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Thermomechanical behavior of surface acoustic waves in ordered arrays of nanodisks studied by near-infrared pump-probe diffraction experiments and finite element simulations

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The ultrafast thermal and mechanical dynamics of a two-dimensional lattice of metallic nanodisks has been studied by near-infrared pump-probe diffraction measurements over a temporal range spanning from 100 fs to several nanoseconds. The experiments demonstrate that in these systems a surface acoustic wave (SAW), with a wave vector given by the reciprocal periodicity of the two-dimensional array, can be excited by ∼120 fs Ti:sapphire laser pulses. We unambiguously show that the observed SAW velocity shift originates from the mechanical interaction between the SAWs and the nanodisks, while the correlated SAW damping is due to the energy radiation into the substrate. In order to clarify the interaction between the nanodisks and the substrate, numerical calculations of both the elastic eigenmodes and the time-dynamics of the system, following the impulsive heating excitation by the laser, are performed. Simulations based on finite-elements analysis, together with a wavelet analysis of our experimental data, suggest the opening of a band-gap at the centre of the super-Brillouin zone. The modes at the centre of the super-Brillouin zone are excited following laser excitation, as opposed to thermal population, of the elastic modes.