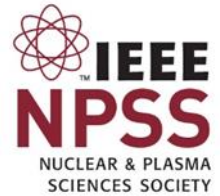


21th Real Time Conference

9-15 June 2018

Woodlands Conference Center, US



High Resolution X-ray Imaging Using Monolithic Silicon Pixel sensor

Chenfei Yang^{1,2}, Changqing Feng^{1,2}, Xiangming Sun³, Jun Liu³, Ping Yang³, Shubin Liu^{1,2}, Qi An^{1,2}

¹State Key Laboratory of Particle Detection and Electronics, Hefei, 230026, China

²Department of Modern Physics, University of Science and Technology of China, Hefei, 230026, China

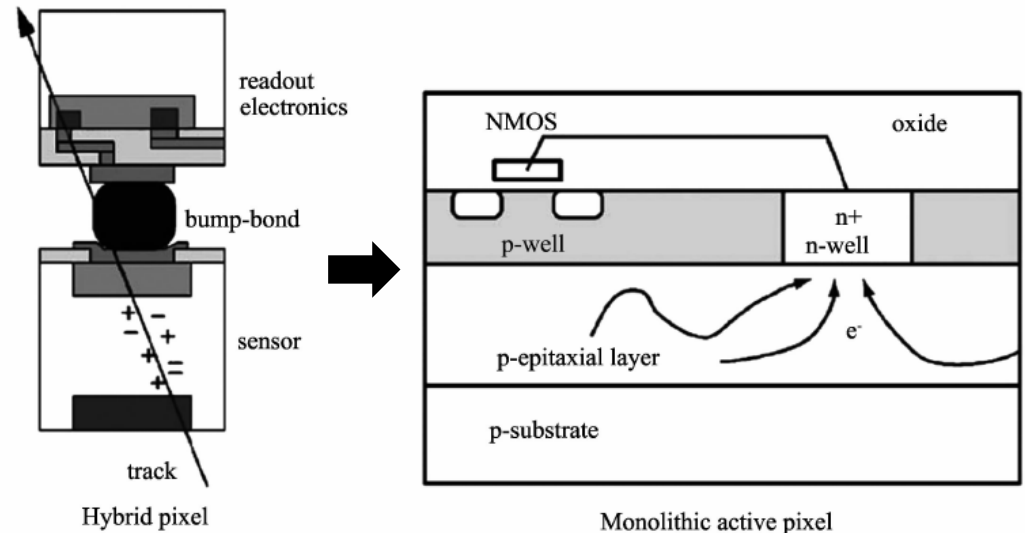
³Pixel Laboratory at CCNU (PLAC), Central China Normal University, Wuhan, 430079, China

Chenfei Yang
SKLPDE/USTC

11 June 2018

• Monolithic Active Pixel Sensor

- Low material budget
- High pixel density/ High spatial resolution
- Low power consumption
- Less signal/ power cables

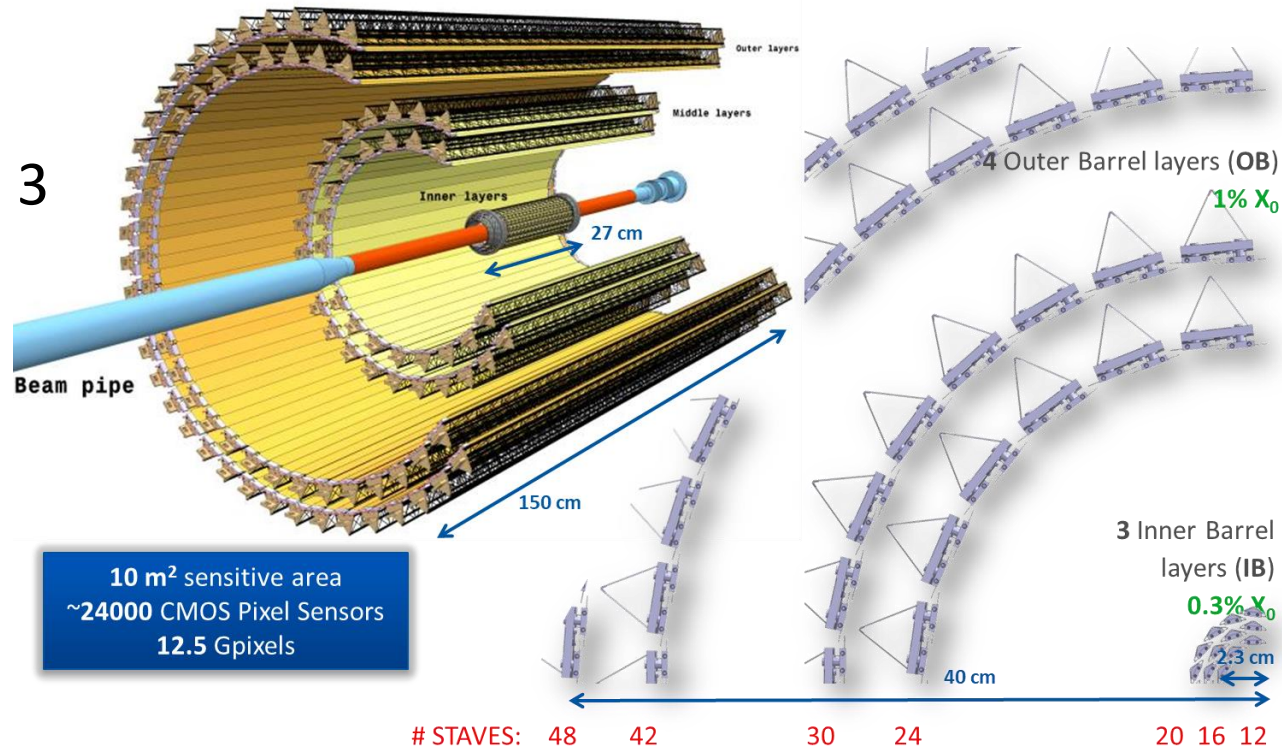


Hybrid Pixel Sensor

MAPS



- Designed for ALICE ITS upgrade 2019-2020
 - 2012: prototype circuits: Explorer-1, 2
 - 2013: pALPIDEss
 - 2014: pALPIDE-1
 - 2015: pALPIDE-2, 3
 - 2016: ALPIDE



Ref: M. Mager, ALICE Collaboration. ALPIDE, the Monolithic Active Pixel Sensor for the ALICE ITS upgrade[J]

