Fast Fly-Scanning for X-ray Microscopy

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Sector 2 - XFD

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Outline

- Introduction & Motivation
- Examples
  - fly scanning with stepper motors @ 2-ID-E
  - fly scanning with piezos @ 2-ID-B
- Setup & Configuration
- Cost & Efforts
- Summary & Outlook

Why do fly scans ?

‘Image’ is built by raster scanning sample through focal spot

- need to oversample (i.e., fine scans with many pixels)
  - to acquire high quality images, which show object details
  - not to miss important object features (e.g., in fast overview scans)

but:

- overhead for step scans w/ stepper motor driven stages (e.g., Newport UTM series): ~100ms / pixel (due to software, motor accel/deccel, ...)
- overhead for step scans w/ piezo driven stages ~20ms / pixel

Why do fly scans ? **Speed!**

- APS: High brilliance source ? focused flux typically 10^9 photons/s
- for contrast modes using the transmitted signal, target: S/N = 3 for structure with 5% contrast
  ? need ~10^4 photons/s ? dwell time = 10 µs at the photon statistics limit

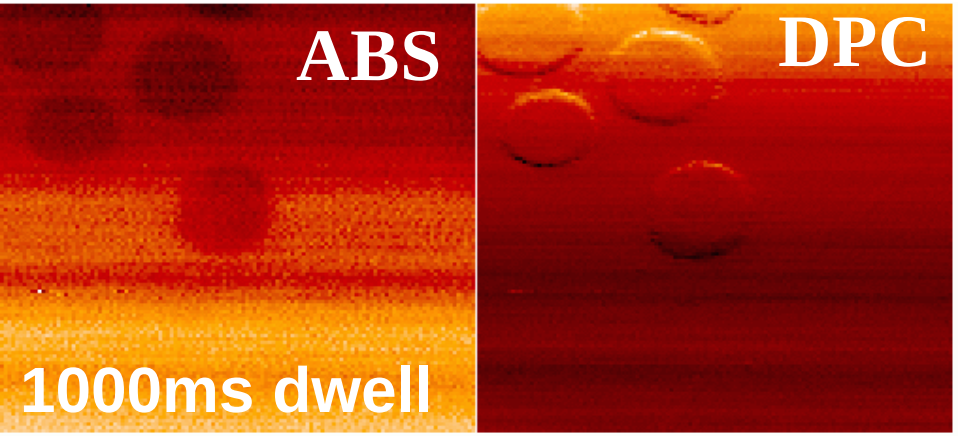
? overhead can be more than 1000x larger than dwell time !

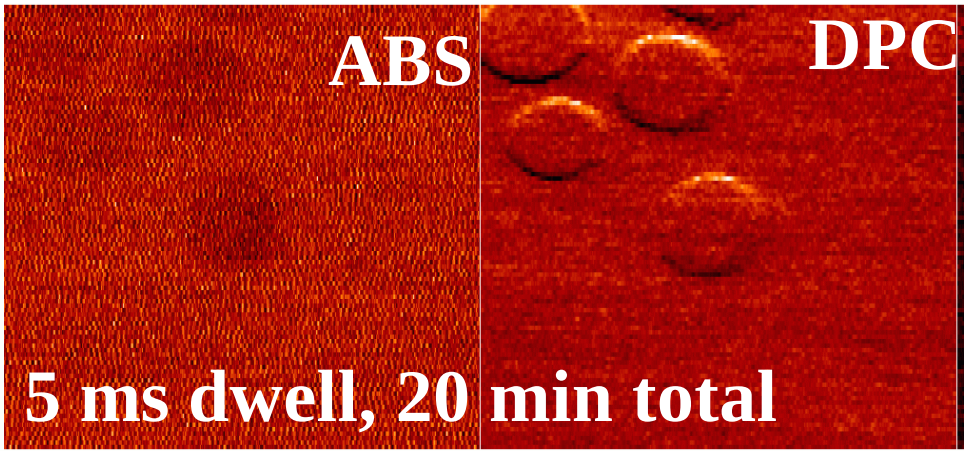
In extension: fly scans can be tremendously useful for any situation where the the data acquisition rate is not limited by photon statistics (i.e., physics).

