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On-axis 3D Microscope for X-ray Beamlines at NSLS-II

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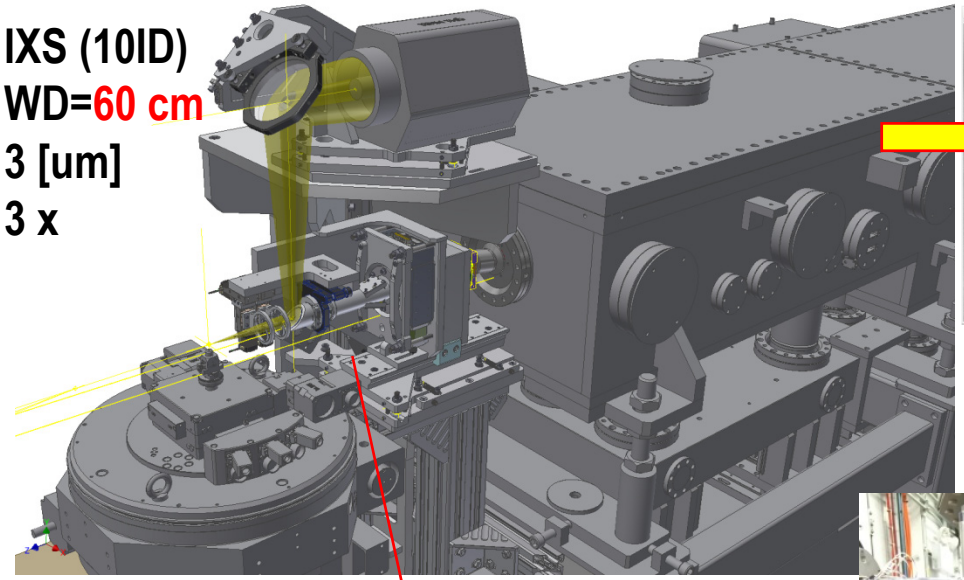
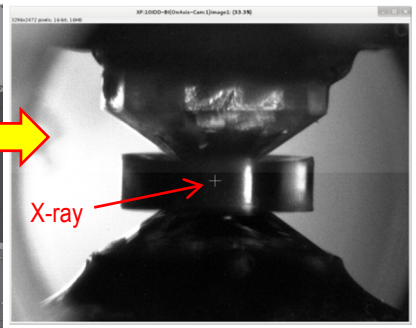
Outline

- Overview –NSLS2
  - Beamlines (19 operational + 9 under constr.)
  - Endstations
  - Beam size(s) @ sample 1 [um], 4 [um], 4x6[um]
  - Sample/features: 1 [um]
- On-axis microscope(s): Non-dispersive (mirror) optics
- Computer Vision
  - Goniostat centering (17-ID, 19-ID)
  - X-ray beam detection, stability studies
  - Real time image processing
  - Focus stacking
  - 3D microscope
- Credits

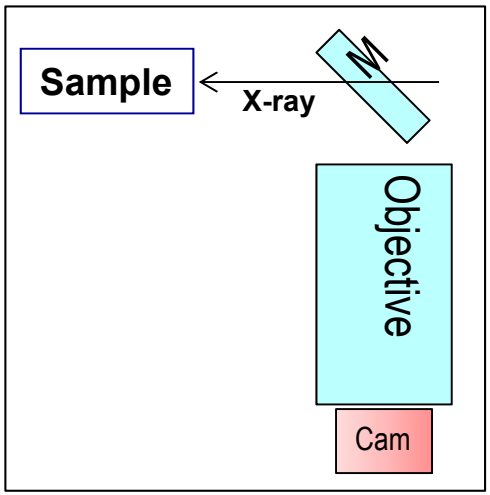
On-axis beamline microscopes

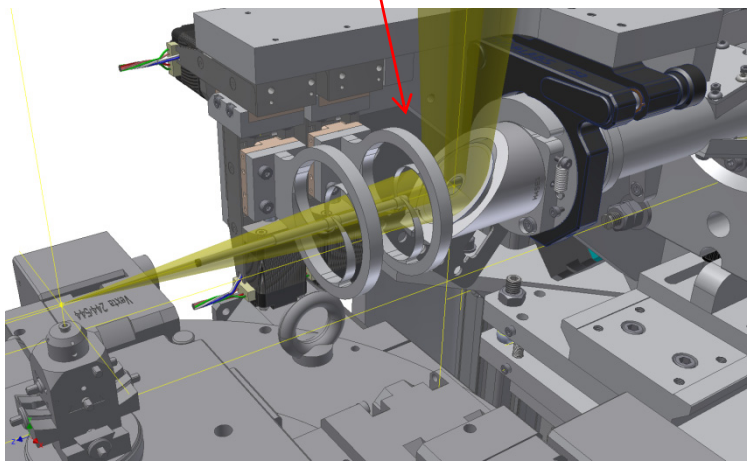
IXS (10ID)
WD=60 cm
3 [um]
3 x

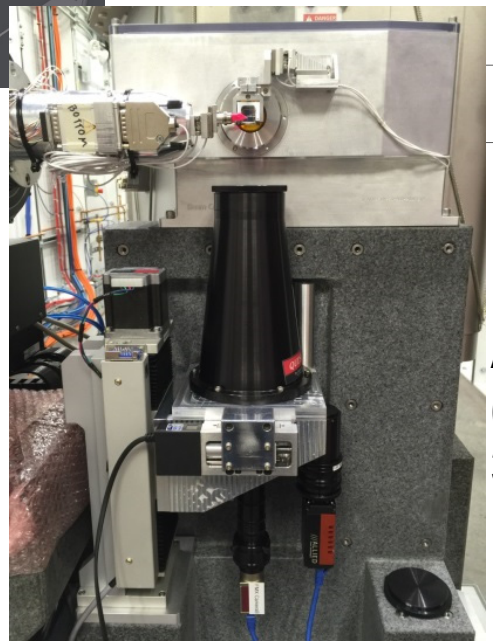




Diamond cell (IXS)

