Towards low frequency 3D broadband filters via elastic metamaterials

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Periodic structures find numerous applications in physics and engineering domains due to their peculiar properties in wave guiding and filtering. A major example in the electromagnetic field is represented by photonic crystals [1], while their counterparts for acoustic and elastic waves are the so-called phononic crystals [2]. Focusing on elastic periodic structures, the frequency range of applications is wide: from extremely high frequencies, i.e. THz region for heat transmission [3], to few Hz in the *seismic metamaterials* domain, often taking the most from locally resonant mechanisms [4, 5, 6]. Among the others, the bandgap (i.e. the frequency range of prevented wave transmission) is one of the most investigated properties: a wide and complete bandgap is generally beneficial to guarantee robust wave attenuation around a certain frequency [2]. In many cases, a complete bandgap is obtained by a periodic arrangement of two or more materials [2, 7], but significant results can also be achieved for a single material [8], among which the one endowed with a very large complete bandgap that the authors show in a previous work [9].

In general, periodic structures endowed with bandgap exhibit attenuation in the transmission spectrum of the finite structure in correspondence of the bandgap frequency range [2, 7, 8, 9]. Conversely, the design presented in this work is such that the transmission spectrum of the finite structure is typical of a low-pass mechanical filter: the attenuation starts in correspondence of the bandgap bottom limit, and it proceeds beyond the bandgaps top limits, merging the subsequent bandgaps. The bandgaps merging is confirmed by both numerical calculations and experimental tests on a finite prototype. Additionally, a comparison with a prototype of a homogeneous solid cube of the same material, production process and dimensions is carried out to highlight the differences between the proposed design and the bulk material.

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