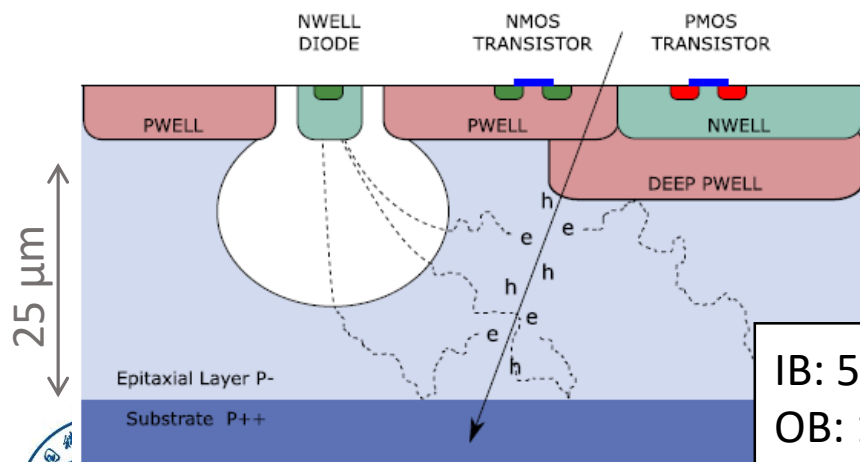
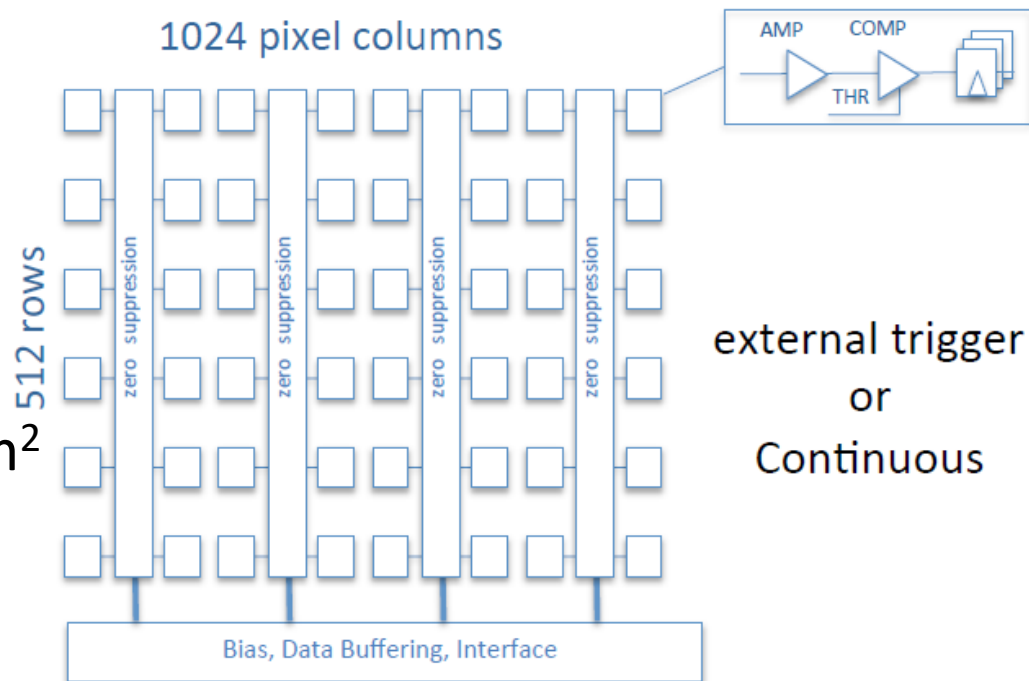
C. Yang, Real Time 2018, Williamsburg



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ALPIDE

- pixel size: $27 \times 29 \mu\text{m}^2$
- spatial resolution: $5 \mu\text{m}$
- max particle rate: $100 \text{ MHz}/\text{cm}^2$
- fake-hit rate: $<10^{-9}$ pixel/event
- power: $\sim 40 \text{ mW}/\text{cm}^2$



IB: $50 \mu\text{m}$ thick
OB: $100 \mu\text{m}$ thick

Ref: Rinella G A, ALICE Collaboration. The ALPIDE pixel sensor chip for the upgrade of the ALICE Inner Tracking System[J]

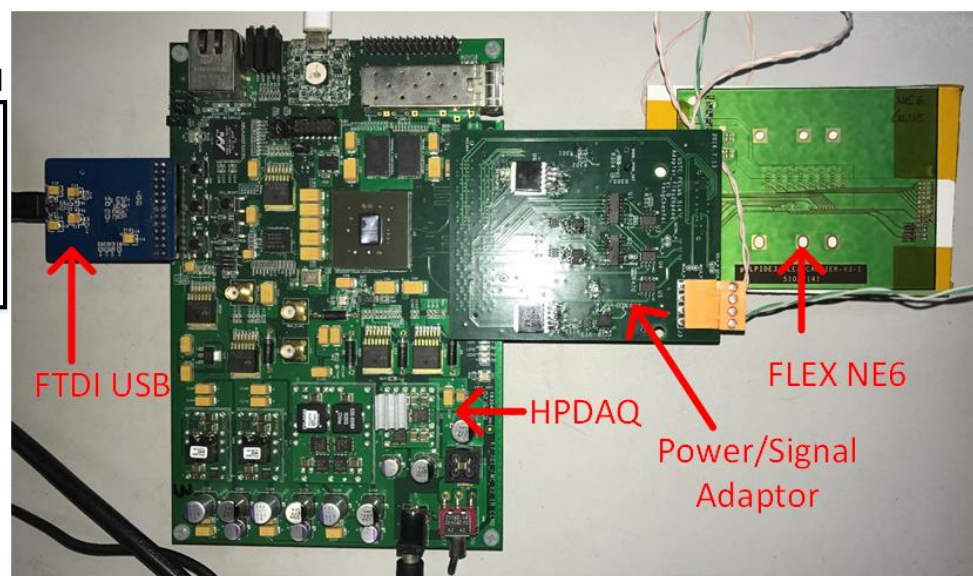
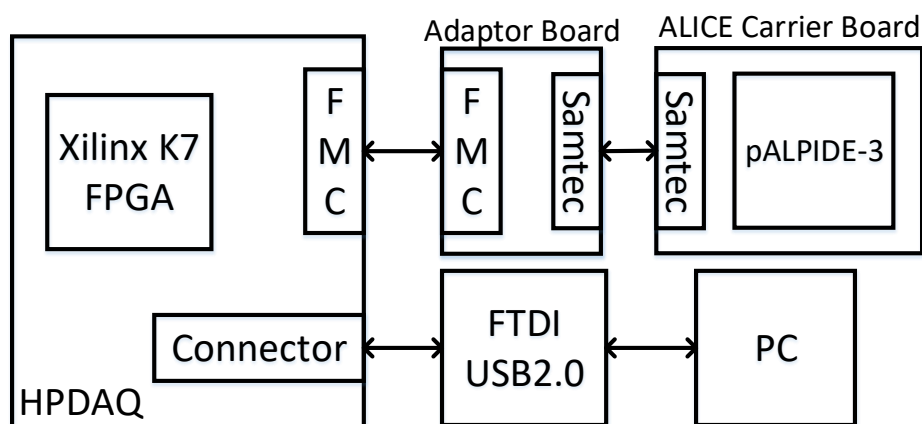
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5

DAQ V1.0

- Designed for pALPIDE-3
- Based on a FPC (Flexible Printed Circuit) pALPIDE-3 Carrier from ALICE
- Used a DAQ board from PLAC/CCNU
- FPGA firmware and PC software



