

Synchrotron과 XFEL을 위한 2차원 X-선 검출기

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국내 방사선 계측기 및 입자검출기 기술 워크샵
(한국원자력학회)

1. Introduction
2. PLS-II and PAL-XFEL(+Characteristics of Synchrotron Radiation)
3. 2-D detectors for XFEL(Requirements)
4. Development of detectors for XFELs
5. Detectors at PLS-II and PAL-XFEL
6. Summary

1. 포항가속기의 **Detector** 관련 연구

A. 독자적인 개발 연구는 아직 없음

B. 통상적인 detector 운용 및 Calibration 업무 수행

C. PERCIVAL Consortium에 참여 중(Soft X-ray pixel detector 개발)

- DESY(Germany), PAL, Trieste(Italy), DLS(G.B), RAL(G.B)
- 2013-2018(Joined in 2014)
- 2M, 13M detectors in soft X-ray
- 120 Frame/Sec

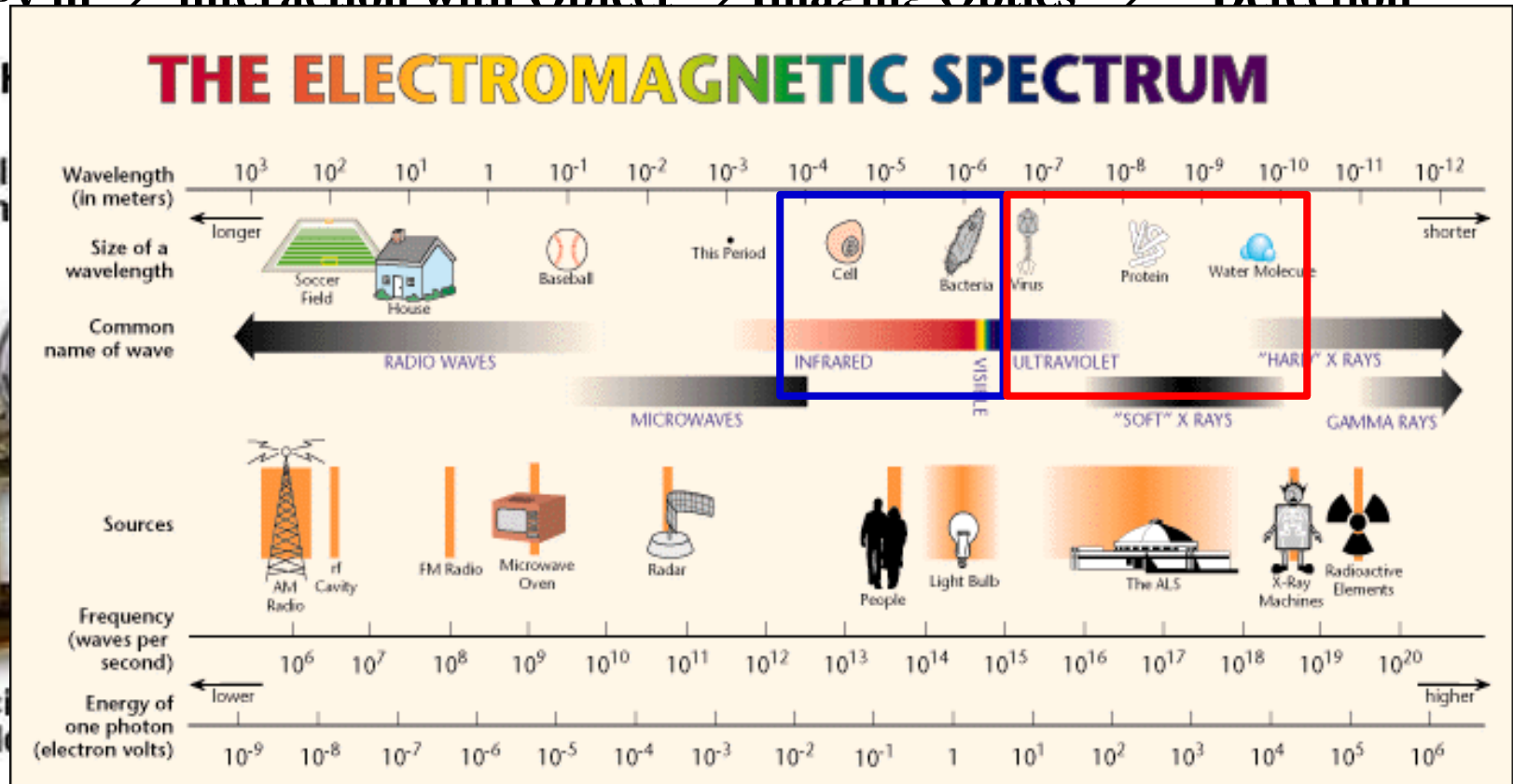
1. Introduction

2. One of major research task in recent history

Microscope (Medical/ Biological Science)

Energy in → interaction with Object → Imaging Optics → Detection

(F



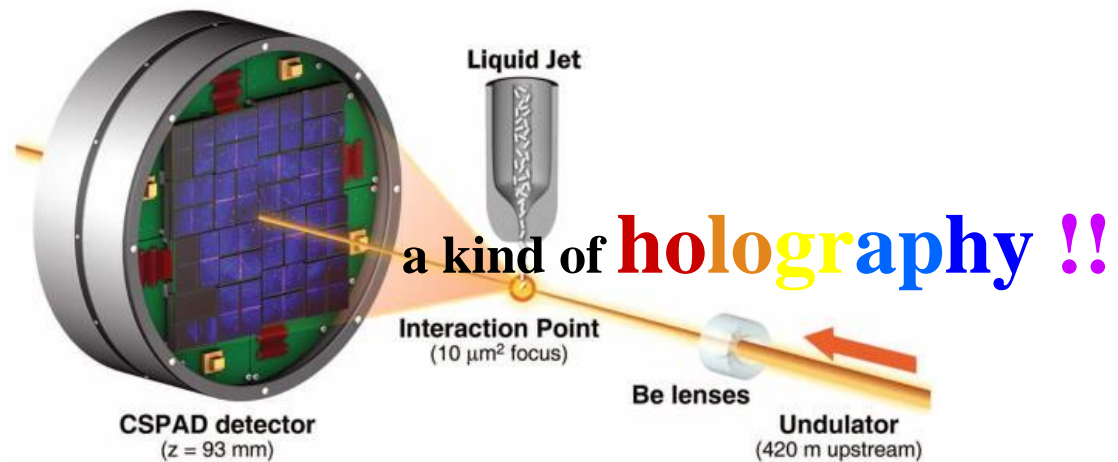
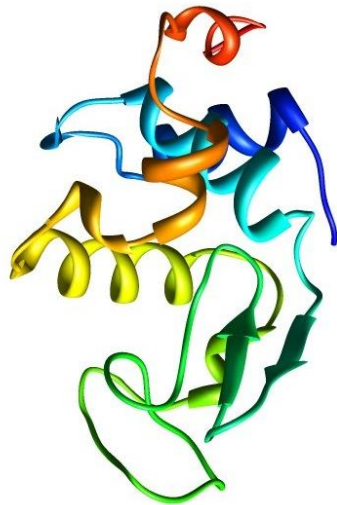
<http://www2.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html>

