Localization and non-reciprocity in nonlinear dissipative lattices

Alireza Mojahed[1], Oleg V. Gendelman[2] and Alexander F. Vakakis[1]

[1]University of Illinois at Urbana-Champaign
Urbana, USA
mojahed2@illinois.edu

[2]Technion – Israel Institute of Technology
Haifa, Israel
ovgend@technion.ac.il

Abstract The effect of on-site damping and other physical parameters on breather arrest, energy localization and non-reciprocity in strongly nonlinear semi-infinite lattices is studied. The study is performed for two lattices: (i) a strongly nonlinear uniform semi-infinite lattice and, (ii) an asymmetric strongly nonlinear hierarchical semi-infinite lattice. A more detailed presentation of these results are given in (Mojahed et al., 2018).

Breathers are localized oscillatory wavepackets formed by nonlinearity and dispersion, and breather arrest refers to breather decay and disintegration over a finite "penetration depth" in a dissipative lattice. First, a simplified system of two nonlinearly coupled oscillators under impulsive excitation is considered. The exact relation between the finite number of nonlinear beats (energy exchanges between oscillators), the magnitude of excitation, and the on-site damping is derived. In the next step, these results are correlated to those of the semi-infinite extension of the simplified system, and it was found out that the breather penetration depth is governed by a similar law to that of the finite beats in the simplified system. The comparison between the characteristic curves (corresponding to disappearance of modulated response after a specific finite number of beats) and breather penetration depths is demonstrated in figure 1. The comparison reveals that the 2DOF reduced order model is able to represent the general breather arrest phenomenon in the semi-infinite uniform lattice.

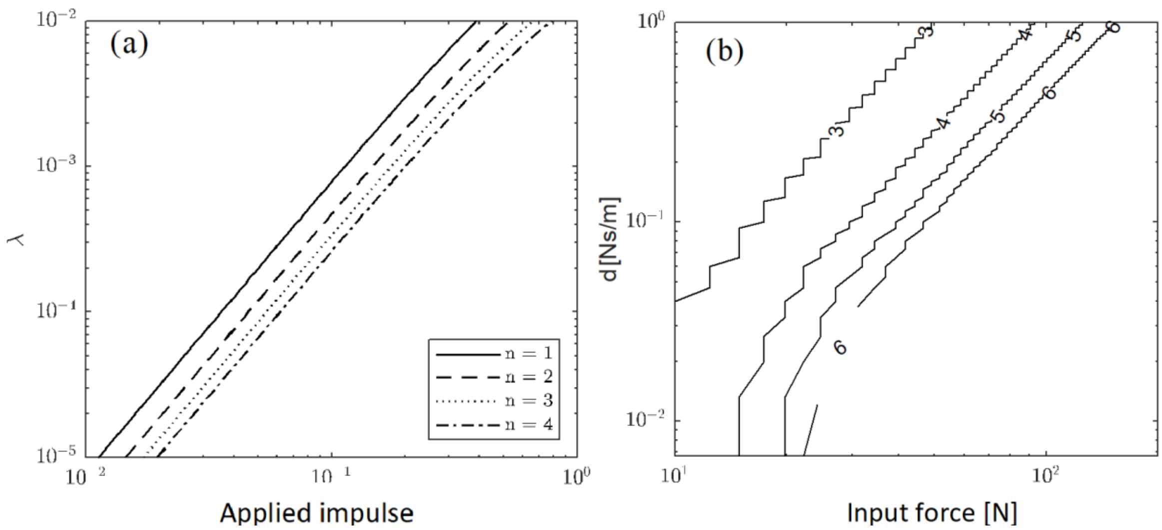

Figure 1: (a) Characteristic curves for specific maximum number of beatings and (b) breather penetration depths in the semi-infinite homogeneous lattice in the parameter space corresponding to (damping-excitation level) in logarithmic scales.

Similarly, for the second nonlinear lattice, energy localization and acoustic non-reciprocity are studied. Due to asymmetric nature of the lattice, depending on from which end the lattice is being excited, one can see energy localization at the excitation site or wave propagation through the lattice from the excitation site. In studying energy localization in this lattice, a very interesting observation in this system is that when the nonlinear coupling stiffness elements are considered non-linearizable, energy localization occurs on the opposite end of the lattice when compared to the similar lattice but with linearizable (small linear stiffness in parallel with the nonlinear stiffness) nonlinear coupling stiffness elements. Figure 2 illustrates the energy localization site for both of the discussed cases, i.e. non-linearizable and linearizable nonlinear coupling.