Example @ 2-ID-E : mammalian cells, absorption and differential phase images using ion chambers

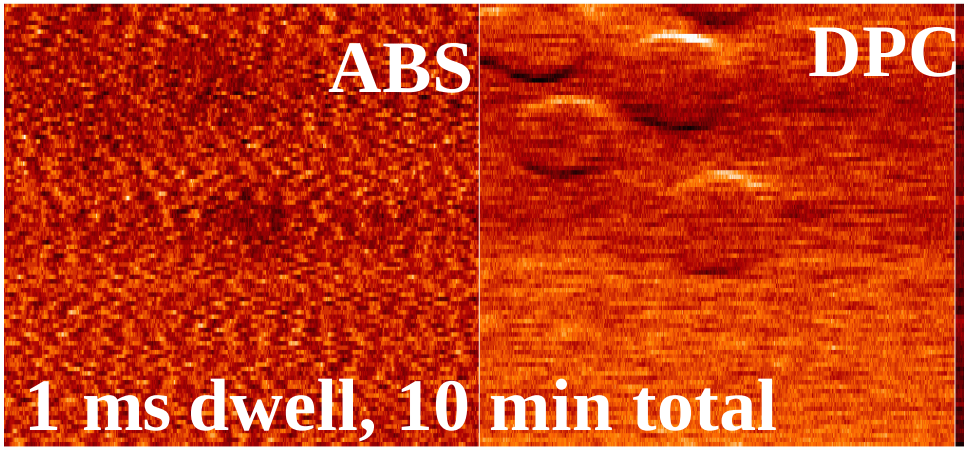
step scan w/ stepping motors:
50x50 microns,
0.4x0.4 microns steps
detected flux: ~ 4*10^9 ph/s
duration: ~4h

