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Image Processing for Improved Visualization & Endpoint Detection

T Lundquist, D Renard, R Jain, Credence
& M Phaneuf, K Lagarec, Fibics

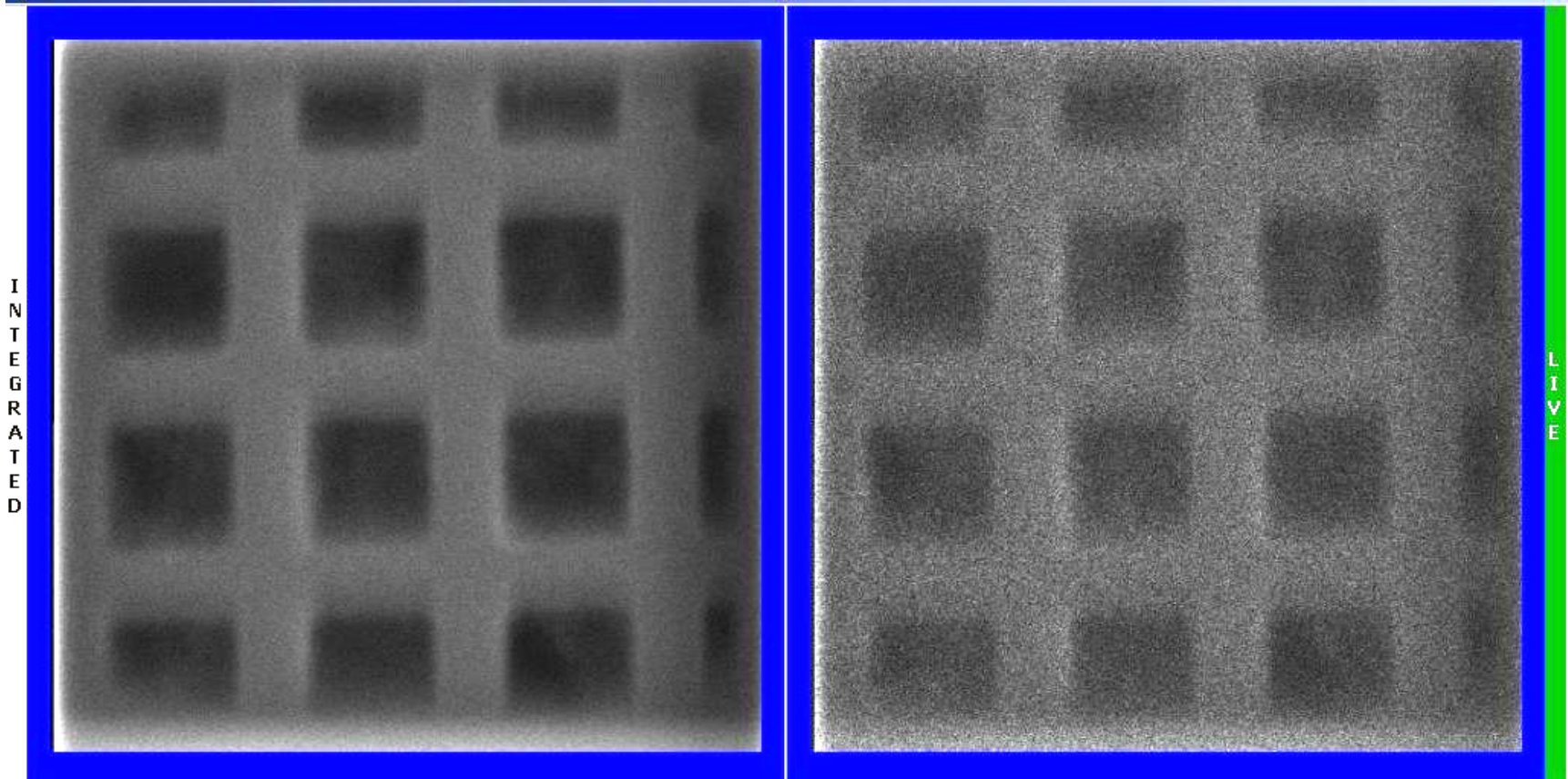
Motivation:

- CE gets more challenging at each process node
- Seeing is key to better driving
 - Seeing is key to better editing
- Detectors seem to be max'd out
 - We're collecting ~all there is to collect
- **Can we see better by using better what we have?**

Visualization

1. SIM: 2nd electrons, ions & photons form image as beam scans
 - 2nd ions & photons give poor results during milling
 - 2nd electron detector improvements max'ed out
 - Increased imaging time increases invasiveness
2. Photon optics sees through dielectric & Si—improved visualization
 - Resolution limited
3. Correlation to CAD helps visualization
4. Data processing: What can be done?
 - **Improve utilization of collected data**
 - **Scaling**
 - **Interpolation**
 - **Uses neighbors to increase number of pixels**
 - **Signal Inversion**
 - **Other**

