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Front end electronics for European XFEL sensor: the AGIPD project

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The European X-ray Free-Electron Laser Facility will generate extremely brilliant, ultra-short pulses of X-rays, imposing challenging constraints to the detectors to be used in the experiments. It is expected to have a peak brilliance of 10ˆ33 ph/(s mmˆ2 mradˆ2 0.1%BW), 9 orders of magnitude more than 3rd generation synchrotron sources. The flux will be such that many pixels will have to cope with much more than one photon (up to 10ˆ4) per pulse, while required to retain single (or better than poissonan statistics) photon sensitivity. This will also expose the system to a substantial amount of radiation, estimated for the readout ASIC to be of the order of tens of MGys. The time structure of the beam will consist in a sequence of tight bunches of Xray pulses (up to 2700 pulses in 0.6ms) separated by a period of 99.4 ms. Each pulse will be around about 100 fs long.
From the detector designer's point of view, this means that the front end has to cope with a high dynamic range, while having a noise low enough to discriminate single photons. Photon counting cannot be use (because of the high flux per pixel), and the sensor is required to provide a way to store the information from several (ideally, all) pulses on-board, to be read out in the interval between trains. At the same time, it also has to be substantially radiation-hard.
The AGIPD (Adaptive Gain Integrating Pixel Detector) is being developed as a way to cope with such challenges. It consists in a 1Mpixel hybrid pixel detector, featuring a pitch of 200µm; the readout will be performed by means of 16x16 ASICs, each composed of 64x64 pixels. The development is shared between DESY, PSI, the universities of Hamburg and Bonn.
The large dynamic range and single photon sensitivity issues was tackled with a dynamically adjustable charge amplifier integrated inside each pixel, ranging over 2 orders of magnitude, so that its gain is adjusted real-time to the number of absorbed photons. Tests prove the system to work correctly, both in terms of dynamic range and in terms of speed. Our target for the noise is to keep it at about 0.1 photons of 12.4 keV (300˜400 e), so to allows for the requested single-photon sensitivity.
Correlated Double Sampling circuitry is included inside each pixel, as well as an embedded memory able to store up to 350 frames per pulse train. This is certainly less than the ideal case, since up to 2700 images are produced during a pulse train, but it comes as a compromise of keeping pixel dimensions reduced, and of course out of leakage minimization and radiation hard design issues. Radiation-hard design techniques have been employed, with the use of Enclosed Layout Transistors and guard rings around the critical devices.
Measurement performed on test prototypes confirm that in the operation range the leakage is low enough to keep the signal loss at less than 0.1% even for the last cells to be read.
As a partial solution of the limited memory depth problem, the memory has been designed to addressable RAM-like, allowing the overwriting of memory cells storing meaningless data by means of a veto schema.
A Command Serial interface has been included to address the pixels and their memory cells by means of 3 LVDS lines
An irradiation campaign has been performed on test prototype using a synchrotron source and exposing them to increasing doses, confirming a good behaviour for 1MGy-irradiated ASICs and the retention of functionality for 10MGy-irradiated ASICs. Several test prototypes have been produced on a reduced scale, mainly by means of MPW runs and I will present the results of extensive tests; we foresee the ASIC for the full detector to be ready for the end of the year.

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