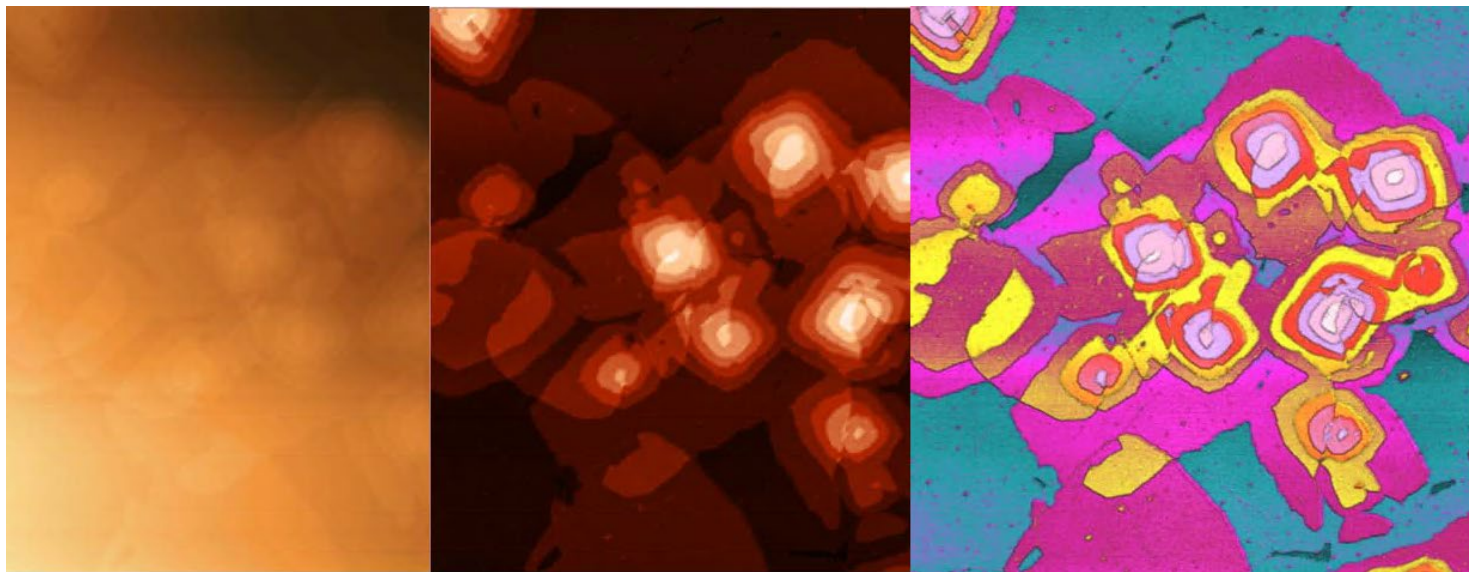# NT-MDT
Spectrum Instruments
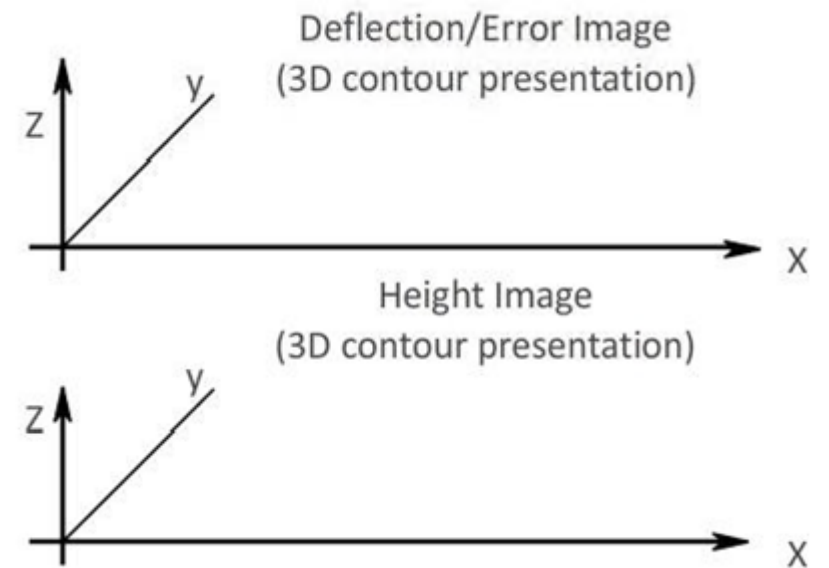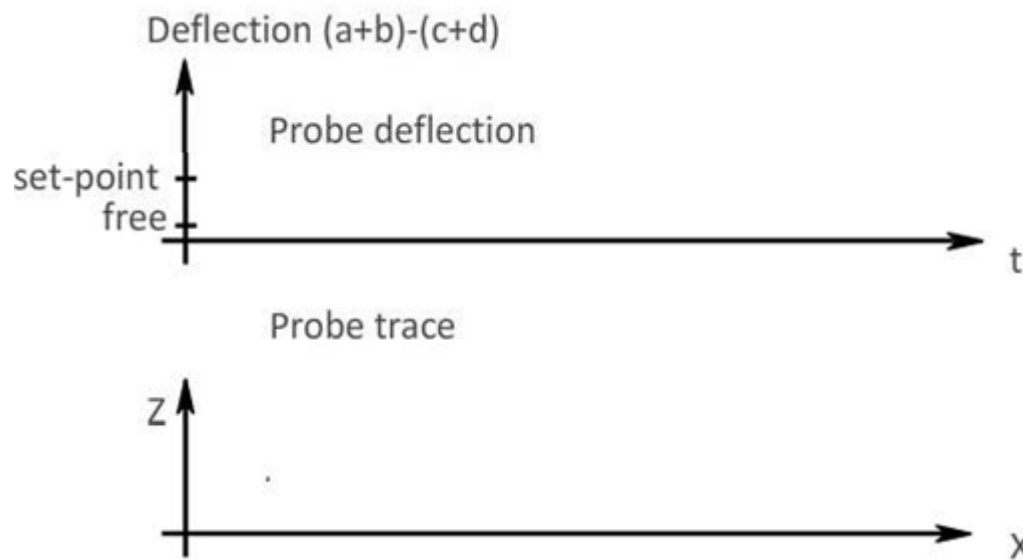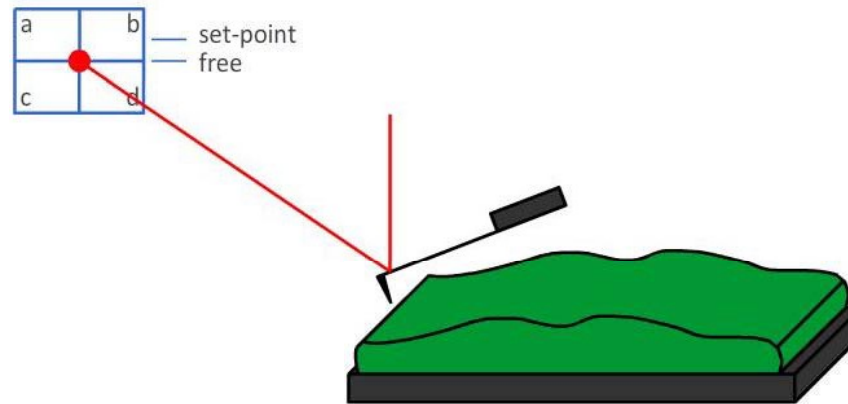
Image Processing and Representation
in Atomic Force Microscopy
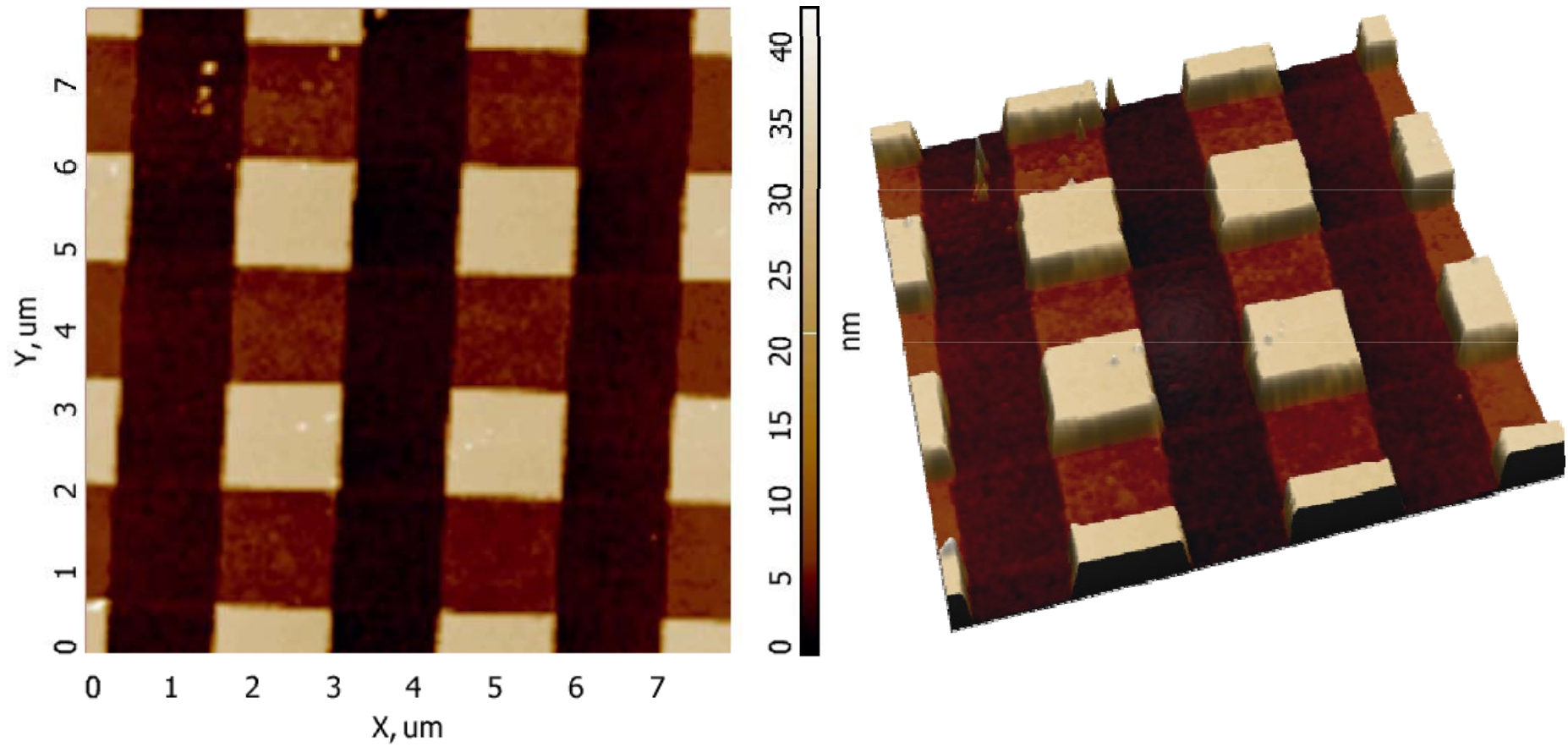
Webinar Summary

How AFM Images are Acquired?

