



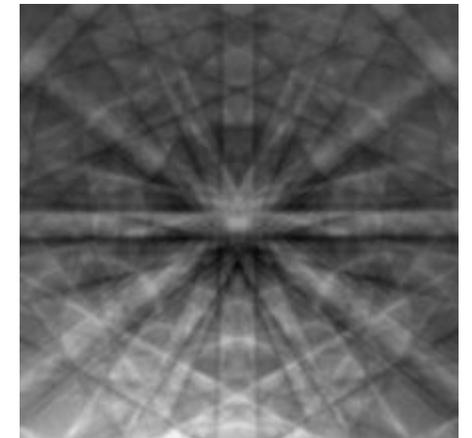
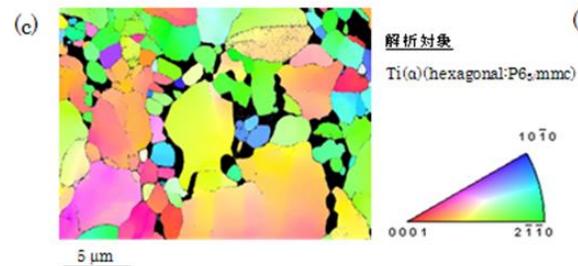
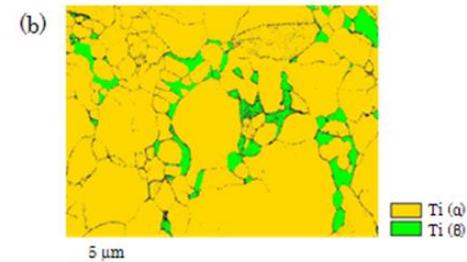
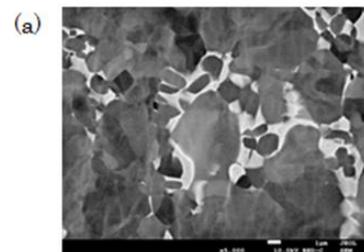
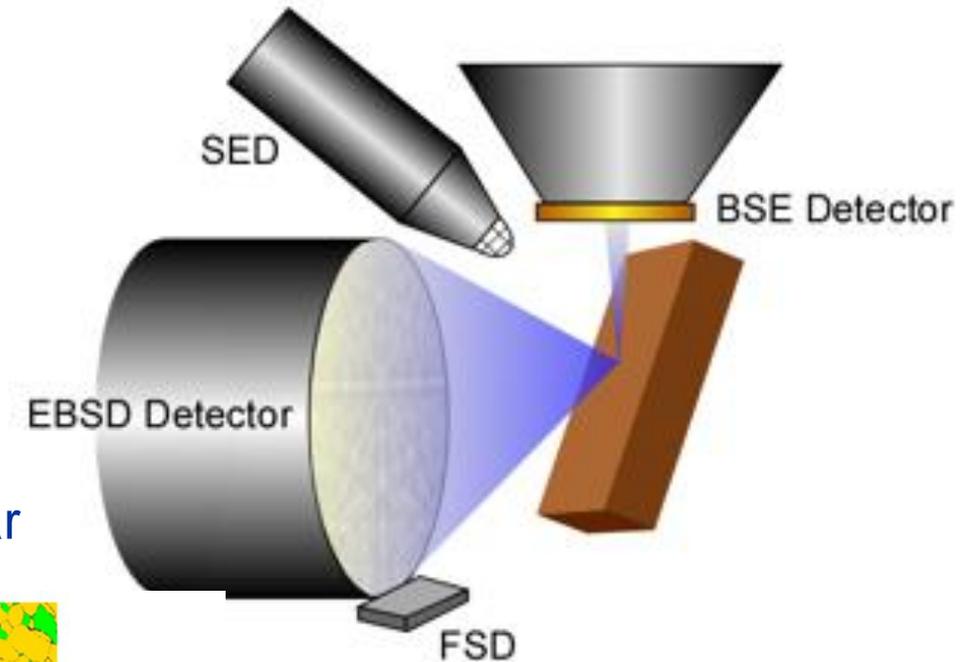
# **EBSD Electron Backscattered Diffraction, Crystallography in the SEM: Detector Requirements**

**Mark Stewart**  
**Materials Characterisation**

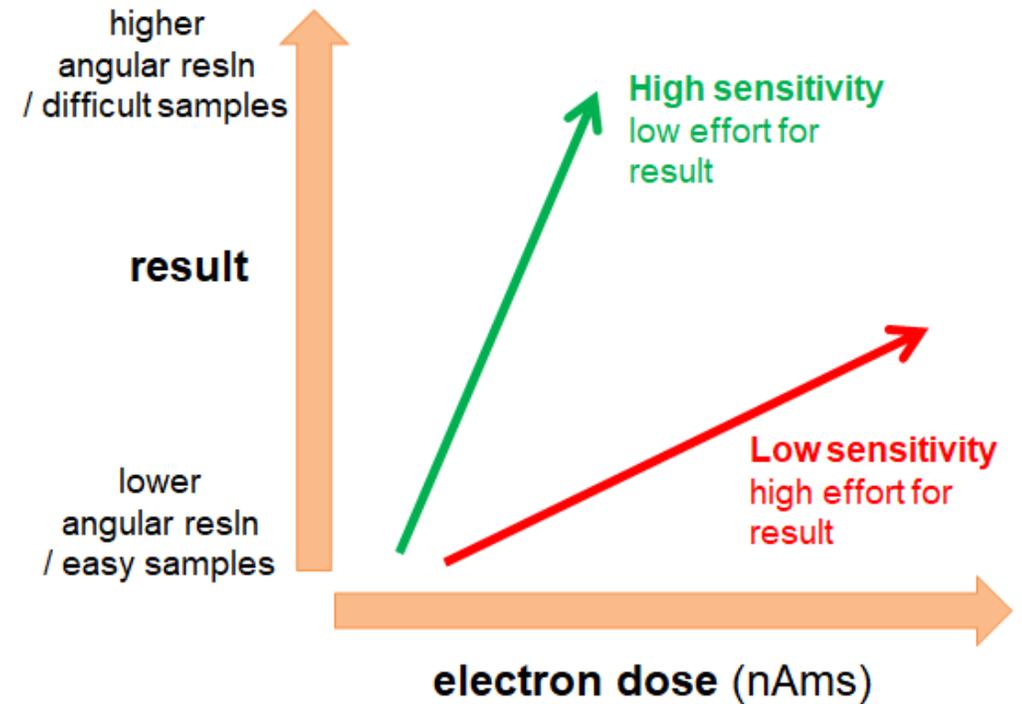
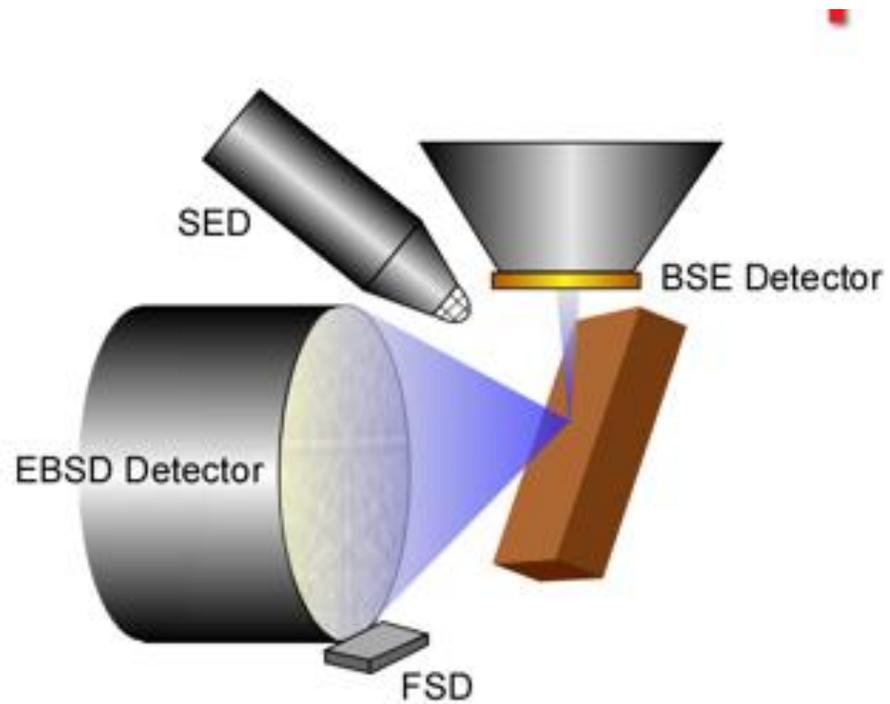
Workshop on low gain fast silicon detectors for EM and synchrotron applications Nov 25th

