CENTRE FOR X-RAY TOMOGRAPHY

WiggleCam

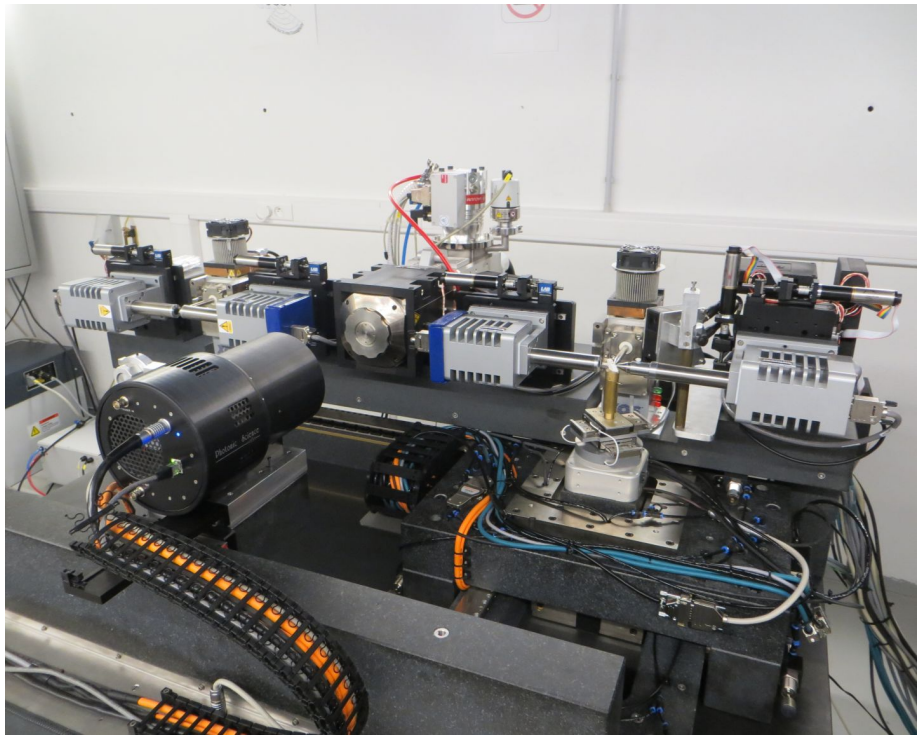
A method to cope with inter-sensor gaps for high-framerate tiled sensor arrays

Frederic Van Assche et al

GHENT UNIVERSITY

Introduction & background

Radiation Physics @ UGent



Lab-based X-ray micro-CT & XRF

Radiation Physics group supports user facility, improves micro-CT state-of-the-art

Radiation Physics @ UGent

“Next Big Thing”: Energy dispersive X-ray imaging at lab sources

But...

Monochromatic lab X-ray sources rare, expensive & large

Alternative approach:

Move energy selection to detector side

Energy dispersive detectors @ UGent

SLcam (pnCCD)
1.2 cm by 1.2 cm
450 µm Si
264 x 264 pixels
Up to 30 keV
144 eV FWHM @ 6 keV

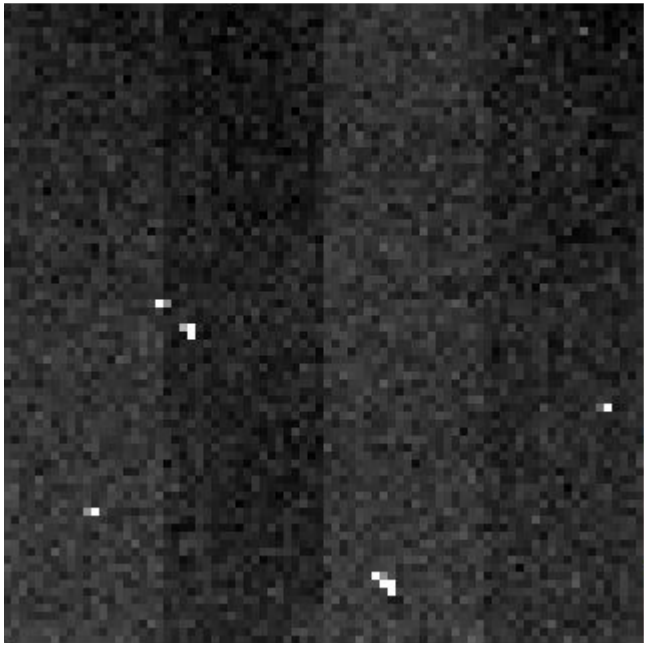
HEXITEC
2 cm by 2 cm
1 mm CdTe
80 x 80 pixels
Up to 160 keV
800 eV FWHM @ 60 keV