Simultaneous Imaging with Different Emphasis

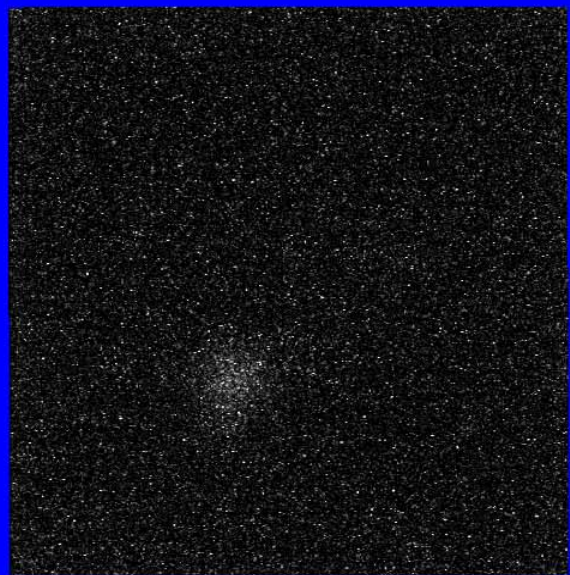
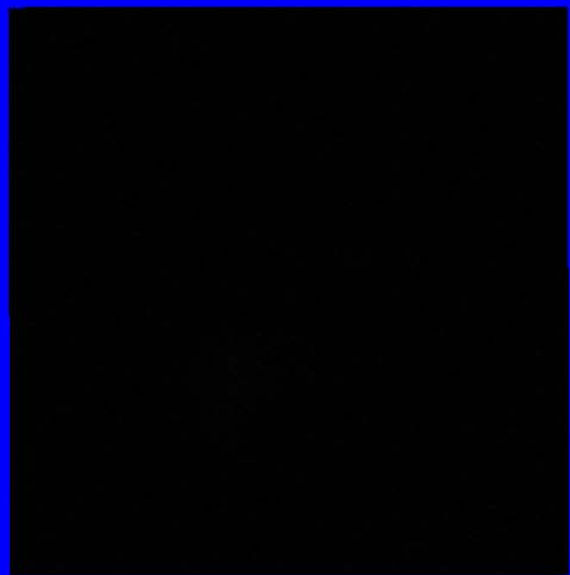


1st thing to do: View mill with two settings

- Better imaging—integrated (left)
- Better sensitivity—live (right)

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Full Image ROI

About FIB Assist
Project setup
Analyze project

Store Clear Hide

1 2 3 4

Show imaging annotations

Overlay image Clear

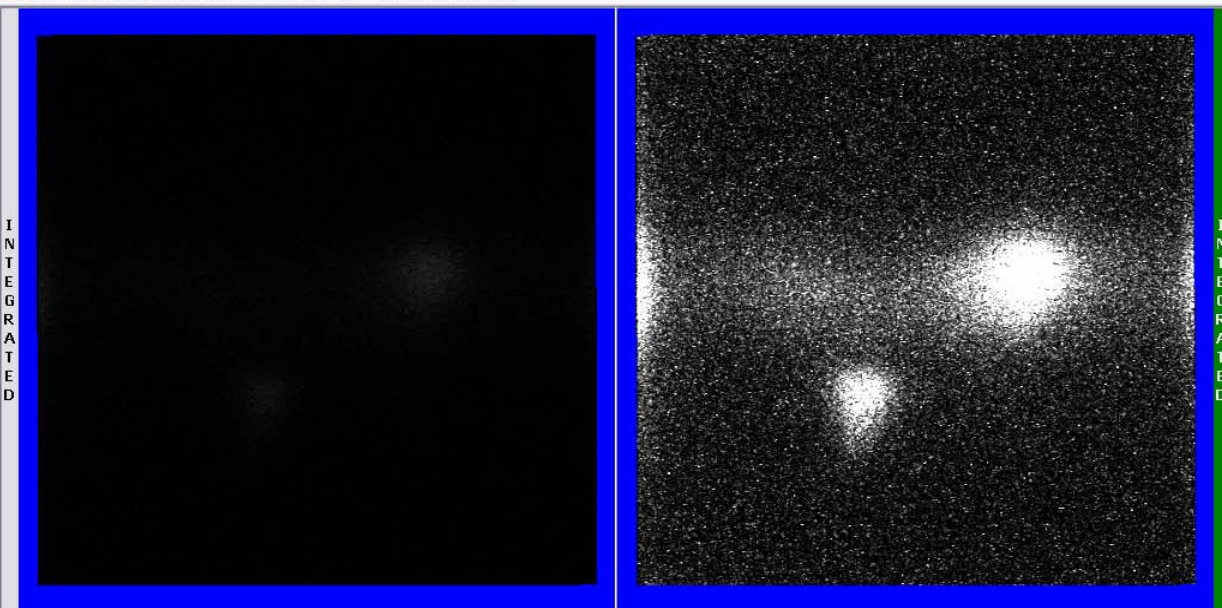
Measure Clear

0 1023

1 Reset 39



SE graph was not adjusted before or after mill, only auto scaling “adjusted” graph. Next mill ~identical graph. No SEs available when milling through dielectric with XeF₂. Just as SE signal increases auto contrast shows something (right frame). Standard image (left frame) shows nothing.



Full Image ROI

About FIB Assist

Project setup

Analyze project

Store Clear Hide

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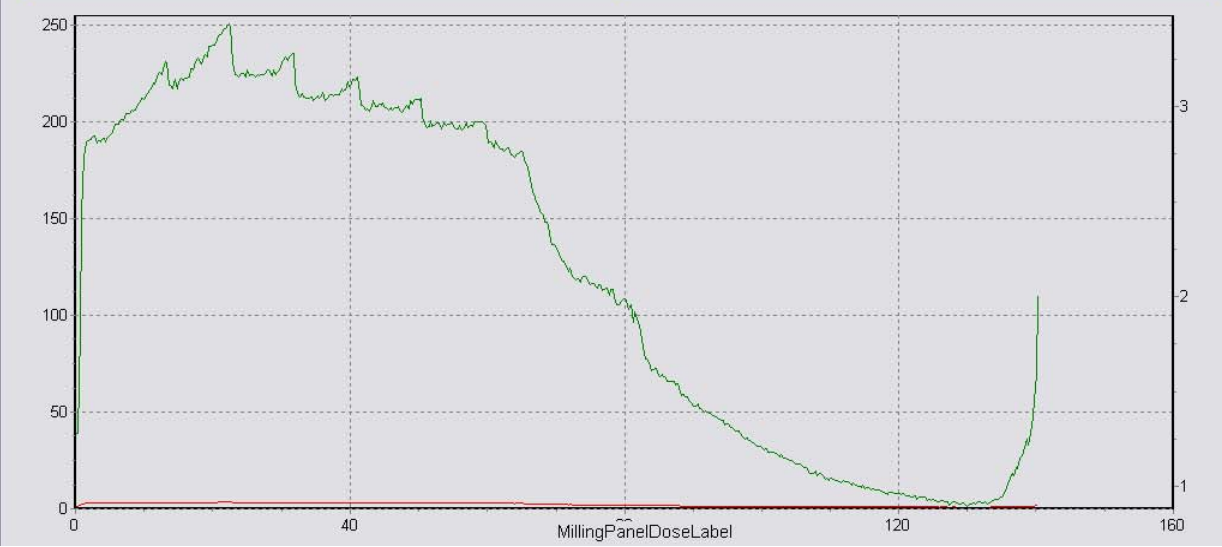
Show imaging annotations

