Medipix2 at kilohertz frame rate

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Outline

- Fast detector needs on SR beamlines
- Readout speeds with Medipix2
- ESRF fast readout system
- Current status

Fast detector needs on SR beamlines

- An experiment can generate 10^9 to 10^{12} X-ray photons/second, this allows to acquire time-resolved data in the ms range or below.
  - Explore dynamic processes in the ms time scale
  - Reduce the data collection time
  - Provide noiseless detection
  - Optimize detection area

SR applications : requirement examples

	SAXS	**XPCS**	**CT**
Dynamic range	10^6 (20 bits)	10^2-10^3	$>10^4$
Readout dead time	< 0.1 s	< ms (ideally)	ms desirable
Detectivity	~single photon	single photon	~single photon

Readout speeds with Medipix2

		serial readout	32 bit parallel bus
clock		**100 MHz***	**100 MHz***
readout time		**9.18 ms**	**0.29 ms**
frame rate	10 ms exposure	52 Hz	97 Hz
dead time	10 ms exposure	48%	3%
frame rate	1 ms exposure	98 Hz	775 Hz
dead time	1 ms exposure	90%	23%
dead time	1 kHz frame rate	-	29%

* possibly > 200 MHz

Medipix2 for SR applications

Increase frame rate to kHz → *time-resolved, reduced dead time*

Enlarge detection area → *more applications*

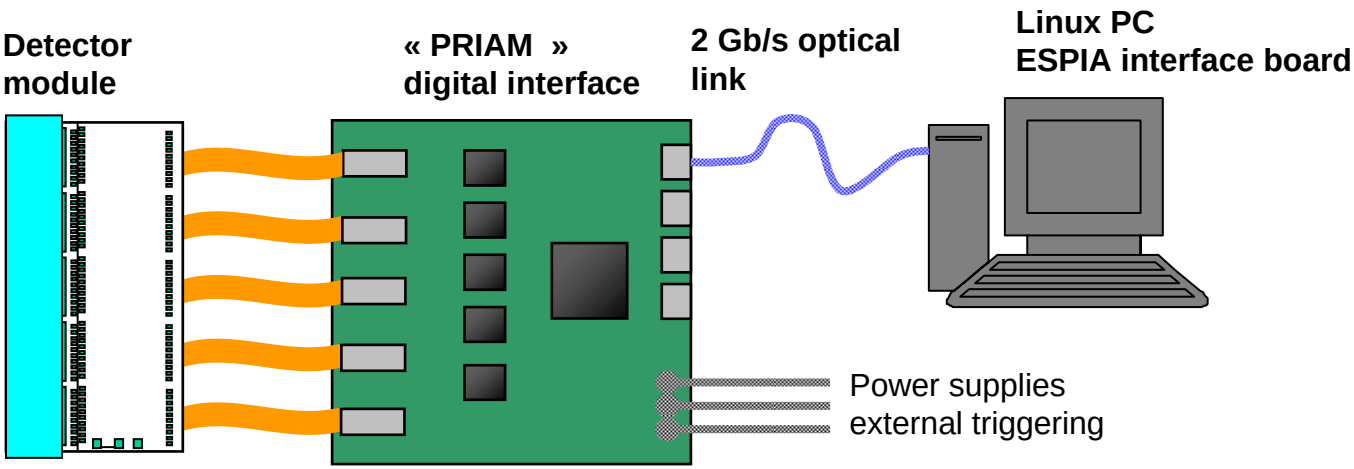
In-house data readout → *easier support/upgrading*

Full beamline integration → *accessible to* ESRF *users*

→ "MaxiPix"

