



Invariance of the transmitted field in a periodic waveguide

E Salemeh, S Félix, V Pagneux

► To cite this version:

E Salemeh, S Félix, V Pagneux. Invariance of the transmitted field in a periodic waveguide. The 13th International Conference on Metamaterials, Photonic Crystals and Plasmonics, Jul 2023, Paris, France. pp.2. <hal-04804651>

HAL Id: hal-04804651

<https://hal.science/hal-04804651v1>

Submitted on 26 Nov 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY 4.0 - Attribution - International License

Invariance of the transmitted field in a periodic waveguide

E. Saleme^{*}, S. Félix and V. Pagneux

Laboratoire d'Acoustique de l'Université du Mans LAUM – UMR CNRS 6613, France
elie.saleme^{*}@univ-lemans.fr^{*}

Abstract: A characteristic of the localized regime in a disordered medium is the insensitivity of the transmitted speckle pattern to the incident wave. We show that a similar phenomenon is possible in an ordered, periodic medium, when the wave is mainly carried by a dominant Bloch mode. The work presented aims to characterize this phenomenon in the case of propagation in a periodic acoustic waveguide.

Among the many striking wave phenomena that arise in disordered media and explain undiminished interest in this field of wave physics over decades [1, 2] the single channel regime is quite remarkable. Since the ratio between successive transmission eigenvalues (TEVs) is large in the localized regime, the first (largest) one dominates all others, hence the corresponding eigenchannel in the transmission problem. A consequence is that “*the speckle pattern of the transmitted intensity is literally frozen*”, that is, at a given frequency, the speckle pattern is independent of the incidence conditions. Note that it was experimentally evidenced (as well as the crystallization of the TEVs) by Shi and Genack with microwaves [3] and later numerically investigated in optics in a two-dimensional medium, and used to probe Anderson localization in a single configuration of this medium [4]. Although this phenomenon is understood as being characteristic of the localized transport, the medium-induced reduction of the transmission problem to a rank-1 matrix is not intrinsically related to disorder and can be observed in other contexts, in particular in regular media. In this work, we show that the transmitted pattern through a periodic medium, though complex, can be *frozen* under proper conditions. The first condition corresponds to a frequency located in a band gap in the periodic medium: no Bloch-Floquet mode is propagating. This case is similar to the case of localized transport: a single channel dominates the transmission. An example of such an evanescent transmission is shown in [Figure 1(a)].

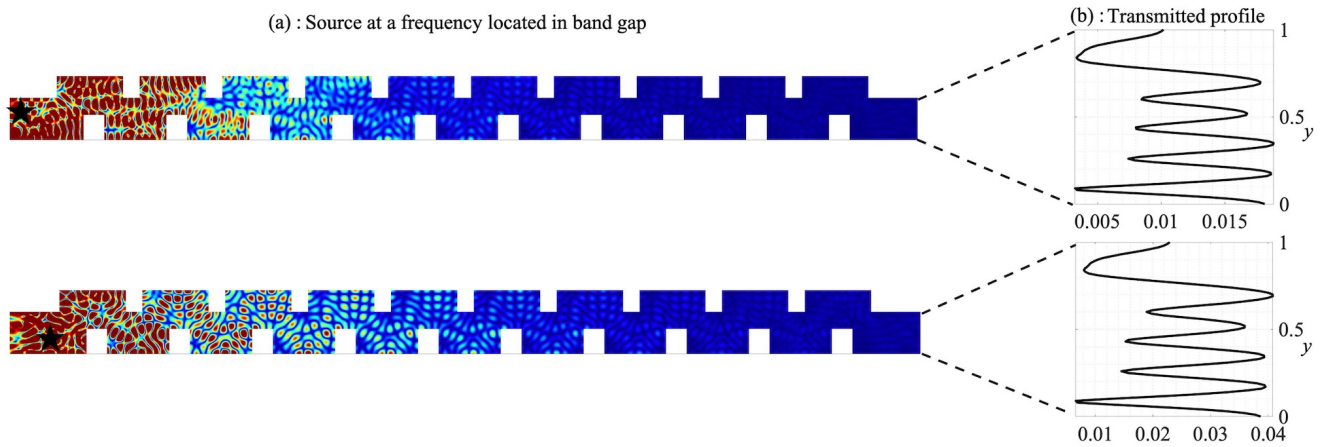


Figure 1 (a) Normalized absolute value of the field in a periodic wave guide which is excited by a source at two different positions at a frequency located in a band gap. (b) Comparison of the absolute value of the transmitted profile.