Overlay image Clear

Measure Clear

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1 Reset 39

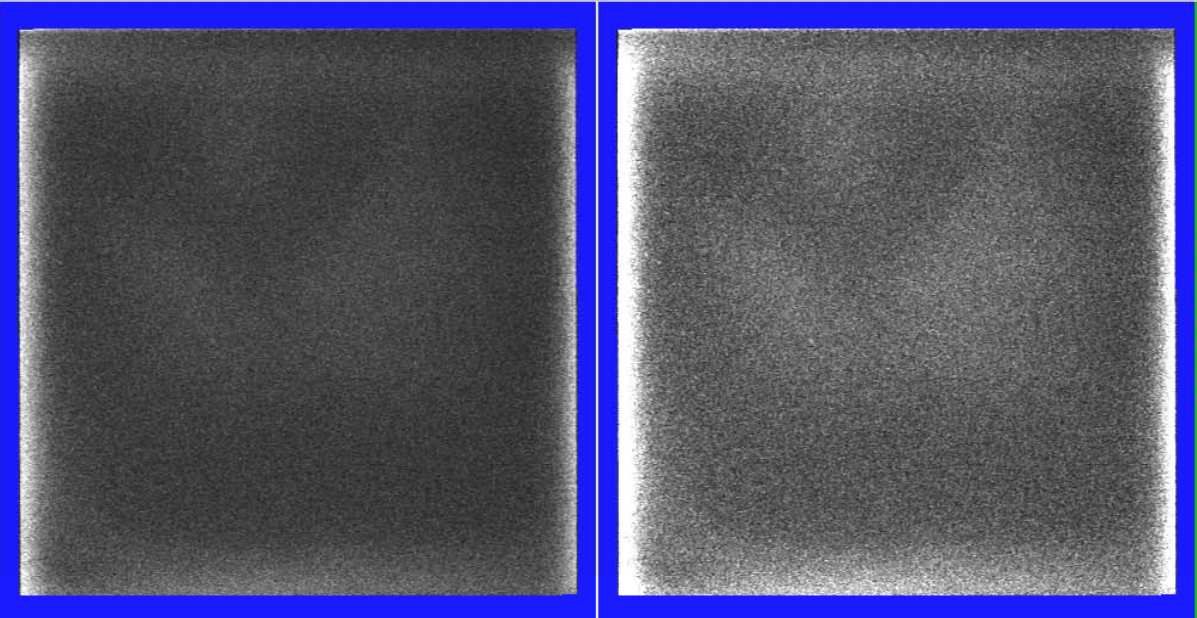


SE signal rapidly rises, but standard image doesn't "show". At this instance auto contrast is a little slow, so increasing SE signal jumps out at user as an advantage for endpoint.

Details of the edit such as these are captured routinely.

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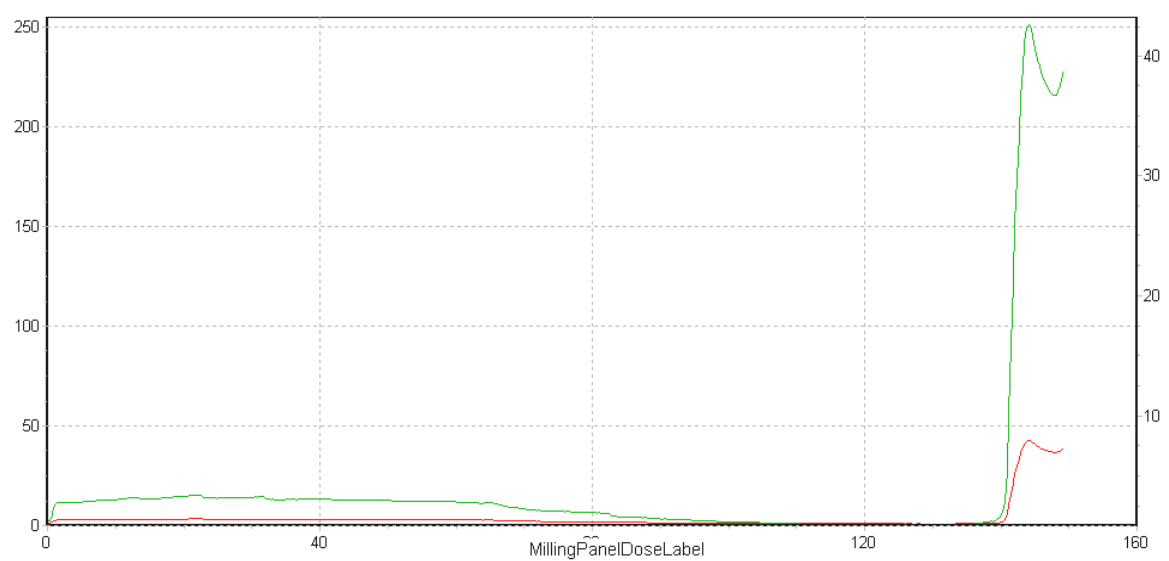
Full Image ROI