Hyperspectral X-ray sensors

1. Sparse frames (< 10% occupancy)

2. Large number of sparse frames processed into one exposure

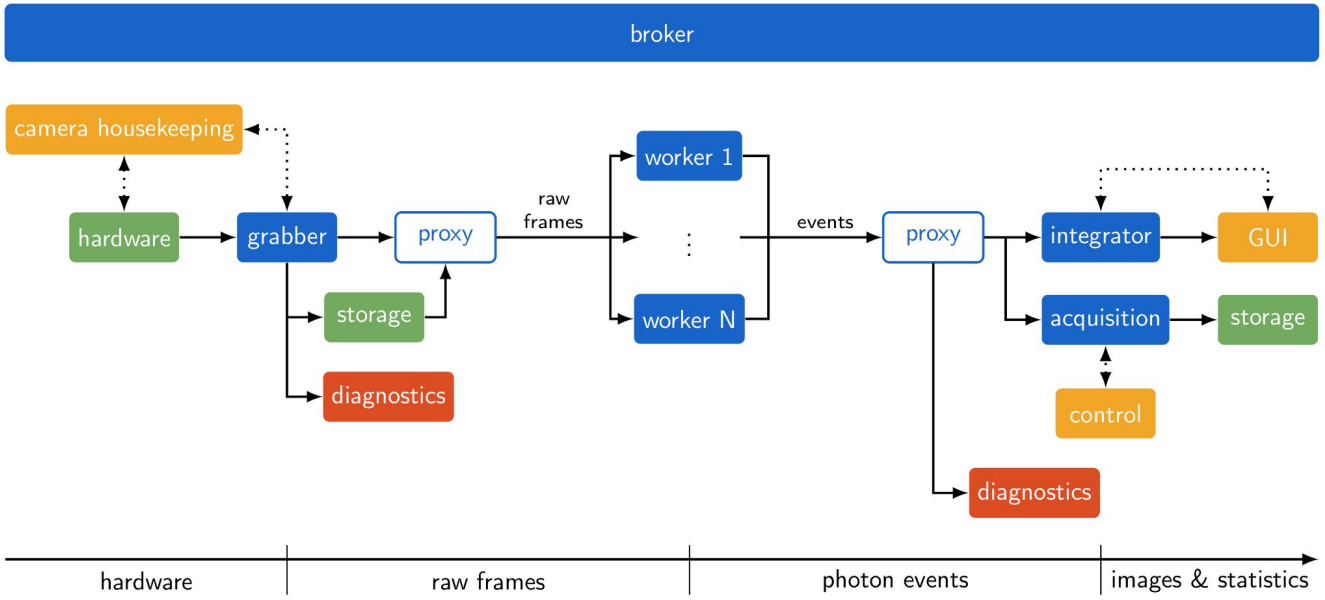
3. Frame rates as high as possible



The ideal hyperspectral sensor

1. Easy to integrate in existing systems
2. Stable, performant & efficient read-out
3. Full control over frame processing
4. Large (tiled) field of view
5. High frame rates (> 10 kHz) for “high” fluxes
6. Flatpanel-like FoV (10s of cm ²)
7. Flux capability comparable to integrating detectors

The SpeXIDAQ framework



Van Assche, F.; Vanheule, S.; Van Hoorebeke, L.; Boone, M.N. The Spectral X-ray Imaging Data Acquisition (SpeXIDAQ) Framework. *Sensors* **2021**, *21*, 563. https://doi.org/10.3390/s21020563

