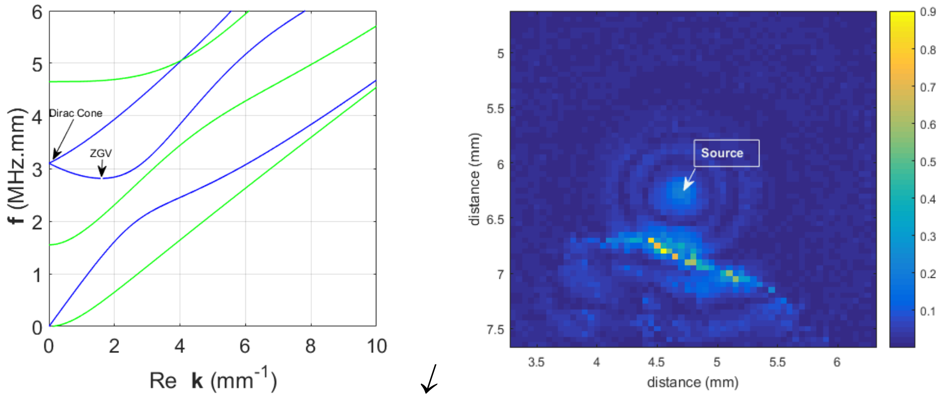
MASTER INTERNSHIP PROPOSAL

Title : Trapping waves in axially varying elastic waveguides.

Summary : Elastic waveguides support the propagation of highly dispersive modes resulting from the coupling of compression and shear waves at the interfaces. Notably, negative phase velocity modes known as "backward wave" and zero group velocity (ZGV) modes exist in simple homogeneous and isotropic waveguides (Fig. Left). We have clearly observed these modes in uniform guides using laser ultrasound techniques [1][2]. Although waveguides with axially varying properties, whether natural or manufactured, are common, propagation in the vicinity of the ZGV frequency has little been explored. An example is the cochlea, a cylindrical guide whose geometric and elastic characteristics vary along a few tens of millimeters with fascinating filtering properties [3]. The understanding of backward and ZGV modes in such guides is therefore of both fundamental and applied interest.



Figures Left: dispersion of symmetric and antisymmetric lamb modes in an aluminum plate. The second symmetrical branch supports a ZGV mode and a Dirac cone. On the right, preliminary experiment trapping of a wave at the ZGV frequency..(courtesy of François Legrand)...

The objective is to observe the behavior of backward and ZGV modes when the properties of the guide, such as cross-section or elastic constants, slowly vary along the axial direction. Through numerical and experimental studies, the impact of axial variations on the ZGV resonance will be studied. Trapping effects that may occur beyond a critical thickness corresponding to a ZGV mode (a model for tonotopy, a characteristic of the inner ear) will also be investigated (Fig right). Non-contact ZGV displacement field and resonance measurements will be performed by laser ultrasonic. For example, an axial elasticity gradient will be produced in a uniform guide by a temperature gradient. Experimental results will be compared to numerical simulations obtained by finite element method using COMSOL Multiphysics software.

[1] "Laser impulse generation and interferometer detection of zero-group velocity Lamb mode resonance", Clorennec, & al. Appl. Phys. Lett., (2006); "Imaging gigahertz zero-group-velocity Lamb waves", Xie & al. Nature comm. (2019).
[2] "Focusing on plate: Controlling guided waves using negative refraction", Philippe, & al. Scientific Reports (2015); "Negative reflection of elastic guided waves ", Gérardin, & al., Scientific Reports, (2019).
[3] "Mode conversion in the cochlea?", Robert S. MacKay, Trans. of Math. and its App. (2017) , and references therein.

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