# Development of Computer Vision and Image Processing Libraries at NSLS-II

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# Purpose

- Development of image analysis software integrated with EPICS control system.
- Computer Vision for synchrotron beamline applications.
- Develop easy to use python modules to access computer vision functions backed by OpenCV.
- Optimized results for fast computation, via C++, Intel IPP/TBB.
- Automate processes from image input such as:
  - Positon, spread, and intensity of X-Ray Beams
  - Isolating and computing data on multiple objects
  - Provide assistance to mounting samples and report any errors

# BPM-1 X-Ray Analysis (IXS)

Purpose:

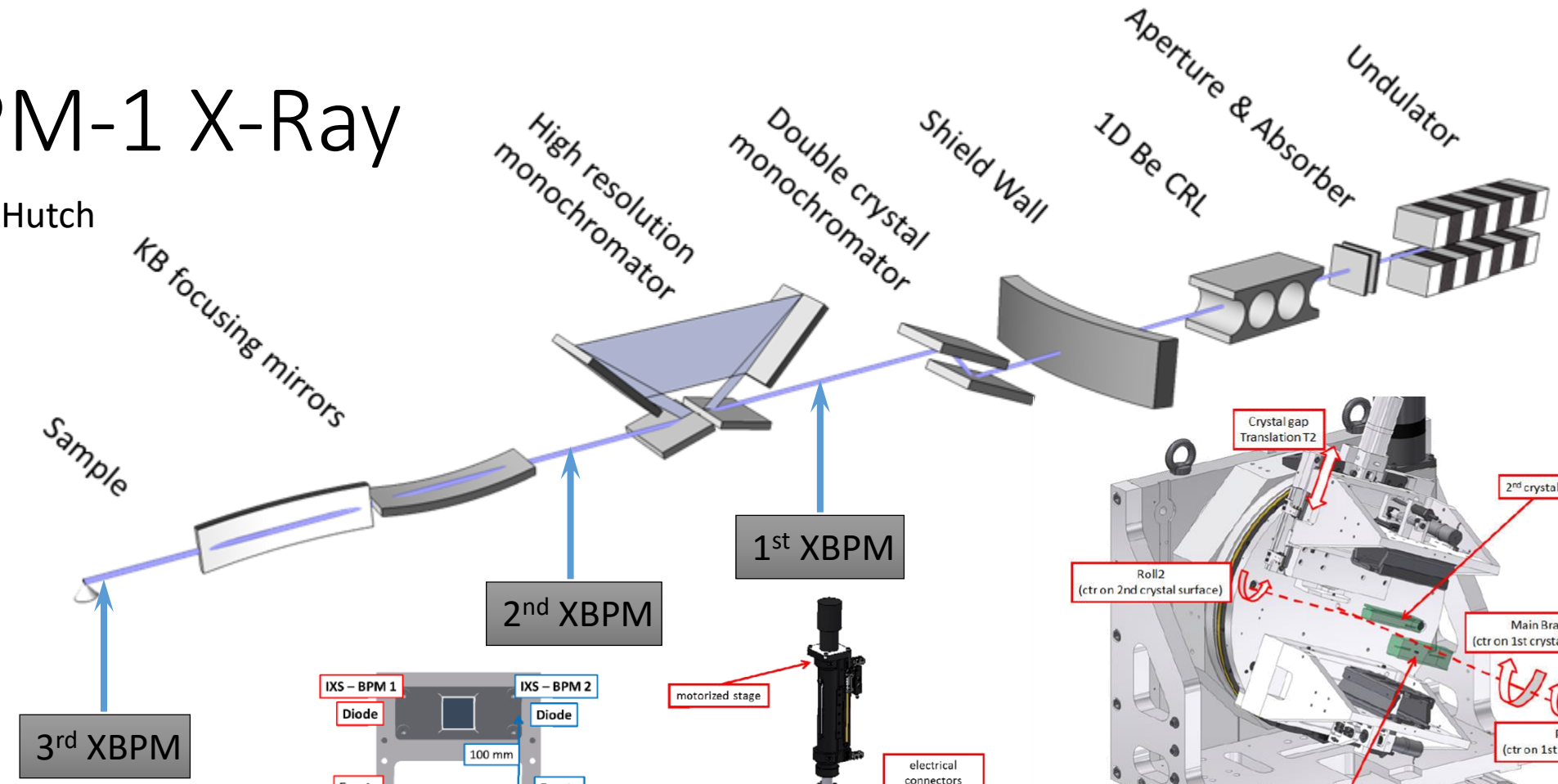
- Discover Position of Beam
- Discover Spread of Beam
- Discover Intensity of Beam
- Discover the Centroid of the Beam

