GREST

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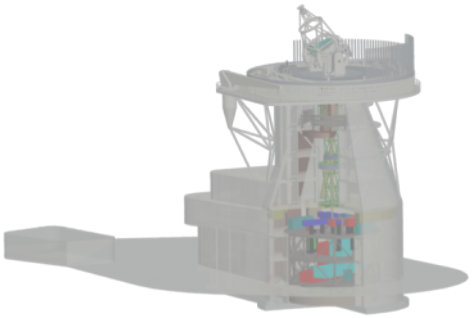

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- First Prototype
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- Comparision of Measurements and Simulations
- Improvements of the Quadropix
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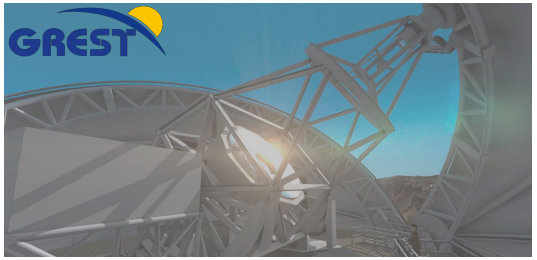
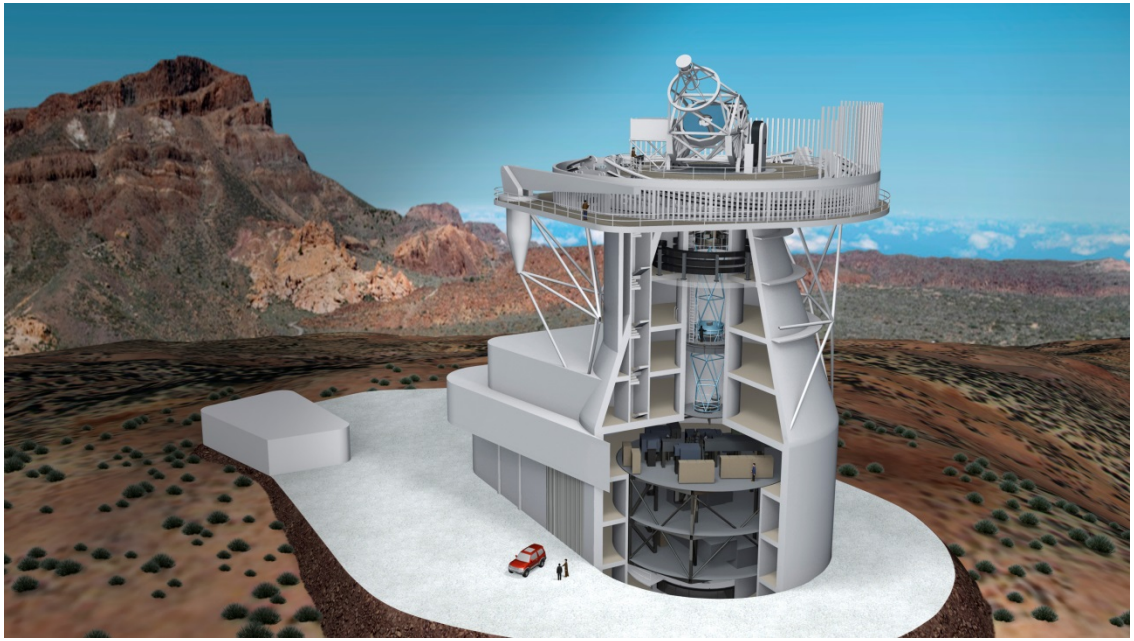
GREST

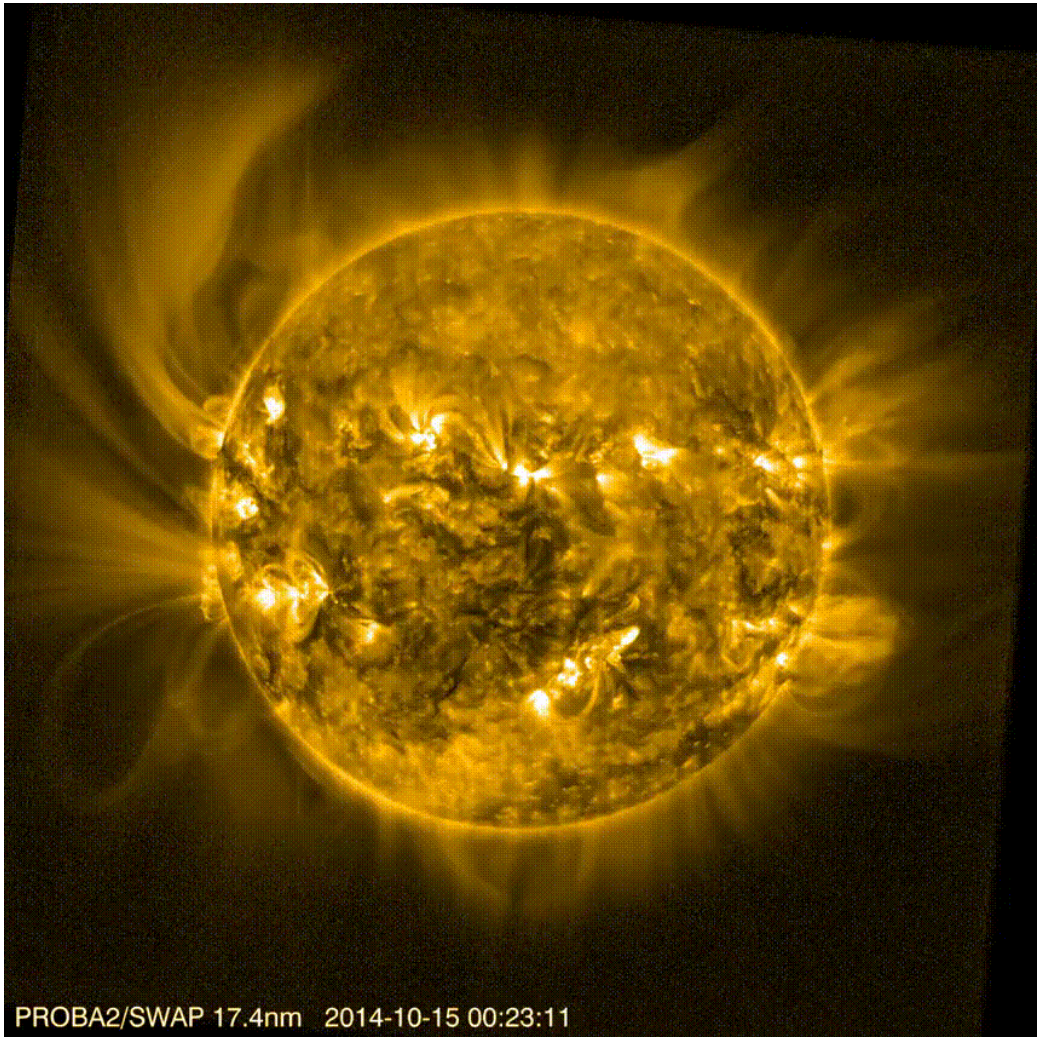
Getting Ready for the European Solar Telescope (GREST)

EST
- largest solar telescope in Europe
- multiple exchangeable instruments
- located on the canary islands
- start of construction ~2020
- start of operation ~2027





Why observe the Sun?

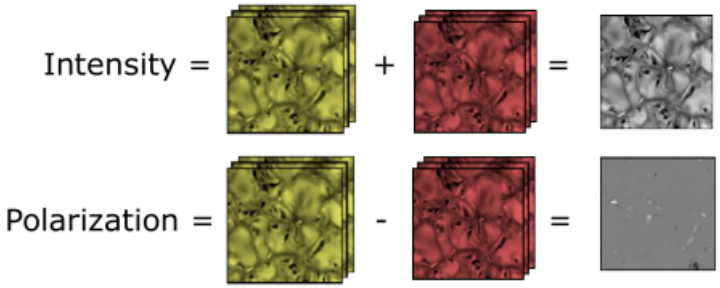


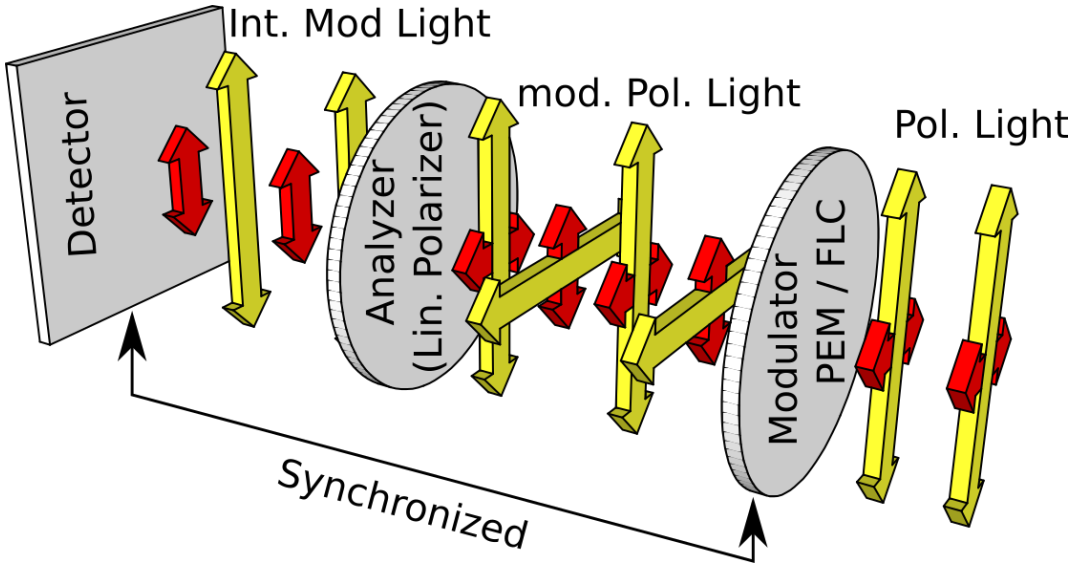
from: https://phys.org/news/2015-04-sun-tenuous-outer-tendrils-revealed.html