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12 Reset 538

Max Contrast Equalize

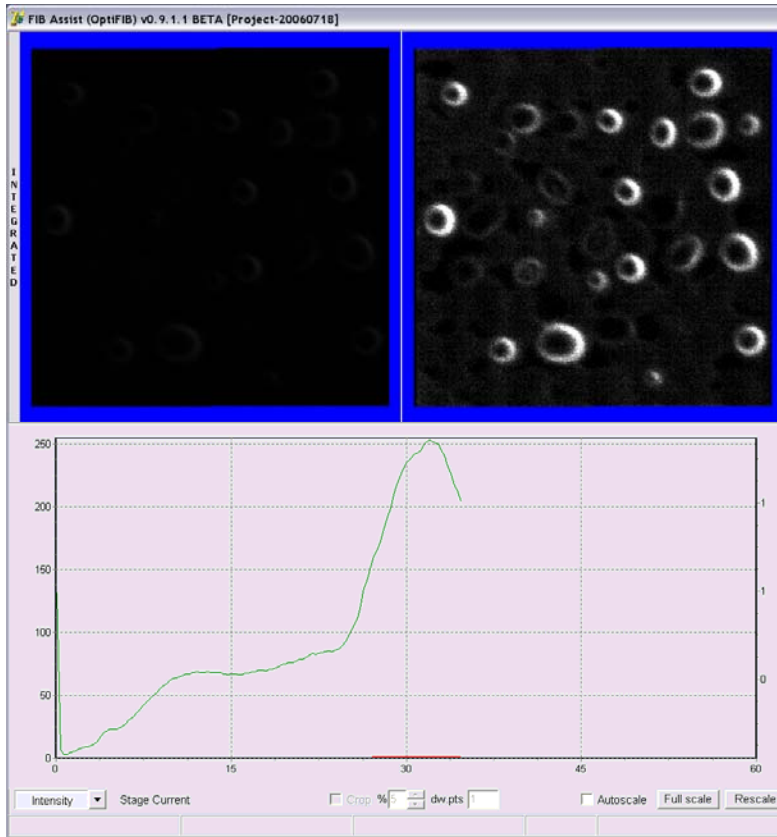
Live histogram update Update



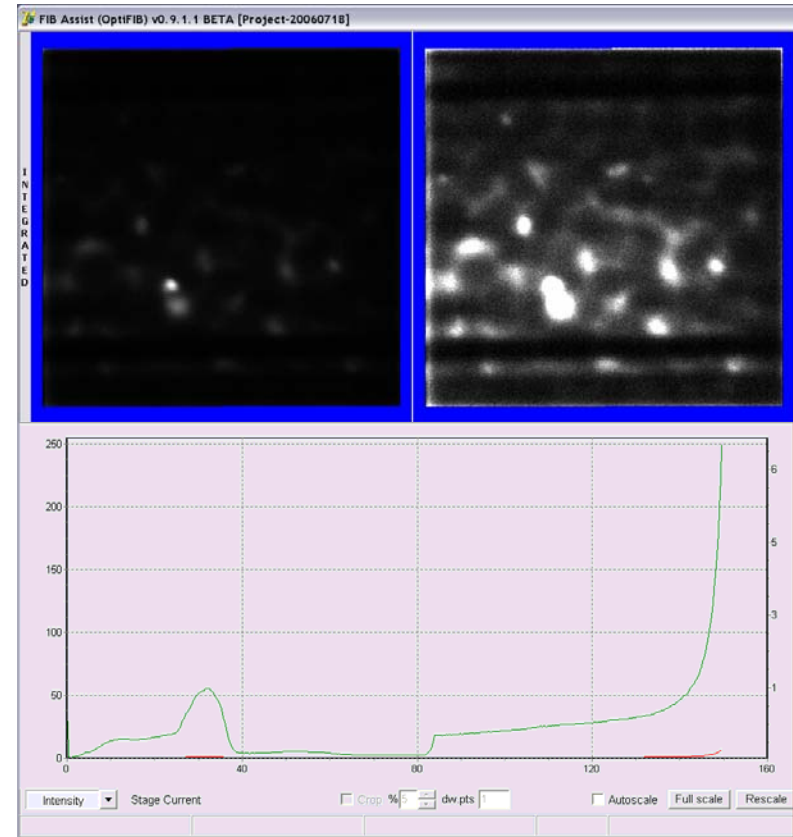
When coating clears, SE signal maximizes. Standard display technique (left) now “sees” image while “auto contrast” has adjusted the rapidly changing signal so both images are ~equal.

Next STOP the edit.