MaxiPix project

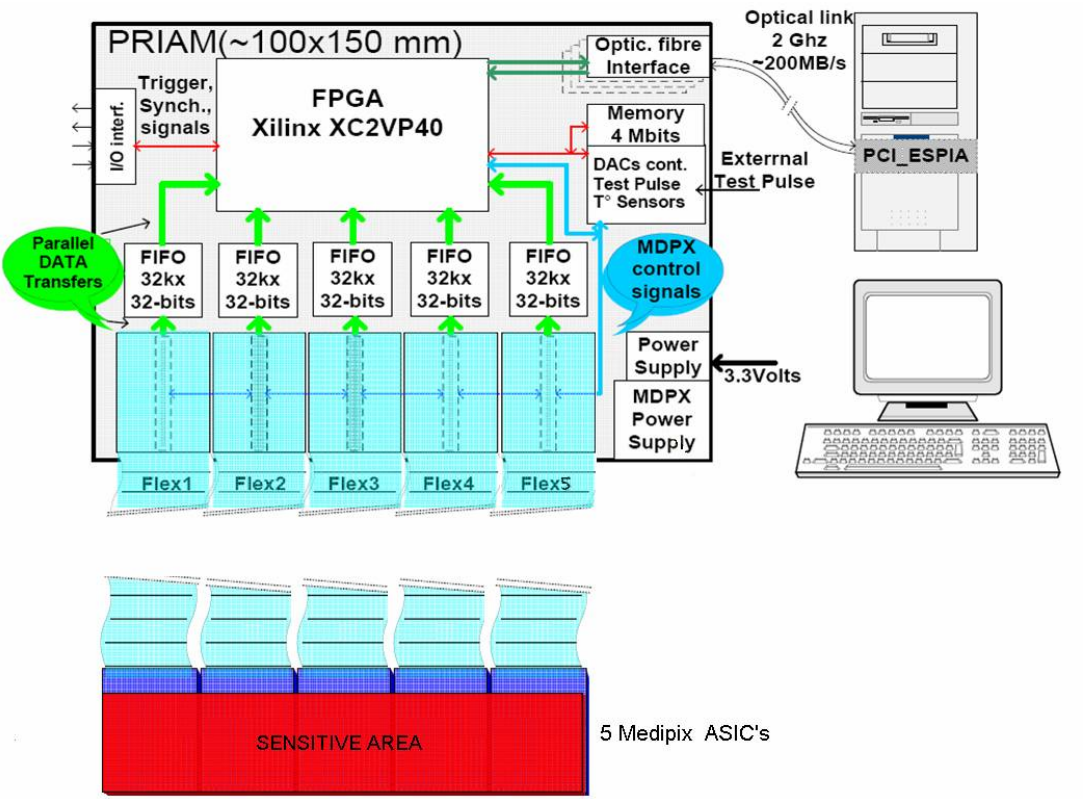
Multichip assembly for X-ray imaging based on a photon-counting pixel array



- Based on Medipix-2 readout chip
- 1280 x 256 pixels (5 x 1 chips)
- **up to 70 x 14 mm^2 detection area**
- 2 (3) sides buttable module
- **0.3 ms readout dead time**
- **>1 kHz/chip frame rate**

MaxiPix : the PRIAM board

PRIAM (**P**arallel **R**eadout **I**mage **A**cquisition **f**or **M**edipix)
... the HEART of the system !



ESRF Instrument Support Group, Detector Electronics (J.Clement, J.M. Rigal)

