Real-time 3D imaging of multi-scale material dynamics

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Hard x-ray microscopy is a new way to three-dimensionally map strain and structure in crystalline matter. It combines complementary imaging techniques to seamlessly switch between fast overviews of a material's structure and detailed maps of individual structural elements. At the smallest scales, an X-ray objective lens is used to generate full-field magnified images from either the transmitted (bright-field) or Bragg diffracted (dark-field) X-rays. In this sense, it is analogous to a transmission electron microscope, albeit one that leverages the penetrating power of hard X-rays to see orders of magnitude further into samples. This capability is demonstrated on a range of problems, including how sub-grains in metal structures re-organize during annealing, how strain fields in ferroelectric crystals influence their functionality, and biomineralization. Spatial resolution is approximately 100 nm, however the ESRF-EBS is expected to improve this ten-fold, while making experiments hundreds or even thousands of times faster. This ability to directly characterize complex, multiscale phenomena in-situ is a key step toward formulating and validating multi-scale models, overcoming a major hurdle in the computational design of materials.