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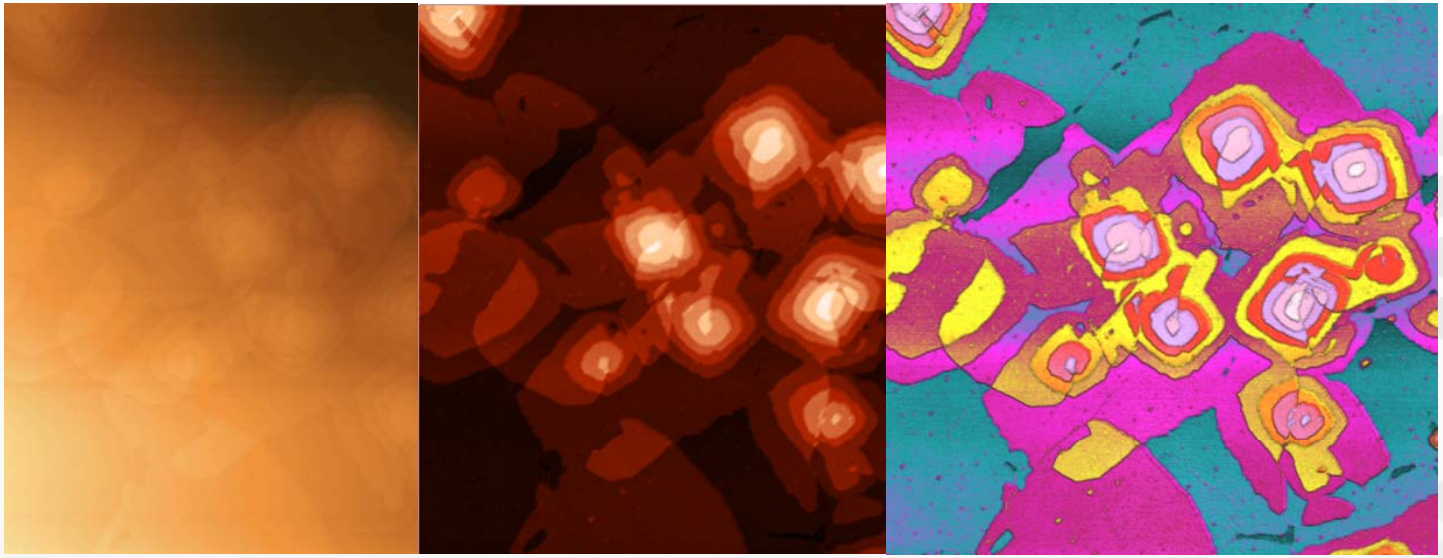
Обработка и представление данных в атомно-силовой микроскопии



Станислав Леесмент

26 мая 2016 г.

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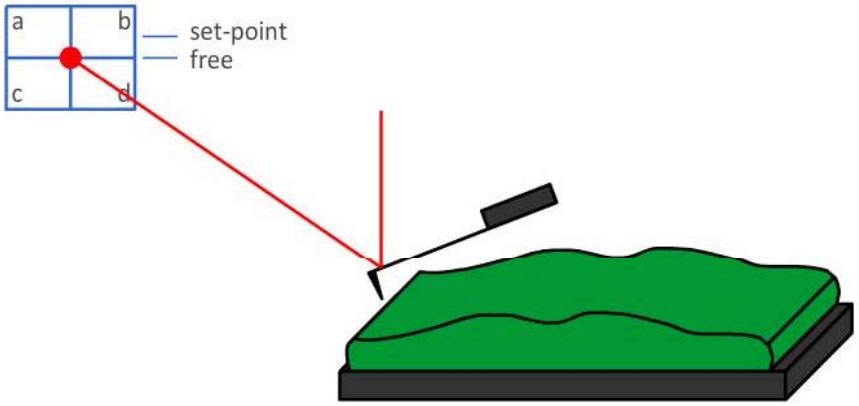
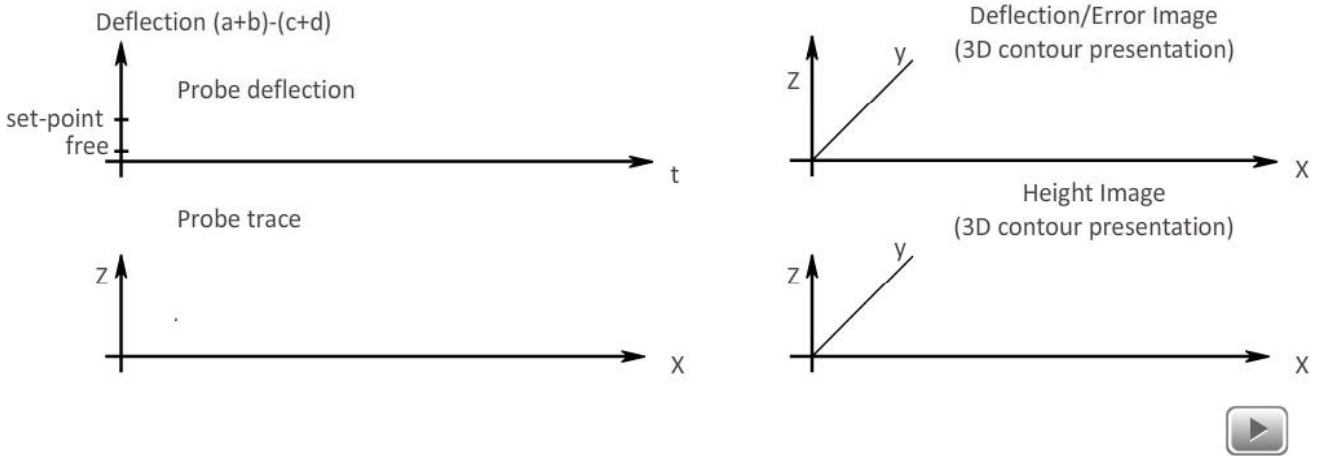
План доклада

1. Вступление, общие принципы
2. «Уплощение»: поверхности и межстрочные скачки
3. Фильтрация: пространственная и частотная
4. «Ретушь» изображений
5. Представление изображений: подбор палитры и 3D-представление
6. Заключение

Как получаются изображения в АСМ?