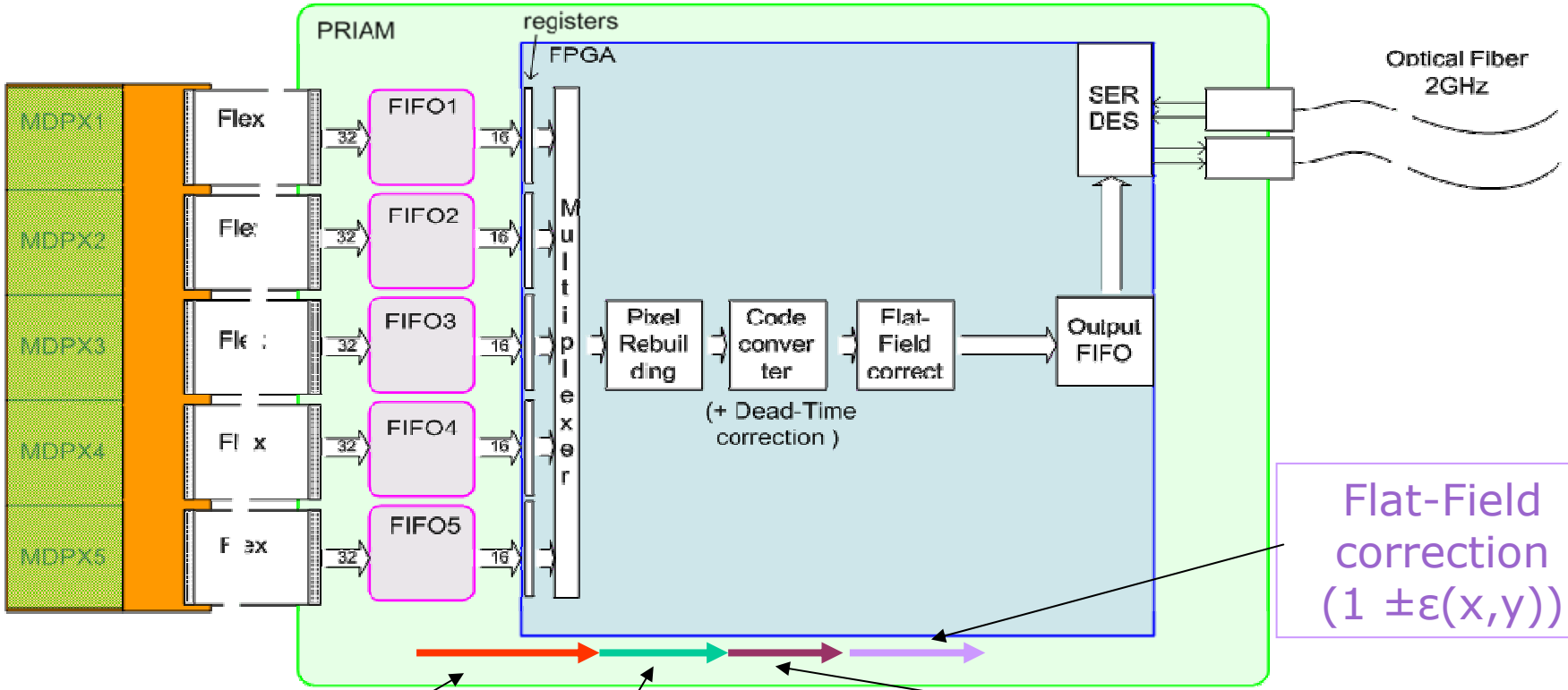
PRIAM Functions

- End-User oriented (not a test board).
- Get the maximum read-out rate of Medipix2.
- Group all features on one system (control, image acquisition, power, ...).
- Controlled by Pers. Computer(Windows /Linux)
- Able to control a detector with up to 5 Medipix2 chips.
- Send formated images(with 5 MDPX2) to PC at a rate better than 100 images/s.

PRIAM Fast Parallel Read-Out

- 32-bit bus from each Medipix is connected to a dedicated 32k*32-bit FIFO on PRIAM.
- These Fifo's allow 150MHz transfer rate (can be updated to a 225MHz version)
- PRIAM board must be as close as possible to Medipix2 chips.....
- For 100MHz transfer rate, the total read-out time(dead-time) of Medipix ASIC is 290µs

PRIAM architecture Image Acquisition/Image transfer



Flat-Field correction (1 ±ε(x,y))

FIFOs are read sequentially (row by row) and a mux is used to steer data to the same process

Rebuilt the original 14-bit pseudo-random value from the flow of bits delivered by the 32-bit // bus of MDPX2)

Convert pseudo-random value to binary value through a LUT. Dead-time correction can be done at that level.

PRIAM Full Control of Medipix ASIC's

- Programmable oscillator for Medipix Clock from 15 to 300MHz.
- All parameters of each ASIC can be controlled by the PC.
- "Operation modes" defined for MEDIPIX2MXR20 are totally available. Compatibility with MEDIPIX2MX20 and MEDIPIX2M
- Test_Pulse generated by PRIAM or from external generator

PRIAM Additional Features

- Local 4-Mbit Serial Flash (up to 64 Mbits)
- Temperature sensors (1 on PRIAM + 1 close to Medipix ASICs). Provide Temperature and an unique serial number.
- The 2 above features will help for calibration, initialization and maintenance.