fly scan w/ stepping motors:
50x50 microns,
0.2x0.2 microns steps

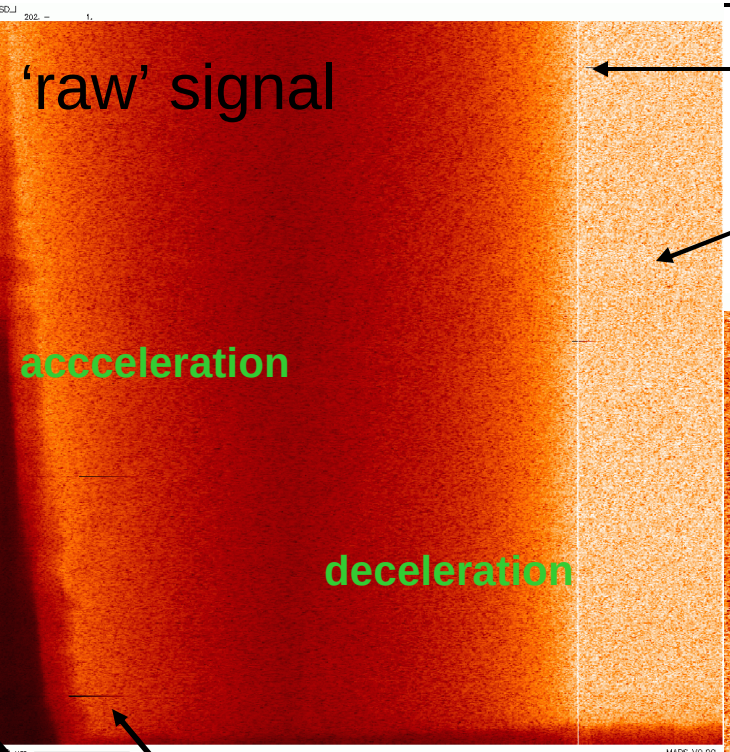




Even with standard detectors, fly scans can enable detailed pre-view scans

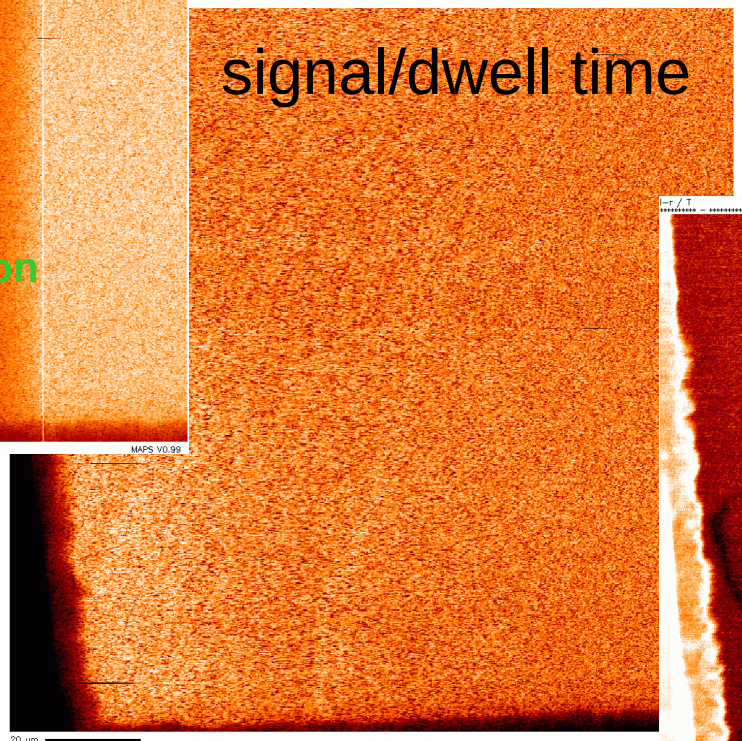


Example @ 2-ID-E: differential phase images of cardiac myocytes with dedicated detector