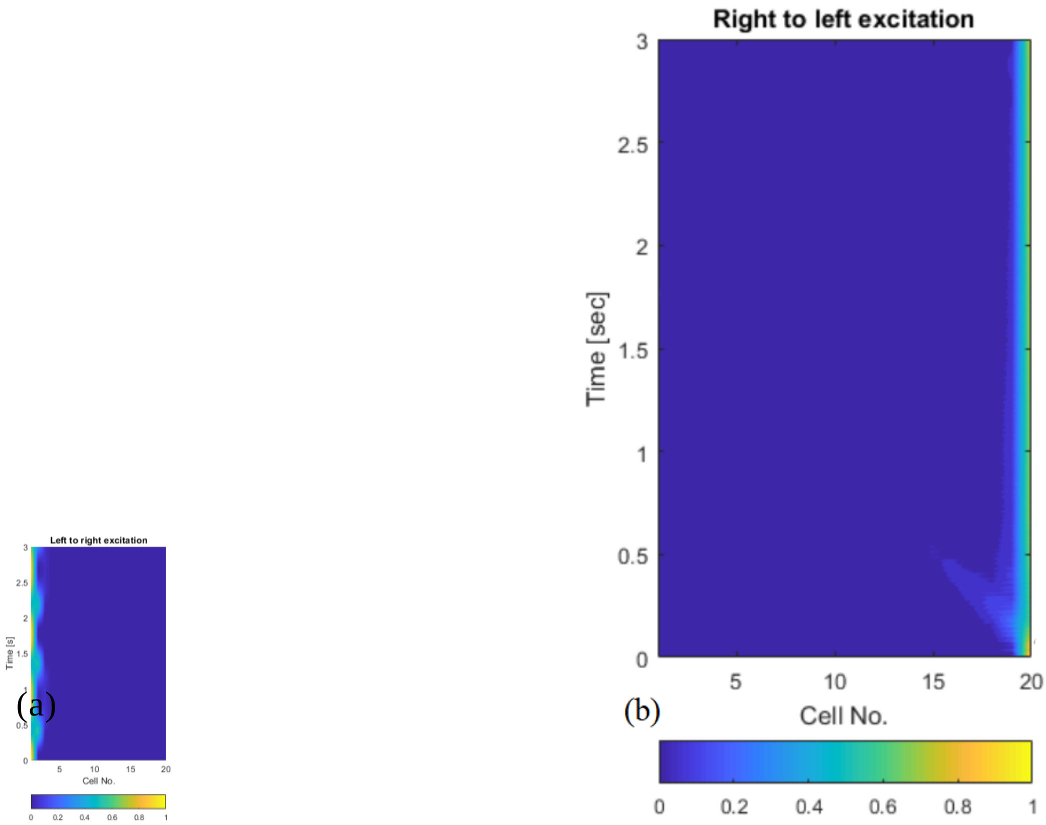

Figure 2: (a) Energy localization on the left end of the lattice (non-linearizable nonlinear coupling). (b) Energy localization on the right end of the lattice (linearizable nonlinear coupling)

The effect of the small linear component in the nonlinear coupling stiffness on the inversion of energy localization site is fully explained through studying the governing nonlinear normal modes (NNMs) [1], of the lattice and the exploring the localized NNMs of this system and their interactions with the nonlinear propagation zones of the lattice.

References

[1] Kerschen, G., Peeters, M., Golinval, J. C., Vakakis, A. F., *Nonlinear normal modes, Part I: A useful framework for the structural dynamicist*, Mechanical Systems and Signal Processing 23.1, 170-194, 2009.

[2] Mojahed, A., Gendelman, O.V., Vakakis, A.F., *Breather arrest, localization and acoustic non-reciprocity in dissipative nonlinear lattices*, Journal of Acoustical Society of America (Special Issue on Non-reciprocal and Topological Wave Phenomena in Acoustics) (submitted).