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Development of hybrid pixel detectors for photon science at the Paul Scherrer Institut

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Hybrid pixel detectors (HPDs) consist in a sensor absorbing the X-ray radiation, usually silicon, connected to the CMOS readout electronics, that processes the signal generated by the sensor signal on a pixel by pixel basis. They were spinned-off from high energy physics tracking applications to photon science at the beginning of the millennium, and they managed to be disruptive in both fields. PSI was one of the first research institutes to develop big size detectors for synchrotron and, successively, for X-Ray free electron lasers (XFELs) applications, which are now present in many facilities around the world. Single photon counting (SPC) HPDs, where every incoming photon is discriminated and counted, are well established at synchrotrons for diffraction applications. However, new needs are appearing at present, in particular with the increasing number of 4th generation synchrotrons, which challenge the state-of-the-art of present SPC detectors: detect low energy photons (<2keV),increase spatial resolution, allow for a higher flux of incoming photons. Additionally, SPCs cannot be used at FELs, where all the photons arrive simultaneously and cannot be counted individually.
In Charge integrating (CI) HPDs,the charge produced by all impinging photons is accumulated per pixel and successively digitized in number of photons. They solve already several of the problems connected with SPCs and, in low illumination conditions, can also provide information on the X-ray energy of the photons. Additionally, this analog information provided by CIs in low illumination can also be used to increase position resolution exploiting charge diffusion to interpolate the photon position at the level of a few microns.
However, they must be equipped with circuitry able to dynamically trade off noise versus dynamic range as the signal builds up in the pixel. Additional challenges come from their high data throughput and their complex calibration.
HPDs can profit from advances in the readout electronics, but this would not be enough to face all the modern challenges of photon science. However, they have the big advantage that the same frontend chip can be bump-bonded to different sensor materials. This way, the huge advancement in sensor research can contribute to the development of detectors that meet the required specs. In particular, sensors with improved quantum efficiency are under development, optimizing a shallow entrance window for soft X-rays or exploiting heavier material than silicon for higher energies (e.g, GaAs, CdTe or CdZnTe). Additionally, sensors with internal amplification (LGADs) can improve the signal-to-noise ratio of low energy photons and allow HPDs to be operated also in the soft X-ray energy range.
This talk presents the challenges of detector development for photon science, and how they have been addressed by PSI. Special emphasis will be given to the detector generations in development at present, to be deployed at the new X-ray sources.

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