High-energy *in-situ* dynamic imaging of shock-compressed materials

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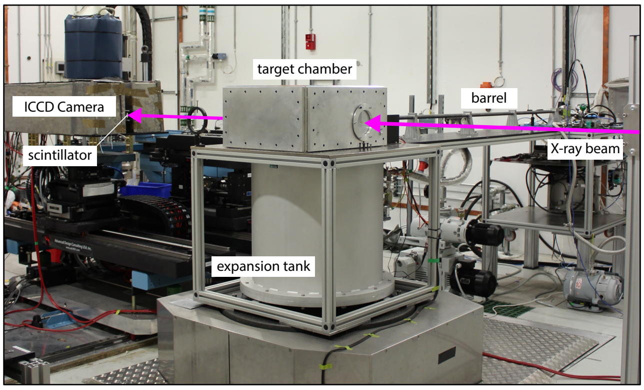
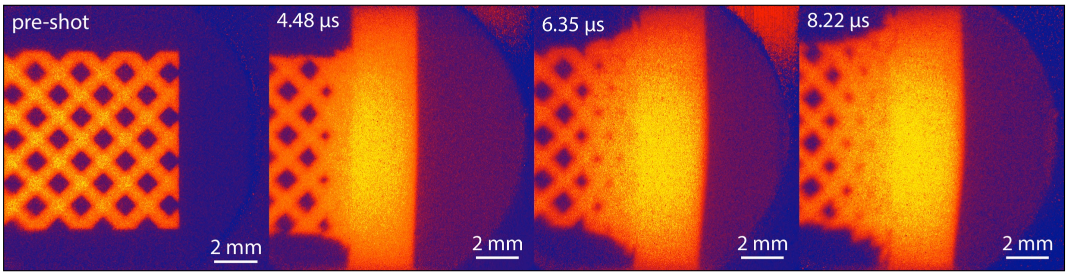
The study of materials under shock-compression is of great relevance to a multitude of areas including nuclear fusion, astrophysics and interplanetary events, materials processing, and national security.

To thoroughly understand the response of condensed matter to the extreme conditions induced by shock-compression requires an appreciation of material behaviour not only at the continuum level but also at the underlying mesoscale. For many years though, the existence and evolution of sub-surface processes responsible for bulk material behaviour have often been inferred from surface-based measurements during compression or the microstructural characterisation of recovered material. Accordingly, the extreme conditions community is heavily reliant upon numerical models for its understanding of early and intermediate stage damage processes such as heterogeneous densification, crack propagation, pore collapse, and ejecta formation.

Shock-induced physical processes last only a few μs during which material can move with speeds of km s^{-1}. Dynamic *in-situ* X-ray imaging is thus one of only a few ways to directly observe sub-surface material behavior during loading. Although the shock physics community has employed flash radiography for decades, the large source sizes of flash X-ray systems typically prohibit probing material processes with the spatial resolution required (sub-mm) to constrain mesoscopic models. Synchrotron radiation, on the other hand, is ideally suited to high-resolution (sub-us, sub-mm) imaging experiments. With this in mind, a portable, single-stage gas-gun was transported to Beamline I12 (Diamond Light Source, UK) and used to drive compression waves into a variety of metal targets and ceramic powders. A photograph of the apparatus in AP14, 2014 is shown in Fig. 1. As shock waves propagated through samples, the high-energy X-rays of Beamline I12 (50 – 250 keV) were used to capture snapshots of deformation *in-situ* via a customized X-ray bunch structure and intensified CCD camera. A series of representative *in-situ* radiographs are shown in Fig. 2.



Annotated photograph of the experimental apparatus at beamline I12 (March 2014).



A series of *in-situ* radiographs captured following the impact of a steel flyer plate (entering from the right of each figure) on a steel lattice. One image was captured per shot with an exposure time of 500 ns. Together, the stroboscopic images highlight phenomena such as sequential pore collapse and densification at the interface.

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