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Tiled arrays

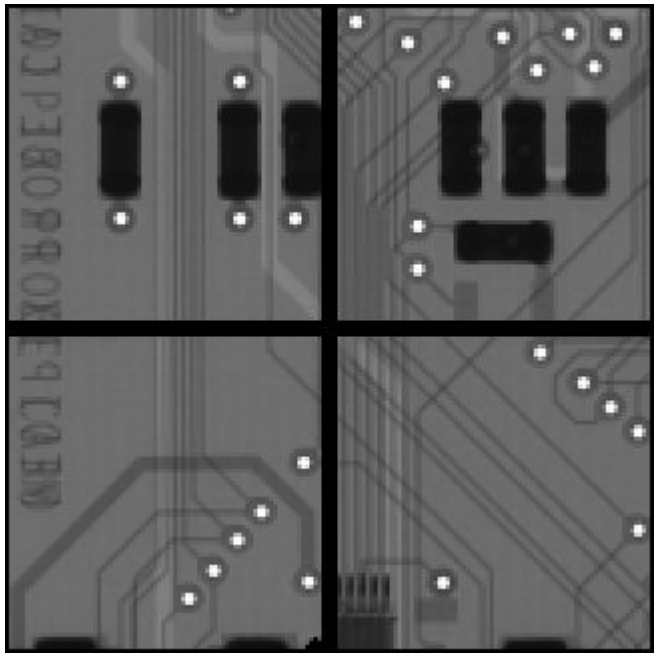
Only realistic way to construct larger hyper-spectral cameras

But...

Tricky artefacts for CT reconstruction

Typical solution:

Multiple exposures, stitched in post-processing



HEXITEC 2x2 imaging a Medipix 2

Our solution: WiggleCam

- Takes advantage of custom software and full control over every single frame
- Deeply integrates multiple exposure & stitching process
- Virtually no overhead for camera user

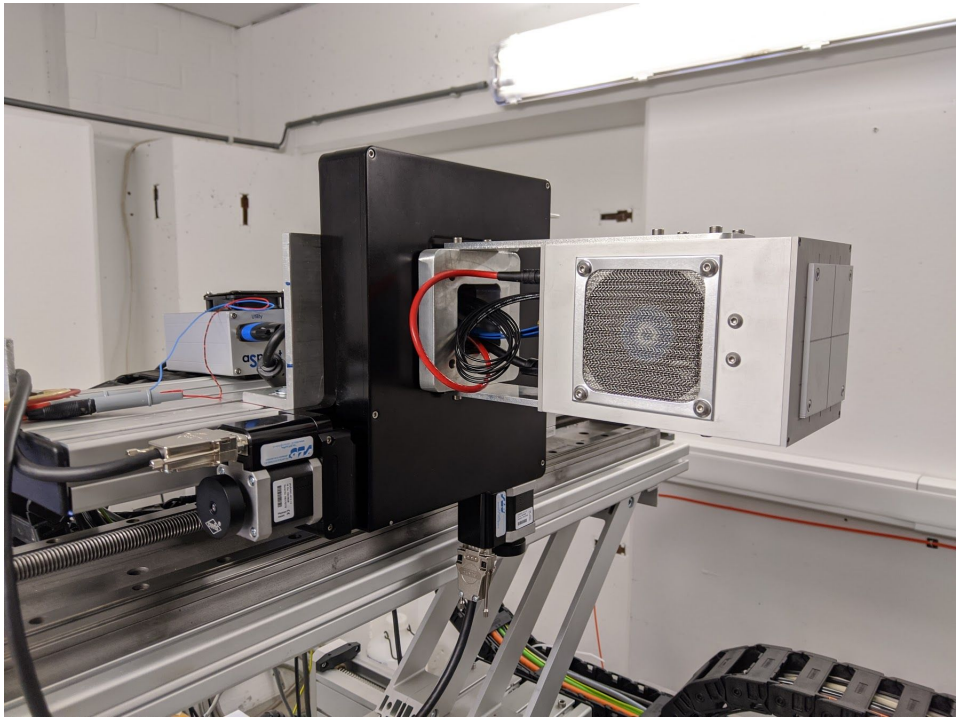
Getting perfect images is responsibility of camera & readout, not user!

WiggleCam requirements

- High framerate (multiple kHz)
- Long acquisition times (seconds or longer)
- Sensor mounted on XY-stage
- Position measurements better than half of a pixel size

Actual example

- HEXITEC 2x2 system
- 6.3 kHz framerate
- Integration times of well over 10 seconds
- 250 µm pixels
- XY-stage better than 100 µm



