# Performance of ePix10K, a High Dynamic Range, Gain Auto-Ranging Pixel Detector for FELs

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ePix10K is a hybrid pixel detector developed at SLAC for demanding free-electron laser (FEL) applications, providing an ultrahigh dynamic range (245 eV to 88 MeV) through gain auto-ranging. It has three gain modes (high, medium and low) and two auto-ranging modes (high-to-low and medium-to-low). The first ePix10K cameras are built around modules consisting of a sensor flip-chip bonded to 4 ASICs, resulting in 352×384 pixels of 100 μm×100 μm each. We present results from extensive testing of 4 ePix10K cameras with FEL beams at LCLS, resulting in a measured noise floor of 245 eV rms, or 67 e^- equivalent noise charge (ENC), and a range of 11,000 8 keV photons. We demonstrate the linearity of the response in various gain combinations: fixed high, fixed medium, fixed low, auto-ranging high to low, and auto-ranging medium-to-low, while maintaining a low noise (well within the counting statistics), a very low cross-talk and perfect saturation response at fluxes up to 900 times the range, and acquisition rates of up to 480 Hz. Finally, we present examples of high dynamic range x-ray imaging and diffraction imaging spanning more than 4 orders of magnitude dynamic range (from a single photon to 11,000 photons/pixel/pulse at 8 keV). Achieving this high performance with only one auto-ranging switch leads to relatively simple calibration and reconstruction procedures. The low noise levels allow usage with long integration times at non-FEL sources. ePix10K cameras leverage the advantages of hybrid pixel detectors with high production yield and good availability, minimize development complexity through sharing the hardware, software and DAQ development with all other versions of ePix cameras, while providing an upgrade path to 5 kHz, 25 kHz and 100 kHz in several steps over the next few years, matching the LCLS-II requirements.
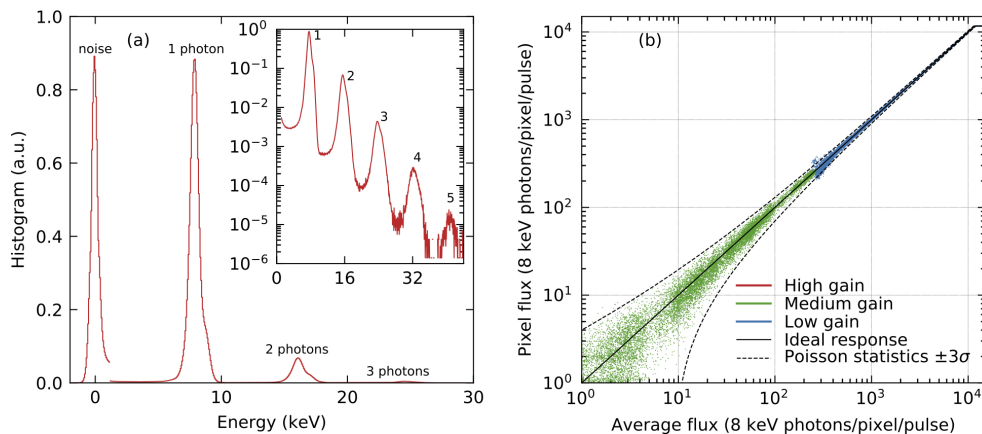
ePix10K gain auto-ranging allows an ultra high dynamic range, with a noise of 245 eV rms (67 e^- ENC) and range of 11,000 photons at 8 keV: (a) histogram of single pixel events with 8 keV photons (Cu fluorescence), collected over all pixels, with 0, 1 and 2 photon peaks clearly visible; the inset displays the same histogram on a logarithmic scale, showing clear separation of at least 5 photons (limited by statistics); (b) displays the calibrated response of a single pixel as a function of average beam flux (measured with a separate beam monitoring diode) over > 4 orders of magnitude (log-log scale); green and blue dots represent medium and low gain measurements, respectively; the black line represents the ideal response; this demonstrates correct auto-ranging behavior, with good linearity and well within the photon counting limits (indicated by black dashed lines).