3. Microscopy, still exciting(in X-ray region)

3-1. It was not common(low attenuation by object)

3-2. It is needed for high resolution-Resolution depends on λ
(sub-micron, sub-nano, atomic scale)

3-3. **Coherent X-ray in** \rightarrow Scattering/Diffraction by Object
 \rightarrow detection \rightarrow **Data processing & visualization**



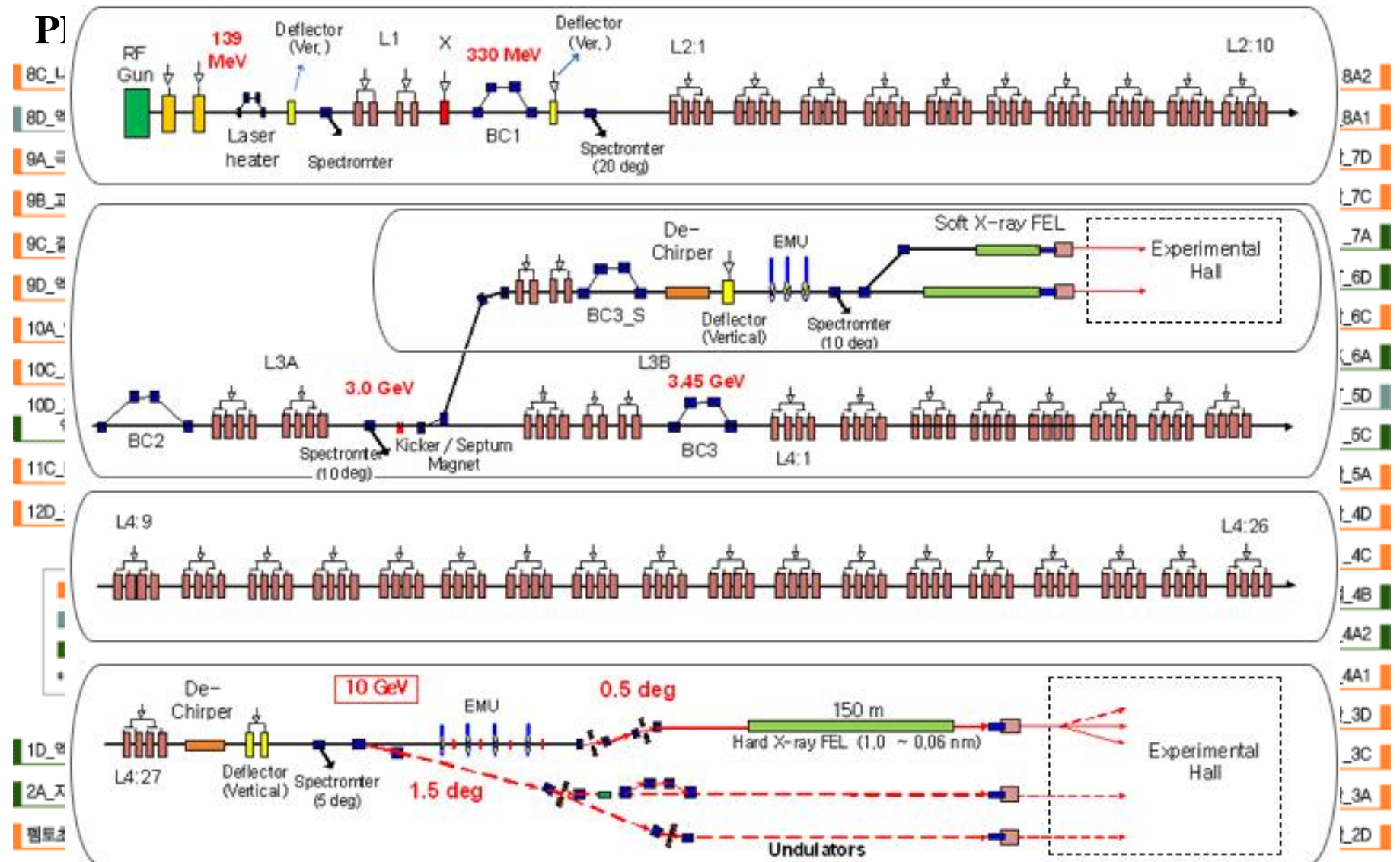
Boutet *et al.*, Science (2012)

