

2D-Nanometrology using Model 300-2D calibration specimen

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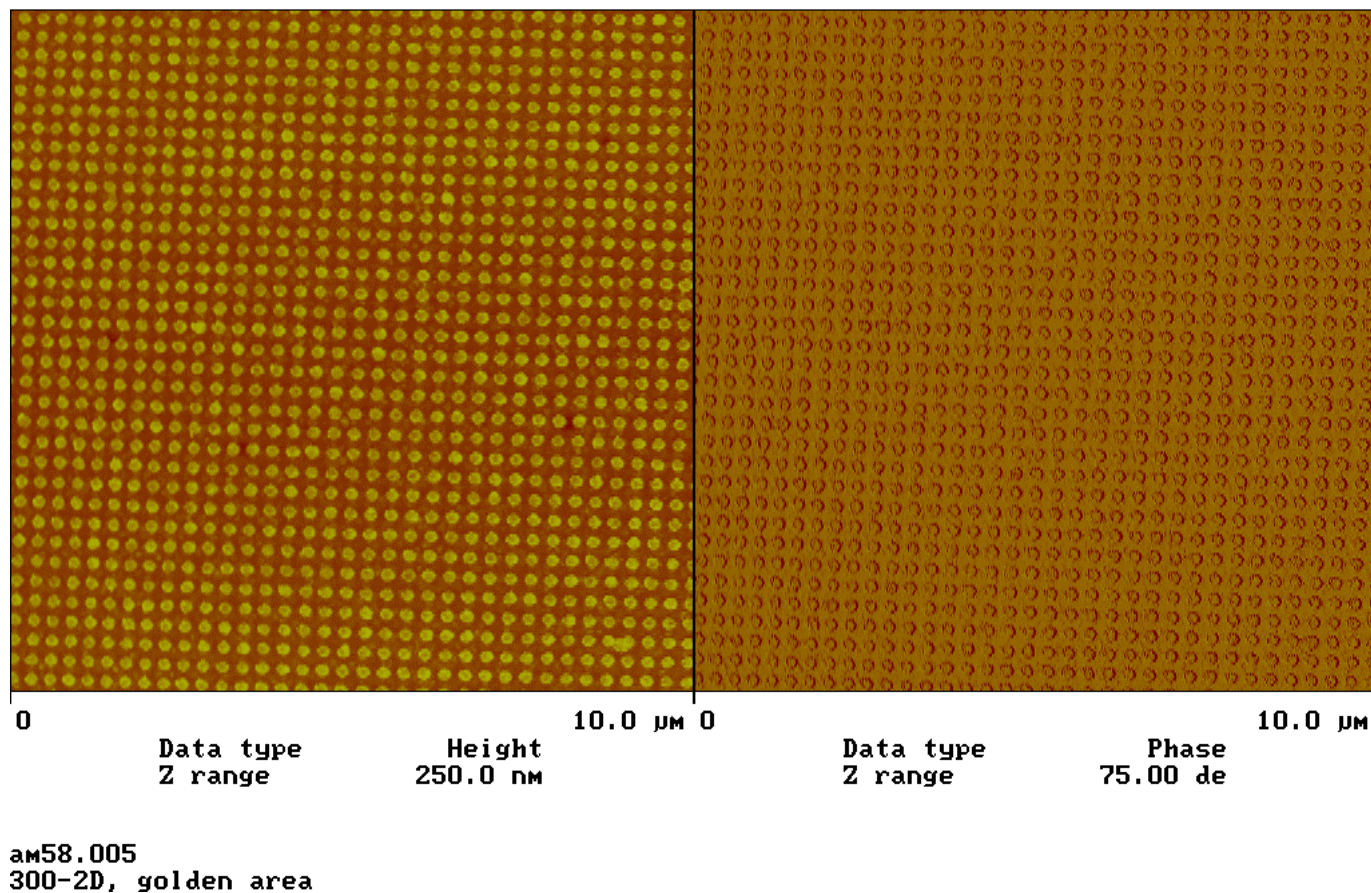
Example of 2D Nanometrology

- Round-robin project of several national labs measures:
 - Pitch along X axis
 - Pitch along Y axis
 - Angle between X and Y axes
- This report shows imaging using a commercial open-loop AFM and data analysis using ASM's software.