# EBSD (Electron Backscattered Diffraction)

- Crystallography in the SEM
- Relatively simple sample prep *cf* TEM
- High tilt angle 70
- Typical max 30kV
- Phosphor detector + low light CCD or CMOS camera.
- Phosphor size ~ 30mm sample to phosphor distance similar
- Structure mapping
- Texture/Grain Size
- Strain & dislocations



# Practical EBSD: Electron Dose



Beam current  $\sim 10\text{nA}$   
For 3000fps (0.3ms)  $\sim 2 \cdot 10^7\text{e}$   
Backscattered coefficients  $\sim 0.1\text{-}0.7$   
Solid angle  $\sim 100\text{e}$  per pixel in 0.3ms  
(55micron pixel)  
Probably only 5% is diffracted signal.

High dose = 10nA beam current  
 $\sim 60$  electrons in 1nS

# State of the Art in EBSD: Speed + Resolution

## C-Nano

Resolution	Speed
1244 x 1024	> 80 pps
312 x 256	400 pps

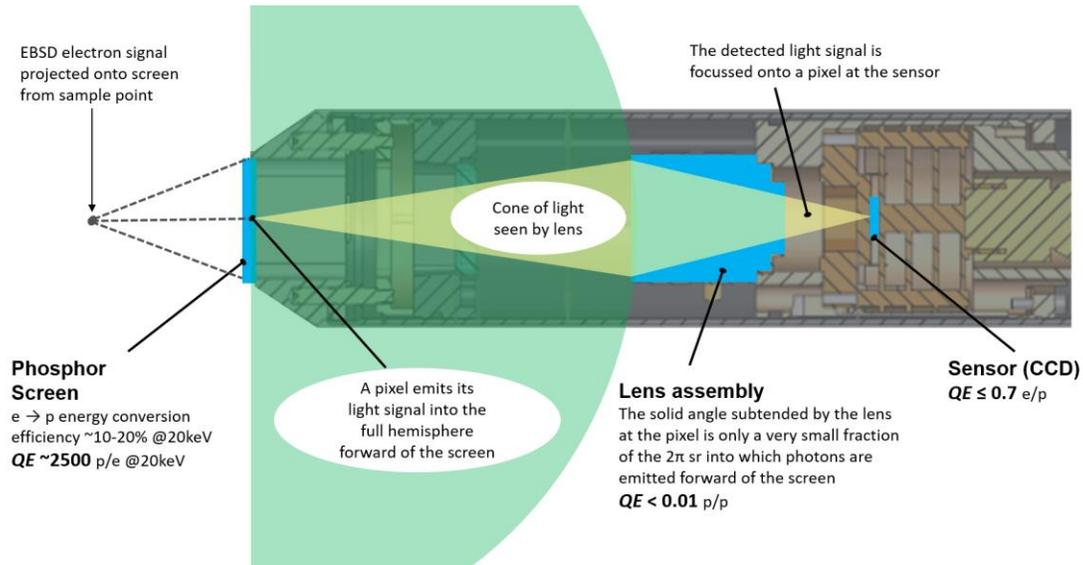
Increased speed achieved through binning.



## Symmetry

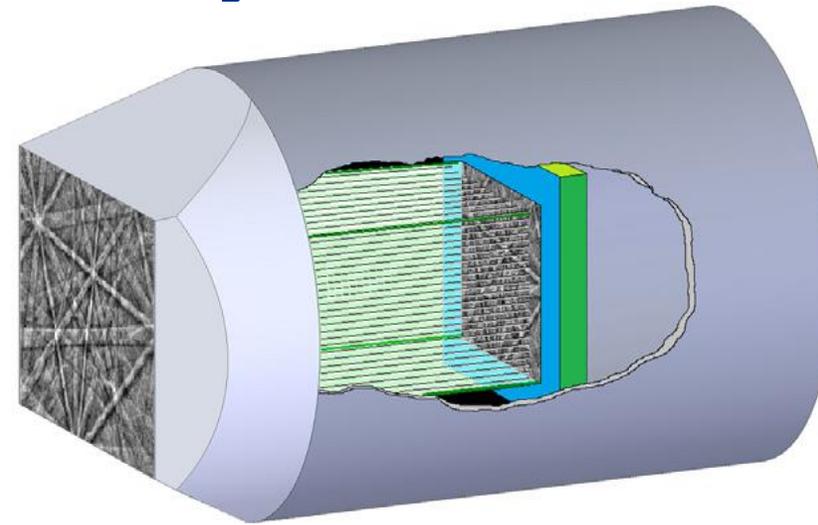
Resolution	Speed
1244 x 1024	> 240 pps
622 x 512	> 800 pps
156 x 128	> 3000 pps

# State of the Art in EBSD: Sensitivity

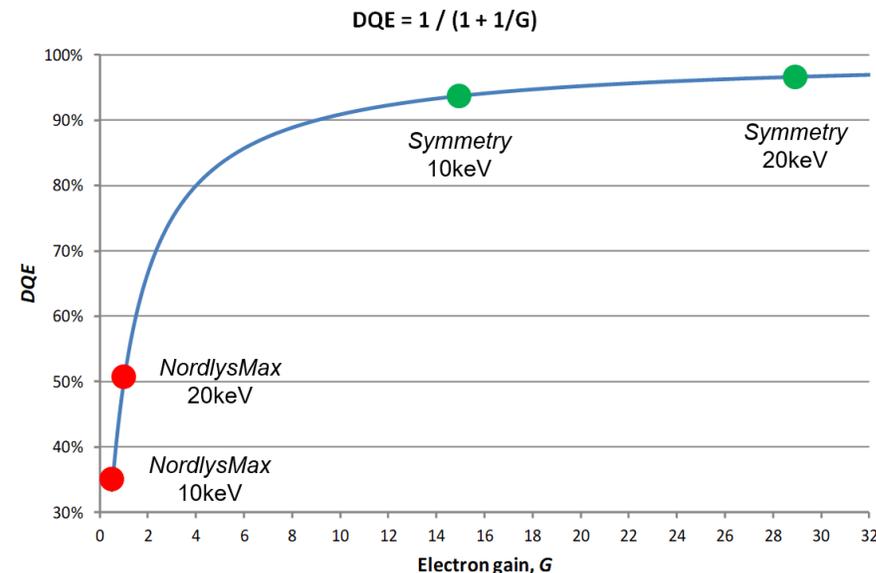


Standard Lens based system  
Lens only collects a small amount of the light

“Note that increasing the electron gain further (as may be possible by using simple direct electron detection, for example) offers no significant benefit.”