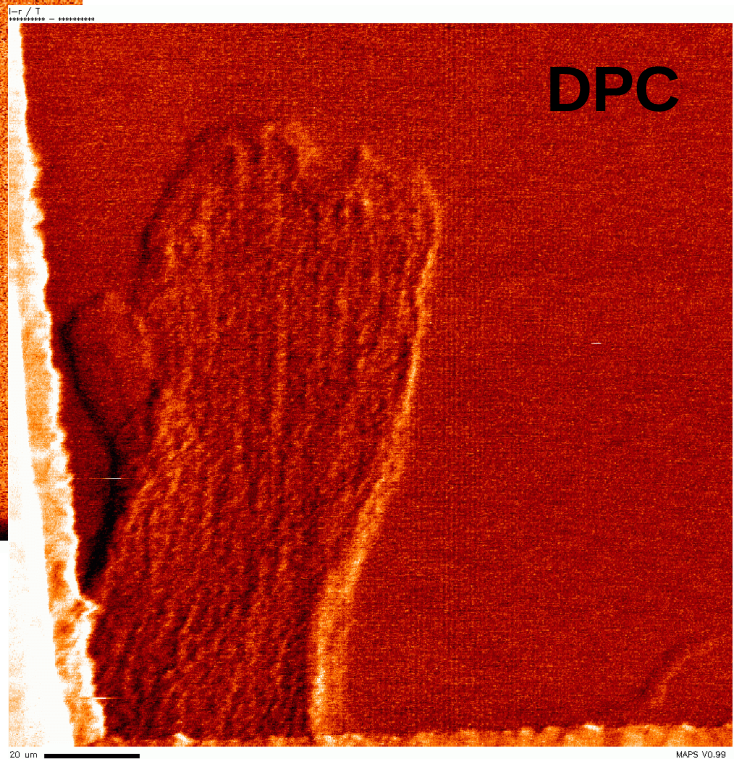


‘glitch’ due to switch from base speed to backlash speed

Slower movement w/ backlash speed

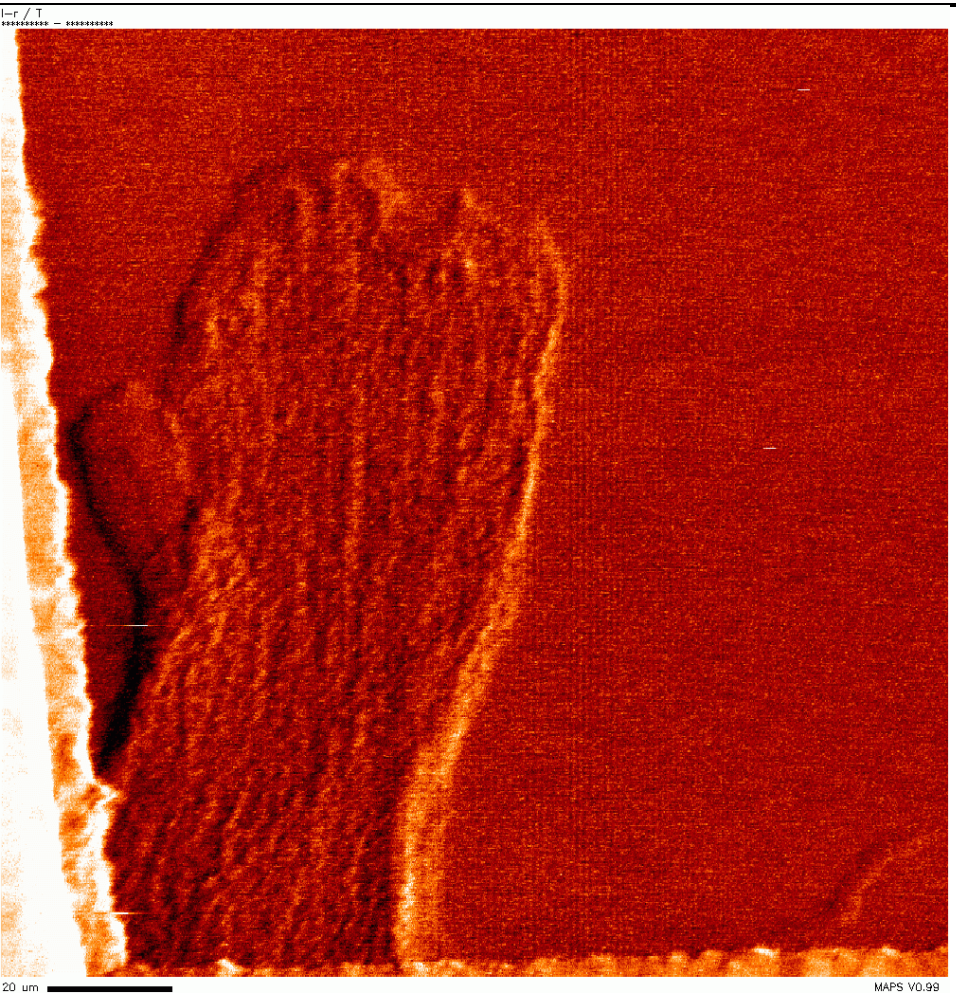


detector in collaboration w/ B. Hornberger, M. Feser et al