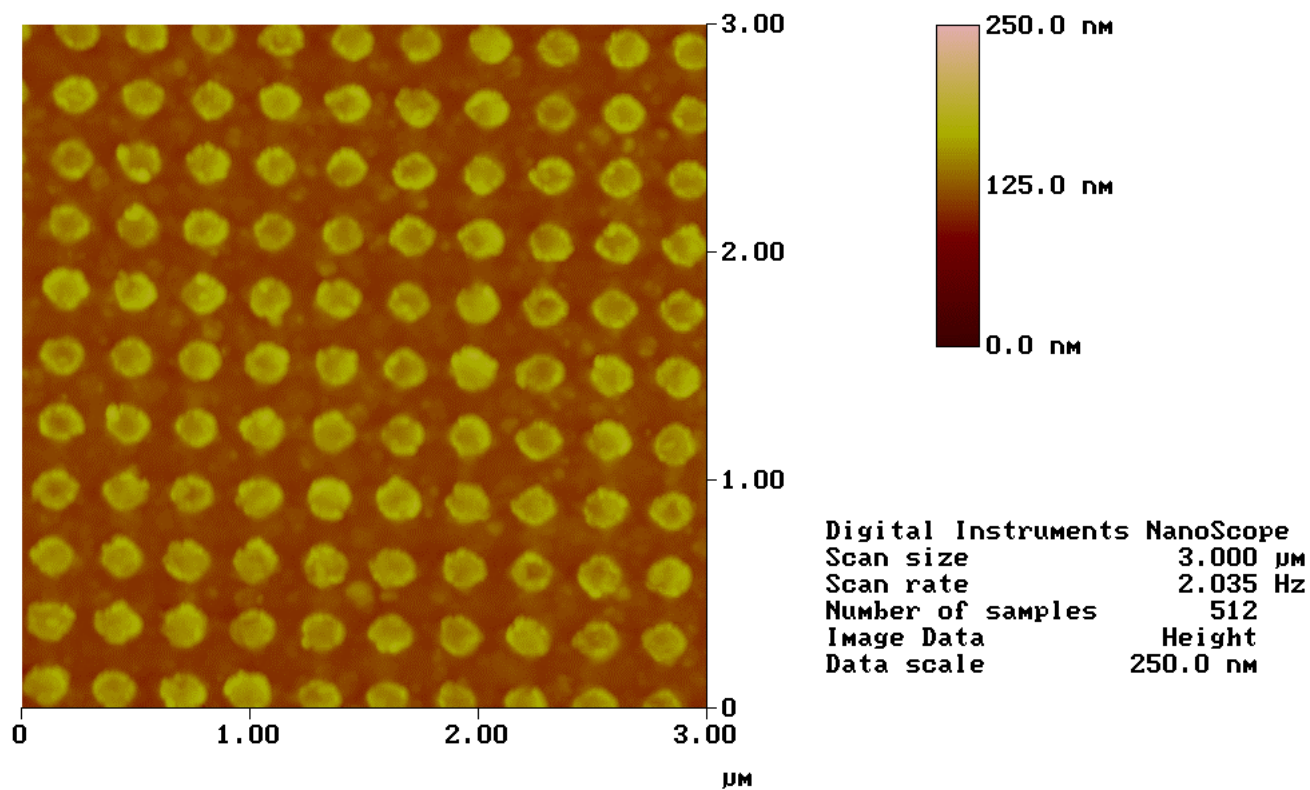
Materials and Methods

- NanoScope Dimension 3100 AFM
- Si tapping mode probe
- Model 300-2D specimen (s/n 2336E0210)
- Most images were captured with 512 pixels/line x 256 lines.

AFM images of typical surface region (golden appearance in bright field reflected light)