2. PLS-II and PAL-XFEL (+Characteristics of Synchrotron Radiation)



2. PLS-II and PAL-XFEL (+Characteristics of Synchrotron Radiation)

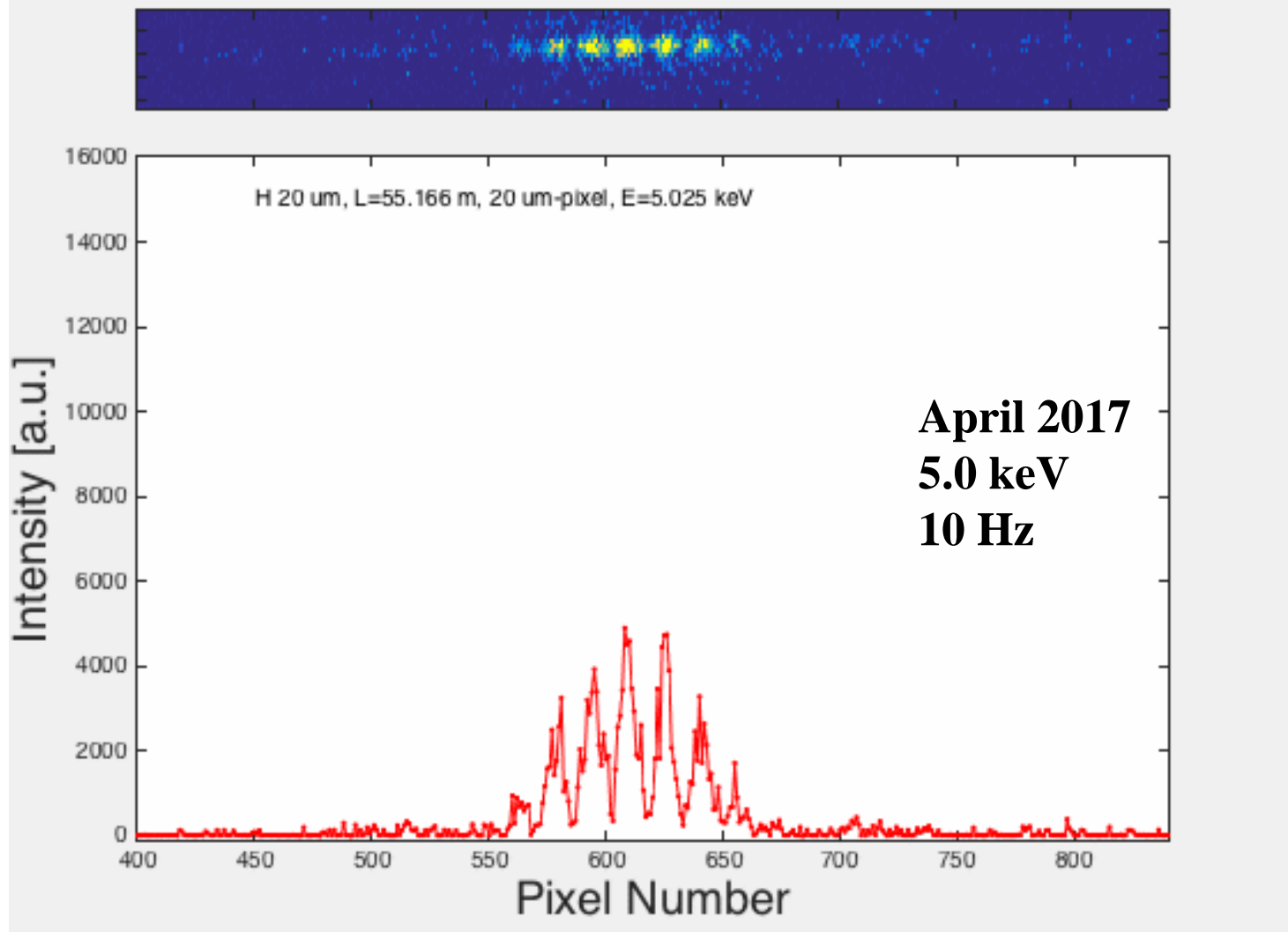
PAL-XFEL Layout



Characteristics of Synchrotron Radiation

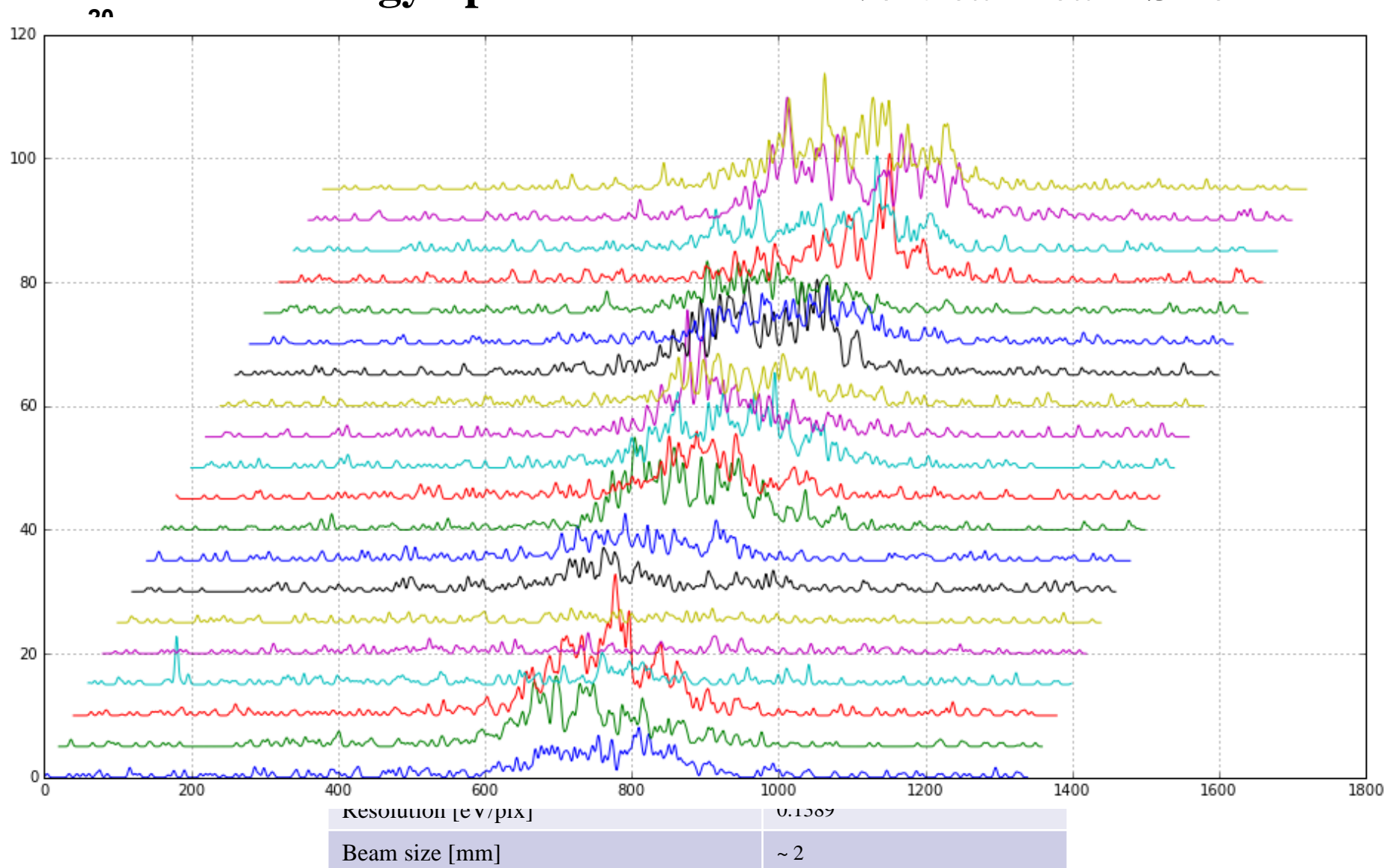
	PLS-II	PAL-XFEL	Remarks
Photon energy [keV] (/wave length [nm]) range	0.02-15 (0.08-62)	0.27-1.2, 2-20 (1-4.5, 0.06-0.6)	
Pulse rate [Hz]	1~500M	60 max	SACLA, LCLS, Swiss-FEL, 4.5MHz (Eu-XFEL), 1MHz (LCLS-II)
Pulse duration [fs]	30,000	10~250	
Coherency	Poor	Excellent	
Flux [$\times 10^{12}$]	~1/sec	0.5~1/pulse	Sample damage
Beam size [mm]	A few	< 0.2	