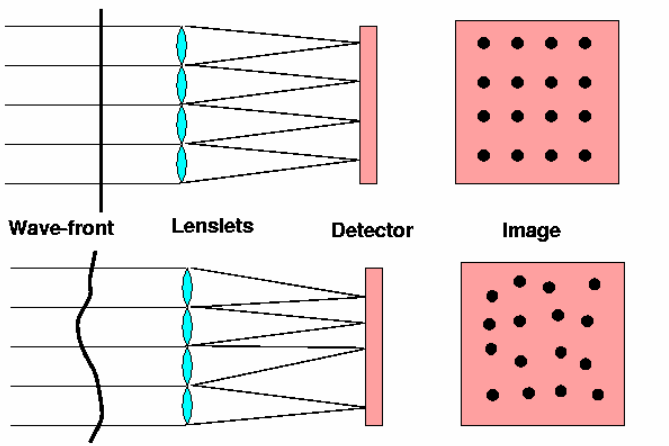
- Analog signal (LEMO00) is provided through a DAC channel(0 to 2.5V).(control of extern. HV)

- 2 TTL inputs and 2 outputs to synchronize image captures with other instruments.

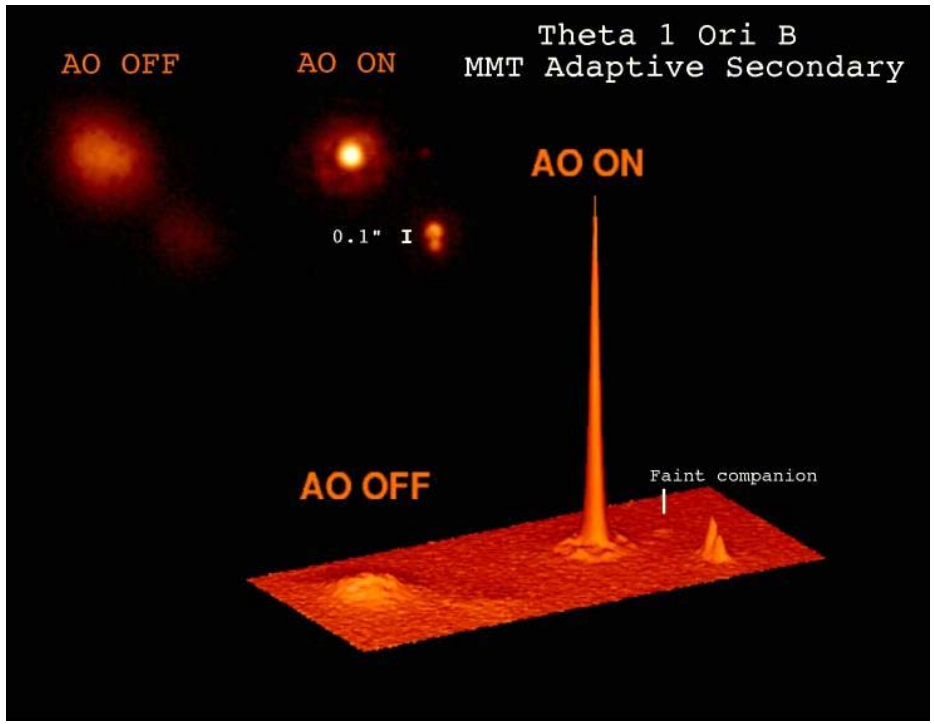
Astronomical adaptive optics

Project partnership with University California Berkeley and University of Genève

J.Vallerga et al., NIMA546 (2005)