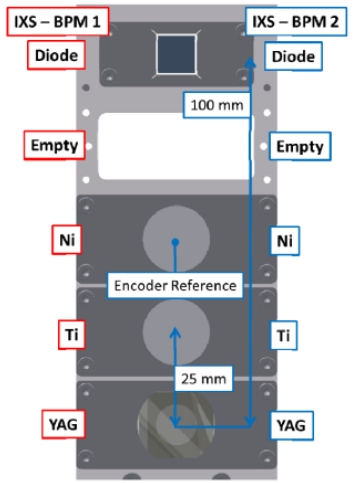
E = 9.1 keV
Scintillator: YAG
Camera: Prosilica
Magnification: 5x

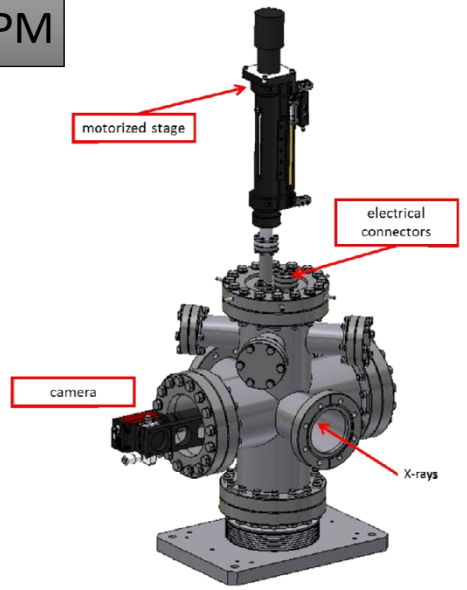
Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

# BPM-1 X-Ray

Located in B Hutch (IXS)





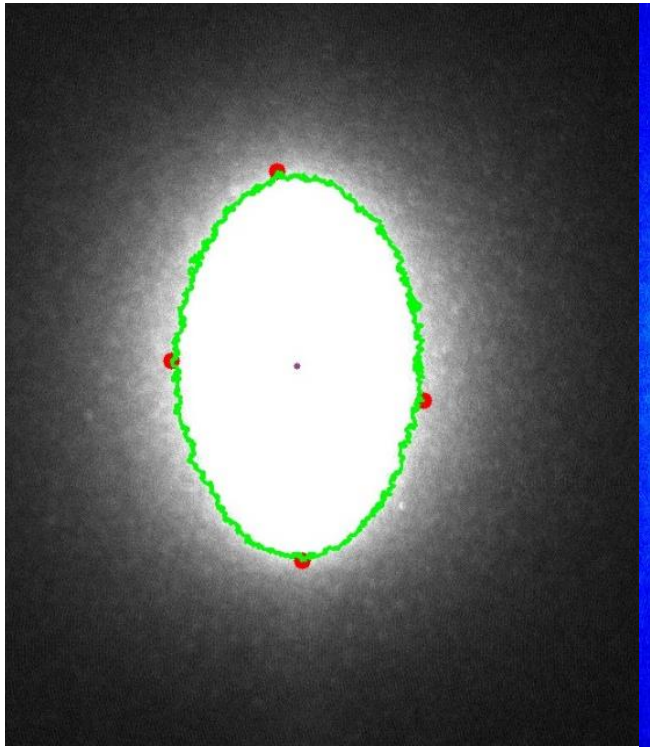


Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

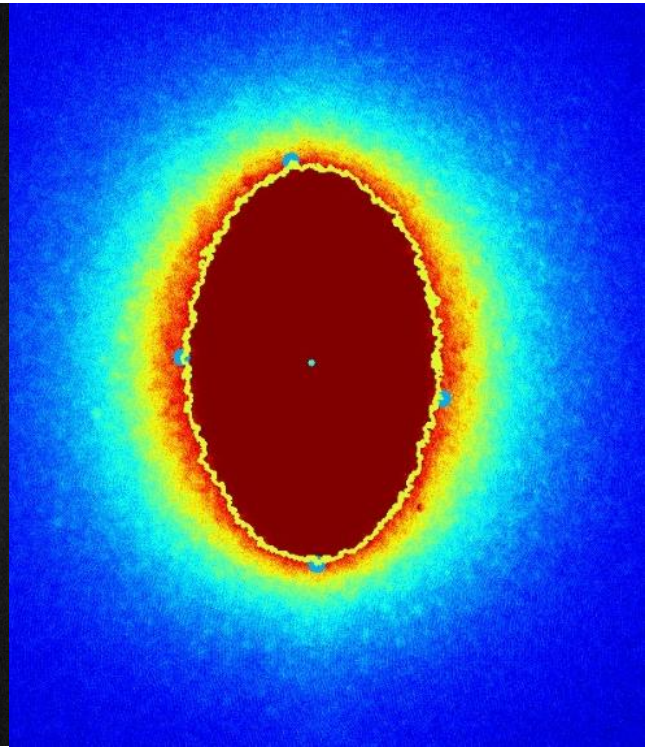
# BPM-1 Data Results

Console Output:

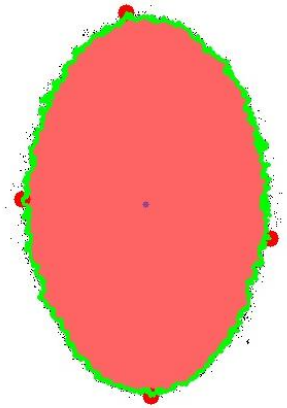
```
Object Details:

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
```



Result Superimposed on Original



Jet Color Map



Thresholding Result

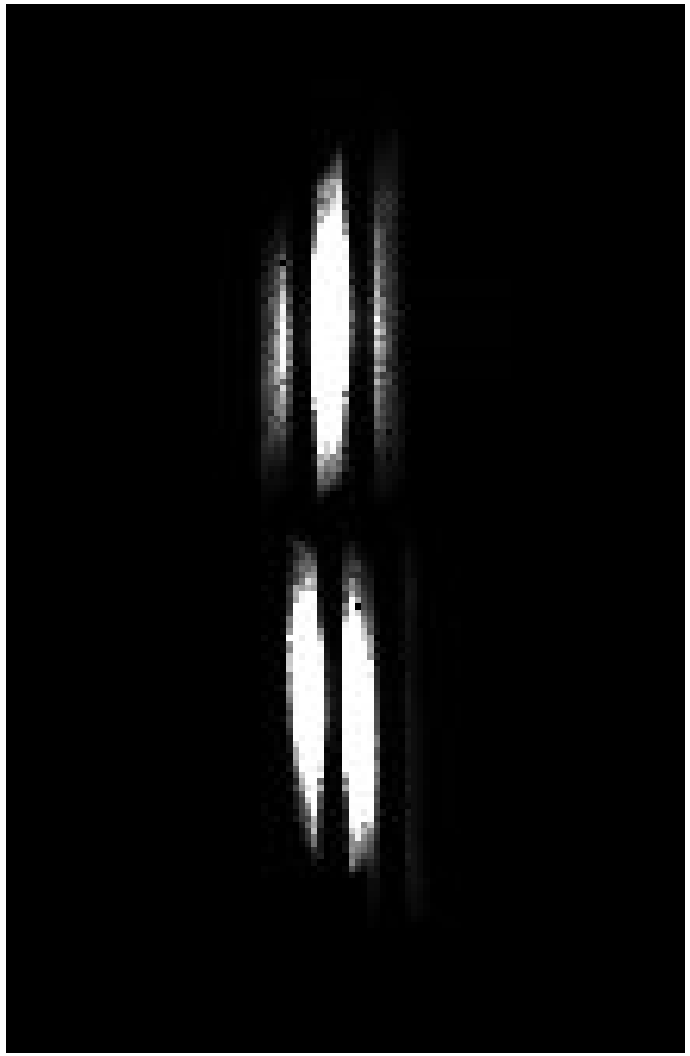
Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

# Analysis -Merlin Quad X-Ray Detector (IXS)

- Data Retrieved from the Merlin Detector at IXS

Purpose:

- Isolate Individual Streaks
- Process each Streak to learn Position, Center, Spread, Intensity, Max Values, etc.
- Count Intensity in each streak