6

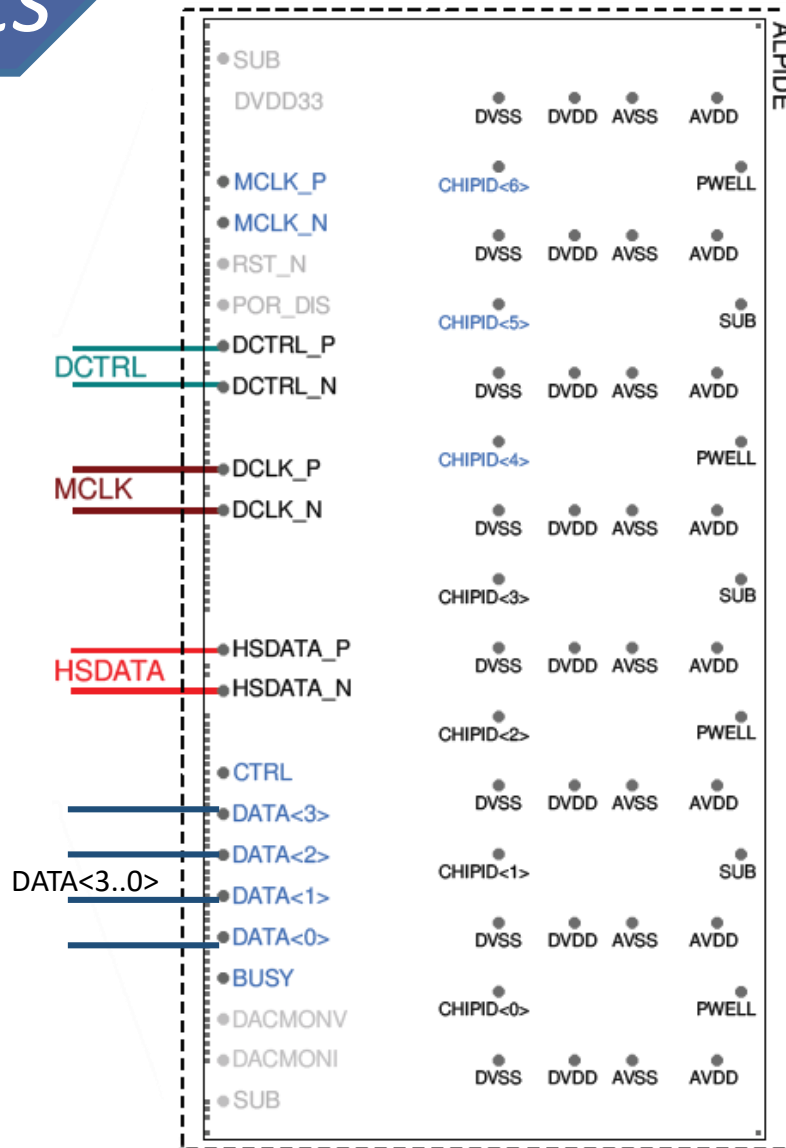
ALPIDE Ports

Control interfaces

40MHz Main Clock

1.2 Gbps Serial Data

40MHz Parallel Data with DDR signaling



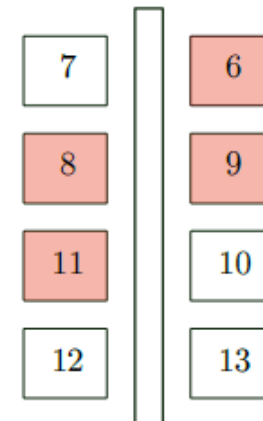
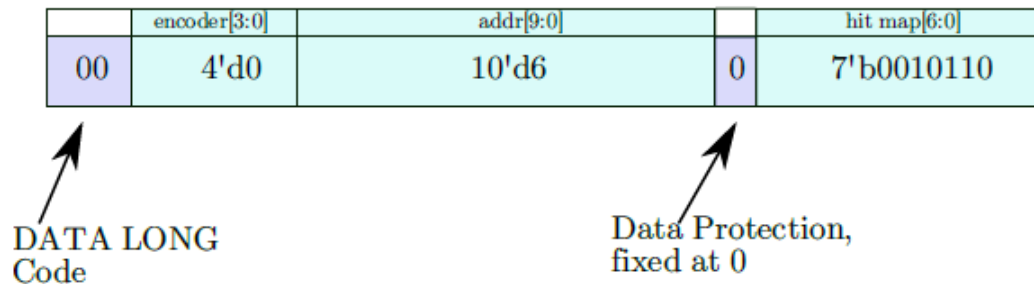
7