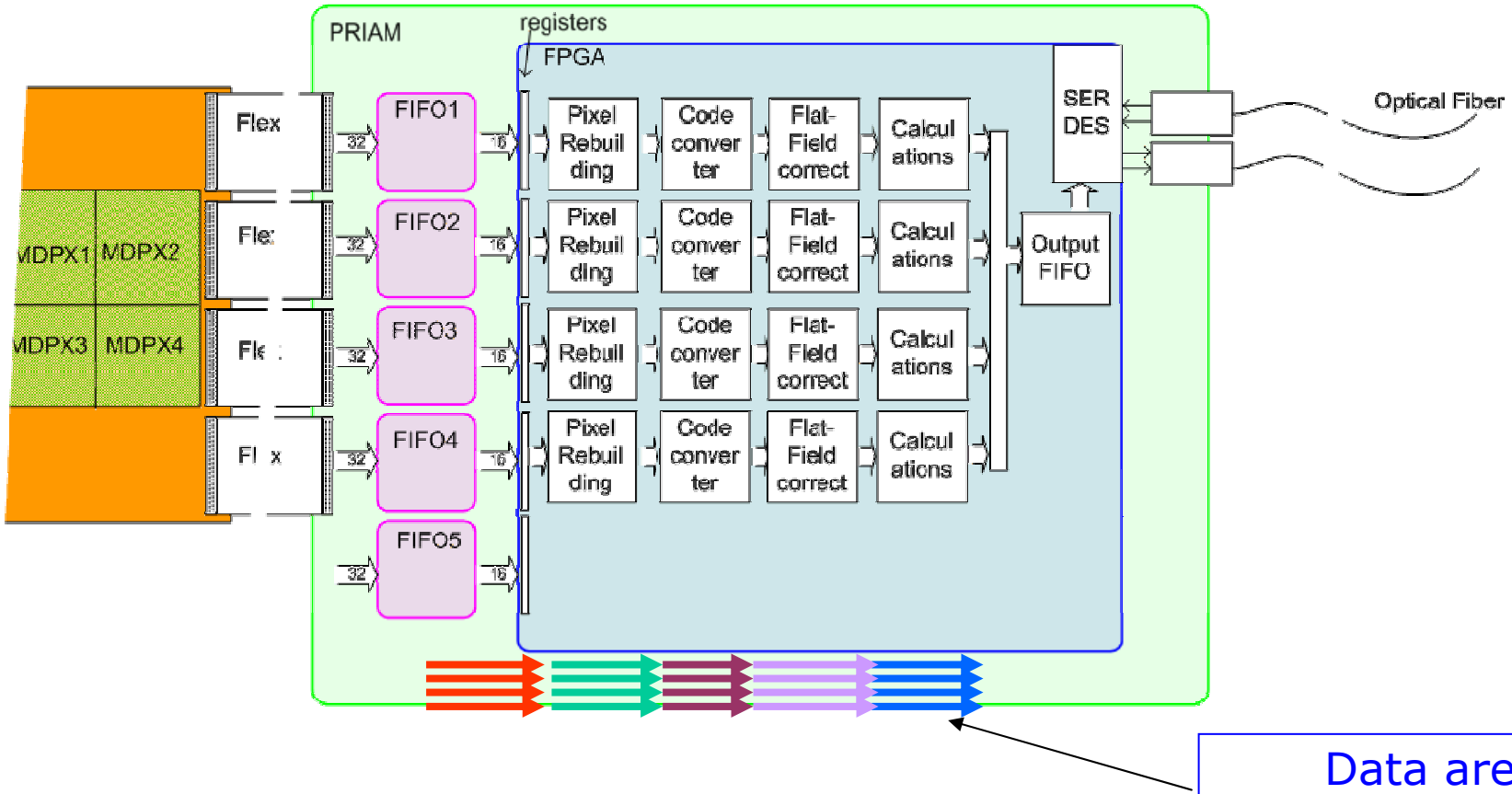
wavefront sensing



effect of adaptive optics on point source image sharpness

- Goal : up to 1 kHz sampling rate

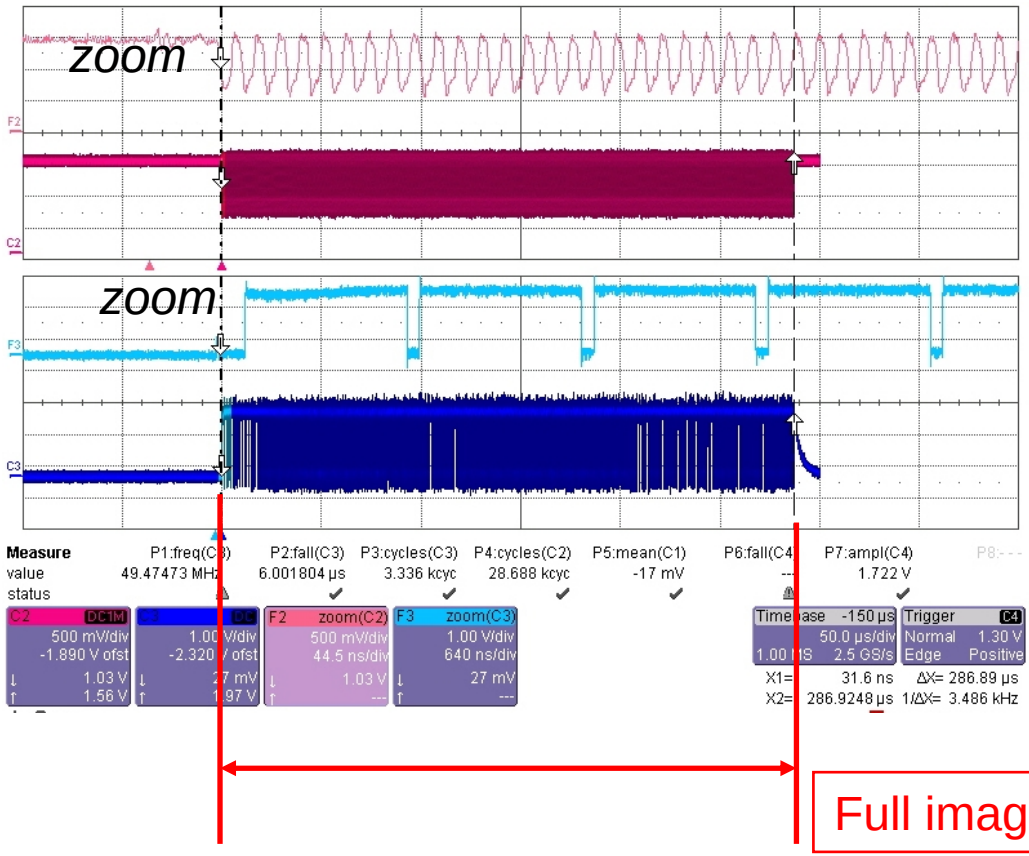
PRIAM architecture: Image Acquisition /Adaptive Optic project



PB: have a 1kHz frame rate and deliver for each frame the centroid(x,y), the variance(x,y) and total count of 5000 spots. (each spot is on a grid of 7*7 or 5*5 pixels)

