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Lattice-level measurement of material strength with LCLS during ultrafast dynamic compression DESPINA MILATHIANAKI, SEBASTIEN BOUTET, DANIEL RATNER, WILLIAM WHITE, GARTH WILLIAMS, SLAC National Accelerator Laboratory, ARIANNA GLEASON, Stanford University, DAMIAN SWIFT, Lawrence Livermore National Laboratory, ANDREW HIGGINBOTHAM, JUSTIN WARK, Oxford University — An in-depth understanding of the stress-strain behavior of materials during ultrafast dynamic compression requires experiments that offer in-situ observation of the lattice at the pertinent temporal and spatial scales. To date, the lattice response under extreme strain-rate conditions ($> 10^8$ s^{-1}) has been inferred predominantly from continuum-level measurements and multi-million atom molecular dynamics simulations. Several time-resolved x-ray diffraction experiments have captured important information on plasticity kinetics, while limited to nanosecond timescales due to the lack of high brilliance ultrafast x-ray sources. Here we present experiments at LCLS combining ultrafast laser-shocks and serial femtosecond x-ray diffraction. The high spectral brightness ($\sim 10^{12}$ photons per pulse, ΔE/E=0.2%) and subpicosecond temporal resolution ($<$ 100 fs pulsewidth) of the LCLS x-ray free electron laser allow investigations that link simulations and experiments at the fundamental temporal and spatial scales for the first time. We present movies of the lattice undergoing rapid shock-compression, composed by a series of single femtosecond x-ray snapshots, demonstrating the transient behavior while successfully decoupling the elastic and plastic response in polycrystalline Cu.

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