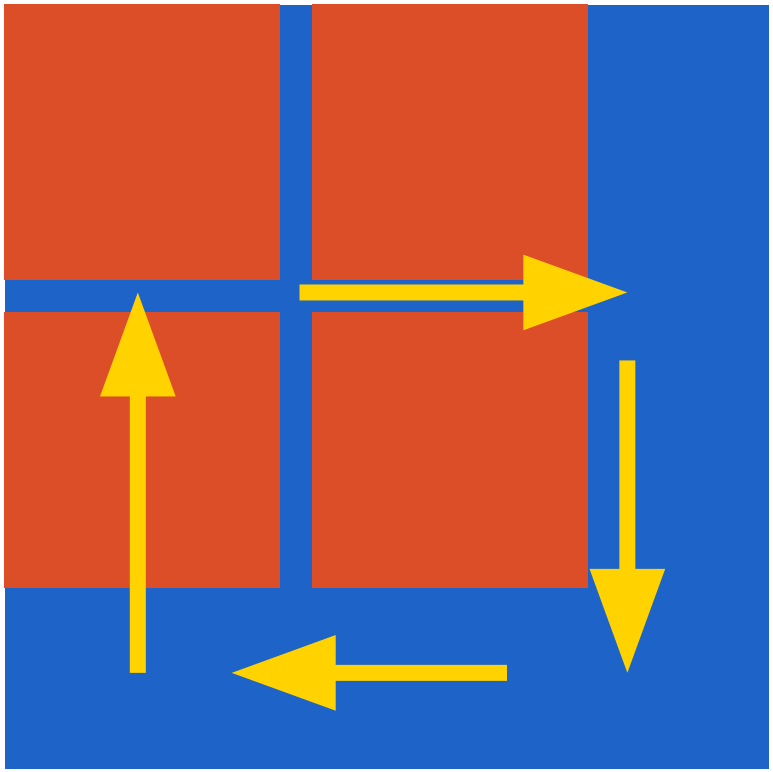
WiggleCam operating principle

1. Define a slightly larger superframe

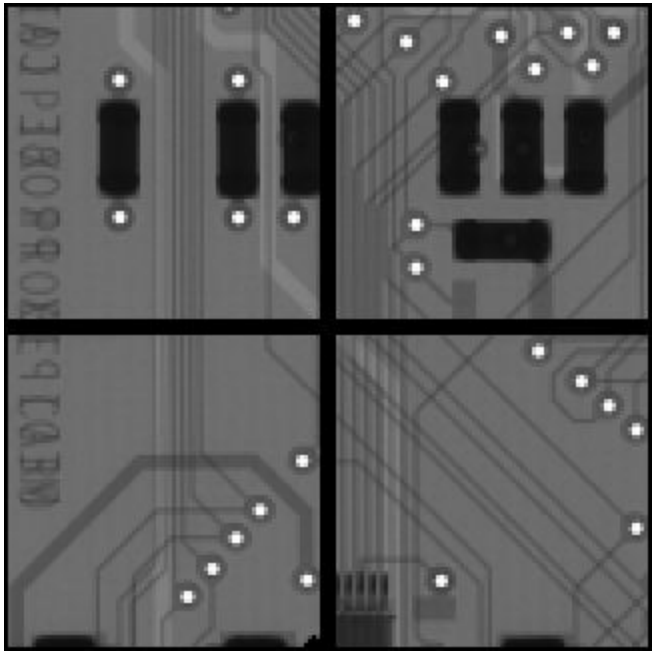
2. Integrate each physical frame at correct offset in superframe

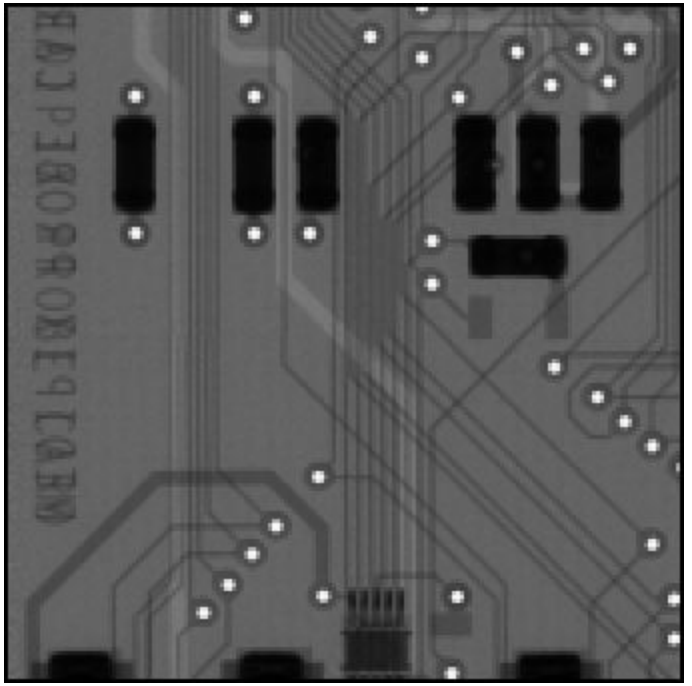
3. “Paint” entire superframe by following path that covers it completely

