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Phonons in composite nanostructures: an analytic approach

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At the micro and nanoscale properties of materials qualitatively differ from the bulk, that requires new methods and approaches for their understanding. Phonons, as quanta of mechanical vibrations, play an important role in this change also due to their ability to interact with other kinds of excitations in solids and propagate in various media. Description of confined composite structures is significantly simplified within a new approach. For instance, in a confined bilayered system the number of variables to be solved for is halved compared to standard methods of the theory of elasticity. It then becomes possible to grasp the characteristics of the vibrational spectrum in the full range of material parameters when the wavelength is larger than the thickness of the layered structure. The analytic solution reveals unexpected trends which are difficult to detect in numerical or experimental studies due to complicated dependence on material parameters. Thus, a large number of vibration modes, including the fundamental one (flexural Ryleigh-Lamb type), depend on the thickness of the added layer in a strongly non-monotonous way: by increasing the thickness of added layer one may have the same propagation velocity for up to three different values of layer thicknesses ratio. The spectrum of composite plate resonances is far from equidistant and changes in a strongly non-monotonous way with parameters (elastic constants, densities, etc.). The approach can be useful for engineering the vibrational properties of layered composite structures.

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