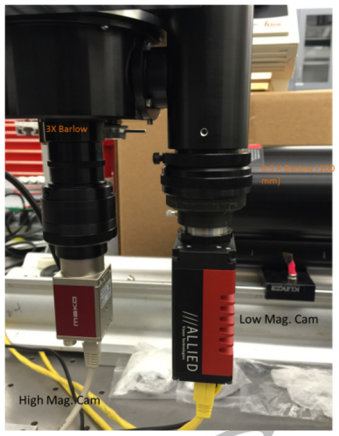




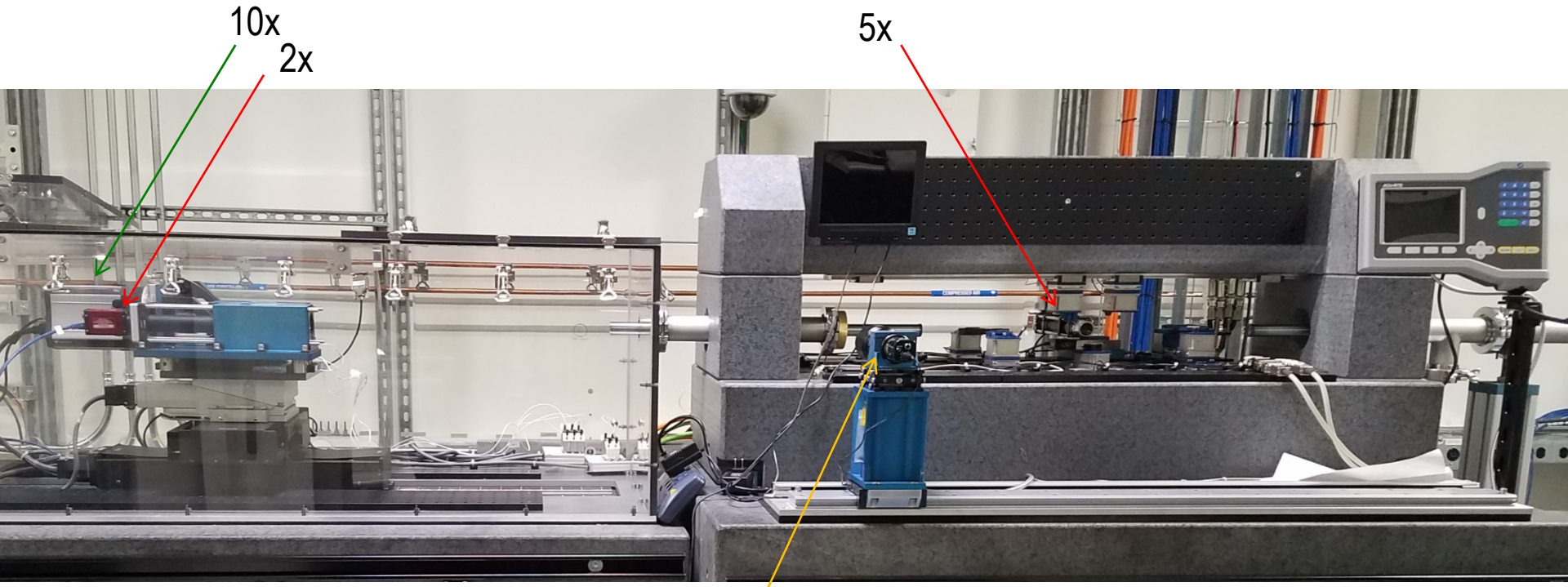


K.J. Gofron, et. al., NIMA, Vol. 649, Issue 1, 1 September 2011, Pages 109-111.

AMX/FMX
(17ID)
30x,5x
1 [um]



Endstation microscopes (TXM)

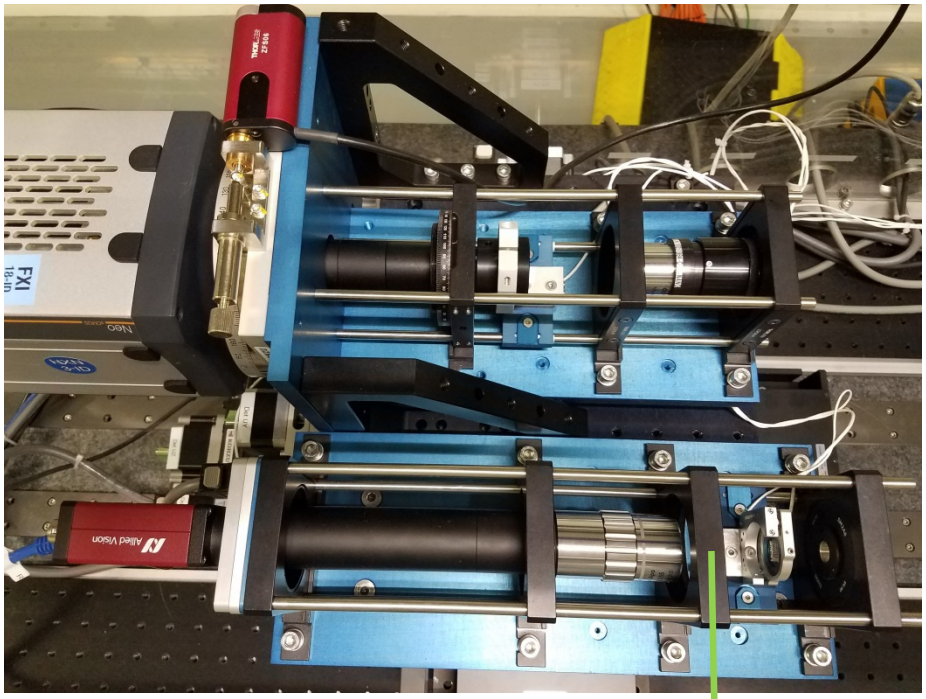


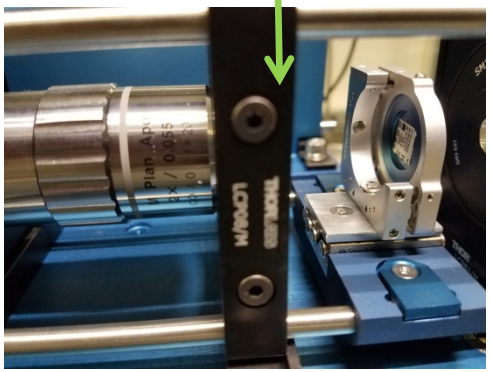
2 X-ray detecting microscopes

2 optical alignment microscopes

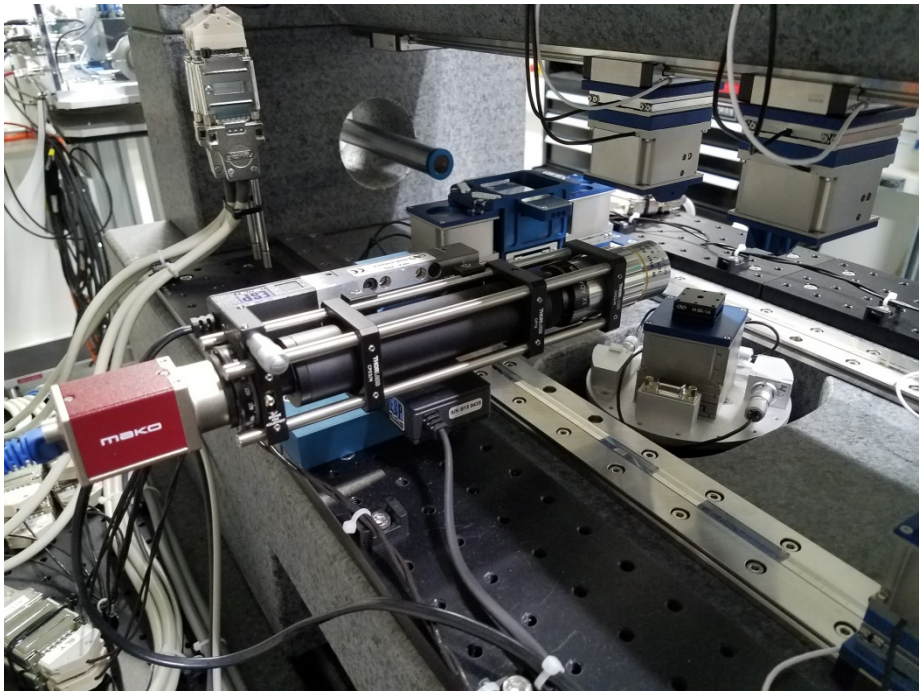
All are home assembled microscopes

Endstation microscopes (FXI)