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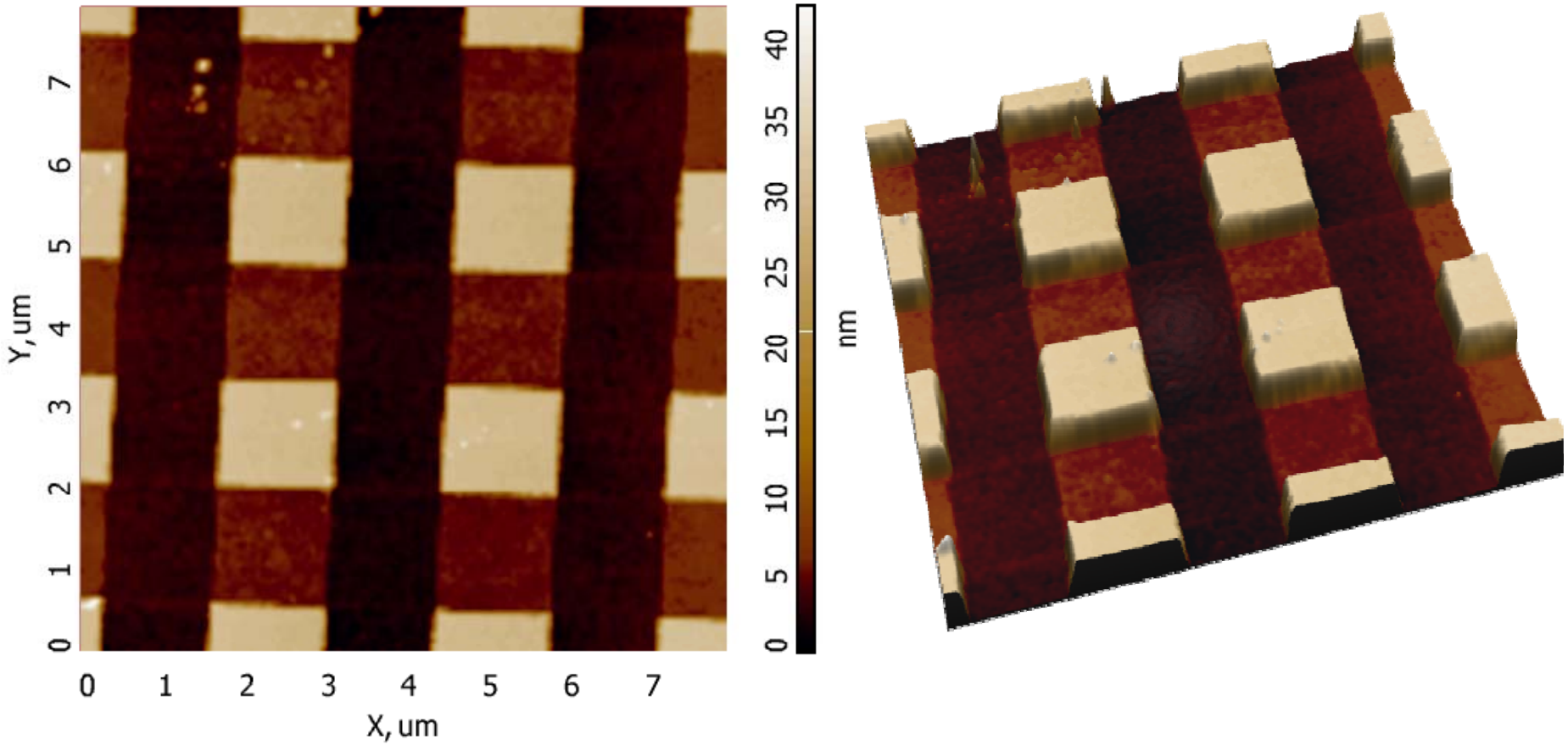
Что такое АСМ изображение?