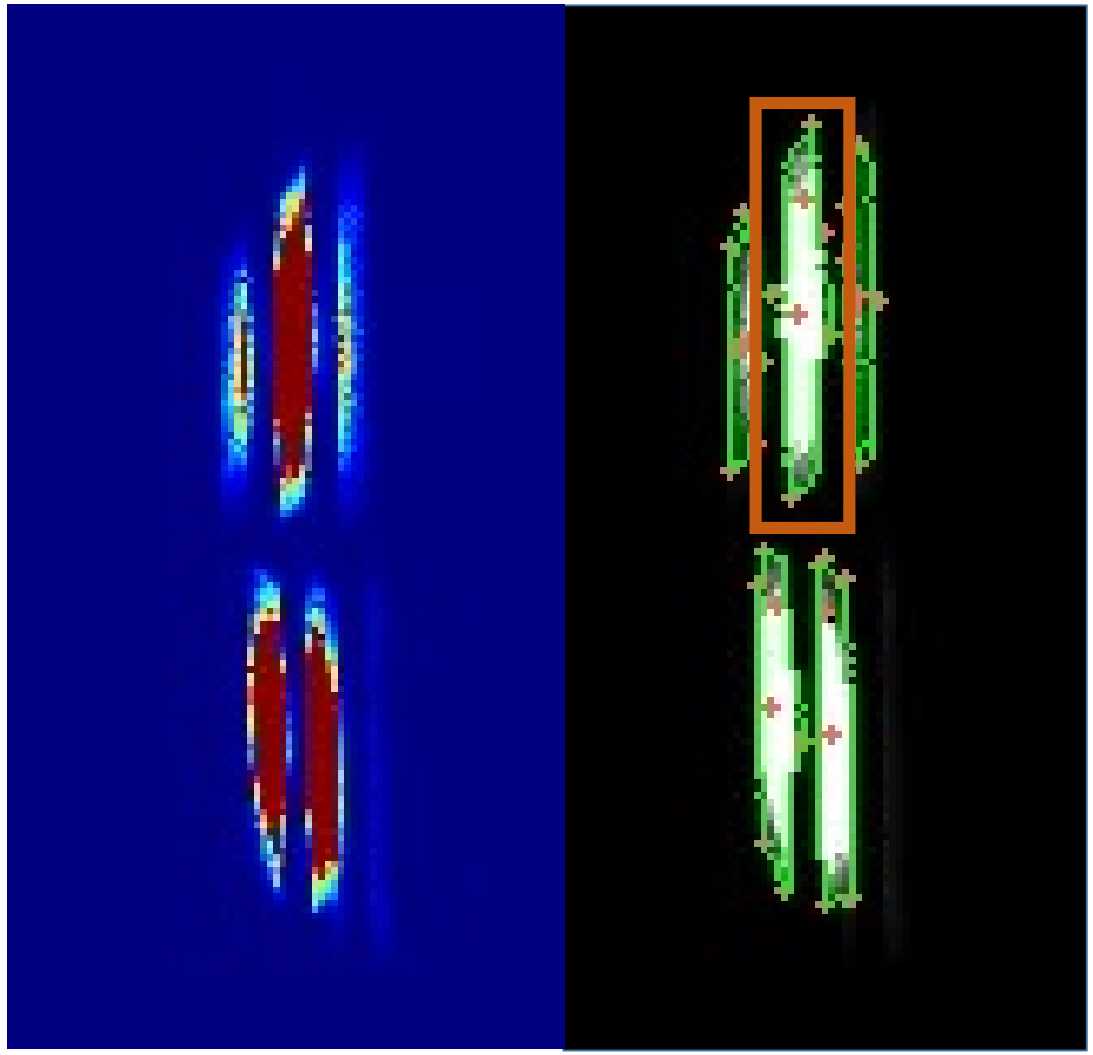
E = 9.1 keV
Direct detection
PEL size = 55 [um]

Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

# Merlin Data Results for First Object (Largest)

## 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
```



Images Courtesy of: Yong Cai, Alessandro Cunsolo, Alexey Suvorov, and the IXS Beamline Staff

# ABBIX Beamlines (AMX) – Pins in a Robotic Gripper

Purpose:

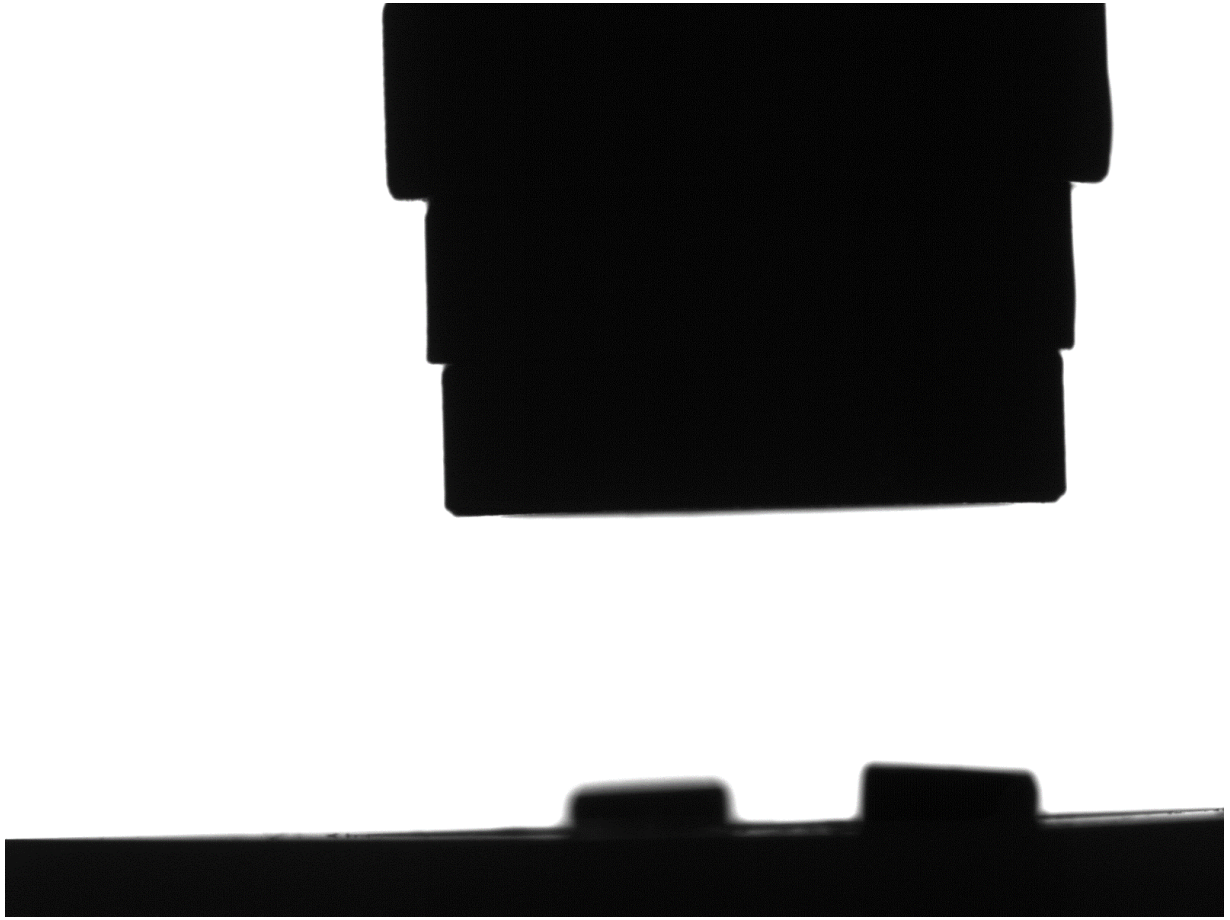
- Find if Pin is in the Gripper
- Determine if Pin is properly mounted
  - Analyze the position of the Gripper and Pin within the image
  - Find the Region of Interest (ROI) for the Pin and Gripper
  - Compare the Pin and Gripper to a ‘Perfect’ Image to determine if anomalies are present
  - Advise the user to any potential problems
  - Discover kinks, check mounting
  - Discover center of mass
  - Use extrema for alignment assistance

Images Courtesy of: Jean Jakoncic, AMX Beamline

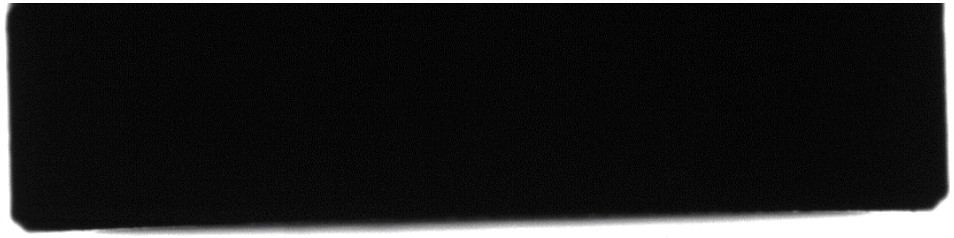