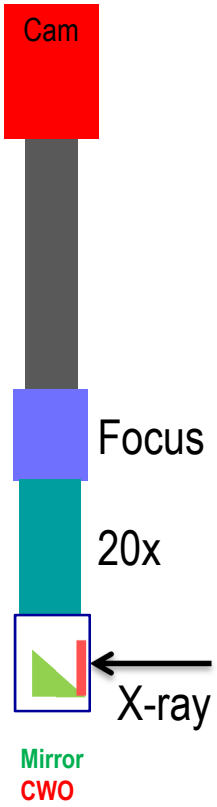


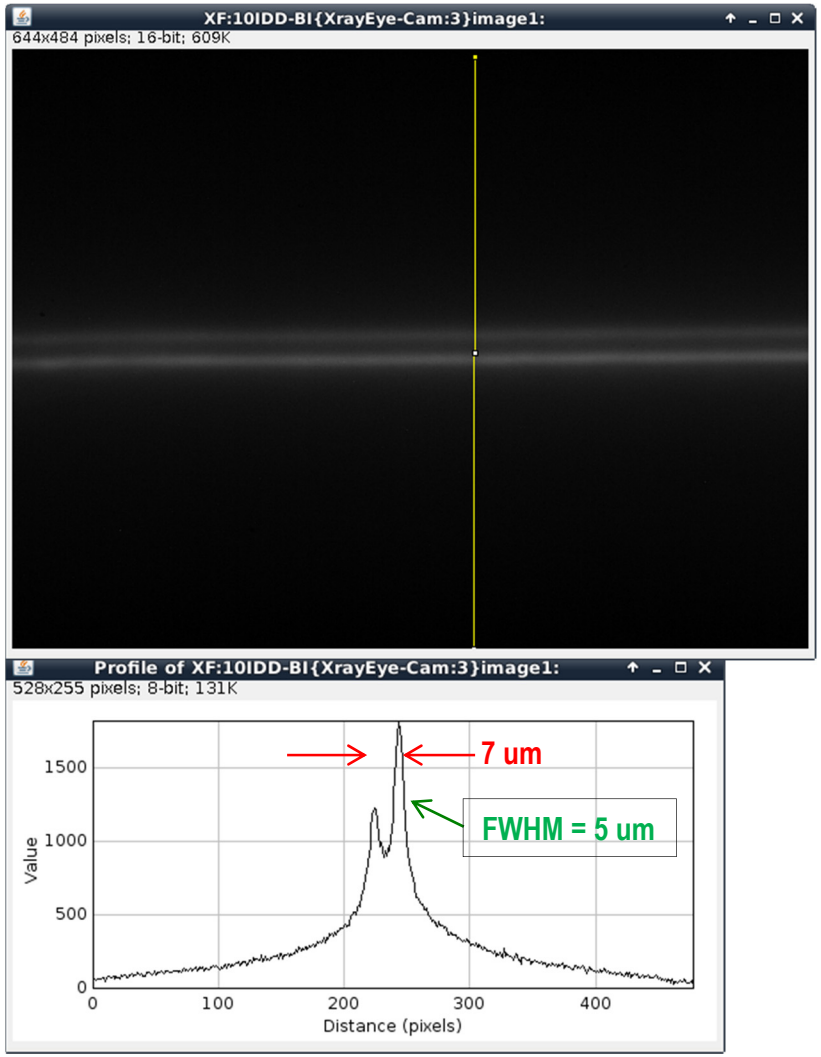
X-ray imaging , TXM



Sample imaging

X-ray eye: 10ID (KB mirror - VFM)





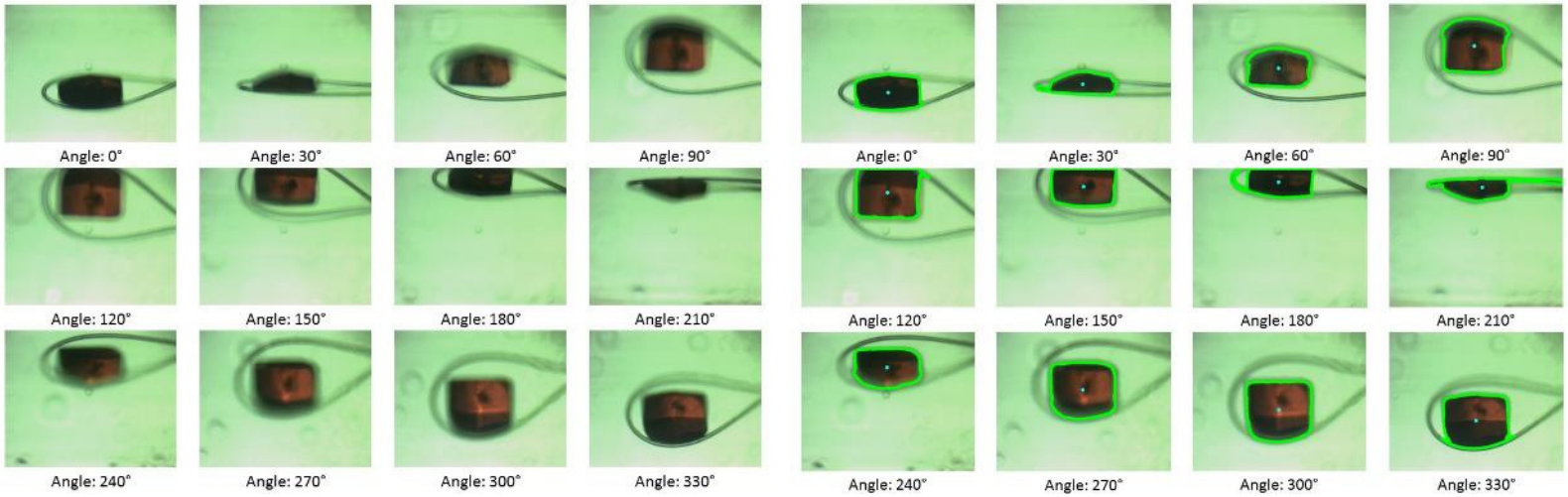
KB mirror (VFM)

Computer Vision

Computer Vision for beamline with openCV:

- Development of image analysis software backed by OpenCV
- Development of easy use python module to access OpenCV functions
- Optimized results for fast computation via C/C++ backed code, along with Intel IPP/TBB libraries.
- GPU role.
- Camera -> areaDetector { | IP based} -> Comp. Vision -> Results {sorted size, intensity, position, pattern,…} -> EPICS PV { | file | control software | …}
- Automate processes such as:
    - Positon, spread, and intensity of X-Ray Beams
    - Isolate crystals and X-Ray streaks
    - Provide assistance to sample mounting
    - Calibrate Goniostat Rotation and Robotic Vision
- 3D microscope

Computer Vision – loop center (5s)



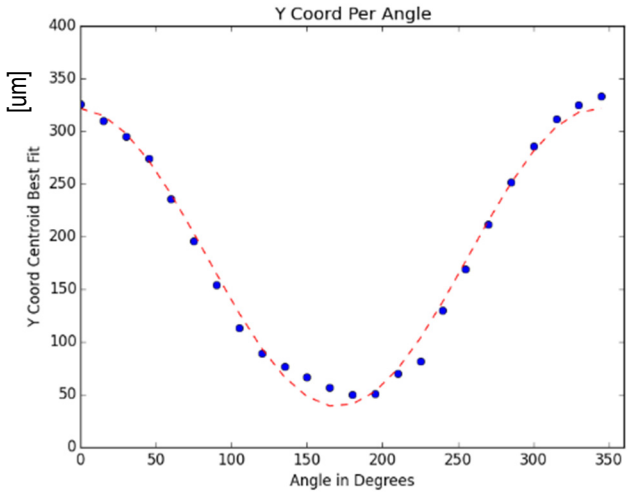


Figure 10:
Top: Input and Tracking Results
Left: Graph Produced, along with fitted sinusoidal curve