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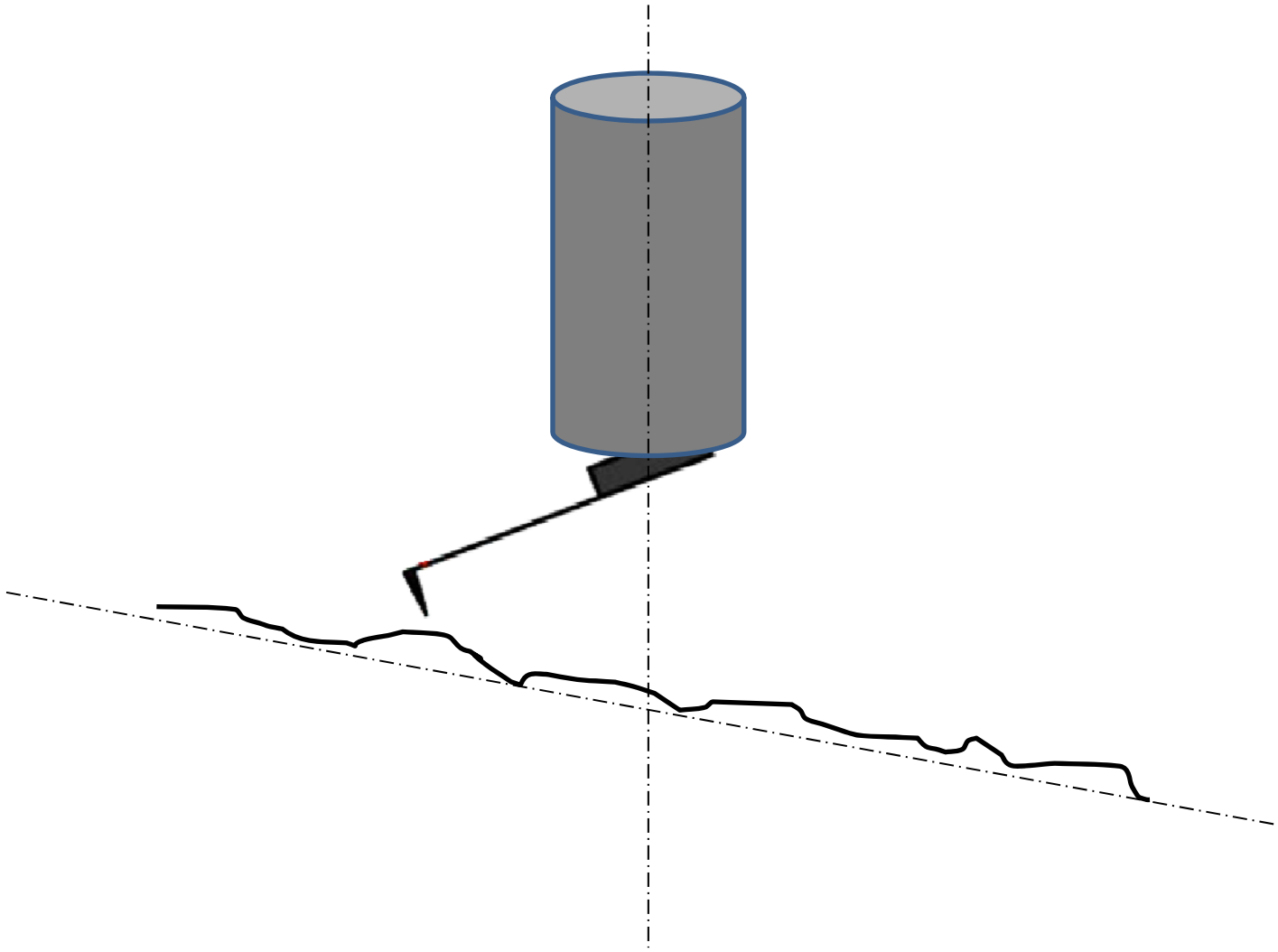
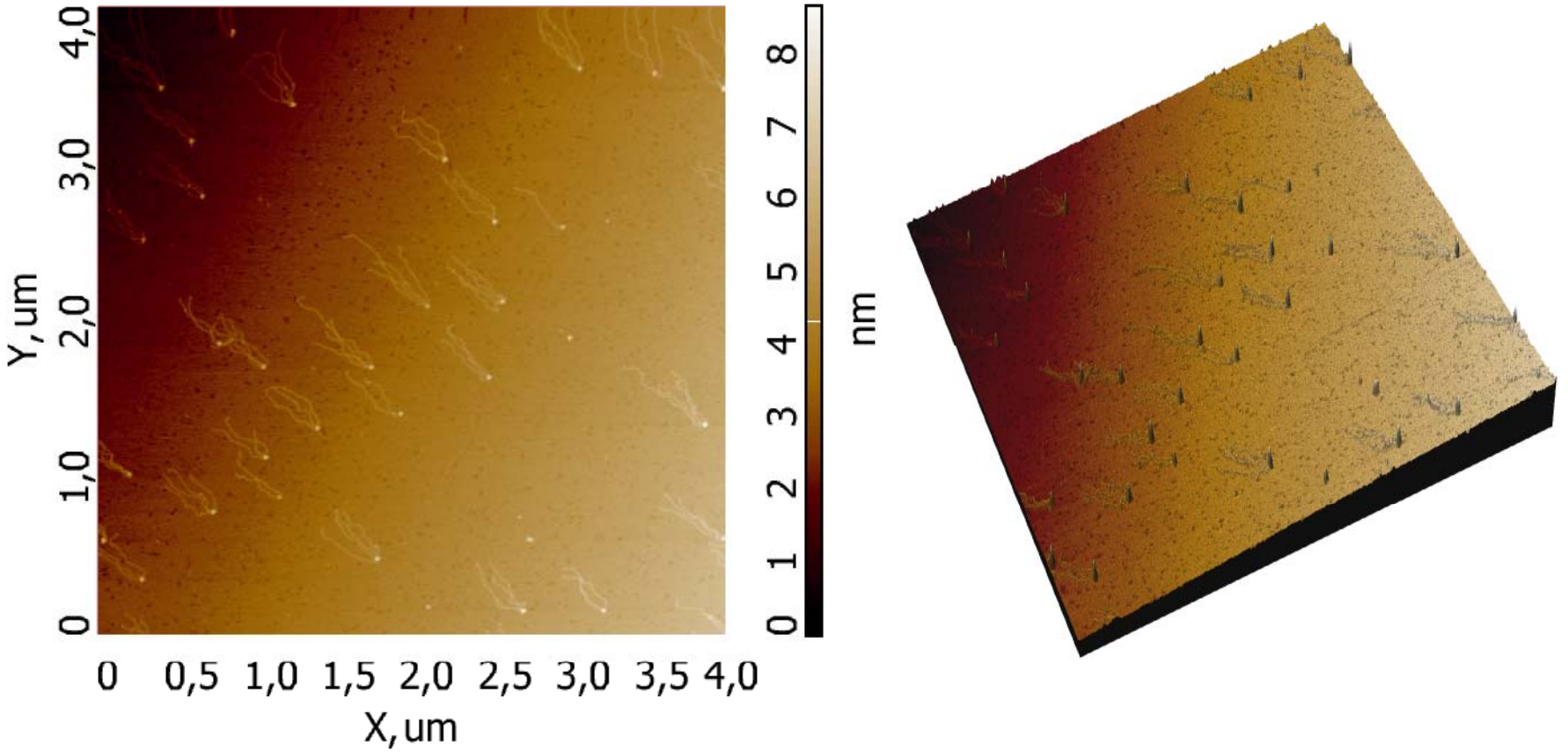
«Уплощение» АСМ изображений