Multiple exposures & stitching @ 6.3 kHz



WiggleCam example images





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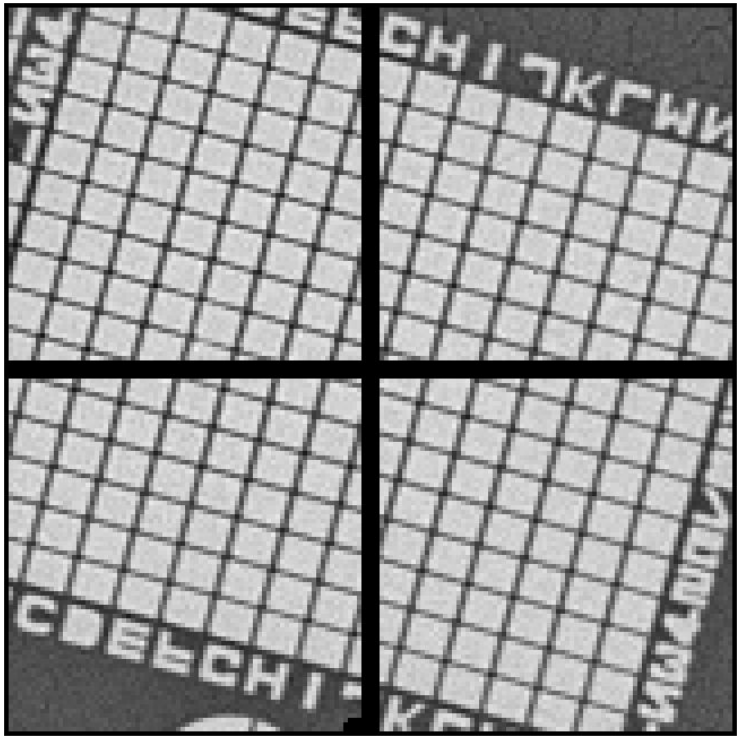
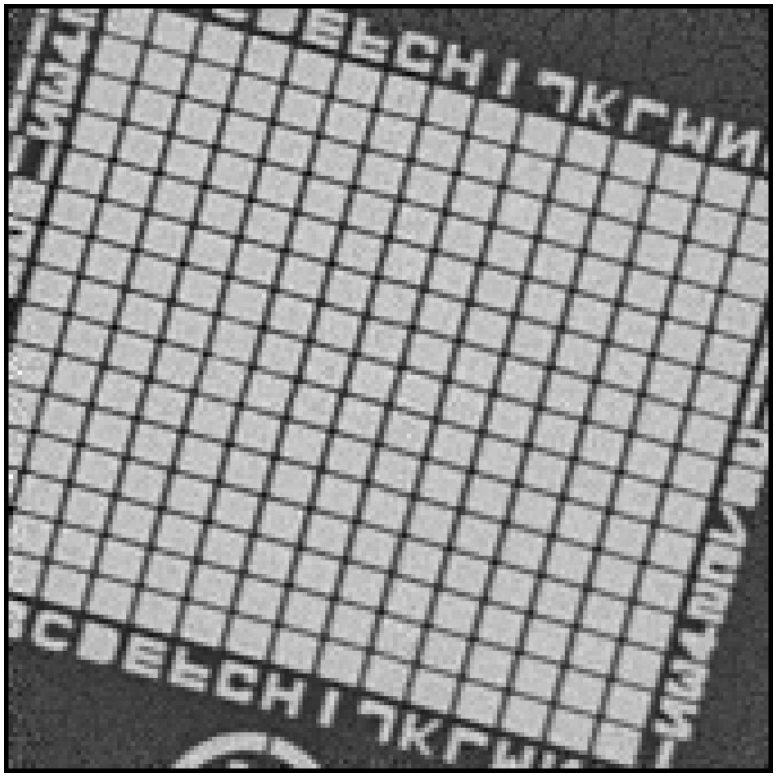
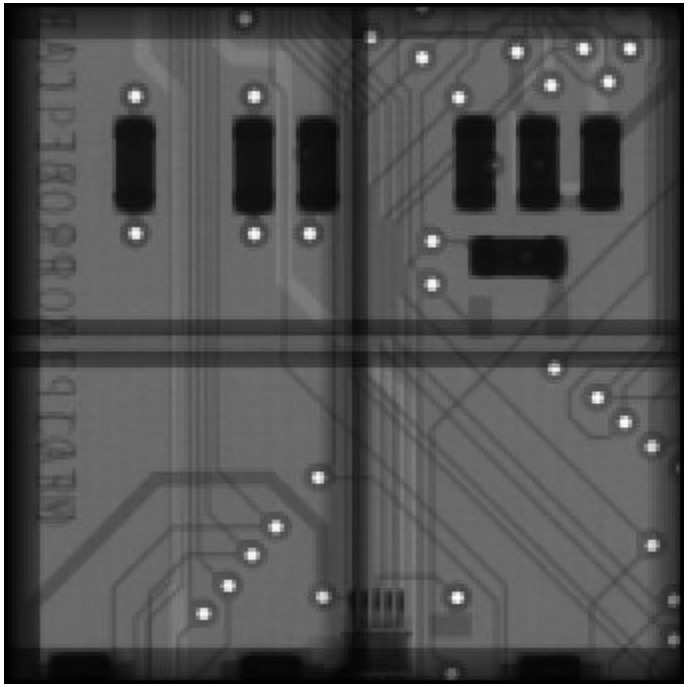
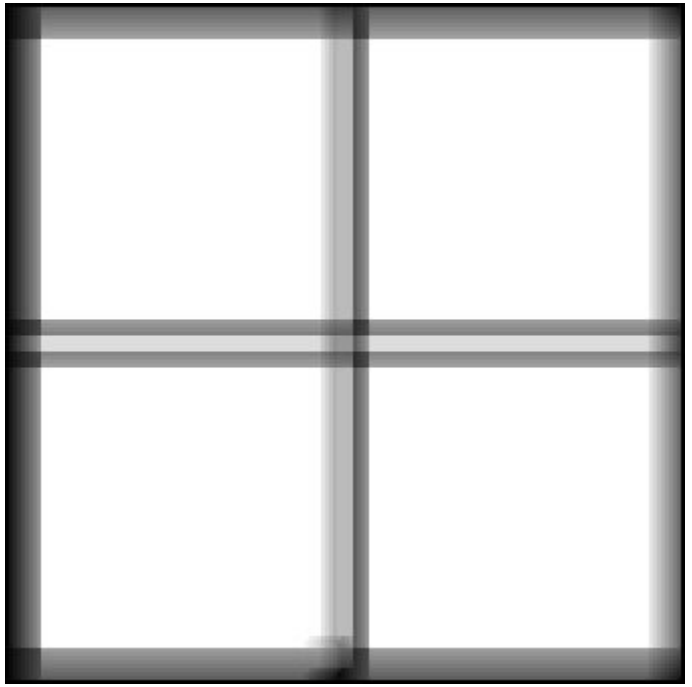




