DETECTORS FOR X-RAY IMAGING AT THE NEW FREE ELECTRON LASER SOURCES

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Presently, great advances on the field of research with synchrotron radiation are being experienced. The advent of new technologies on the fields of particle accelerators and the application of the SASE principle allow to make coherent synchrotron beams of unprecedented brilliance available to the users. As the detector instrumentation has to keep pace with the development, increasing requirements in terms of frame rate, dynamic range and area coverage drive the development towards a new class of synchrotron radiation detectors.
For the requirements of existing sources like FLASH (Free Electron LASer in Hamburg) dedicated pnCCD-based camera systems have been developed. pnCCD devices with a total sensitive area of around 60 cm^2 have been manufactured (see Fig. 1) alongside with high speed readout electronics and data acquisition systems, which make an operation at framerates of up to 250 Hz possible. Special operating modes have been introduced, which allow to drastically increase the charge handling capacitance to cope with the huge required dynamic range required for significant imaging of e.g. X-ray diffraction patterns . The fabrication of even larger devices, providing for a larger angular coverage, is in progress.

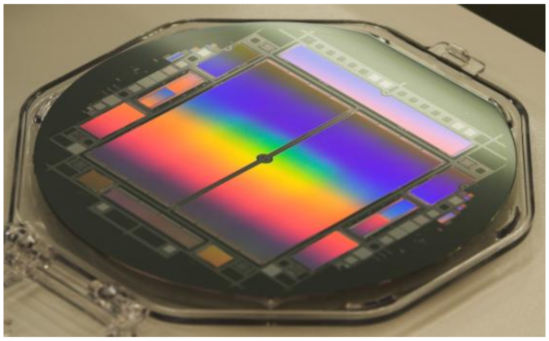

Fig. 1: Photo of a wafer containing CCD detectors for the CAMP (CFEL ASG Multi-Purpose) camera system.

But for the near future, entirely new concepts need to be applied to cope with the further increasing requirements from the experimental facilities. From 2014 on, the European **X**-ray **F**ree **E**lectron **L**aser (XFEL) research facility will use superconductive accelerator technology to generate X-ray trains with a length of 600 µsec containing 2.700 X-ray flashes separated by 220 nsec, followed by a break of 99.4 msec. The corresponding sensor arrays applied at the experimental stations must combine single-shot imaging capability, i.e. they have to operate at a framerate of 4.5 MHz. In addition, large size is needed for large angular coverage and high dynamic range. The extreme photon flux will generate a total absorbed dose in the 100 Grad range within few years of operation and requires radiation tolerant sensor technologies.
The DSSC (**D**ePFET **S**ensor with **S**ignal **C**ompression) system will be based on the integrated detector/amplifier system DePFET (**De**pleted **P** channel **F**ield **E**ffect **T**ransistor). It features noise due to internal amplification and has a built-in signal storage capability for readout on demand. In the DSSC-adaptation, a built-in signal compression feature has been invented for the DEPFET to cope with the simultaneous requirements of high resolution and high dynamic range. In addition, the full signal processing cycle can be handled in the 220 nsec timeslot as imposed by the XFEL machine time slice. The final DSSC system will consist of a 1024 x 1024 pixel sensor, consisting of a tiled array of modules with 128 x 256 pixels, each of which is connected to its individual readout electronics cell via bump bonding. Each readout cell contains a pre-amplifier, a filter amplifier, an ADC and a local storage for 500 frames, which is to be read out during the breaks between the pulse trains.
The free electron laser sources as well as their new challenging detectors offer new opportunities for a large variety of material analysis techniques, including X-ray diffraction crystallography and X-ray fluorescence analysis.