Auto Contrast Real-time, Post Collection-2

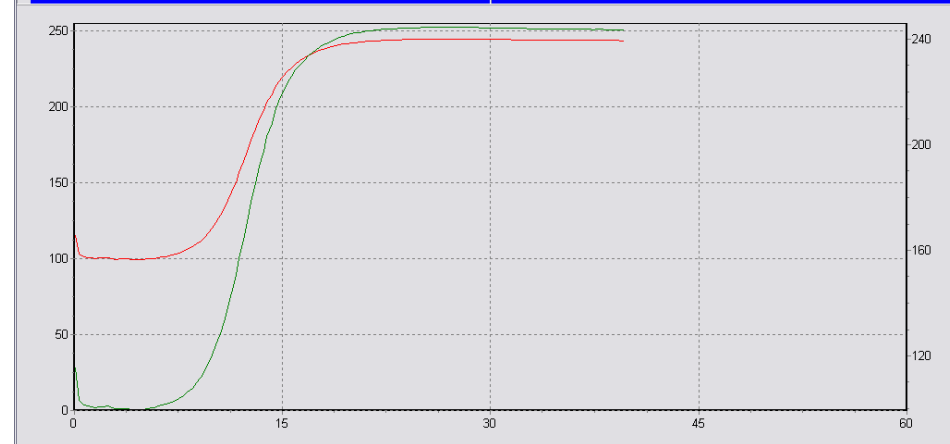
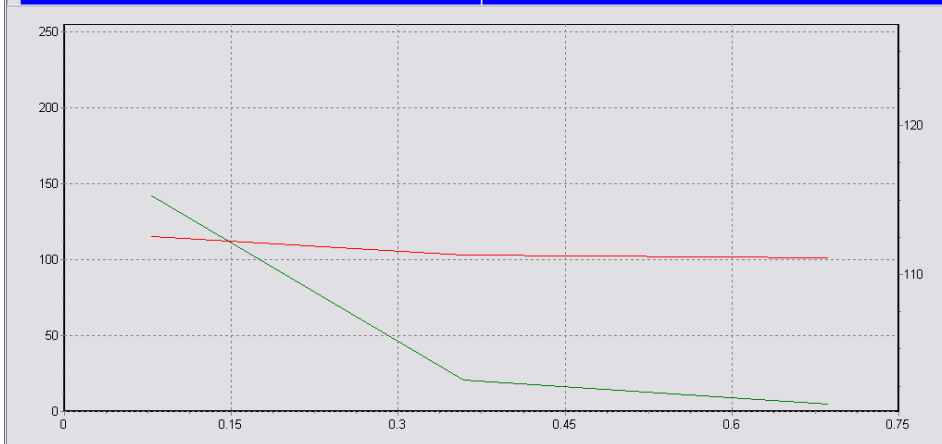
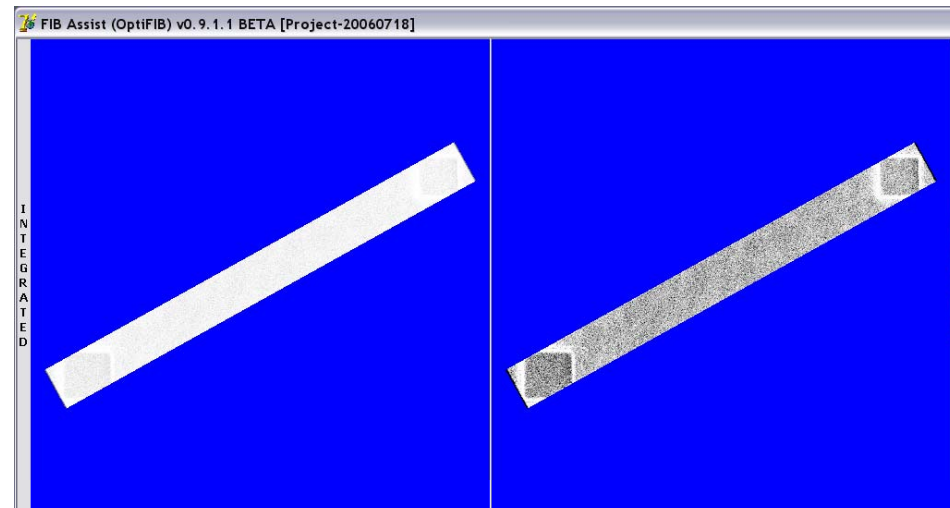
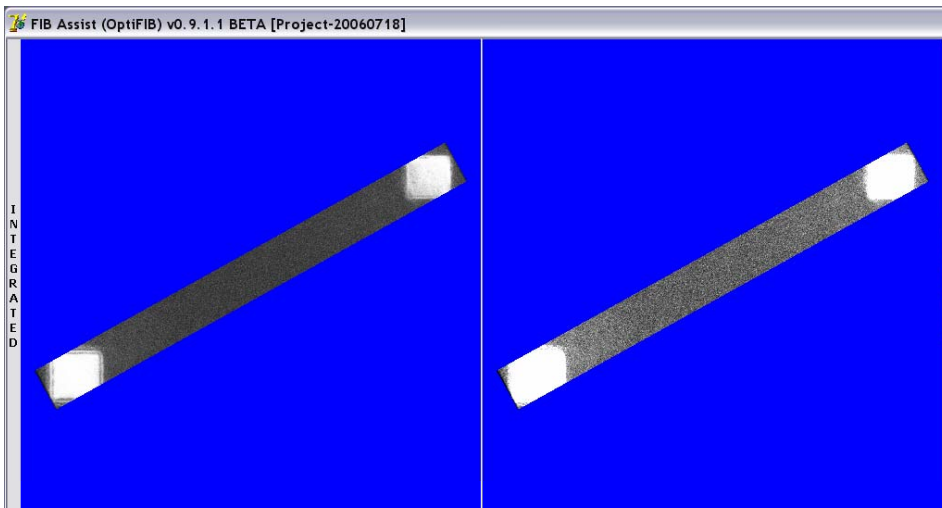


Removal just beginning
 XeF2 being used
 120x120 μ m mill box
 Die has de-cap residue