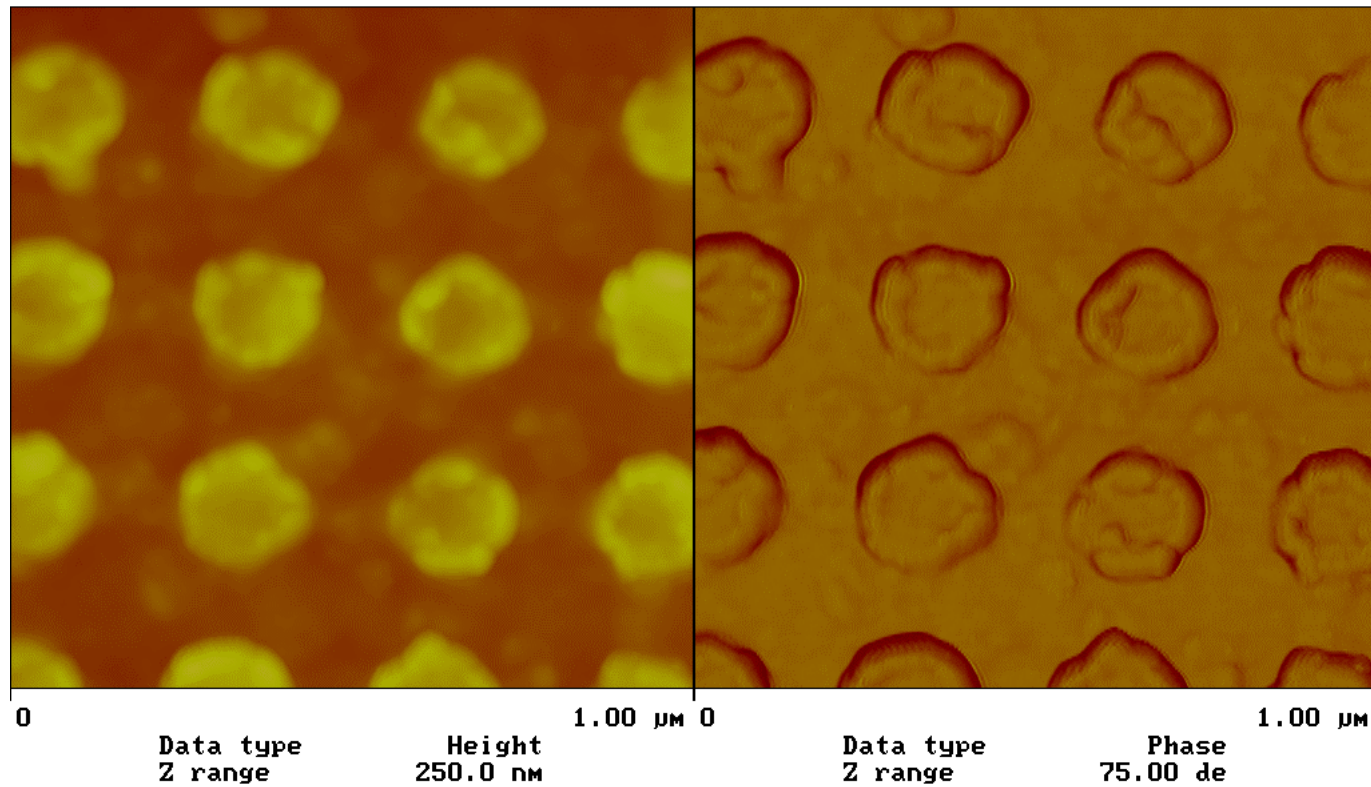


Golden region



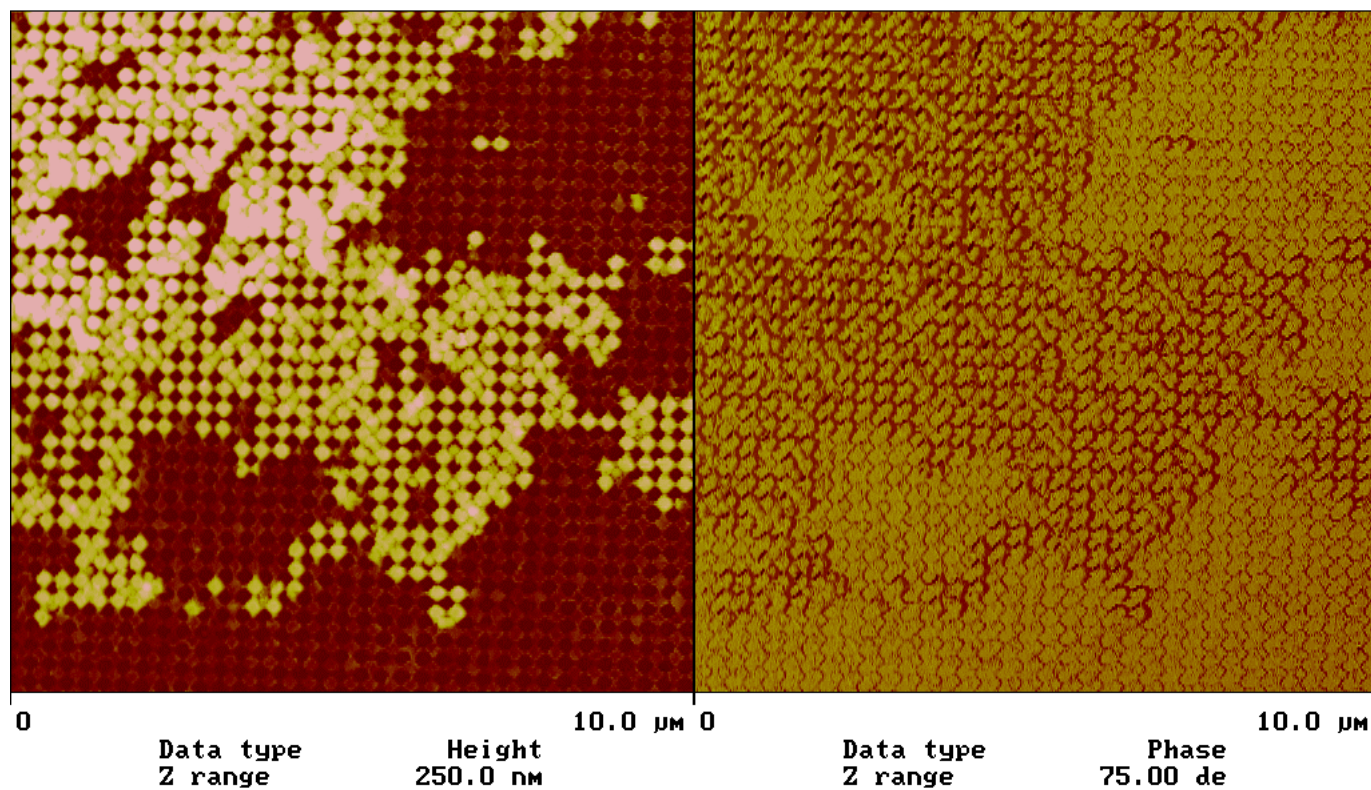
300-2D, golden area
am58.004

Golden region



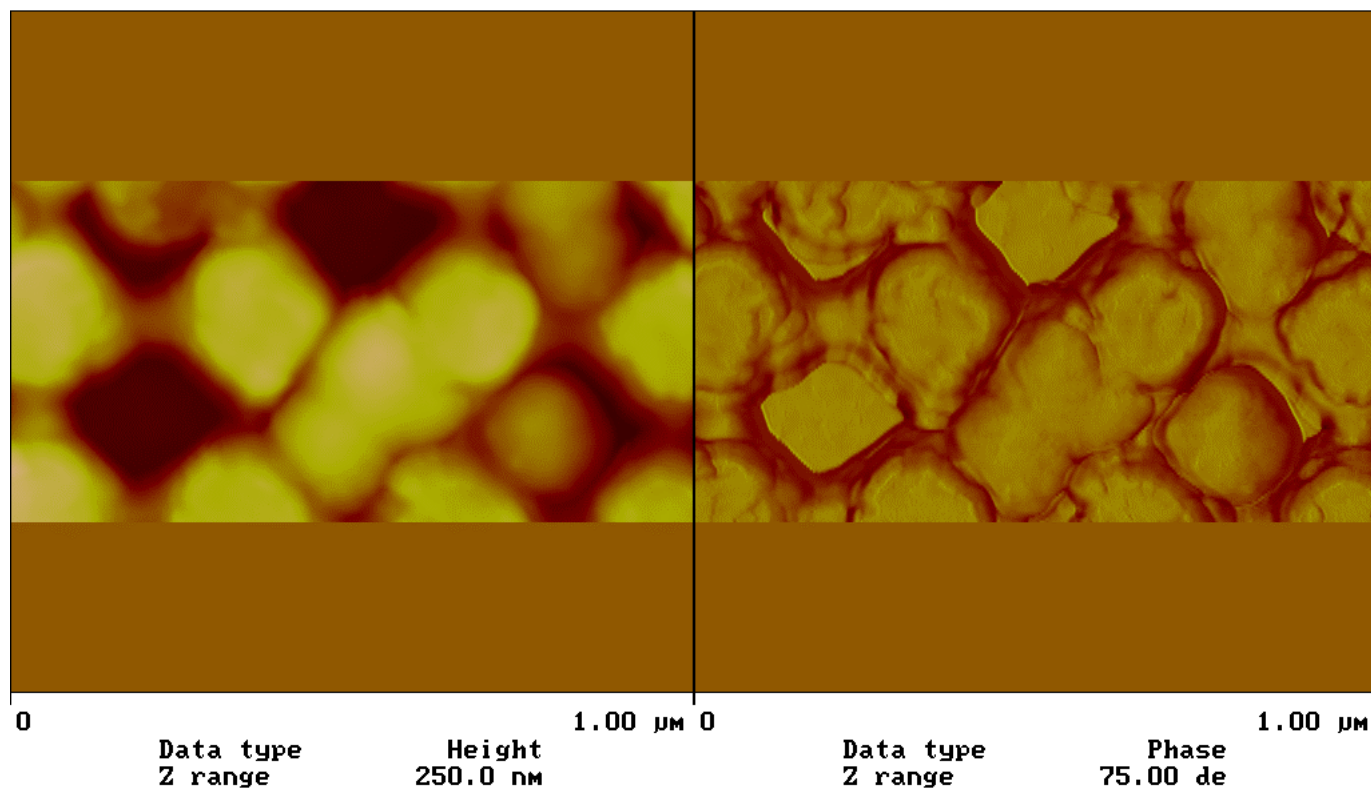
am58.003
300-2D, golden area

At a small spot that appears dark in bright field reflected light



am58.f02
300-2D, dark spot

Dark spot

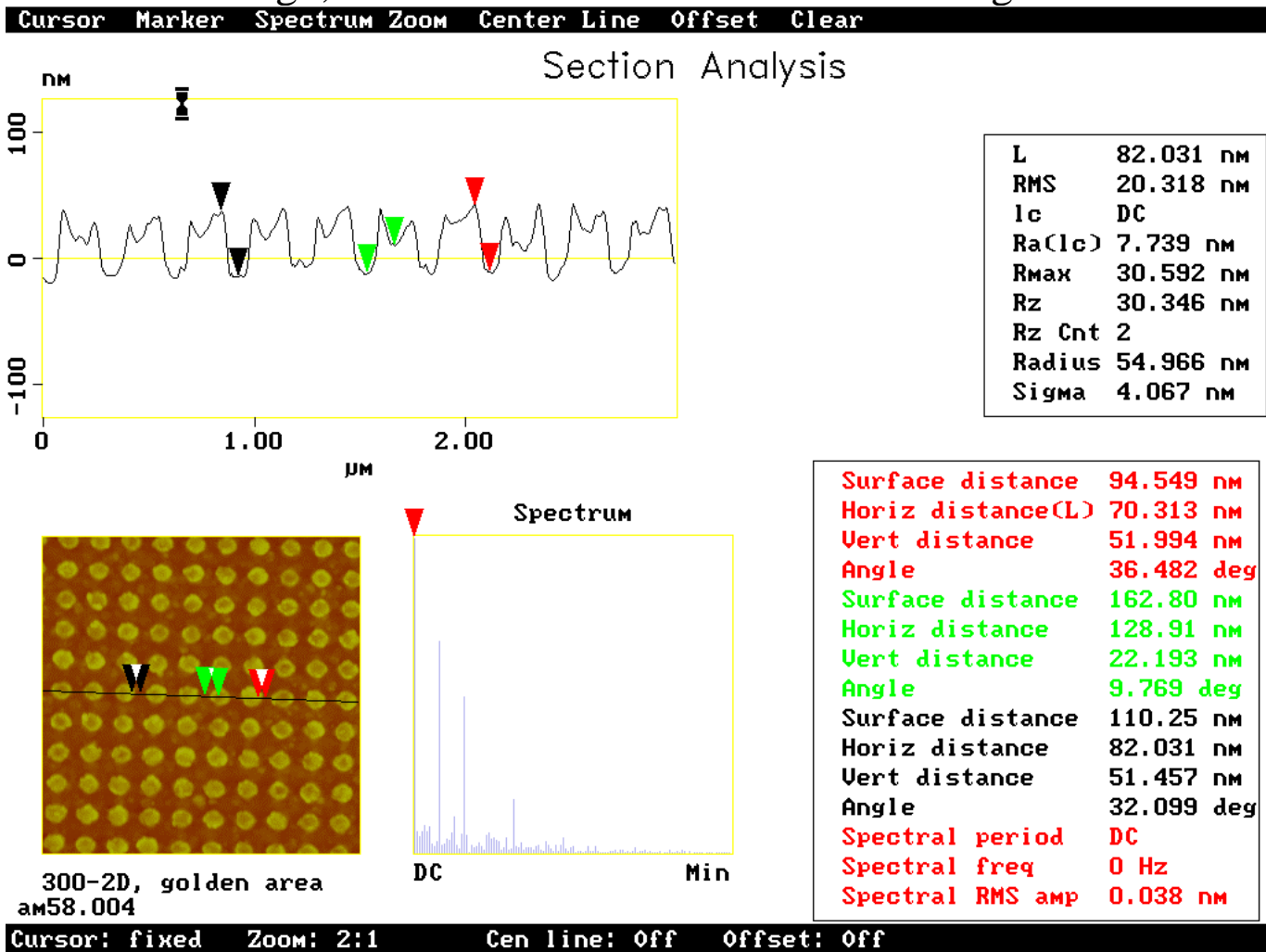


am58.001
300-2D, dark spot

