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Single-Photon Thresholding for Low-flux Measurements in Charge-Integrating Pixel Array Detectors

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Many important experiments using next generation light sources produce extremely high instantaneous count rates that preclude the use of detectors that count individual photon pulses. Detectors that integrate and measure the total charge produced by x-ray conversion do not have the same limitation and are better suited to many of the demands of experiments at new sources. Instruments based on a charge integrating pixel array detector (PAD) designed and developed at Cornell University have been installed at the Linac Coherent Light Source (LCLS) for coherent x-ray diffraction imaging (CXI) and x-ray pump probe (XPP) experiments. Even though the ability to measure signal from extremely high count rates is necessary, reaping the full benefit of new sources also requires accurate measurement of extremely low x-ray fluxes incident on the detector. We present data on extremely low-flux diffraction measurements collected with a single module (small-scale) detector in our lab using the same ASIC design used in the LCLS instruments. Mean fluxes of less than 1/10000 x-ray per pixel per frame are used to recover diffraction patterns from large data sets. Thresholding using the high signal-to-noise ratio for single photon measurements and other aspects of data analysis are discussed. This type of data analysis is of particular importance to the CXI experiment because high-q features of diffuse, single-particle diffraction patterns are expected to have extremely low fluxes and many frames of data will be needed to extract meaningful information. At the same time, the detector has to be able to handle the arrival in femtoseconds of hundreds of x-rays per pixel in the low-q region.

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