Opening just beginning
 SE graph increasing

Auto Contrast, Real-time, Post Collection-4

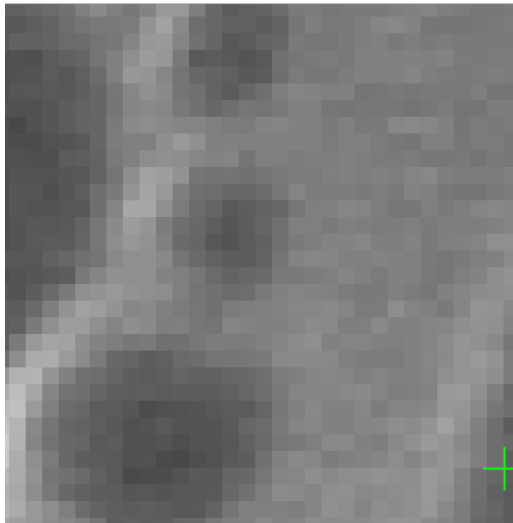


- Deposition begins
- Auto contrast image somewhat better

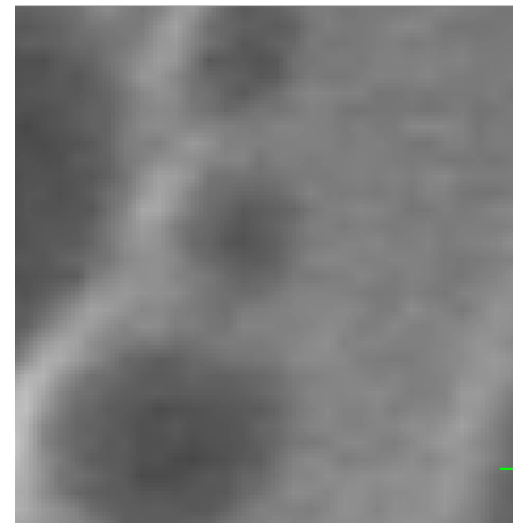
- Deposition stopped
- Auto contrast image much better