- closest Star
- directly influences life on earth
- laboratory for fundamental physics
  - plasmaphysics
  - magnetohydrodynamics
  - fusion

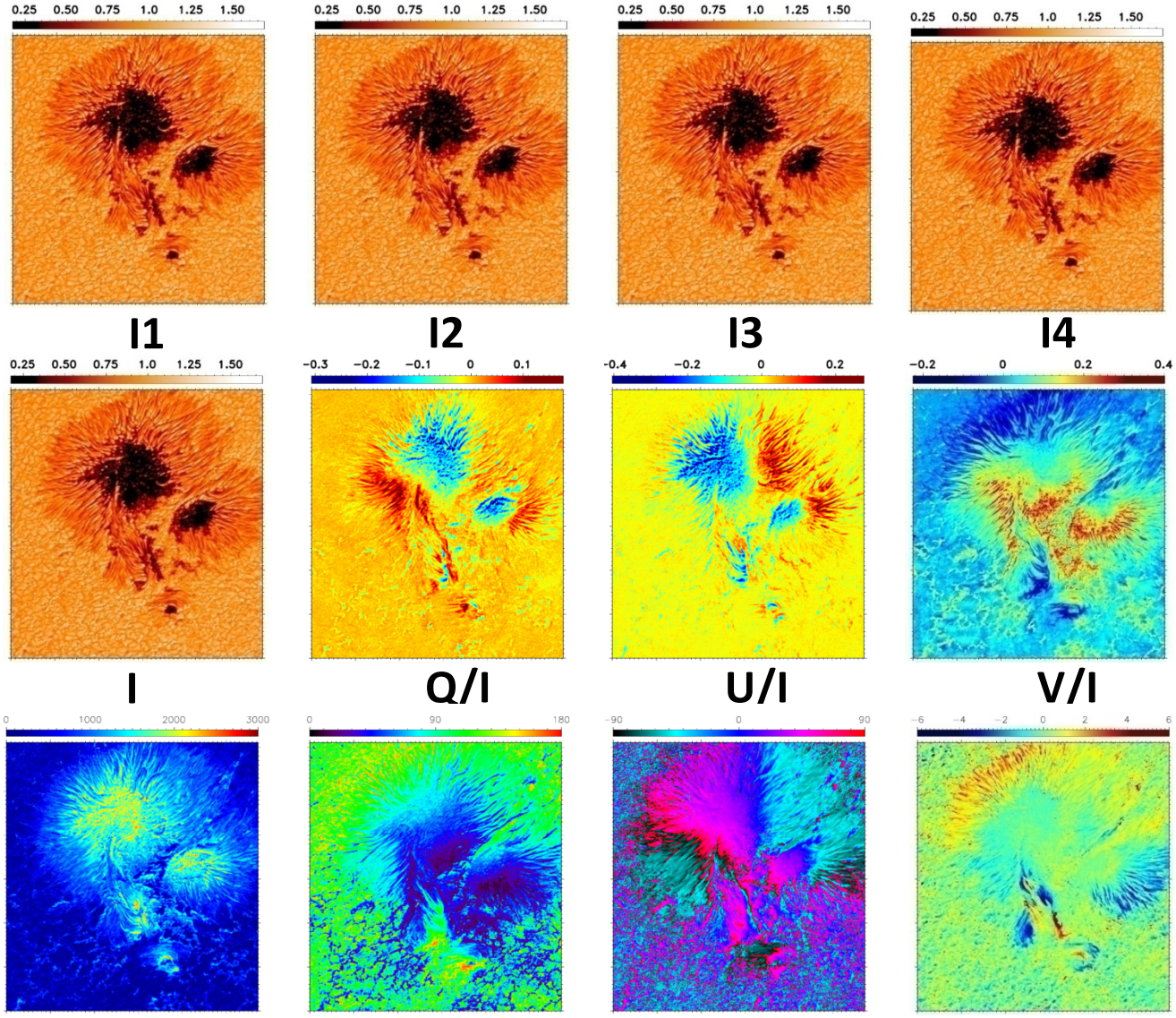
Optical Imaging Polarimetry

- incident light passes a modulator and a following analyzer
- modulator (e.g. piezo elastic modulator) operates at up to 50 kHz
- sensor synchronized to modulator
- generates and measures 4 different modulated intensity states,
- Stokes Parameter, I (intensity), Q, U (linear pol.) and V (circular pol.) can be calculated from the measured modulation states





Optical Polarimetry

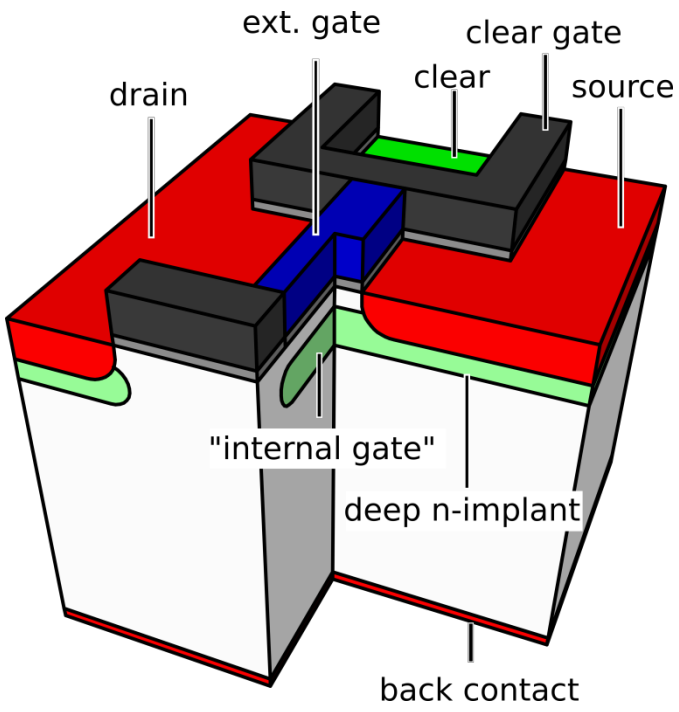


Measurement from the Swedish solar telescope, La Palma
Credits: J. Hirzberger (MPS)

Derived physical parameters of the solar atmosphere:
-B-Field (abs. and direction)
-plasma-velocity into Line of Sight (LOS)
Credits: A. Lagg (MPS)

Quadropix

DePFET



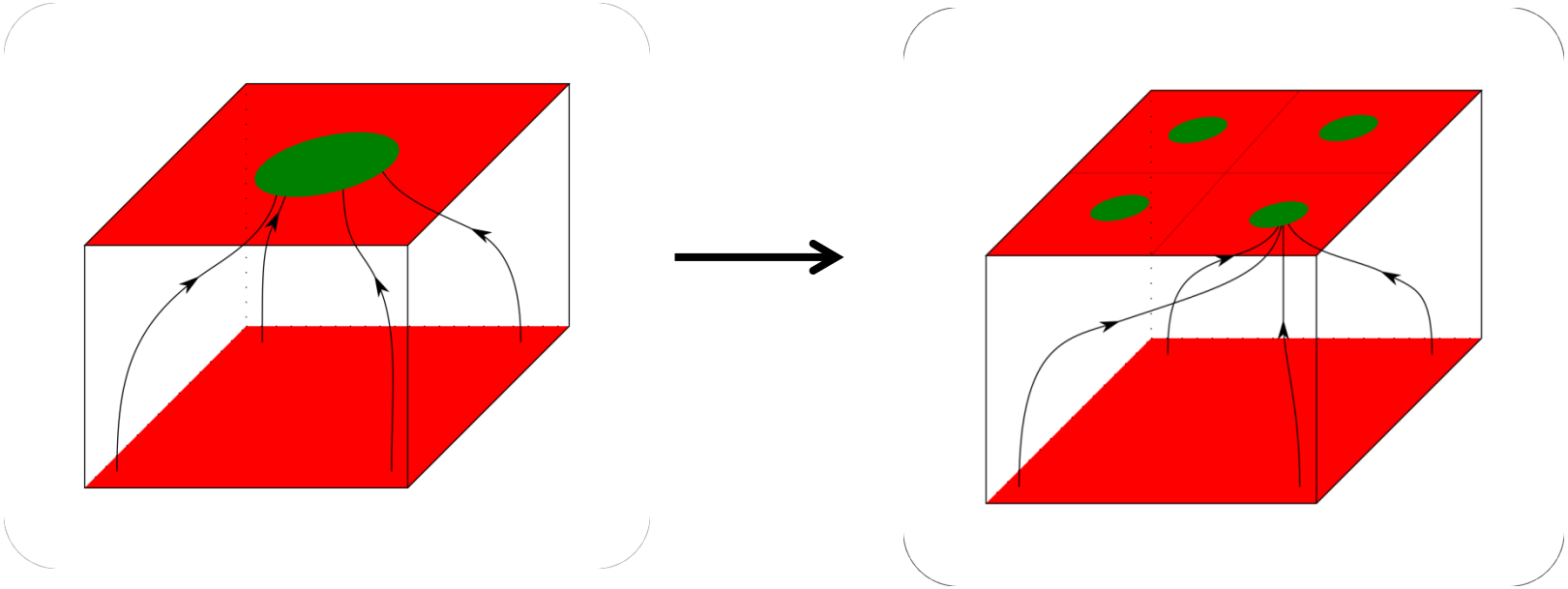
- MOSFET on n-substrate
- deep-n implant below gate
  - potential minimum for electrons
  - „internal gate“
- current modulated by electrons in internal gate
- reset via clear and clear gate