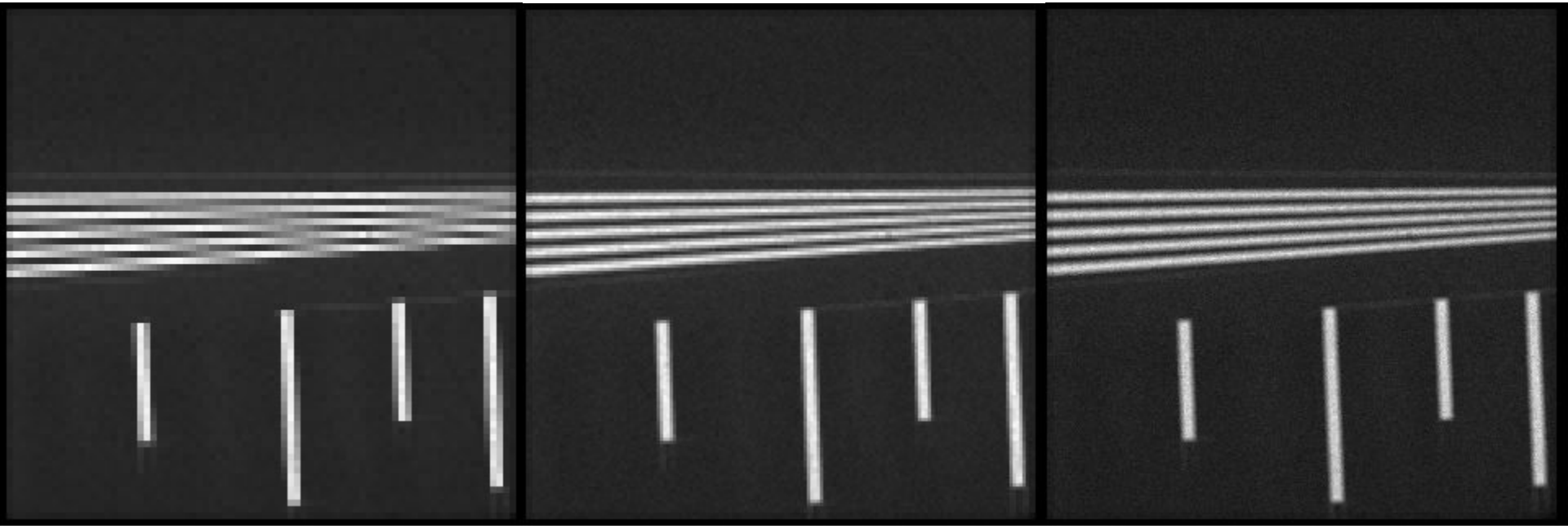
Non-uniform exposure

- **Oops:** uneven exposure time for different parts of superframe
- Store exposure frame: per-pixel counter of actual integrated number of frames in that superframe pixel
- Normalise final image to virtual gapless exposure