Equation:

$$141.58 \times \sin(angle + 1.61) + 180.19$$

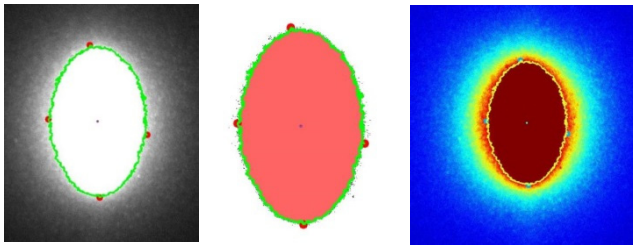
Adjustment:

$$x = -\frac{MC}{PEL} \times Amplitude \times \sin(phase)$$

$$y = -\frac{MC}{PEL} \times Amplitude \times \cos(phase)$$

Computer Vision

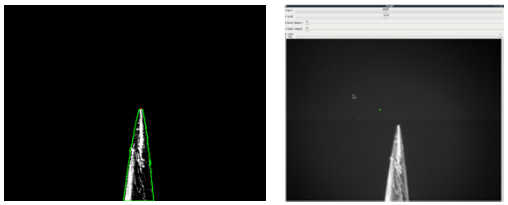
IXS – BPM1



Console Output:

```
Object Details:
perimeter: 2356.99022925
orientation: 179.838363647
max: (925, 198)
height: 372
extrema: {'B': (938, 568),
          'R': (1054, 415),
          'L': (813, 377),
          'T': (914, 196)}
```

```
area: 65058.5
min: (1047, 564)
sum intensity: 20426526
width: 241
centroid: (933, 382)
mean intensity: 227.842390577
```

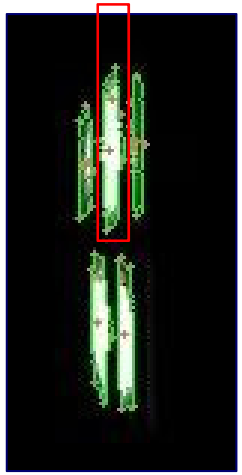


IXS Point & Click: Left: Image Result with Contour and Top Extrema
Right: Point & Click GUI Interface (X, Y, MC Scale Bars, Green Cursor)
Console Output: `PIN TOP: (1723, 1306)`

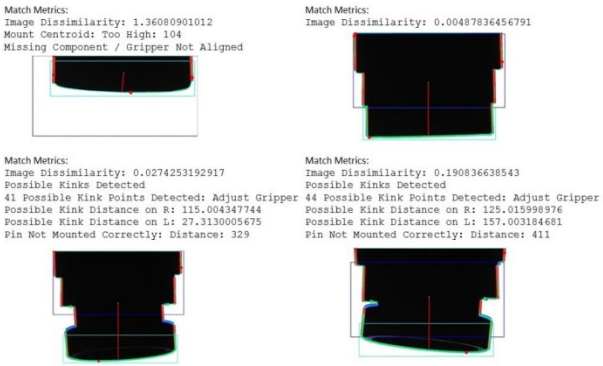
IXS: Merlin Data Results for First (Largest) Object

Console Output:

```
Object 1:
perimeter: 125.840619564
orientation: 179.981033325
max: (131, 78)
height: 55
extrema: {'B': (129, 122), 'R': (135, 98),
          'L': (126, 92), 'T': (132, 67)}
area: 270.5
min: (134, 83)
sum intensity: 62689
width: 9
centroid: (130, 95)
mean intensity: 126.644444444
```

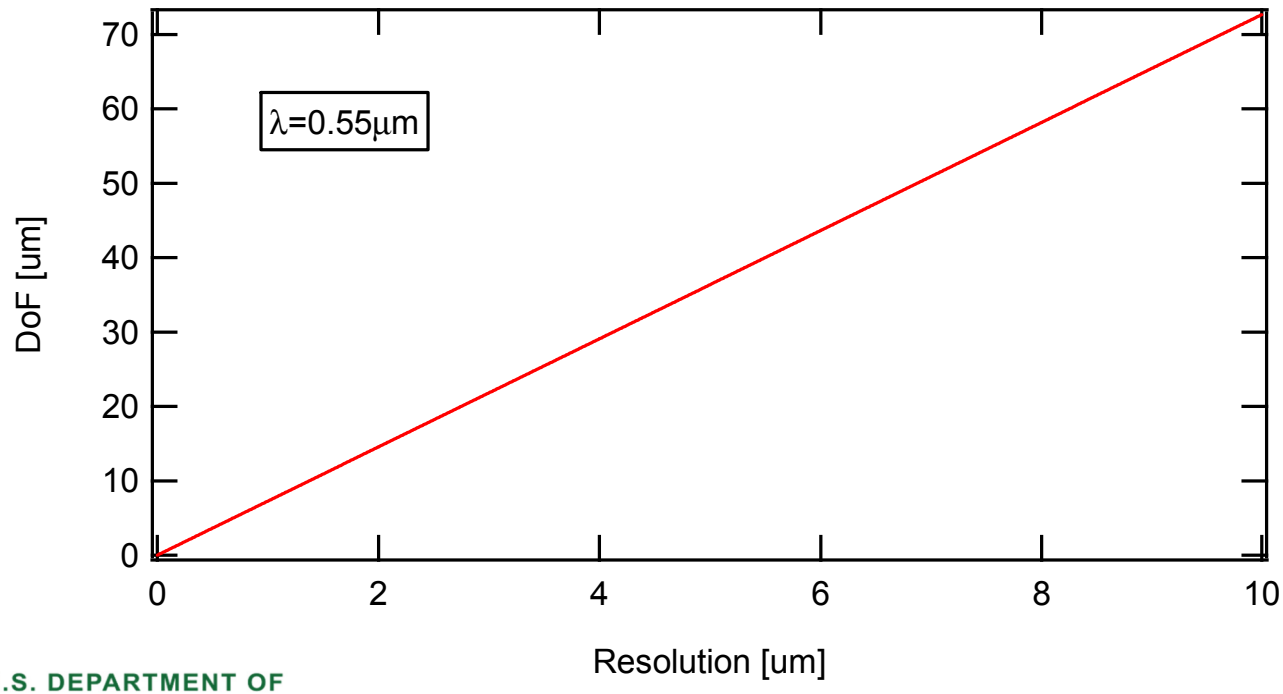


AMX: Robot gripper – sample detection



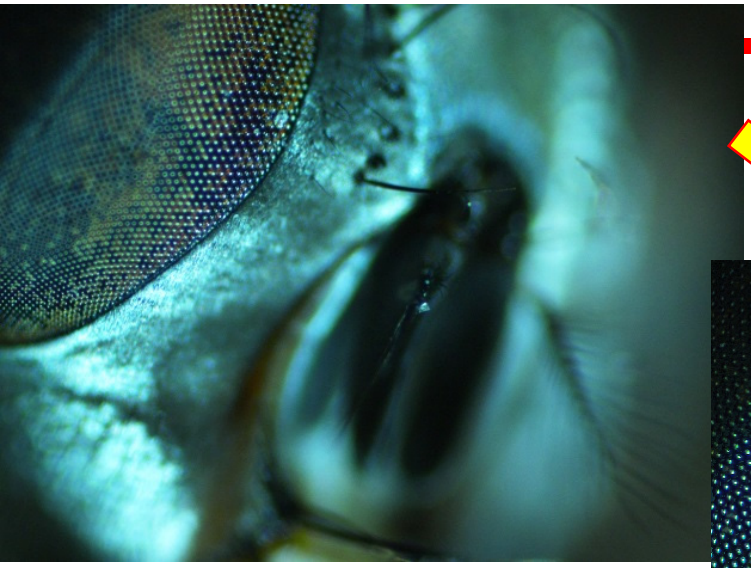
Resolution and Depth of Focus

- Resolution = wavelength / (2*NA)
- Depth of field = wavelength*n/(NA)^2; n=1 for air
- Depth of field = 4*Resolution/wavelength