Fluctuation and coherency



XFEL Energy Spectrum

Vertical Beam Size



3. 2-D detectors for XFEL(Requirements)

3-1. Detectors for Synchrotron

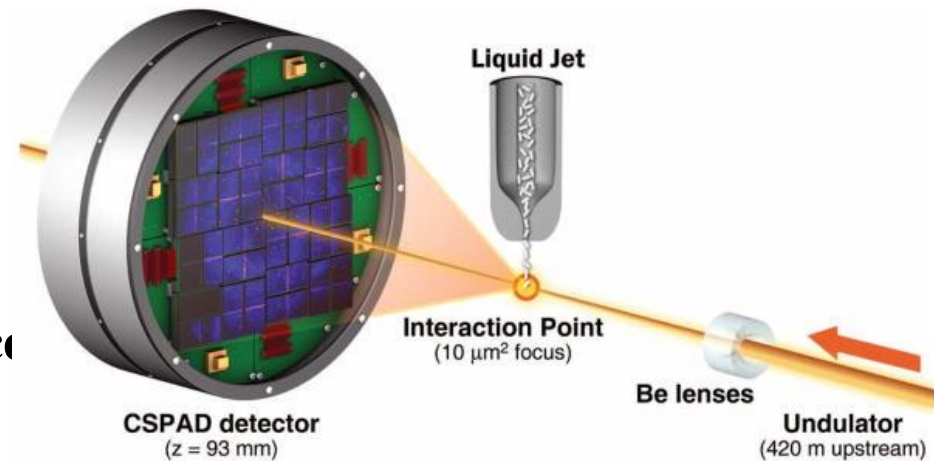
Low flux

Low coherence

Very fast exposure frequency

Big x-tal sample(Fixed in the space)

small contrast
multiple Exposure



Boutet *et al.*, Science (2012)

Image plate

Direct/Indirect CCDs

Direct/Indirect CMOSs

(Integration/Counting)

3-2. Detectors for XFEL

High coherence

High flux

Fast(MHz)/Slow(~100Hz) exposure frequency

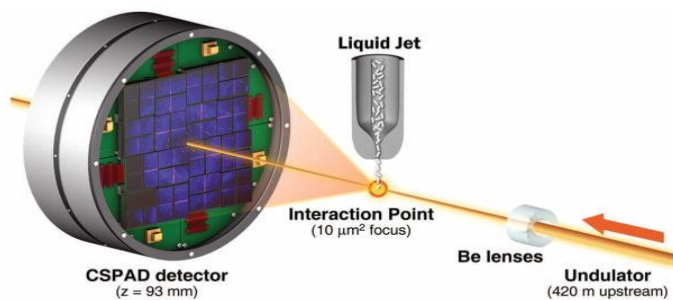
tiny x-tal sample

(Radiation damage/ shot-by-shot orientation/position change)

Pulse by pulse Exposure

good contrast

Shot-by-shot change



Boutet et al., Science (2012)

1. Single photon detection(Low noise)
2. Wide dynamic range ($\sim 10^4$)
3. High conversion efficiency(direct detection)
4. Large area (4M ~16M)
5. High frame rate (~ 60 Hz, ~ 4.5 MHz)
6. Central hole
7. High radiation resistance

3-3. Development of detectors for XFELs

CCDs

- low noise
- reasonable dynamic range
- slow readout
- cooling
- deeper charge well
- multiple readout
- buttable design

CMOSs

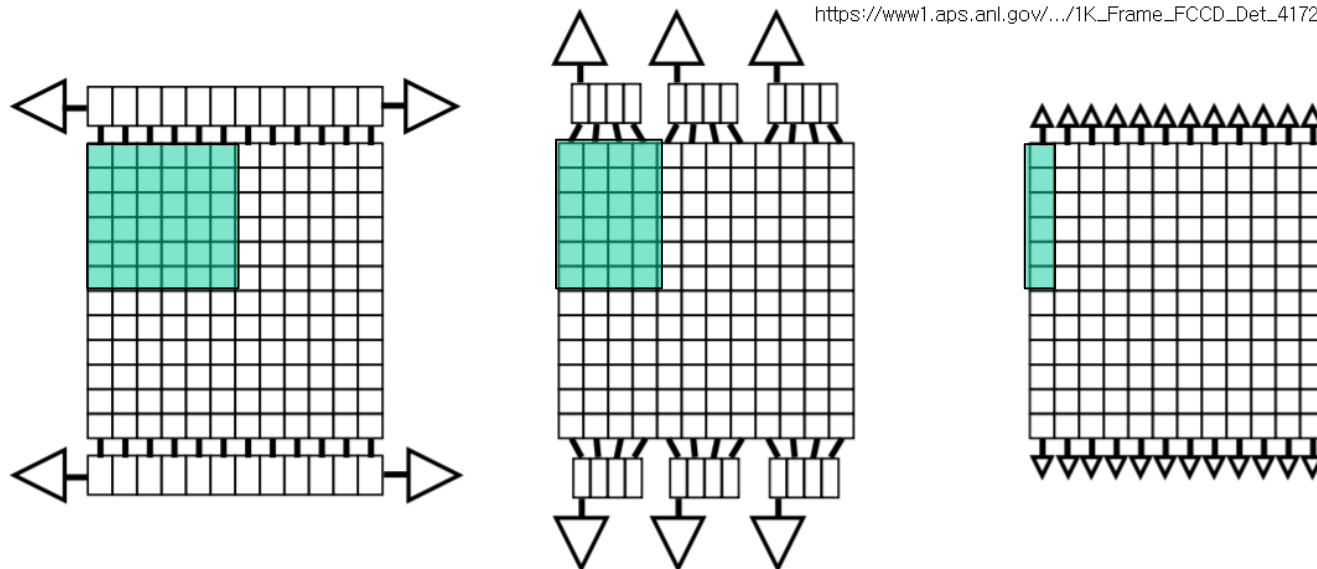
- noise
- small dynamic range
- fast readout
- cooling
- multiple (adaptive/adjustable) gain
- large analog memory in pixel
- buttable design