Data Read

- Data Format
 - Data Short: 16 bits

2'b 01+4'b encoder id + 10'b address

- Data Long: 24 bits



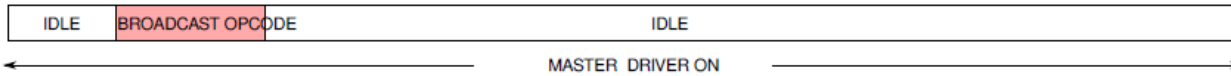
Portion of Priority Encoder



8

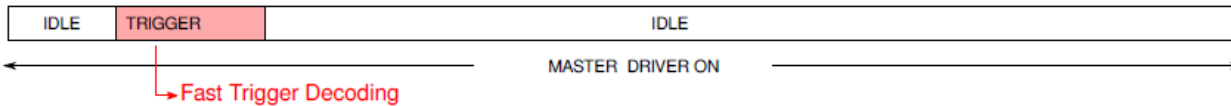
Chip Control

BROADCAST COMMAND



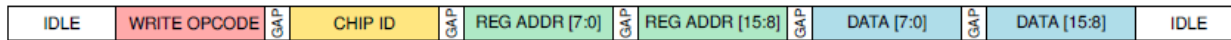
Reset, Pulse, Debug

TRIGGER COMMAND



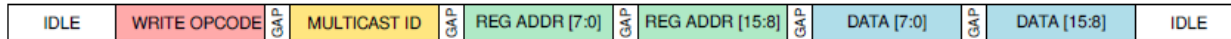
Trigger

UNICAST WRITE



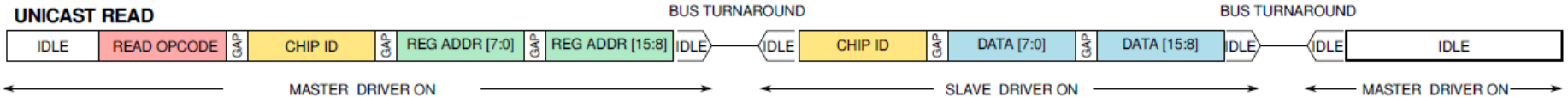
Register Write

MULTICAST WRITE



Register Read

UNICAST READ

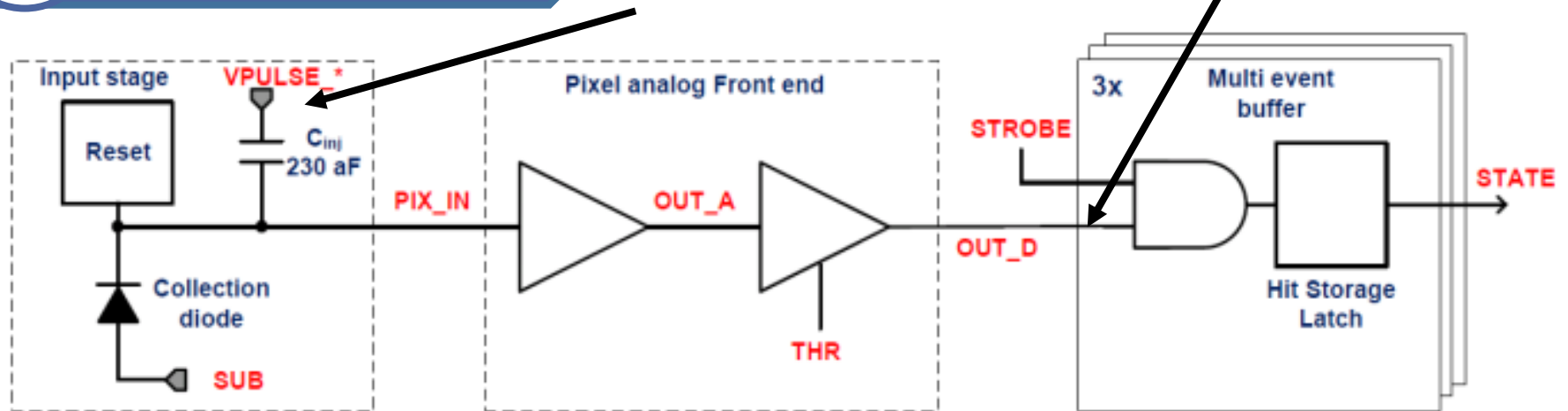


9

Pulse Test

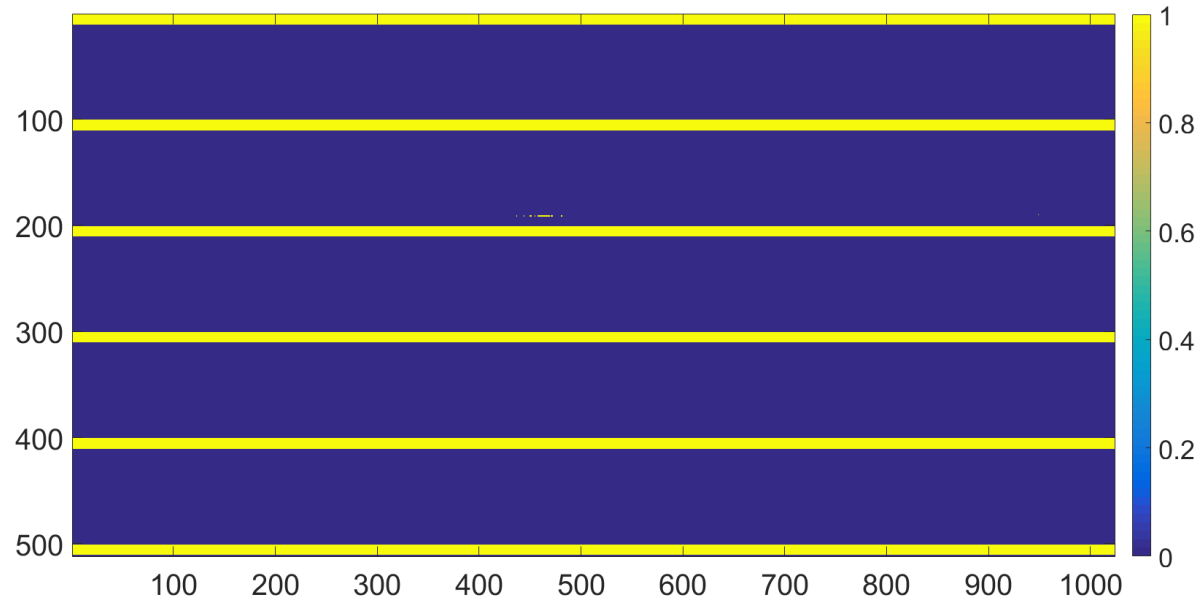