Наклон образца

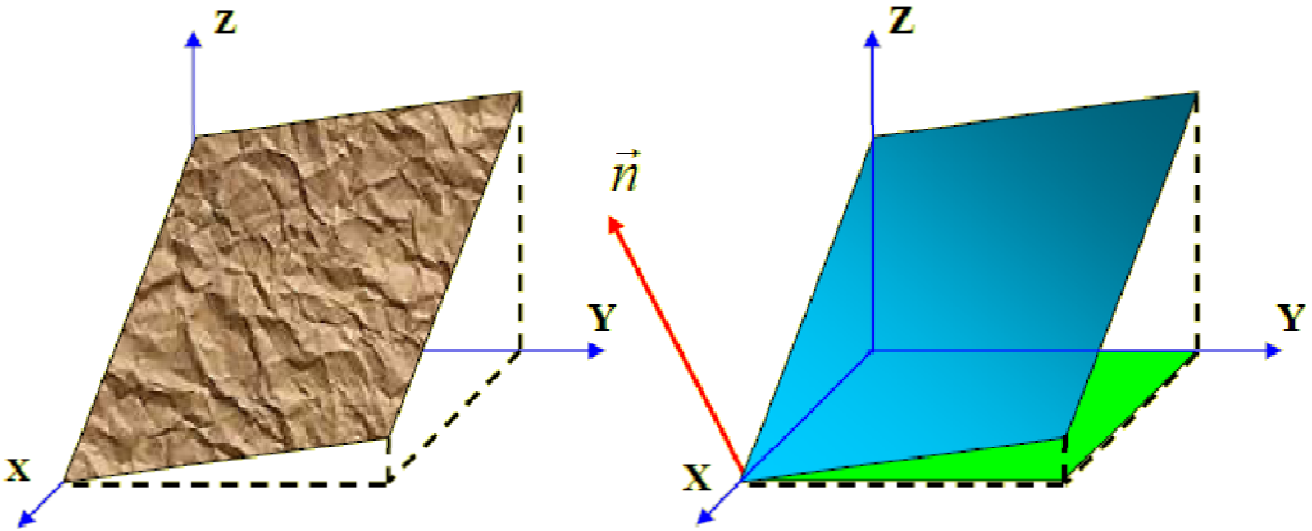


Наклон поверхности

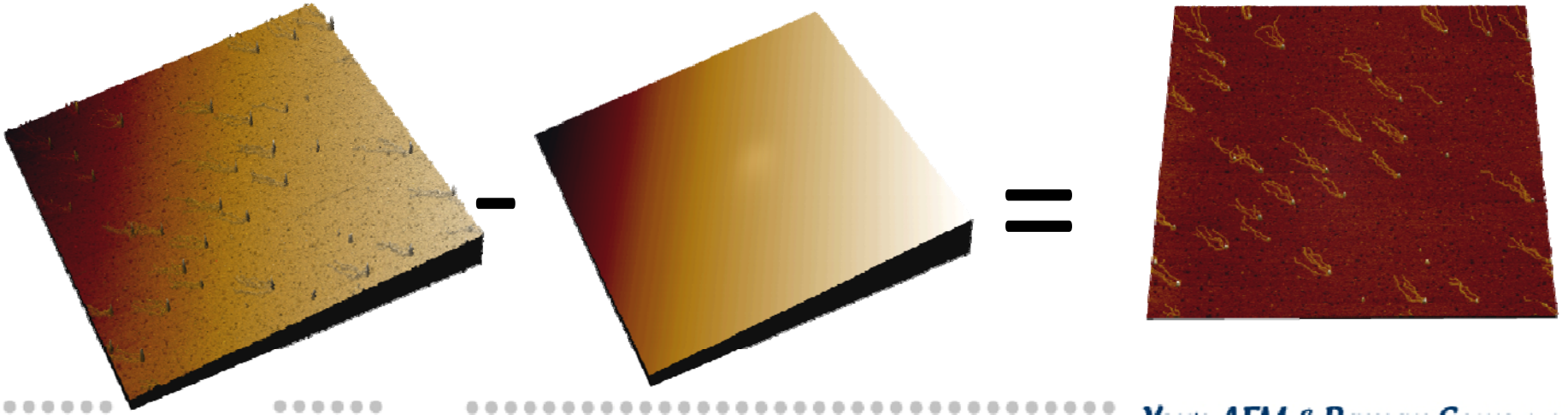


Наклон к нормали: 0,06°

Вычитание наклона поверхности



$$Ax + By + Cz + D = 0$$



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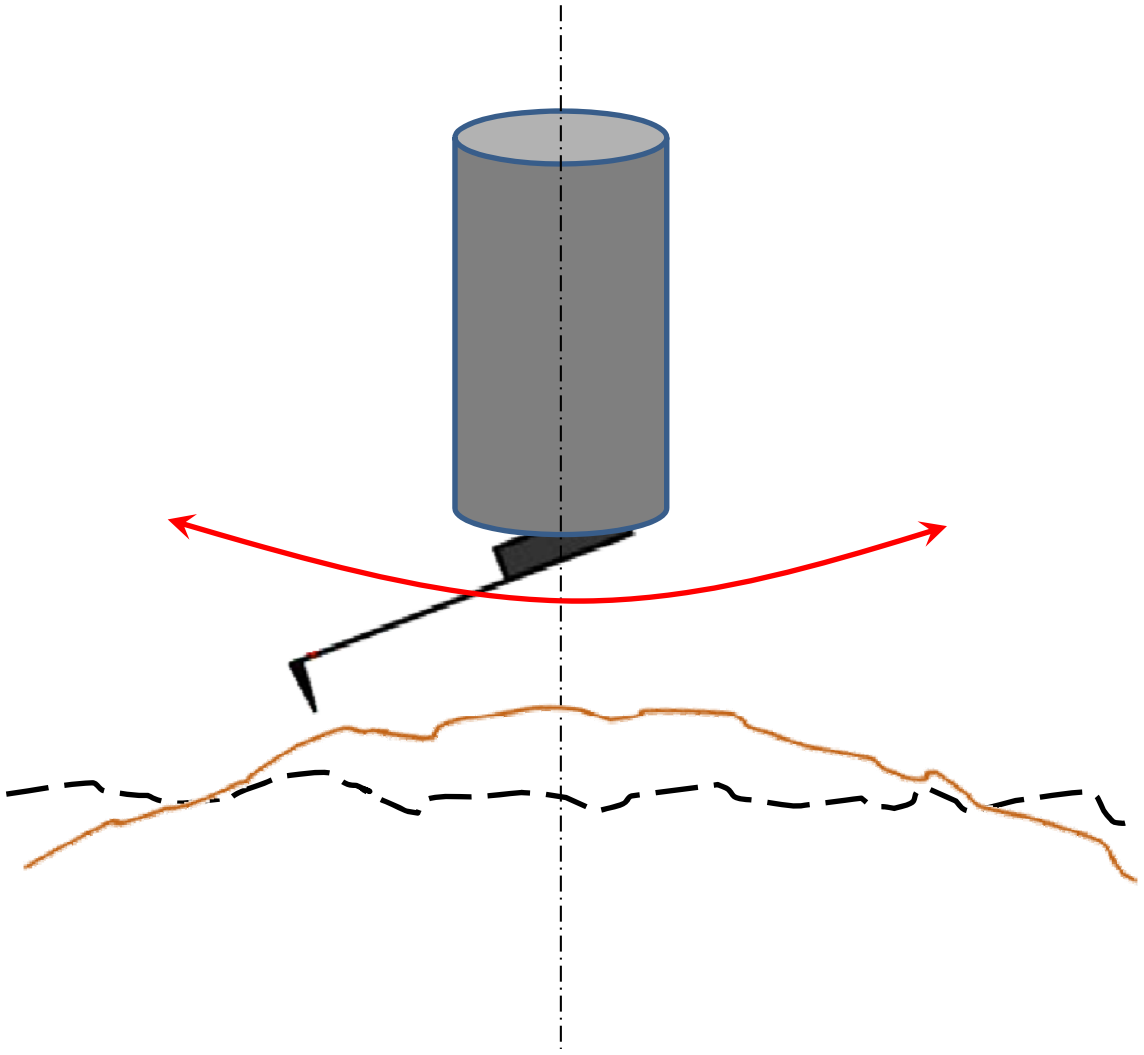
Искривления высших порядков