4. Development of detectors for XFELs

For the fast readout of CCDs(FastCCD, pnCCD, MPCCD)

3rd Generation Detector - Very Fast CCD

https://www1.aps.anl.gov/.../1K_Frame_FCCD_Det_4172012.pdf



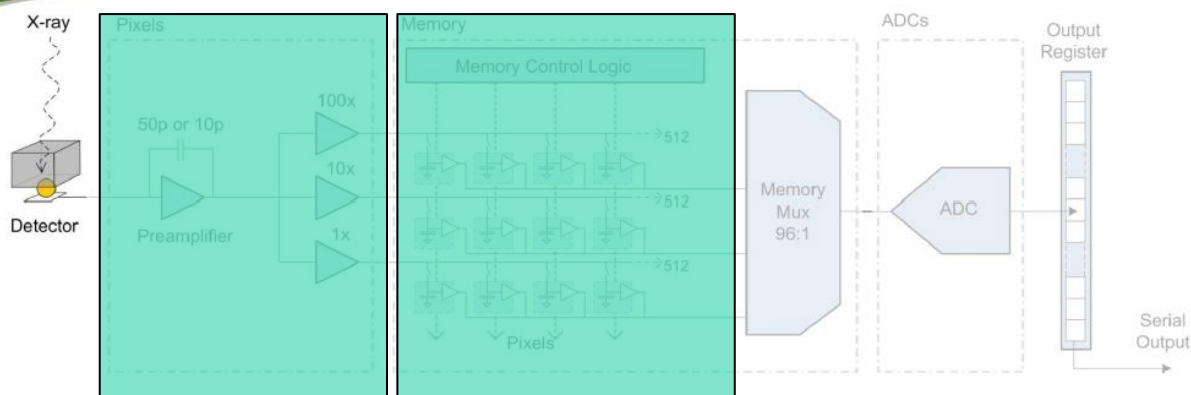
Conventional CCD	FastCCD	Very FastCCD
4-port	(almost)Column Parallel	Column Parallel
Commercial readout	<i>fCRIC</i> (custom 0.25 μm CMOS readout IC)	<i>HIPPO</i> (custom 65 nm CMOS readout IC)
10^0 fps	10^2 fps	$>10^{3.5}$ fps

20110620 FastCCD Status P. Denes

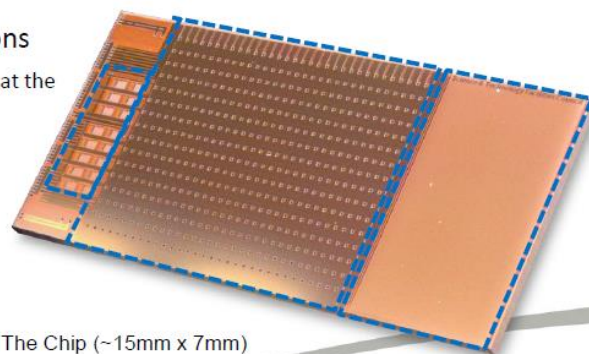
Multiple gain for large dynamic range(LPD, SOPHIAS)

Readout ASIC

https://indico.cern.ch/event/174805/.../1434478/.../PSD_LPD.pdf



- 512 Channels
- Preamplifier with 50pF feedback – 10^5 12keV photons
 - An additional high mode gives sub photon noise performance at the expense of some dynamic range.
- 100x, 10x and 1x parallel gain stages
- 512 frames of memory for each channel and gain
 - Veto System
- 16 ADCs – 12 Bit
- 100MHz digital output
- IBM 130 nm