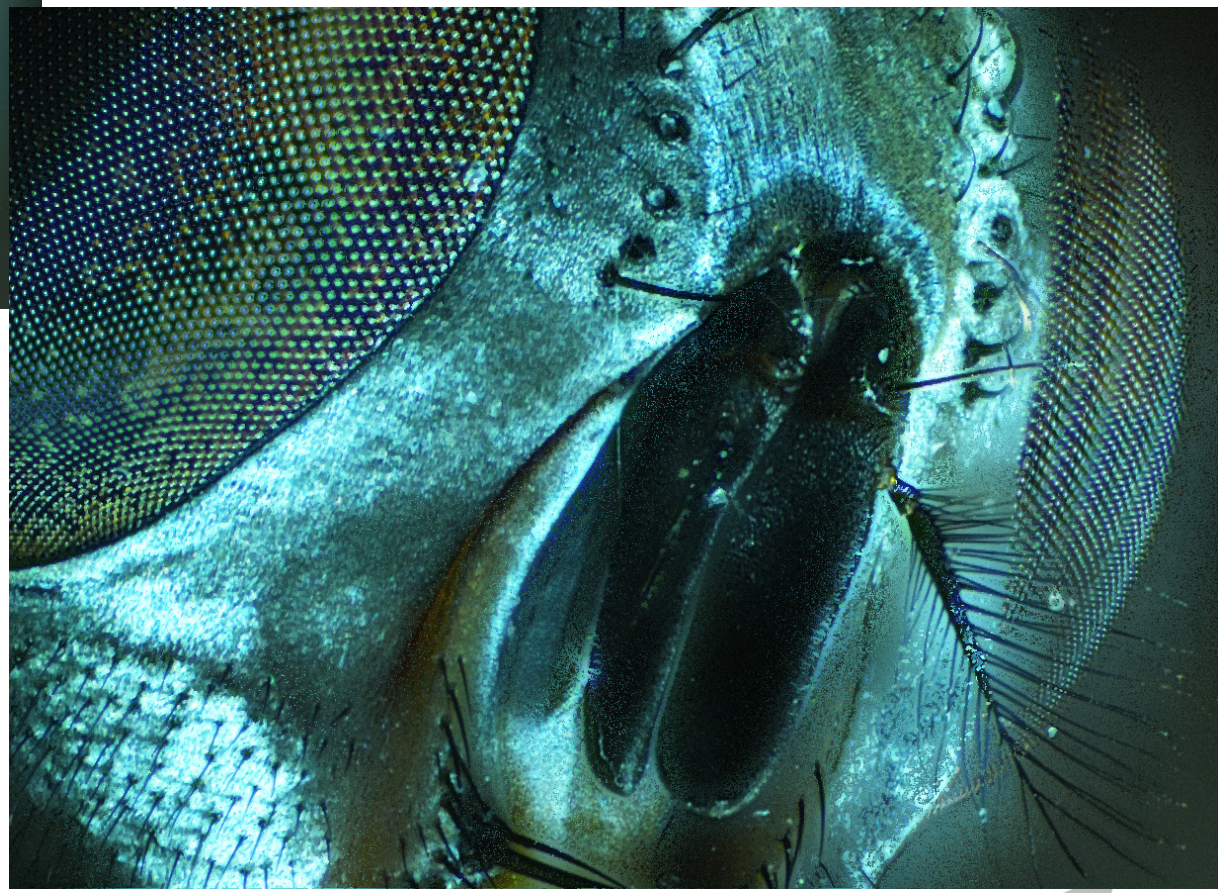


Shallow DoF is a Weakness

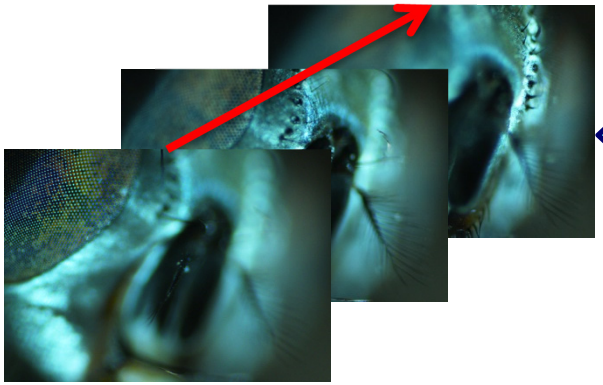
Focus – Horse Fly



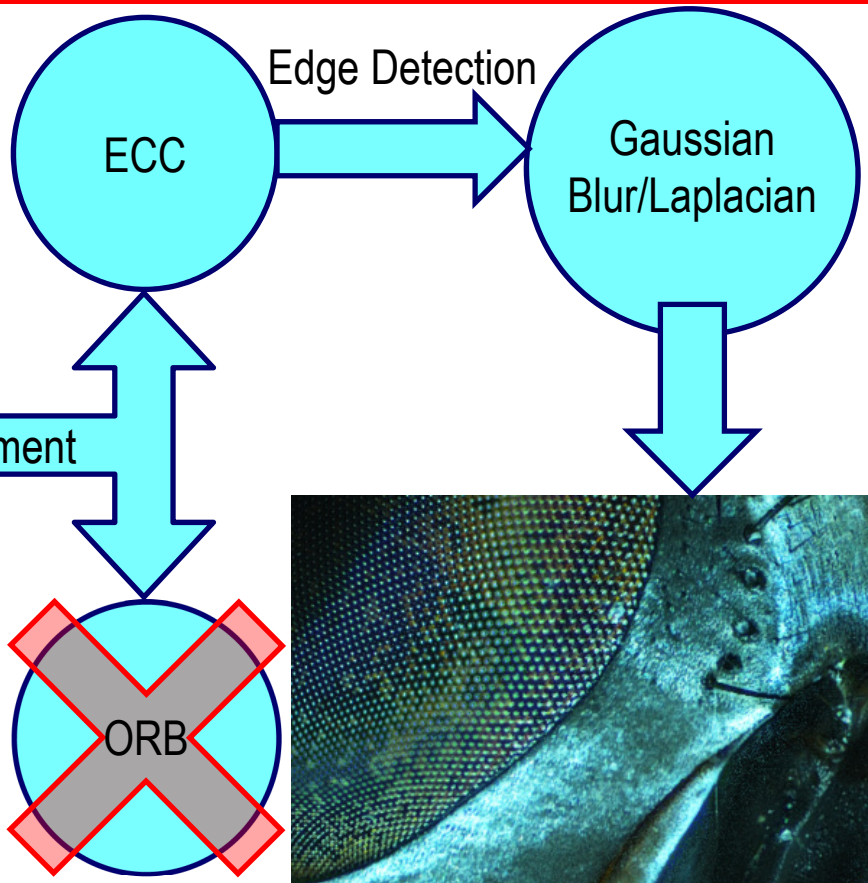
?

