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MESO-SCALED PHOTONICS MEET ECOLOGICAL MONITORING OF HARMFUL IMPURITIES

Detecting and identification of ecologically harmful impurities subject into media matrix still among important subject of environmental safety technologies.

Among others the problem of wave scattering by impurities could be invited along this way. We study a wave transport in strongly precompressed granular chains which reflect some characters of impurities spectral monitoring [1,2]. We explore the linear scattering of plane waves and identify a closed-form expression for the reflection and transmission coefficients for the scattering of the waves from both a single impurity and a double impurity. For single-impurity chains, we show that, within the transmission band of the host granular chain, high-frequency waves are strongly attenuated (such that the transmission coefficient vanishes as the wave number $k \to \pm\pi$), whereas low-frequency waves are well-transmitted through the impurity. For double-impurity chains, we identify a resonance – enabling full transmission at a particular frequency – in a manner that is analogous to the Ramsauer–Townsend (RT) resonance from quantum physics. We also demonstrate that one can tune the frequency of the RT resonance to any value in the pass band of the host chain. We corroborate our theoretical predictions both numerically and experimentally, and we directly observe complete transmission for frequencies close to the RT resonance frequency. Finally, we show how this RT resonance can lead to the existence of reflectionless modes even in granular chains (including disordered ones) with multiple double impurities.

One-dimensional (1D) granular crystals (i.e., granular chains) consisted of closely packed chains of elastically colliding particles has been used as a setup for the investigation of wave phenomena in chains of strongly nonlinear oscillators, and the interplay between nonlinearity and discreteness in granular chains has inspired the exploration of a diverse set of coherent structures, including traveling waves, breathers, and dispersive shock waves [3–5].

Our study paves the way for a systematic study of the properties of Ramsauer–Townsend resonances in granular crystals. One could study such resonances in the context of more impurities, or more systematically in the case of (ordered or disordered) distributions of impurities in such granular media. One possible application of RT resonances in granular crystals is embedding foreign objects, such as sensors, in systems so that they induce minimal interference with the existing structures. It is also of considerable interest to explore disordered granular crystals, rather than merely placing a disordered segment in otherwise homogeneous chains.

We plan to apply analysis which given vide supra for developing of algorithms of detection and identification of structure and dynamics of the impurities subject into matrix system in particular in the case of relevant environmental problems (for instance for monitoring of intruders incorporated inside of large massive conglomerations of granules). Connection of relevant spectral characters with the types of nonhomogenities and their structurization will be an output of such approach. Such efforts are currently in progress.

References

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