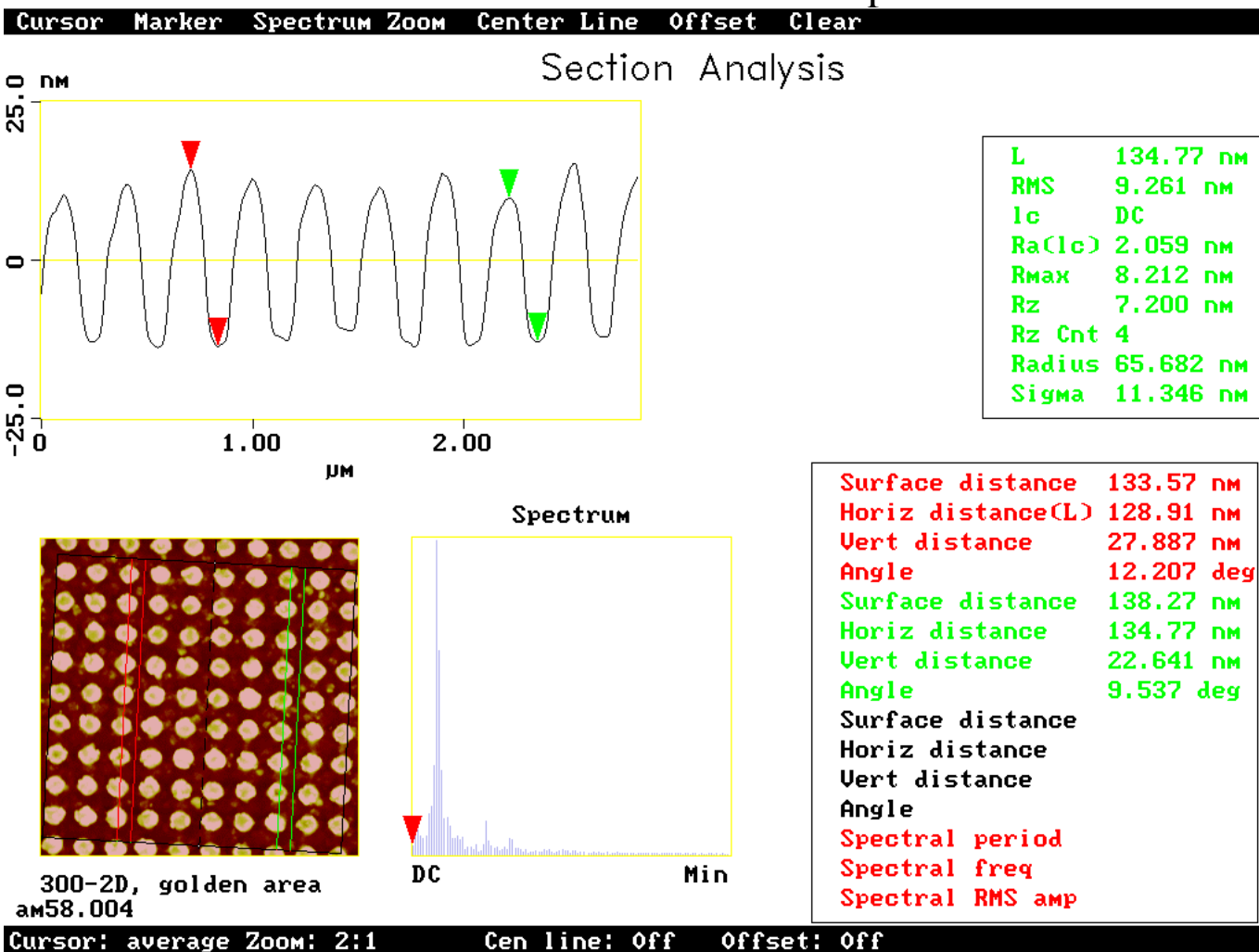
Section Analysis

- Use NanoScope to manually draw and display single and average section profiles.

single line section profile shows some height variation – edge of crater is 52 nm high, center can be as shallow as 22 nm high



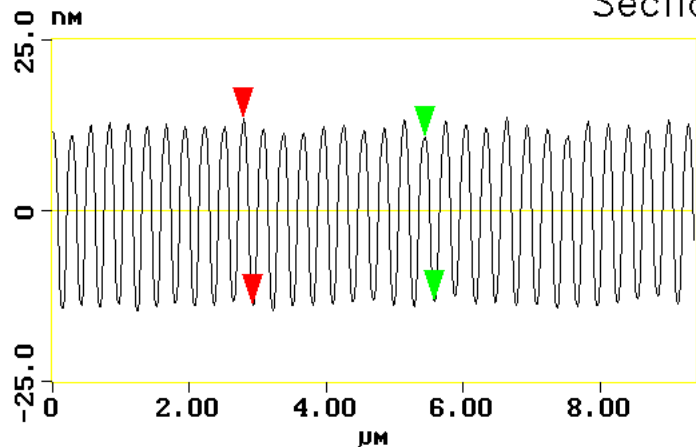
an average cross-section has much less height variation and the center of a column is at or near the maximum of the profile.



An average cross-section in the 10 μm image would be good for pitch measurements.

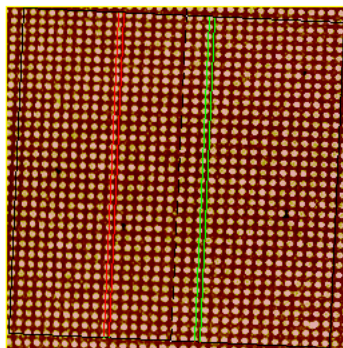
Cursor Marker Spectrum Zoom Center Line Offset Clear

Section Analysis

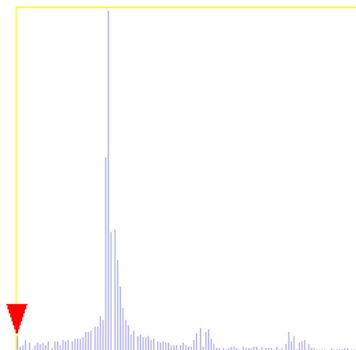


L	136.72 nm
RMS	9.649 nm
lc	DC
Ra(lc)	1.564 nm
Rmax	6.819 nm
Rz	5.948 nm
Rz Cnt	4
Radius	65.806 nm
Sigma	14.405 nm