What Does AFM Image Mean

Flattening

Surface Slope
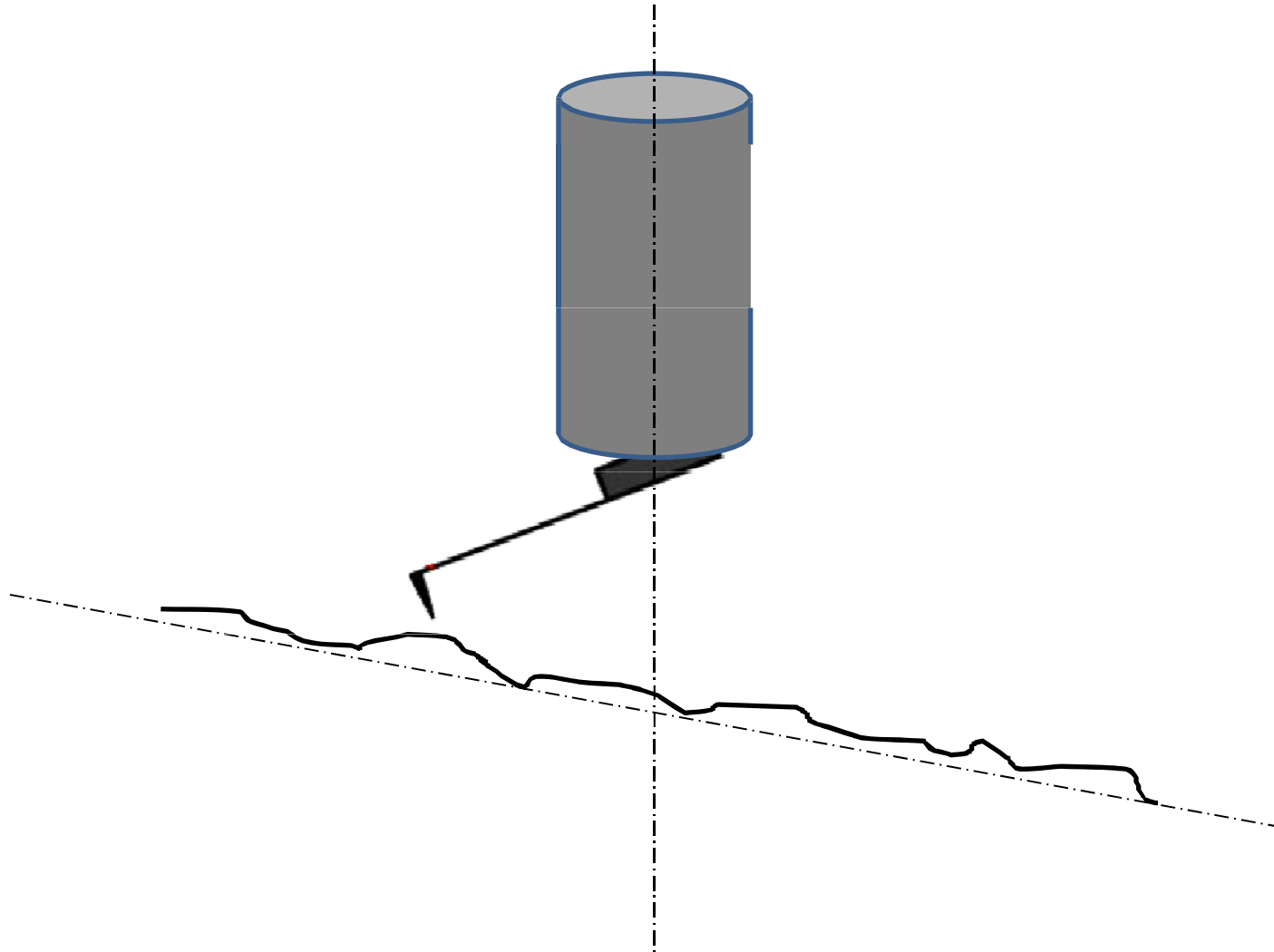
Surface Slope
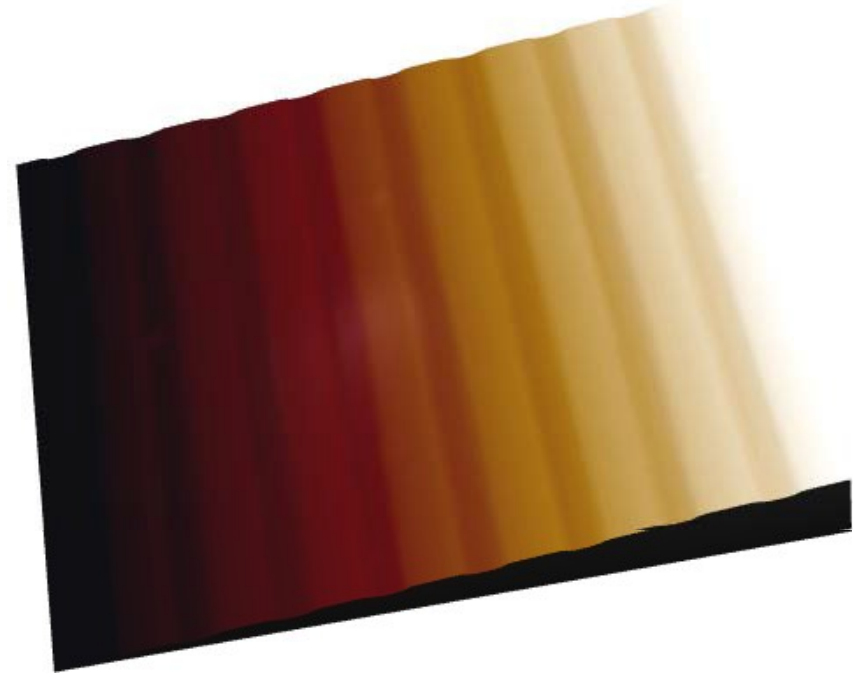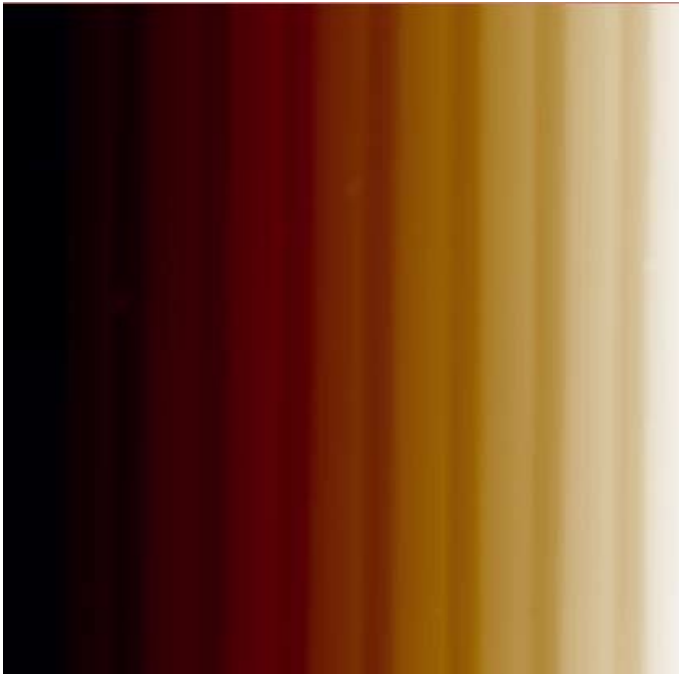
Slope Subtraction
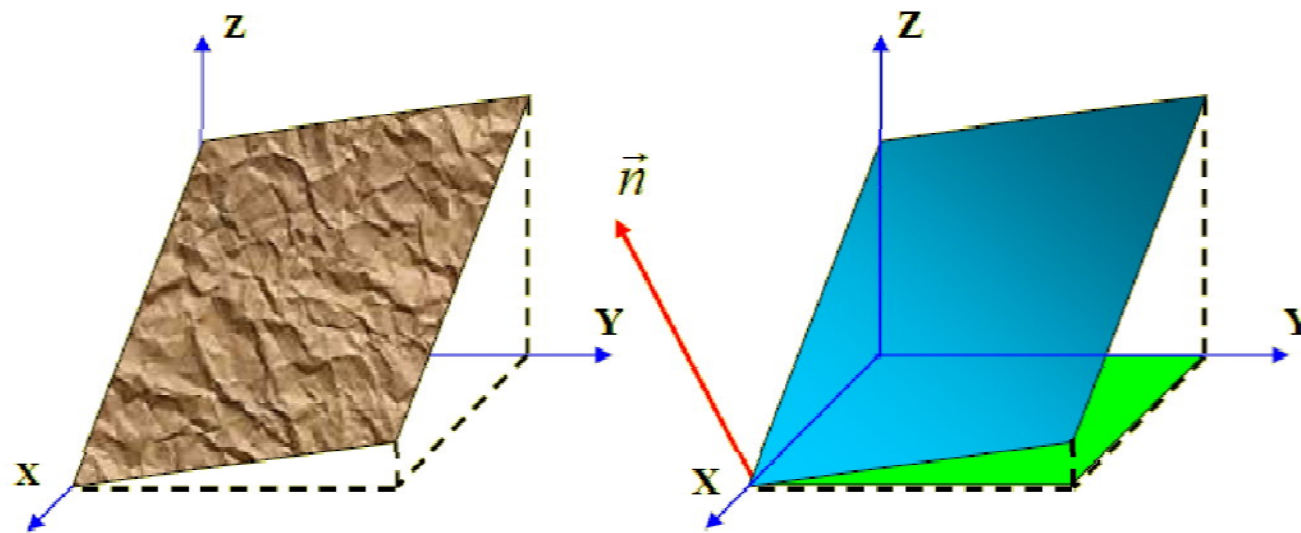
$$Ax + By + Cz + D = 0$$
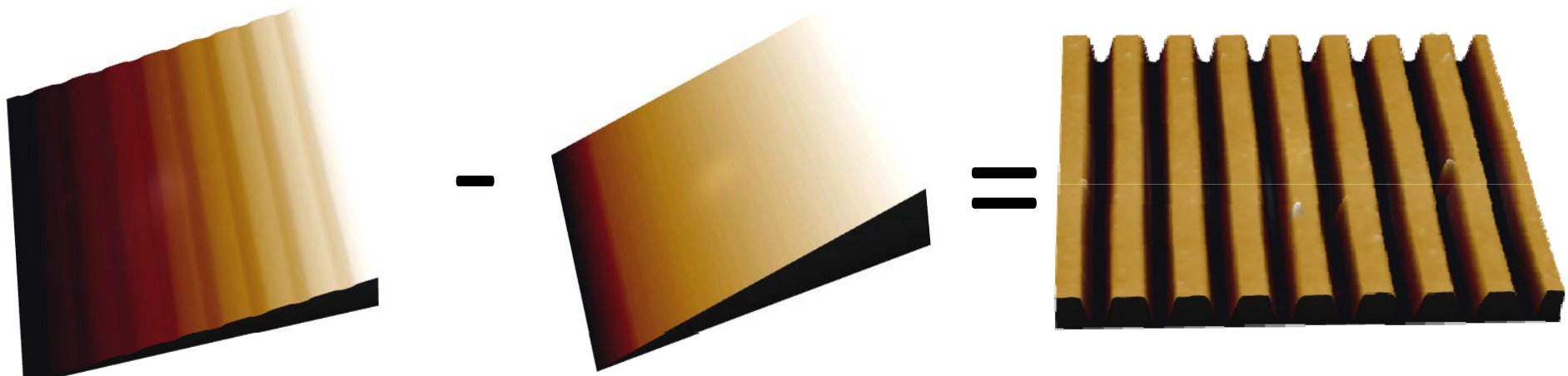
Bow
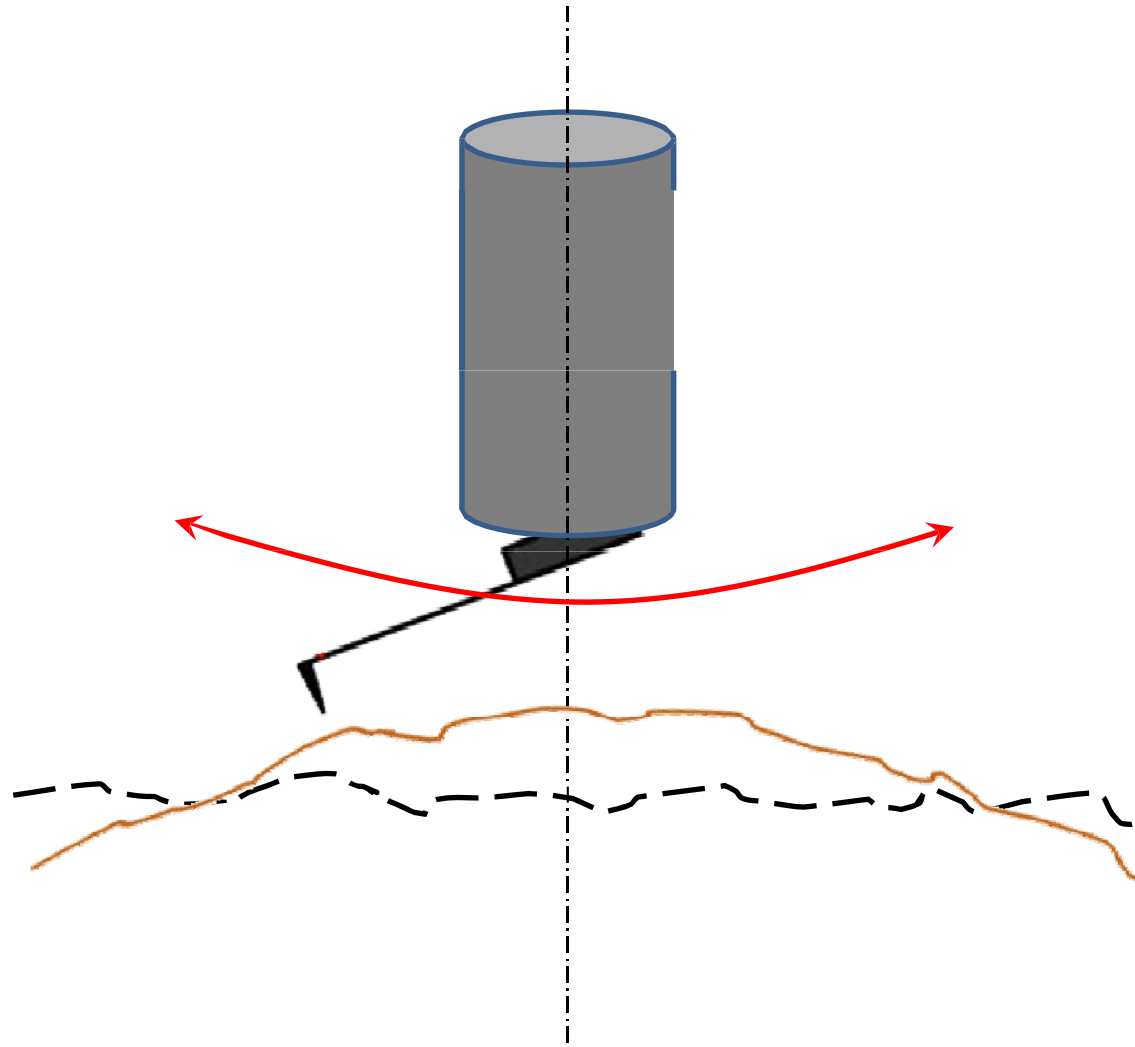
Bow
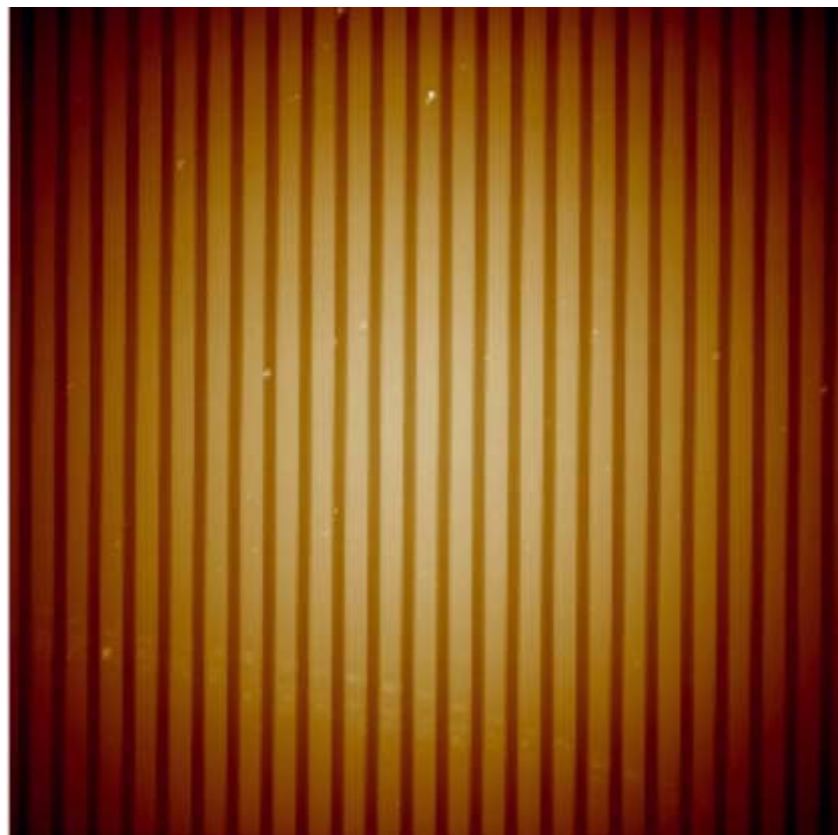
2-nd Order Subtraction
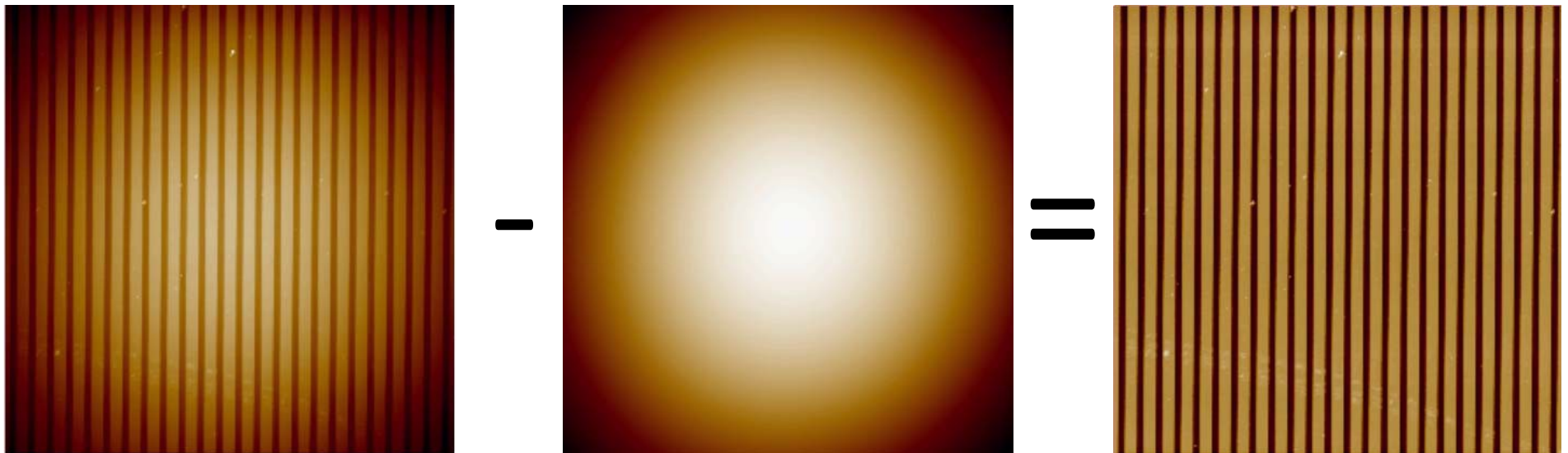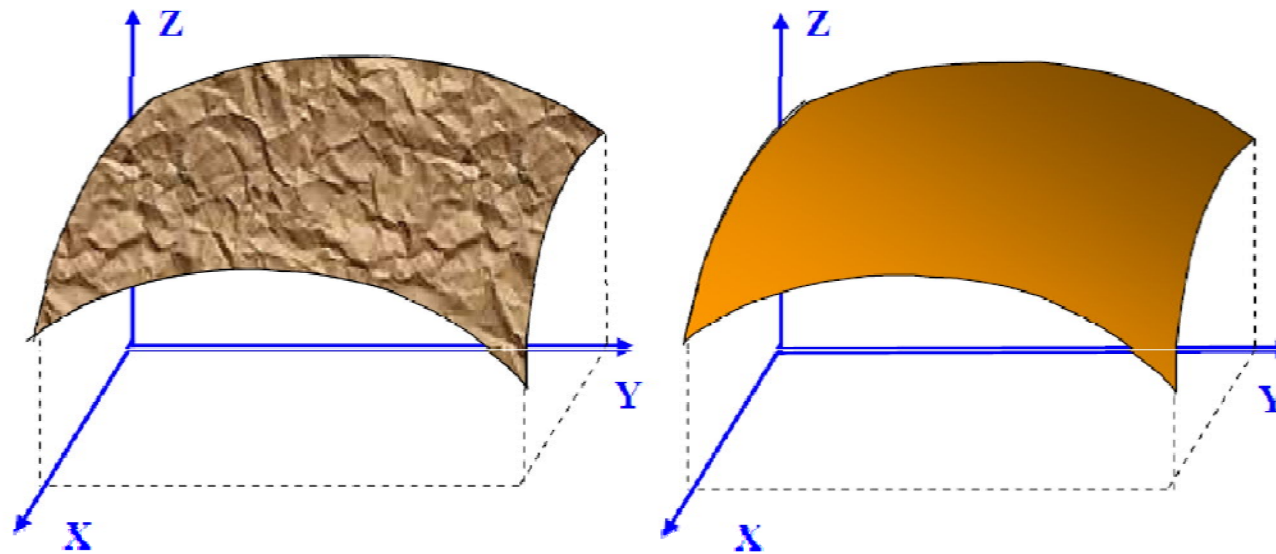
Interline Jumps
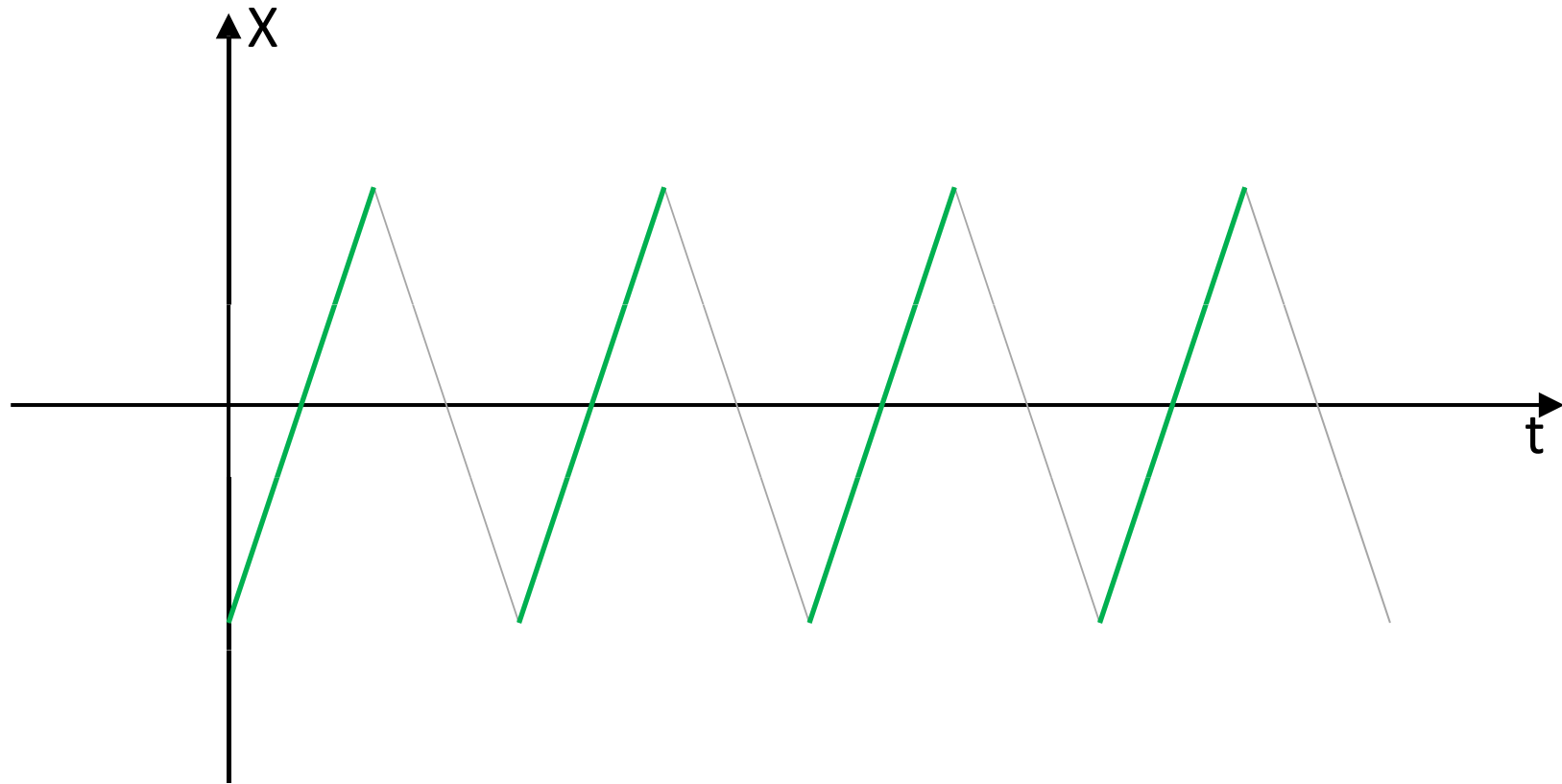
Interline Jumps
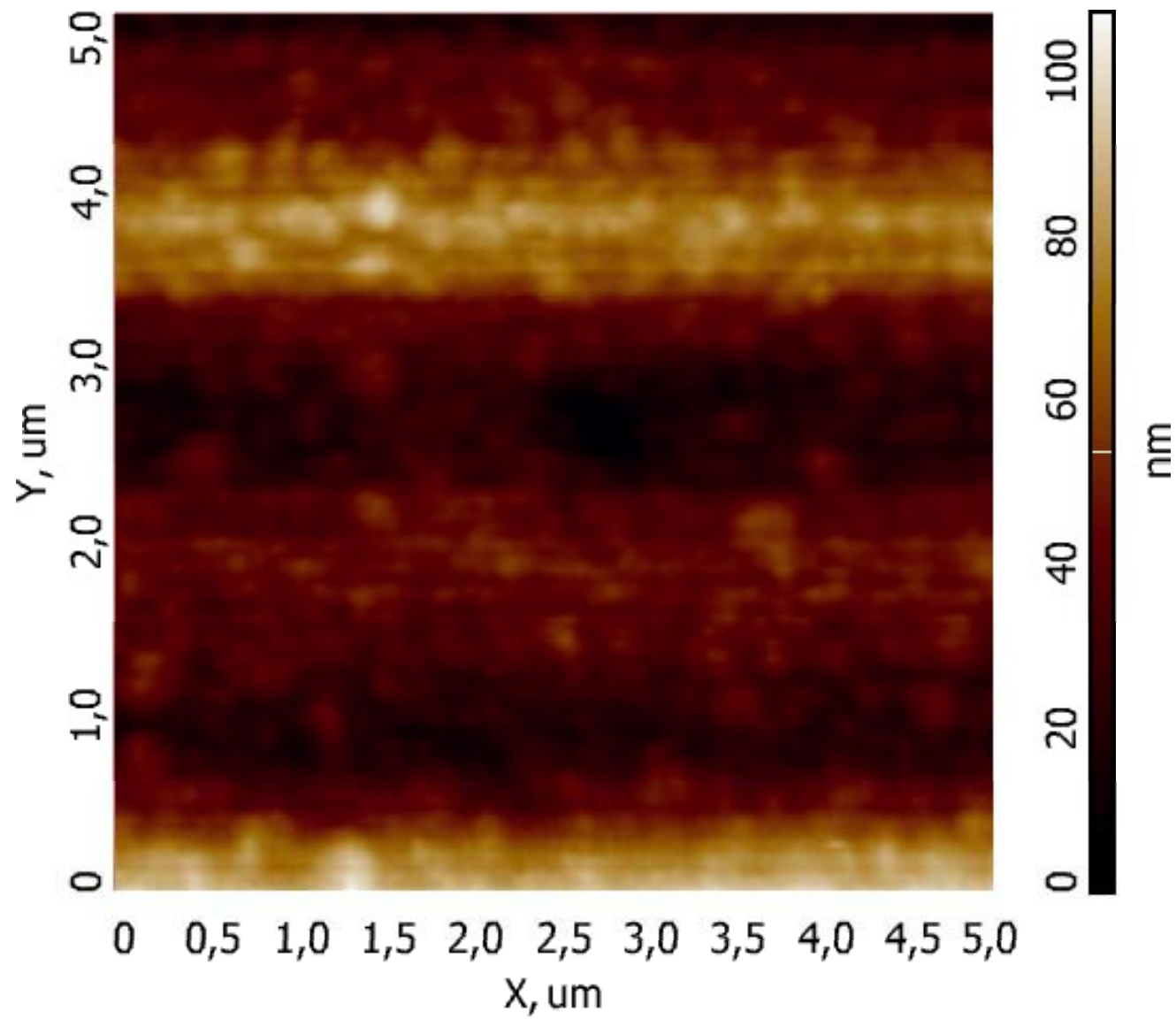
Linear Fitting
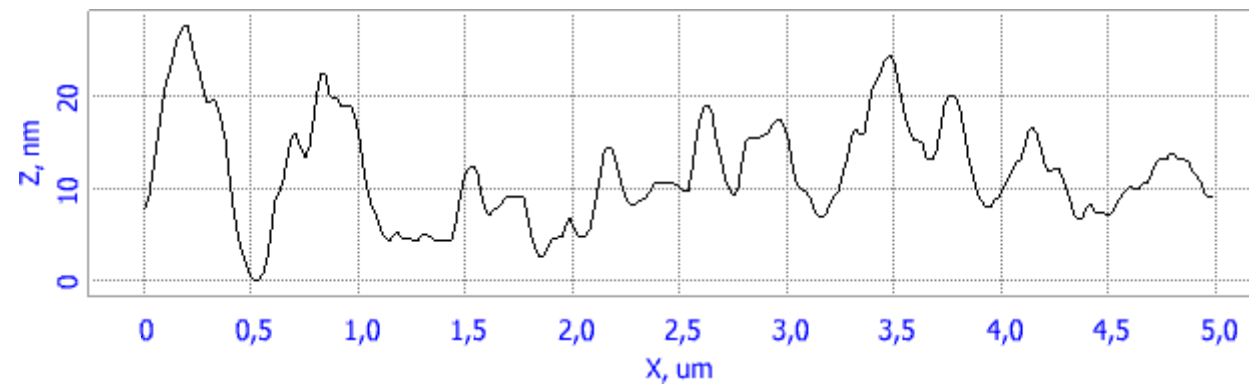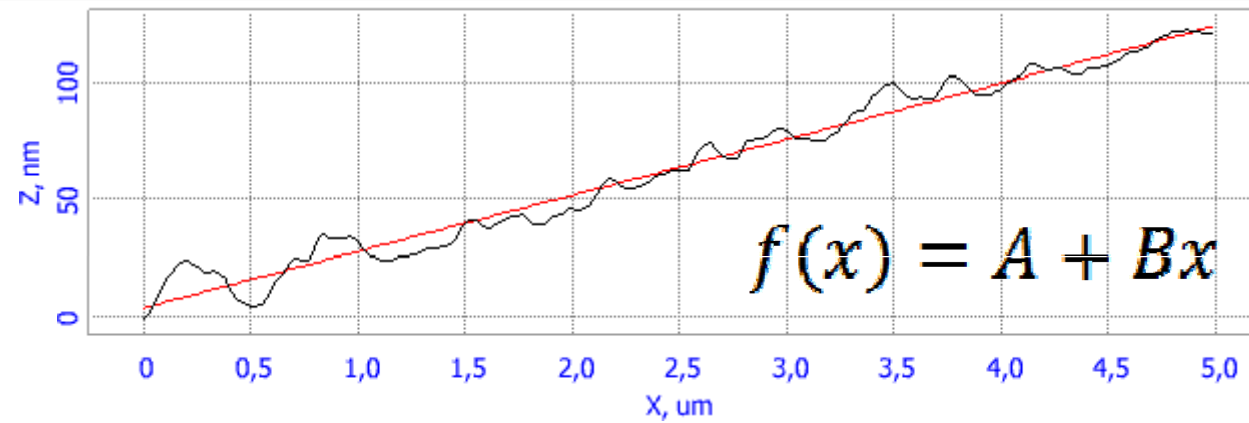
$$f(x) = A + Bx$$