Data are processed on 4 independent fluxes and a calculation stage is added

Results



LVDS clock in 100 MHz

CMOS out D0

Full image frame readout in 290 µs

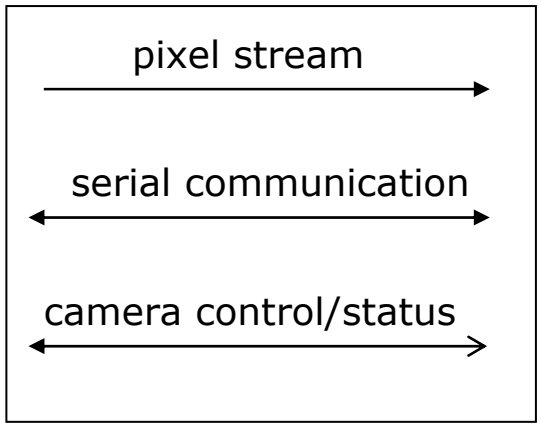
Computer interface

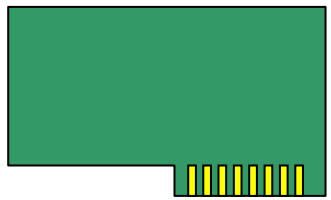
imaging system

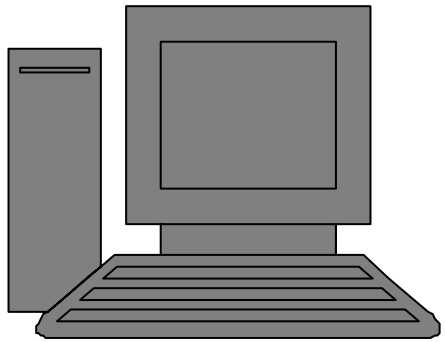
serial link
2 GBaud optical
(Xilinx Aurora IP)