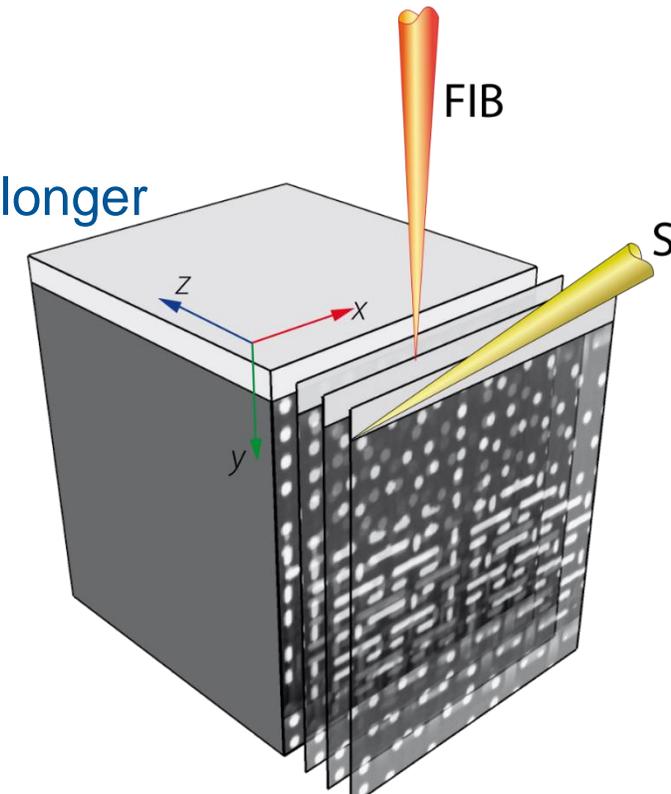
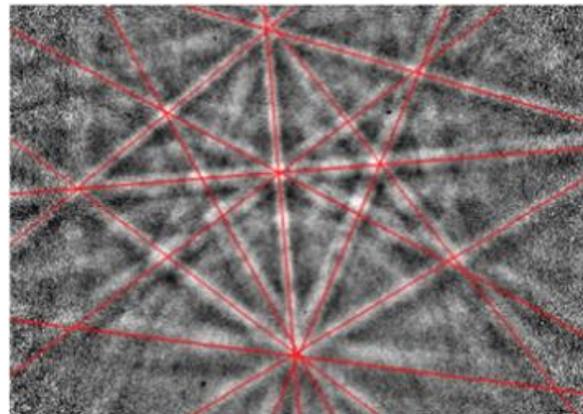
Fibre optic collection system  
Order of magnitude greater sensitivity



# EBSD: Why is speed important?

- Typical digital SEM images are at least 1k
- ~ capture times of 10-200 seconds will give excellent images
- For EBSD longer dwell times mean tens of minutes to hours are more typical
- Typically EBSD images are processed on the fly and not stored
  - Data storage difficulties + processing time
  - Don't want to come back after an hour and find its been wasted
- 3D characterisation with FIB – Typically would do ~100 slices = 100 times longer
  - Typical 3D FIB run is overnight, if not a weekend and more

Increased resolution only becoming important now as better models available  
Until now mainly used lines to index patterns  
Not used detailed dynamic information

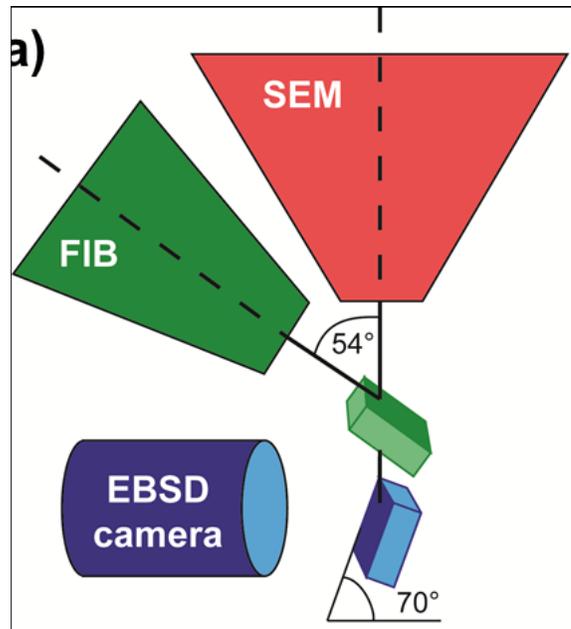


# What can Direct Detection give/promise us?

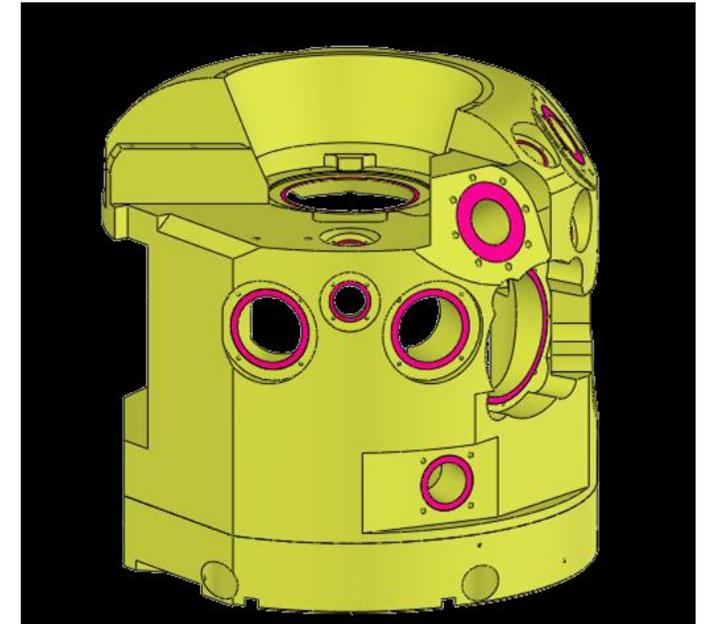
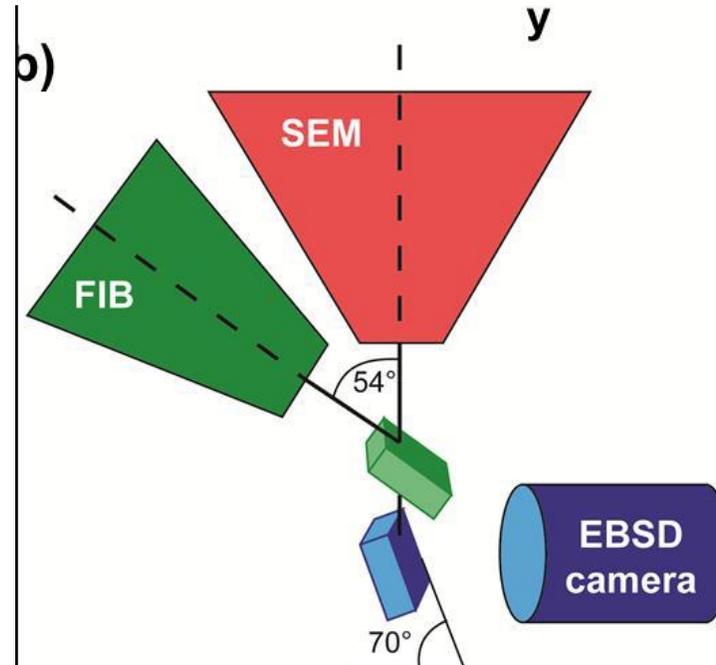
- Ease of install
- Energy Filtering
- Calibration?
- Improved low energy (kV) performance?
- Better sensitivity no phosphor?
- Prospect of higher speed?
- Variable Gain?