# ABBIX Beamlines (AMX): Pins in a Robot Gripper

- Images are from AMX, Displays a Pin and a Gripper, in an attempt to grab the pin

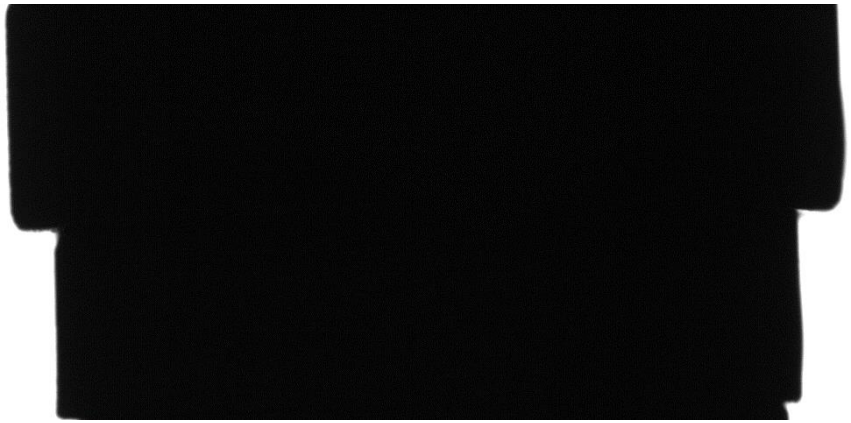
Pin and Gripper ‘Perfect’ Image



Pin Template Image



Gripper Template Image



Images Courtesy of: Jean Jakoncic, AMX Beamline

# Pin/Gripper – ‘Perfect’ vs Test Cases

‘Perfect’

Image 1

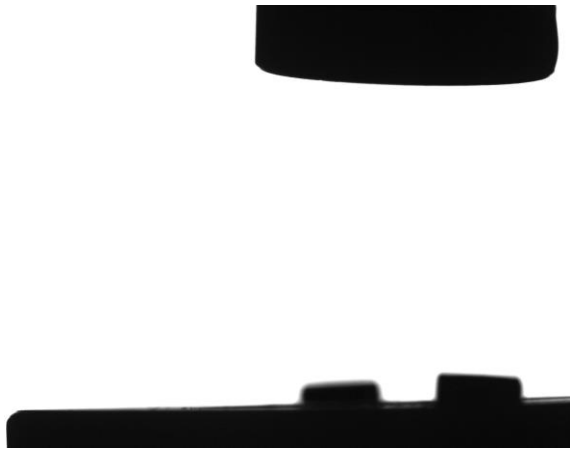
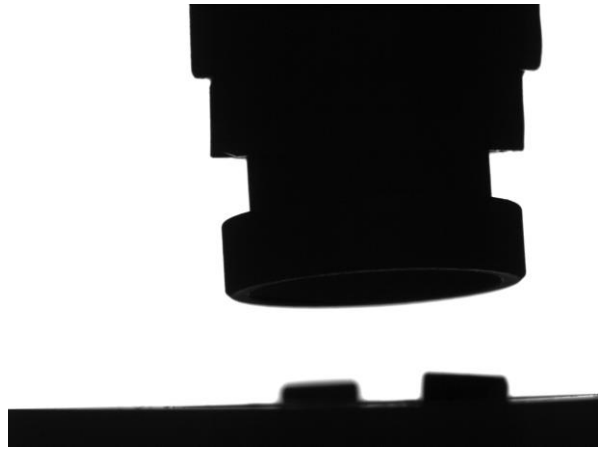


Image 2

Image 3

Image 4

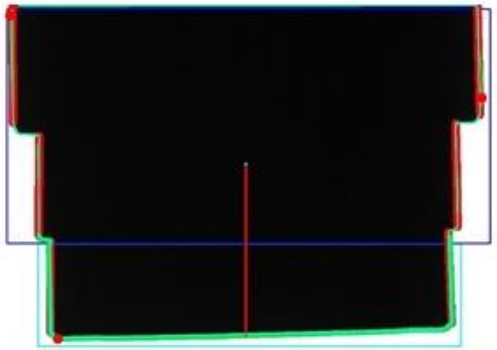


Images Courtesy of: Jean Jakoncic, AMX Beamline

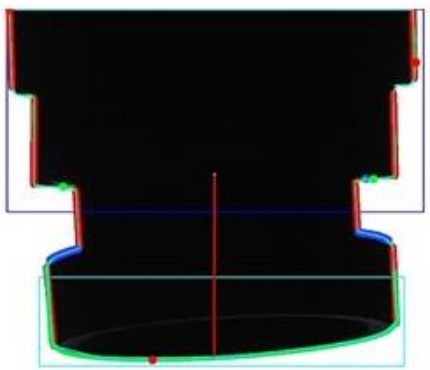
# Pin/Gripper Image Analysis – Results

Match Metrics:
Image Dissimilarity: 1.36080901012
Mount Centroid: Too High: 104
Missing Component / Gripper Not Aligned

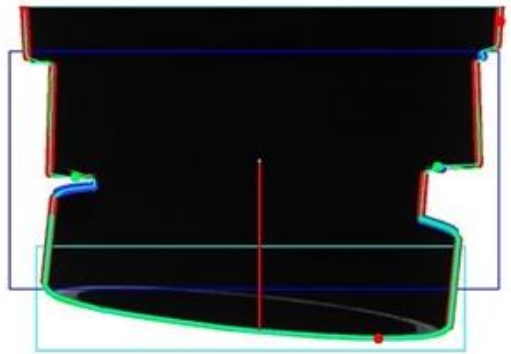
Match Metrics:
Image Dissimilarity: 0.00487836456791



Match Metrics:
Image Dissimilarity: 0.0274253192917
Possible Kinks Detected
41 Possible Kink Points Detected: Adjust Gripper
Possible Kink Distance on R: 115.004347744
Possible Kink Distance on L: 27.3130005675
Pin Not Mounted Correctly: Distance: 329



Match Metrics:
Image Dissimilarity: 0.190836638543
Possible Kinks Detected
44 Possible Kink Points Detected: Adjust Gripper
Possible Kink Distance on R: 125.015998976
Possible Kink Distance on L: 157.003184681
Pin Not Mounted Correctly: Distance: 411

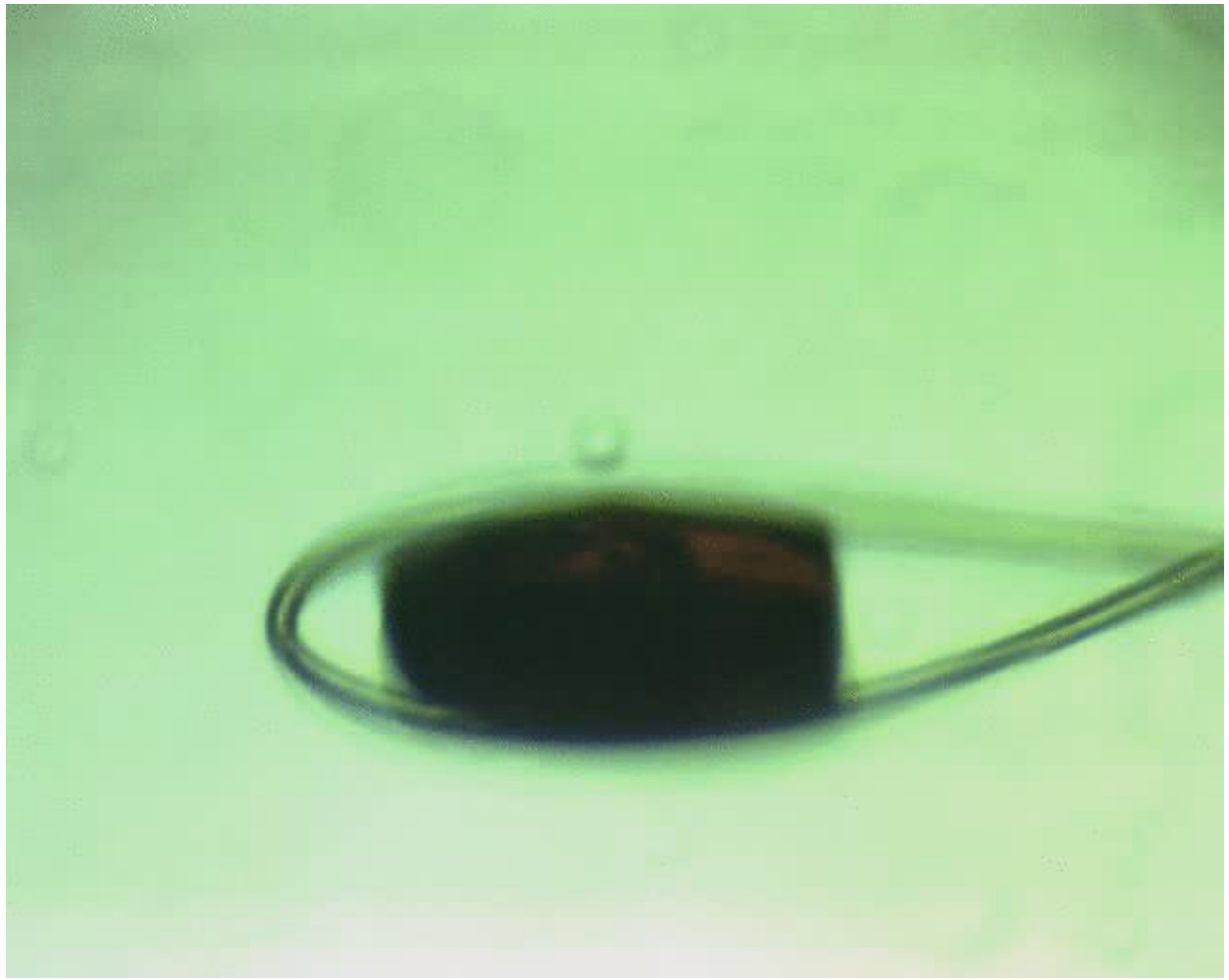


Images Courtesy of: Jean Jakoncic, AMX Beamline

# Crystal Rotational Alignment - AMX

Purpose:

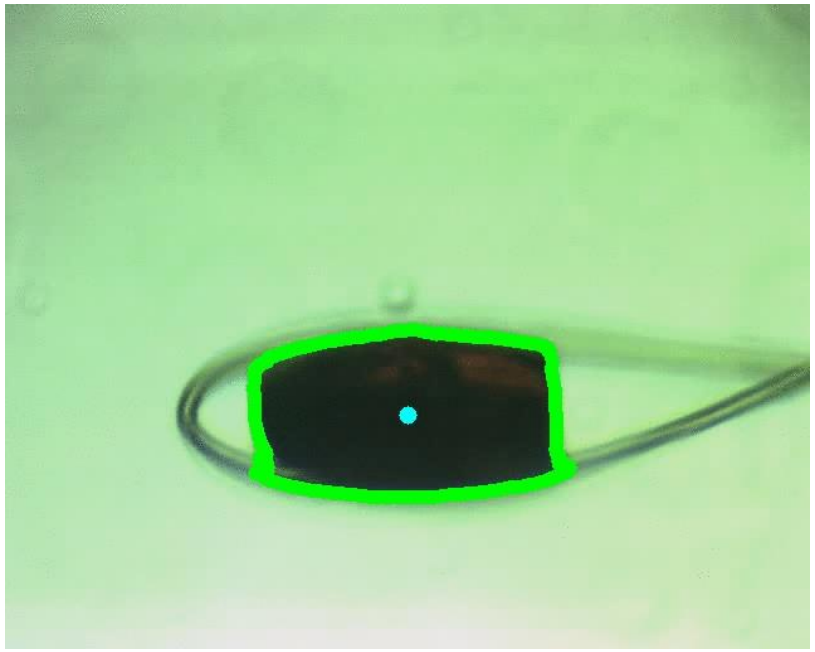
- Locate the Crystal
- Center the Crystal in Goniostat
- Plot as a function of angles the Y Pixel coordinate of Crystal during rotation



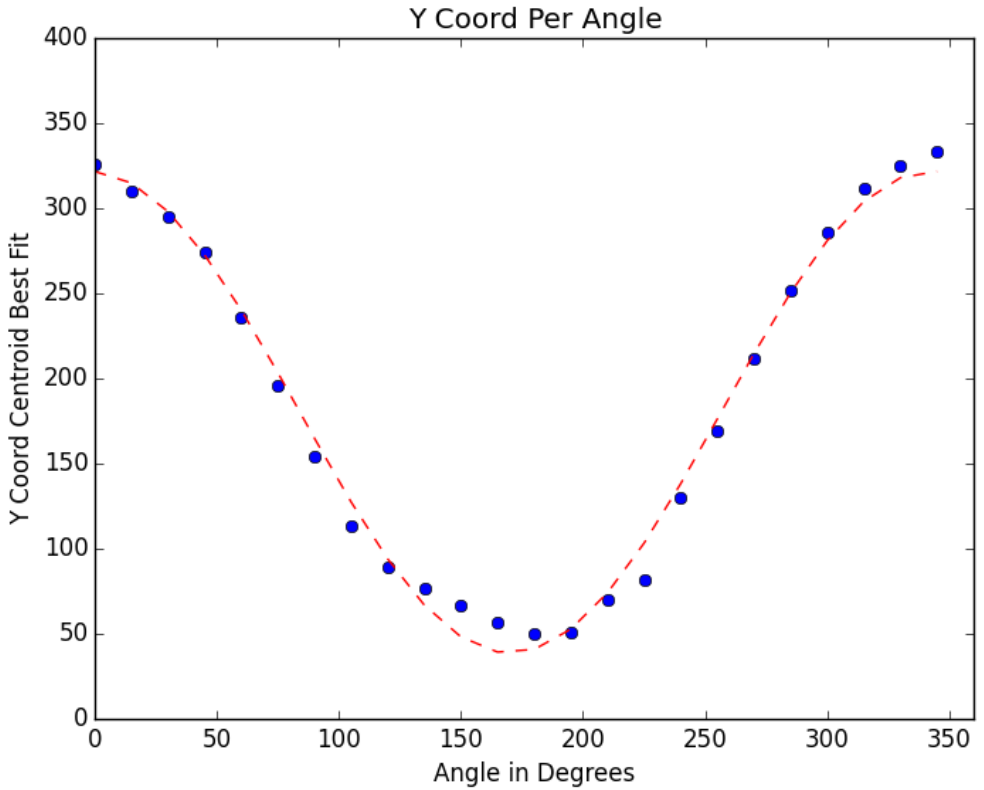
Images Courtesy of: Jean Jakoncic, AMX Beamline

# Crystal Rotational Alignment - AMX

- Centering Crystal:



Images Courtesy of: Jean Jakoncic, AMX Beamline



# Loop Centering - AMX

$$Motion = A \times \sin(\theta + phase) + shift$$

$$Y\ Motor = -\frac{MC}{PEL} A \times \sin(phase)$$

$$Z\ Motor = -\frac{MC}{PEL} A \times \cos(phase)$$

Images Courtesy of: Jean Jakoncic, AMX Beamline

# Conclusion

- Computer Vision is integrated with EPICS control system.
- Computer Vision provides:
  - Center Samples in Goniostat (ABBIX, IXS, etc.)
  - Automated Robotic Mounting and Sample Detection (AMX)
  - Assist in alignments of samples, crystals, and beams
  - Discovers and reports information about objects within an image
  - Prevent potential problems by alerting users of anomalies
- With OpenCV 3.1.0 and the Intel IPP Library, all CV functions run at optimized speeds, providing the best computational results currently available.