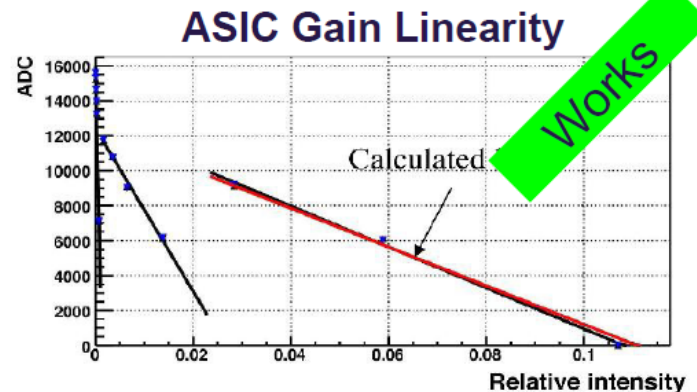
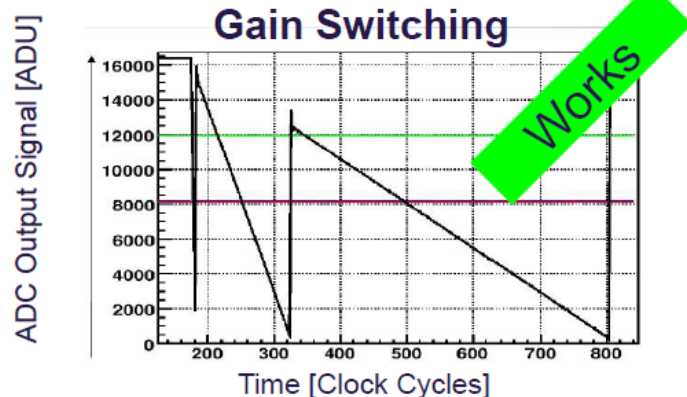
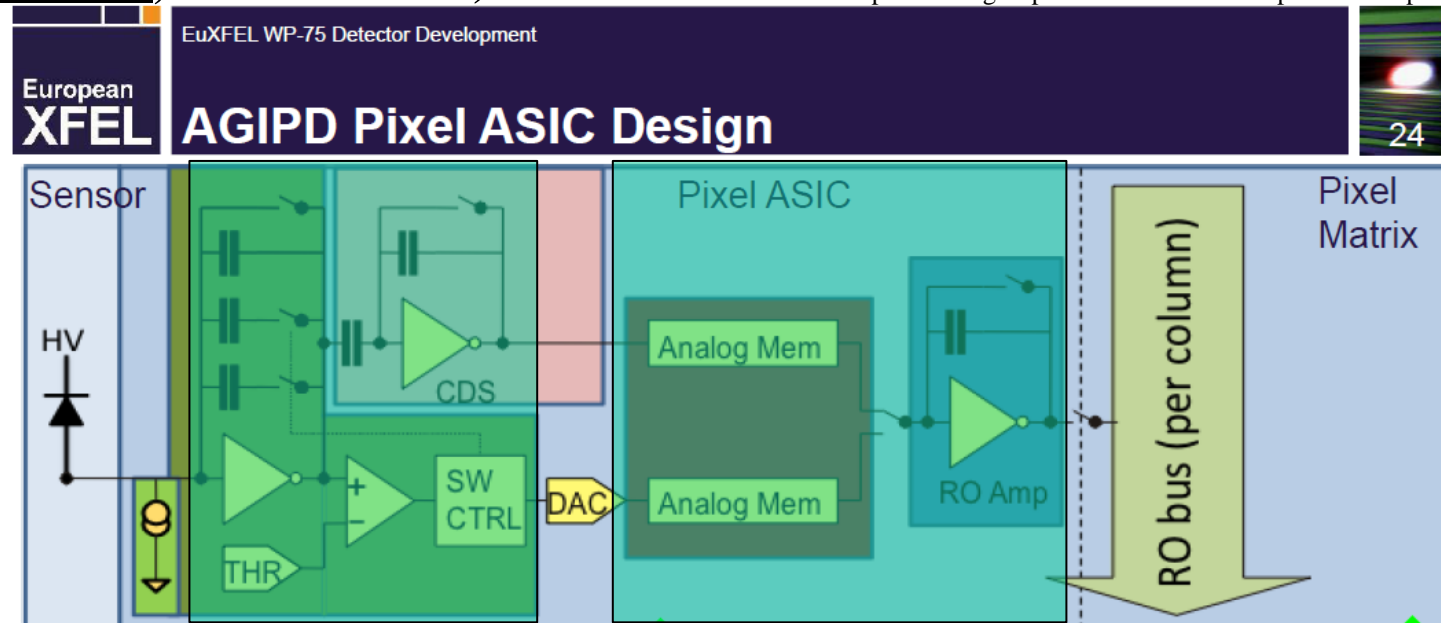


The Chip (~15mm x 7mm)

4. Development of detectors for XFELs

Adaptive(/dynamic) gain control for large dynamic range(csPAD, AGIPD, JUNGFRAU)

<https://www-group.slac.stanford.edu/ais/publicDocs/presentation170.pdf>



November 8, 2012

Instrumentation Seminar, SLAC

M. Kuster

4. Development of detectors for XFELs

Assembly of large area detector system with central hole, out of buttable modules(csPAD)

<http://slac.stanford.edu/pubs/slacpubs/15250/slac-pub-15284.pdf>

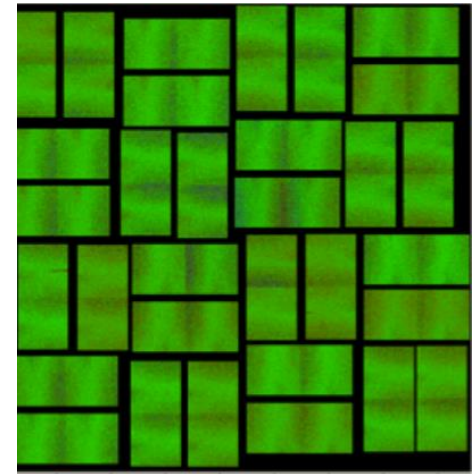
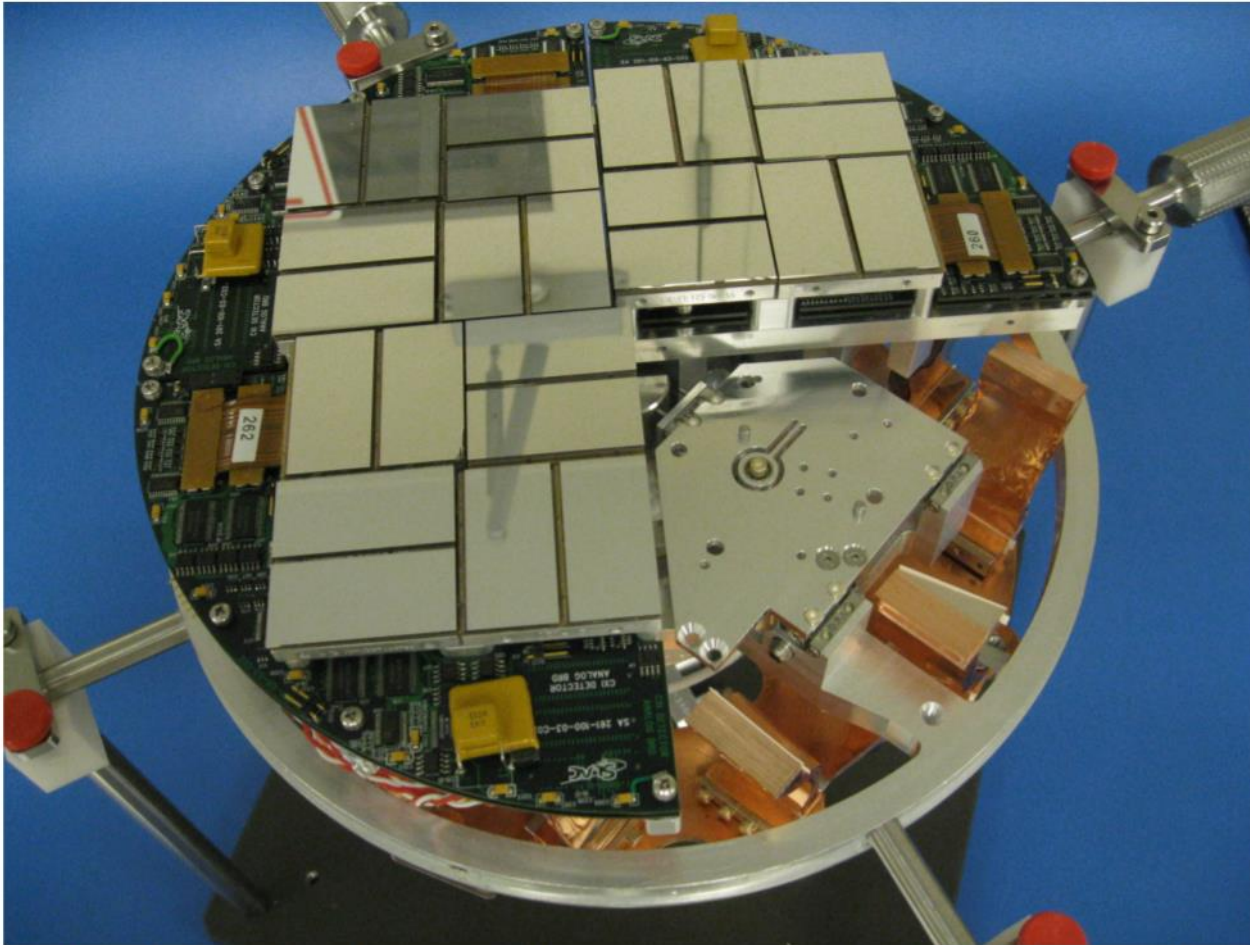