# Ease of Install: 3D FIB

Rotation

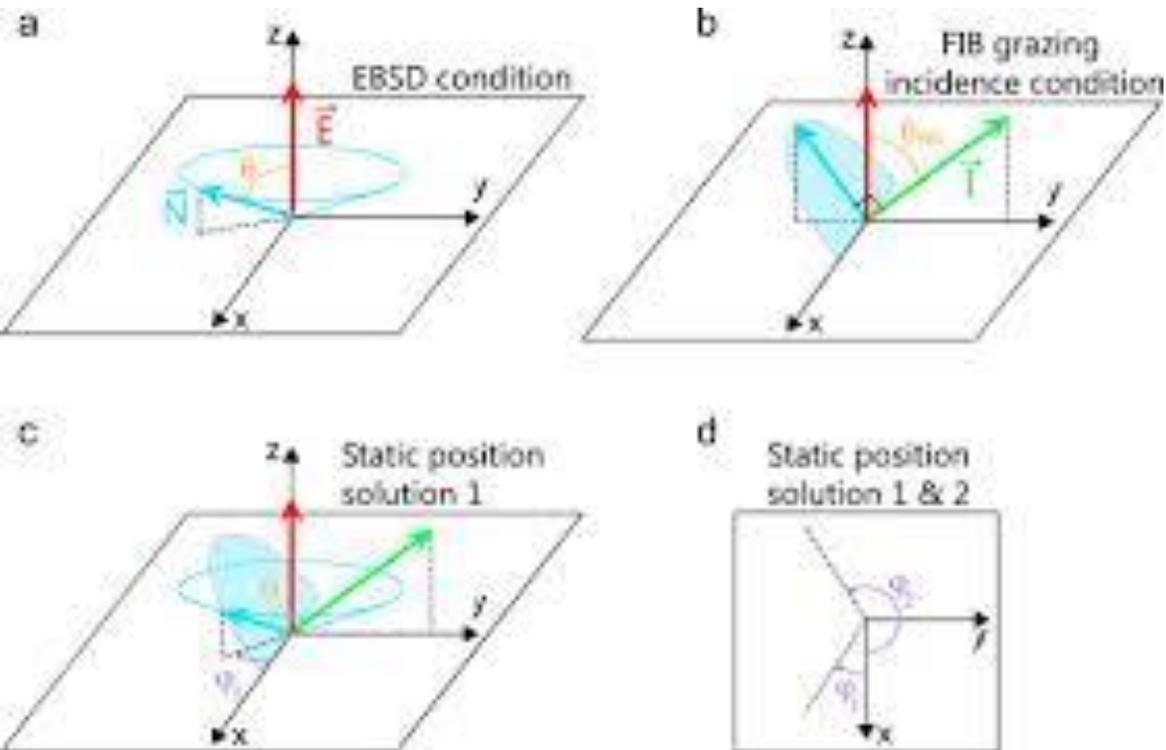


Tilt

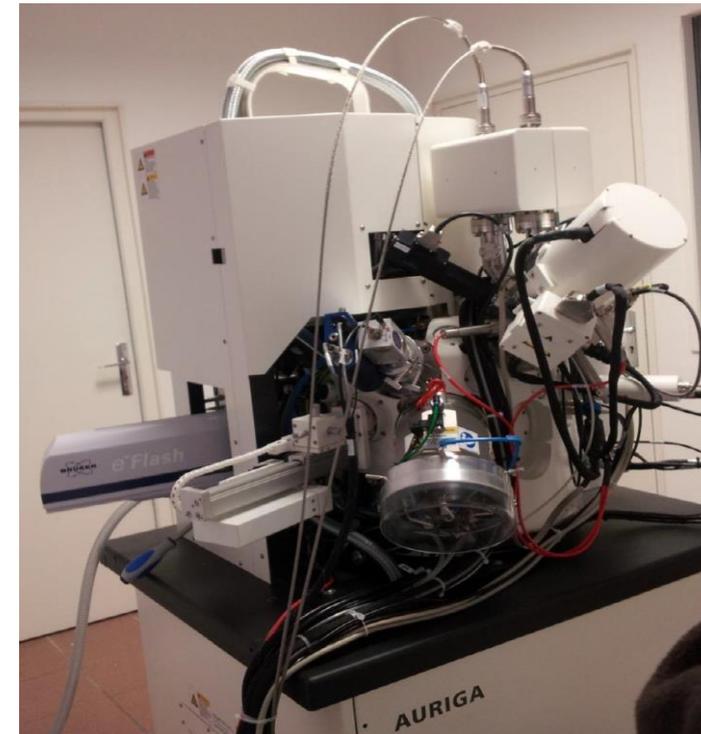


SEM chamber cramped  
~5mm WD for FIB  
EBSD camera positions limited

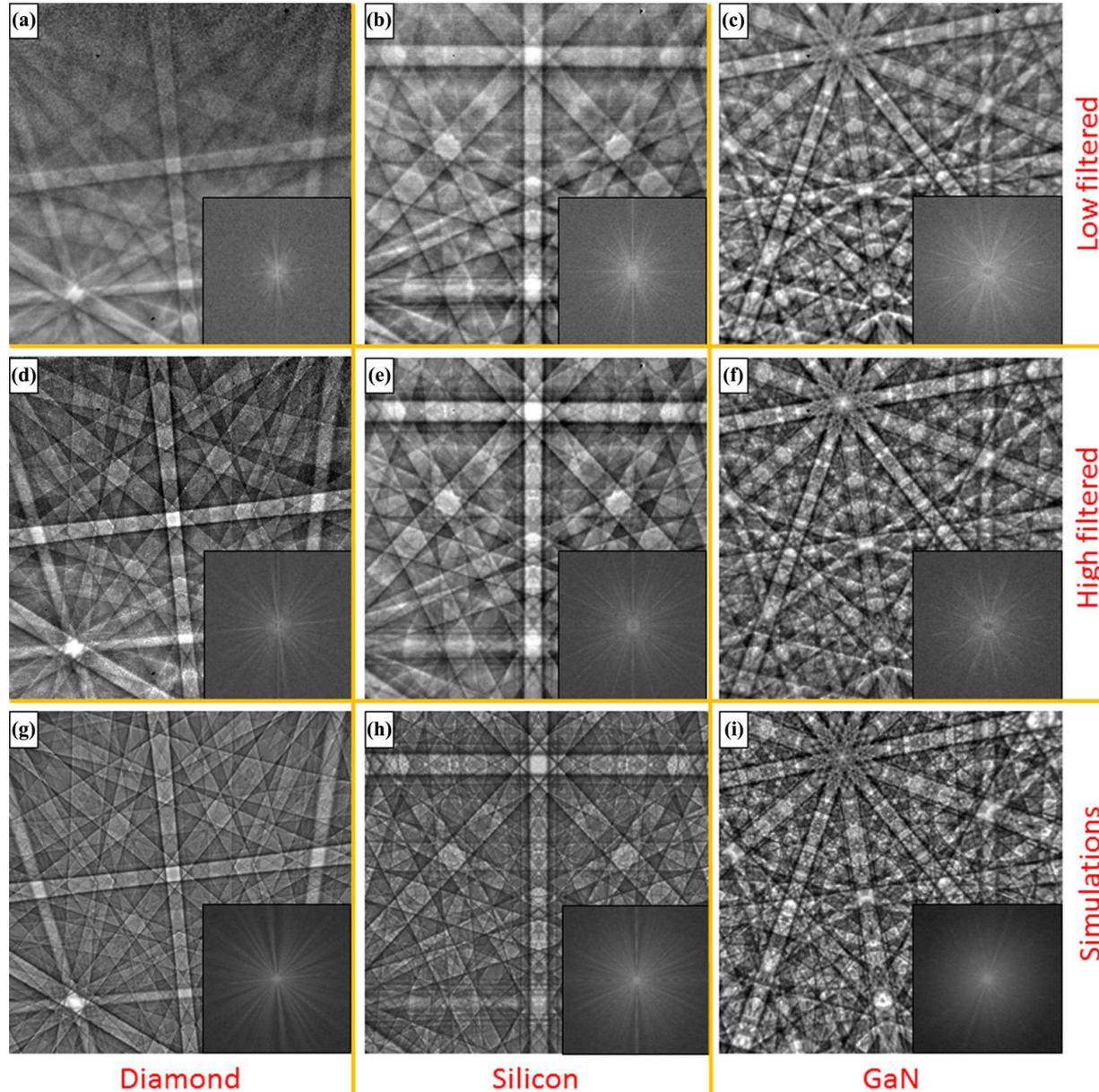
# Ease of Install: 3D FIB static setup



- a) A cone where surface is 70 to e-beam
- b) Angle which FIB grazing incidence
- c) 2 possible planes for 3D EBSD
- d) 2 positions in the SEM chamber for camera