Linear Fitting
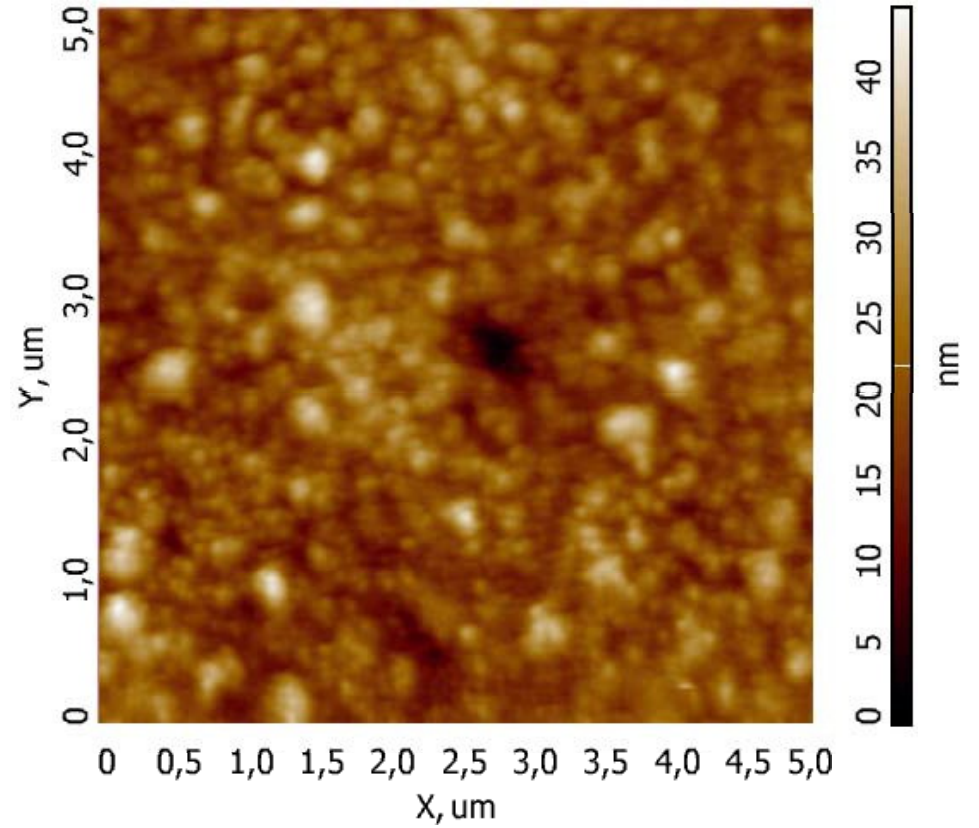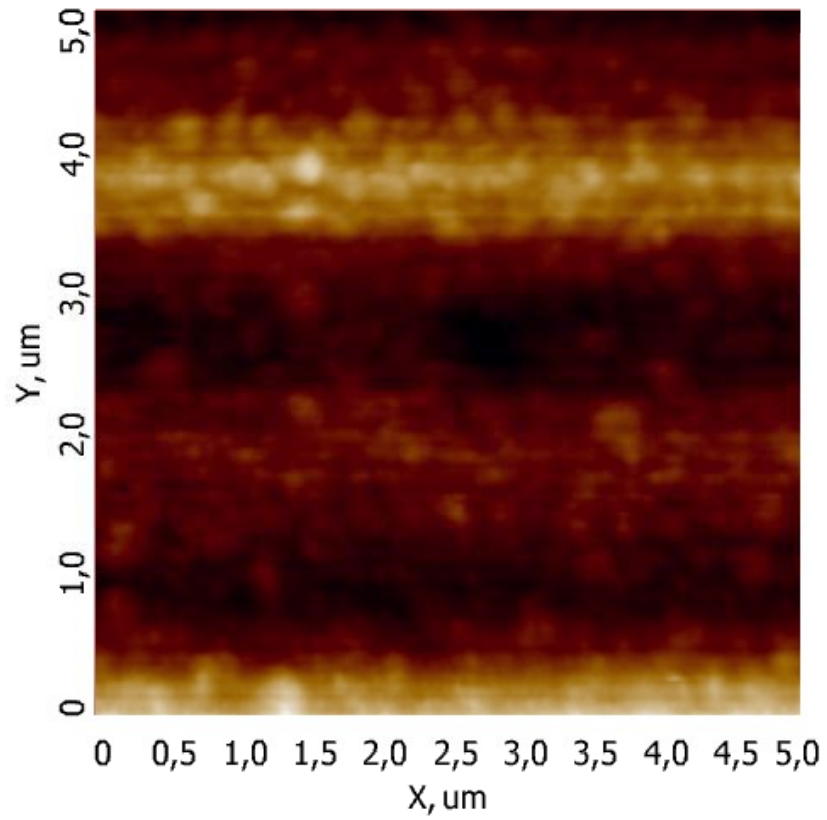
High Objects on Flat Substrate
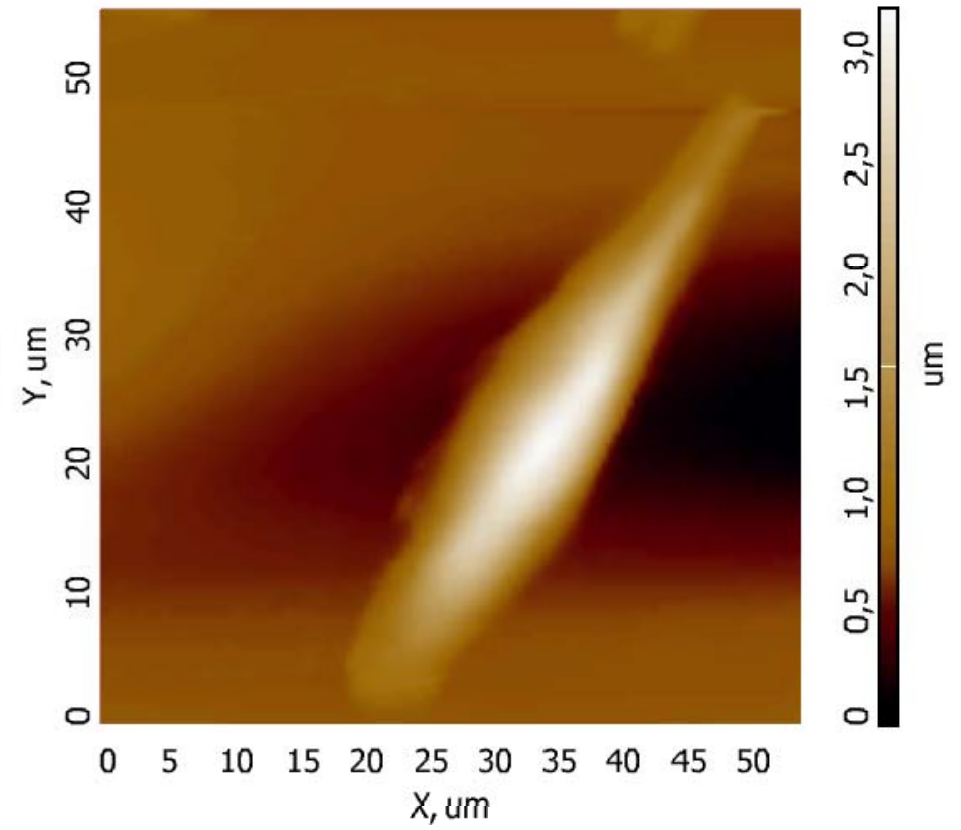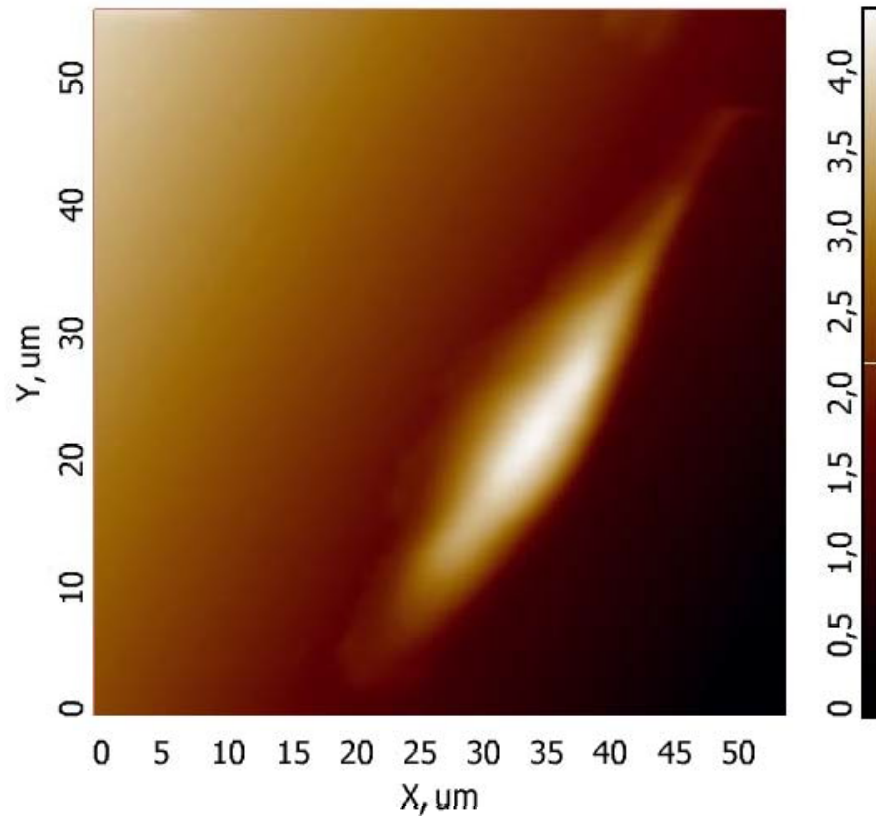
High Objects on Flat Substrate
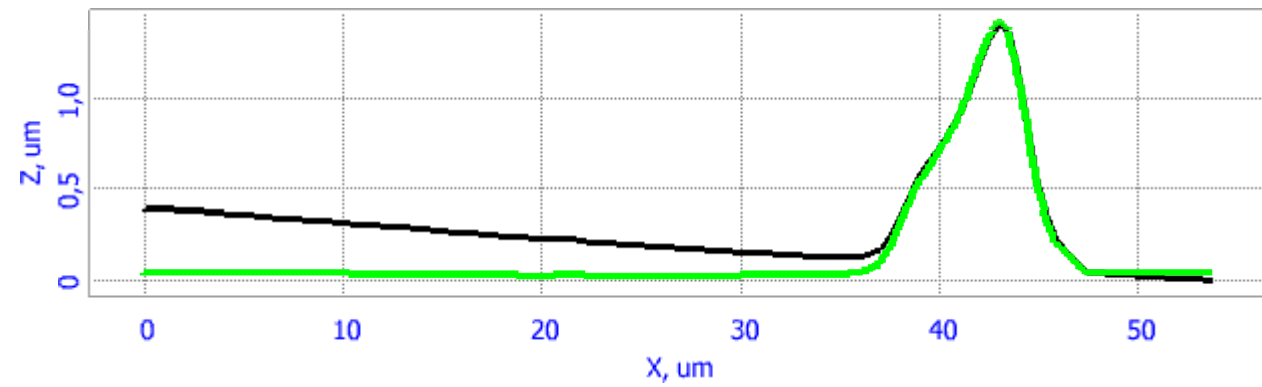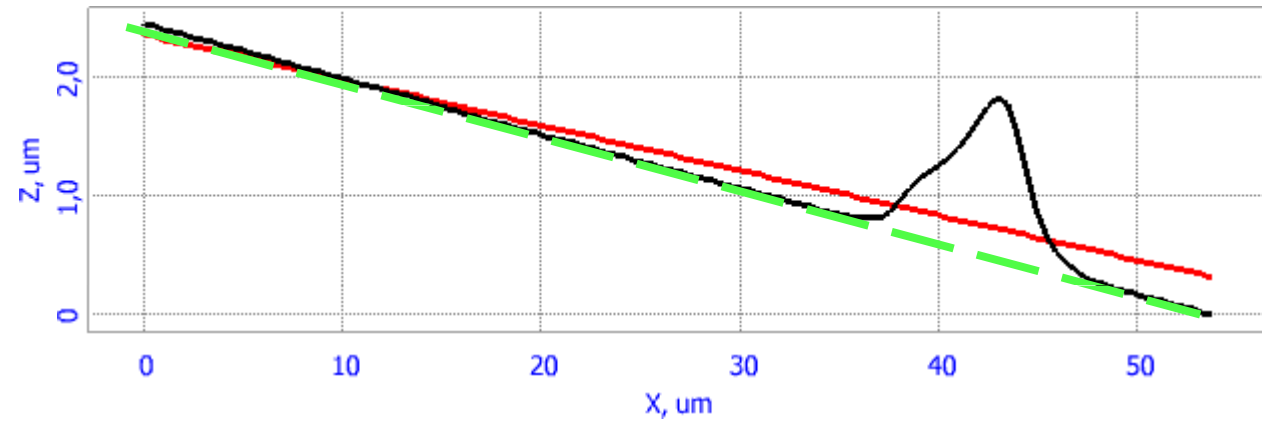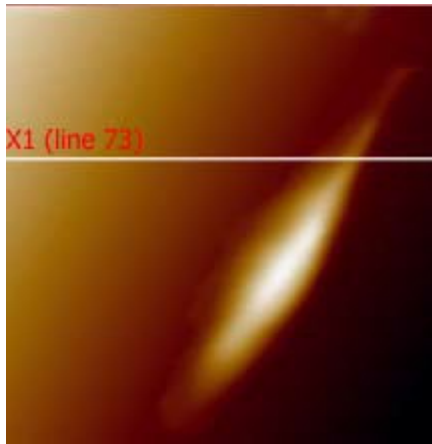
Too High Order
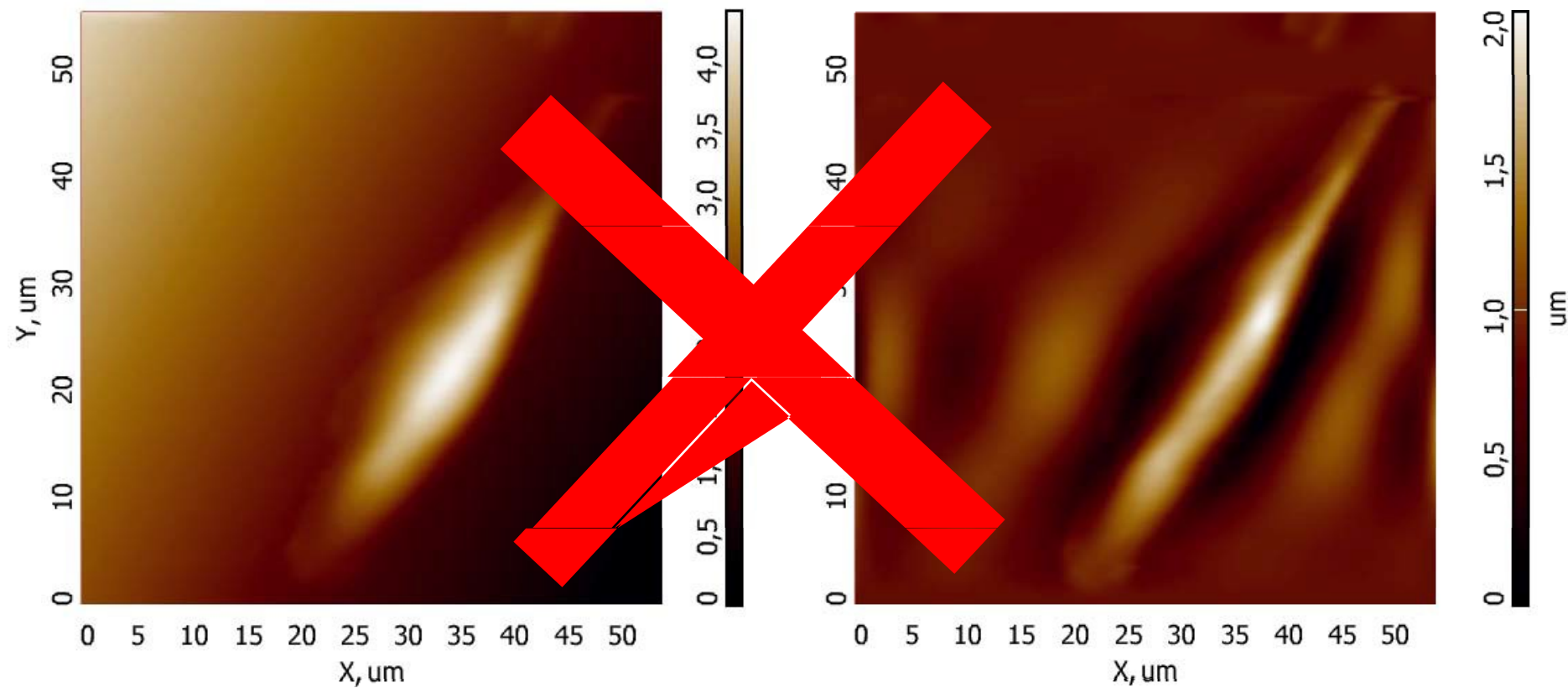
$$f(x) = A + Bx + Cx^2 + Dx^3 + Ex^4 + Fx^5 + Gx^6 + Hx^7$$

Fit Lines by Area
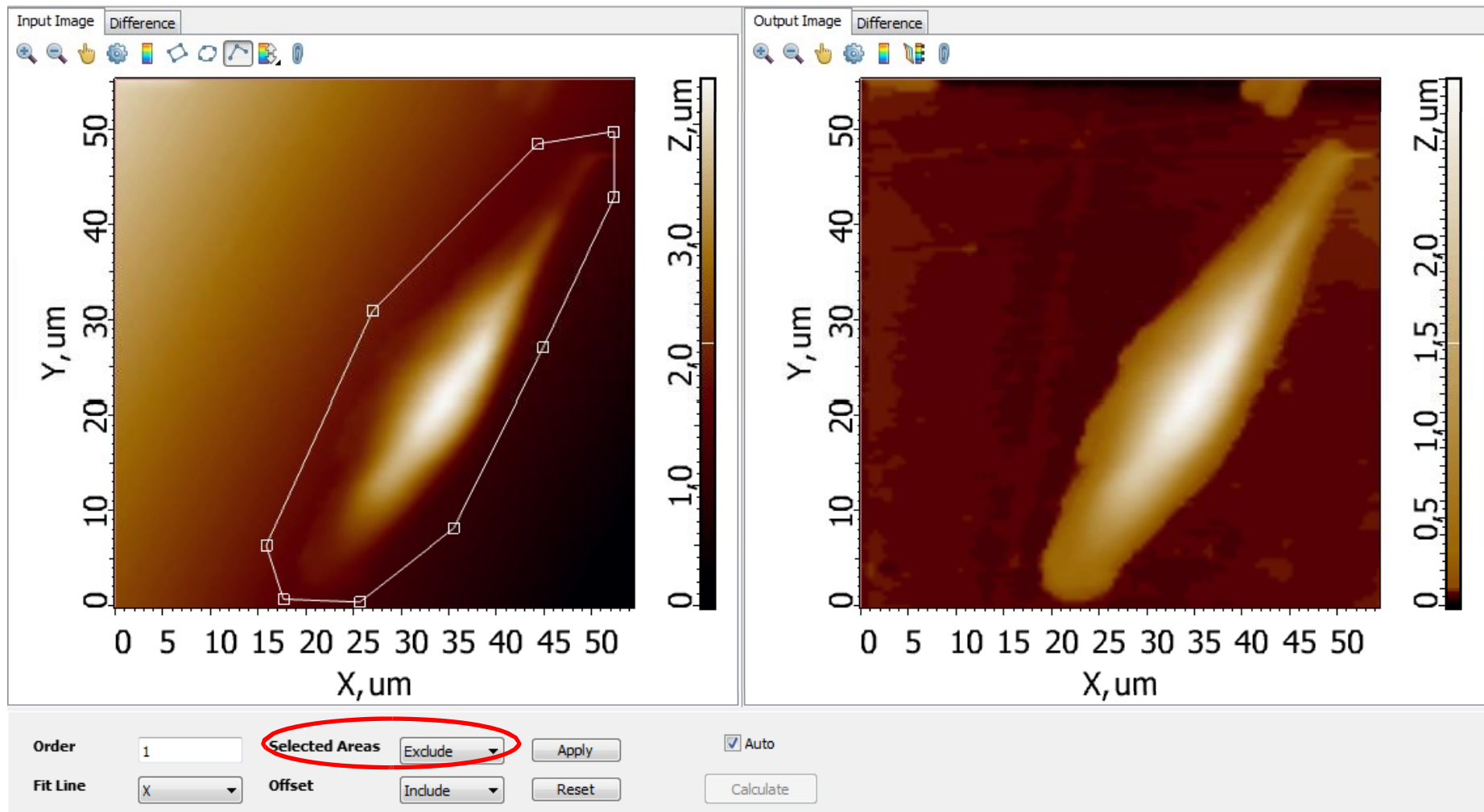
Numerous Objects
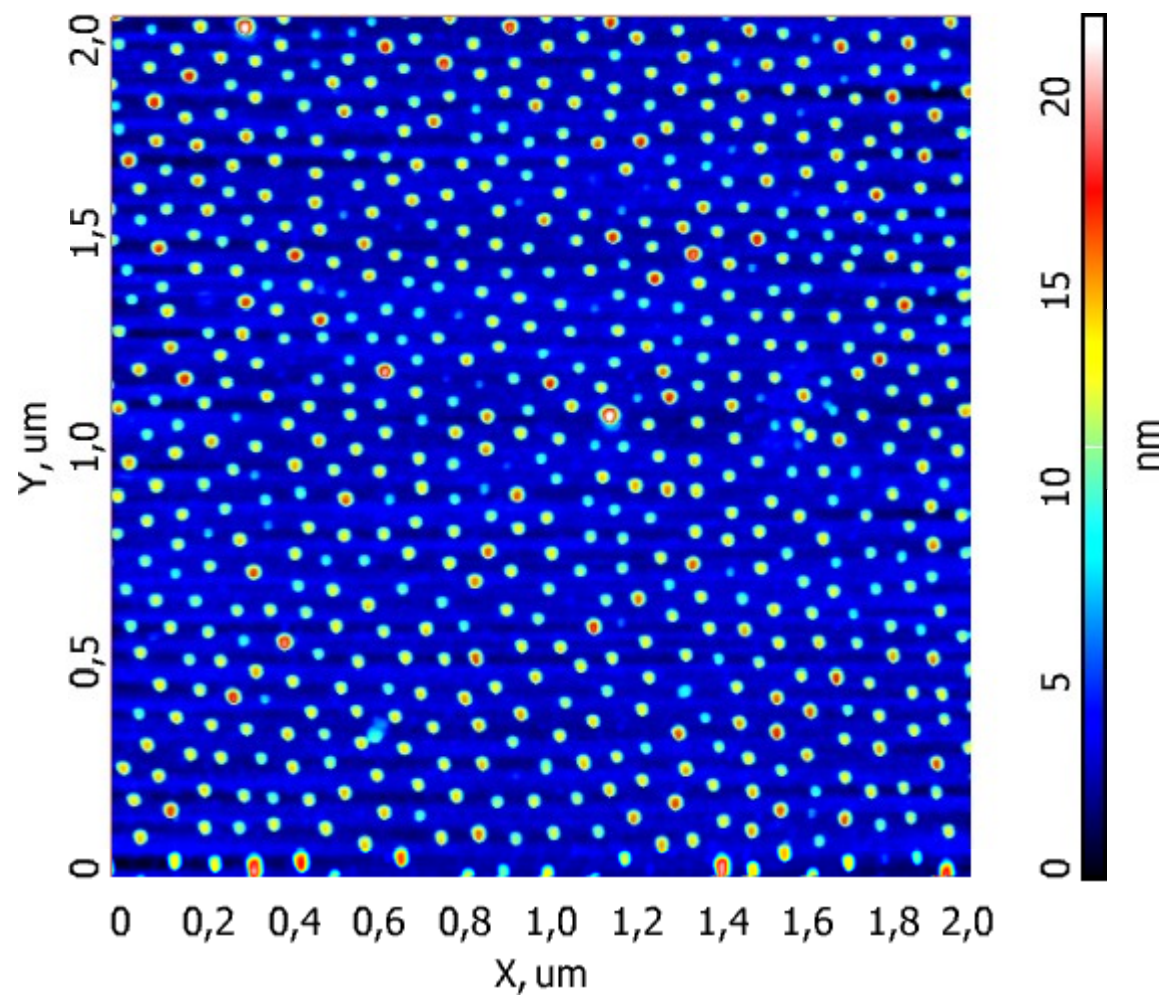
Fit Lines by Histogram
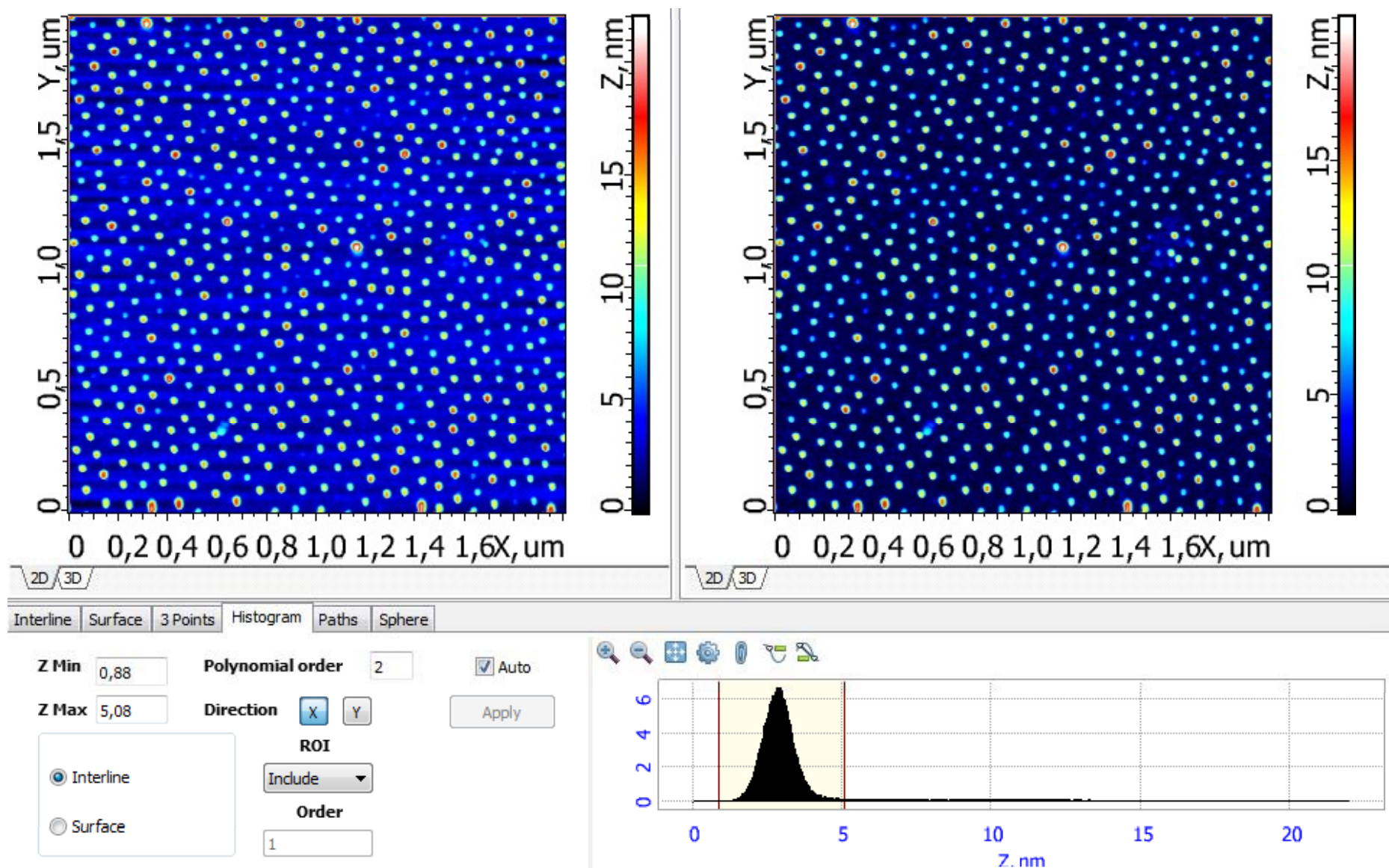
Three Points Leveling