Spectrum



300-2D, golden area
am58.005



DC Min

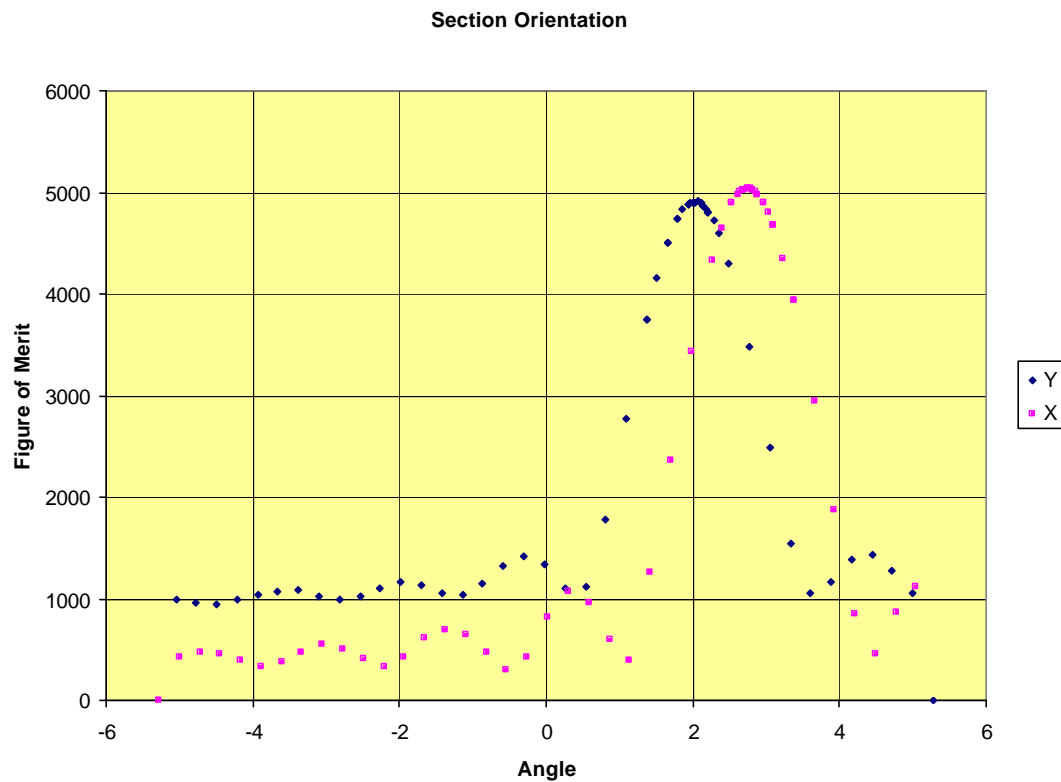
Surface distance	140.50 nm
Horiz distance(L)	136.72 nm
Vert distance	27.327 nm
Angle	11.303 deg
Surface distance	139.87 nm
Horiz distance	136.72 nm
Vert distance	24.016 nm
Angle	9.963 deg
Surface distance	
Horiz distance	
Vert distance	
Angle	
Spectral period	
Spectral freq	
Spectral RMS amp	

Cursor: average Zoom: 2:1 Cen line: Off Offset: Off

Make average cross-sections by an automated procedure free of operator error.

- Use ASM's Autoskew rev7.exe to automatically compute best averaging direction of X and Y section profiles
- “X” means the section direction is approximately parallel to the X axis.
- The analysis shows non-orthogonality of 0.7 degrees – not a surprise. We did nothing to measure or correct for AFM drift.

Section Orientation and non-orthogonality of image (we did not measure or correct for drift)



2.749	degrees	X section
2.074	degrees	Y section
0.674	degrees non-orthogonality	



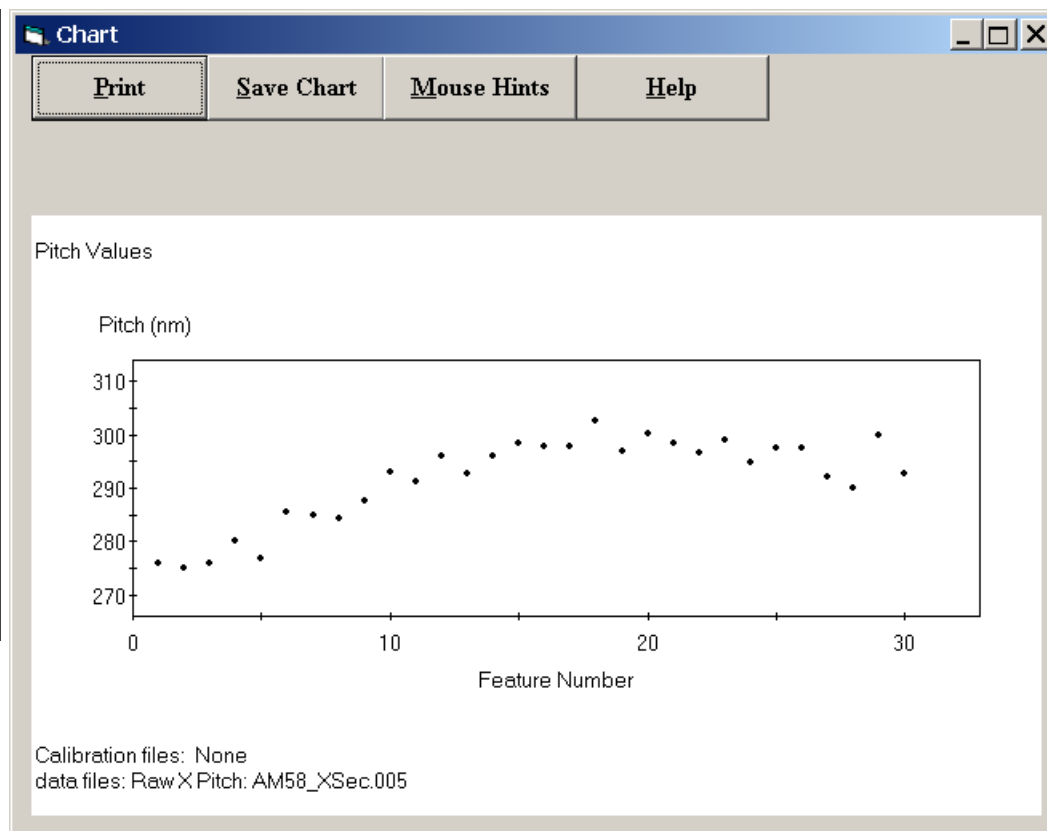
Pitch Analysis

- Use ASM's DiscTrack Plus software
- We first present raw pitch measurements for average cross-sections from the 10 um image. The standard deviation is large because of systematic effects: residual nonlinearity in the AFM scanner.
- We then present self-calibrated pitch results. These amount to an offline correction of the AFM's nonlinearity.
- The standard deviation indicates residual error that may be related to AFM noise, pattern error, pattern feature roughness, etc.