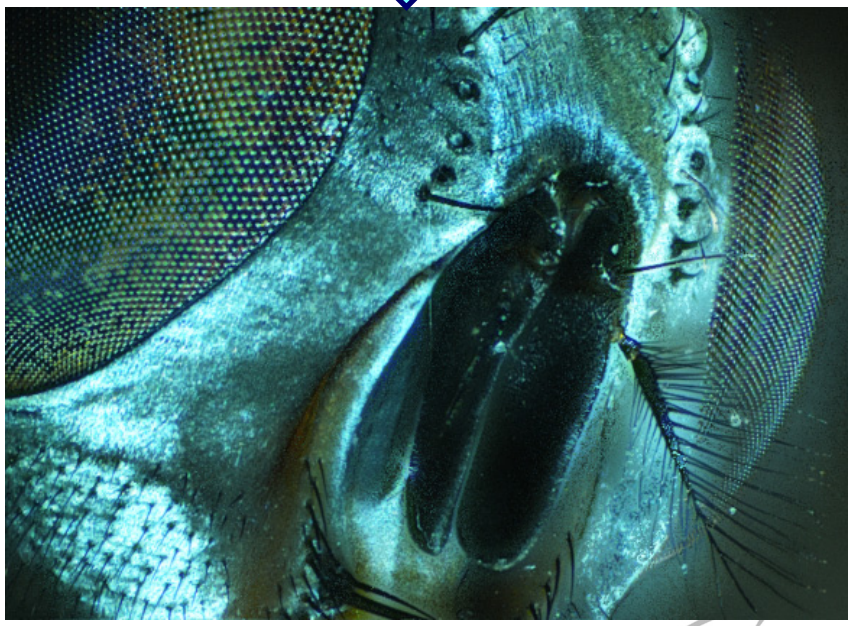


Focus Stacking – Horse Fly (5x)