Facet Leveling

$$\nabla f(x) \rightarrow min$$
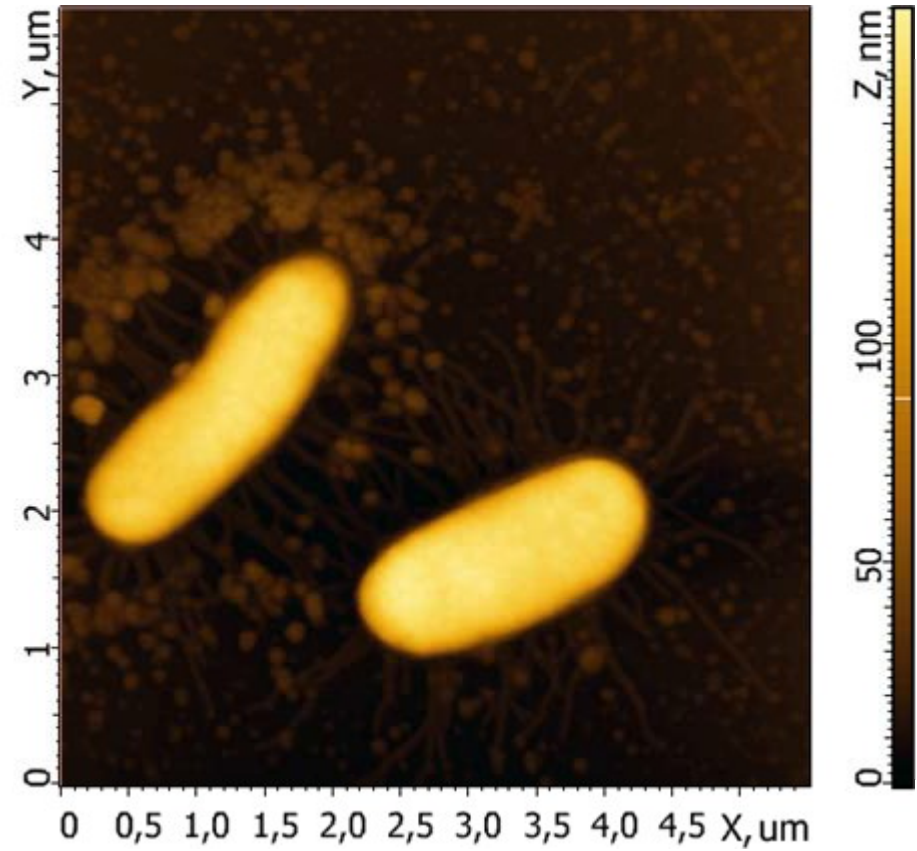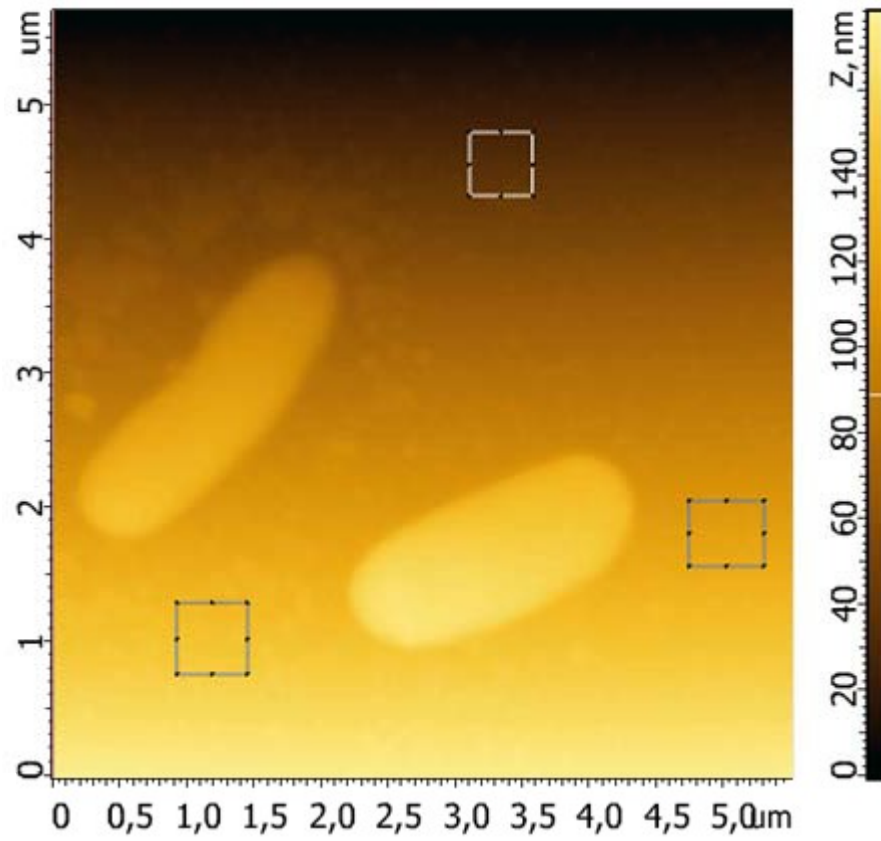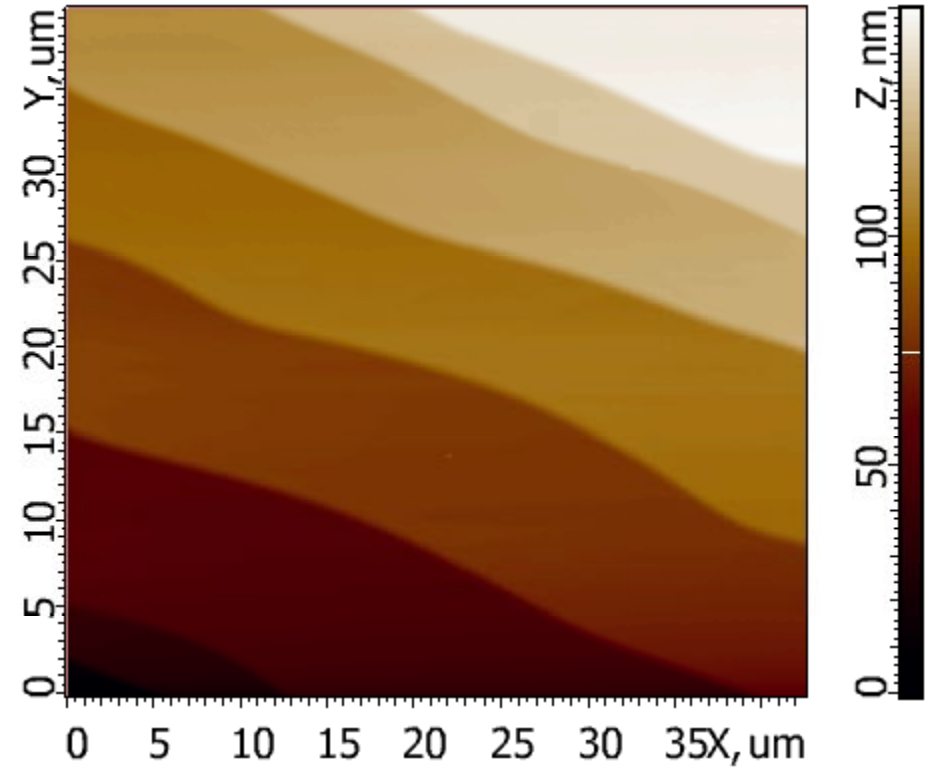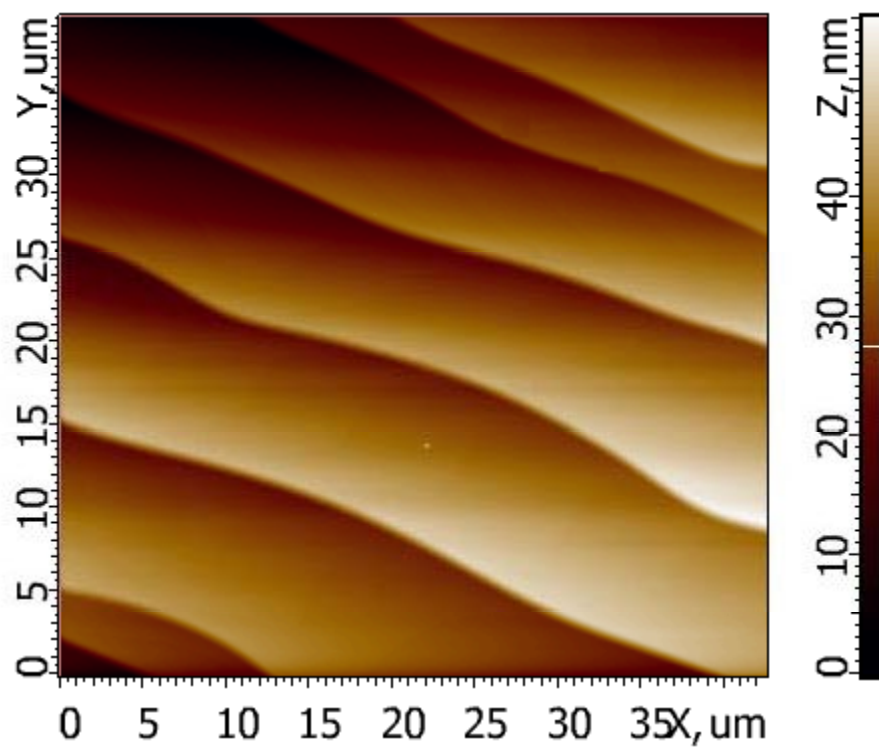
Image Analysis 3.5 GUI
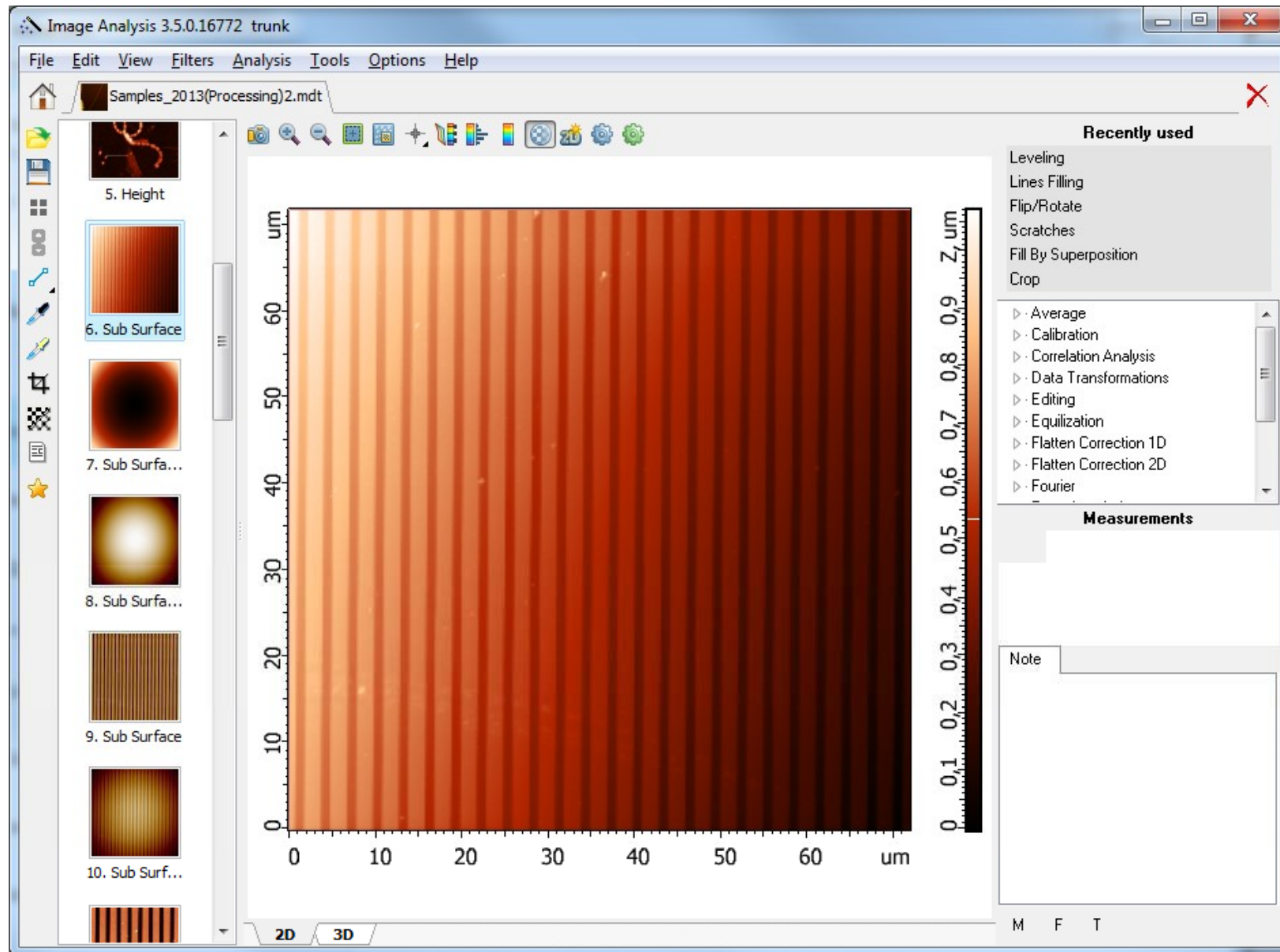
Leveling Module GUI (Leveling->Leveling)
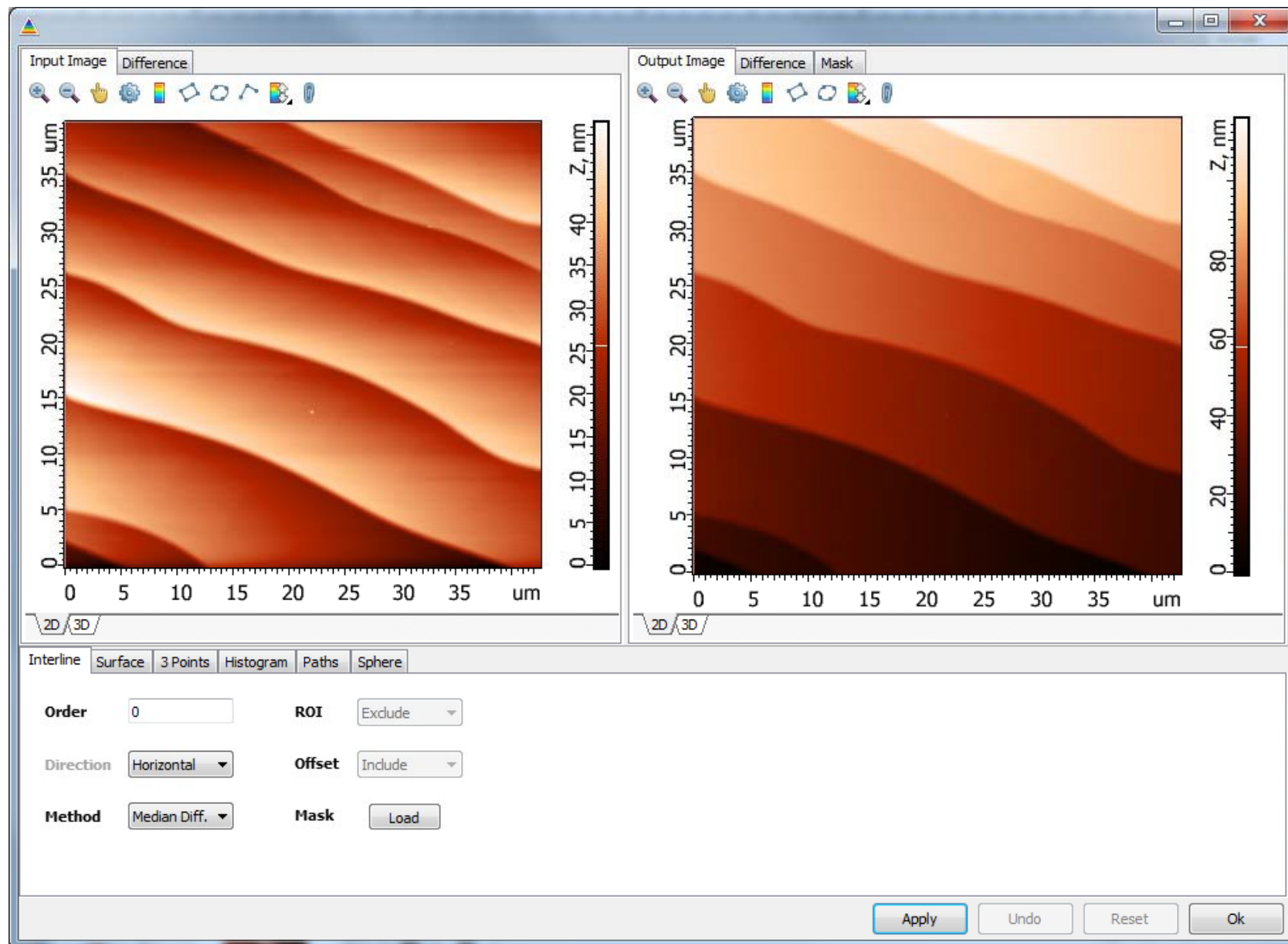
Image Filtration

Spatial Window Filtration

$$G[i,j] = \sum_{u=-k}^{k} \sum_{v=-k}^{k} H[u,v] F[i+u, j+v]$$
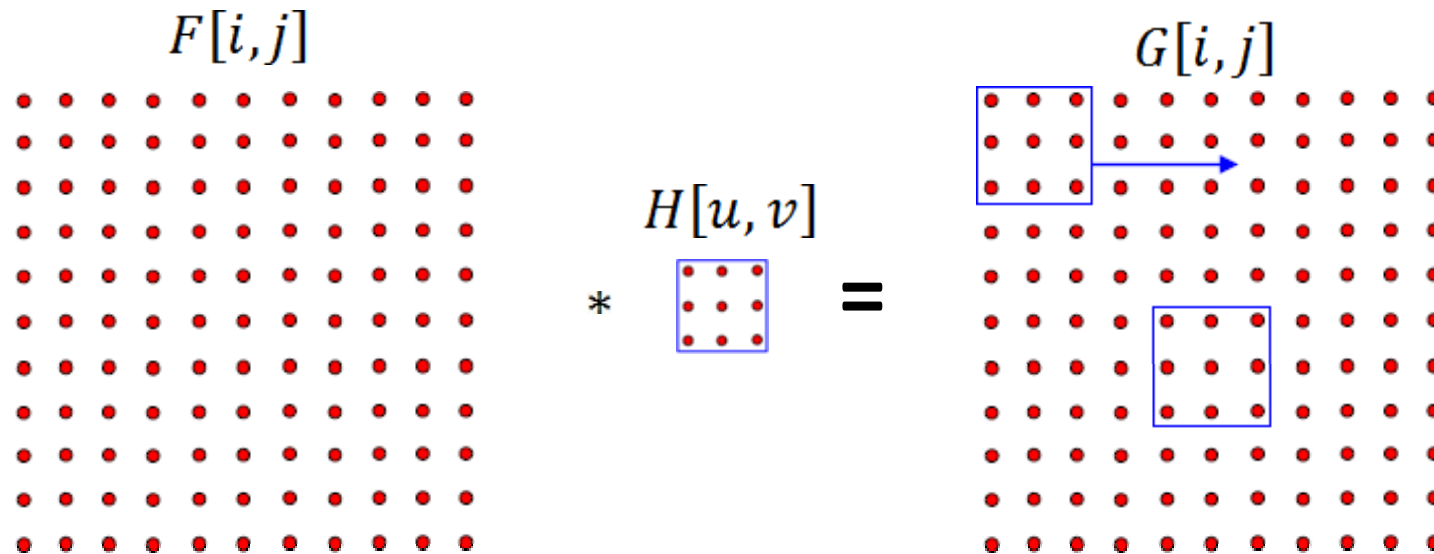
Filter Generator Module GUI

Editing → Filter Generator
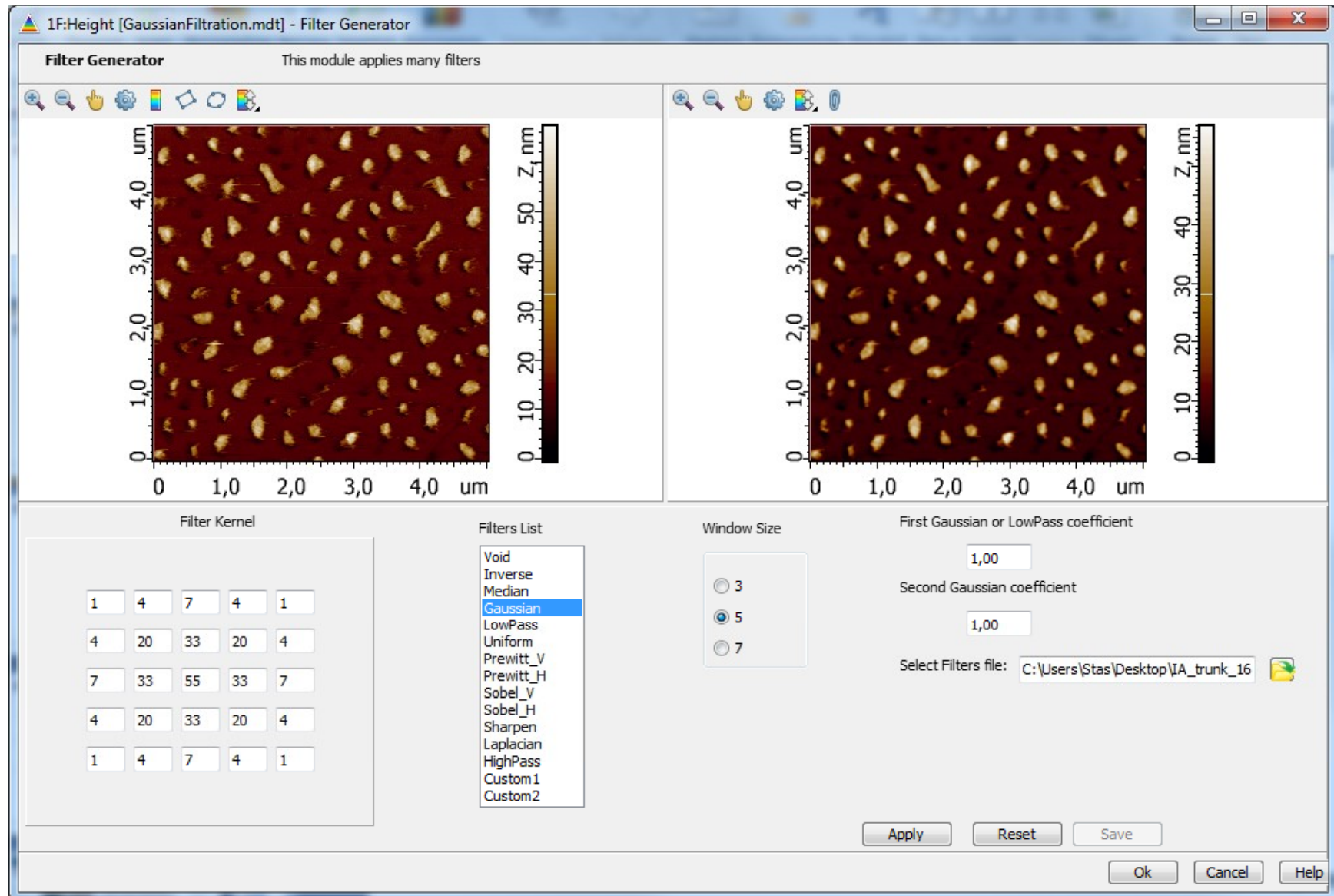
Low-Pass Filtration

