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Ultrafast generation of coherent shear phonons in halide perovskites via anisotropic photostriction

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Optically generated sub-THz coherent acoustic phonons exhibit significant potential for controlling and manipulating various material properties. Halide perovskite semiconductors, such as lead-free double $Cs_2AgBiBr_6$, are particularly interesting for these purposes due to cubic to tetragonal phase transition and strong polaron effects. Using time-domain Brillouin spectroscopy, we demonstrate the efficient generation of coherent transverse acoustic phonons in the tetragonal phase of $Cs_2AgBiBr_6$ with amplitudes comparable to the longitudinal ones. Notably, only one of the two TA modes is selectively excited, demonstrating a sharp temperature dependence of sound velocity near a structural phase transition at approximately 122 K. In cubic phase, at the temperature above structural phase transition $T > 122$ K, only longitudinal phonons are observed. The polarization of photoinduced transverse phonons in tetragonal phase is dictated by the projection of the c-axis on the surface plane, which leads to a prominent anisotropic polarization response in the detection.

The shear strain generation mechanism relies on anisotropic photostriction of crystal lattice and should be present in large variety of perovskites materials with tetragonal crystal symmetry. Anisotropic photostriction is directly related to the strong interaction of electrons with optical phonons in combination with crystallographic phase transition. Our findings highlight halide perovskites as promising materials for developing active hypersonic devices with tunable frequency and polarization of acoustic phonons.