ANALOGUE PULSE

DIGITAL PULSE



Digital Pulse Test

10/100 rows enabled



pALPIDE-3 Hit Map C. Yang, Real Time 2018, Williamsburg

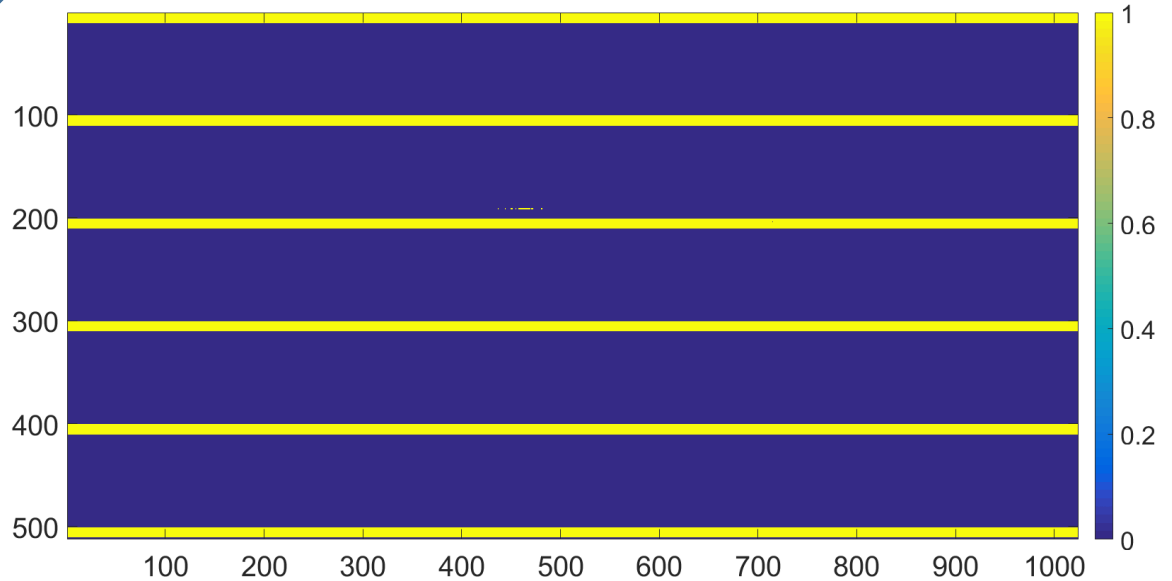


10

Pulse Test

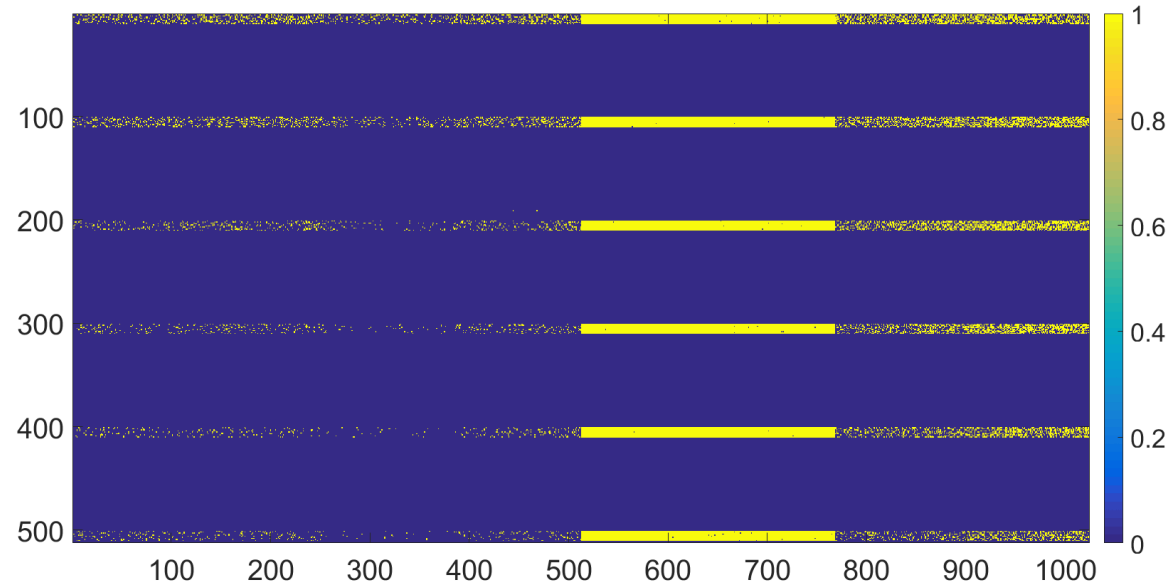
Analogue Pulse Test

10/100 rows enabled
700 electrons injection

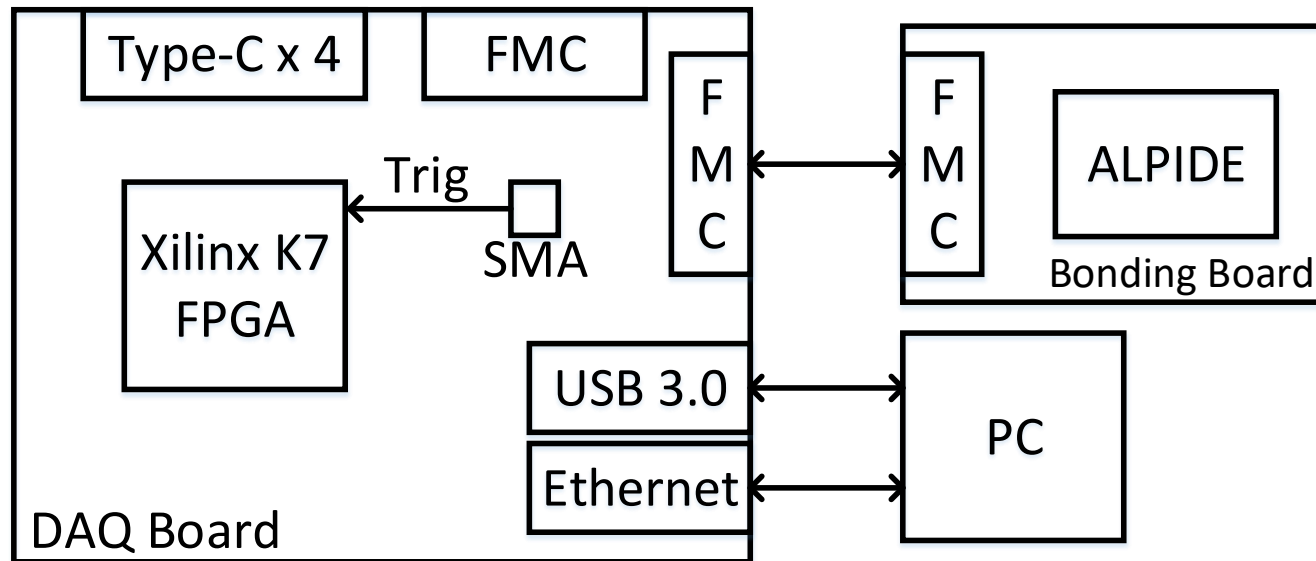


Analogue Pulse Test

10/100 rows enabled
70 electrons injection

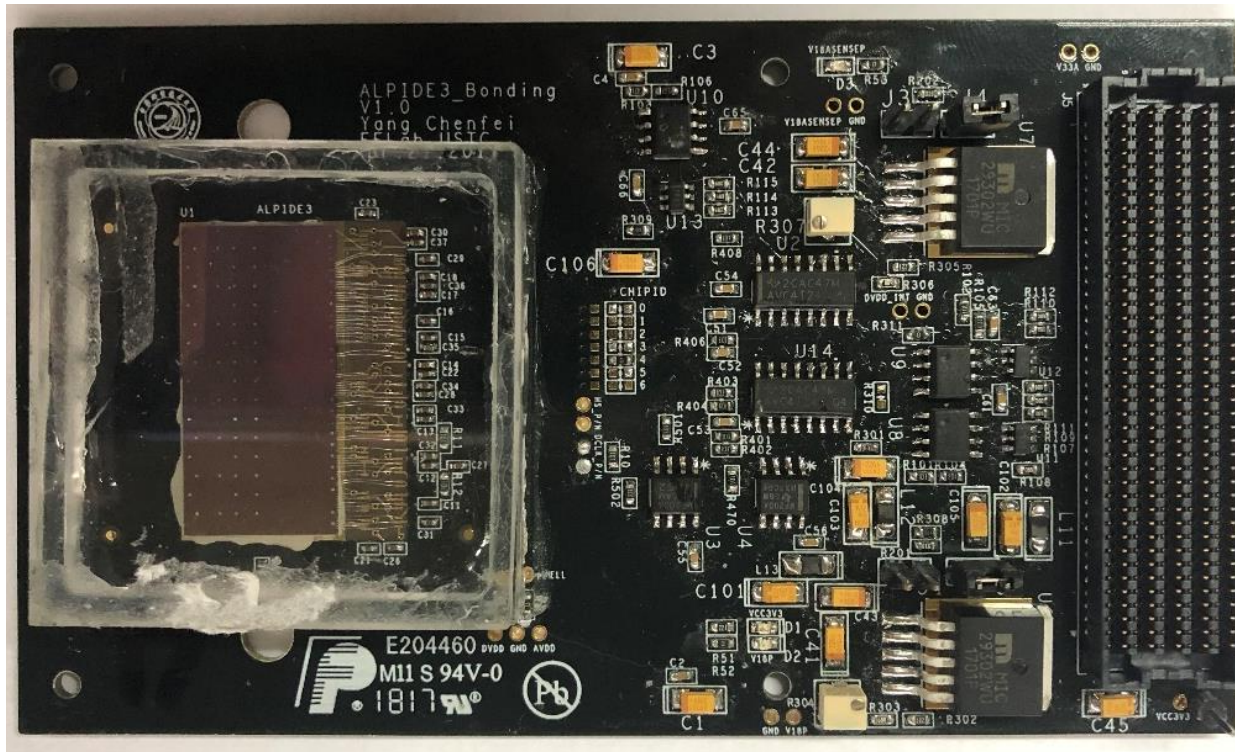


- Designed for ALPIDE. X-ray imaging and beam monitoring
- Self-designed ALPIDE Bonding Board
- Redesigned DAQ Board
 - USB 3.0 / Gigabit Ethernet
 - External trigger