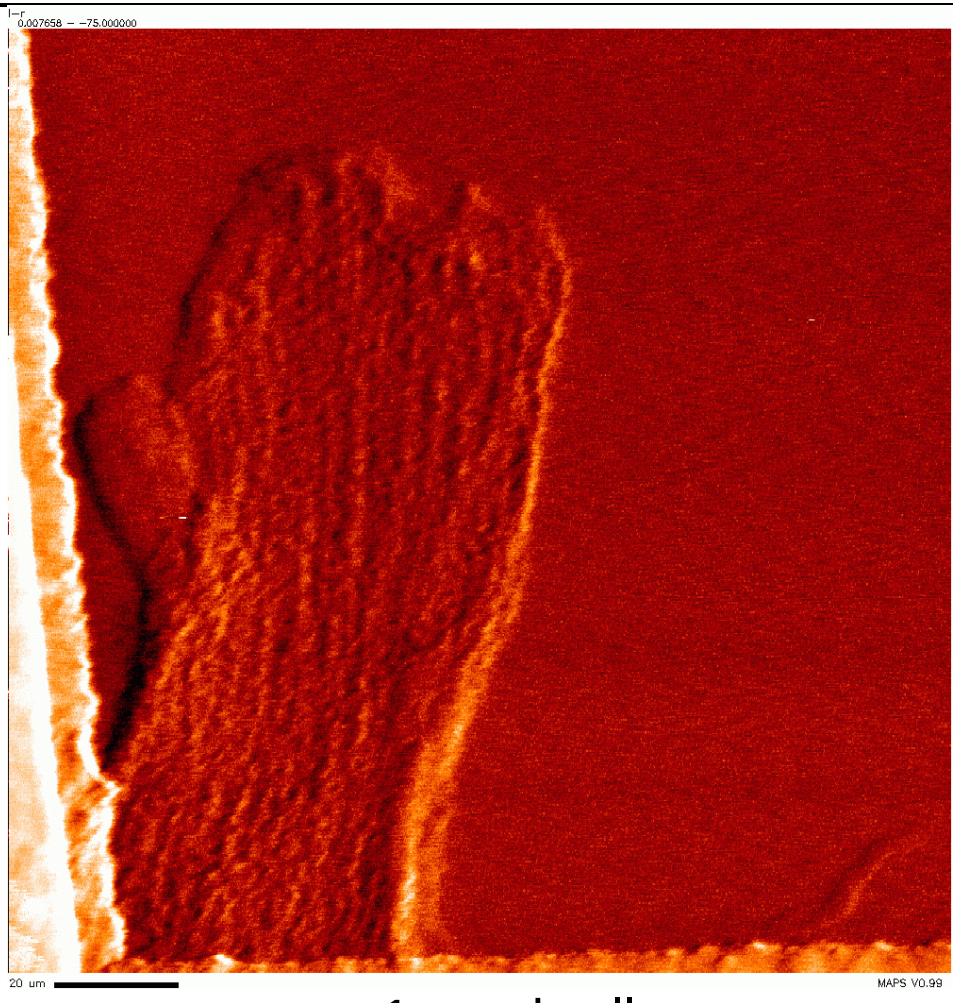
fly scan w/ stepping motors: 50x70 microns, **0.1 ms** dwell; 1000x700 pixel; scan time: ~30 min; estimated scantime w/o fly scans: 20h

Example @ 2-ID-E: differential phase images of cardiac myocytes with dedicated detector



