Characterizing Dislocation Defects in Dark Field X-ray Microscopy Images of Bulk Aluminum

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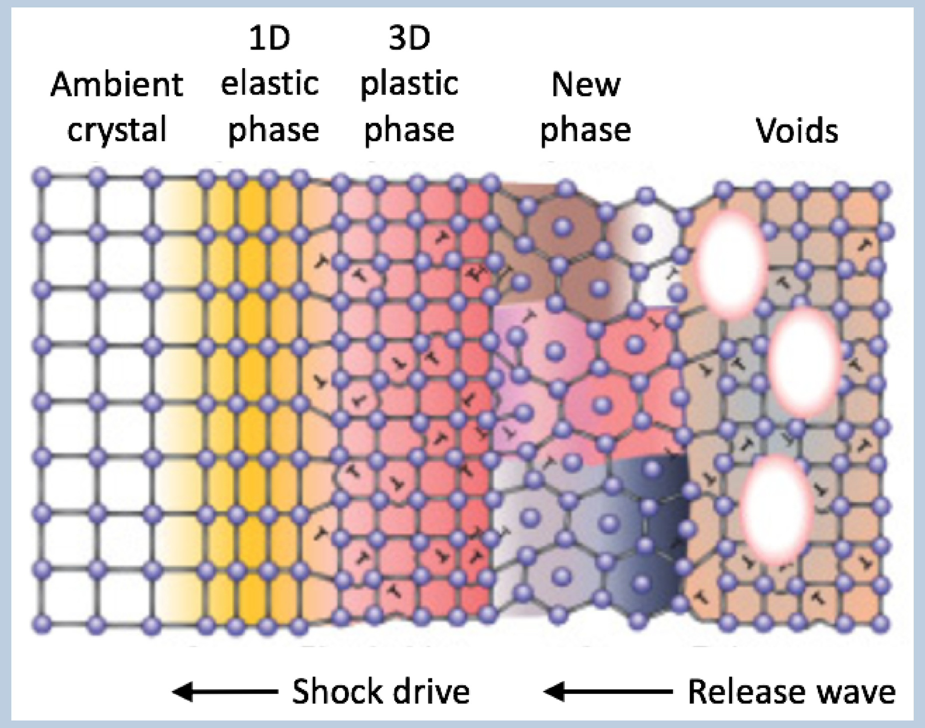
Abstract

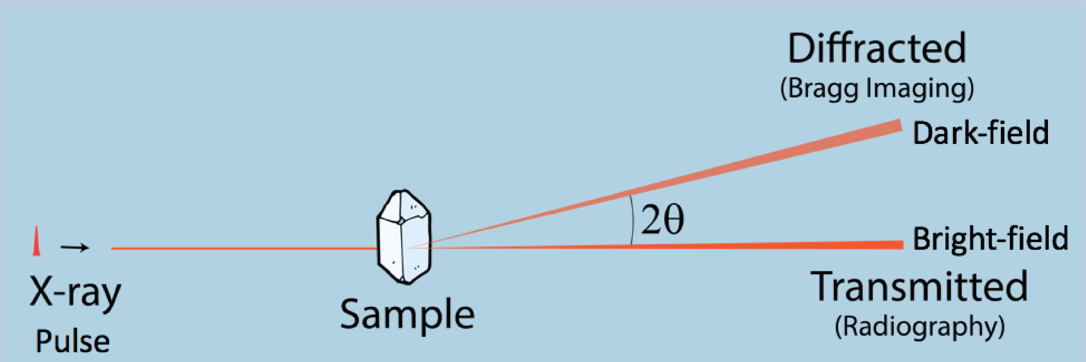
Material defects play a large role in material response under shock loading, yet our understanding of how these defects initiate, propagate, and annihilate are not well understood. Using a newly developed diagnostic, dark field X-ray microscopy (DFXM), we can now visualize the behavior of dislocation defects in materials at the mesoscale under varying conditions. Using data from the European Synchrotron Radiation Facility, we apply a variety of image processing techniques to capture relevant features to locate and characterize size and orientation of dislocation defects in bulk aluminum DFXM images. Beyond simple visualization, this analysis drives statistical characterization of the defects and their dynamic response to further improve the relevant physics models.