12 Bonding Board

- Compatible with ALPIDE and pALPIDE-3
- Bonded at PLAC/CCNU



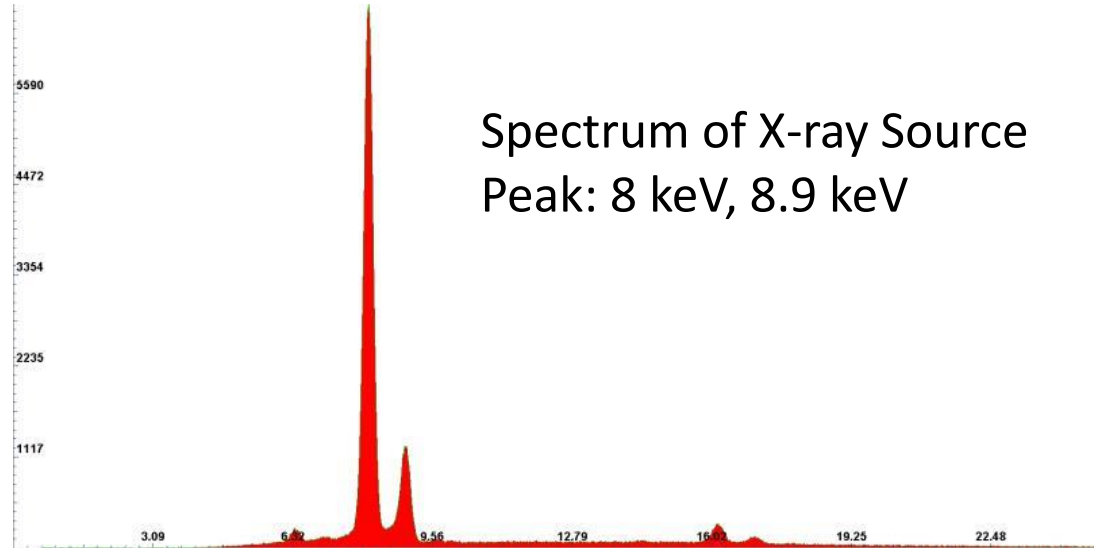
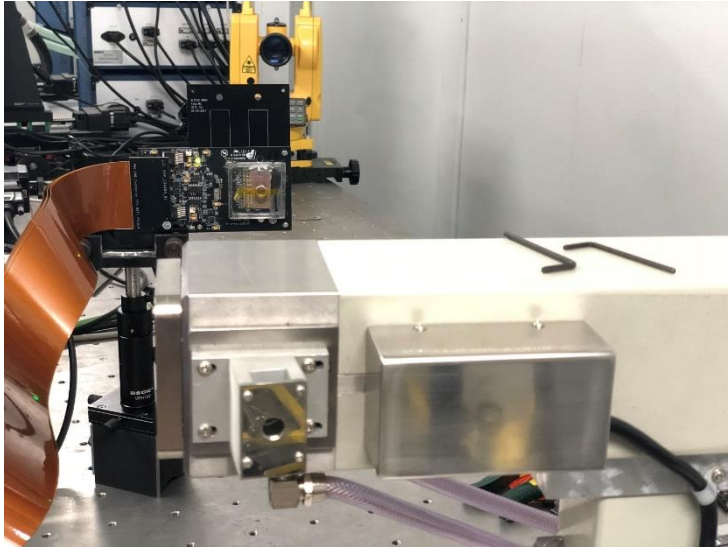


ALPIDE DAQ

FMC-FMC FPC Connector

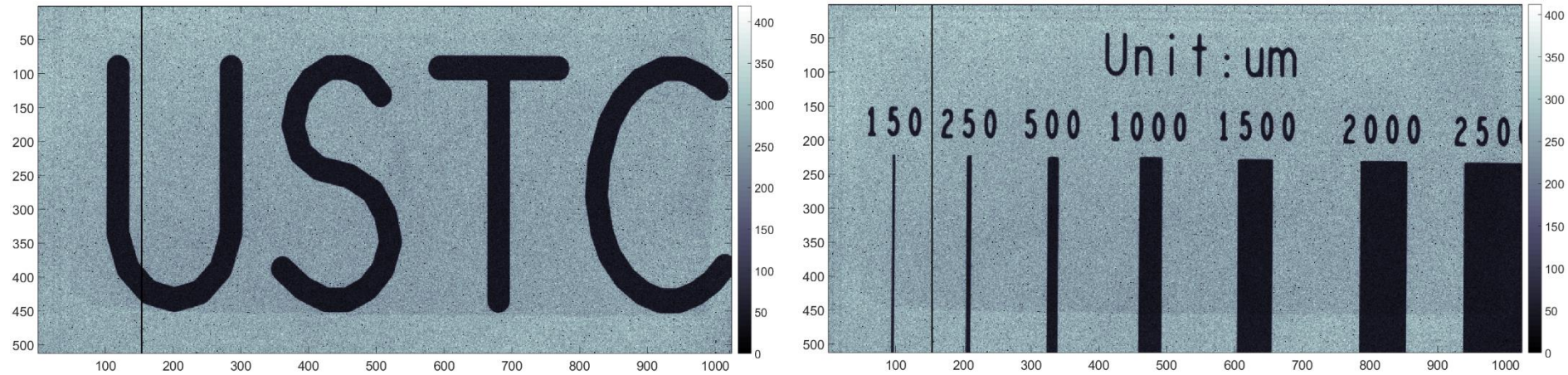
Bonding Board

14 X-ray Imaging



Location: National Synchrotron Radiation Laboratory (NSRL)
X-ray apparatus: 50 kV, 40 mA

