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Beyond single photon counting X-ray detectors

Synchrotron radiation applications require detectors with a high sensitivity and large dynamic range in order to study both the strong and weak features of the samples. Moreover, a high spatial resolution is necessary for imaging and diffraction studies.
The photon counting technique is so far the best solution to these requirements but it presents some limitations which can only be partially overcome by technological improvements i.e. the count loss at high impinging intensities, due to the readout electronics shaping time, and the restrictions on the minimum pixel size, due to the charge diffusion in the sensor.
In order to overcome both these limitations a new generation of charge integrating hybrid detectors with single photon sensitivity is being developed. These preserve the advantages of counting detectors and at the same time allow a processing of the data in order to enhance the spatial resolution and perform some spectral analysis.
Simulations and measurements comparing X-ray photon counting detectors and charge integrating systems with single photon sensitivity will be presented.

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

The detector group of the Swiss Light Source at the Paul Scherrer Institut is active in the development of X-ray detectors satisfying the strict requirements of synchrotron radiation applications i.e. mainly a high sensistivity, a large dynamic range and a good spatial resolution [1].
Hybrid single photon counting detectors providing the necessary dynamic range and spatial resolution have been developed and are used for a wide range of applications like powder diffraction, protein crystallogrophy, small angle scattering and X-ray imaging [2,3,4].

However, single photon counting detectors present some intrinsic limitations due to the pure binary information they provide [5].
Firstly, the pile up of the analogue signal determines a loss of counts at high rates which does not allow to correctly compare the strong and the weak features of the image under high impinging fluxes.
Moreover, the spatial resolution of single photon counting detectors is limited by the diffusion of the charge produced by the X-ray while drifting towards the sensors pads [6]. This effect can still be corrected using pixel-to-pixel communications in case the charge shared between first neighbors but is extremely challenging when the diffusion length is larger than the pixel size and the spread involves many pixels [7].

Measurements using microstrip detectors with small pitches show the presence of a minimum photon counting pitch at about 20um for 300um thick silicon sensors, below which the charge produced by photons is shared between several strips and single photon counting is not possible any longer [8]. The restrictions are even more critical in the case of pixels because of the presence of the corners where the charge is shared between at least four pixels.

However, it has been demonstrated that with the use of a charge integrating redout electronics with photon counting sensitivity it is possible to preserve the advantages of counting systems while exploiting the wider information given by the analogue readout [9].
Such an analogue detector read out at high frame rates in fact not only allows operation under extremely high photon fluxes, but also the processing of the data in order to preserve the photon counting capability, to enhance the spatial resolution by interpolation between strips and to perform some spectral analysis of the detected photons [10].

In this work measurements acquired with microstrip systems read out using the MYTHEN photon counting ASIC and the GOTTHARD charge integrating chip (both developed at PSI) will be compared in terms of signal to noise ratio and spatial resolution.
Simulations concerning the charge collection for sensors with small pitches will also be shown in order to highlight the differences between the two read out modes.

The goal is the optimization of the design parameters in order to develop charge integrating detectors with single photon counting sensitivity (both strips and pixels) and improved signal to noise ratio and spatial resolution.

Preliminary extimations show that a 25um pitch pixels sensor could give a spatial resolution of 5um by applying interpolation between pixels.

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