Bonus trick: super-resolution

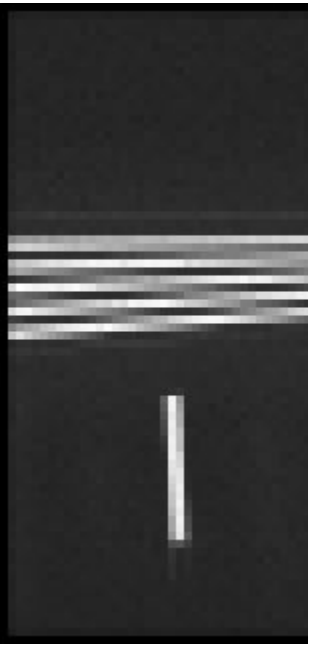


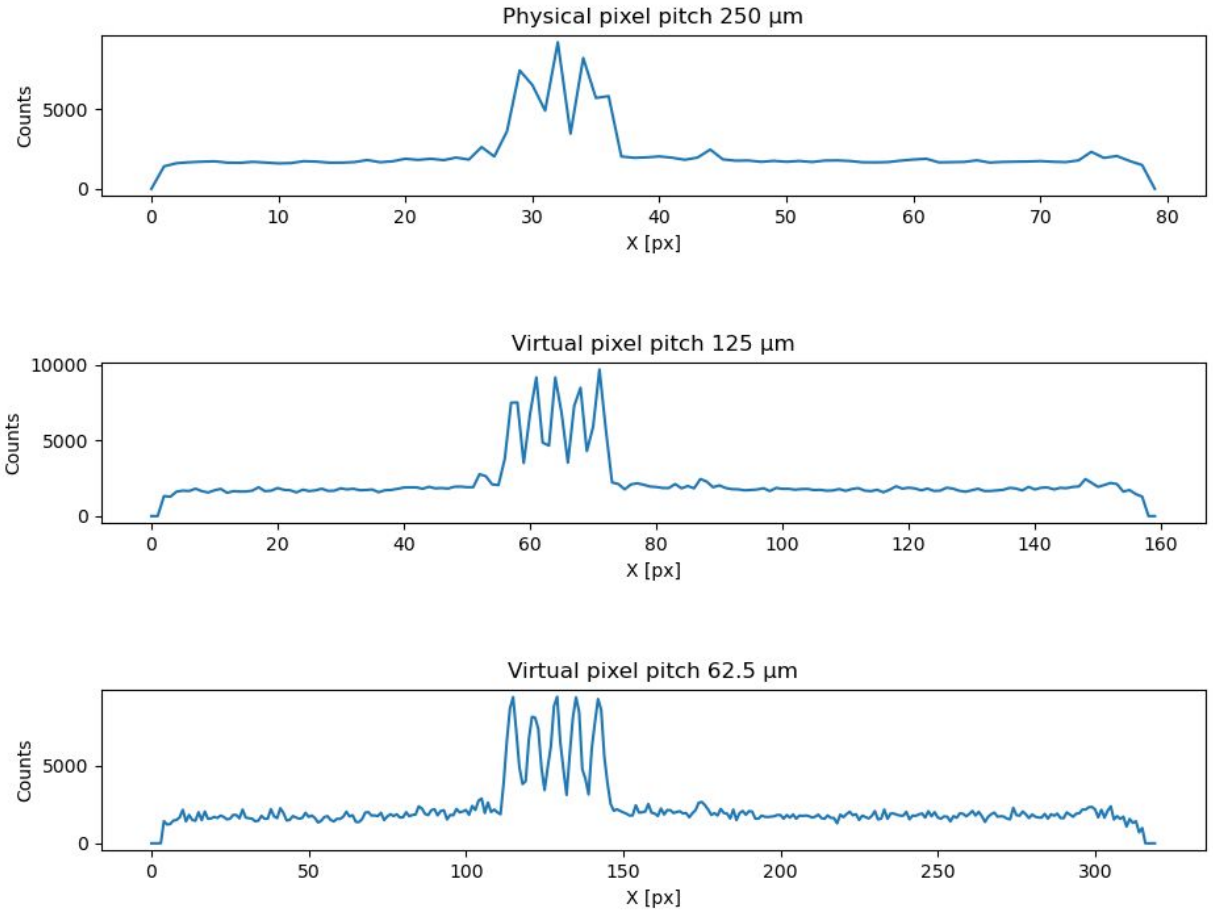
Physical 250µm pixels
80 x 80

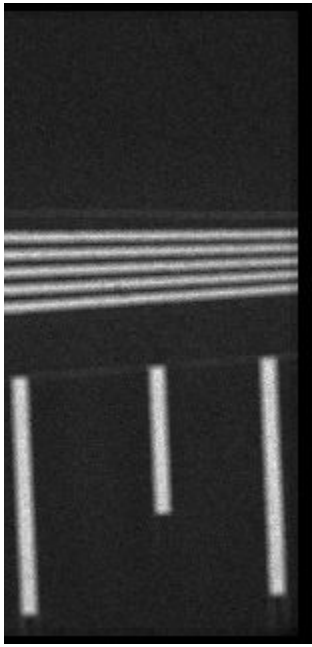
Virtual 125µm pixels
160 x 160

Virtual 62.5µm pixels
320 x 320

Bonus trick: super-resolution







Physical 2 µm pixels
80 320

WiggleCam pros & cons

PRO

- Gapless images
- Spectral performance preserved
- No overhead
- Virtual pixel pitch < physical pixel pitch
- Faulty pixels masked

CON

- Moving parts add failure points
- Less compact
- Slightly more complicated noise profile
- Flux still limited by physical pixels

...or…

Virtual pixels of half the physical pitch require 4x the measurement time for equivalent statistics