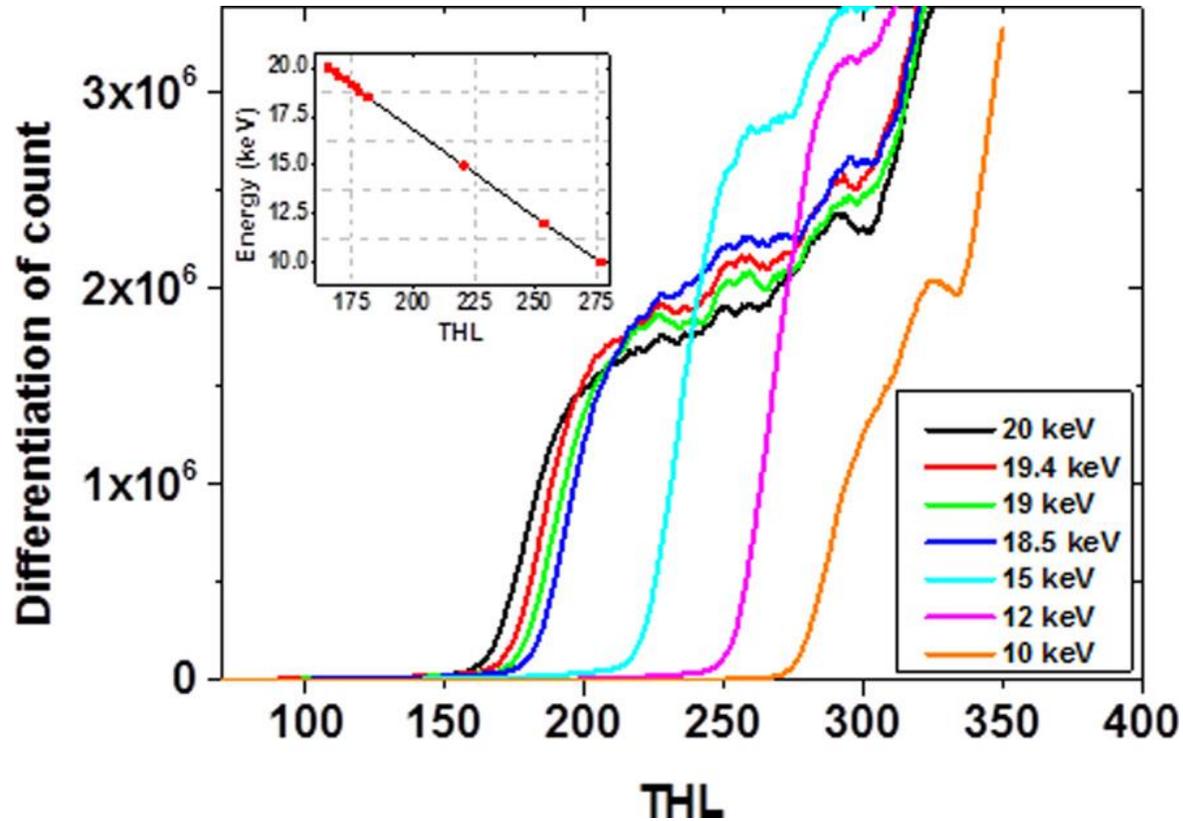


# Energy Filtering & low kv performance

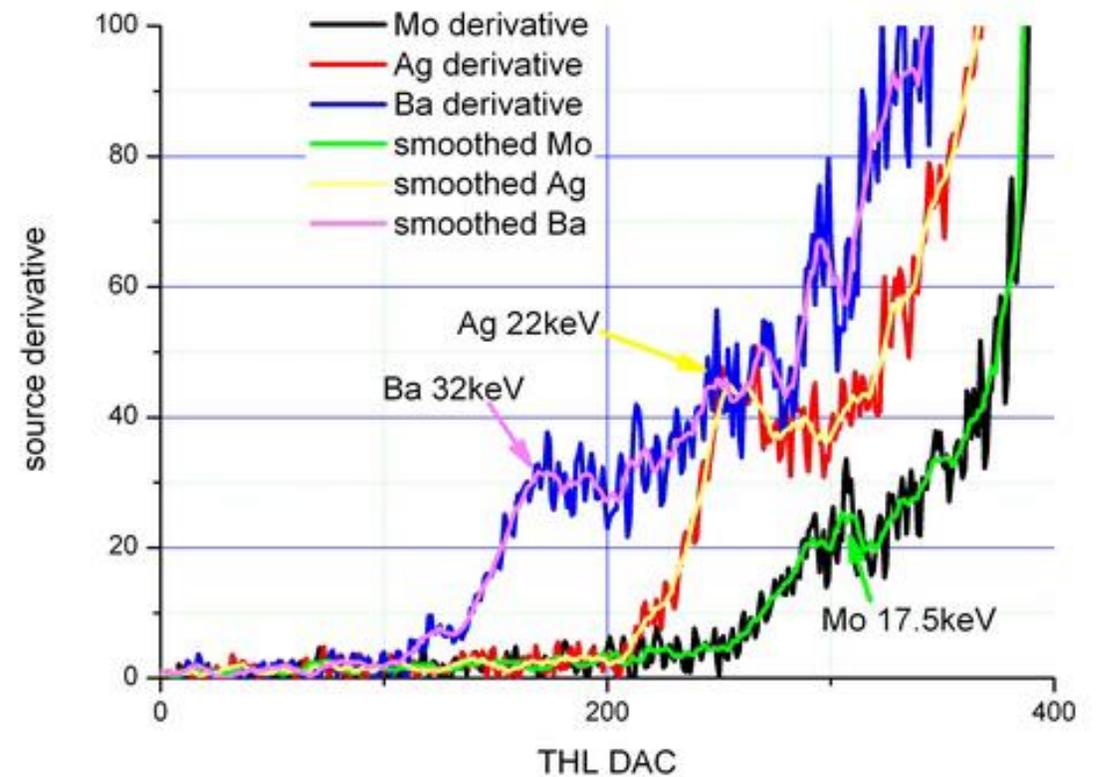


Improved performance from energy filtering

# Calibration?



a) Calibration using electrons



b) Calibration using X-rays

Good agreement – yet find still get viable EBSD patterns when threshold set way above the incident beam energy

