Special SLS Symposium on

Detectors

Tuesday, December 12, 2017

9:30 to 12:15, WBGB/019

09:30 - What are hybrid pixel detectors? - An introduction with focus on single photon counting detectors
Erik Fröjdh

09:55 - Charge integrating photon detectors, and a comparison with single photon counting systems
Sophie Redford

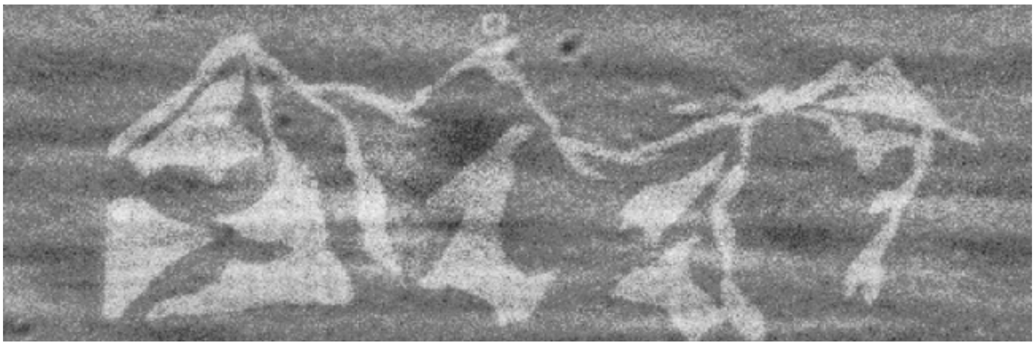
10:25 - Single photons with charge integrating detectors: towards high resolution and spectroscopy
Anna Bergamaschi

10:45-11:00 Coffee Break

11:00 - Hard X-ray Detectors for synchrotron radiation sources and Free-Electron Lasers
Jiaguo Zhang

11:25 - Detecting low energy photons and electrons
Gemma Tinti

11:50 - Future detectors: summary, perspectives and discussion
Bernd Schmitt



What are hybrid pixel detectors? - An introduction with focus on single photon counting detectors

Erik Fröjdh

Single photon counters have during the last decade become the standard area detector at synchrotron beamlines, providing "noiseless" images at ever higher frame rates. This talk introduces the concept of hybrid pixel detectors and discusses fundamental properties such as charge interaction in the sensor layer and signal generation during charge transport. From this the strengths of counting detectors such as noise suppression, the ability to cut fluorescence using the threshold and gating of the detector are derived. We also look at limitations of photon counters like maximum count rate and signal loss around pixel corners. The talk is given in the context of the work of the SLS Detector Group and includes an introduction to our detectors and presentation of the EIGER detector.

Charge integrating photon detectors, and a comparison with single photon counting systems

Sophie Redford

Charge integrating detectors hold certain advantages over single photon counting systems. They can detect fractions of a photon, for example as a result of charge sharing. They are also sensitive to many photons arriving 'at the same time' without suffering the effects of pile-up, for example 10^4 photons arriving within femto-seconds of each other in an FEL environment. These benefits are accompanied with additional challenges, such as a higher data rate and a complex set of corrections to apply before the number of detected photons is recovered. The charge integrating JUNGFRAU detector will be presented, and compared and contrasted with the EIGER single photon counting detector both in terms of operation and results. The process of converting a raw JUNGFRAU image to an image of photons will be explained. The so called 'corner effect', present in single photon counters but not in charge integrating systems, will be discussed. Count rate (single photon counters) and dynamic range (charge integrating systems) will be addressed. Experience and results from recent measurements at the SLS PX beamline will be shown, as well as the first diffraction images recorded by JUNGFRAU at SwissFEL ESB.

Single photons with charge integrating detectors: towards high resolution and spectroscopy

Anna Bergamaschi

When operated with low radiation fluxes and at high frame rates, charge integrating detectors can discriminate single photon events and the analog information can be exploited to simultaneously obtain position and spectroscopic information.
The energy resolution is limited by the electronic noise and is about 250 eV FWHM for MÖNCH and 600 eV FWHM for JUNGFRAU.
This high resolution, together with the large number of pixels and high frame rate, can be exploited for high throughput fluorescence emission spectroscopy like the MAIA detector.
Furthermore, these detectors can be used for Laue diffraction, where the position and energy of the diffraction peaks can simultaneously be detected.
Charge integrating detectors can also be used with X-ray tubes for color imaging, since they can provide a full energy spectrum per pixel.
In the case of MÖNCH, with its 25 µm pixel pitch, the signal of a single photon is usually shared between neighboring pixels, due to the diffusion of the charge in the sensor during the collection process. The signal from neighboring pixels can be summed together (clustering) and assigned to a single pixel, avoiding the signal loss due to charge sharing.
Furthermore, we can apply interpolation algorithms to improve the position resolution beyond the pixel pitch. We have obtained a spatial resolution of the order of a few microns, allowing high resolution direct conversion imaging.
We will discuss the possibilities offered by single photon detection using charge integrating detectors and discuss challenges and limitations of these techniques.

Hard X-ray Detectors for synchrotron radiation sources and Free-Electron Lasers

Jiaguo Zhang

Silicon is commonly used as the sensor material of hard X-ray detectors aiming for a photon energy < 20 keV. With increasing photon energy, the quantum efficiency (QE) of silicon detectors degrades dramatically. Benefiting from their high atomic numbers, GaAs (Z=31,33) and CdTe (Z=48,52) sensors extend the possibility to efficiently absorb X-ray photons of energies up to 60 keV and 100 keV with a good QE of >70%, respectively.

GaAs and CdTe sensors, segmented either into strips or pixels, have been wire-bonded/bump-bonded to photon-counting and charge-integrating readout chips (Mythen, Gotthard and Jungfrau) which were developed by the detector group of the Swiss Light Source. Their performance has been investigated extensively using both lab X-ray source and synchrotron radiation sources: The obtained results will be summarized in this talk. In addition, drawbacks caused by imperfections of the GaAs and CdTe crystals used as base material for the sensors will be discussed.

Detecting low energy photons and electrons

Gemma Tinti

This presentation will cover the main challenges encountered in detecting low energy photons and electrons.
Low energy and soft X-rays (90 eV-2 keV) and low energy electrons (8-20 keV) have a short interaction length. To avoid absorption of the radiation in air, detectors need to be in vacuum.
The first layer of the sensor encountered by the radiation (i.e. the entrance window) does not detect signal, so its thickness plays a crucial role in determining the quantum efficiency. We will show that standard sensors, with a small modification, are sensitive down to 600 eV, while newly designed sensors, with a thinner entrance window, could achieve good quantum efficiency down to 200 eV.
The readout chip needs to have low noise to access low energies. In single photon counting detectors (e.g. EIGER) the noise limits the minimum energy to which the threshold can be set. We are studying the possibility of using Low Gain Avalanche Diodes as sensors to amplify the signal generated by X-rays with energies lower than the minimum threshold. First preliminary results will be presented here.
The effect that the noise has in charge integrating detectors (e.g. JUNGFRAU and MOENCH) on (i) single photon resolution (down to 800 eV for MOENCH, 1.5 keV for JUNGFRAU), (ii) clustering of pixels and (iii) the limitation to the integration time will be presented.

Future detectors: summary, perspectives and discussion

Bernd Schmitt

In this last part of the symposium we will summarize the developments we are carrying on in the Detector group and will open the meeting to a discussion between the speakers and the audience on the needs of beamlines and how to implement them in our next generation detectors.