0.1 ms dwell

total scan time: ~30 min



1 ms dwell

total scan time: ~1 h

remaining overhead: flyback & y motion

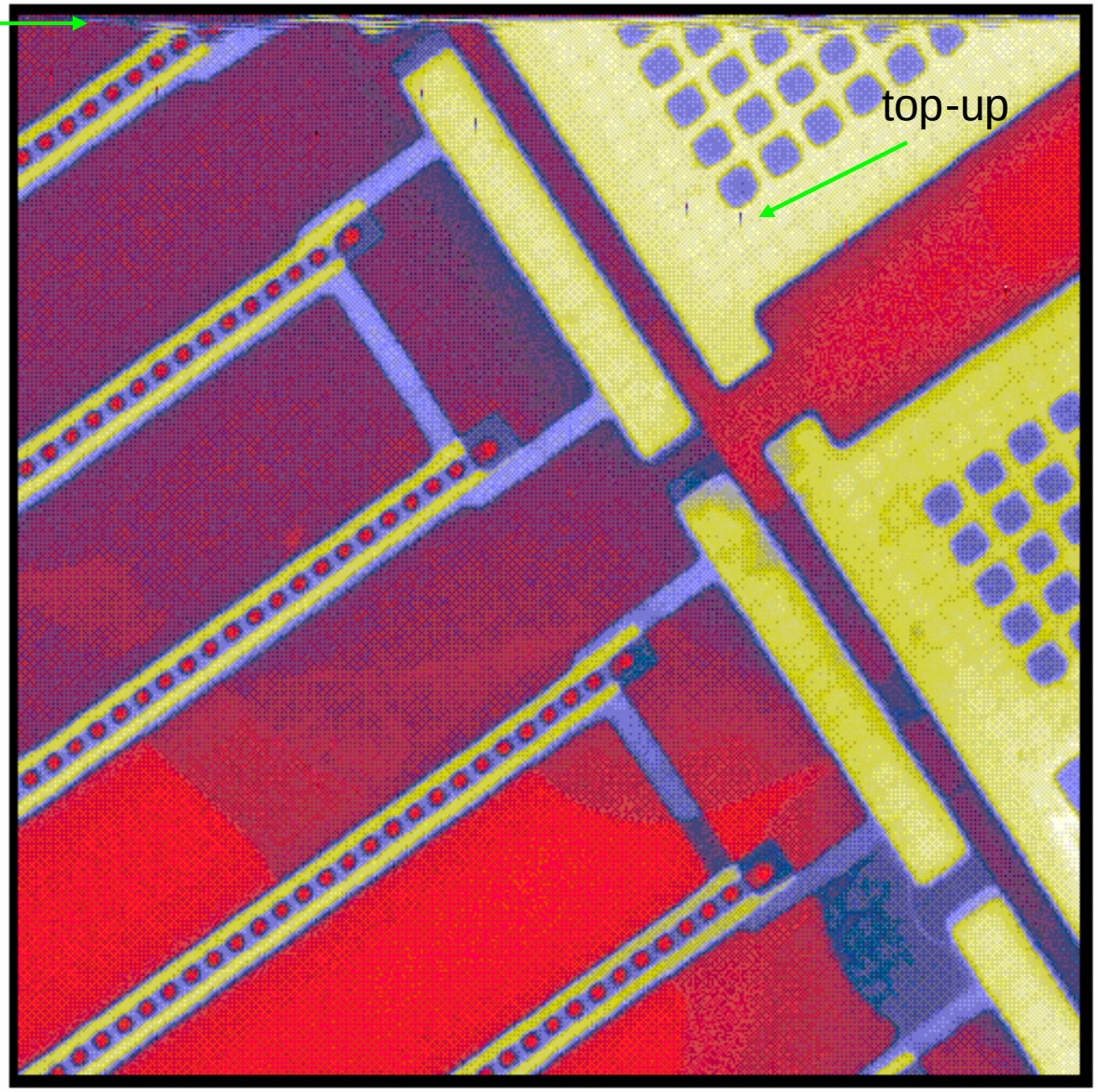
Example @ 2-ID-B: Transmission X-ray Image of Intel Semiconductor Chip

