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Studies of Dynamics Using Coherent X-rays

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X-ray photon correlation spectroscopy (XPCS) has emerged over the last decade as a new technique for studies of fluctuation dynamics at small length scales. Such dynamics is ubiquitous in countless processes in condensed matter systems, such as viscoelastic flow of glasses, polymer diffusion, phase transitions, or domain switching. Like the dynamic light scattering techniques originally developed using visible wavelengths, XPCS is based on scattering a coherent beam from structural fluctuations in a material to produce a speckle pattern. The speckle pattern reflects the exact arrangement of the disorder, and thus evolves in time in concert with fluctuations. The time correlations of the speckle intensity provide a direct measure of fluctuation dynamics at the length scale corresponding to the scattering wavenumber. The extension of this technique to x-ray wavelengths provides access to atomic-scale dynamics. In practice, however, XPCS studies using 3rd-generation synchrotrons have been limited by the available coherent flux. Experiments to date have been most successful using small-angle scattering to study dynamics of $\sim$100 nm structures, which have sufficiently high scattering efficiency and relatively long time constants (e.g. milliseconds). Future accelerator-based x-ray sources such as free-electron lasers and energy recovery linacs will provide significantly increased coherent x-ray flux, which will greatly expand the applicability of XPCS to shorter length scales, faster time scales, and more weakly scattering systems. In particular, the ultrashort pulse structure of the new x-ray sources will allow observation of dynamics into the femtosecond range. I will discuss potential experiments as examples of the anticipated capabilities. Work supported by the U.S. Dept. of Energy contract DE-AC02-06CH11357.