

undertaken at the FLASH soft-X-ray FEL at DESY, Hamburg, to develop the experimental methods for FEL diffractive imaging. We have reconstructed images from single-pulse ultrafast diffraction patterns that show no evidence of the effects of the FEL pulse on the structure even though the object was completely vaporized by the intense pulse. We also performed quantitative measurements of the explosion of test particles in the focused FEL pulse by recording their transient diffraction patterns. No motion occurred during the pulse and we followed the evolution of the explosion with a novel holographic time-resolved technique. Our results confirm the basic principles of flash imaging and provide clear demonstration of flash imaging with simultaneous nanometer spatial and femtosecond temporal resolution.

Keywords: XFEL, ultrafast imaging, phase retrieval

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Coherent X-ray diffraction microscopy of extended objects

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Coherent Diffractive Imaging (CDI) techniques use coherent sources of radiation - such as x-rays from high-brilliance synchrotrons and free-electron laser sources - to extract information on a specimen from its diffraction pattern. This approach can produce high-resolution images of both the absorption and the phase shift within the specimen. However, replacing the lenses with a reconstruction algorithm involves solving the notoriously hard phase problem and imposes strong constraints on the specimens' preparation. Scanning Transmission X-ray Microscopy (STXM) is an alternative imaging method that can yield high-resolution images through the raster scan of a focused x-ray beam on the specimen. STXM is fast, efficient, and does not require sophisticated data analysis, but it is resolution limited by the spot size at the specimen plane. This presentation will focus on how CDI and STXM can be combined into one method that bridges the gap between coherent imaging and scanning techniques. We will review the principles of this new Scanning X-ray Diffraction Microscopy (SXDM) approach and show first experimental results obtained with a coherently focused hard x-ray beam. For a buried nanostructure test specimen we demonstrate that the resolution can be improved by a factor of more than five beyond the focal size. In addition to providing the full complex-valued transmission function of the specimen, the new analysis procedure retrieves the complete structure of the wavefront incident on it.

[1] J.M. Rodenburg, et al., *Phys. Rev. Lett.* 98, 034801 (2007).

[2] O. Bunk, et al., *Ultramicroscopy* 108, 481 (2008).

[3] M. Dierolf, et al., *Europhysics News* 39, 22 (2008).

Keywords: phase problem, super resolution microscopy, X-ray imaging

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Fresnel coherent diffractive imaging with X-rays

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Coherent diffractive imaging (CDI) attempts to replace a resolution-limiting lens with a calculation on a Nyquist-sampled far-field diffraction pattern. In essence, this shifts the resolution limit of X-ray microscopy from the lens to the detector, promising images with resolution far below the spot size of even a modern zone plate. In Fresnel coherent diffractive imaging, one keeps the resolution limiting properties of CDI, but places a lens before the sample. This provides two important advantages: the iterative scheme used to recover an image is much more robust and the beam may be used to restrict the area to be imaged on the sample. Here, we present a collection of experimental results from biological and materials samples, demonstrating both high-resolution imaging and the ability to choose an arbitrary region of interest to image within a sample.

Keywords: coherent diffractive imaging, coherent X-ray scattering, X-ray imaging

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Coherent small angle scattering from polymer nanocomposites

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Polymer nanocomposites are a novel class of multifunctional hybrid materials which are obtained by appropriate mixing of nanoparticles and polymers leading to a wide range of potential applications in terms of their unique electrical, optical and thermal properties. However, to realize such potentials it is very crucial to understand their micro-structure and their microscopic dynamics. The enormous enhancement of surface-to-volume ratio in such materials over conventional composites implies that interface morphology determines to a large extent the properties of these materials. Small angle x-ray scattering is a very powerful technique to probe the interface morphology of multi-phase materials. We have shown [1] using incoherent SAXS how interface morphology determines the glass transition in such materials. Using synchrotron multi speckle coherent SAXS or XPCS on gold nanoparticle embedded polymethyl methacrylate polymer nanocomposites we explore the rich phase behavior of their dynamics. We have performed temperature and wave vector measurements of the relaxation dynamics of such nanocomposite system and find a cross-over from compressed to stretched exponential relaxation with decreasing temperature from above the glass transition temperature of the composite. This is contrary to a recent observation in XPCS measurement on nanoparticles in supercooled liquids where compressed exponential relaxation was observed on cooling from above the glass transition of the liquid. We also find a wave vector dependence of the exponent of the relaxation which is similar to that observed for jammed systems.

Reference:

1.S. Srivastava and J. K. Basu *Phys. Rev. Lett.* 98 165701(2007)

2.C. Caronna et al, *Phys. Rev. Lett.* 100 055702(2008)

Keywords: X-ray small-angle scattering, nanocomposites, polymers