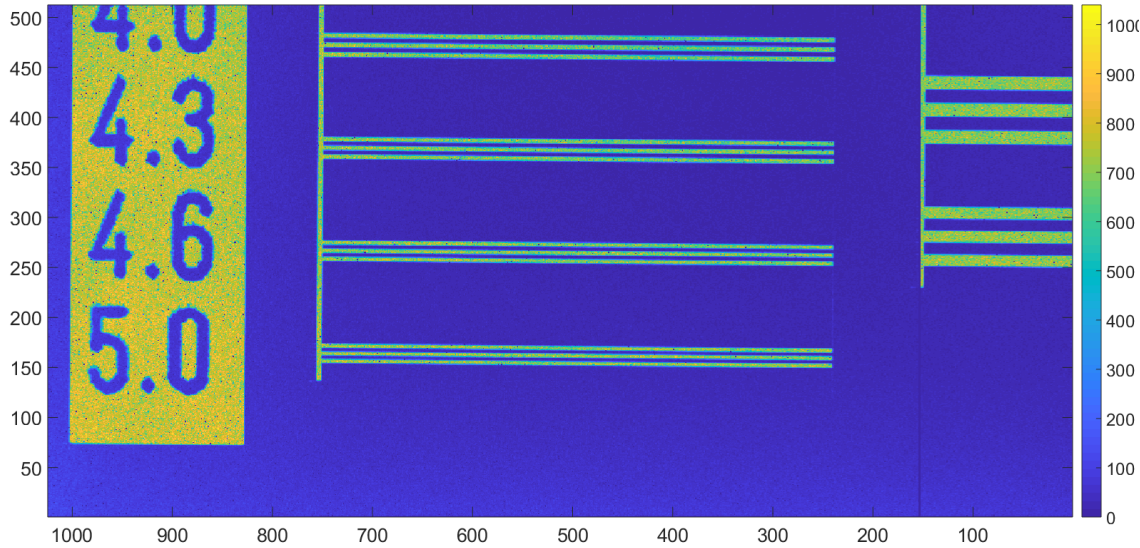




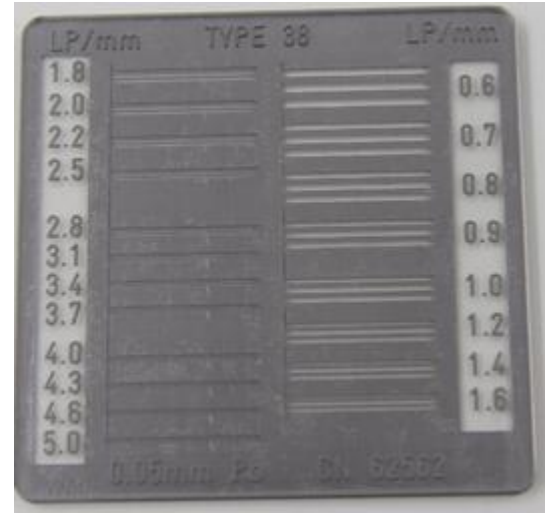
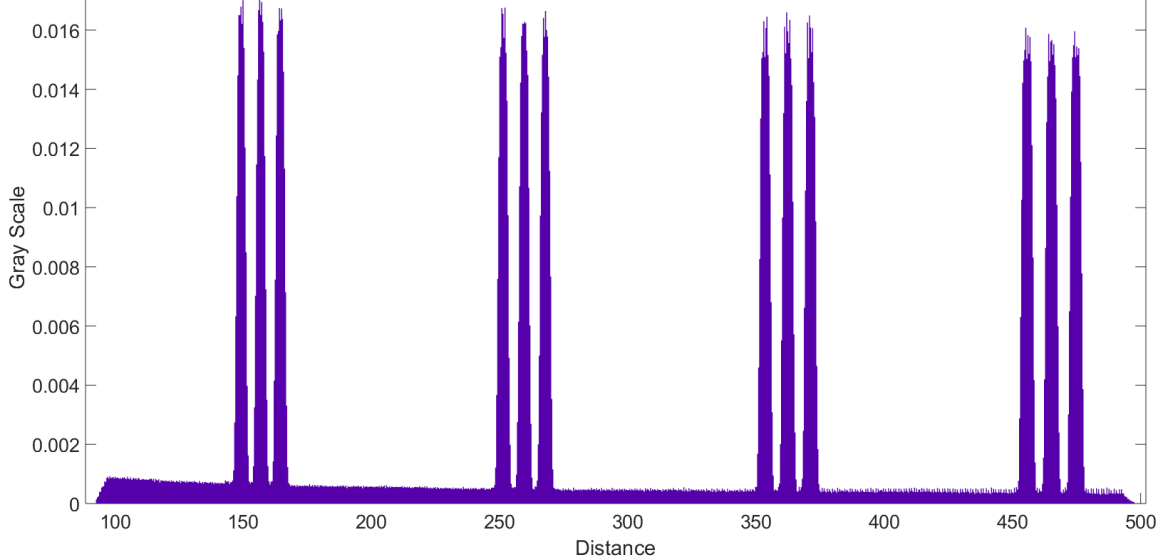
FPC material: 0.24 mm Polyimide
Patterns: 1 ounce ($\sim 36\mu\text{m}$) copper



