Advances in hybrid pixel detectors for photon science

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Hybrid detectors developed at the Paul Scherrer Institut are widely used in X-ray applications as they are able to fulfil most of the requirements of the experiments: single-photon sensitivity, large dynamic range, wide area coverage, fast frame rate, and simple, stable and user-friendly operation. However, only recent developments in the noise reduction paved the way for their usage as energy dispersive and soft X-ray detectors and progresses in the bump bonding technique allowed a higher segmentation for high resolution imaging [1, 2].

Photon counting detectors like EIGER, with its 75 µm pixel pitch and 23 kHz frame rate [3], can provide an outstanding data quality for synchrotron experiments and they are essential for stroboscopic measurements and weakly interacting samples. However, their limited count rate capability is a disadvantage when dealing with the huge fluxes delivered by state-of-the-art synchrotron radiation sources. Moreover, photon counting detectors cannot be used at X-ray Free Electron Lasers (FELs) where all photons impinge simultaneously.

These challenges motivated the complementary development of charge integrating detectors like JUNGFRAU [4], which offers the same 75 µm pixel pitch, but can deal with at least 10 times higher radiation fluxes, offering a dynamic range up to 1E4 12 keV photons per frame and single photon sensitivity down to 2 keV. Although developed for experiments at FELs, with its 2 kHz frame rate, it can find application also at synchrotrons, improving the throughput for high flux experiments without deterioration of the detective quantum efficiency compared to photon counting detectors.

When operated with low radiation fluxes, charge integrating detectors can discriminate single photon events and the analog information can be exploited to simultaneously obtain position and spectroscopic information.
In this framework, the MÖNCH detector [2], with its 120 eV noise r.m.s., can be used for energy resolved experiments (e.g. Laue diffraction) and in the soft X-ray energy range, offering single photon sensitivity down to about 600 eV. Its 25 µm pixel pitch suites very well imaging applications and, at low fluxes, the position resolution can be further improved down to the micron level thanks to interpolation techniques.

This presentation will review the detectors under development at PSI for both synchrotrons and FELs and discuss direct conversion hybrid detectors as an alternative to indirect conversion and monolithic detectors in a wide range of applications.

[1] J. H. Jungmann-Smith et al. (2016) J. Synch. Rad. 23, 385.
[2] S. Cartier, M. Kagias et al. (2016) J. Synch. Rad. 23, 1462.
[3] G. Tinti et al., (2015) J. Instr. 10, C03011.
[4] A. Mozzanica et al. (2016) J. Instr. 11, C02047.