Raw Pitch Results

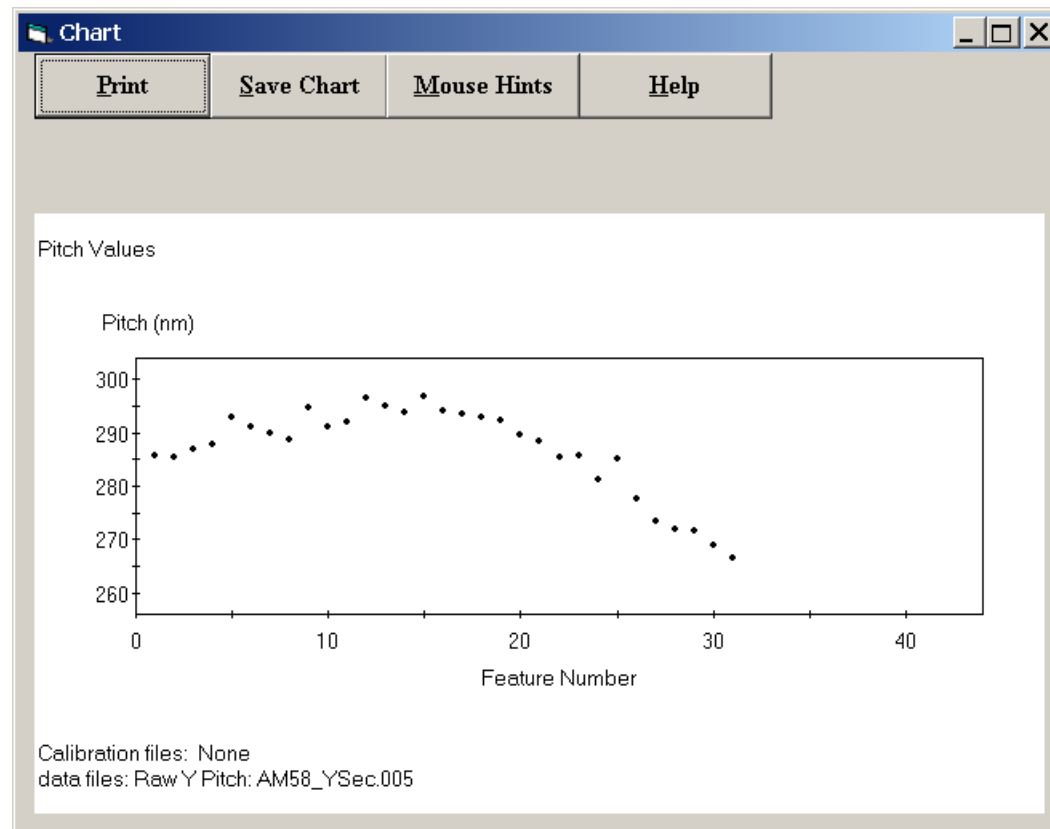
DiscTrack Plus raw Pitch analysis of X average cross-section profile of 10 um image

Pitch Results		
<div>Save Results Display Graph Print Sheet</div>		
B2	30	
	A	B
1		Pitch (nm)
2	Count	30
3	Sum	8746.90
4	Mean	291.56
5	Standard Deviation	8.20
6	Standard Error of Mean	1.50
7	Maximum	302.60
8	Minimum	274.90
9	Range	27.70
10		
11		
Statistical Summary		



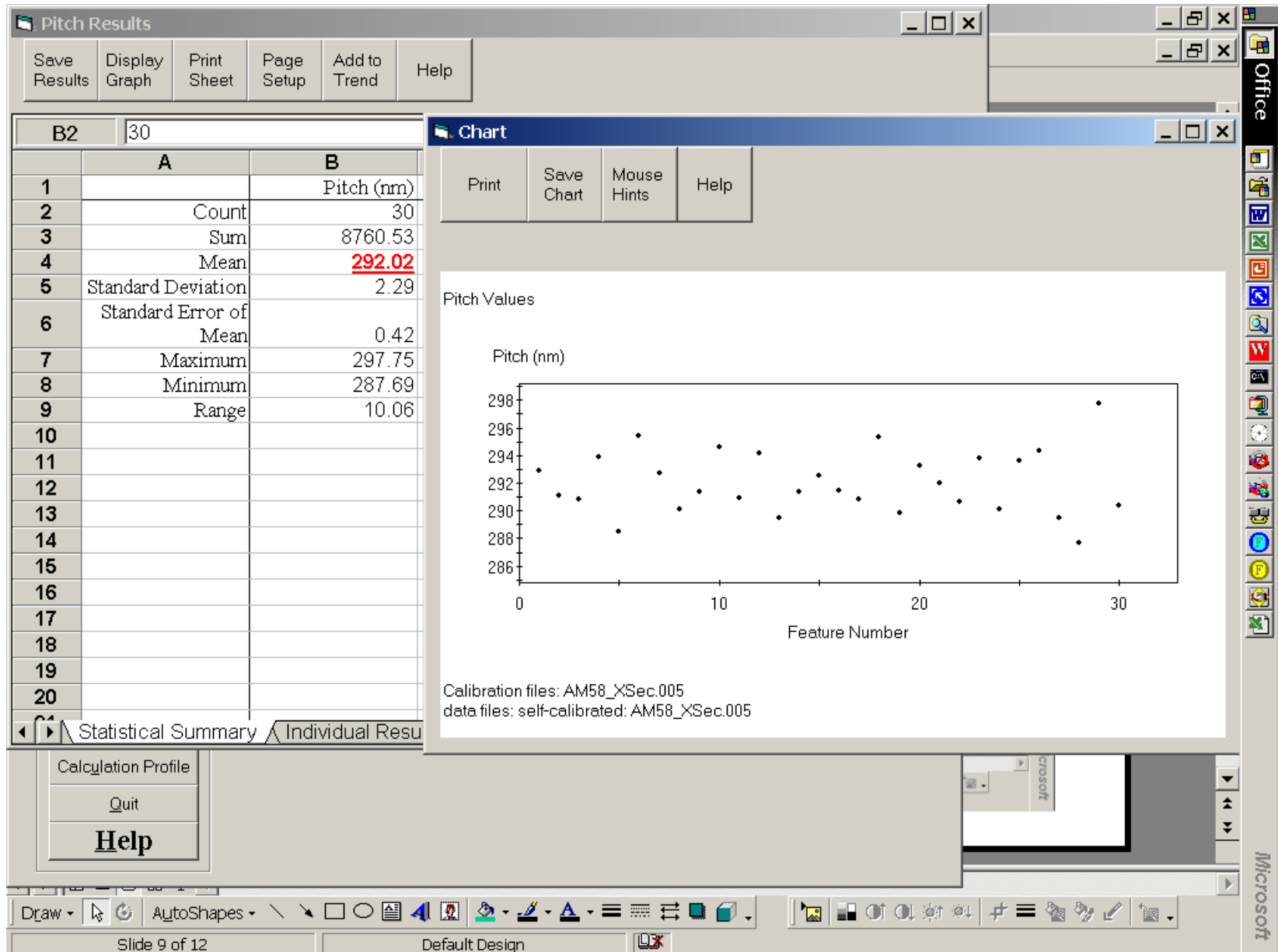
DiscTrack Plus raw Pitch analysis of Y average cross-section profile of 10 um image