$$\left(\frac{1}{9}\right)$$
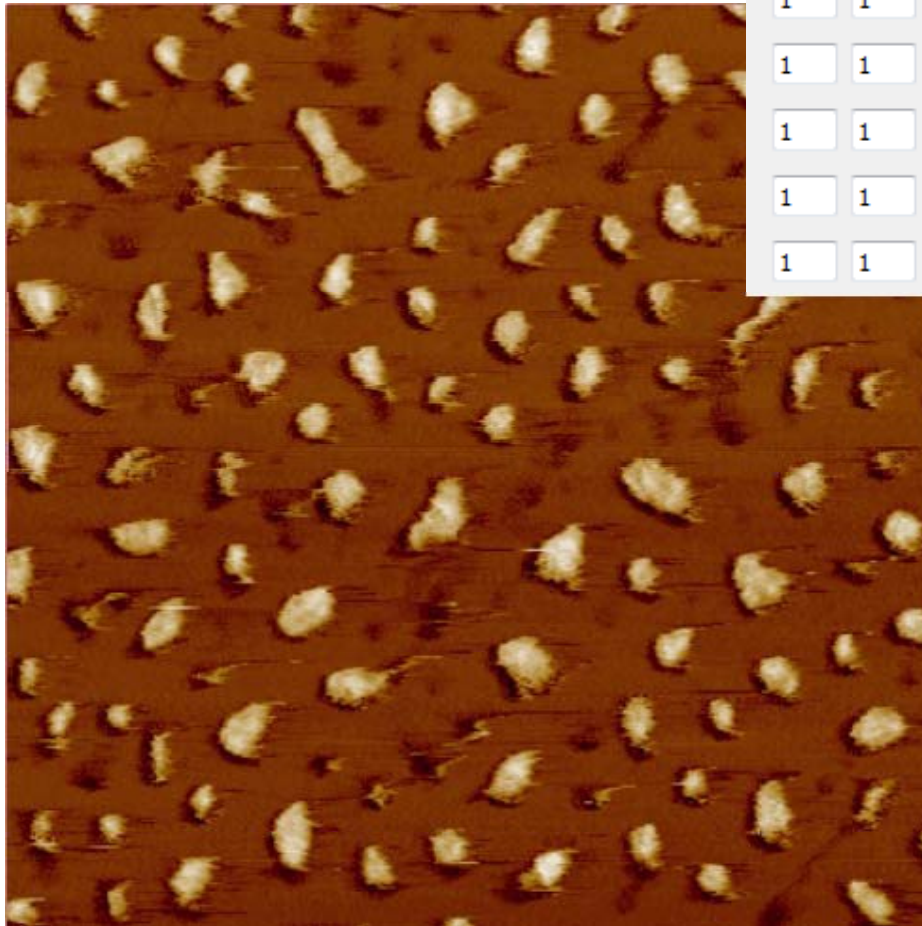
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
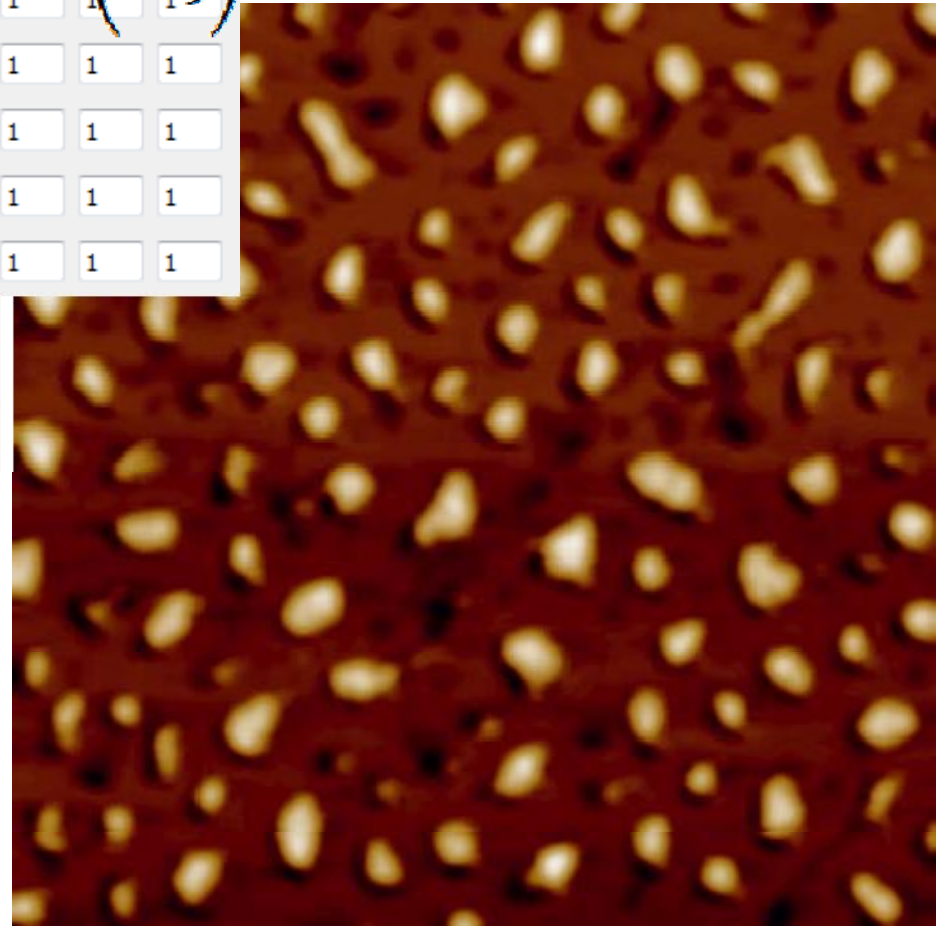
High-Pass Filtration
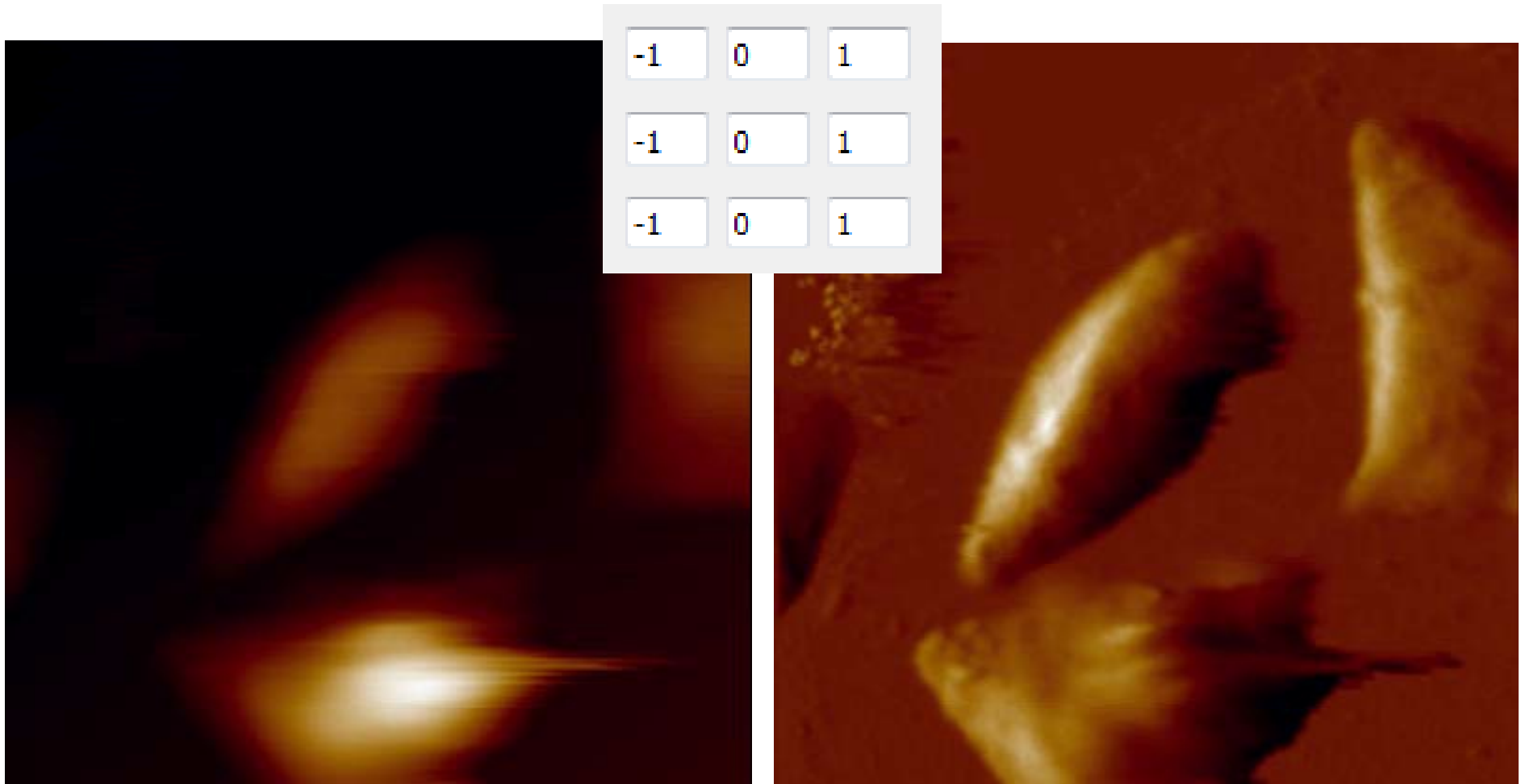
Filter Generator

Uniform
$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Sobel Vertical
$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Gaussian
$$\begin{bmatrix} 1 & 2 & 1 \\ 2 & 3 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

Sobel horisontal
$$\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Prewitt vertical
$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

Laplacian
$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Prewitt horisontal
$$\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

High Pass
$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

Sharpen
$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 16 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

Custom
$$\begin{bmatrix} ? & ? & ? \\ ? & ? & ? \\ ? & ? & ? \end{bmatrix}$$

Median Filtration
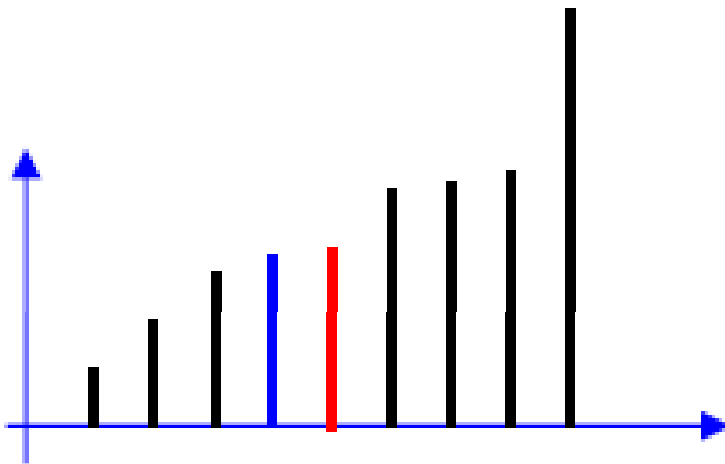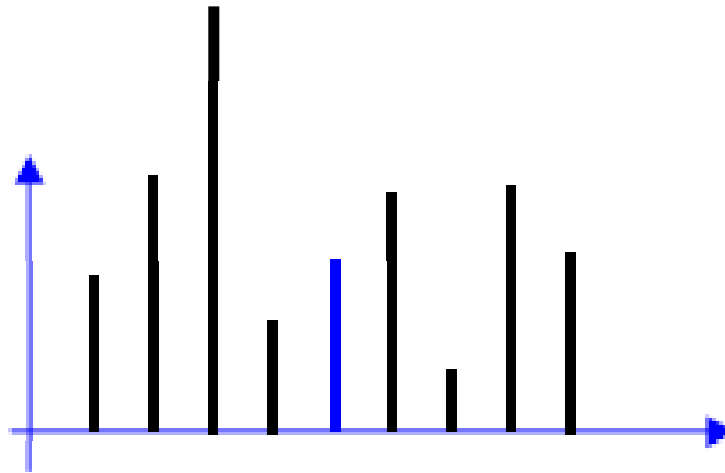
Median Filtration
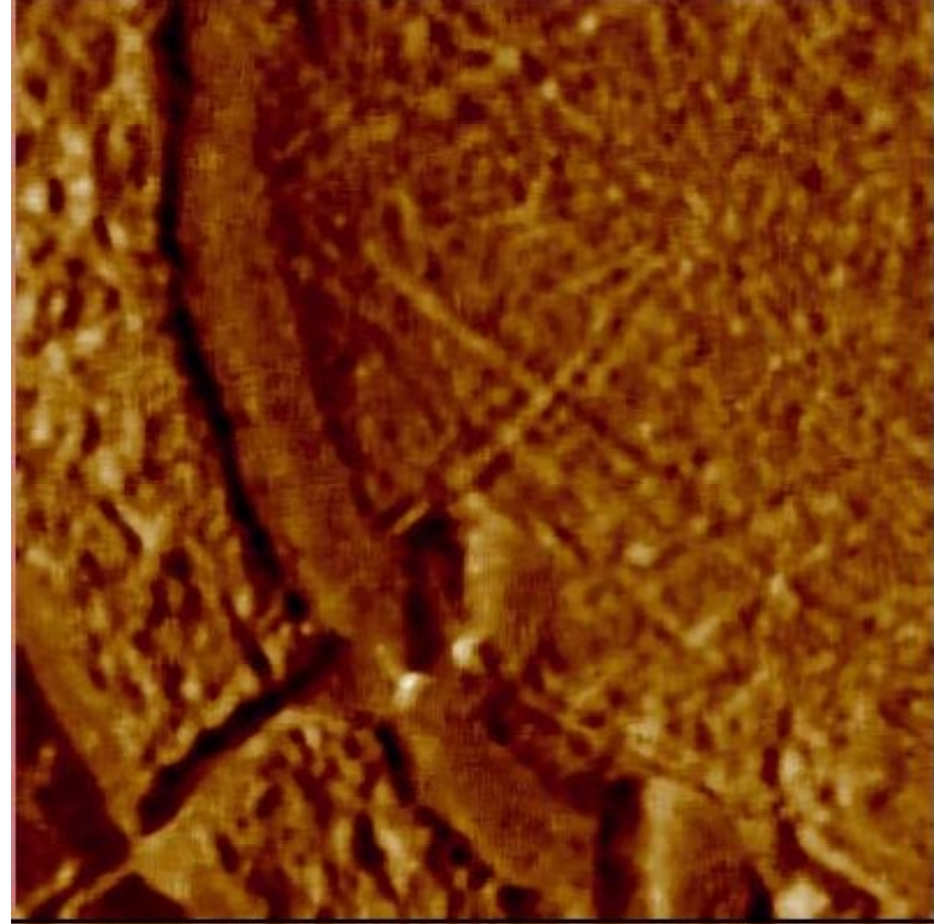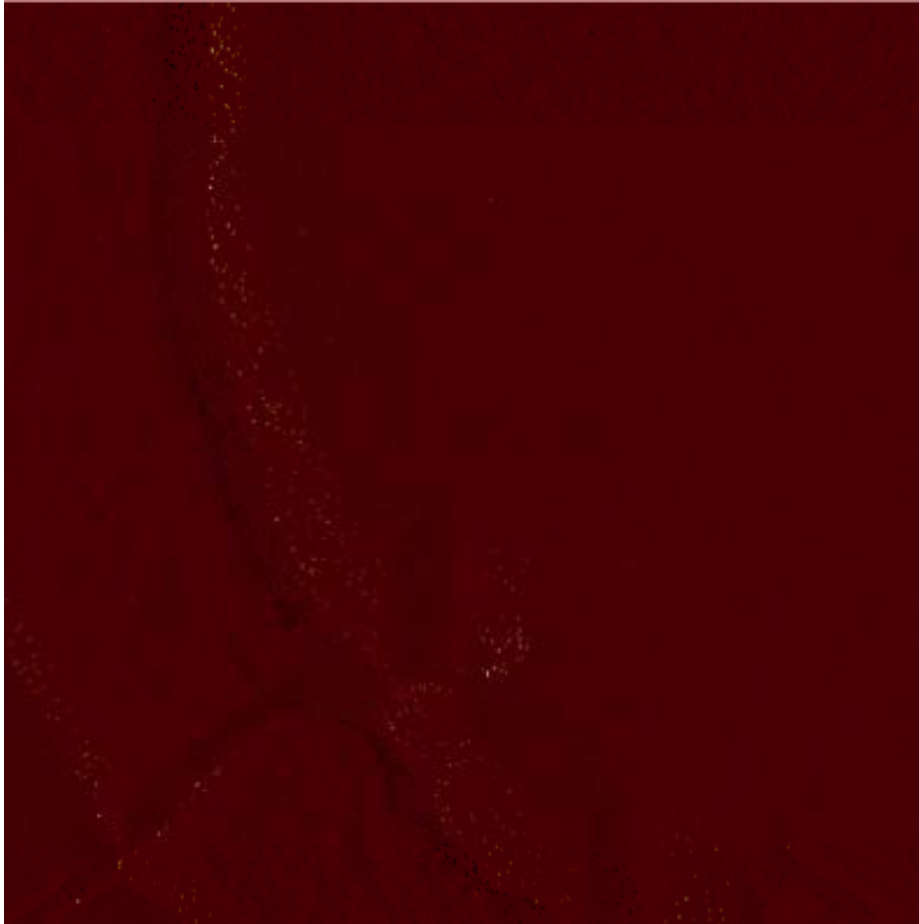
Fourier Filtration

$$F(v) = \int_{-\infty}^{\infty} f(t) e^{-i2\pi vt} \, dt \qquad F_n = \sum_{k=0}^{N-1} f_k e^{-2\pi ink/N}$$

$$f(t) = \int_{-\infty}^{\infty} F(v) e^{i2\pi vt} \, dt \qquad f_k = \frac{1}{N} \sum_{k=0}^{N-1} F_n e^{2\pi ikn/N}$$

Fourier-> FFT Filtration
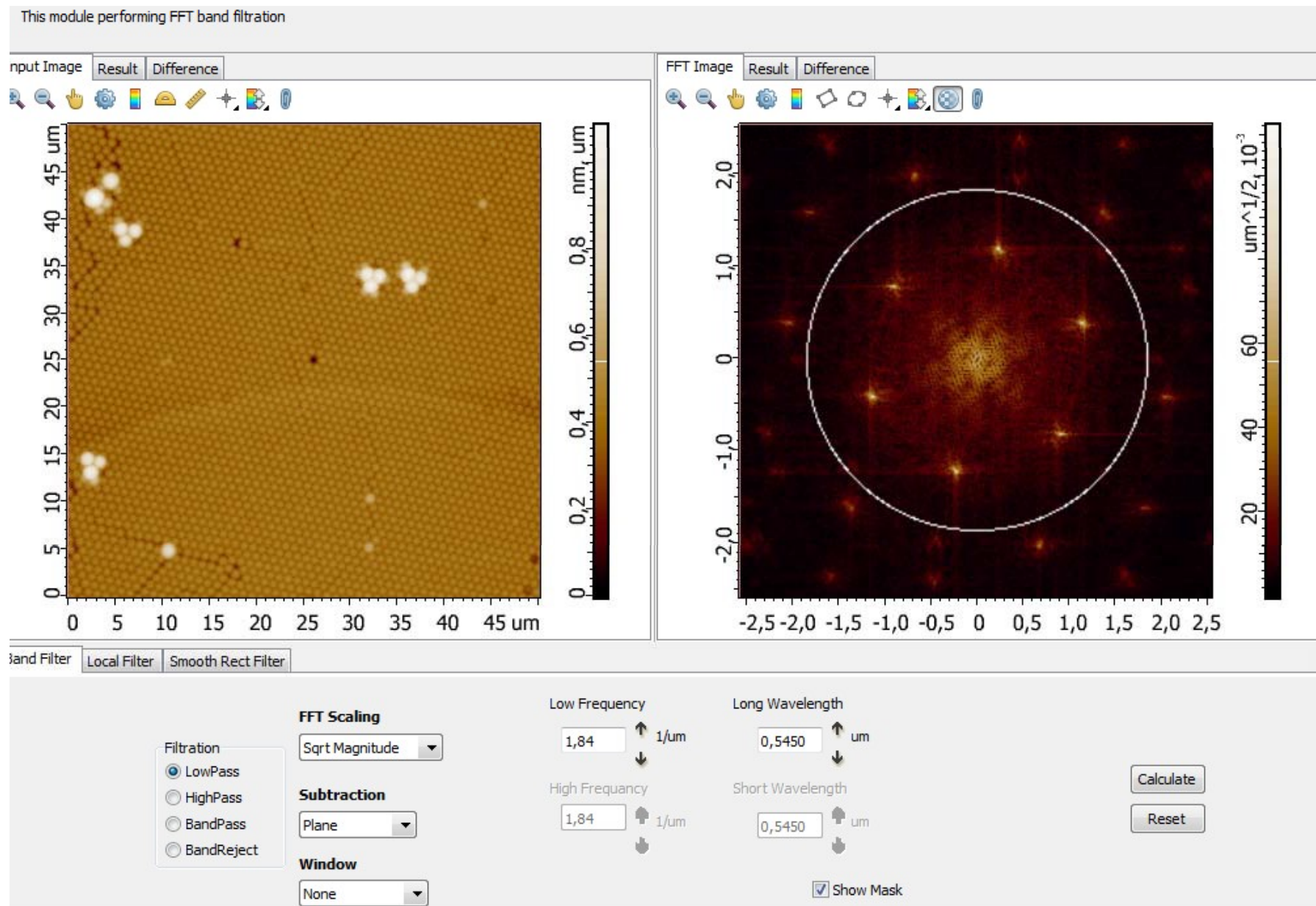
Low Pass FFT
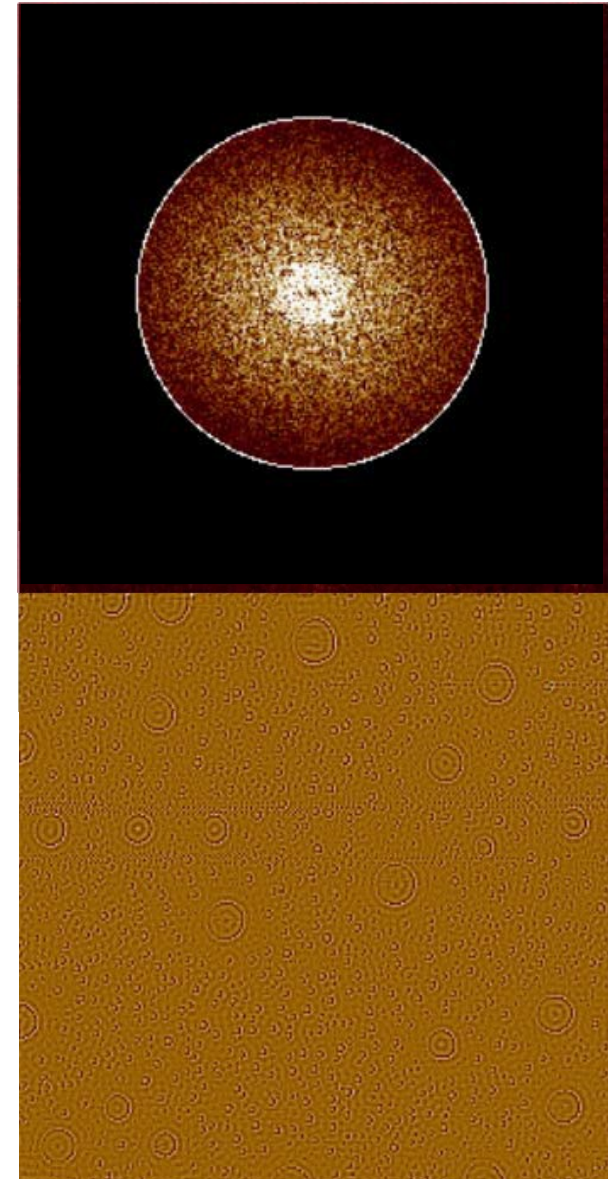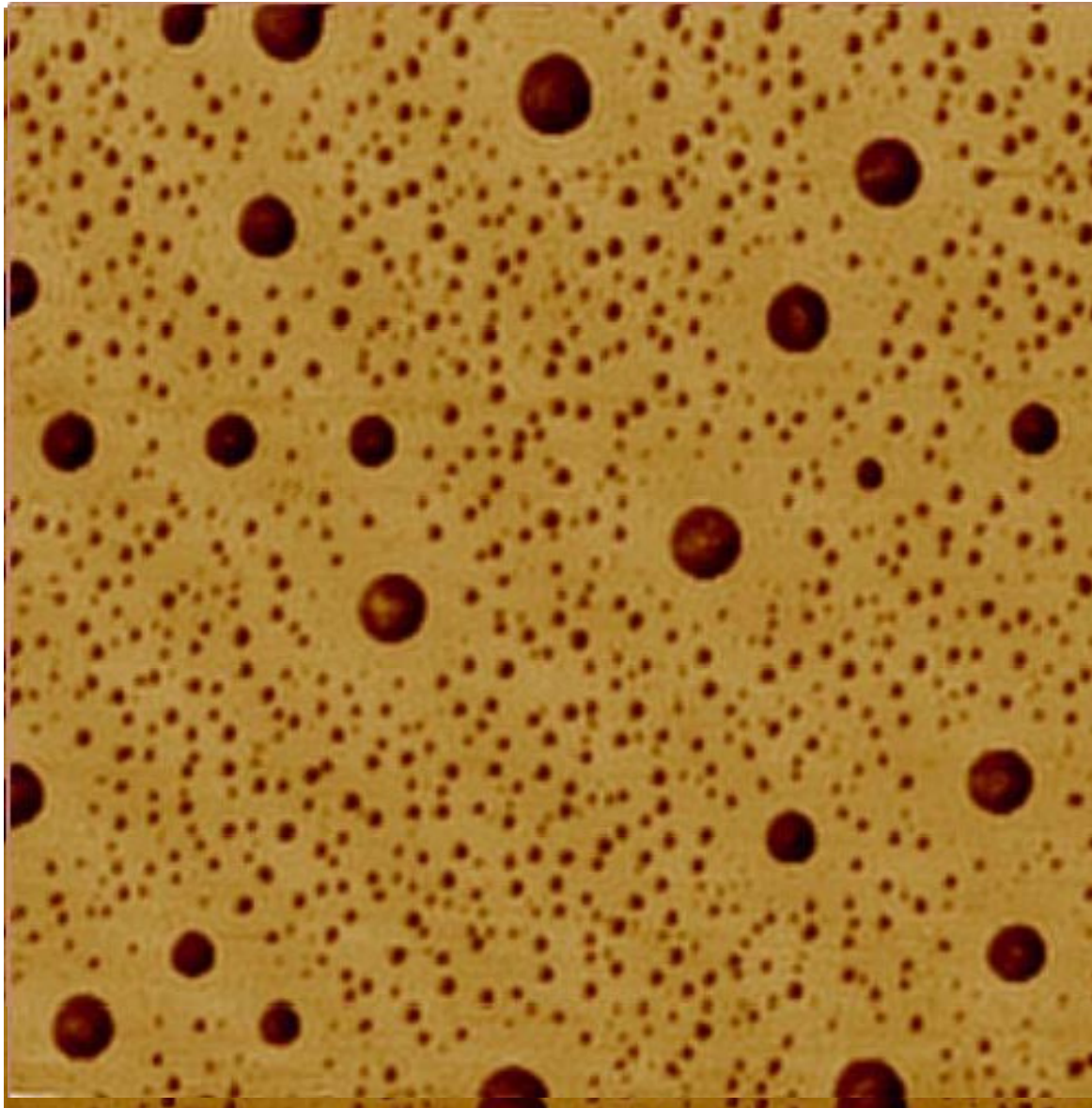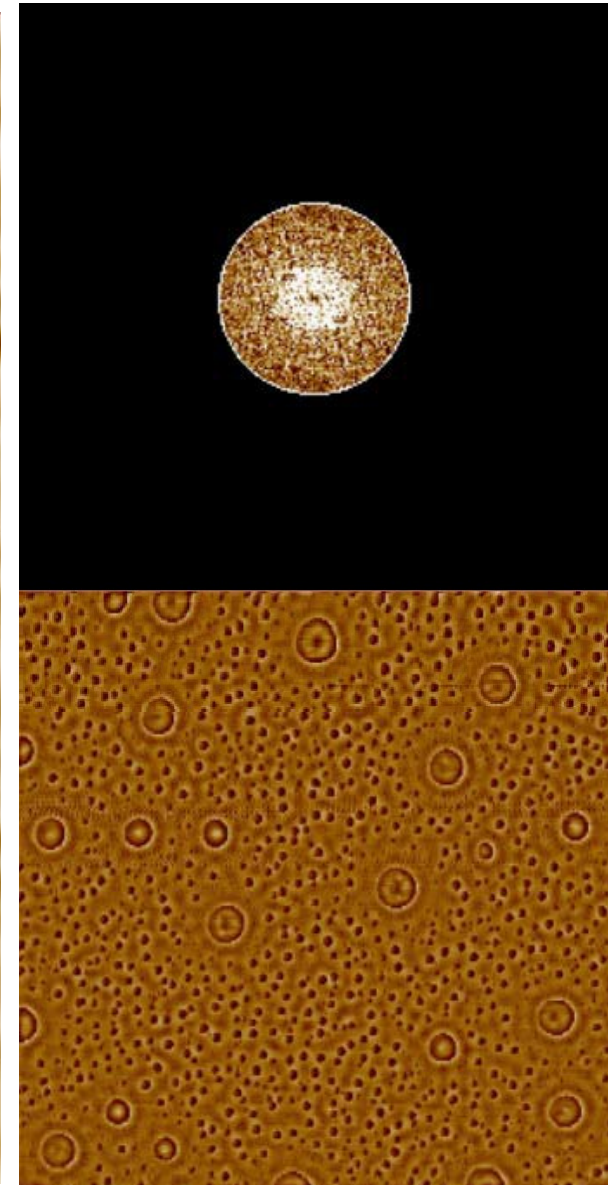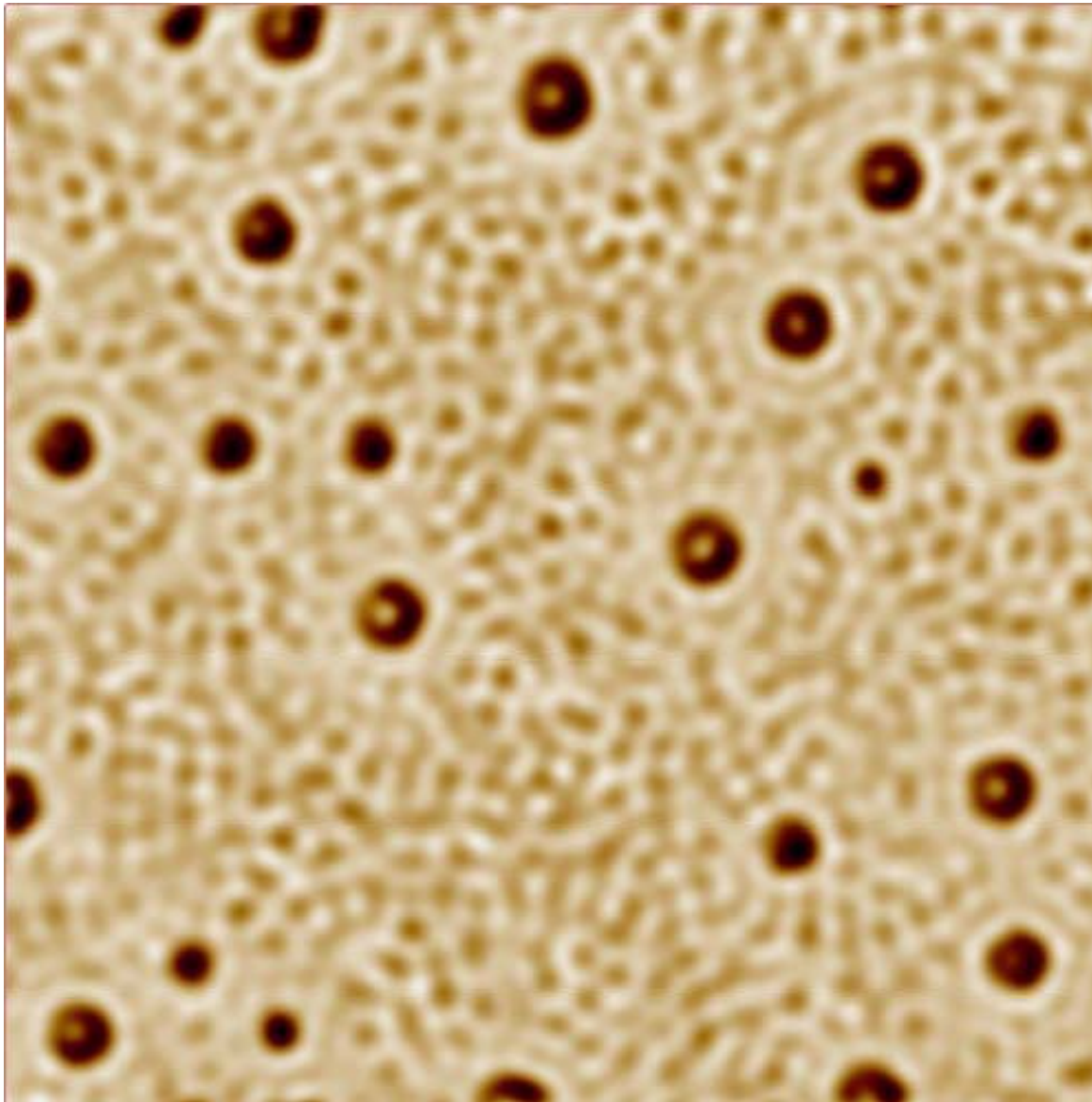
Local Filter FFT