Fig. 4. Overhead view of the camera in construction, showing three of four quadrants.

4. Development of detectors for XFELs

Direct detectors available and under development

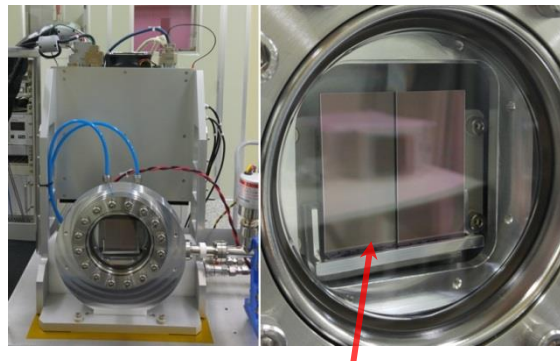
Sensor	Developer	Format (/Module)	Pixel size [$\mu\mu\times\mu\mu$]	Frame rate [Hz]	Dynamic range	Energy range [keV]
FastCCD	LBNL	1920×960	30×30	60/120	10^3 @ 3.2 keV	0.25~6
pnCCD	MPI PNDetector	1024×512	75×75	200	2×10^3 @ 6 keV	0.05~20
MPCCD	SACLA	1024×512	50×50	30	2×10^3 @ 6 keV	~20
SOPHIAS	SACLA	2157×819	30×30	60	3.6×10^3 @ 6 keV	5~12
csPAD	Cornell U.	185×194 /ASIC	110×110	120	350/2700 @ 8keV	4~20
ePIX10k	LCLS	176×192 /ASIC	100×100	1000	10^2 / 10^4 @ 8keV	
PERCIVAL	DESY Consortium	1408×1484 3520×3710	27×27	120	10^5 @ 0.25 keV	0.25~1
AGIPD	DESY	128×512	200×200	4.5M	10^4 @ 12 keV	3~13
LPD	RAL collaboration	128×512	500×500	4.5M	10^5 @ 12 keV	5~20
JUNGFRAU	PSI	1024×512	75×75	2000	10^4 @ 12 keV	>2

5. Detectors at PLS-II and PAL-XFEL

Detectors for PAL-XFEL(Available)

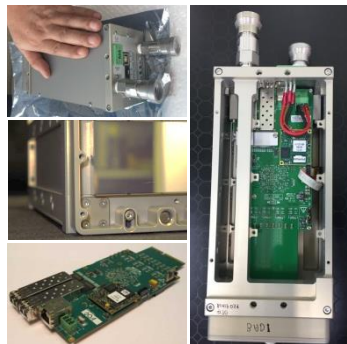
	MPCCD	JUNGFRAU	Rayonix					
			MX225-HS			LX255-HS		
Binning	-	-	1 × 1	2 × 2	4 × 4	1 × 1	2 × 2	4 × 4
Pixel Size [μm × μm]	50 × 50	75 × 75	39 × 39	78 × 78	156 × 156	44 × 44	89 × 89	177 × 177
Pixel Number	512 × 1024 / module	512 × 1024 / module	5760 × 5760	2880 × 2880	1440 × 1440	1920 × 5760	960 × 2880	480 × 1440
Active Area [mm × mm]	25.6 × 51.2 (0.5M) 51.2 × 51.2 (1M)	40 × 80 (0.5M) 160 × 160 (4M)	225 × 225			85 × 255		
Quantum Efficiency	> 80% @ 6 keV < 20% @ 12 keV	> 75% @ 4 ~ 12 keV	< 80% (Detected Quantum Effy.) @ 8-12 keV					
Frame Rate	30 Hz	Up to 2.4 kHz	2.5 Hz	10 Hz	40 Hz	2.5 Hz	10 Hz	40 Hz
Dynamic Range	~ 2500 @ 6 keV	Up to 10 ⁴ @ 12 keV	> 10 ⁴ @ 12 keV (2 × 2)					