- good signal to noise
  - ~3 e^- @ 2.5 µs/line
- unobstructed backside contact; 100% fill factor

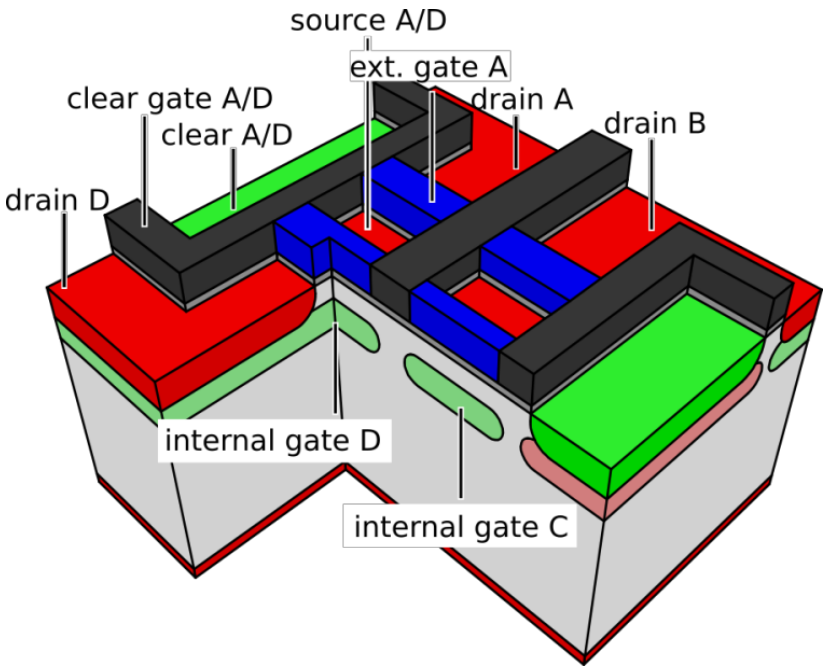
Quadropix

- simplified it's a collection node for charge

- superpixel containing 4 DePFET subpixels
- charge collected only in one subpixel
- sensitivity controlled by drain voltage



Quadropix

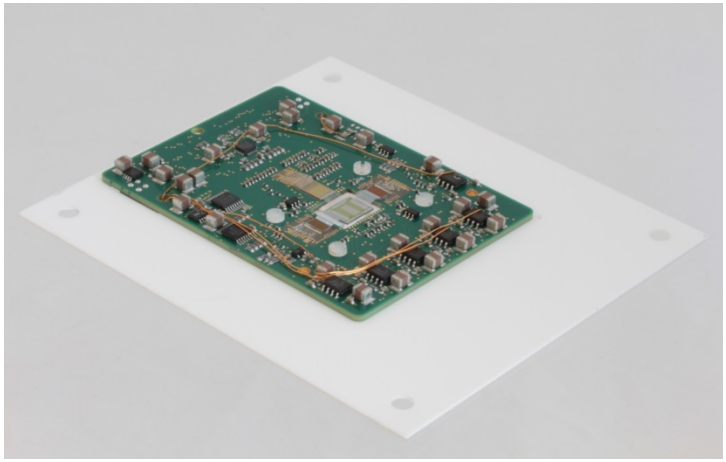


- superpixel containing 4 DePFET subpixels
- charge collected only in one subpixel
- sensitivity controlled by drain voltage

- fast modulation (given by switching time)
- at readout rate of 2.5 µs/line
  - ↳ ~100 Hz rate for full set of stokes parameters

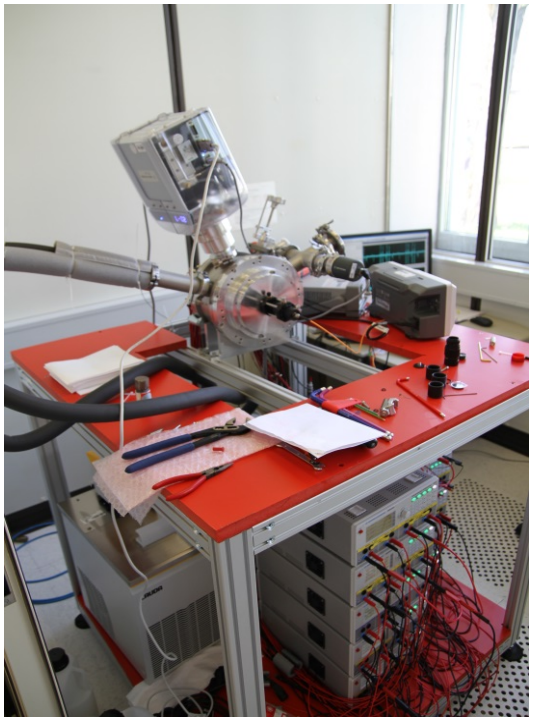
First Prototype

First Prototype

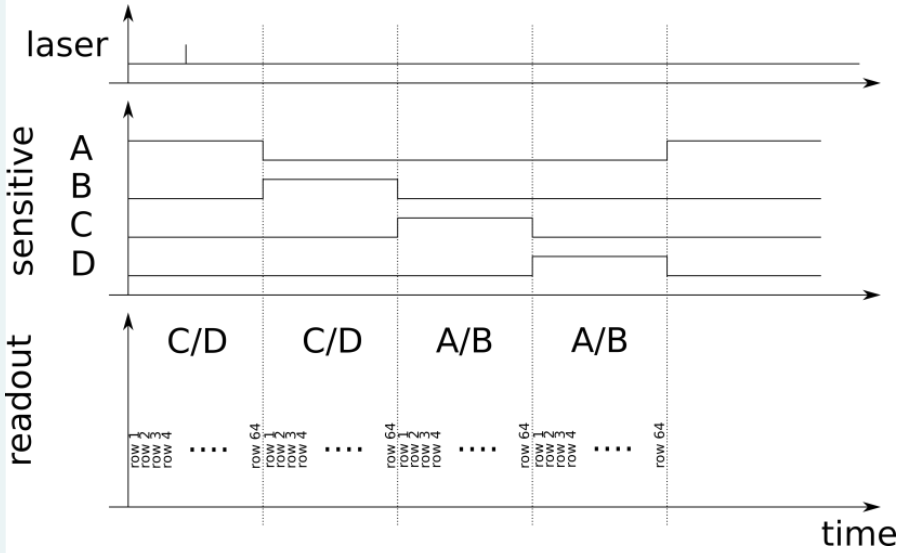


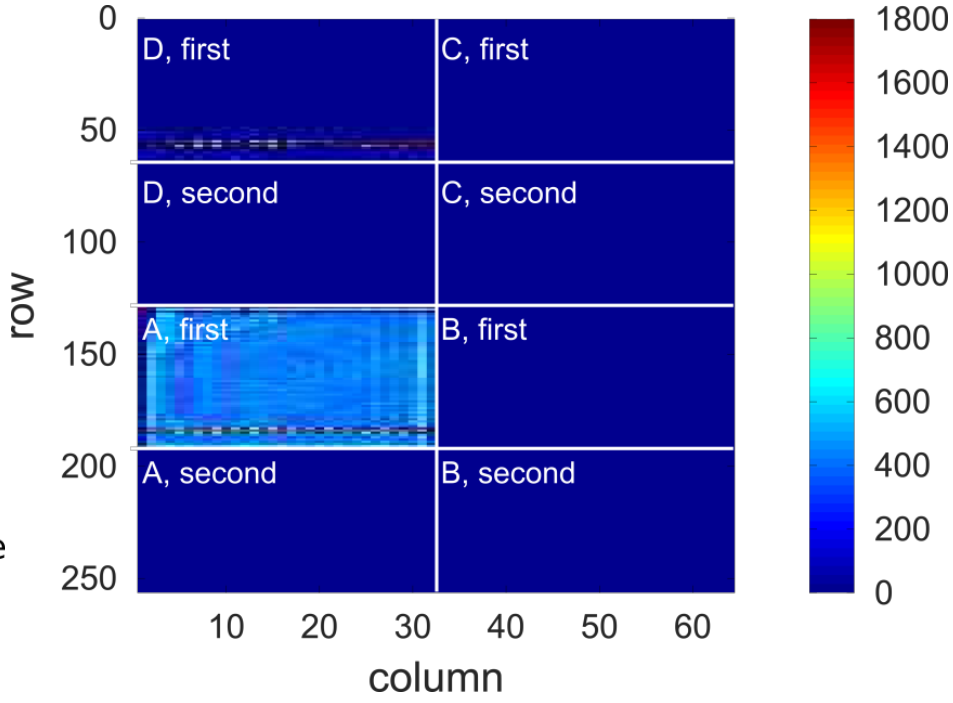
- testmatrix
  - 64x32 pixels
  - (60 µm)² pixels
  - controlled by 2 SwitcherS ASICs
  - readout by Veritas 2.1 ASIC
    (M. Porro et al., proc IEEE, 2014)