Dark Field X-ray Microscopy

Strong shock waves rapidly push materials beyond their yield stress, causing ultrafast plastic deformations forcing the material to exotic transformations and failure.

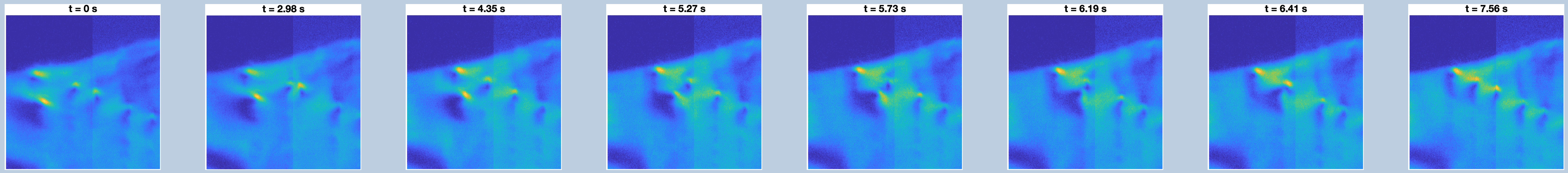


Detailed mechanisms underlying the onset of plasticity and the resulting deformations are not well understood, and ultrafast dark field X-ray microscopy (DFXM) is a novel imaging technique in development to capture how defects initiate large-scale deformations in materials.



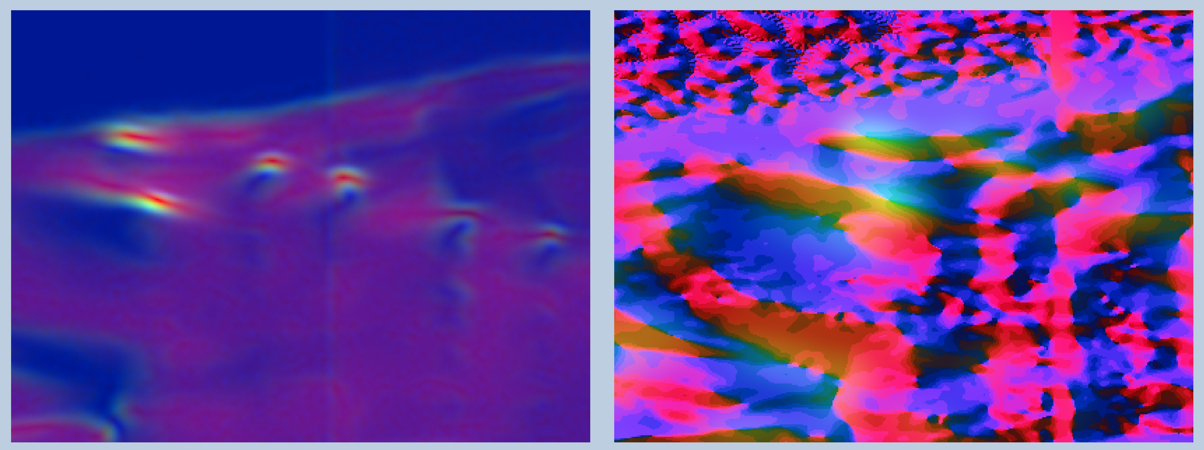
Experiments at European Synchrotron Radiation Facility (ESRF)

At ESRF, dark field X-ray microscopy images were taken on bulk aluminum. Dislocation defects, a type of plane defect, are present in the data collected and present as paired dark/bright regions in the images. In the images below, sequenced in time, a dislocation inserts into a dislocation boundary.

