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The Gotthard-II readout ASIC and detector system

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Gotthard-II is a charge-integrating microstrip detector developed for experiments and diagnostics at free-electron lasers using hard X-rays of 5 keV–20 keV. Its potential scientific applications include X-ray absorption/emission spectroscopy, energy dispersive experiments, as well as veto signal generation for pixel detectors. The Gotthard-II ASIC has been designed in several optimization steps in order to meet the requirements of the European XFEL, i.e. single photon sensitivity, large dynamic range as well as a high frame rate of 4.5 MHz. The ASIC design and performance will be presented. The detector system as well as the results from beam tests will be discussed.

Summary (500 words)

The scientific and operational requirements at the EuXFEL are very challenging, and have driven the development of the Gotthard-II readout ASIC. Among all detectors for the European X-ray Free-Electron Laser (EuXFEL), Gotthard-II will be the most widely employed detector for energy dispersive experiments which are well suited for the 1-D geometry of Gotthard. The Gotthard-II detector uses a silicon microstrip sensor with a pitch of 50 µm or 25 µm and with 1280 or 2560 channels wire-bonded to 10 or 20 readout ASICs respectively. In both cases, the length of the sensitive area is 64 mm.

The Gotthard-II readout ASIC is shown in figure 1. It features: (a) a high speed, dynamic gain switching pre-amplifier(PRE) allowing to cope with the 4.5 MHz frame rate. The implementation of the dynamic gain switching circuit enables the detection of up to 10^4 X-ray photons of 12.4 keV maintaining single photon resolution with a Signal-to-Noise Ratio (SNR) greater than 10 for low photon fluxes; (b)an on-chip Analog-to-Digital Converter (ADC) and a Static Random-Access Memory (SRAM) capable of storing all digitized images from the 2700 pulses in a bunch train; (c) an on-chip digital comparison circuit to generate veto signals for pixel detectors, for example the Adaptive Gain Integrating Pixel Detector (AGIPD) and Large Pixel Detector (LPD), which are able to record at most 352 and 512 images, respectively, per bunch train. With the veto signals, memories of the pixel detectors storing empty images due to poor interactions between X-ray pulses and samples in user experiments or due to unqualified X-ray pulses can be re-used for the other forthcoming pulses in the same bunch train. In addition, the Gotthard-II ASIC is capable of taking images continuously at a frame rate of up to 495 kHz for synchrotron experiments, the future upgrade of the EuXFEL to CW mode, and potentially for other FELs which are planned to be operated in CW mode, for example LCLS-II and SHiNE.

The Gotthard-II ASIC has been fabricated in UMC-110 nm CMOS technology. The characterization results show a good single-photon resolution at photon energy > 5 keV with a SNR greater than 5, as well as a large dynamic range up to 10^4 12.4 keV X-ray photons. In addition, the noise is below the Poisson limit over the entire dynamic range for 12.4 keV X-ray photons; the non-linearity is found to be better than 1% over the entire dynamic range as well. A summary of the characterization results are shown in figure 2.

The detector system has been designed and extensive experimental tests at the Swiss Light Source (SLS) as well as at Soleil synchrotron have been performed. The results are promising and the performance of the Gotthard-II detector in energy dispersive experiments has been demonstrated as shown in figure 3.

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