- test setup
  - sensor in vacuum
  - liquid cooling system
  - light and X-ray sources
  - timing provided by proprietary firmware written for a Xilinx Kintex 7 on a Mercury KX1 board



First Prototype

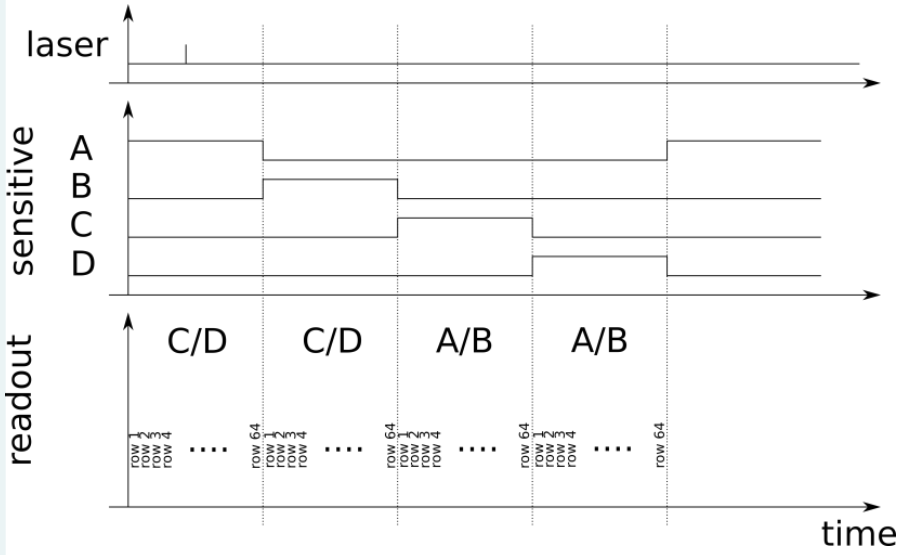


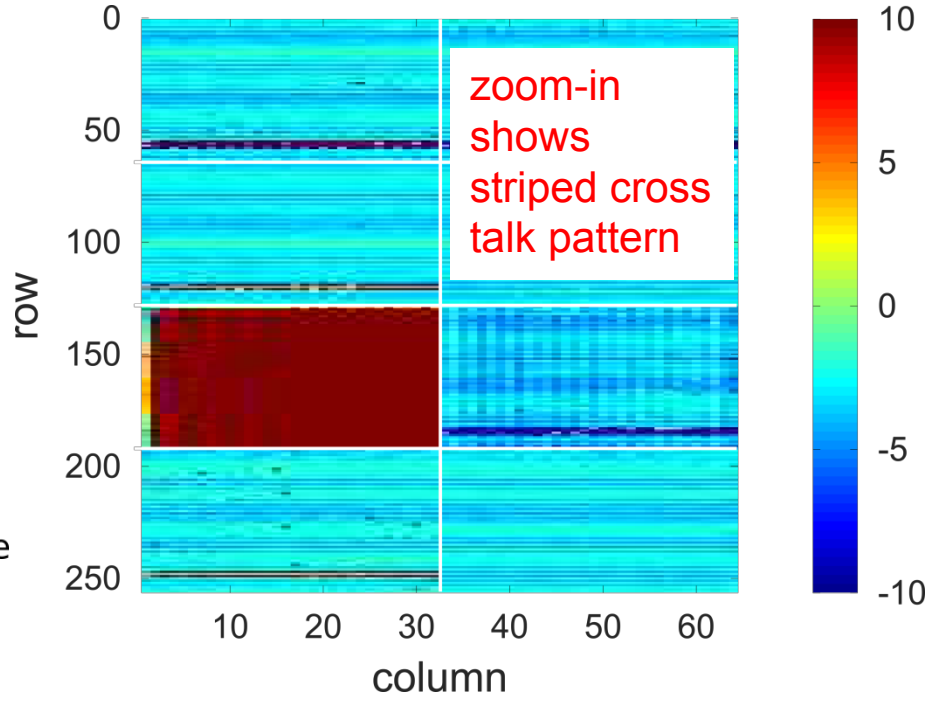


- first test-sequence
  - sub-matrices sensitive successively
  - readout of two insensitive submatrices during one sensitive state
  - frame consists of 8 sub-matrix readouts

- illuminated while sub-matrix A was sensitive
- sensor had two damaged rows
- only signal in first readout of sub-matrix A
- behaves as expected

First Prototype

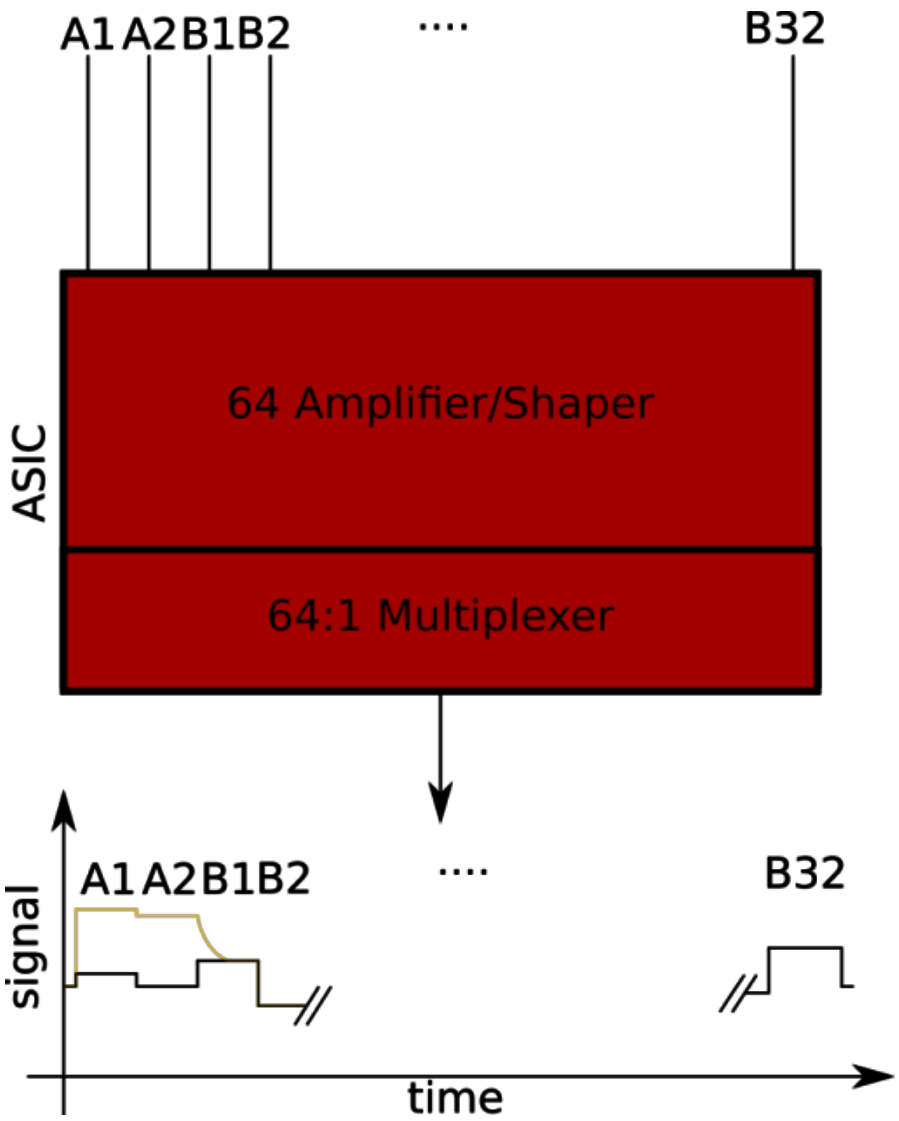




- first test-sequence
  - sub-matrices sensitive successively
  - readout of two insensitive submatrices during one sensitive state
  - frame consists of 8 sub-matrix readouts

- illuminated while sub-matrix A was sensitive
- sensor had two damaged rows
- only signal in first readout of sub-matrix A
- behaves as expected