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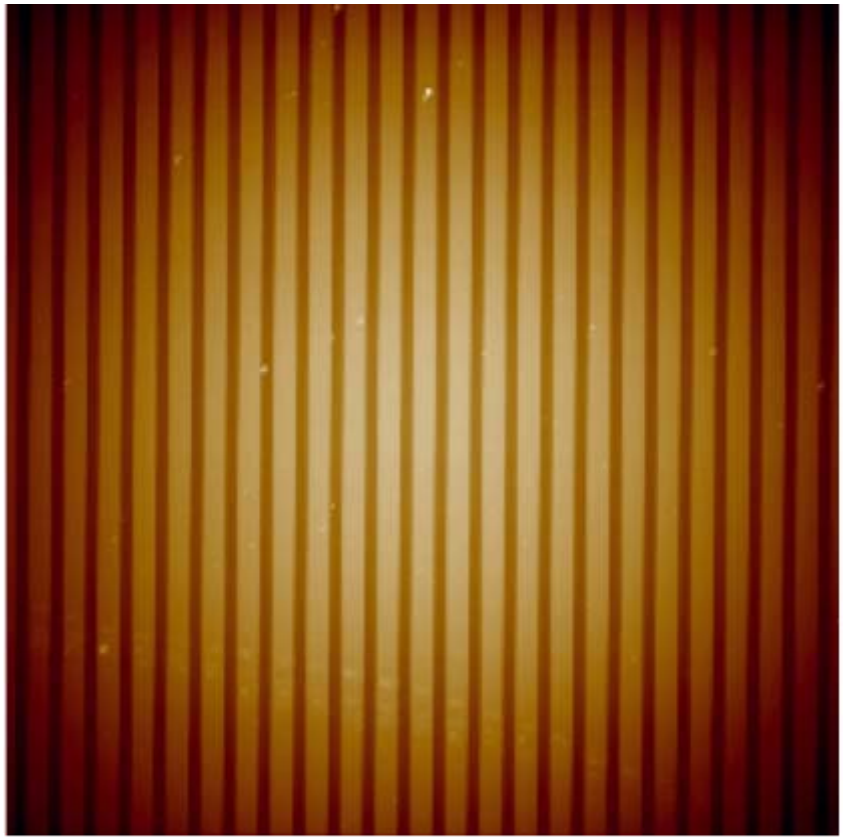
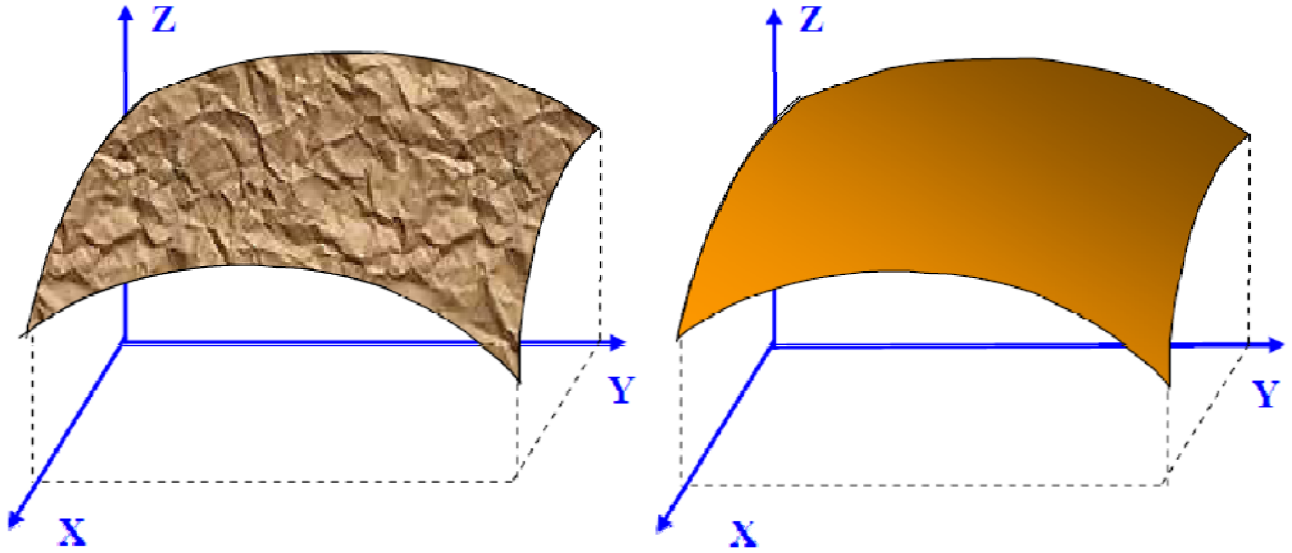
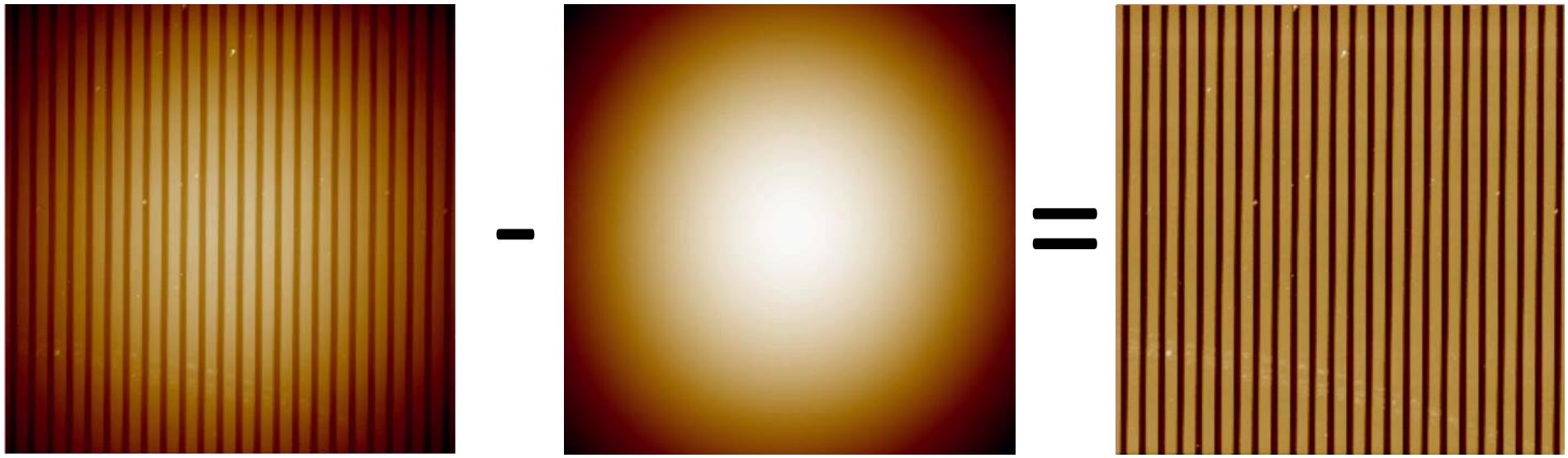
Паразитная выпуклость

