WAVE CONTROL VIA SCATTERING: FROM SPATIAL TO SPACE–TIME INTERFACES

Abstract:

Wave scattering in structured and time-modulated media provides a versatile framework for controlling energy transport beyond the limits of conventional materials. By combining spatial design with temporal variation, it becomes possible to tailor how waves propagate, interact, and exchange energy across a wide range of scales. In structured media, geometric features and material heterogeneity govern dispersion, polarization, localization, and directionality. In time-modulated systems, variations in material properties introduce additional degrees of freedom, enabling phenomena such as frequency conversion, non-reciprocal behaviour, and dynamic energy redistribution.

This thesis presents a broad investigation of wave control strategies that draw on both spatial structuring and temporal modulation, addressing practical design applications as well as more fundamental physical phenomena.

In the first part, arrays of coupled resonators are employed to manipulate the propagation of surface waves induced by low frequency ground vibrations.

Building on similar design principles in acoustics, a sound absorbing panel is then developed for room acoustic applications.

The third considered example examines elastic wave mode conversion in corrugated beams, showing how a nominally homogeneous structure can, through geometric modification, couple longitudinal and bending waves.

The final part of the thesis focuses on more fundamental aspects of mechanics related to the interaction of waves with space-time interfaces. The propagation

of a continuous deformation within a material is considered, giving rise to a moving transition front between distinct deformation states. The interaction between this front and propagating waves is analyzed, highlighting the underlying mechanisms of energy exchange in dynamically evolving media.

Overall, this work shows that wave control can be systematically achieved through the engineering of scattering across space and time. From practical implementations in vibration mitigation and acoustic absorption to geometry-driven mode conversion and wave interaction with space–time interfaces, the results demonstrate a unified framework for manipulating wave propagation and energy transport. This approach provides both effective design strategies and a deeper understanding of wave–matter interactions in structured and dynamically evolving media.