Local Filter FFT

Band Filter | Local Filter | Smooth Rect Filter
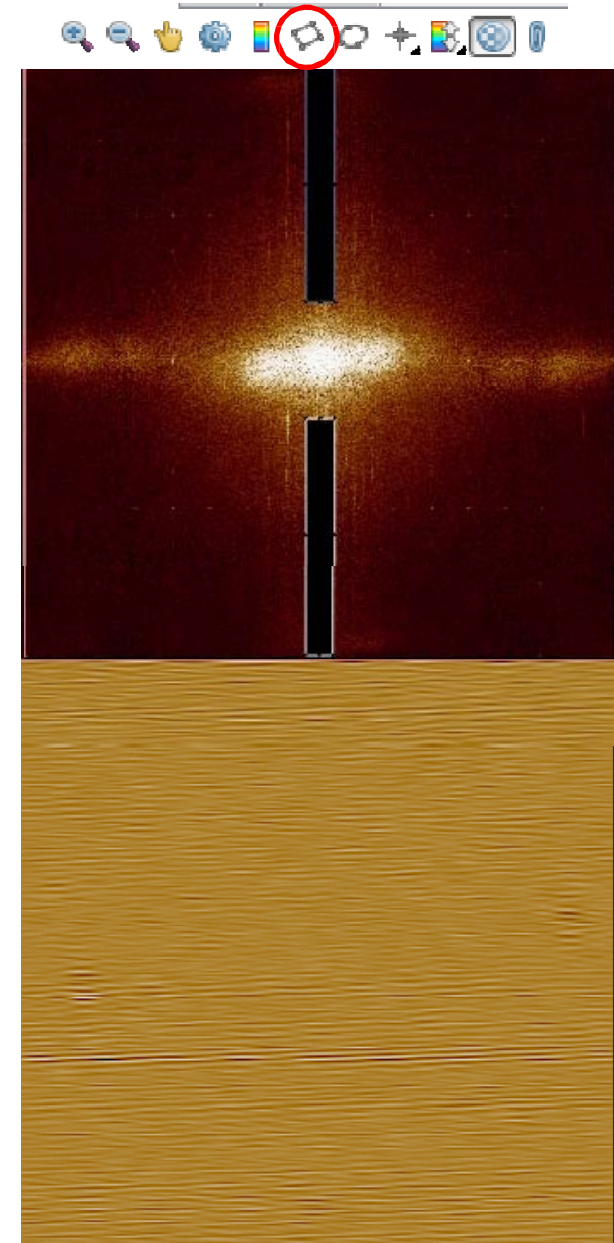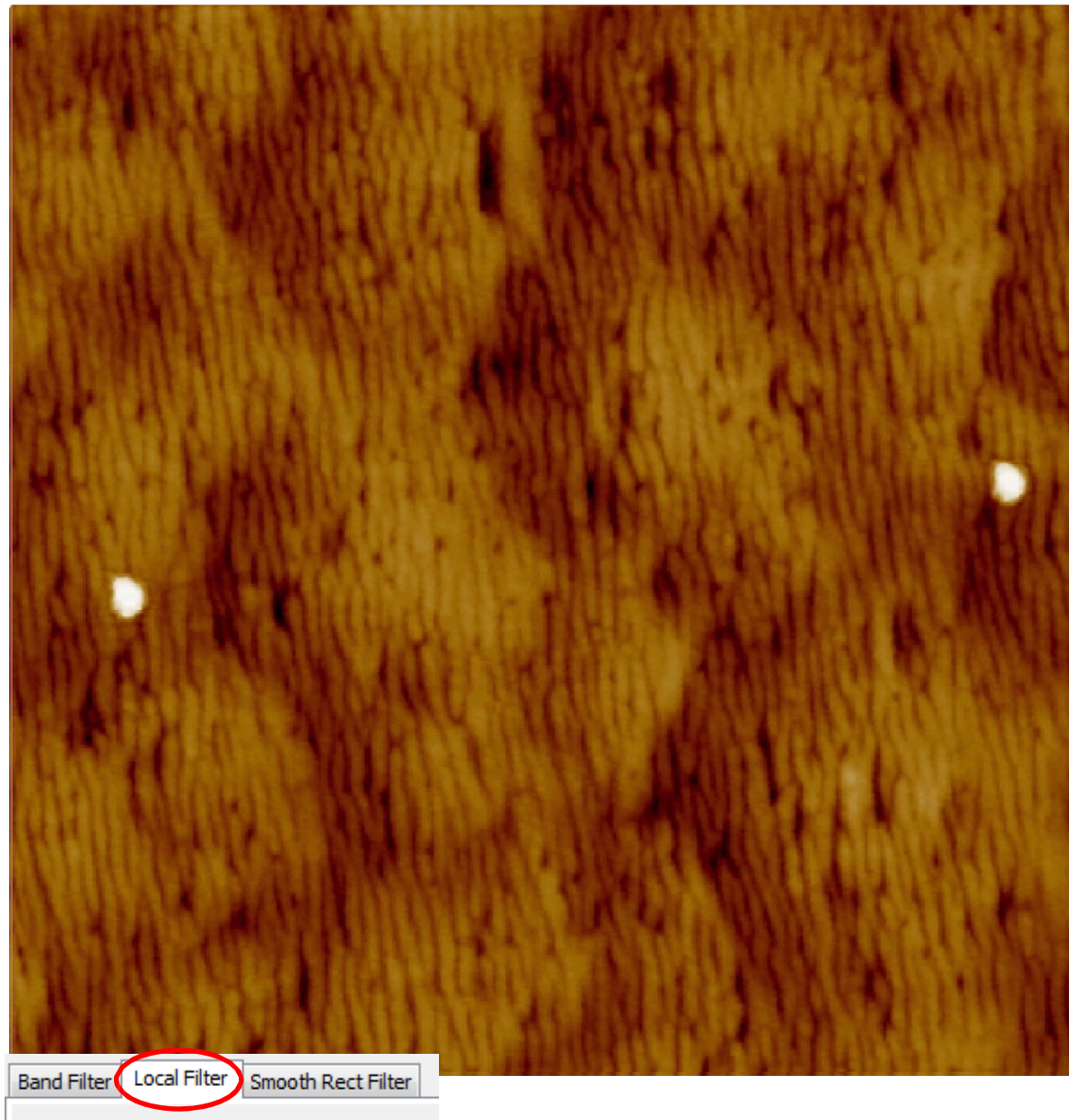
Local Filter FFT
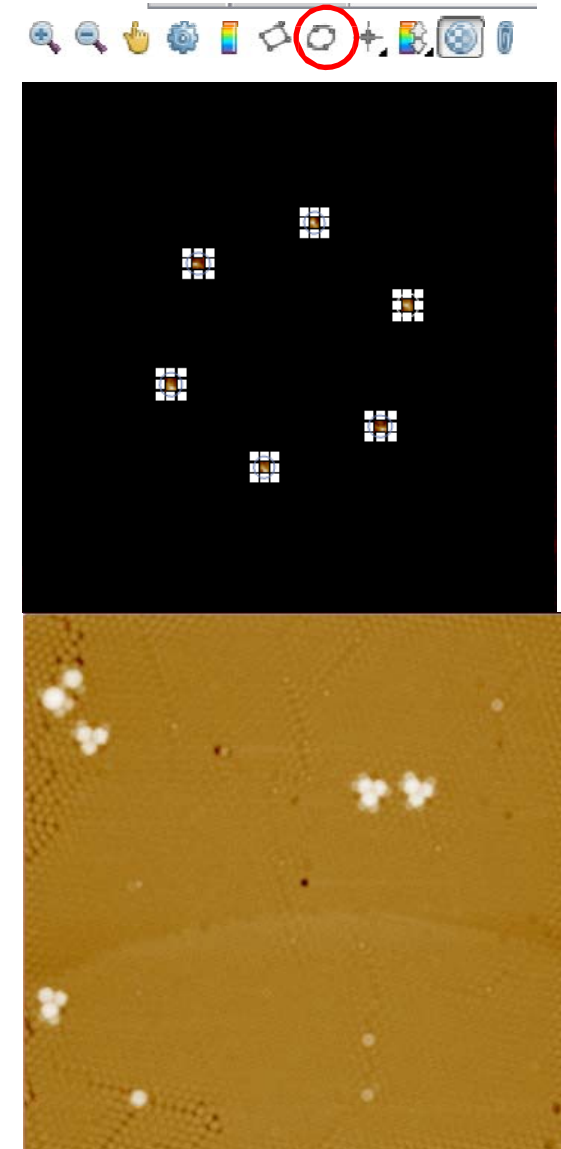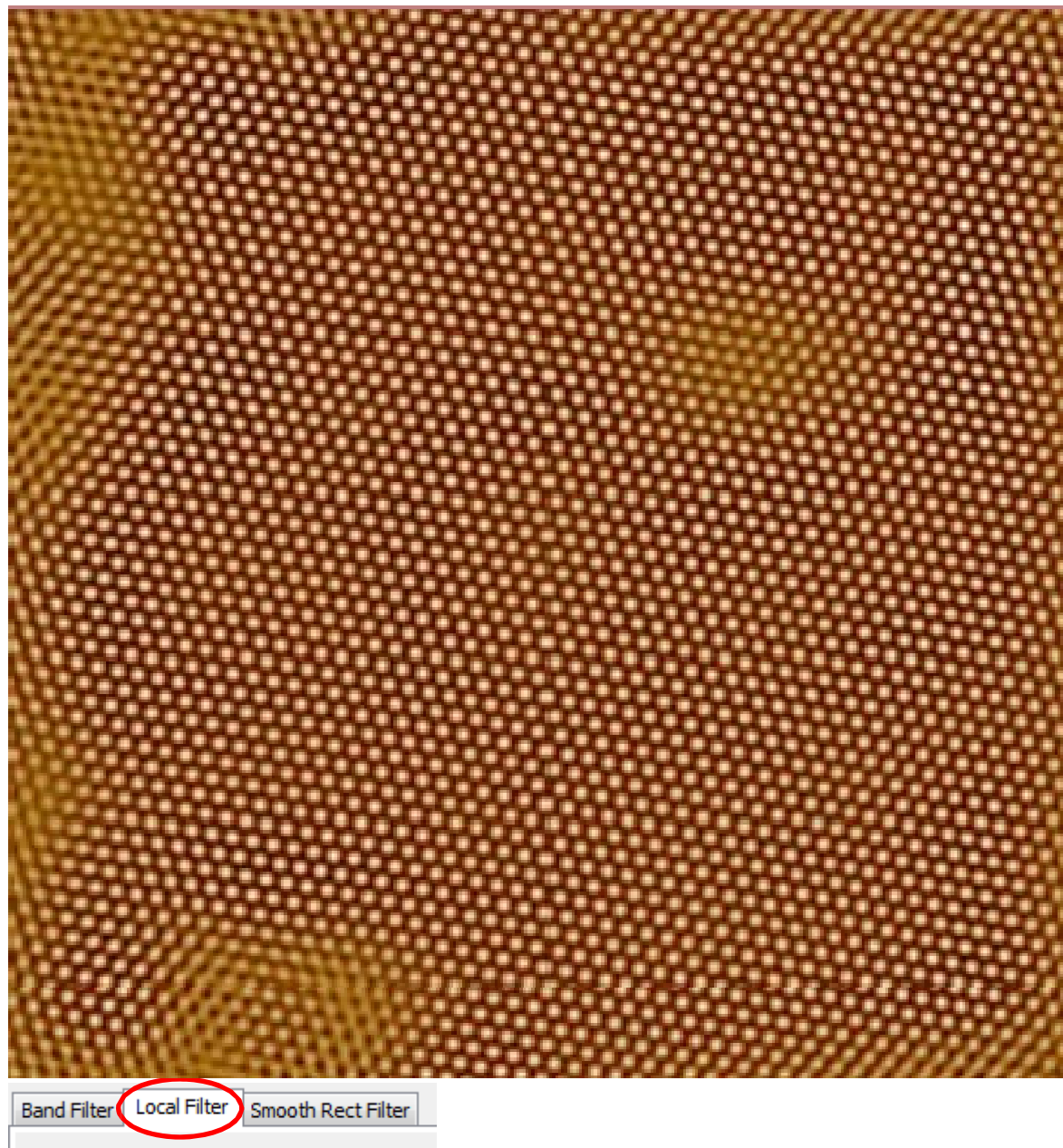
"Aftertouch"