Real-time Interpolation for images of few pixels

64 x 64
pixels

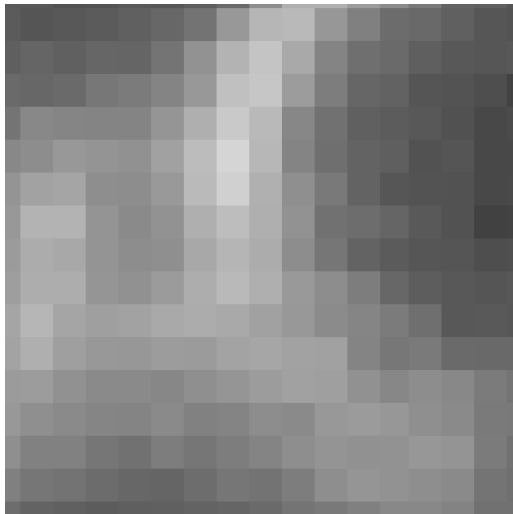


Without

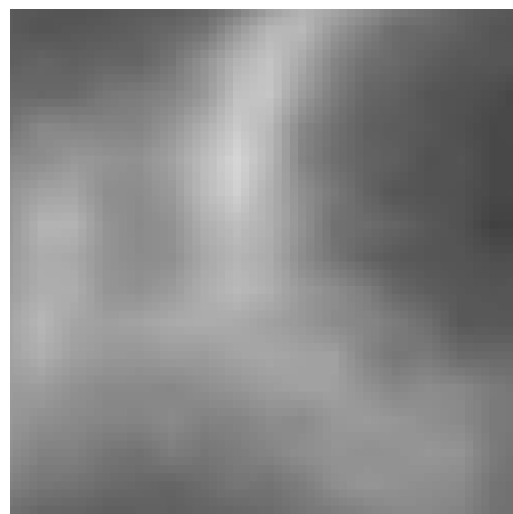


With

32 x 32
pixels



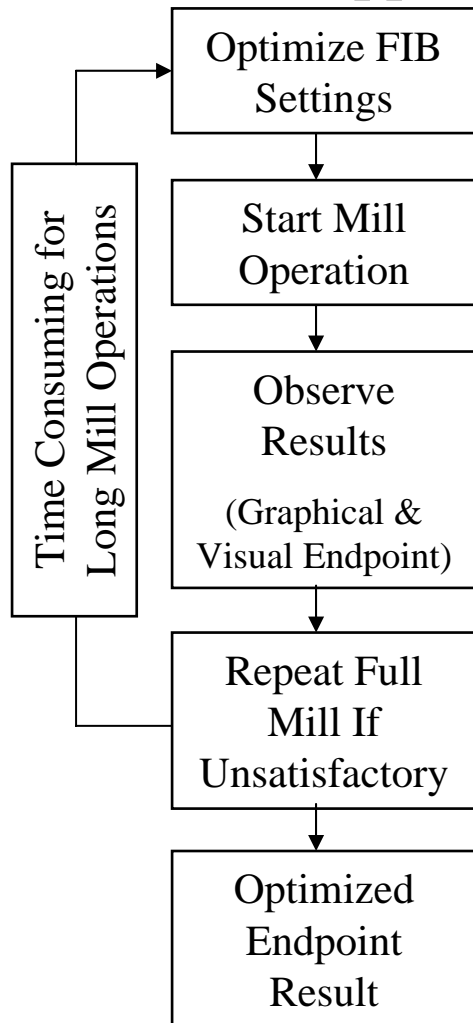
Without



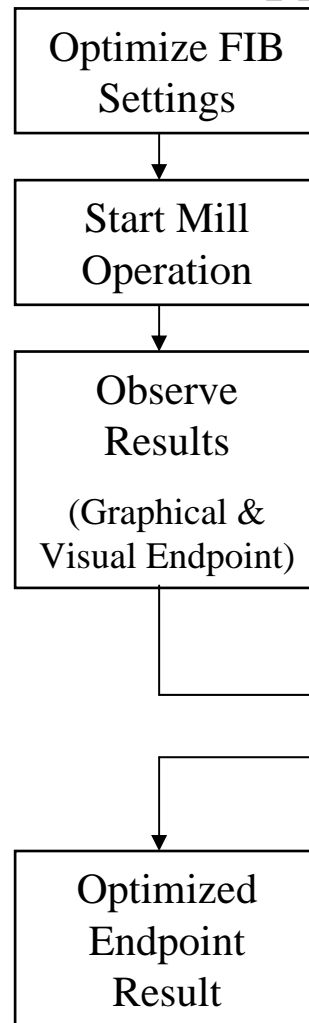
With

Edit Analysis/Debug/Review

Standard Approach



Better Approach



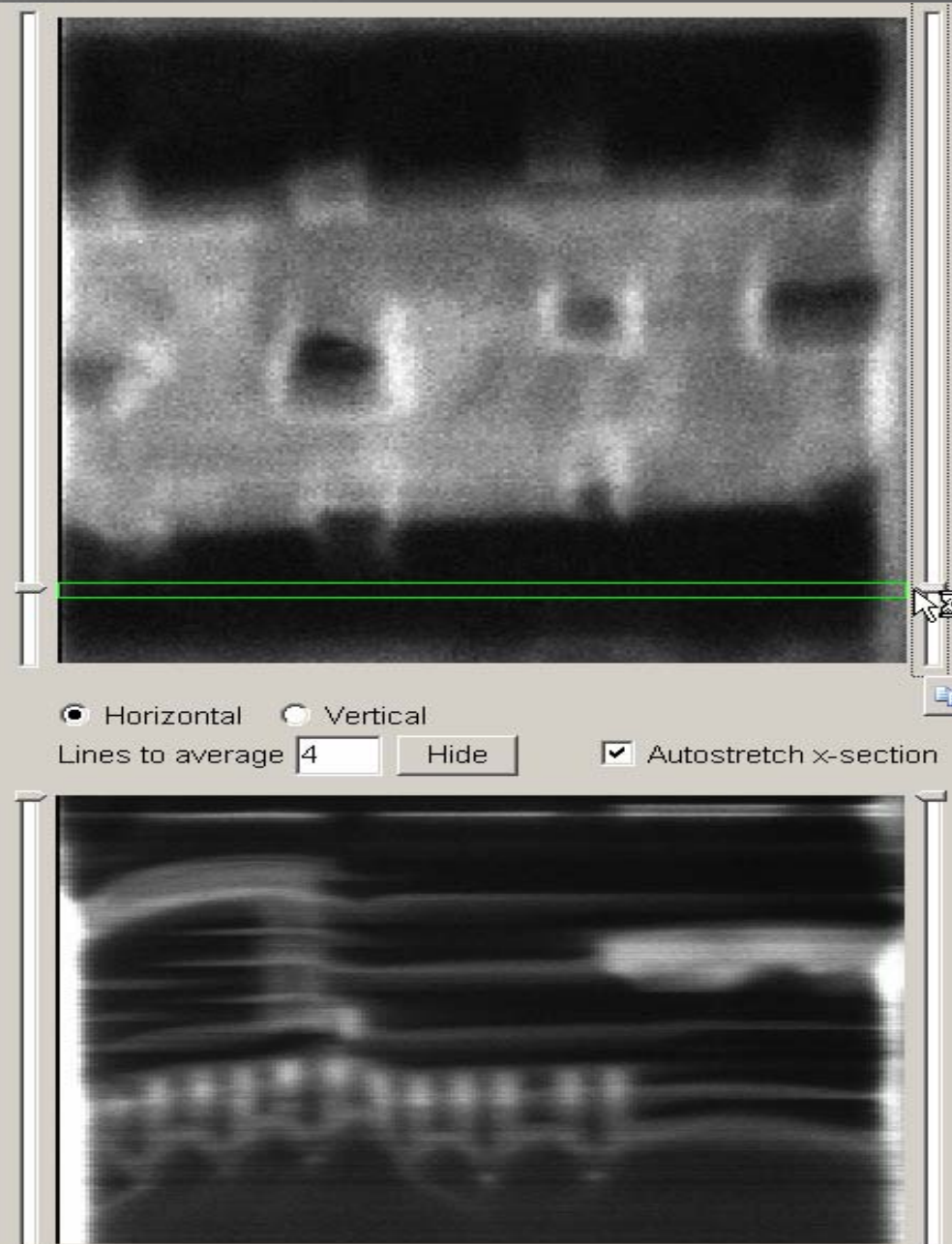
Edit Process Debug Tool

Digitally Recall & Replay Milling Operation to Optimize:

- Contrast
 -
- Processing of:
 - Visual Endpoint Image
 -
 - Graphical Endpoint Signal
 -
- Job Recording Details

