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AGIPD systems: performance optimization challenges and new developments.

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AGIPD is one of the detectors developed for the experimental stations of the European XFEL, one of the newest free-electron laser sources. The detector pixels write high dynamic images from single up to 10⁴ 12.5 keV-photons at a maximum frequency of 4.5 MHz operating in a burst mode –read-out is performed between the bursts. There are certain challenging optimizations done to the different detector blocks, like ASIC and back-end electronics since its commissioning in 2017. Details and results as well as latest developments will be reported.

Summary (500 words)

A high coherent high flux beam is often required in modern photon science experiments. This can be provided by free-electron lasers (FELs). One of the world leading facility in the field is the European XFEL. Its specific operational parameters impose challenging requirements for the detectors used at the experimental stations. These include a dynamic range up to 10ˆ4 12.5 keV-photons per pixel with single photon sensitivity. The photon bunches are organized in trains of 2700 pulses at 4.5 MHz repetition rate. The train frequency is 10 Hz. In order to use the mentioned key features of the source the Adaptive Gain Integrating Pixel Detector (AGIPD) was developed. It uses a hybrid detector architecture, resulting in front-end units consisting of a semiconductor sensor bump-bonded to 16 ASICs with a pixel pitch of 200 um. AGIPD operates in a burst mode, acquiring up to 352 analogue images separated by 220 ns into random-access memory (RAM). An adaptive gain technique is used in order to provide the required dynamic range: in each pixel of the ASIC, the output of the charge-sensitive preamplifier is connected to an adjustable comparator. It drives the logic controlling the gain of the preamplifier by adding a larger capacitance in the feedback loop. The switching can occur twice during the writing phase. The amplitude value along with its gain information is read out from the memory cells between the bunch trains within approximately 99 ms.
6 multi-project wafer (MPW) and 3 engineering runs were used in order to produce the AGIPD ASIC. The first full chip version 1.0 showed basic and conceptual functionality although some design adjustments were needed in order to get rid of a few unexpected effects (reported on TWEPP-2015). The next version, 1.1, with corresponding patches was submitted in fall of 2015 and became the main ASIC variant for the first systems delivered to the SPB and MID instruments of the European XFEL. After successful commissioning and user operation another important issue was discovered –indistinguishable gain encoding. The gain information is being encoded as 3 different voltage levels, stored in analog RAM and read-out through the fully differential analogue interface by the back-end electronics. 2 out of 3 levels become indistinguishable, making the gain determination impossible for a significant fraction of the stored images during the readout of a burst. This issue was strongly mitigated in the last version 1.2 of the AGIPD ASIC, of which design details and test results will be presented.
• Apart from the iterative ASIC design optimization certain improvements to the back-end electronics were done: the high voltage biasing circuit of the system at the SPB instrument was altered in order to provide faster recharging during high flux signal operation.
• New back-end electronics for the second generation systems has been designed and tested in the laboratory and in real experiments.

• A new detector cooling concept is being validated.
• The electron-collecting version 1.3 of the ASIC for High-Z sensors was submitted for manufacturing.
Updated results will be presented.

Primary authors: Dr KLUJEV, Alexander (Deutsches Elektronen-Synchrotron); ON BEHALF OF AGIPD CONSORTIA

Presenter: Dr KLUJEV, Alexander (Deutsches Elektronen-Synchrotron)

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