# Direct Detection: Higher Speed?

## High Speed CMOS camera

Resolution	Speed
1244 x 1024	> 240 pps
622 x 512	> 800 pps
156 x 128	> 3000 pps

## Timepix USB 2 Advacam

Resolution	Speed
256 x 256	>850 pps

Practical pps ~50

Power 2.3W

Vacuum compatible

## Timepix 3 USB 3 Advacam

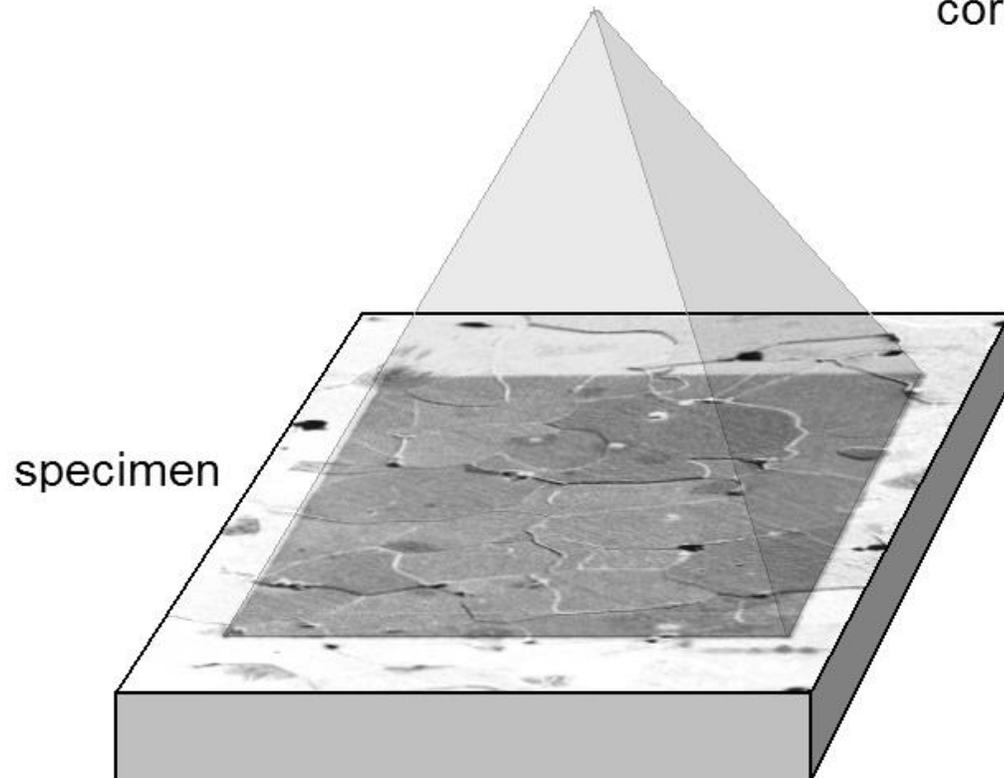
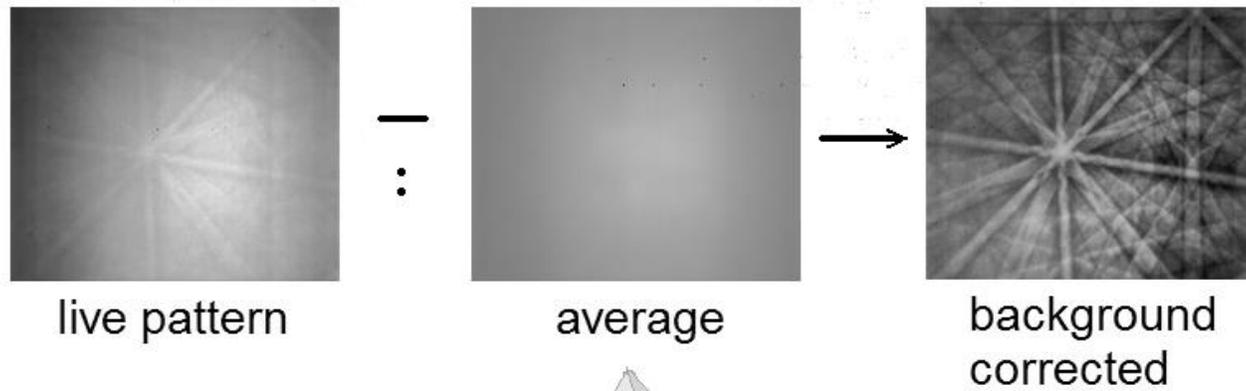
Resolution	Speed
256 x 256	40M hits/s

Frame readout time 33ms?

Power 7.5W

Not Vacuum compatible

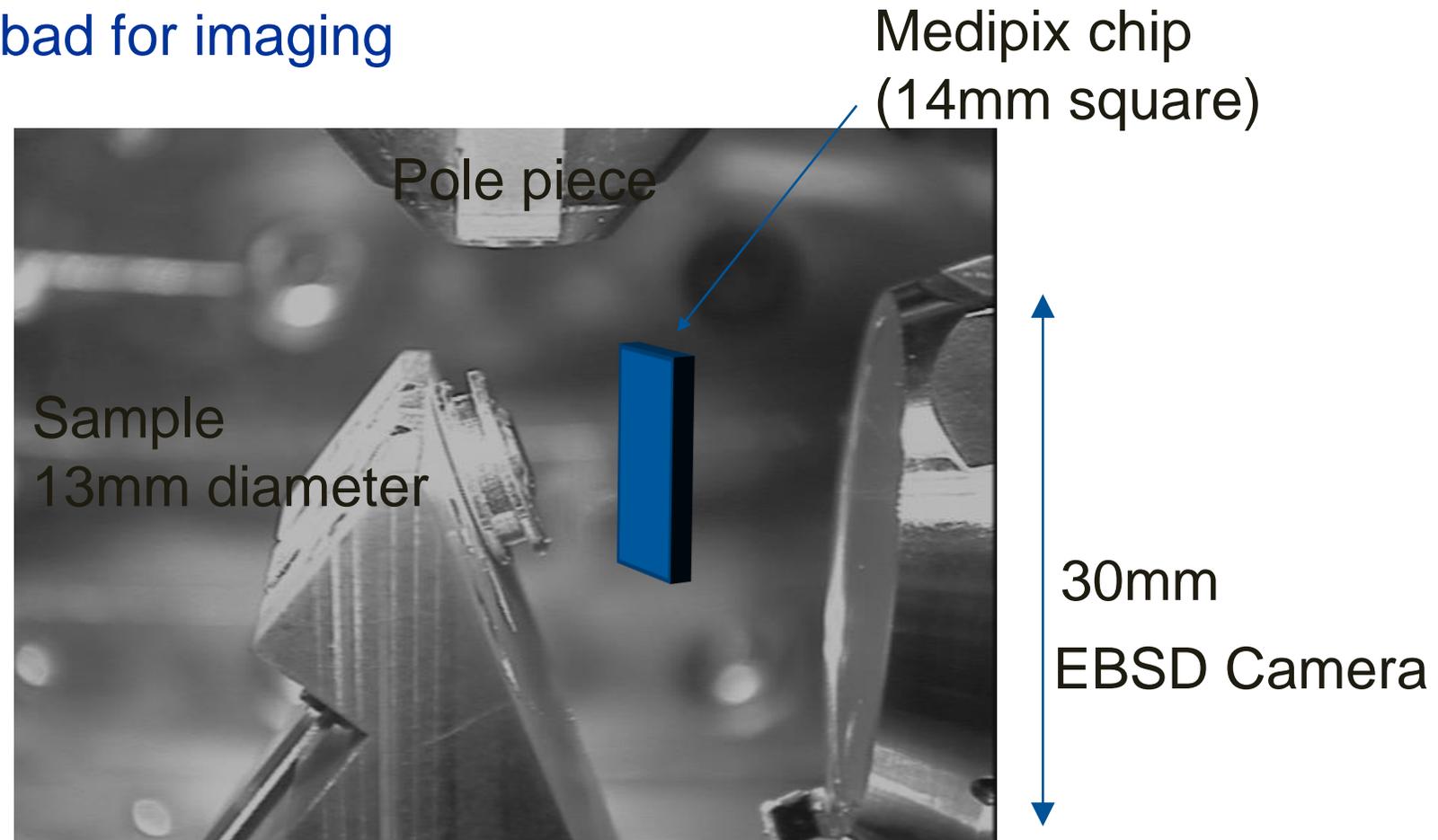
# Direct Detection: Variable Gain?



Large Dynamic range needed on image  
Can variable gain pixels improve this?

