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Sub-pixel spatial resolution of single soft x-ray photons using the JUNGFRAU hybrid pixel detector with iLGAD sensors

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Soft x-ray photon science at free-electron laser (FEL) and synchrotron radiation (SR) facilities plays a vital role in many research fields. With light sources advancing and upgrades such as SLS 2.0 (PSI, Switzerland) and LCLS-II (Stanford University, USA) on the horizon, detector systems that meet the requirements of high-performance x-ray science at next generation sources are becoming a necessity. Experimental techniques such as resonant inelastic x-ray scattering (RIXS) require high-frame-rate, large-area detectors that can resolve single photon hits at energies around the oxygen K-edge (525 eV) with a spatial resolution of, ideally, 1-2 µm.

Current systems that can fulfill resolution requirements (CCDs and CMOS monolithic sensors) struggle to meet the high frame rate and large area requirements. Hybrid pixel detectors (HPDs) such as JUNGFRAU, on the other hand, provide frame rate and size but, until recently, were limited to experiments with tender and hard x-rays due to their electronic noise (i.e., 34 electrons r.m.s. in high gain for JUNGFRAU). Recent advances have combined charge-integrating (JUNGFRAU and MÖNCH) and single-photon-counting (EIGER and MYTHEN) readout chips with inverse low-gain avalanche diode (iLGAD) sensors with a thin entrance window. This approach successfully increased the signal of low-energy photons above the noise threshold while achieving quantum efficiencies > 80% in the soft x-ray regime.

HPDs can utilize charge sharing between neighboring pixels to interpolate the photon position down to a fraction of the pixel pitch. We recently designed JUNGFRAU-iLGAD prototypes featuring rectangular pixels ("strixels"). To match the ASIC array of square pixels, the strixels measure a fraction of the original 75 µm pitch in the vertical direction (25 µm, 18.75 µm, and 15 µm) and a multiple in the horizontal direction. This sensor design is aimed at experimental techniques such as RIXS, which only require high spatial resolution in one dimension.

We report on the spatial resolution capabilities of these iLGAD strixel prototypes as evaluated in recent experiments. The modules were raster-scanned with a micron-sized x-ray beam at the SLS POLLUX beamline. We compare the photon detection efficiency and interpolation performance at x-ray energies between 400 eV and 1 keV and discuss the prospects of spatially resolving soft x-ray photons in the sub-10 µm range. Based on these recent results, we will give an outlook on the promising prospects of JUNGFRAU for high-throughput, low-energy x-ray applications such as RIXS at FELs and SR facilities.

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