First Prototype – Stiped Cross-Talk

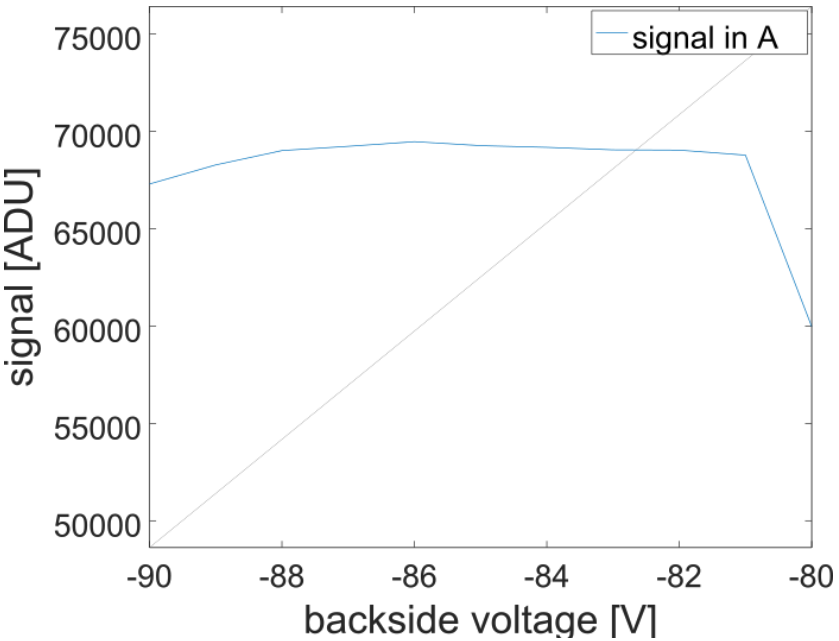


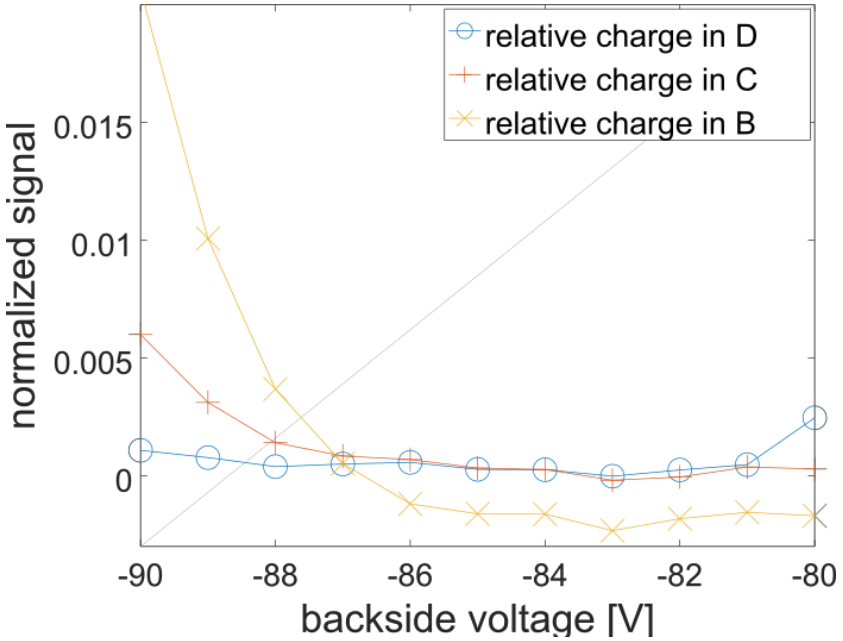
- on-chip wiring:
  - A1-A2-B1-B2 …
- time multiplexing of signals limited by bandwidth of output driver
- cross-talk between adjacent channels possible
- A2-B1 B2-A3 etc. -> striped pattern

Critical Parameters

- Seperation of Charge Collection
  (and dependence on operation voltages)
- Swtiching Time
- State Dependence of charge collection

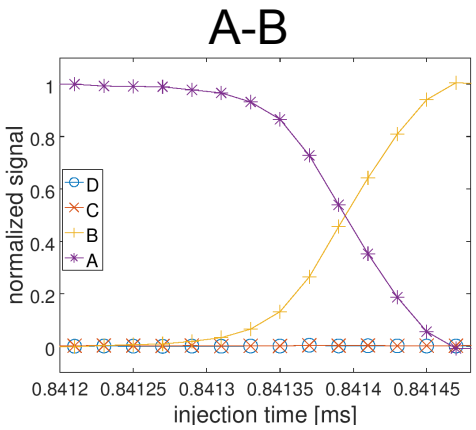
Seperation of Charge Collection

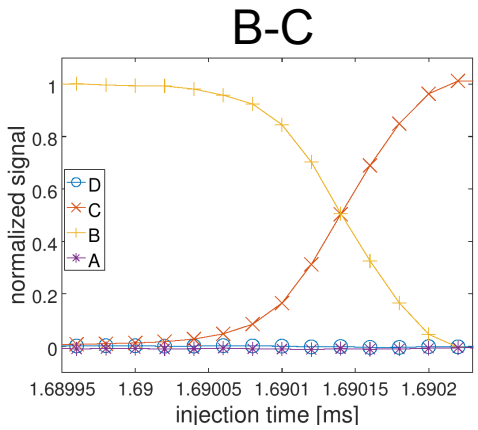


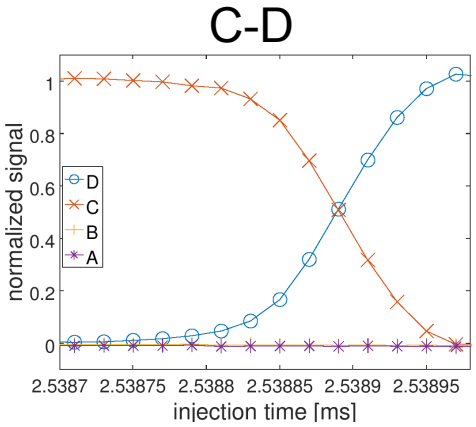


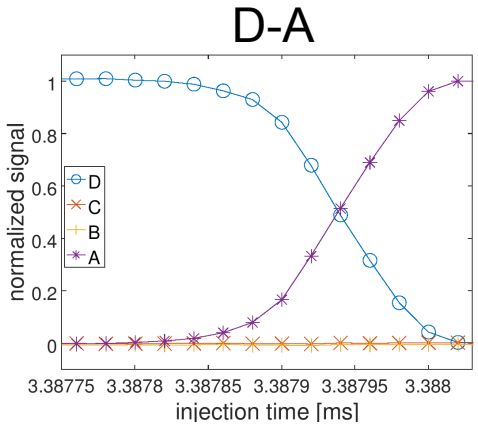
- depletion at -81 V
- significant charge losses at ~ -86 V
- operation window of 5 V