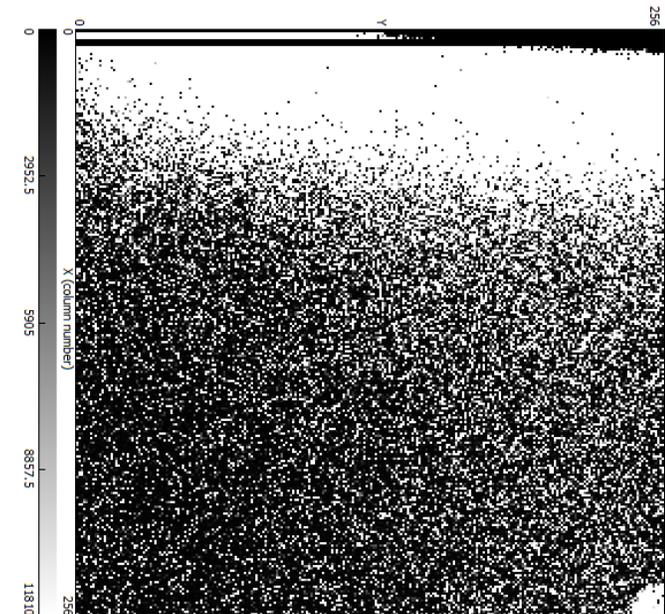
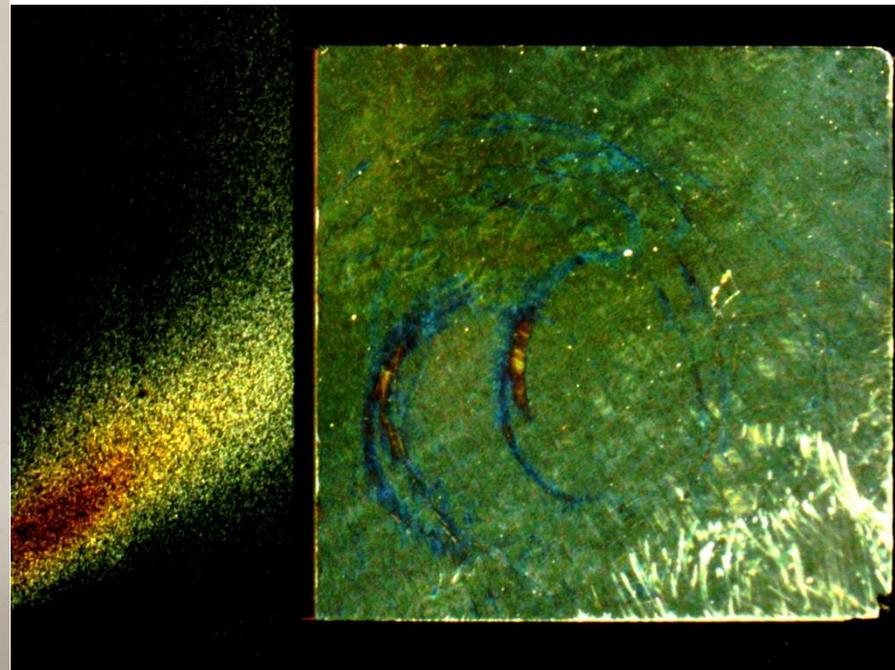
# Direct detector issues: Proximity

- Shadowing
- Bias required for detection bad for imaging
- Mechanical Damage



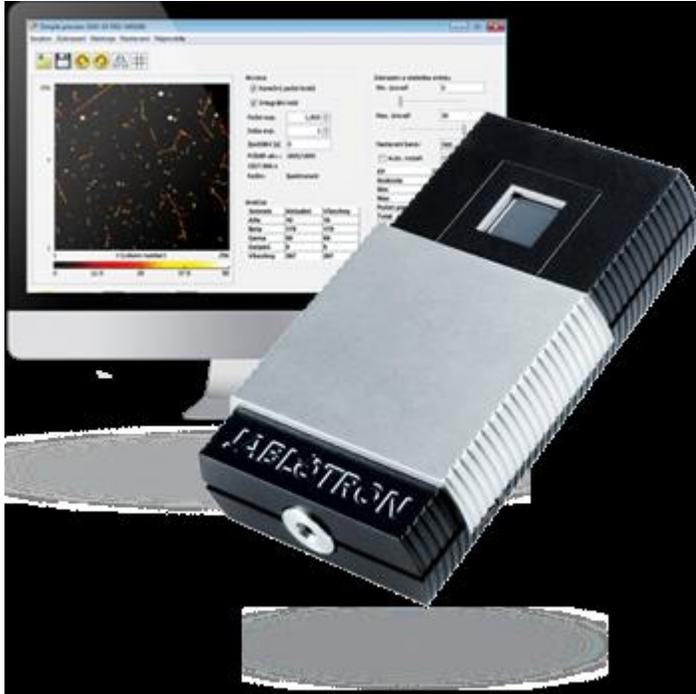
# Direct detector issues: Damage

- Physical damage and issue because of proximity to sample and pole piece
- Worse than for conventional camera because of size
- Direct Detector needs to be closer for same solid angle
- In FIB ion beam damage is also an issue
- Both problems minimised by a shutter.