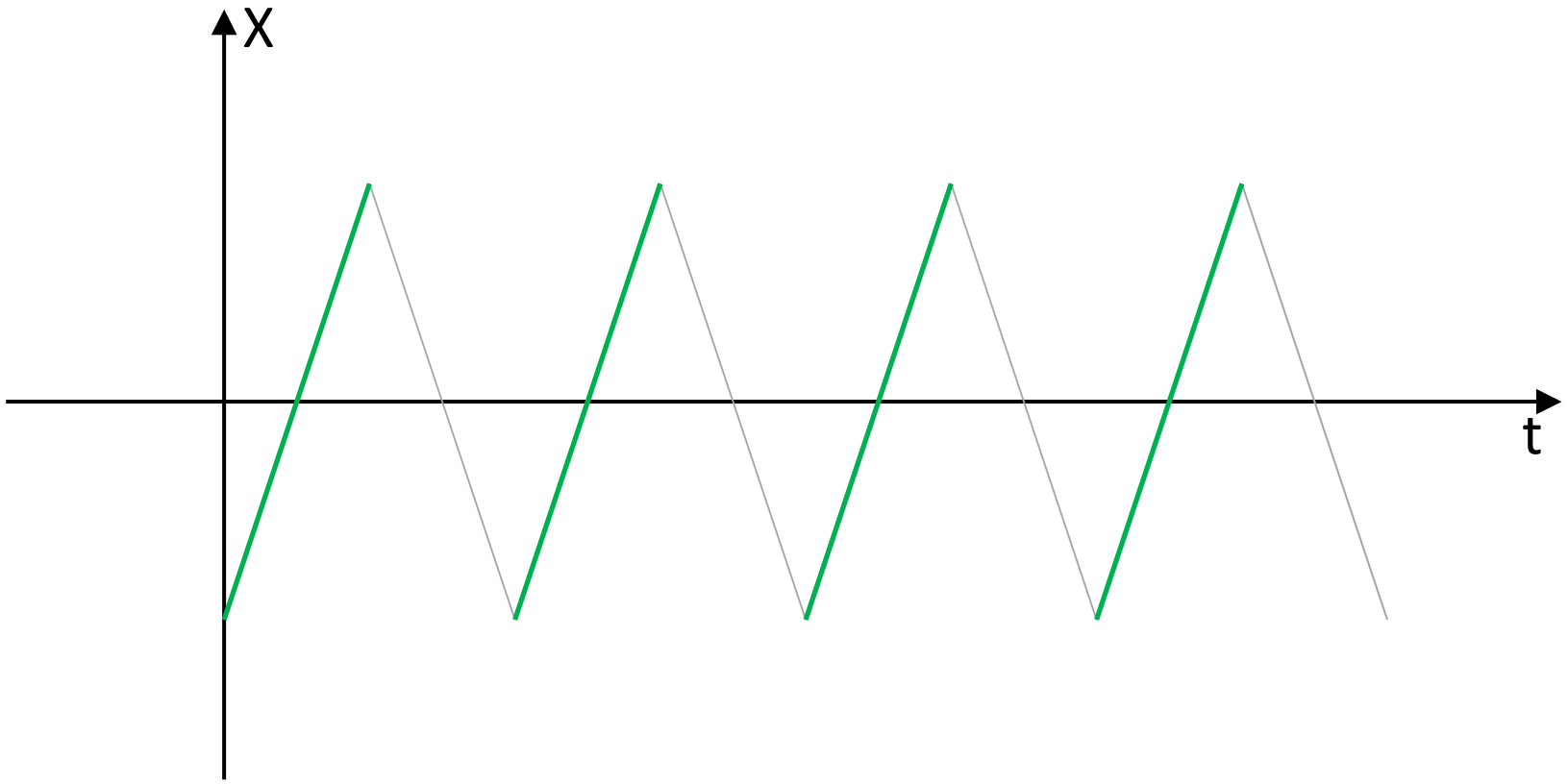


Вычитание поверхности 2-го порядка

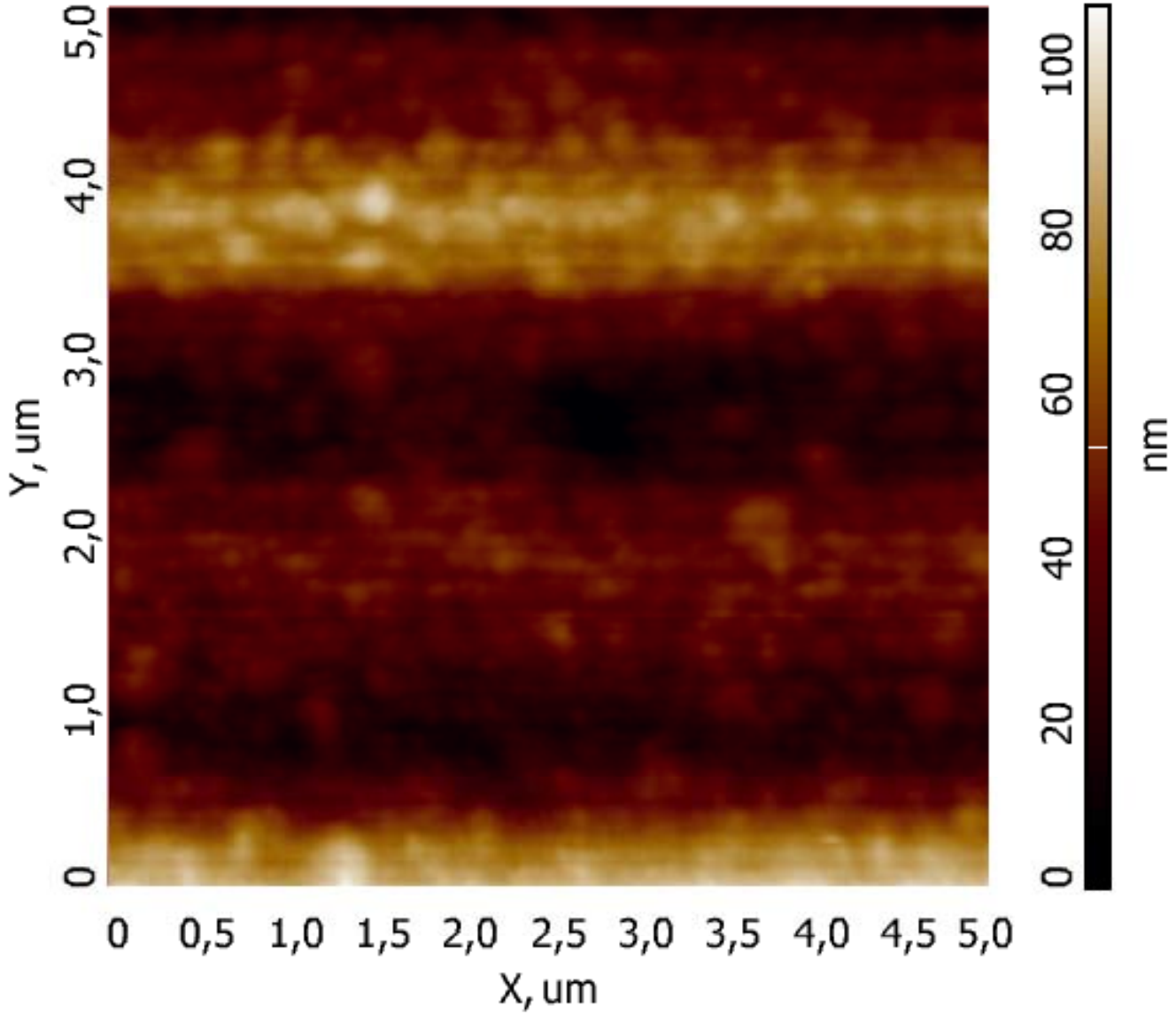




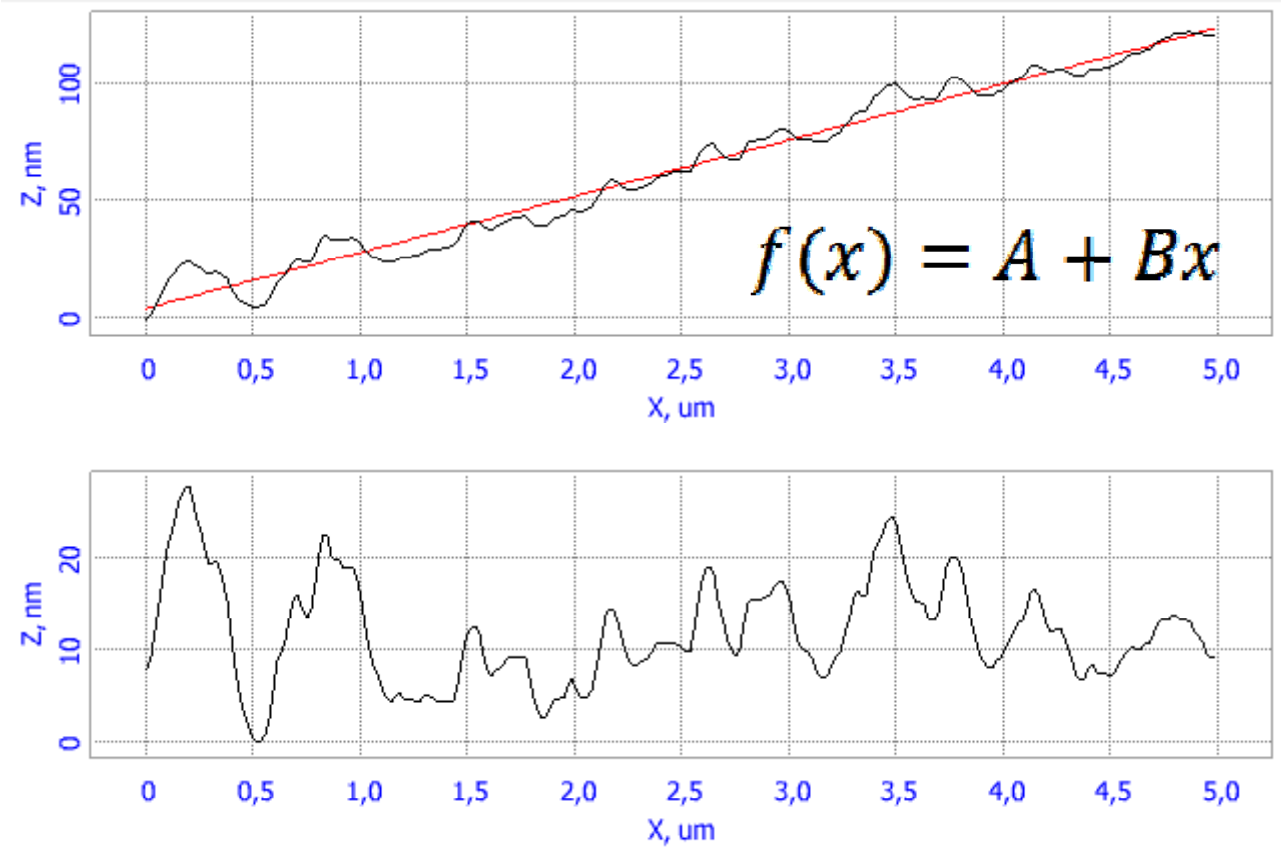