Switching Time



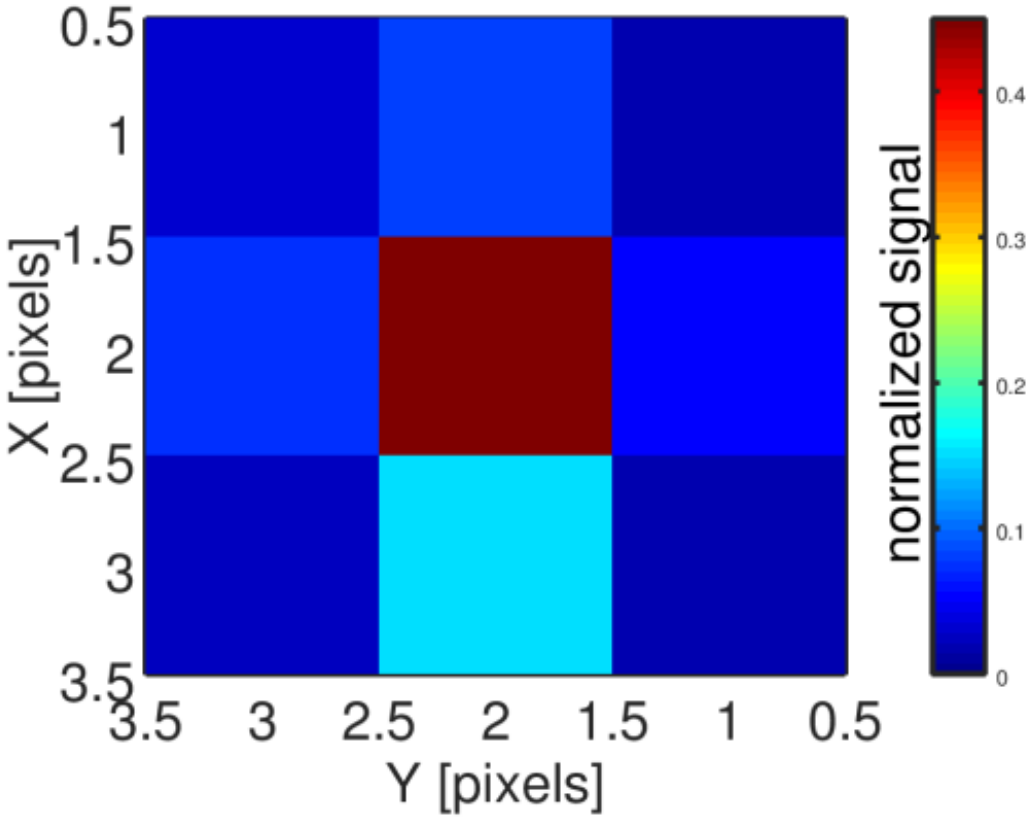




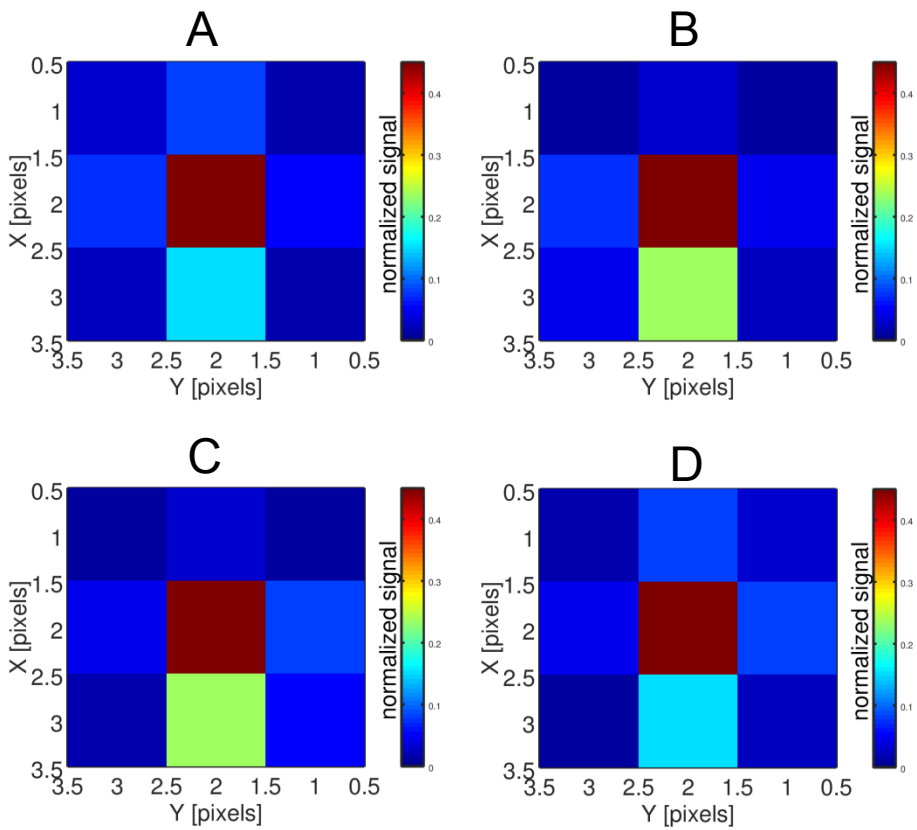


- switching from A-B, B-C, C-D, D-A
- switching time < 100 ns
  (10% to 90% sensitivity)

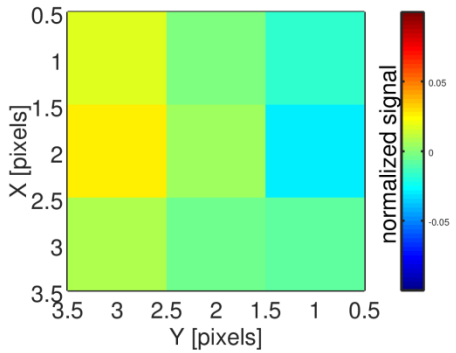
State Dependency of Charge Collection



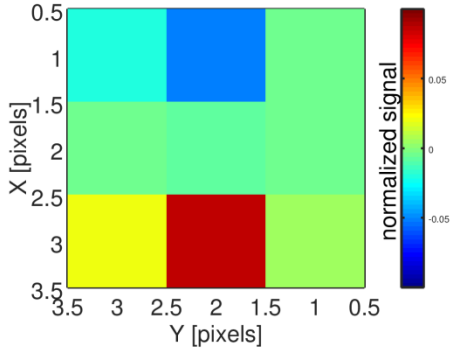
State Dependency of Charge Collection



▷ e.g. A-D



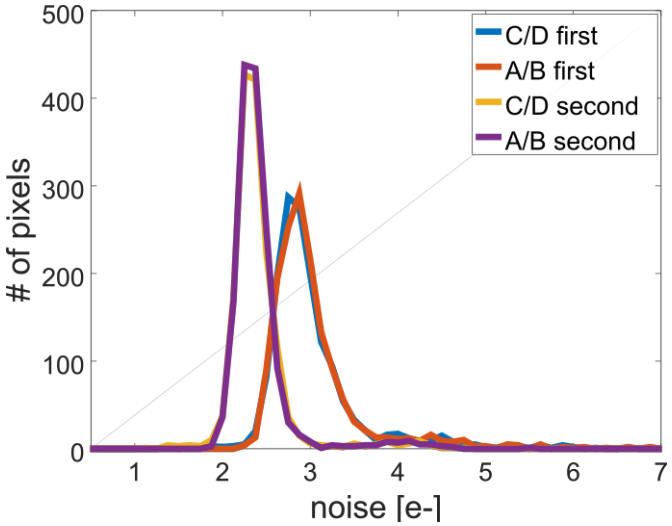
▷ e.g. A-B

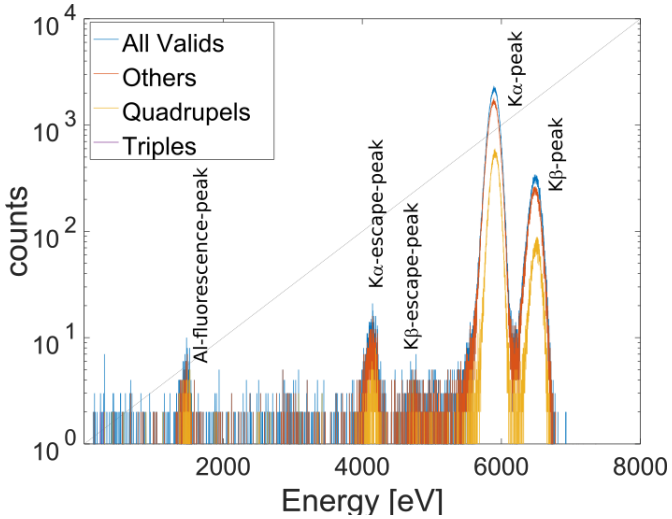


▷ asymmetry clearly visible

▷ critical as polarimetric information is obtained by subtracting images

^{55}Fe Calibration





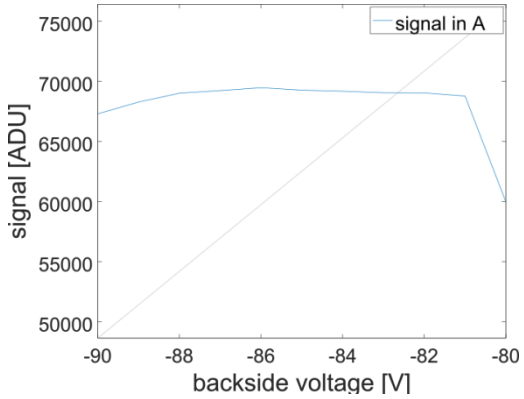
- ▷ calibrated noise distribution
- ▷ filter-time of 2.5 µs
- ▷ first readout 2.9 e^- ENC rms
- ▷ second readout 2.4 e^- ENC rms
- ▷ difference –> leakage current

- ▷ spectra show nearly no events with multiplicity < 3 (apart from cross talk events)
- ▷ 150 eV FWHM @ 5.9 keV
- ▷ P/B of (4800±360):1

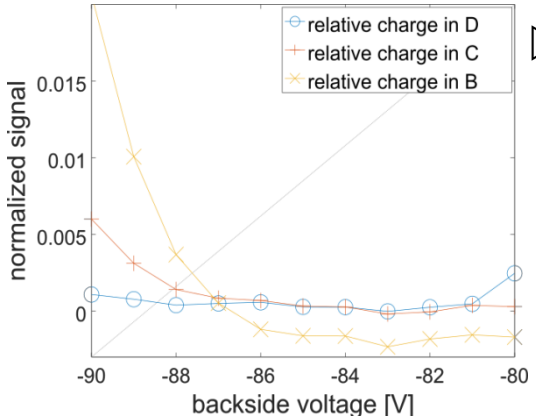
Comparision of Measurements and Simulations