# Direct detector issues: Vacuum compatibility

- Feedthroughs
- Overheating



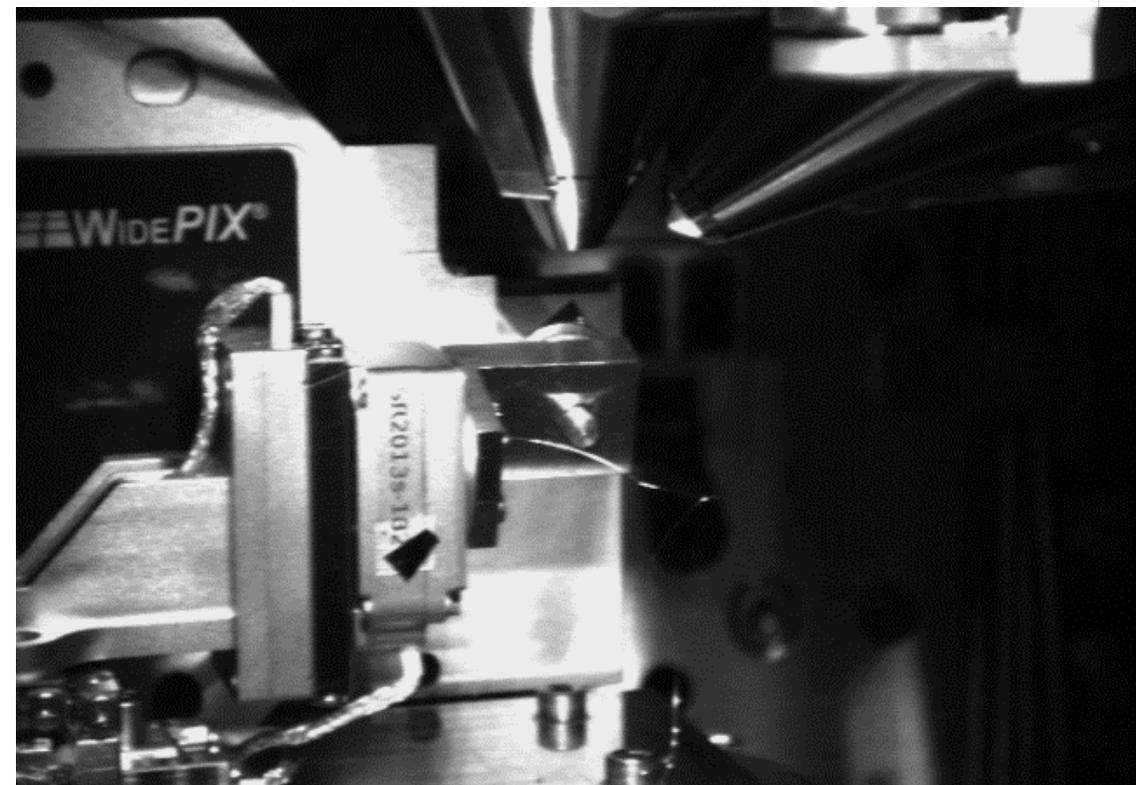
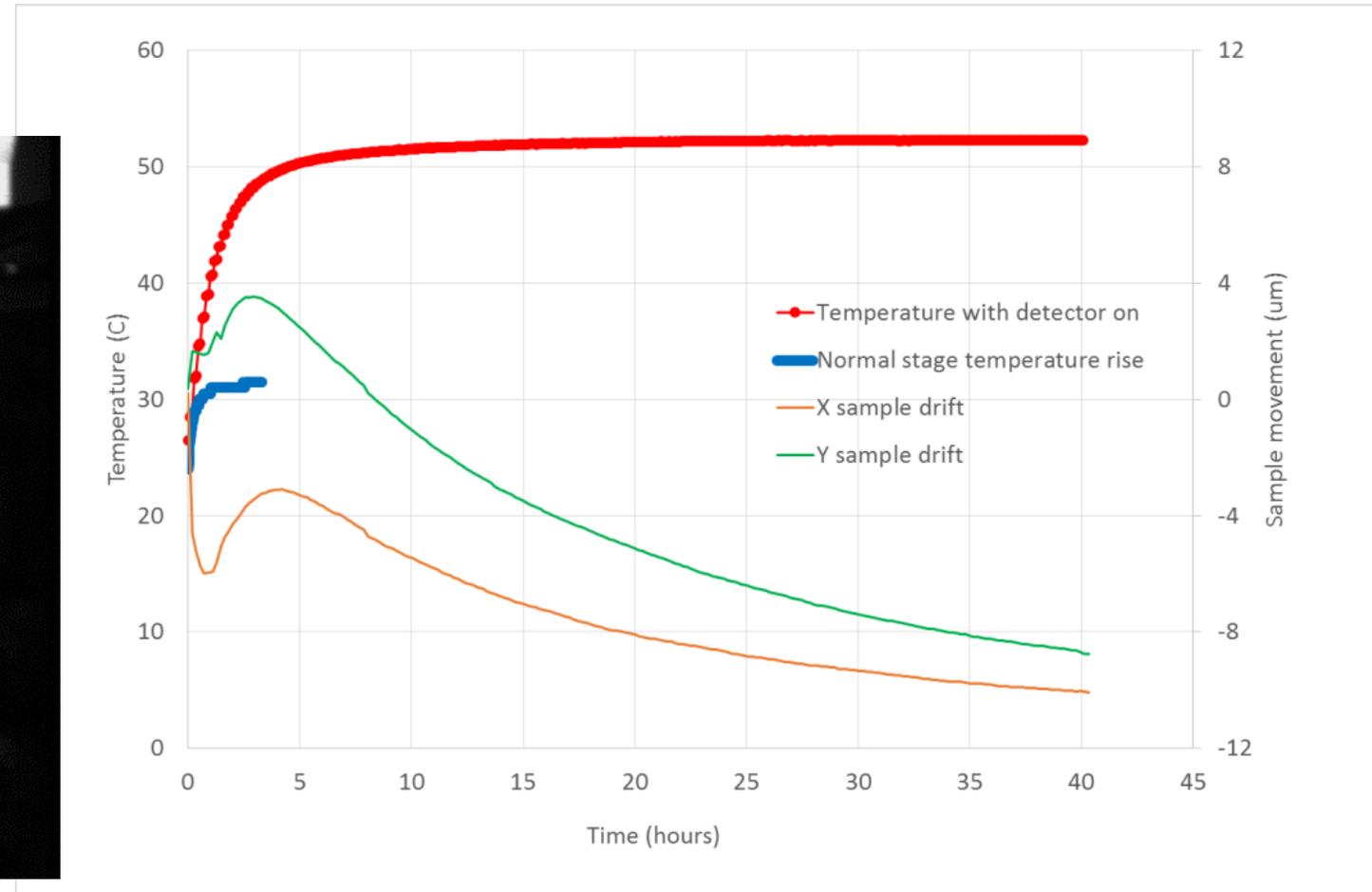
Not designed as Vacuum compatible  
Only lasts 15 minutes before overheating



Difficult finding feedthrough for  $> 180$  lines  
Also long lead lengths unreliable

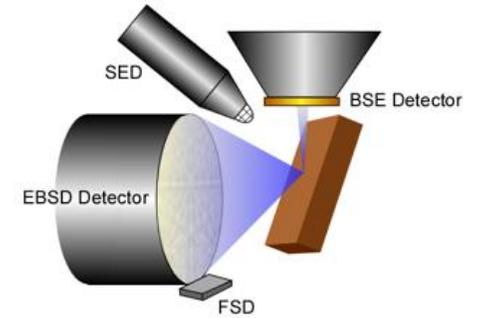
# Direct detector issues: Thermal issues

- Sample stage drift from heating
- Power consumption of Modupix ~2.3W
- Passive cooling



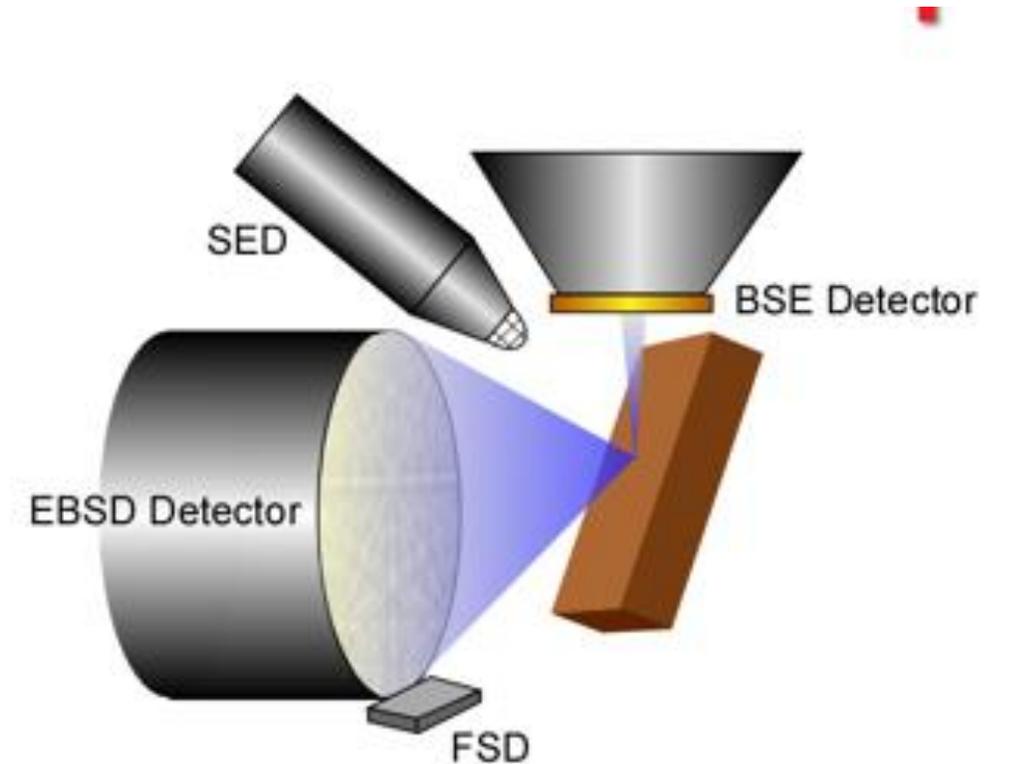
# Direct detector issues: Geometry

- Detector needs to go close and under the pole piece



# Wishlist

- Small form factor
- Calibration
- Higher Speed - Binning
- Energy filtering
- Higher pixel count
- Variable gain
- Don't need ps or even ns response time?
- SEM only 30kV electron beam
- Low heat output



# Thank you for listening



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