ESPIA board

PC
PCI 64 bits/66 MHz



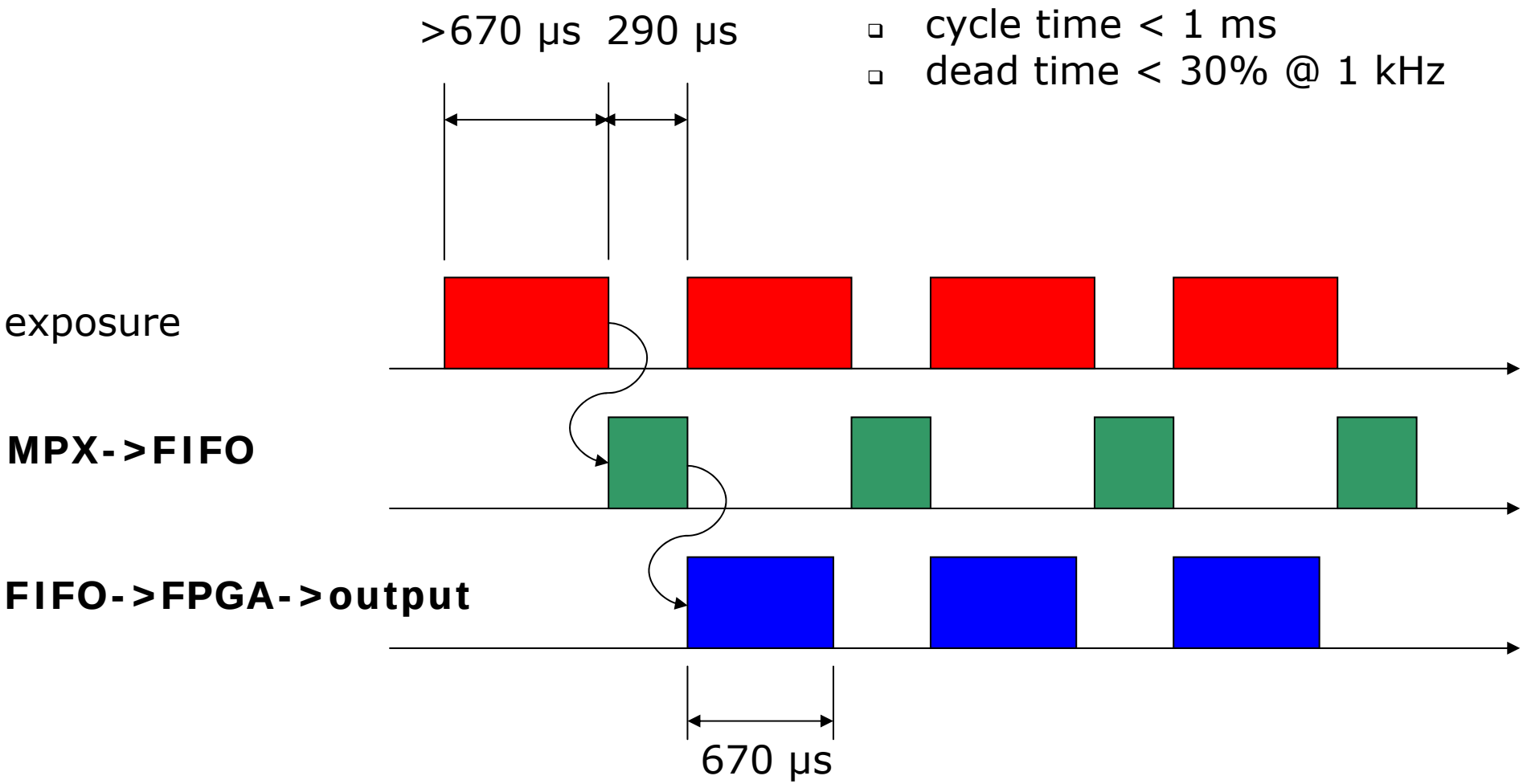




- max. theoretical pixel rate = **100 Mpixels/s/fibre**
- min. readout time = **0.67 ms**
- Windows and Linux drivers
- commercial product (http://www.secad.fr/)
- used in the ESRF "**FreLoN**" fast CCD camera system

