field and precisely measure the scattering matrix indeed opens up many

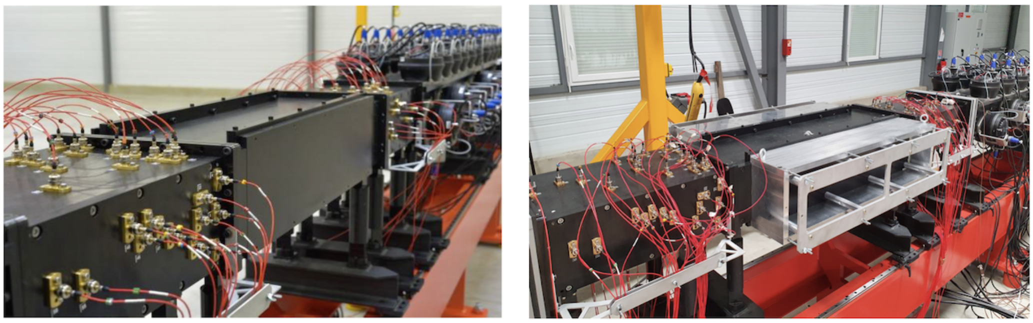

Figure 2: *MAINE Flow* experimental facility

opportunities for research, since the scattering matrix and its algebraic properties are particularly relevant descriptors of the properties of complex media and of the possibility of controlling wave transport, as the following examples illustrate:

- anti-reflection structures that allow to improve greatly the transmission when put in front of complex arrangement of reflecting scatterers [4];

- scattering invariant modes provided by the measurement and post-processing of transmission matrices and whose transmitted pattern is the same, irrespective of whether they scatter through a disordered sample or propagate through a homogeneous medium [5];
- principal modes that are eigenvectors of the Wigner-Smith time-delay operator and that do not suffer from modal dispersion, such that the output-field pattern does not vary with frequency [6].

Besides, following research recently conducted at LAUM, the student can also contribute to the investigation on symmetry-induced or disorder-correlation effects in the transport through complex waveguides [7, 1, 8].
While some scattering problems will be addressed through numerical modeling, this research places significant emphasis on experimentation. During this period, the student will acquire knowledge about the tools and concepts underpinning modal decomposition and wavefront shaping. It is undeniable that the implementation of these tools in *MAINE Flow*, which already possesses capabilities for modal control and modal decomposition, will open up exciting avenues for sound field control. Using the *MAINE Flow* facility will also enable investigating the scattering matrix properties and the possibilities for wave control in the presence of losses, inherent to audible acoustic waves, and in the presence of flow (precisely regulated in this facility), notably breaking reciprocity.

Profile: We are looking for a student enrolled in a master's degree in physics, mechanics, acoustics or related fields, with a taste for wave physics, and motivated by experimental research in fundamental physics. They will develop skills in both modeling and experimentation. This internship may lead to a PhD position, starting from Fall 2025 (application before March 2025).

Location and Environment: The student will conduct their research at the Laboratory of Acoustics of Le Mans University (LAUM, Le Mans, France), which specializes in acoustics and wave physics. They will join the *Acoustic Propagation and Materials with Flow* and *Waveguides and Lattices* groups, focusing on the propagation of waves in complex waveguide systems.

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References

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[5] Pritam Pai, Jeroen Bosch, Matthias Kühmayer, Stefan Rotter, and Allard P Mosk. Scattering invariant modes of light in complex media. *Nature Photonics*, 15(6):431–434, 2021.

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