Pitch Results		
<div>Save Results Display Graph Print Sheet</div>		
B2	31	
	A	B
1		Pitch (nm)
2	Count	31
3	Sum	8886.88
4	Mean	<u>286.67</u>
5	Standard Deviation	8.47
6	Standard Error of Mean	1.52
7	Maximum	296.66
8	Minimum	266.52
9	Range	30.13
10		
11		
Statistical Summary		

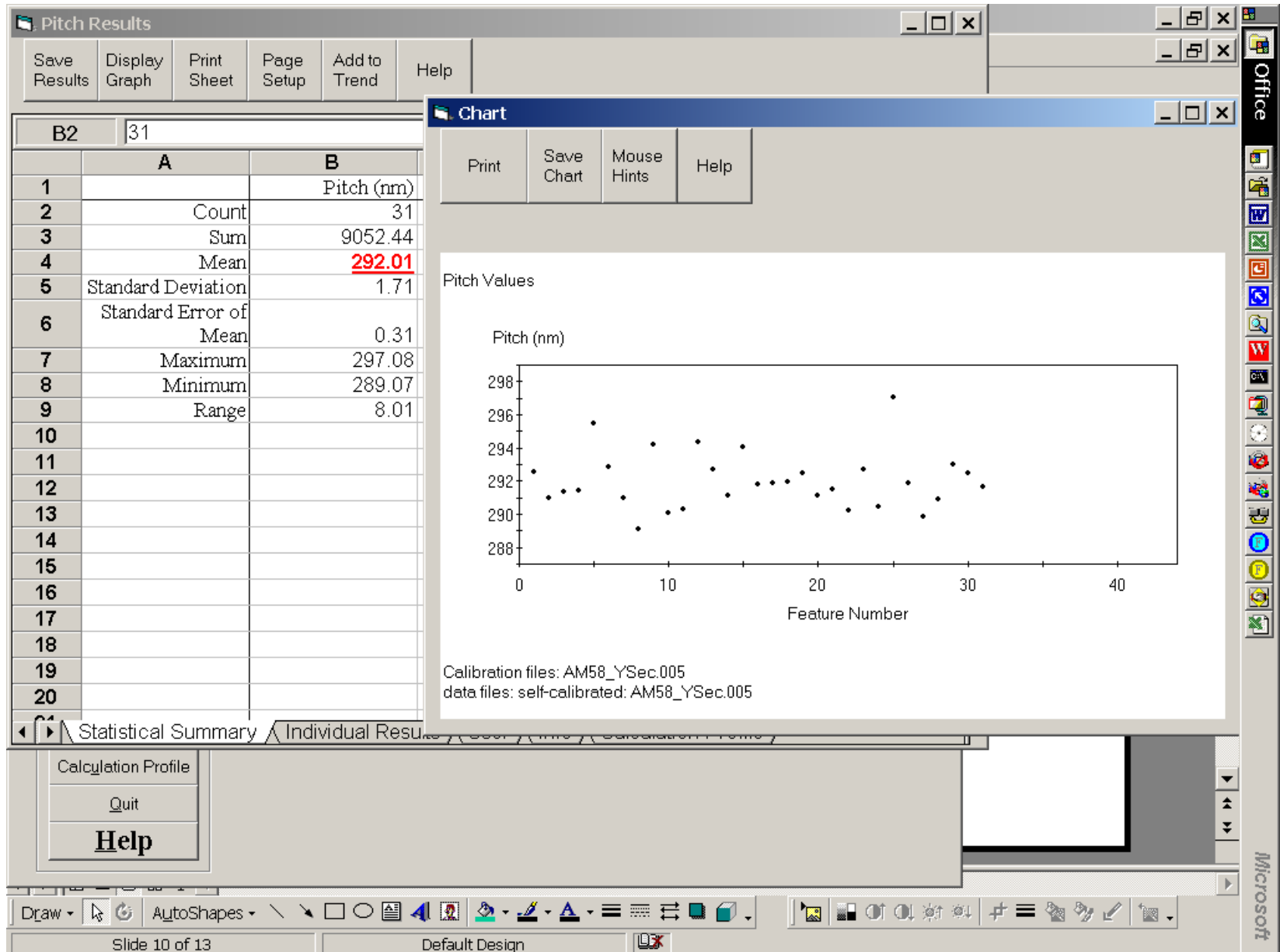


Self-Calibrated Pitch Results

DiscTrack Plus Self-calibrated Pitch analysis of X average cross-section profile of 10 um image



DiscTrack Plus Self-calibrated Pitch analysis of Y average cross-section profile of 10 um image



Further Reading

- "Automated, high precision measurement of critical dimensions using the Atomic Force Microscope", Donald A. Chernoff and David L. Burkhead, J. Vac. Sci. Technol. A 17, 1457 (1999).
- "High precision calibration and feature measurement system for a scanning probe microscope", Donald A. Chernoff and Jason D. Lohr, U.S. Patent # 5,644,512, issued July 1, 1997.
- "High precision calibration and feature measurement system for a scanning probe microscope", Donald A. Chernoff and Jason D. Lohr, U.S. Patent # 5,825,670, issued October 20, 1998.