Comparison: Measurements – Simulation / Backside Voltage

- measured

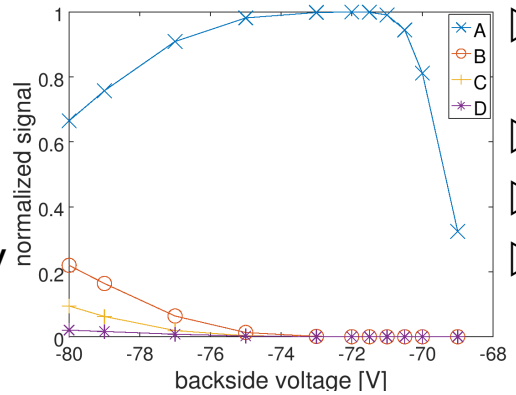


- depletion – 81 V
- losses -86 V

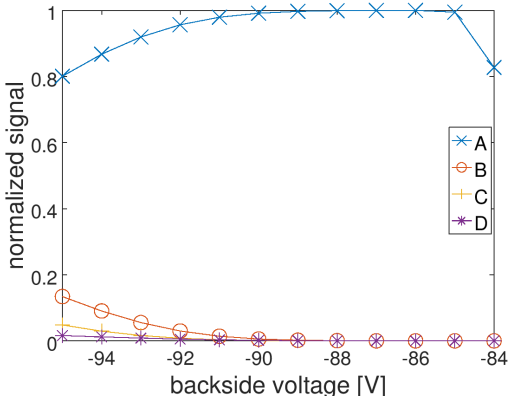


- window of 5 V

- simulated

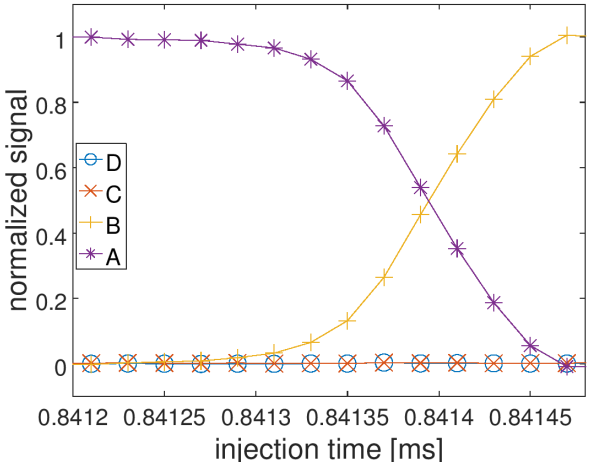


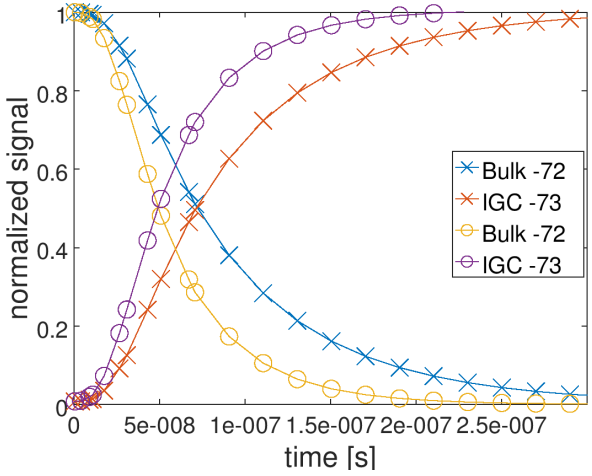
- first simulation of operation window
- depletion ~ -71.5 V
- losses ~ -73 V
- window of 1.5 V



- adjusted thickness and doping to match real device
- depletion ~ -85 V
- losses ~ -90 V
- window of 5 V

Comparison: Measurements – Simulation / Switching Time



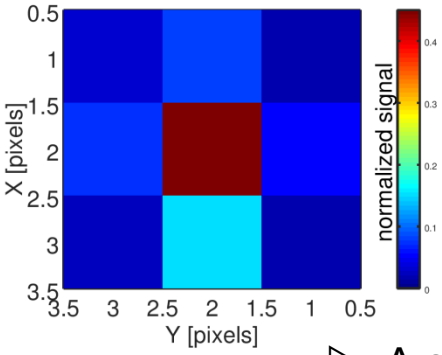


- measured Switching time convolution of
- laser pulse width (100 ps FWHM)
- ASIC switching time (10 ns 10%-90%)
- transmission line RC (< 1 ns)
- collection time (simulations)

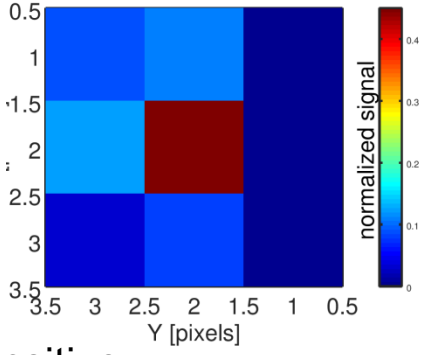
- simulated collection time 150 ns / 80 ns (10%-90%) for -72 V and -73 V
- switching time dominated by collection time

Comparison: Measurements – Simulation / Charge spreading

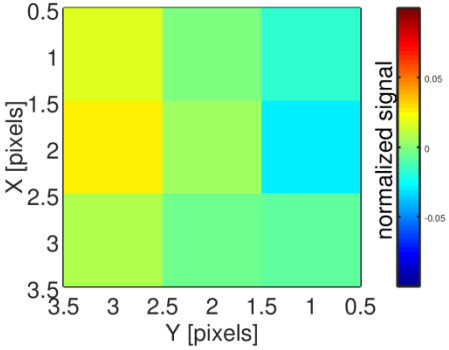
▷ measured

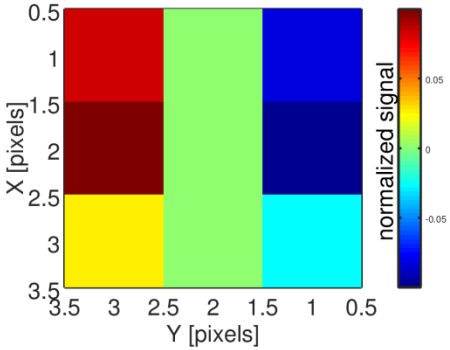


▷ simulated



▷ A sensitive



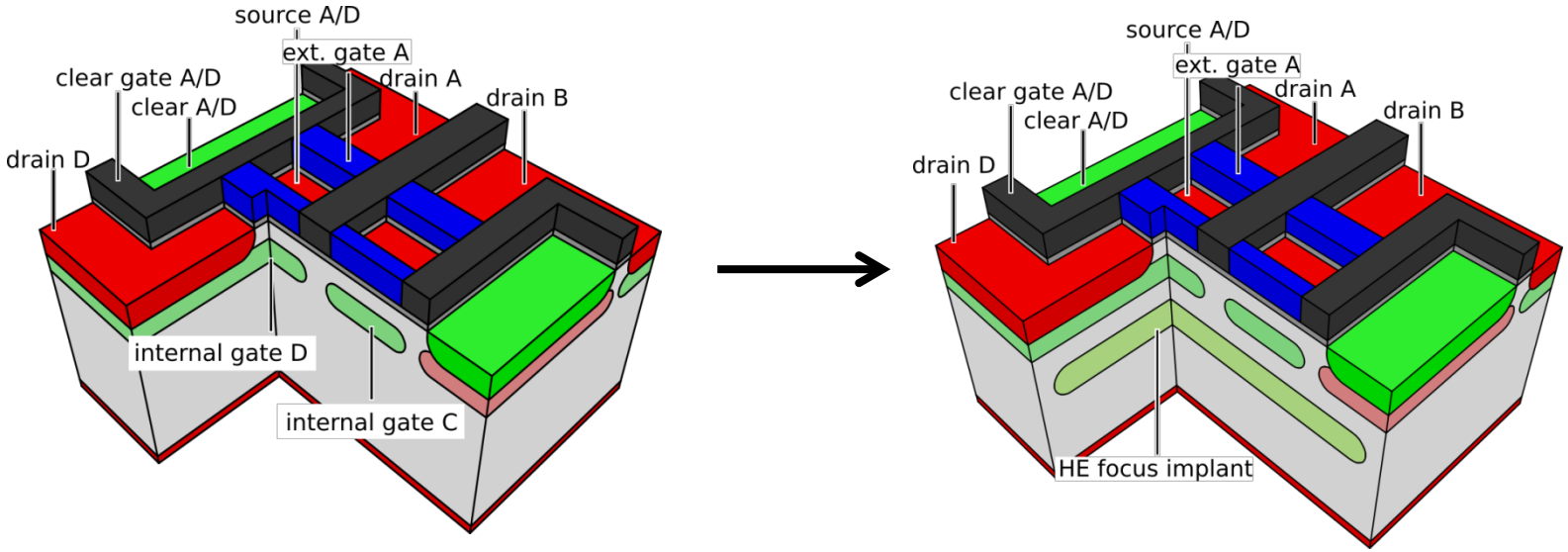


- ▷ qualitative agreement
- ▷ simulated spreading worse than measured
  - ↳ “illumination spot” not identical
  - ↳ different bulk thickness
  - ↳ simulation covers only a 3x3 array (edge effects possible)