MPCCD 1M

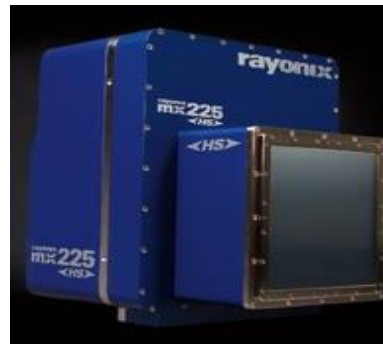


Two 0.5M sensors
are tiled

JUNGFRAU 0.5M



MX225-HS



LX255-HS

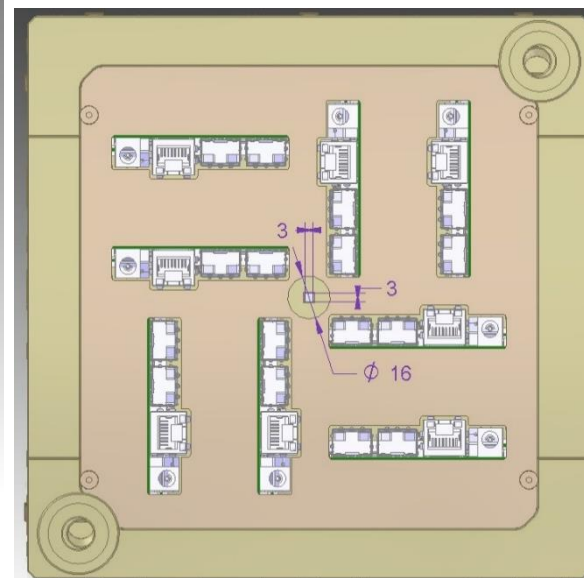
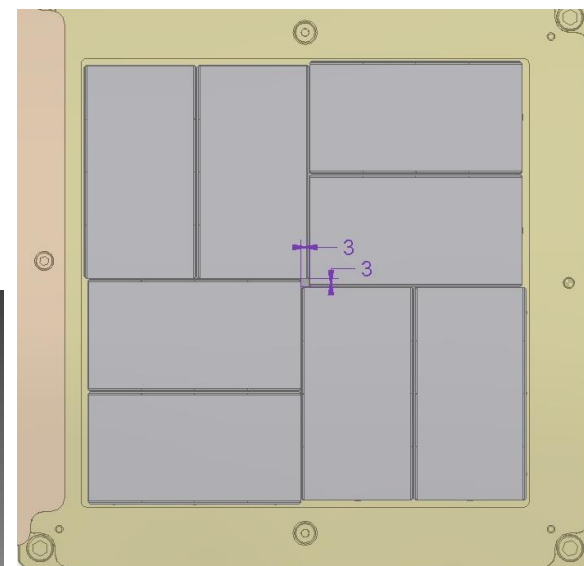
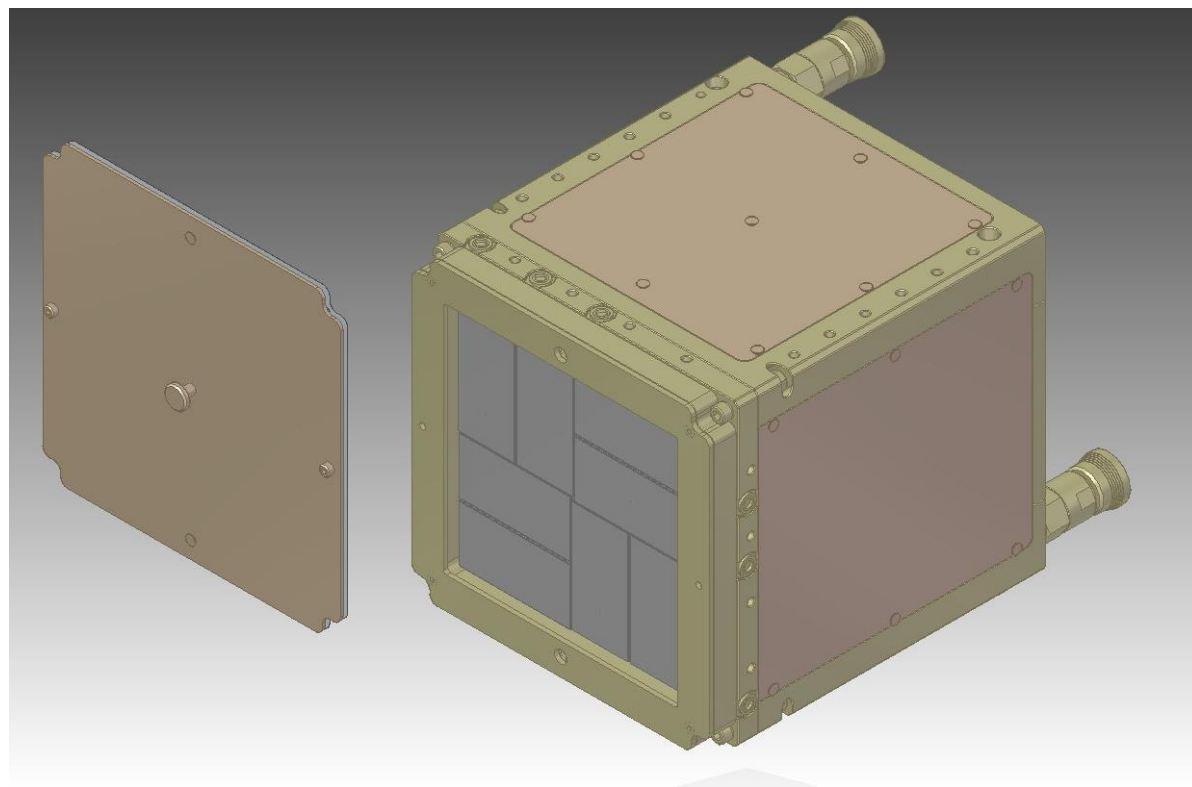


5. Detectors at PLS-II and PAL-XFEL

Larger detectors to come for PAL-XFEL

JUNGFRAU 4M

JUNGFRAU 16M



Project supervision

DESY



Electronics & Testing

Separate
agreement



STFC/RAL



Sensor developed

Elettra



Elettra Sincrotrone Trieste

Electronics

DLS



DAQ

PAL



**Joined from Nov. 2014
Man power & Testing**

Target Performance

Energy range	Primary: 250 eV ~ 1 keV Extended: 300 eV ~ 3 keV	
Dynamic range	1 ~ 10 ⁵ photons/pixel @ 250 eV	
Noise	< 15 e-rms	
Q.E.	> 85%	
Frame rate	120Hz	
Pixel pitch	27 μ m	
Number of Pixels	2 Mpixel (1408 × 1484)	13 Mpixel (3520 × 3710)
Sensor Size	4 × 4 cm ²	10 × 10 cm ²

Detectors for PLS-II(Synchrotron, Available)

Image plate

Mar 345 2set

Φ 345mm

In direct detectors

CCDs

Integration Detector

Front illuminated

Low frame rate(~0.1FPS)

ADSC Q210 1set

ADSC Q270 1 set

ADSC Q315r 1 set

Rayonix SX 165 3 set

Rayonix Mar 165 1 set

Rayonix MX 225 1 set

Direct detectors

Hybrid pixel detectors

Counting detector

Pilatus 200k 1 set

Pilatus 1M 1 set

Pilatus 6M 1 set

CCD

Integration detector

Back illuminated

PIXIS-XO 2048B 1set

요약

1. X-선의 **microscopy** 소개
2. 포항가속기의 소개
3. X-선 **laser** 활용을 위한 검출기에 요구되는 조건 소개
4. X-선 **laser** 활용을 위한 검출기의 개발에 대한 소개
5. 포항가속기의 검출기 현황에 대한 소개

감사합니다.