Data Transformations -> Crop
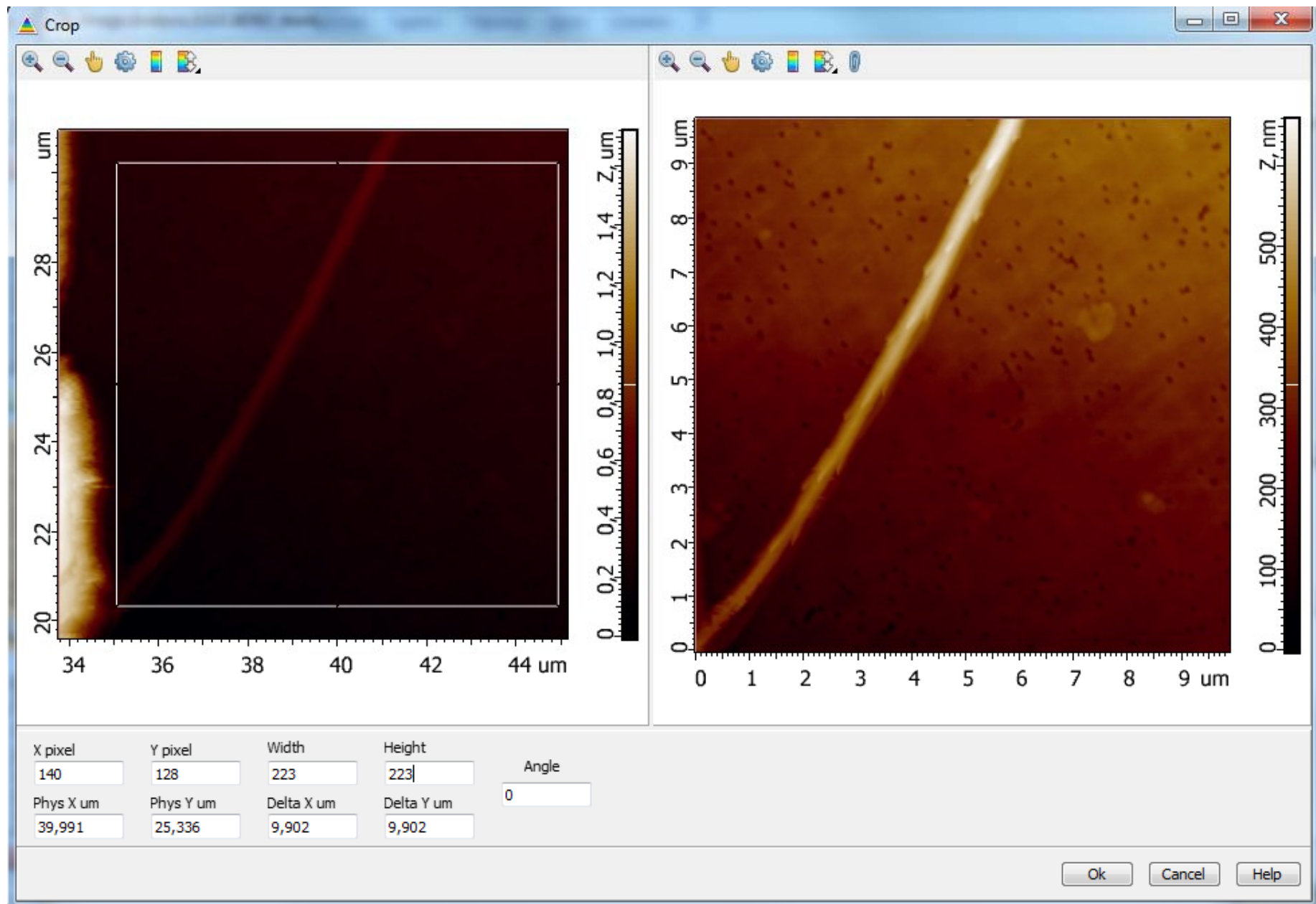
Editing -> Cut Peaks
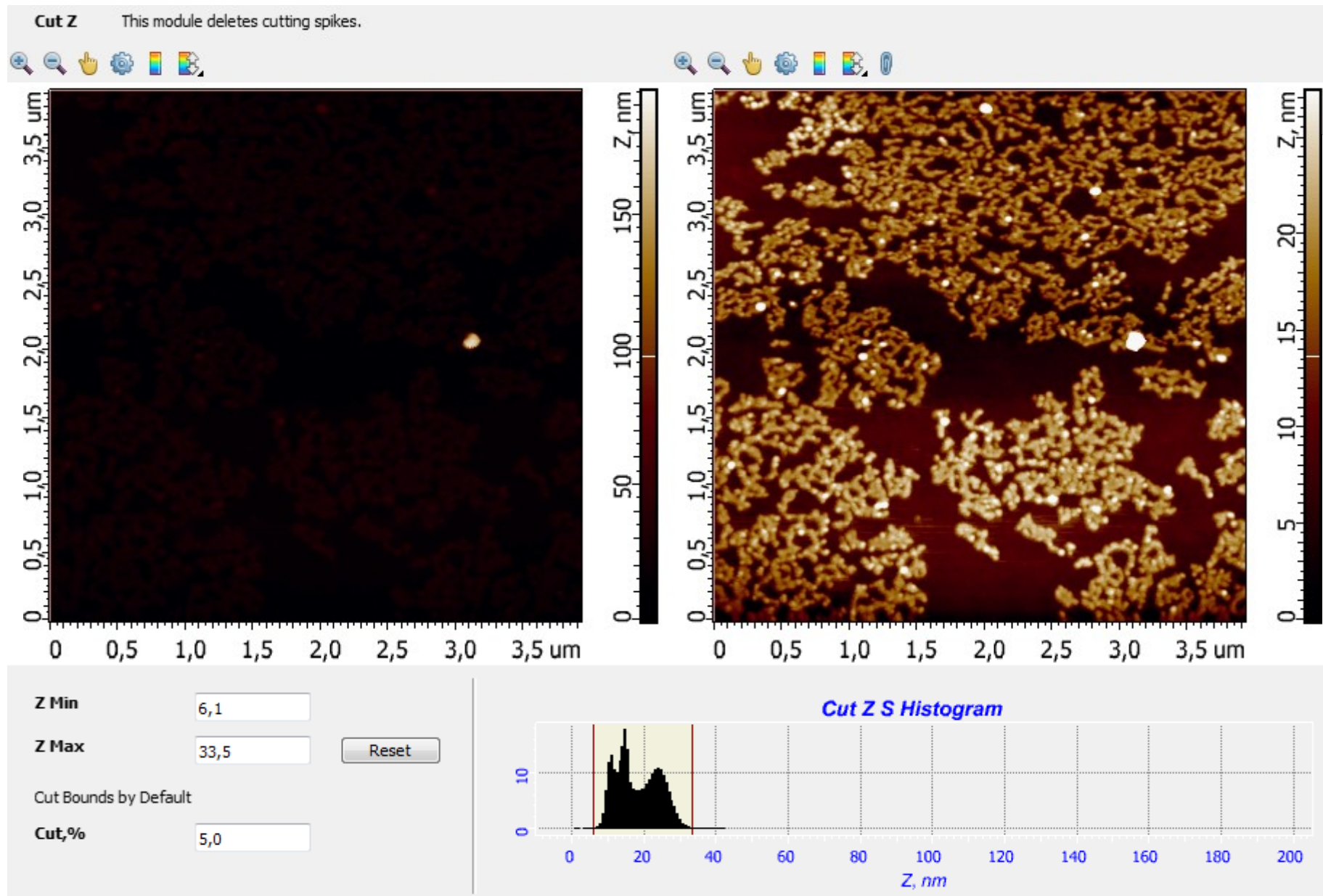
Editing -> Cut Peaks
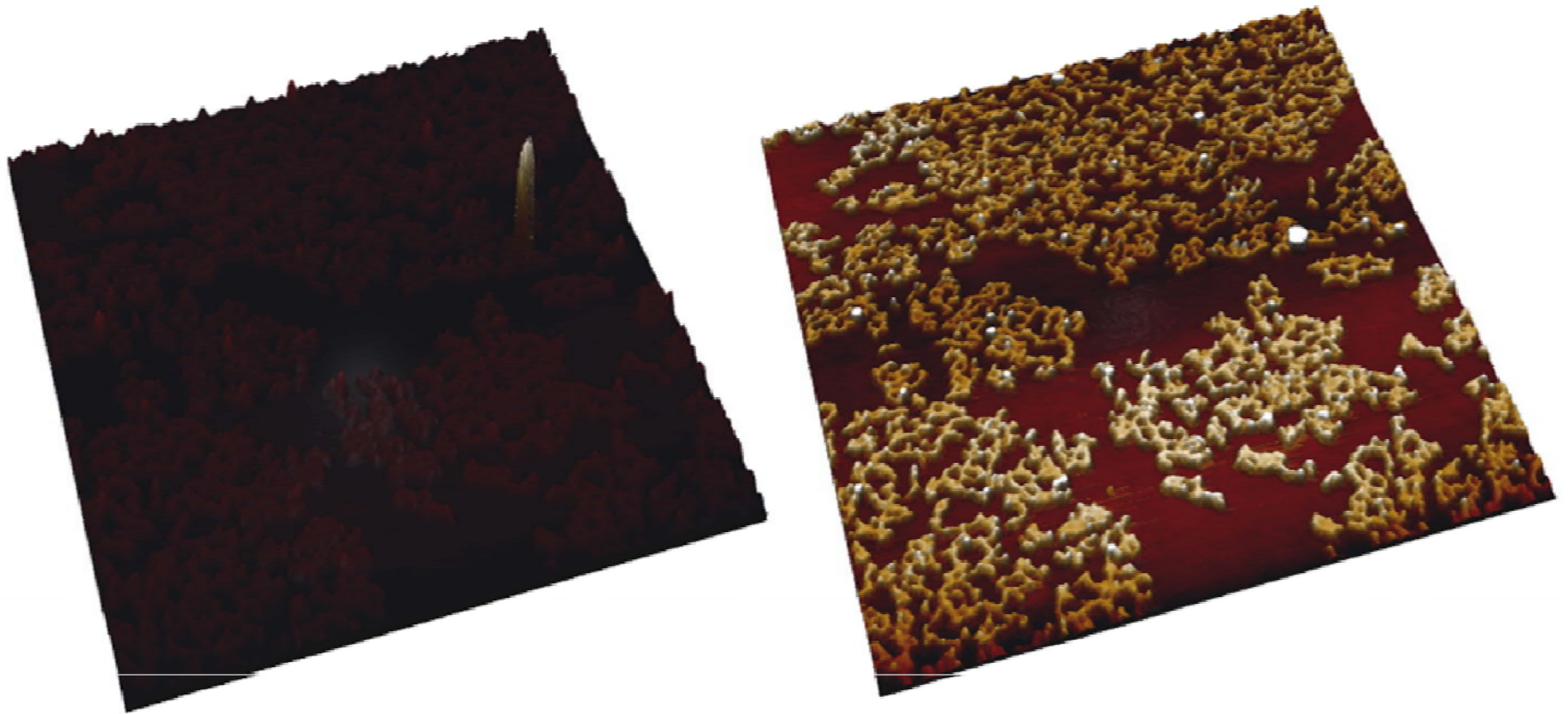
Editing -> Lines Filling
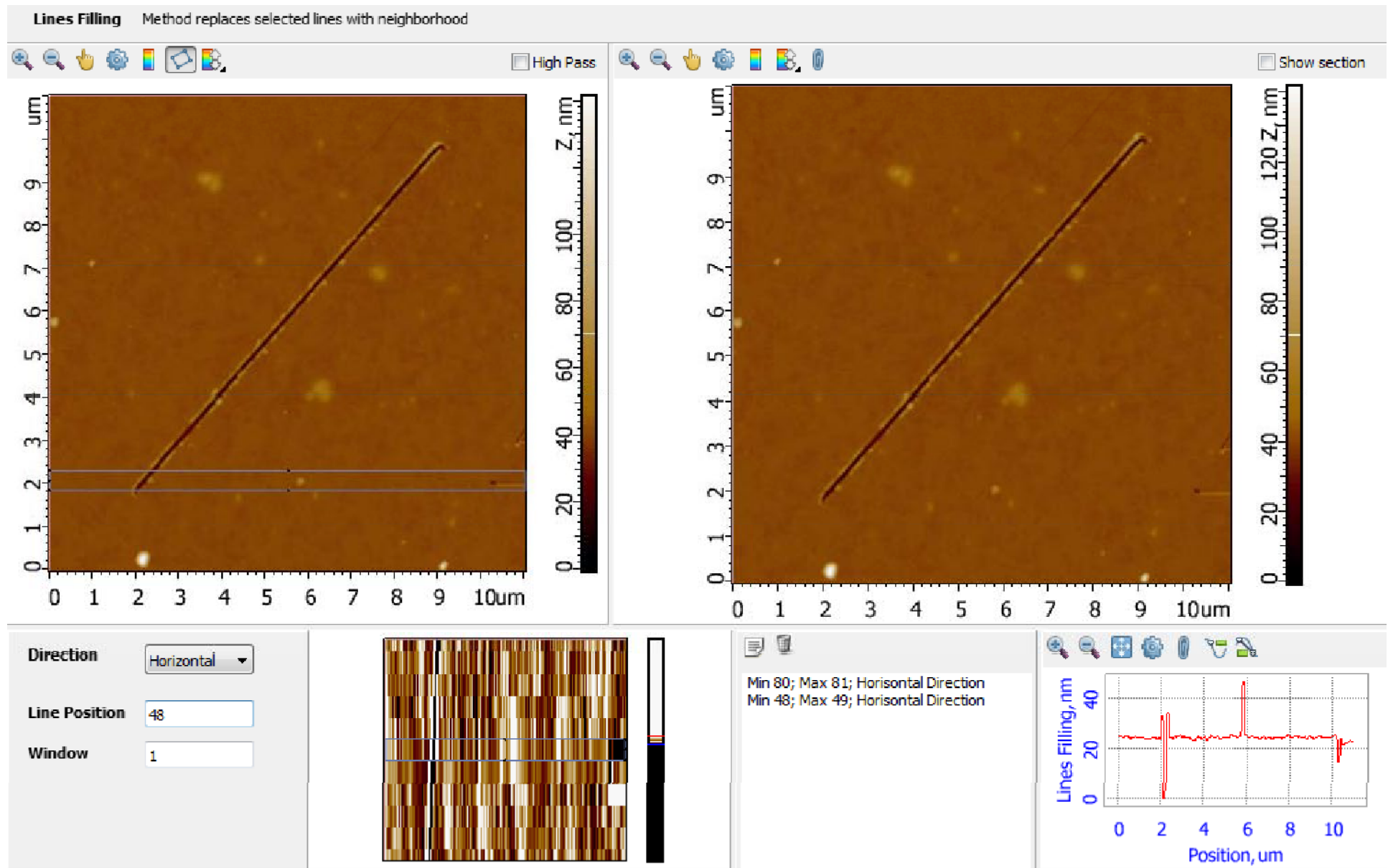
Editing -> Scratches
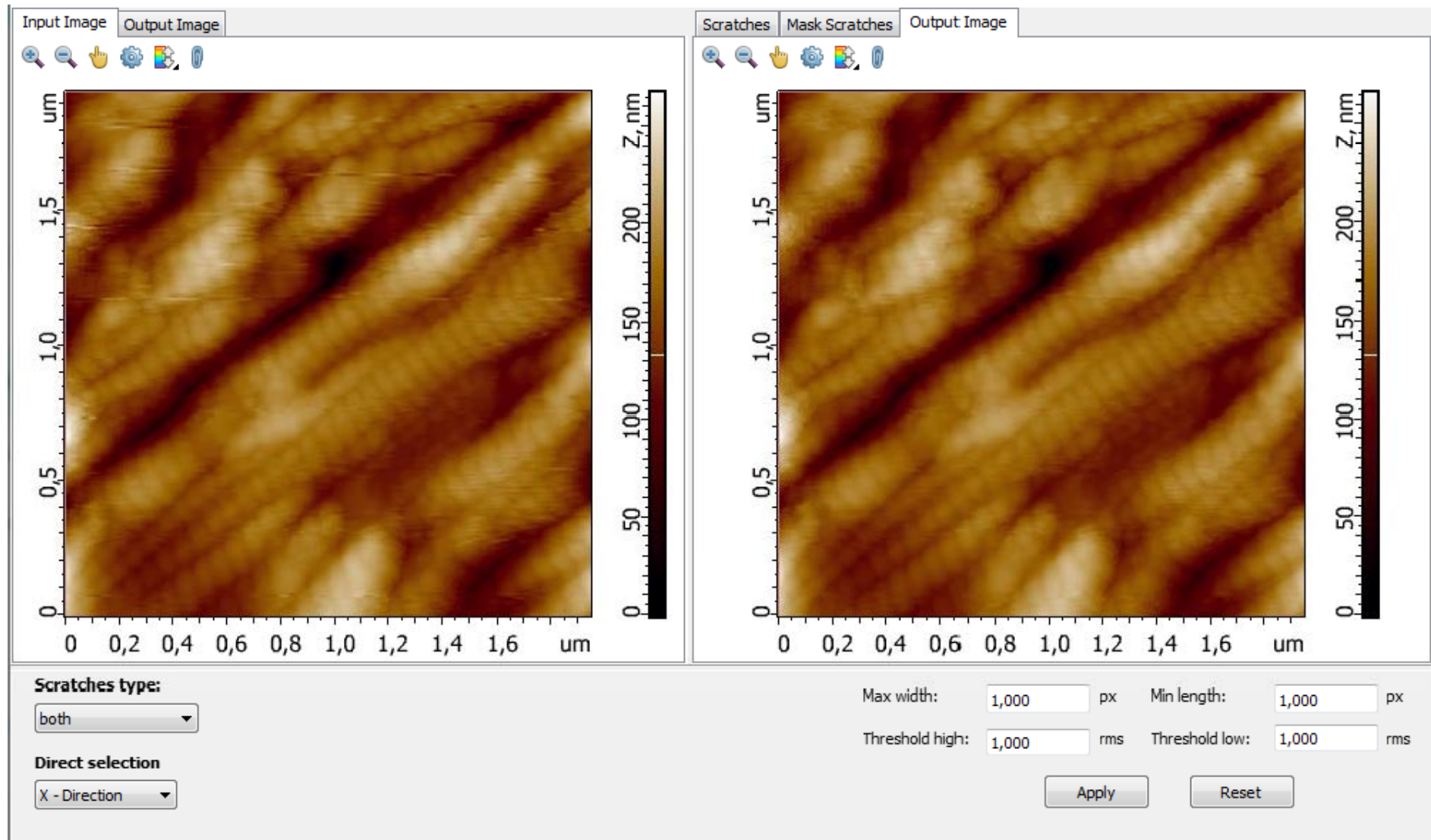
Editing -> Fill by Superposition
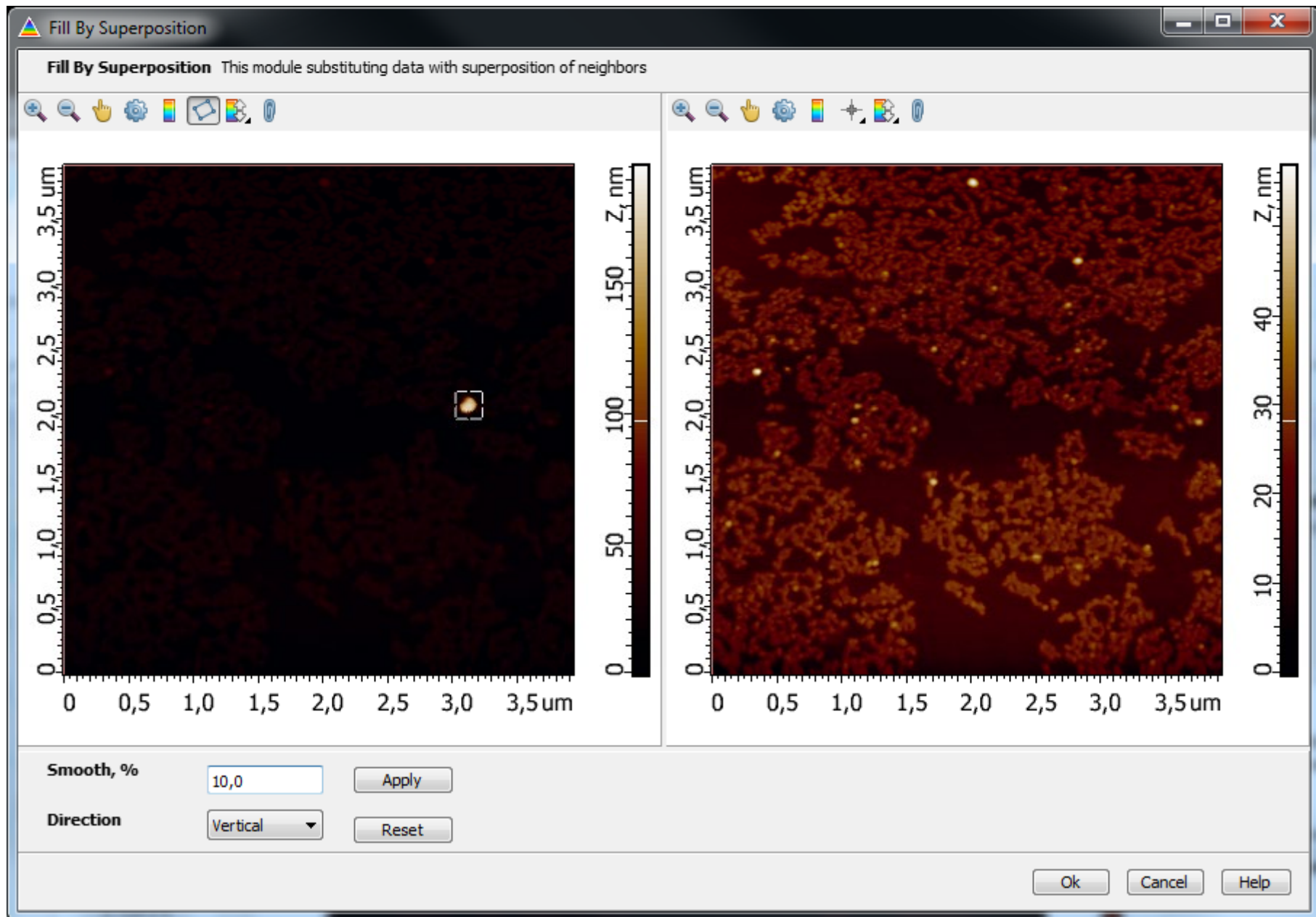
AFM Images Representation

Overall Principles

1. Image should be informative
2. Image should be not far from reality

Coloration Modes: Min-Max
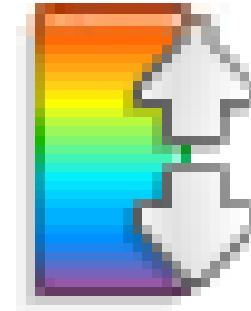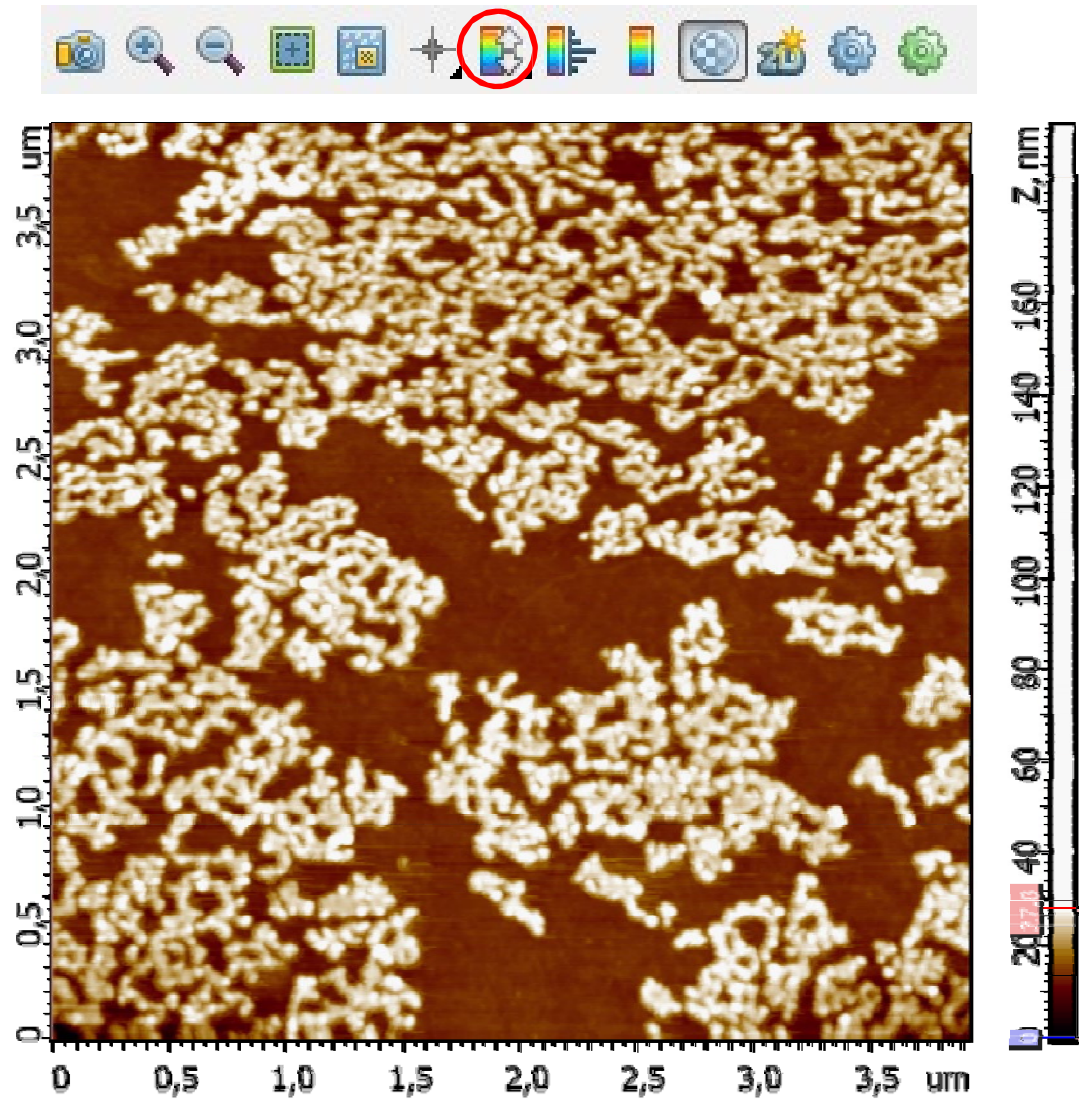
Coloration Modes: Auto
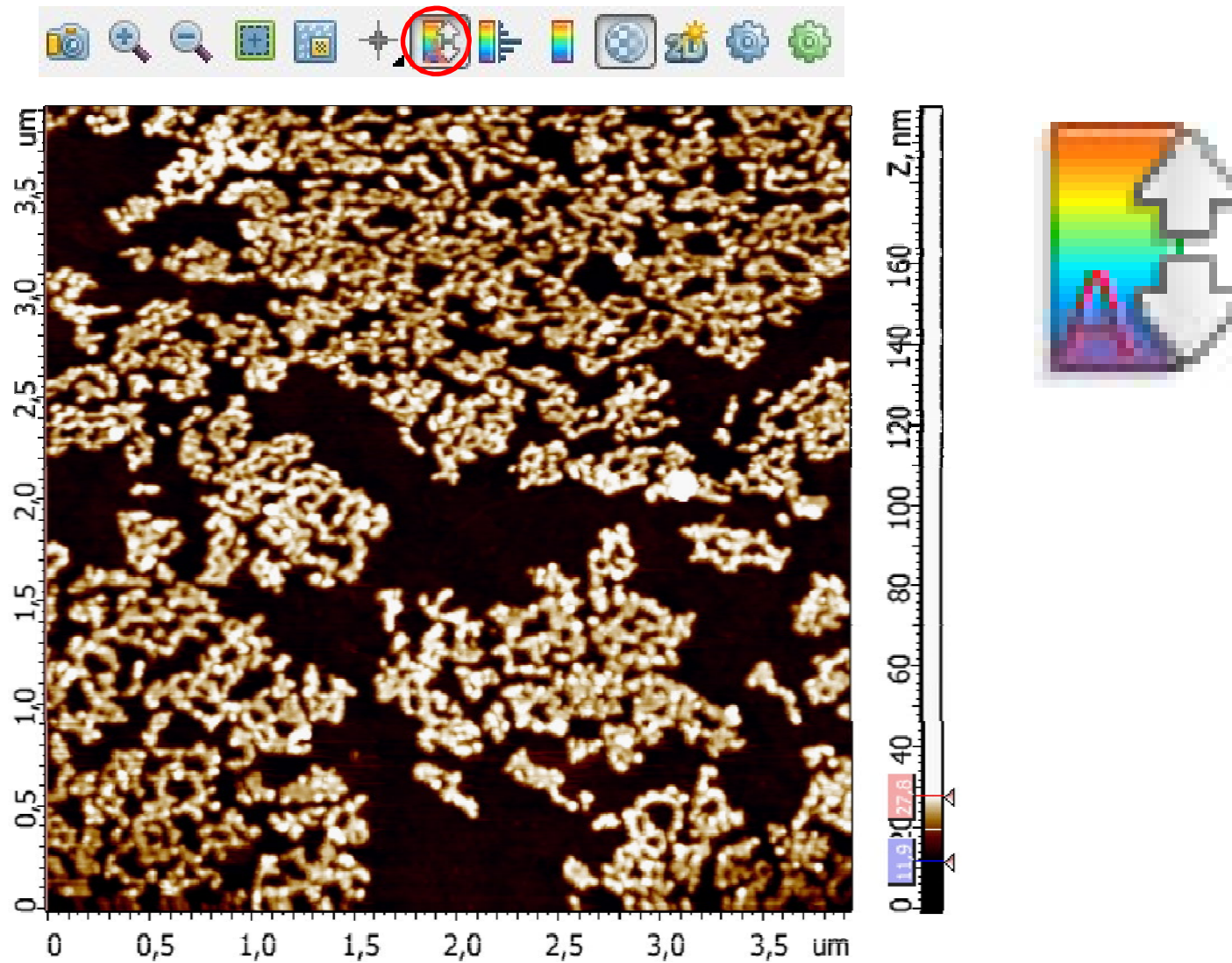
Settings-> 2D Settings -> Axes -> Histogram -> Auto Coloration Percent