Improvements of the Quadropix

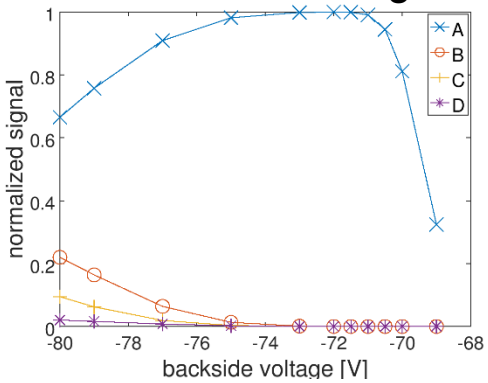
Improving the Quadropix

- high energy implant aligned to the pixel structure

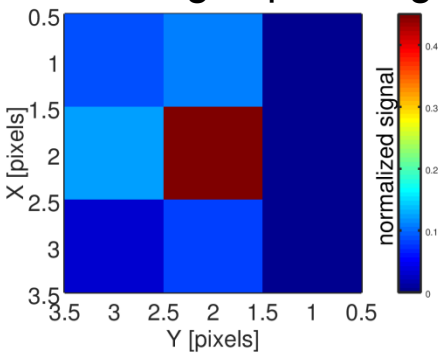


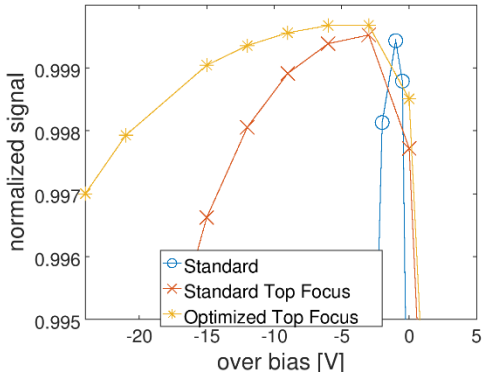
Improving the Quadropix

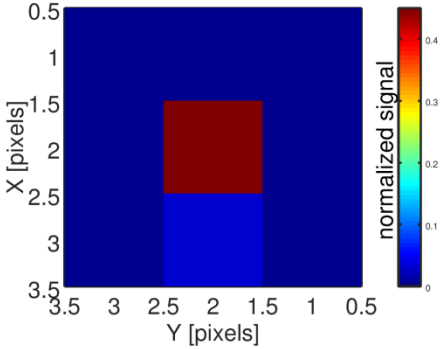
▷ backside voltage



▷ charge spreading







▷ standard
- ↳ functional
- ↳ selectivity > 1e4
- ↳ limited backside voltage
- ↳ large asymmetry of CC

▷ focussing he-implant
- ↳ improved operation window
- ↳ reduced charge spreading

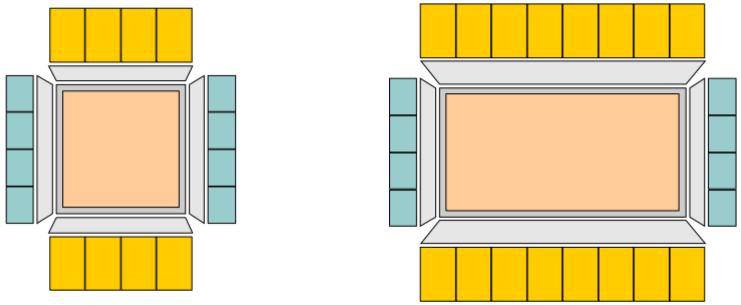
Follow-ups

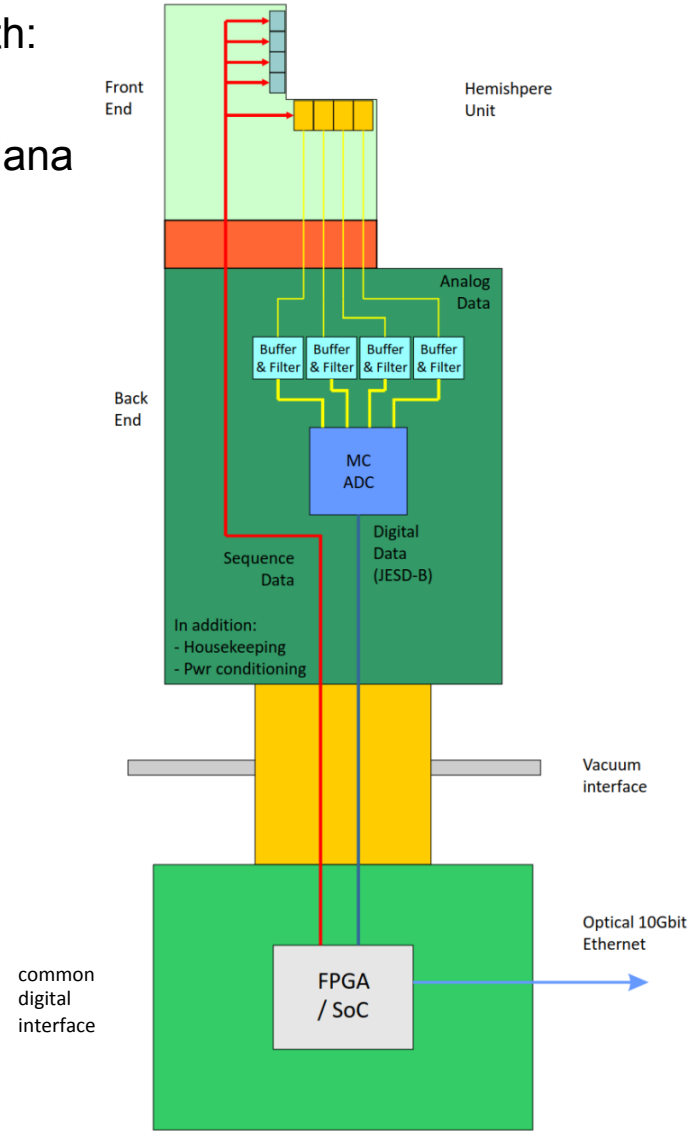
Follow-ups – Mid Term

Development of science capable camera prototype with:

Instituto Ricerche Solari (IRSOL)

Scuola univeritaria professionale della Svizzera italiana (SUPSI)



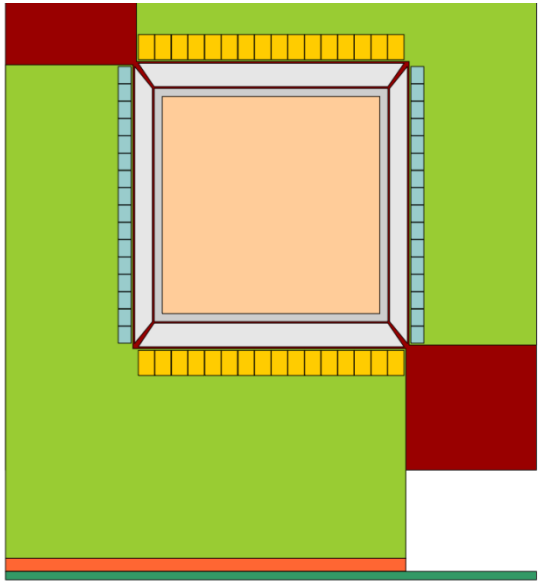


- 256x256 / 512 x 256 Superpixels
- Superpixel area 60 x 60 µm² or 48 x 48 µm²
- On-chip or discrete pitchadapter
- t_{rfrm} = 1.28 ms, ν_{rfrm} ≈ 780 Hz

Follow-ups – Long Term

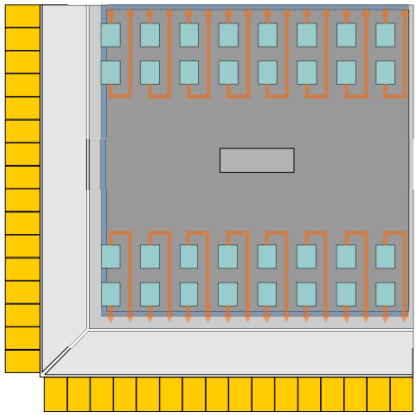
▷ Development of a 1kx1k Superpixel camera

- Conservative option
- VERITAS ICs and Switcher onsensor edges
- SwitcherS on Sensor

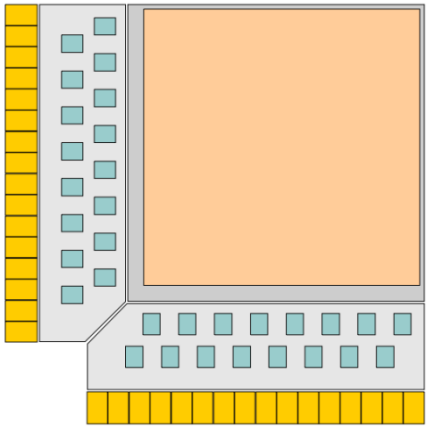


- 2-side buttable option

Option:
Integration of Switchers
on interposer



Option:
Integration of Switchers
on pitchadapter



Requirements

- 1 Mpix camera
- Max Modulator Frequency = 50kHz
  - change of state all 5 µs
  - synchronization of sensor and modulator (sensor slave to modulator)
- Full Frame Rate ~ 100 Hz (for all subpixels)
  - equal to 5µs per electrical row
- Low Noise
- No mixing of polarization states
- Compact Camera System

Thanks for your Attention

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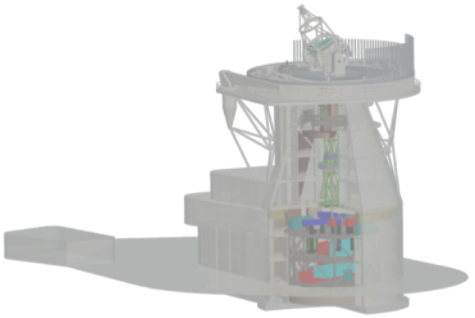

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Quadropix - Layout

	Poly 1&2	Al 1	Al 1&2
min Width	4.5 µm	5.6 µm	10 µm
min space	6 µm	3 µm	3 µm