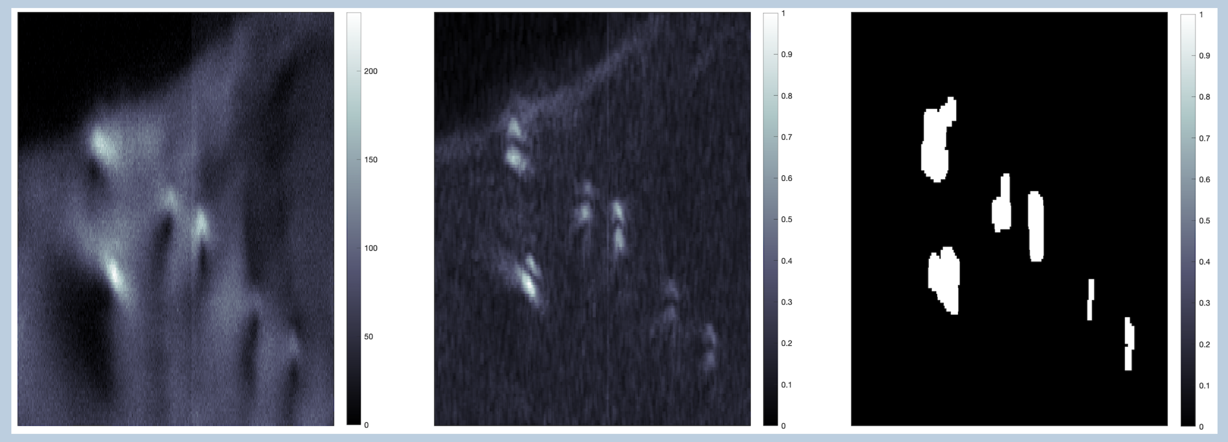


Identifying dislocations and relevant statistics through image processing is essential to informing physics models.

Image Processing Techniques

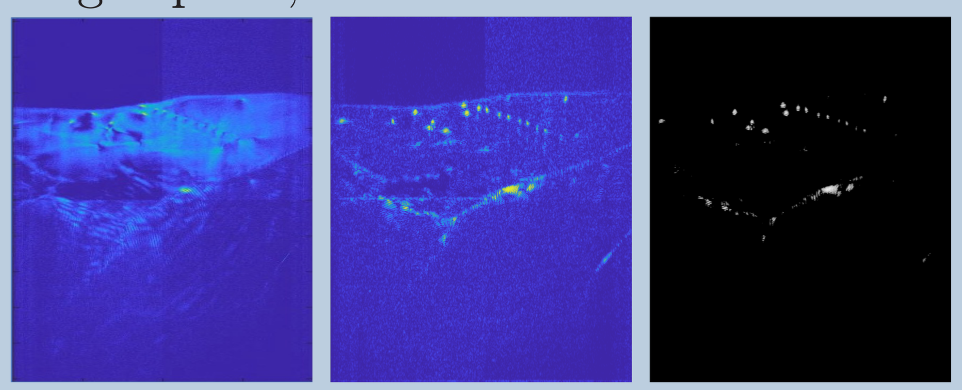


Ryan, we need words here to describe what was done to create these images that enhance the pearls.

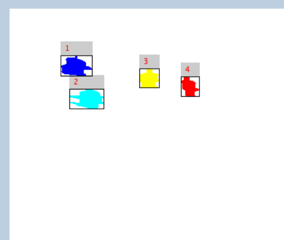


The original image reduced to a region of interest around the inserting dislocation (left). A standard deviation filter of size 5x5 was convolved across the image (middle). After applying a threshold, the dislocation dark/bright pairs are identified (right).

Applying a 2D stationary wavelet transform to the image assists in identification of the dislocation dark/bright pairs, as well in locations where the contrast between dark and bright is not as strong.



The full, raw image data for one observation in time (left) with its wavelet decomposition (middle). A threshold of the wavelet image (right) lends to identifying and enumerating the dislocations.



The wavelet analysis with threshold zoomed in to a smaller region of interest, similar to images above. Features and motion of the dislocations can be tracked in time to include statistics such as orientation, velocities, angular velocities, accelerations, and correlations of the velocities.

Defect	Avg. Vel.	95% C.I.	Avg. Accel.	95% C.I.	Avg. Ang. Vel.	95% C.I.
1	1.29	[1.14, 1.44]	0.006	[-0.721, 0.700]	0.70	[-7.91, 9.40]
2	1.95	[1.59, 2.31]	-0.064	[-1.885, 1.741]	0.61	[-44.05, 44.86]
3	1.68	[1.35, 2.11]	-0.146	[-1.887, 1.569]	-5.19	[-33.70, 26.14]
4	1.57	[1.37, 1.84]	-0.105	[-1.229, 1.162]	4.31	[-38.78, 51.16]

Acknowledgements

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Who else would like acknowledgements here?

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