16 Grating Imaging



5.0 LP/mm 4.6 LP/mm 4.3 LP/mm 4.0 LP/mm

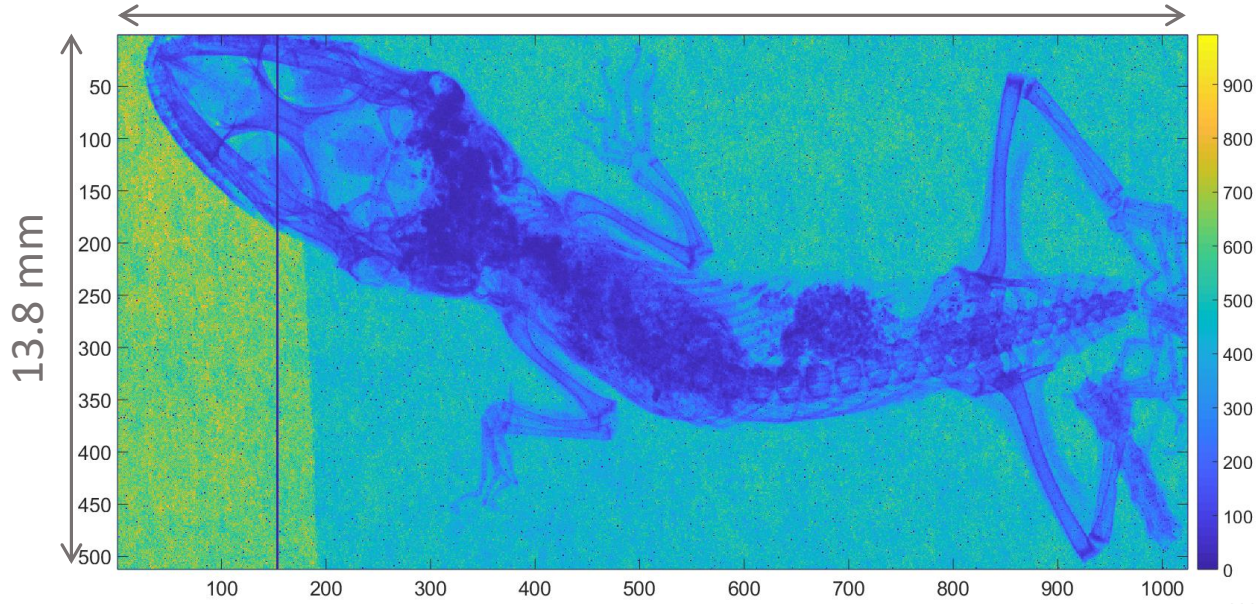


$$MTF = \frac{Peak - Valley}{Peak + Valley}$$

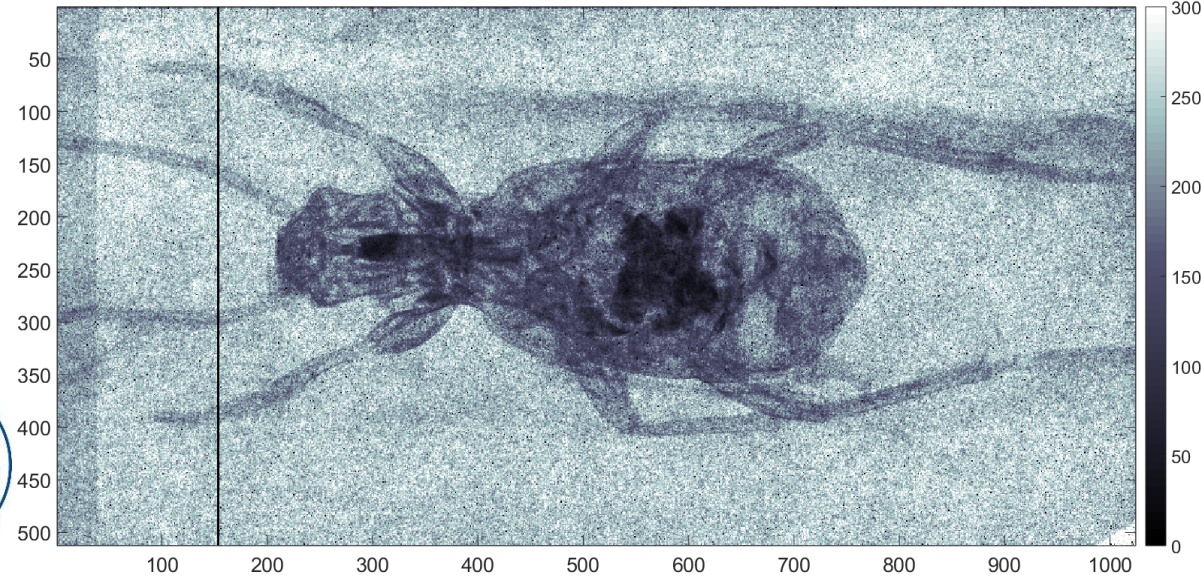
MTF > 92%

17 Specimen Imaging

30 mm



Gecko



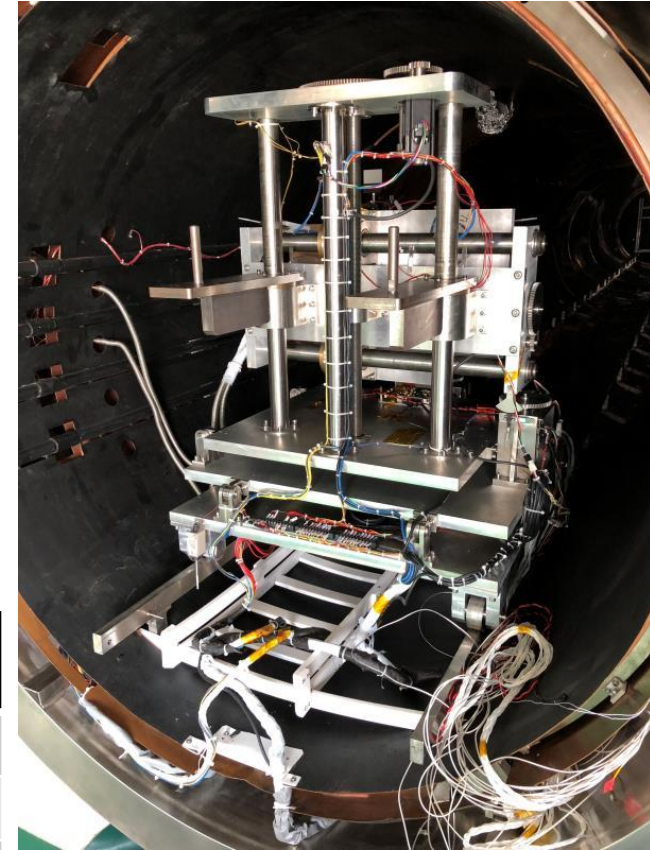
Bombardier Beetle

Yang, Real Time 2018, Williamsburg



18 Efficiency Test

Location: Shandong Institute of Space Electronic Technology



Detection efficiency of ALPIDE to X-rays at different energies

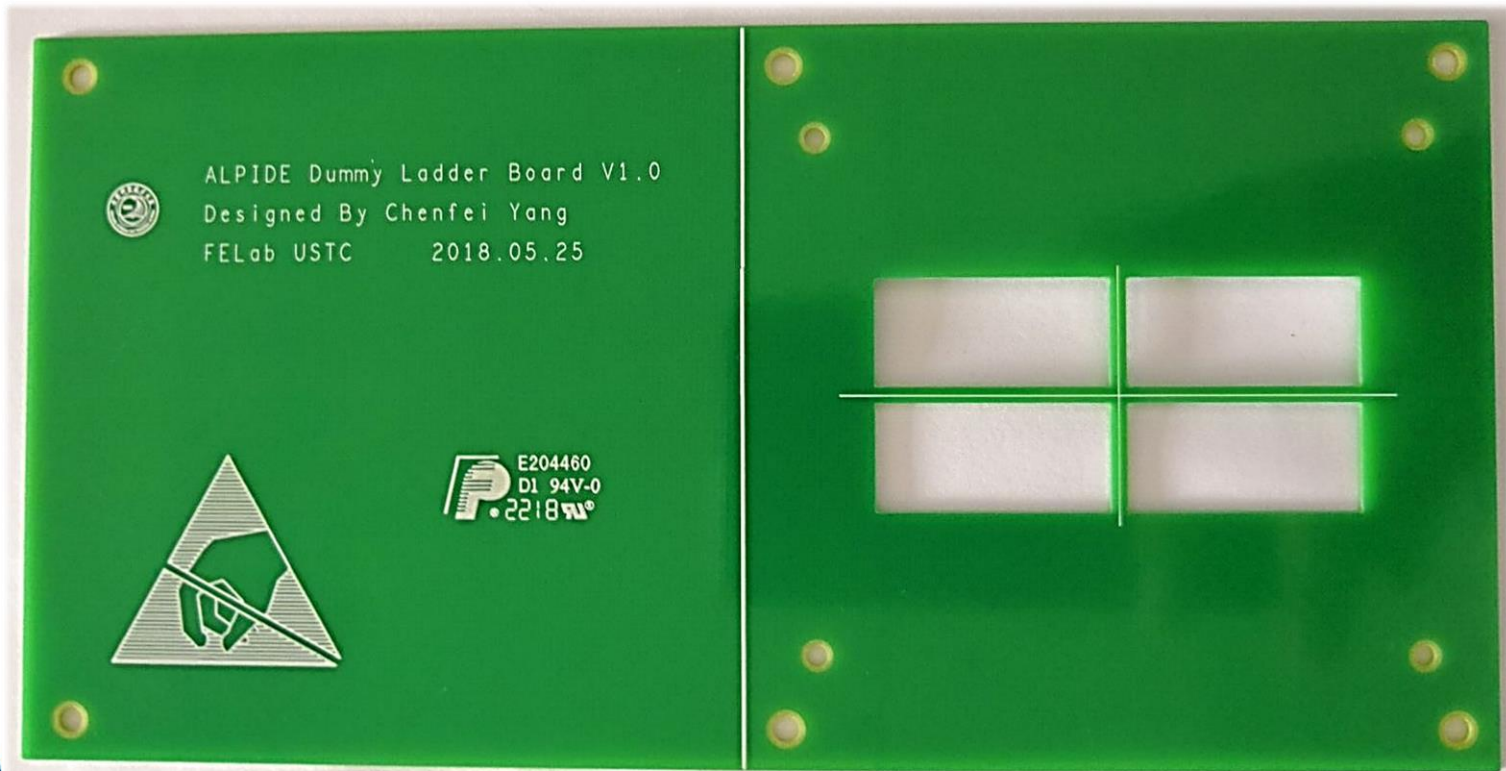
Target	Energy (keV)	Calibrated Value cnt/(s*cm ²)	ALPIDE cnt/(s*cm ²)	Efficiency (%)
Ti	4.51	14.00	7.41	53.00
Cr	5.41	21.01	10.83	51.56
Fe	6.40	31.50	12.80	40.65
Cu	8.05	41.58	12.44	29.91



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Next-step

- A 3 layers x 4 chips detector
- Other usages: space experiments



Dummy Ladder Board

C. Yang, Real Time 2018, Williamsburg



- 2 DAQ systems were designed for pALPIDE-3 and ALPIDE chips.
- High resolution X-ray imaging was achieved.
- ALPIDE detection efficiency of soft X-ray was measured.

Acknowledgement: PLAC/CCNU, NSRL

Thanks !