piezo stage
50 µm x 50 µm fly-scan
50 nm x 50 nm pixels
2 ms/pixel dwell

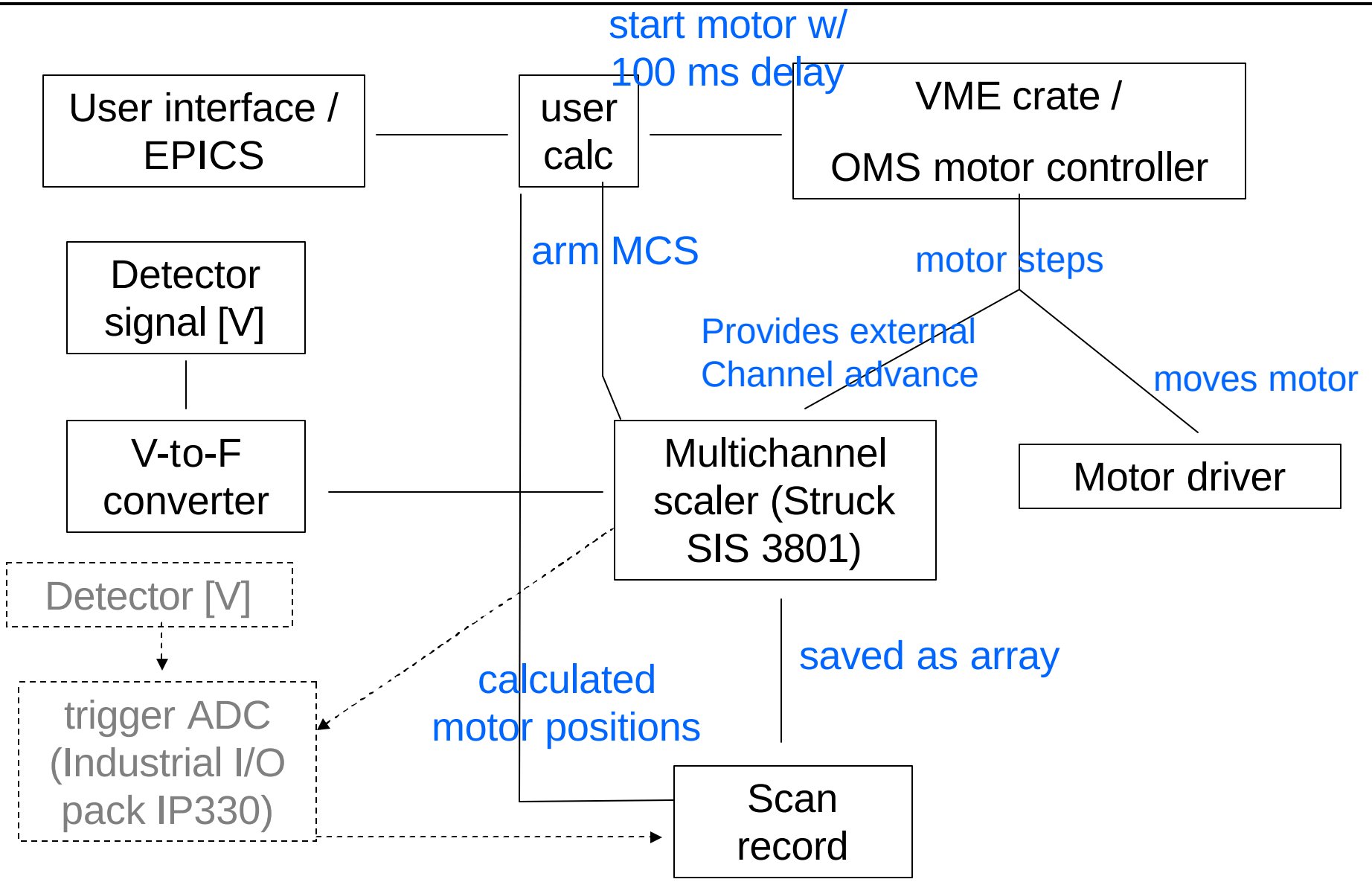
Total scan time: 1.5 h

Counts/pixel ~ 9000
RMS noise/pixel ~ 110
Shot noise limit ~ 95

Compare: estimated scan with step scans: 15 h !
(w/ 40 ms /pixel overhead)



Hardware Setup



Software ‘Setup’ w/ EPICS

- install drivers
- for fly scan @ desired dwell time, calculate & set motor speed, # of points, … (e.g., with user transforms)
- possibility to use dedicated scanrecord, for fly scans only, or use other programming language to ‘poke’ values into appropriate PVs
- user calc to provide delay between arming of MCS and starting of motor movement; need to use scan positioner in absolute mode
- for slow scans (> 10 ms dwell) possibility to use scan pause to speed up ‘fly-back’

- possibility to setup MCS to function as a ‘normal’ scaler

Cost & effort

- Cost:
  - essential: multi channel scaler
    e.g: Struck SIS3801 3.5 k$
  - possibly: IP330 ~2.5k$
  - possibly: NOVA V-to-F 3.5k$ /4 channels
- Effort:
  - install software: 2h
  - setup & test software w/ templates: 6h
  - Develop/implement GUI 6h
  - Tweaking 6h

Summary

- For ~3.5k$ and 2 days work a fly scan system can be implemented
- An increase in the data acquisition rate of an order of magnitude can be expected for all signals that are not photon limited

Outlook (and wish-list):

- over-scan to eliminate acceleration/decceleration artifacts
- option in scanrecord to trigger (arm) a detector with a variable delay before starting a scan motion
- allow for fast fly back speeds and slow ‘fly scan’ speeds to further reduce overhead
- software switch to select motor to drive fly scans