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Generation and Propagation of Coherent Phonon Beams

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Narrow coherent beams of longitudinal acoustic waves are injected into a single crystal of $PbMoO_4$ at gigahertz frequencies, and their properties are observed by means of Brillouin scattering (Figure 1). The waves are generated via the thermoelastic strain that results from periodic surface heating of a thin metallic transducer by interfering cw dye lasers. Frequency tuning is achieved simply by varying the optical difference frequency. A model based on heat diffusion and thermoelastic expansion agrees with the observed frequency dependence of the acoustic intensity, inclusive of acoustic resonances within the transducer, as well as its quadratic dependence on the laser power.

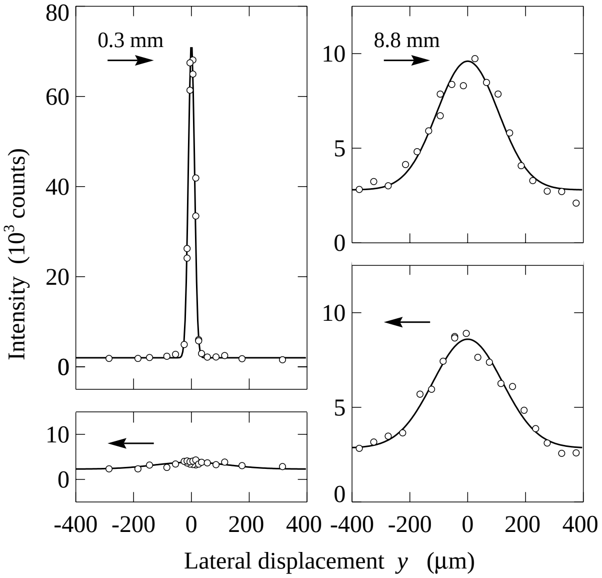

Figure 1. The intensity profile of the acoustic wave close to the transducer (z = 0.3 mm) and close to the end face of the 10-mm long crystal (z = 8.8 mm). Anti-Stokes Brillouin scattering measures the wave traveling away from the transducer (→), and Stokes scattering the wave reflected from the end face (←). The phonon frequency is 4.1 GHz. The temperature is 2.1 K. The solid lines are Gaussians.

The propagation of the acoustic beams is found to be governed by Fresnel diffraction provided due account is taken of phonon focusing. The beam furthermore is responsive to the phase profile over the laser-illuminated area, which allows to manipulate the beam in various ways, such as modifying its divergence as if an acoustic lens were positioned just below the transducer, or sweeping the beam sideward by a moving grating. Combined with Brillouin detection, distinguishing between phase and group velocities, this makes possible a direct measurement of phonon focusing.

The decay of the acoustic beam with the distance is furthermore measured at various frequencies, to confirm Herring's asymptotic theory for anharmonic phonon decay in anisotropic crystals. Finally, the beam is passed through a Ag-Au superlattice inserted between the transducer and the crystal, to find that the transmission drops to order one percent in well-defined stop bands.