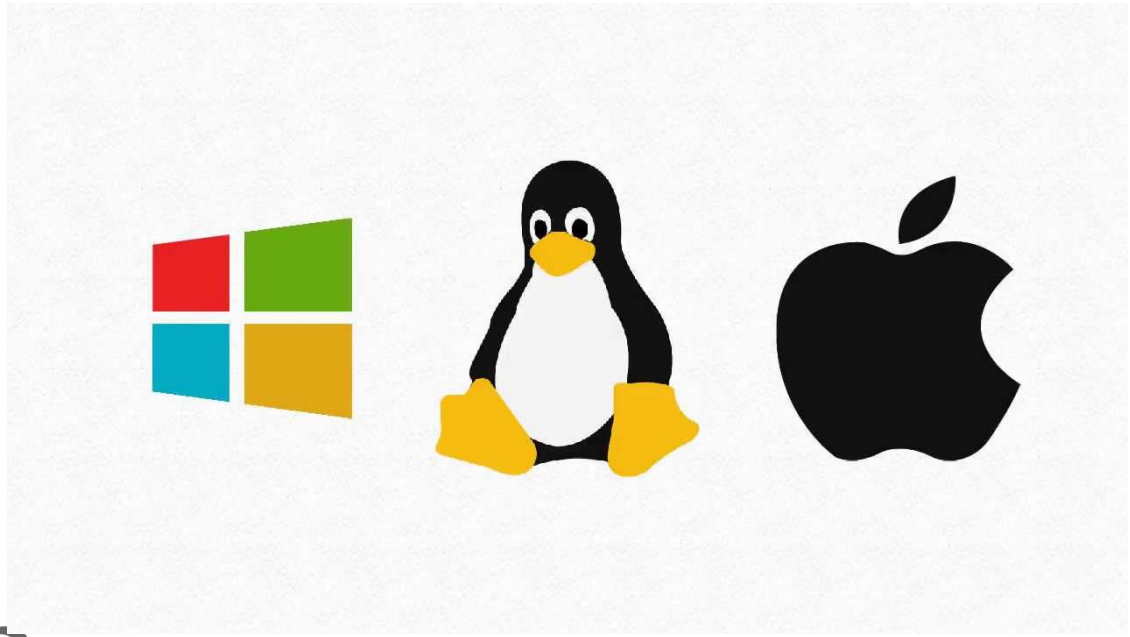


Original 38 Image Stack



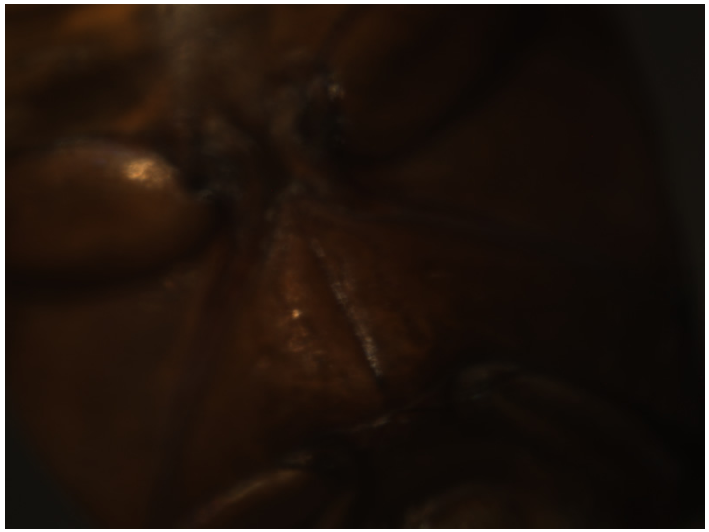


The code



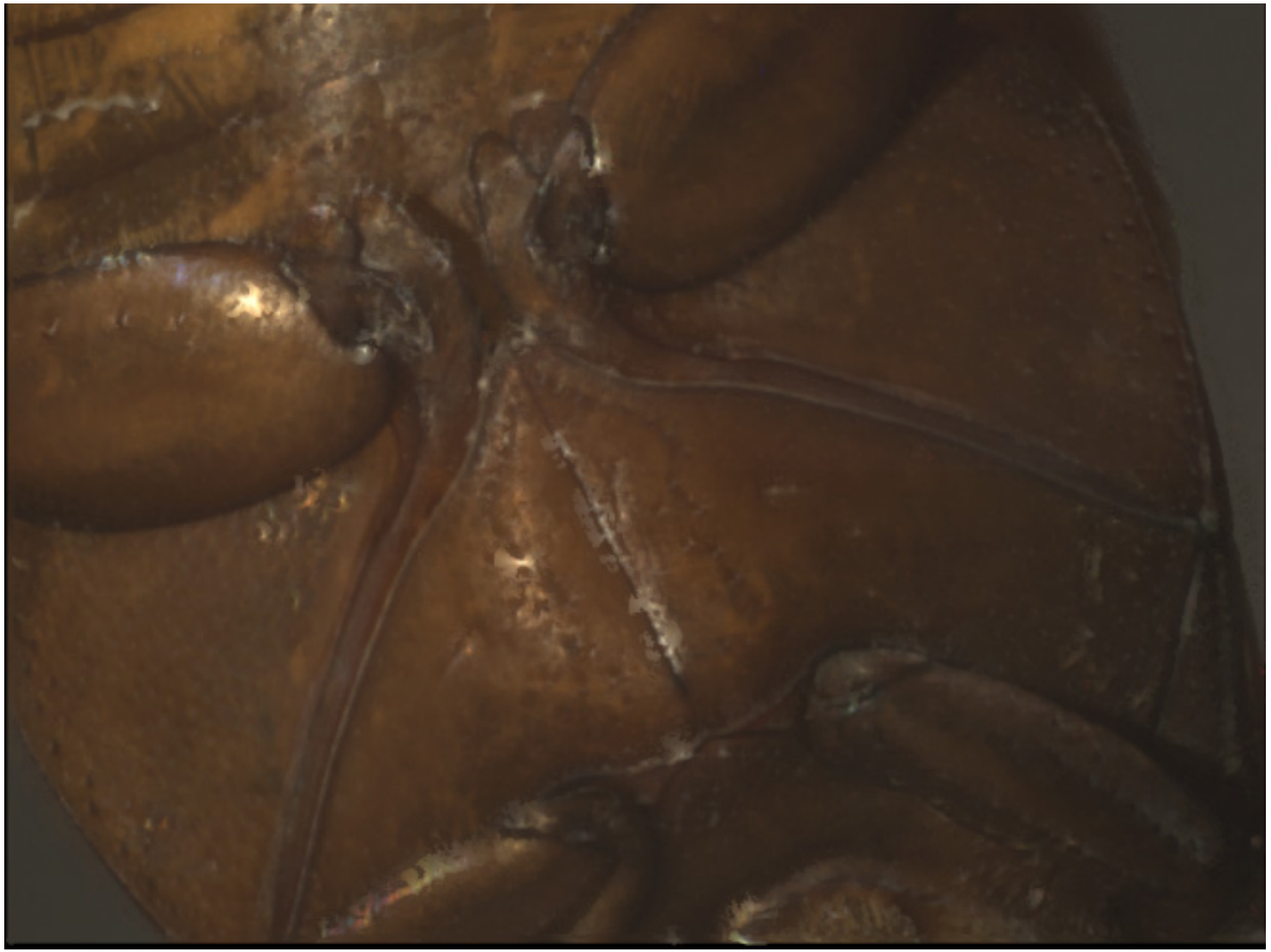
Real Time

Beettle (10ID, 3x/3um)



Two examples out of a stack of 19 images. First we performed focus stacking and gamma correction. Images were taken at the IXS 10ID beamline.
https://www.youtube.com/channel/UC-SfBpwDIiuw41_r0qqYkZQ?view_as=subscriber

The Beetle – merged/gamma corrected (3x)



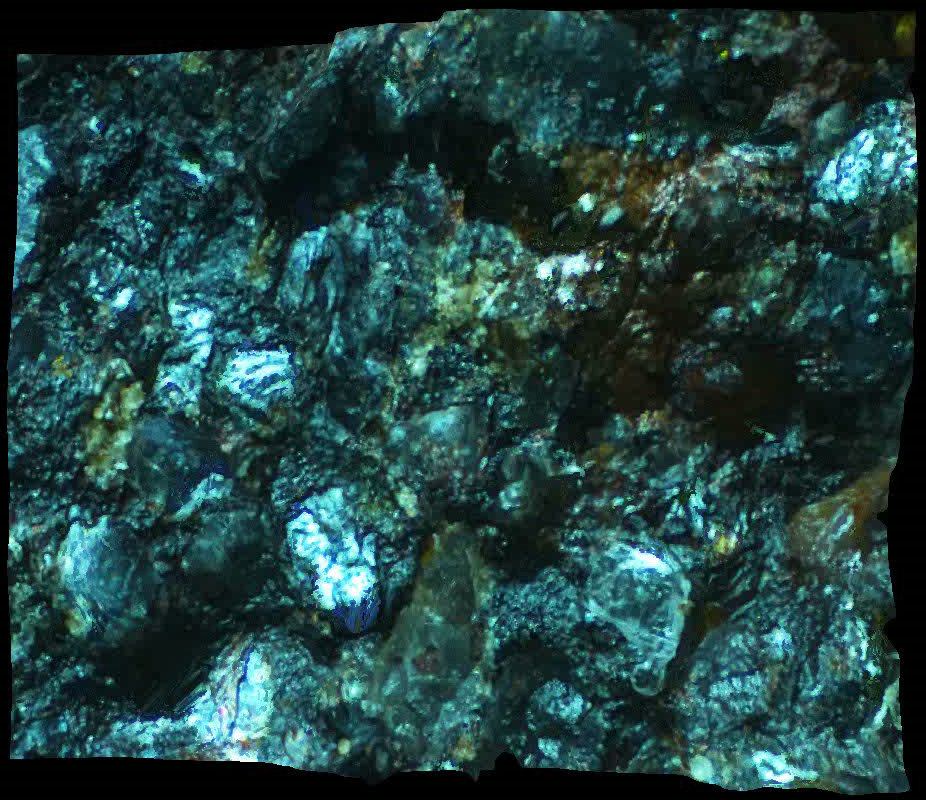
10ID

The Beetle – depth map

The Beetle: focus=3rd dimension

https://www.youtube.com/watch?v=UFx2EDouO-k

Mineral



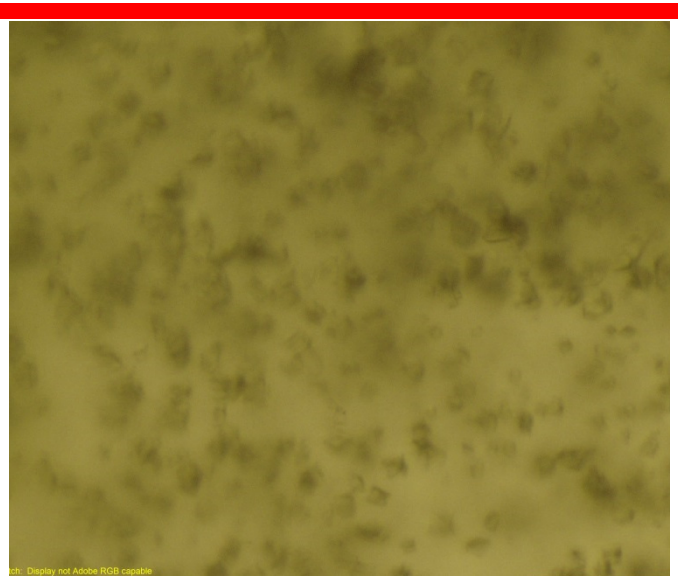
https://www.youtube.com/watch?v=FdpdAdoirwA