Data flow timings

- cycle time < 1 ms
- dead time < 30% @ 1 kHz



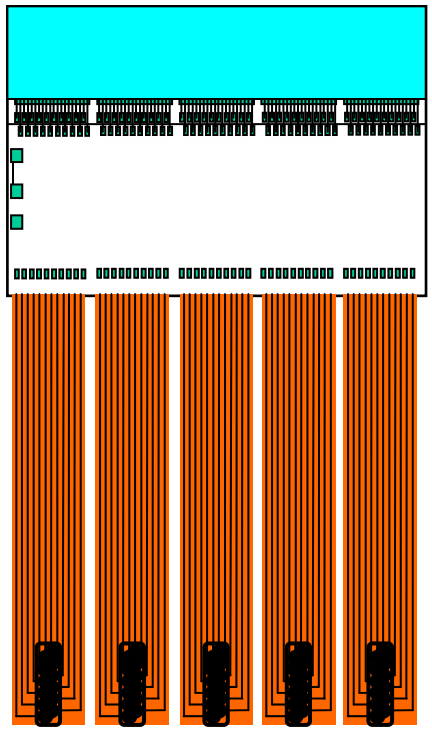
PRIAM Status

- Board under test since November 2005
  - Serial and parallel access to MEDIPIX have been done at 100MHz
  - **1000 frames/s rate (from MDPX to PC memory) have been validated**
  - Software control of all parameters and features of PRIAM board

- Options not tested :
  - temperature sensor control
  - on-line Look-up-table for flat-field correction
  - architecture for Adaptive optics system
  - parallel read-out speed ? 100 → 150 → **200 MHz** → ??

- New PRIAM board (ready in September 06) with minor changes:
  - Pin-Out of flex connectors.
  - Clock circuitry for Fifos
- Future:
  - **Compatibility with TIMEPIX** ?
  - Board (with local memory and local "image processing") to collect data from several MaxiPix systems and send to PC acquisition system a formatted image of the whole detector.

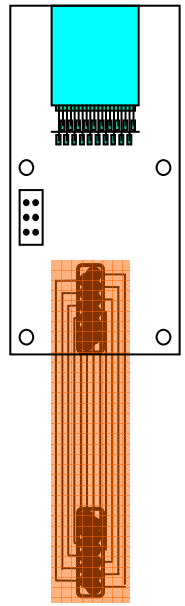
MaxiPix : detector modules

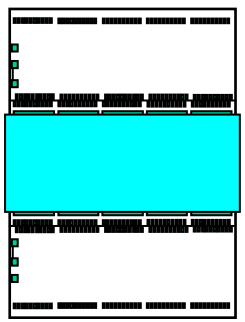


monolithic 5x1 sensor

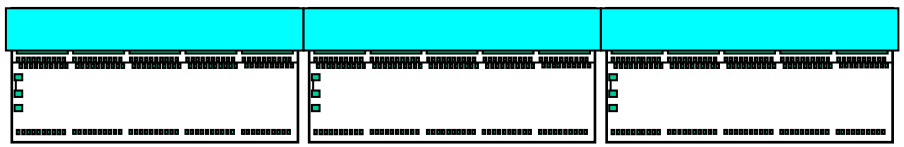
carrier (PCB or ceramic)

flex connectors





5x2 layout
(~70x30 mm^2)



5Nx1 arrangement

SR applications

Powder diffraction

- improved data SNR
- possible reduction of data collection time by a factor 100 or more
- increased time resolution

X-ray photon correlation spectroscopy

- simultaneous correlation measurements in time and Q domains with ms resolution

Pump-probe (= spectroscopic) experiments

- accumulation of frames at high rate with no noise build-up

Small-angle scattering

Surface diffraction

Computed tomography

...

MaxiPix : a team project

ESRF

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F. Lesimple
E. Papillon
A. Homs
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Medipix collaboration