Real time imaging and dispersion of surface phonons

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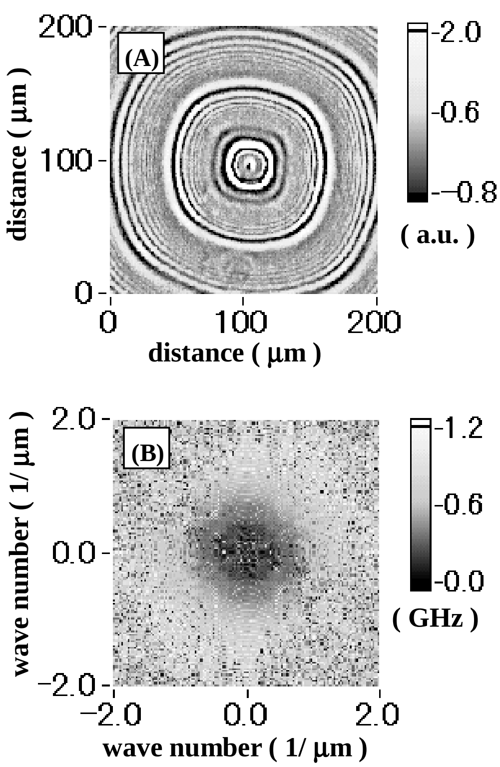
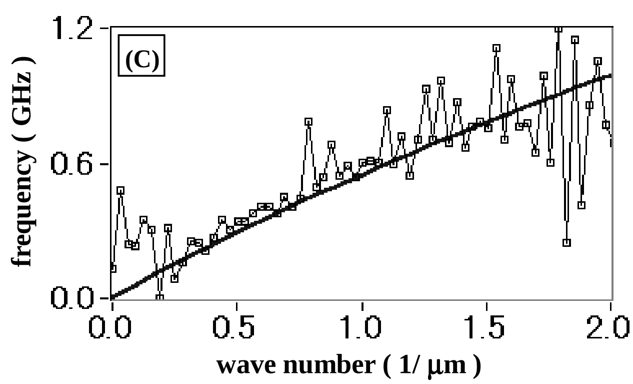
Surface phonon propagation in anisotropic thin film structures displays beautiful and complex wavefronts. However, in spite of the diverse applications of surface acoustic waves, real time two-dimensional imaging of MHz-GHz surface phonon propagation has not been demonstrated effectively. Using an interferometic optical pump and probe technique, we have imaged the propagation of surface phonons at frequencies up to 1 GHz in real time, allowing movies of their wavefronts to be made with picosecond temporal and micron spatial resolution. We image the propagation in a variety of thin film structures, and in particular for Au films on the cubic crystal LiF, and show how the dispersion relation can be directly derived from such movies.

The image (A) shows the measured optical phase change, proportional to the surface displacement, at a given moment in time for the (100) surface of a single crystal of LiF coated with a Au thin film of nominal thickness 30-50 nm. The surface phonon wavefronts, excited every 12 ns from a 2 μm diameter optical spot of wavelength 415 nm and duration 700 fs, are broadened and split by dispersion that depends on the product of the film thickness and the phonon wave number. The image (B) shows the dispersion relation calculated from the Fourier transforms of three optical phase change images at different times. The graph (C) shows the dispersion relation obtained from the [010] direction in (B) together with a theoretical fit assuming a gold film thickness of 50 nm Good agreement is obtained.





Figures (A)-(C) show results for surface phonon propagation in the (100) plane of LiF coated with a Au thin film. (A) Experimental optical phase change snapshot. (B) Experimental dispersion relation calculated from three snapshots at different times. (C) Dispersion relation for the [010] direction: dots are experimental data obtained from the data for the (horizontal) [010] direction in (B). The smooth solid line is a theoretical fit.