Further development

Implications for hardware implementation

- Position measurement critical
- Actuators don’t matter much
- Position reports directly to FPGA, embed in frames
- Minimise moving mass: integrate movement stage directly in camera

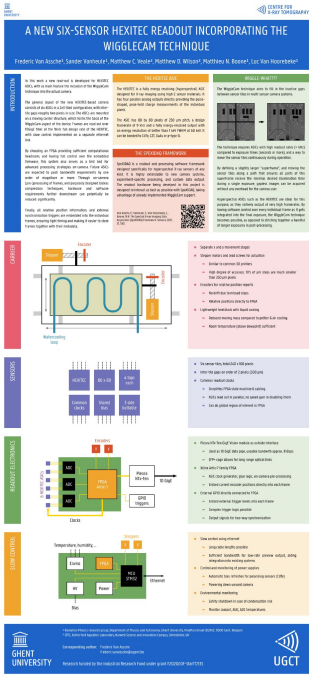
New HEXITEC readout hardware

Currently being developed:

1. HEXITEC readout with 2 x 3 sensors
2. Fully integrated WiggleCam parts

Poster 2D-08

A new six-sensor HEXITEC readout incorporating the WiggleCam technique



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Thank you!

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Funded by FWO grant G0A0417N
and IOF grant F2020/IOF-StarTT/135

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