Межстрочные скачки



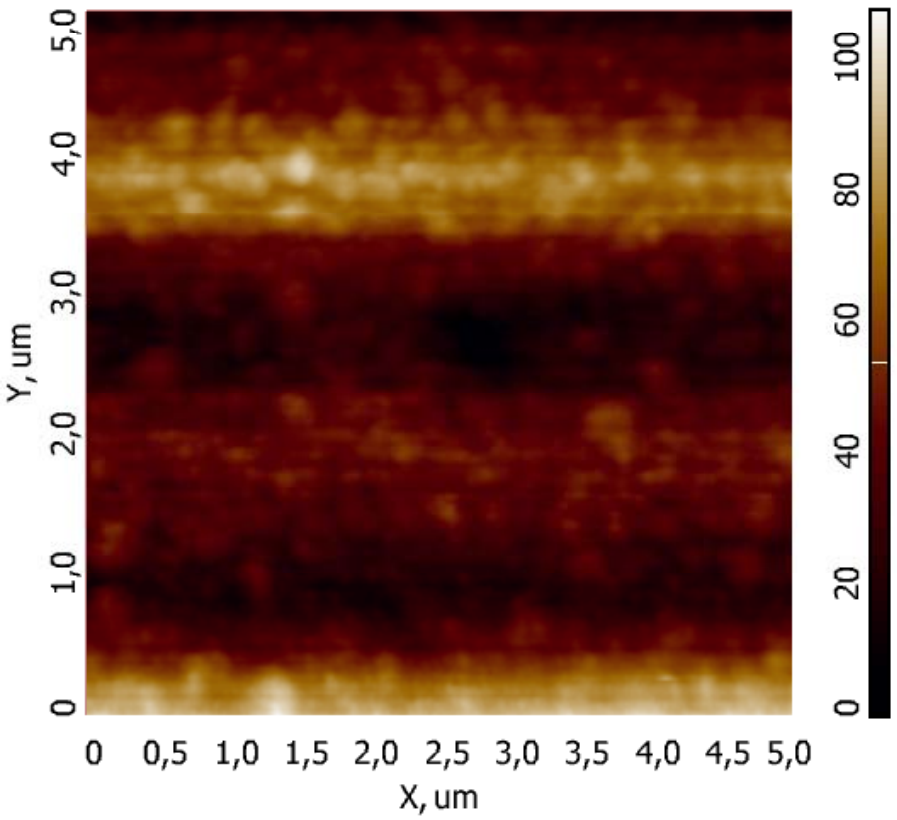
Межстрочные скачки

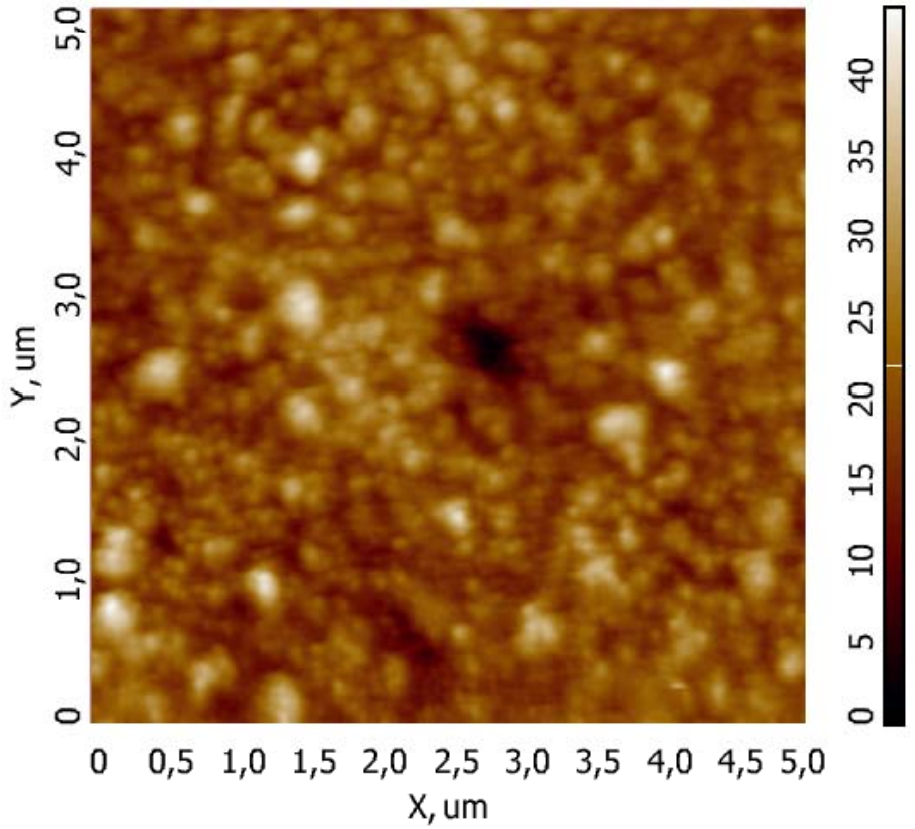


Межстрочные скачки

