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Femtosecond X-ray Imaging using Free Electron Lasers

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The development of free electron lasers in the X-ray regime has opened up new frontiers in X-ray imaging. With X-ray pulses of only a few femtoseconds duration and sufficient peak power to produce high-quality diffraction patterns from a single pulse, recent experiments at the Linac Coherent Light Source (LCLS) have demonstrated structural determination from both isolated viruses and streams of hydrated sub-micron crystals. Samples are continuously fed into the X-ray focal region producing a diffraction pattern each time a sample particle happens to intersect the FEL beam, with these 'hits' occurring at a rate dependent on sample concentration. Such experiments push the limits of detector technology: femtosecond diffraction requires integrating detectors with single-photon sensitivity and high dynamic range capable of reading out full frames at the machine repetition rate (120Hz in the case of LCLS). Typical data sets consist of many millions of images. Here, we will discuss our experiences to date using high-frame-rate imaging detectors at LCLS, describe the essential characteristics of the measured X-ray diffraction patterns, and look ahead to detector requirements for future femtosecond diffraction experiments at upcoming free electron laser sources.

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