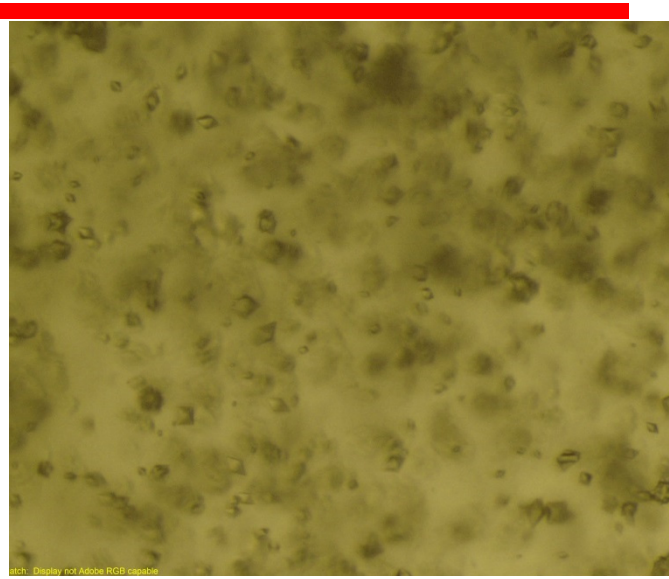
Crystal harvesting – sonic ejection

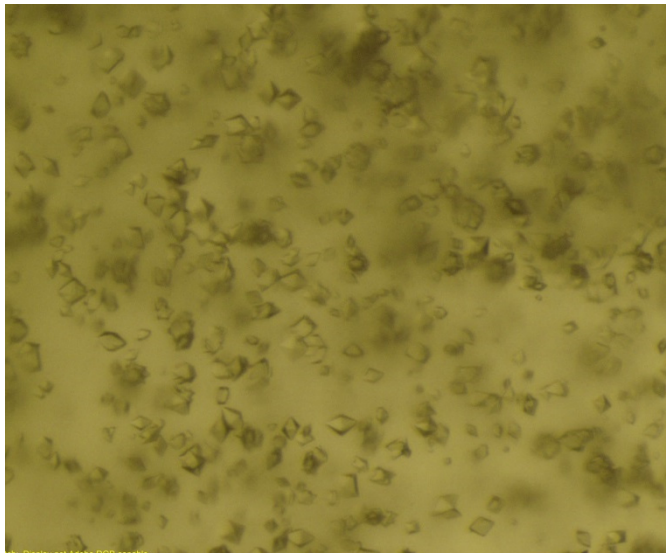
Crystal images are all courtesy of Alexei Soares and the Click to Mount Team. Focus stacks of 15 images.

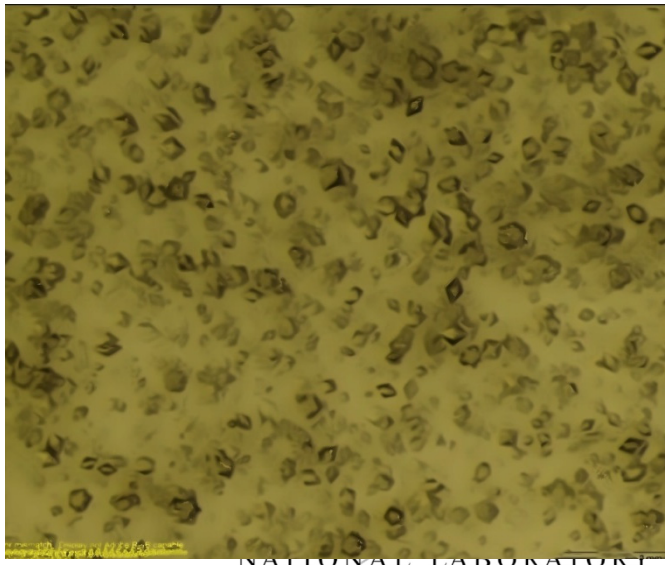
Crystal are sonicly ejected only from top layer, and surface layer moves (with crystals) to “heal” the surface.

Crystals from lower layers are not harvested.

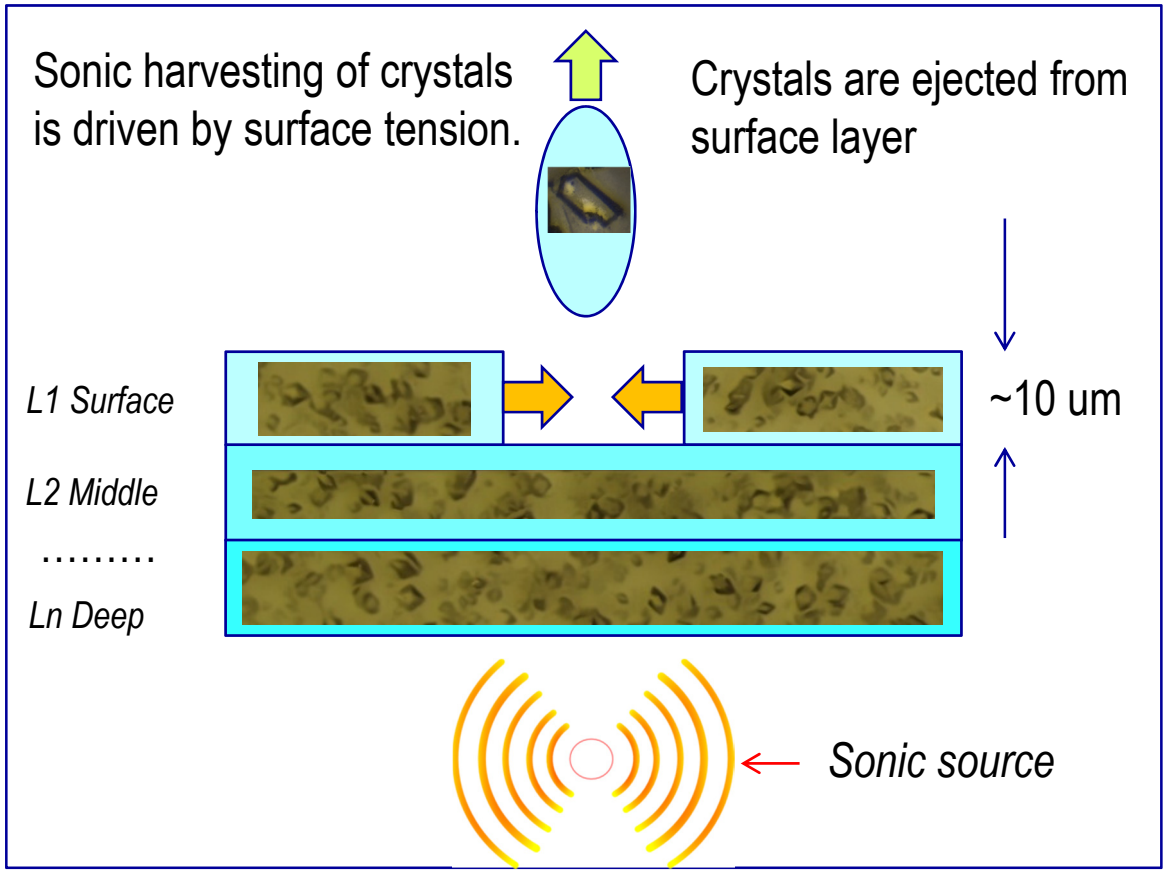








Crystal harvesting



Conclusion 1:
Prevent crystals from settling to the bottom. Thus consider using Bingham fluid solutions. (to be published)

Depth map

SUMMARY: **Converted weakness (shallow DoF) into strength (recovered 3rd depth dimension)**

References

Moeller, Michael, et al. “Variational Depth From Focus Reconstruction.” *IEEE Transactions on Image Processing*, vol. 24, no. 12, 2015, pp. 5369–5378.,doi:10.1109/tip.2015.2479469.

“OpenCV Library.” *OpenCV Library*, opencv.org/.

Group, Khronos. “The Industry's Foundation for High Performance Graphics.” *OpenGL.org*, www.opengl.org/.

Credits

Jakub Wlodek (focus stack)
Yong Cai (10ID)
Bill Watson (comp. vision)
Scott Coburn (mechanical)
Stephen Antonnelli (mechanical)
Bruno Martins
Martin Fuchs (17ID)
Jean Jakoncic (17ID)

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