Coloration Modes: Nonlinear
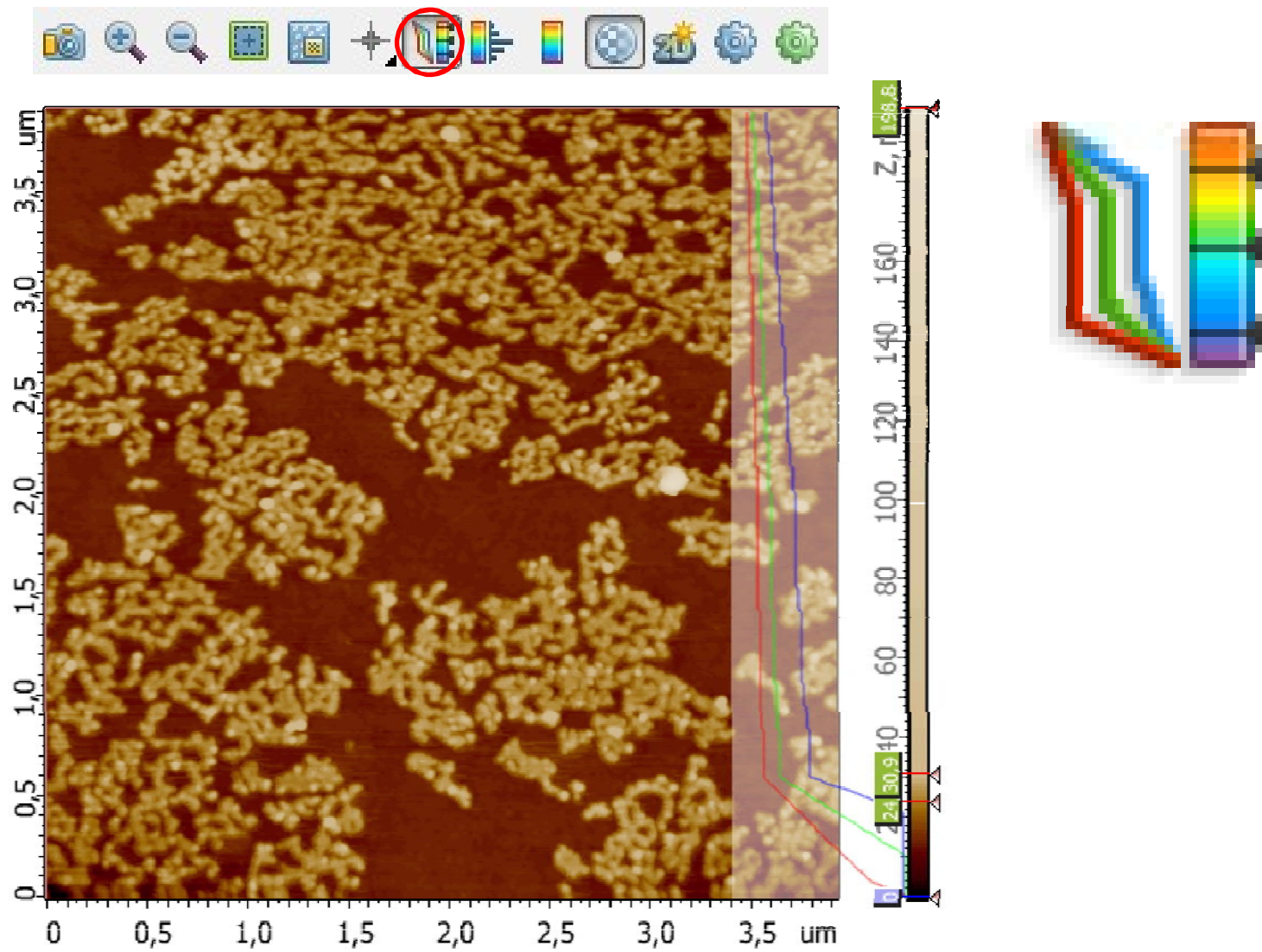
3D
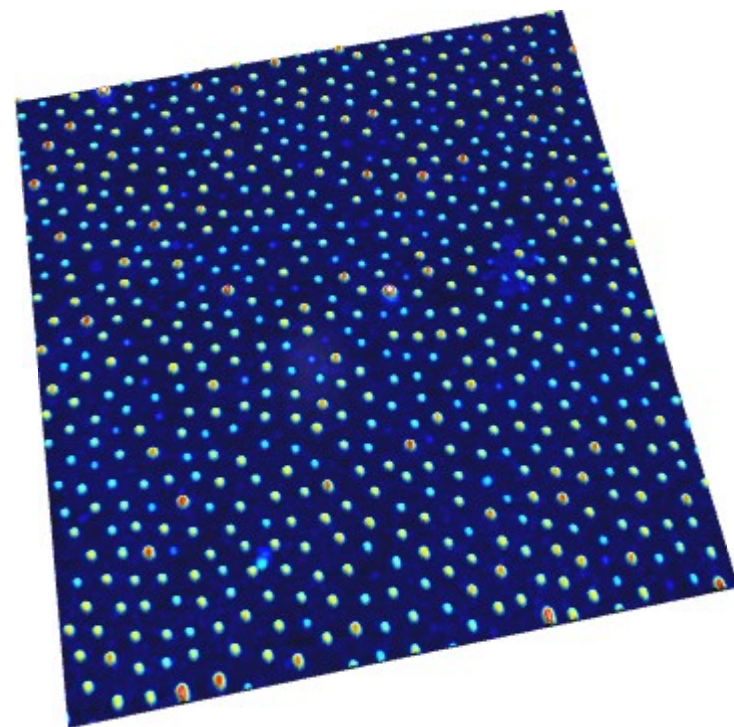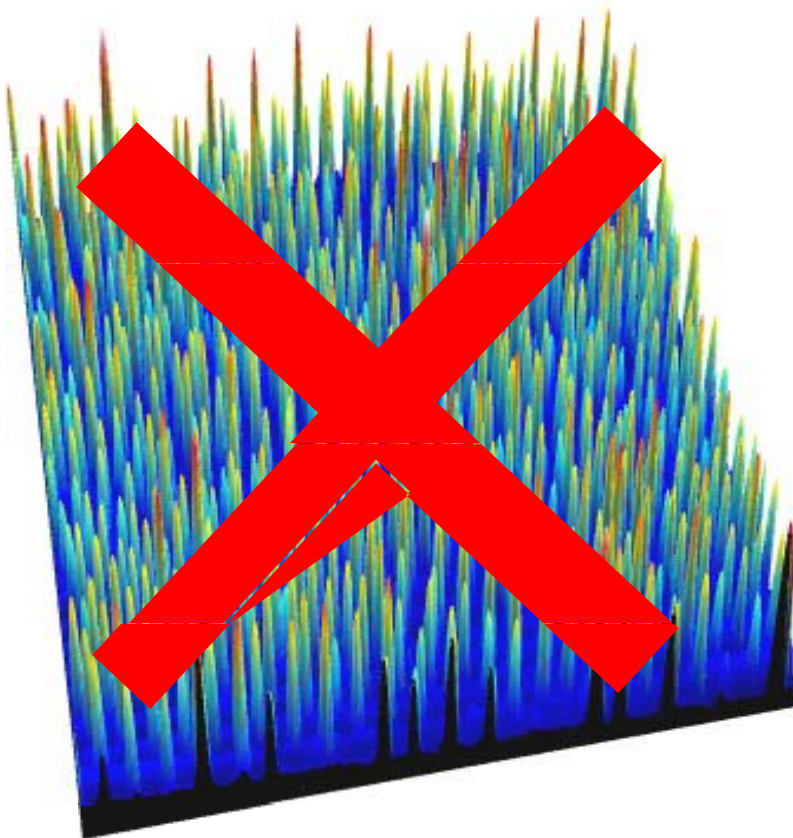
3D
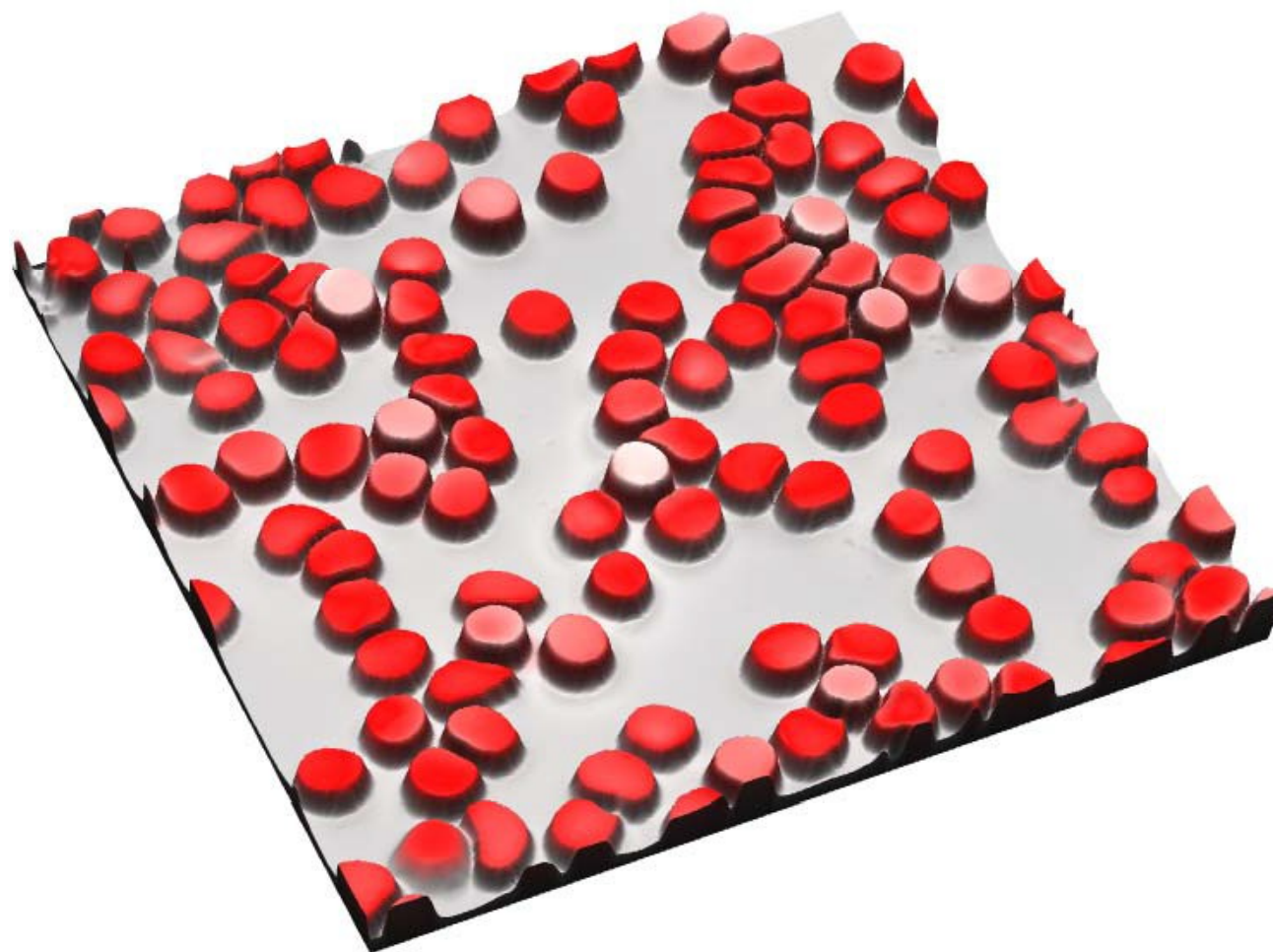
Perception

BLOODY LETTERS
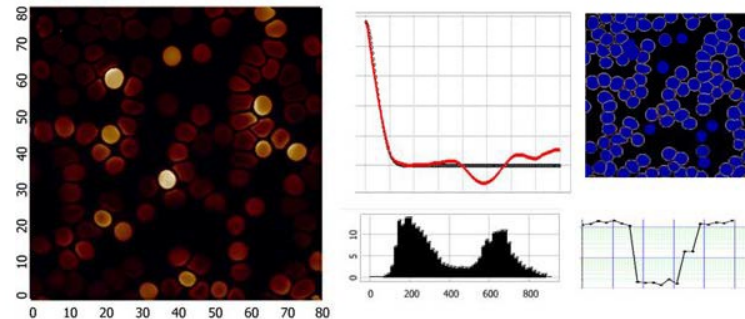
Figure 1. Though this image of blood cells may have a high scientific value, it is not eye-catching and will attract less attention.

NT-MDT Co., the oldest brand on AFM market, was founded back in 1989 in Zelenograd, also known as "Russian Silicon Valley". Starting with the first "STM-MDT-1-90" model (Scanning Tunneling Microscope), for over 25 years it has constantly been involved in development and production of research instrumentation in the field of nanotechnology, primarily scanning probe microscopes, confidently holding the leading position on this market.

NT-MDT primary goal is customer's success in exploring the nanoworld with their innovative equipment – Scanning Probe Microscopes (SPM). The combination of strong motivation, fundamental knowledge, multi-year experience, hard-working ethics, and full integrity makes this undoubtedly possible. The fundamental knowledge and continued thirst for innovation of the NT-MDT team members stems from being educated at the highly regarded Moscow Institute of Physics and Technology (MIPT) and other top schools. At the same time close relations with their customers – Worlds leading institutions, educational centers and industry players – help NT-MDT to be on the cutting edge of this area. All these factors allow NT-MDT to provide the broadest spectrum of unique solutions for customers around the world.

The excellence of NT-MDT's Atomic Force Microscopes (AFM) has been proven in numerous applications many of which were developed and demonstrated by NT-MDT scientists. Articles with the results obtained with a help of NT-MDT equipment are being published in hundreds of reputable scientific journals. Amount of such publications grows every year. More than 1000 papers were published in English-language magazines with an average impact factor of 3.3 during the year 2015. NT-MDT's AFM product line covers the broadest range of options. SOLVER Nano, compact footprint and affordable model, is successfully used for professional research and educational purposes. This machine utilizes.

Systems with an open and modular design are represented by NTEGRA Prima and NTEGRA Aura. Superior performance and unlimited configurations are backed by thousands of researchers all over the world who discover nanoworld and its secrets. These machines are being constantly kept up to date by their compatibility with new high-end controllers and modern software.

Family of Automated AFM-s is represented by NEXT, a winner of "R&D 100 Award" in 2009. Combination with Fully Automated hardware design and smart software solutions provides real "Three Mouse-click" path from putting the sample to getting the result. This performance makes NEXT ideal for multiuser facilities.

TITANIUM model, representing a new generation of automated machines, shows unbeaten low drift and high signal to noise ratio capabilities along with a unique REVOLUTION HEAD. It utilizes a single-chip 38-tip CARTRIDGE which will make you forget the AFM tip replacement operation for a long time.

Almost two decades of expertise in combination with optical techniques makes NT-MDT a world leader in providing fully integrated, turnkey AFM-RAMAN-SNOM systems including TERS option. Such a hot topic as AFM-IR & s-SNOM integration is also ready for purchasing.

All mentioned setups are driven by modern modular high-speed digital controllers which provide the widest range of AFM modes not limited by license. Combination of Contact, Amplitude modulation, Frequency modulation and HybriDTM (Jumping mode) techniques leads to the number of 100+ modes implemented. This allows running the versatile examination of morphological, electromagnetic, nanomechanical and chemical sample properties. Within the single system. Backed by more than 3000 installations worldwide, NT-MDT nowadays is a truly international.
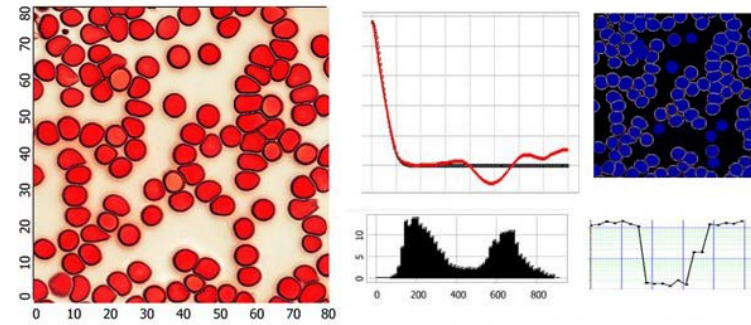

BLOODY LETTERS

Figure 1. This is an example how simple steps for interception improvement make your publication more remarkable

Systems with an open and modular design are represented by NTEGRA Prima and NTEGRA Aura. Superior performance and unlimited configurations are backed by thousands of researchers all over the world who discover nanoworld and its secrets. These machines are being constantly kept up to date by their compatibility with new high-end controllers and modern software.

Family of Automated AFM-s is represented by NEXT, a winner of "R&D 100 Award" in 2009. Combination with Fully Automated hardware design and smart software solutions provides real "Three Mouse-click" path from putting the sample to getting the result. This performance makes NEXT ideal for multiuser facilities.

TITANIUM model, representing a new generation of automated machines, shows unbeaten low drift and high signal to noise ratio capabilities along with a unique REVOLUTION HEAD. It utilizes a single-chip 38-tip CARTRIDGE which will make you forget the AFM tip replacement operation for a long time.

Almost two decades of expertise in combination with optical techniques makes NT-MDT a world leader in providing fully integrated, turnkey AFM-RAMAN-SNOM systems including TERS option. Such a hot topic as AFM-IR & s-SNOM integration is also ready for purchasing.

All mentioned setups are driven by modern modular high-speed digital controllers which provide the widest range of AFM modes not limited by license. Combination of Contact, Amplitude modulation, Frequency modulation and HybriDTM (Jumping mode) techniques leads to the number of 100+ modes implemented. This allows running the versatile examination of morphological, electromagnetic, nanomechanical and chemical sample properties. Within the single system. Backed by more than 3000 installations worldwide, NT-MDT nowadays is a truly international.

NT-MDT Co., the oldest brand on AFM market, was founded back in 1989 in Zelenograd, also known as "Russian Silicon Valley". Starting with the first "STM-MDT-1-90" model (Scanning Tunneling Microscope), for over 25 years it has constantly been involved in development and production of research instrumentation in the field of nanotechnology, primarily scanning probe microscopes, confidently holding the leading position on this market.

NT-MDT primary goal is customer's success in exploring the nanoworld with their innovative equipment – Scanning Probe Microscopes (SPM). The combination of strong motivation, fundamental knowledge, multi-year experience, hard-working ethics, and full integrity makes this undoubtedly possible. The fundamental knowledge and continued thirst for innovation of the NT-MDT team members stems from being educated at the highly regarded Moscow Institute of Physics and Technology (MIPT) and other top schools. At the same time close relations with their customers – Worlds leading institutions, educational centers and industry players – help NT-MDT to be on the cutting edge of this area. All these factors allow NT-MDT to provide the broadest spectrum of unique solutions for customers around the world.

The excellence of NT-MDT's Atomic Force Microscopes (AFM) has been proven in numerous applications many of which were developed and demonstrated by NT-MDT scientists. Articles with the results obtained with a help of NT-MDT equipment are being published in hundreds of reputable scientific journals. Amount of such publications grows every year. More than 1000 papers were published in English-language magazines with an average impact factor of 3.3 during the year 2015. NT-MDT's AFM product line covers the broadest range of options. SOLVER Nano, compact footprint and affordable model, is successfully used for professional research and educational purposes. This machine utilizes the same high quality components as their other high-end systems.

Your AFM & Raman Company

3D Overlay
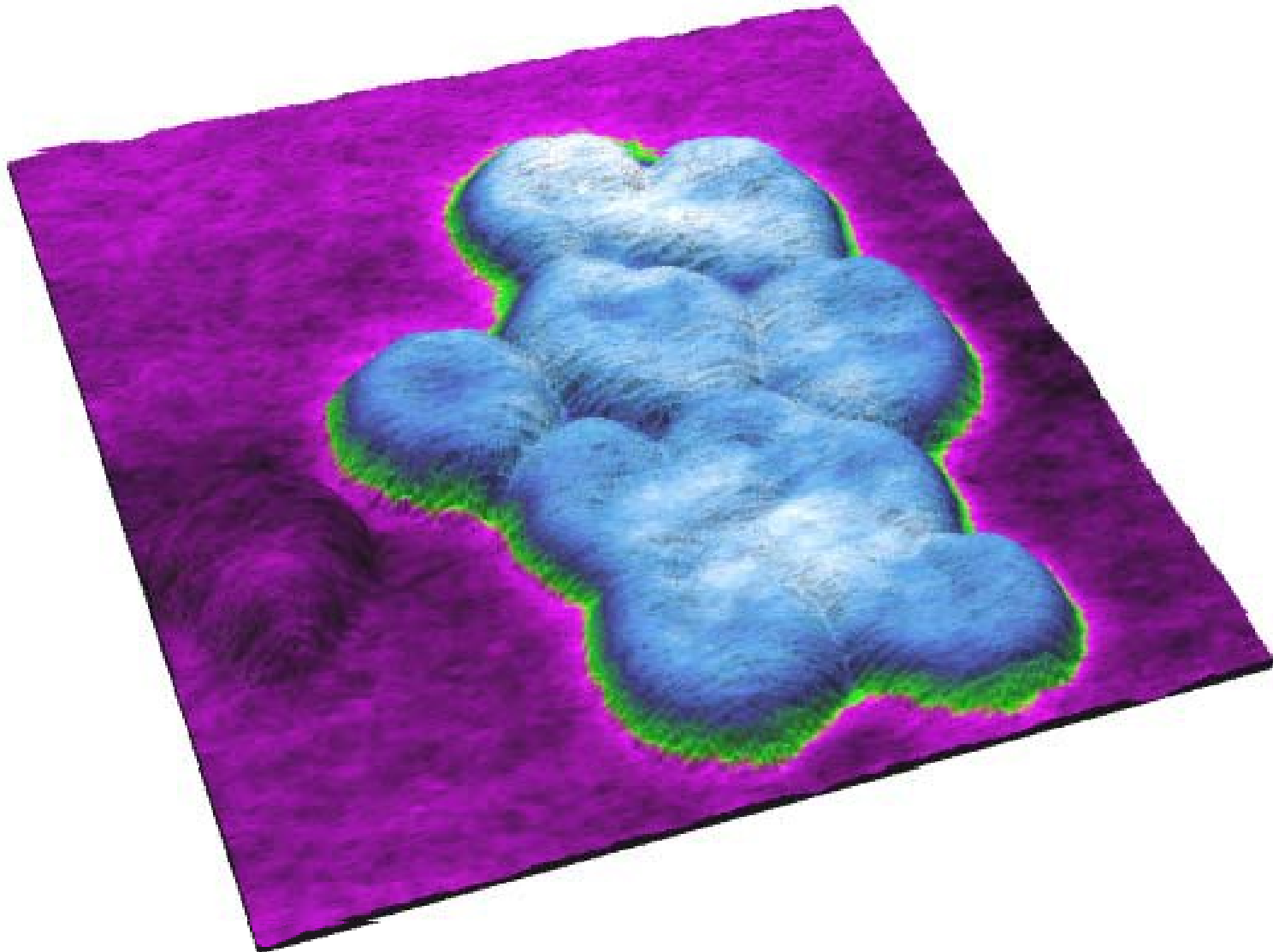
Summary

1. Use different approaches
2. Use a priori information (flat substrate should be flat)
3. Don't "overfilter" – always examine the difference
4. Image should be informative and close to reality
5. Good looking images are understood better

Acknowledgements

Dr. Sergei Magonov
Dr. Raluka Gavrila
Dr. Oksana Karban
Dr. Valery Kuryavy
Dr. Viktor Novak

Dr. Yuri Bobrov
Anton Podstrelov
Sergey Nesterov
Arseny Kalinin
Andrey Gruzdev

Literature used:

Mironov V.L., **Fundamentals of Scanning Probe Microscopy** *(2004)*

Gonzales R.C., Woods R.E. **Digital Image Processing.** 2 ed. PH, 2001.

AFM Probes online shop   Scan-Gallery   Contacts   Ask on-line

Atomic Force Microscopy for Nanotechnology, Scientific Research & Education

| TITANIUM | AFM - Raman - SNOM | Modular AFM | Automated AFM | Practical AFM |

Follow us on social media!!
YouTube/LinkedIn/Twitter/Instagram

»**Twitter: @ntmdt**
»**Instagram: @ntmdt**
»**Web: www.ntmdt.com**