A point source (★) at a frequency located in a band gap is located in the left lead at two different positions. While the excitation, hence the incident wave, is modified from one case to the other, the pattern of the transmitted field is almost the same [Figure 1(b)]. Computing the wavefield (solution of the Helmholtz equation) in the whole waveguide allows us to go further than the only analysis of

the transmitted pattern. We can already observe the strong decrease of the amplitude but, above all, the progressive freezing of the wave pattern as we move away from the source. Thus, the transmission in a band gap of a periodic waveguide displays characteristics which, although resulting from different mechanisms, are similar to those of a Anderson-localized medium, and therefore lead to the freezing of the wave pattern.

However, the periodic system makes possible another regime of single channel transport, which cannot be observed in the disordered case. This is the case where the first TEV dominates all others without being itself small, this case corresponds to a frequency located in a region when a single Bloch-Floquet mode is propagating. It is then possible to freeze the transmitted pattern, without the counterpart of having a very low energy transmission. An example of freezing of a propagating field is shown in [Figure 2].

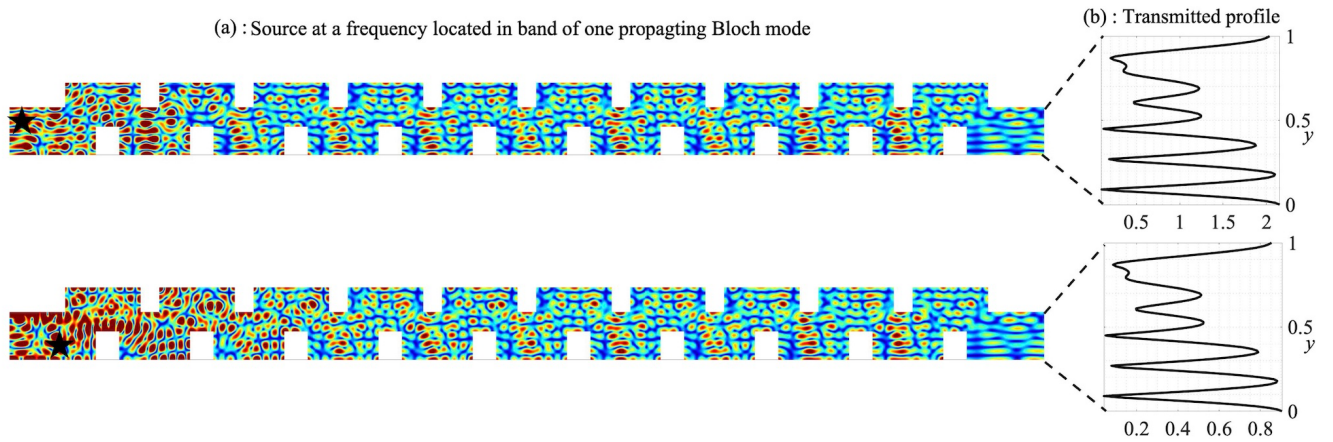


Figure 2 (a) Normalized absolute value of the field in a periodic wave guide which is excited by a source at two different positions at a frequency located in a band of one propagating Bloch mode. (b) Comparison of the absolute value of the transmitted profile.

References

- [1] Rotter S. and Gigan S., "Light fields in complex media: Mesoscopic scattering meets wave control," Rev. Mod. Phys., vol. 89, p. 015005, 2017.
- [2] Beenaker C.W., "Random-matrix theory of quantum transport," Rev. Mod. Phys., vol. 57, p. 731, 1997.
- [3] Shi Z. and Genack A. Z., "Transmission eigenvalues and the bare conductance in the crossover to Anderson localization," Phys. rev. Lett., vol. 108, p. 043901, 2012.
- [4] Leseur O., Pierrat R., Sáenz J. and Carminati R., "Probing two-dimensional Anderson localization without statistics," Phys. Rev. A, vol. 90, p. 053827, 2014.