XPAD, a hybrid-pixel detector

The spectacular progress achieved in the so-called third-generation synchrotrons permit the production of a synchrotron beam of very great brightness. New experiments are therefore possible, notable those necessitating the taking of measurements both finely resolute in space and time, all while maintaining a large information dynamic. In order to have access to detectors at the performance level of its machine, SOLEIL has collaborated in the development of a new generation of so-called 'hybrid-pixel' detectors, adapted to the characteristics of its 'hard X-ray' beamlines.

Current instrumentation, especially that of detectors, does not allow to take full advantage of the technological advances accomplished in the area of synchrotron beams. Actually, numerous experiments have already been conducted; for example, with the help of scintillators connected to a photo-multiplier or of CCD cameras coupled to a phosphorescent screen placed side-by-side with a demagnification optic. Photo-multiplier and CCD device have disadvantages, including permitting point detection and, for another, being limited in dynamic range and read out.

Hybrid-pixel detectors

Detectors are thus the instrumental field where technological leaps are quite necessary, and today they are possible. Physics experiments using large accelerators such as the LHC at CERN have permitted the development, for the counting of particles, of a new generation of so-called hybrid-pixel detectors (figure 1). These are made up of a sensor (silicon diode), the rear face of which is pixelized. Each pixel is coupled via 'bump-bonding' (linking via a microscopic metallic ball) to an electronic counting device in a dedicated circuit.
In order to achieve large detection surfaces, the circuits are placed side-by-side and coupled to a sensor whose dimensions may reach 7x1.5cm^2. These ensembles, or modules, are then assembled in tiles.

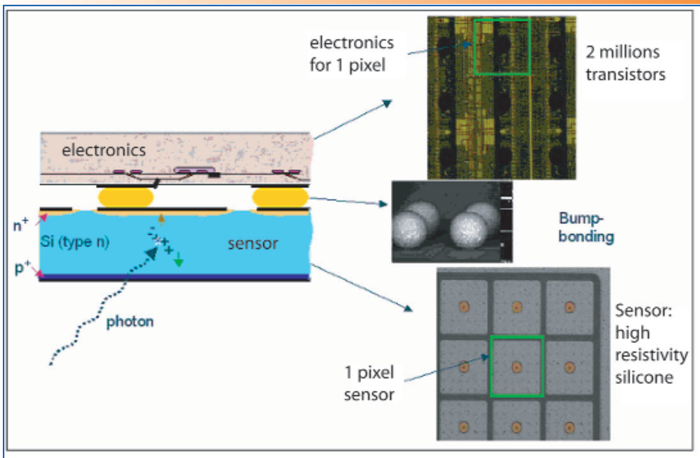

Figure 1: Principle of a pixel detector

On the strength of its experience in the development of this type of detector for high-energy physics (Delphi, Atlas), the CPPM/IN2P3[1] Laboratory has led, in collaboration with the D2AM[2] beamline of French CRG[3] at the European synchrotron ESRF (CNRS – CEA), works demonstrating the feasibility of this type of detector for experimentation within a 3rd-generation synchrotron.

Three generations of XPAD

The results obtained from experiments in crystallography with the 6,000 pixel prototypes based on XPAD1[4] circuits, then on 34,000 pixels based on XPAD2[5] circuits (figure 2 – characteristics; see table) are very promising. Indeed, in comparison with conventional systems, the data collected are of equally good quality; the signal to noise ratio is greatly improved, and temporal performances are heightened. In order to have access to high-performance detectors for its machine, SOLEIL has collaborated in the development of a third-generation circuit, the XPAD3, adapted to the characteristics of its 'hard X-ray' beamlines (table below). A first XPAD3 circuit bump-bonded on a silicon converter (500 µm thickness) was tested on the D2AM/CRG beamline at the ESRF as well as on the DIFFABS and PROXIMA1 beamlines at SOLEIL.

Figure 2: XPAD2 module (8 chips) mounted on a small Printed Circuit Board card (above) and 6.4x6.4 cm² imager composed by 8 tiled modules

The detector is perfectly linear up to 2.10^5 photons per second per pixel, which corresponds to 10^7 photons per second per mm². The image of a 10 µm-wide slit (figure 3) permits spatial resolution of 1 pixel. Figure 4 shows an image of diffraction produced by a quasi-crystal. Tests have also showed the good functioning of the reading during acquisition, permitting the reduction to zero of the time between two images.

The results obtained are also a very good sign for the 8cmx12cm imager being built, which will be available at the end of this year, 2007. With the XPAD, a necessary and hoped-for technological leap for instrumentation in the area of the synchrotron beam has just been accomplished.

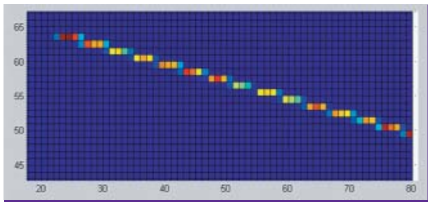

Figure 3: Image of a 10 µm-wide slit

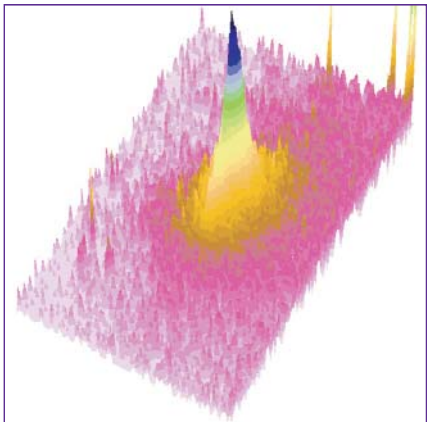

Figure 4: Diffraction of a quasi-crystal

Features of the XPAD2 and XPAD3 detectors

	XPAD2	XPAD3
Detection substrate	Si (500µm)	Si (500µm) or CdTe
Submicron technology	AMS 0.8 µm	IBM 0.25 µm
Pixel size	330 x 330 µm²	130 × 130 µm²
Adjustable threshold	15 to 25 keV	5 to 35 keV
Number of pixels / circuit	24 x 25	80 × 120
Maximum count rate (random)	2 10^6 ph/s/pixel	2 10^5 ph/s/pixel
Read out time	2 ms	2 ms possible continuous mode
Total surface of the imager	8 x 8 circuits *i.e.* 6.4 x 6.4 cm²	8 x 8 circuits *i.e.* 8 x 12 cm² (in progress)

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1 Centre de Physique des Particules de Marseille/Institut National de Physique Nucléaire et de Physique des Particules.
2 Diffraction Diffusion Anomale Multi-longueurs d'onde.
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4 Berar et al., J. Appl. Cryst. 35 (2002) p471-476.
5 Berar et al., NSS-MIC/IEEE, Rome (2004) (Oct. 16-22).