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Nonharmonicity in vibrated granular solids

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We have shown that granular packings composed of frictionless particles with repulsive contact interactions are strongly nonharmonic. When infinitesimally perturbed along linear response eigenmodes of the static packing, energy leaks from the original mode of vibration to a continuum of frequencies due solely to contact breaking even when the system is under significant compression. Further, vibrated packings possess well-defined equilibrium positions that are different than those of the unperturbed packing. The vibrational density of states obtained using the displacement matrix and velocity autocorrelation function methods exhibit an increase in the number of low-frequency modes over that obtained from linear response of the static packing. The form of the density of states in vibrated granular packings is reminiscent of the low-frequency behavior of the vibrational density of states in fluid systems. We also investigate the effects of inter-particle friction, dissipation, particle shape, and degree of positional order on the density of states and thermal transport properties in driven granular packings.