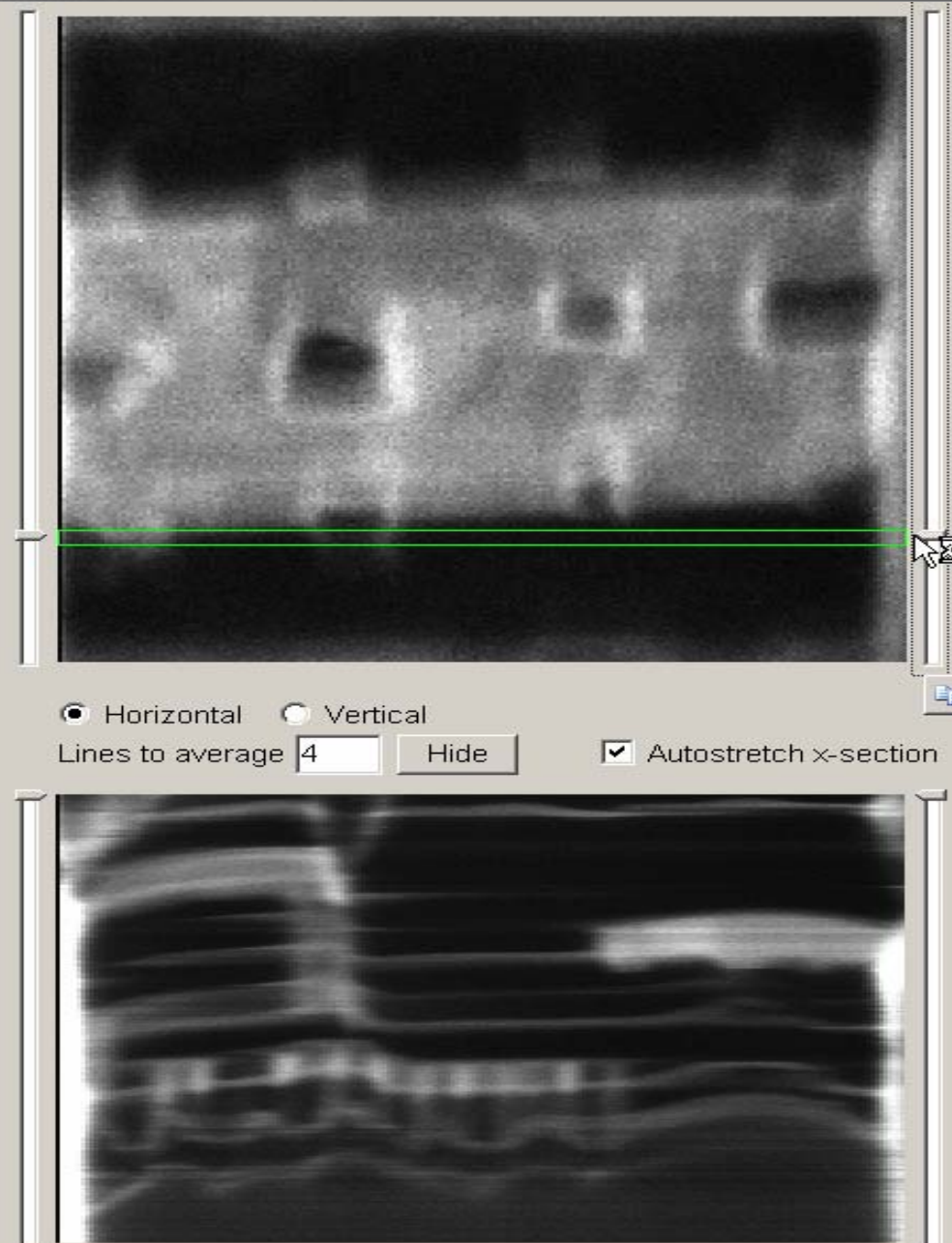
Edit Process Debug Tool

- Cross Section Visualization:
The holy grail of optimal data utilization
- Band with green border selects where the cross section is reconstructed



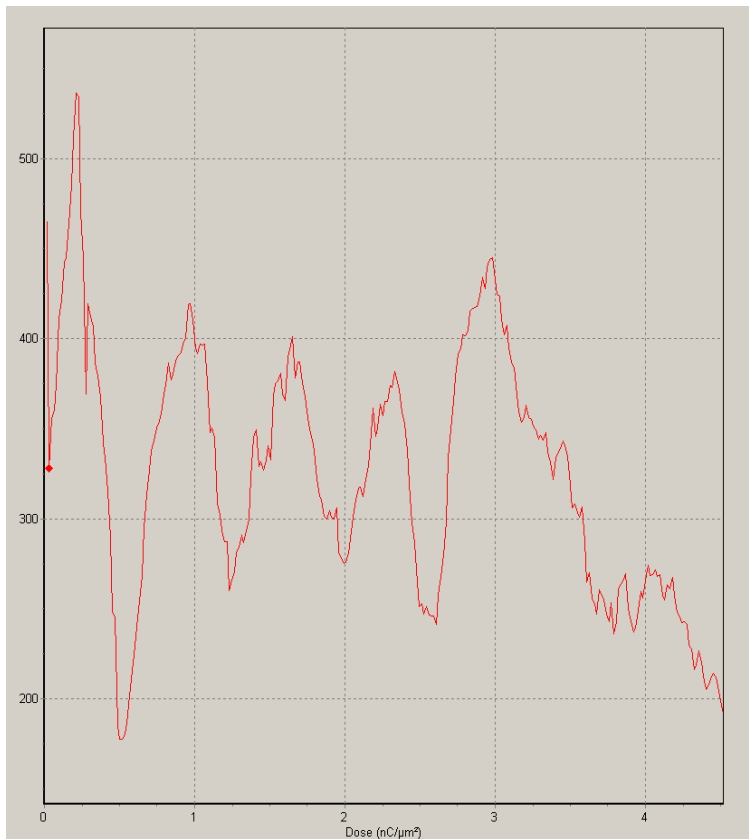
Pseudo-Cross Section

- Cross Section Visualization:
The holy grail of optimal data utilization
- Digitally Recall & Replay
Milling Operation



Edit Process Debug Tool

- Cross Section Visualization:
The holy grail of optimal data utilization



The screenshot shows the 'Edit Process Debug Tool' interface. The top panel displays a grayscale image of a process with a green horizontal line indicating the cross-section. The bottom panel shows the resulting cross-section visualization. The control panel includes:

- Horizontal Vertical
- Lines to average:
- Autostretch x-section

Summary

- Idea: Apply image processing algorithms dynamically to better “see”—Enhanced visualization
- Enhanced SE Endpoint Graph
 - **Brightness & Contrast** adjustments do not affect endpoint graph (adjustments are post detection, so great looking and trackable SE graph for repeatable endpoint)
 - Greater sensitivity (digital milling)
 - Determine if line is cut
 - Auto Contrast
 - Navigating into new area contrast adjustment is automatic
- Automated, real-time interpolation increases image pixels (Digital imaging) to improve image recognition
- Edit Process Debug
- Greater confidence