

A hard x-ray diffraction microscope at an XFEL: a new paradigm for bulk materials

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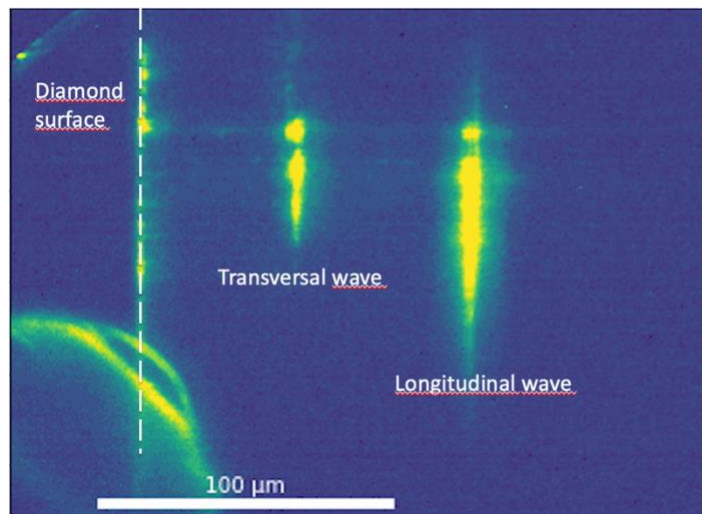
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Materials science often involves samples that are structured on many length scales in a hierarchical way. Associated with this are competing dynamics spanning many time scales. Probing these simultaneously is notoriously difficult as most probes are destructive. The dark field x-ray microscope, DFXM, at ESRF is designed to zoom into bulk materials and visualise the local structure evolution *in situ* – and in 3D. The microscope probes the diffracted beam, giving contrast to phases, orientations and strains. In this way unique movies can be made of the self-organisation of grains, domains and dislocations. The spatial resolution is at best 30 nm, the time resolution at a synchrotron is milliseconds.

Having summarised the basics of DFXM, I will present results from an ad hoc set-up made at LCLS where the method was combined with a pump-probe scheme, thereby improving the time resolution by 10 orders of magnitude. As a proof-of-concept 3D movies were made of strain waves in diamond. The S/N of each pulse is sufficient to provide good contrast. The interaction of the strain waves with defects was explored.

Next I will present the science case for a DFXM set-up at a hard x-ray beamline at the European XFEL. A prime science case will direct visualisation of stochastic and **irreversible** phenomena such as nucleation events, dislocation movements and phase transformations, which are well matched to the time structure of the European XFEL. This will be illustrated for the case of Martensitic transformations. Moreover, I will discuss options for acquisition of 3D information from a single shot, such as Compton cameras.



Phonon photography: snapshot from a movie of sound waves emitted into the interior of a diamond single crystal using a pump probe DFXM set-up at LCLS. The time lapse from the pump pulse is 6.0 ns.

References : H. Simons *et al.* (2015). *Nature Comm.* **6**, 6098 ; H.F. Poulsen. Multi scale hard x-ray microscopy. *Cur. Opinion Solid State Mater. Sci.* (2020) **24**, 100820