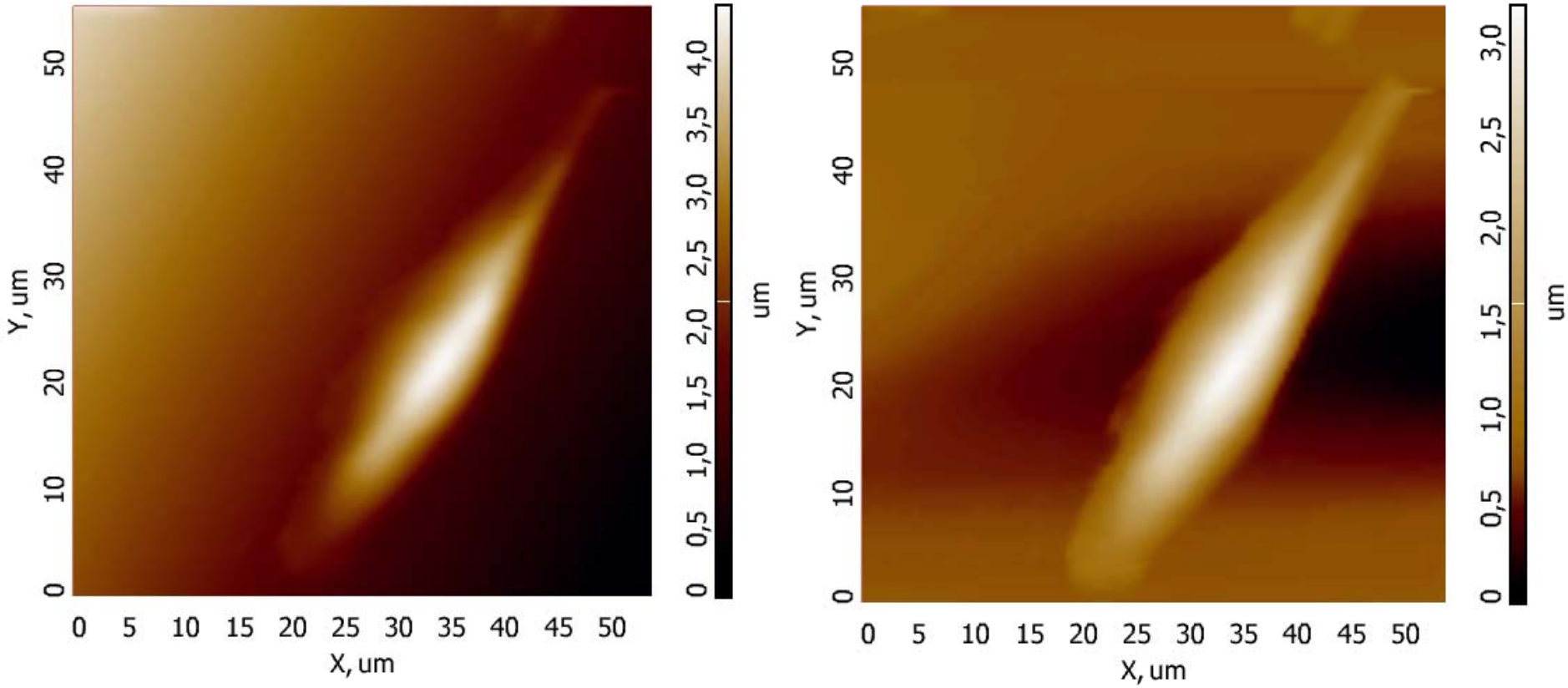


Удаление межстрочных скачков

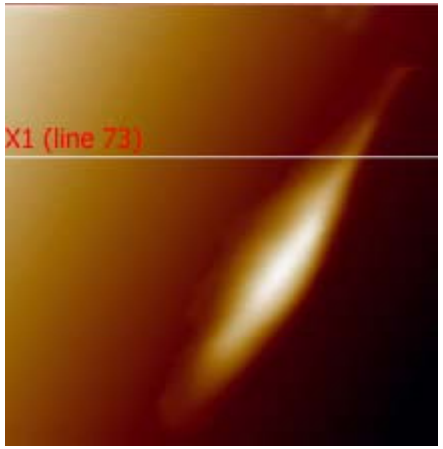


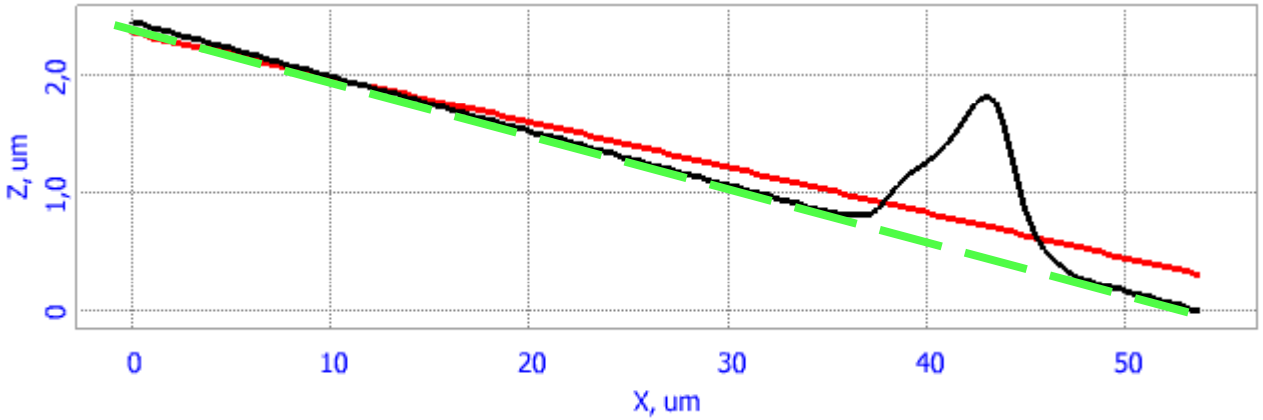


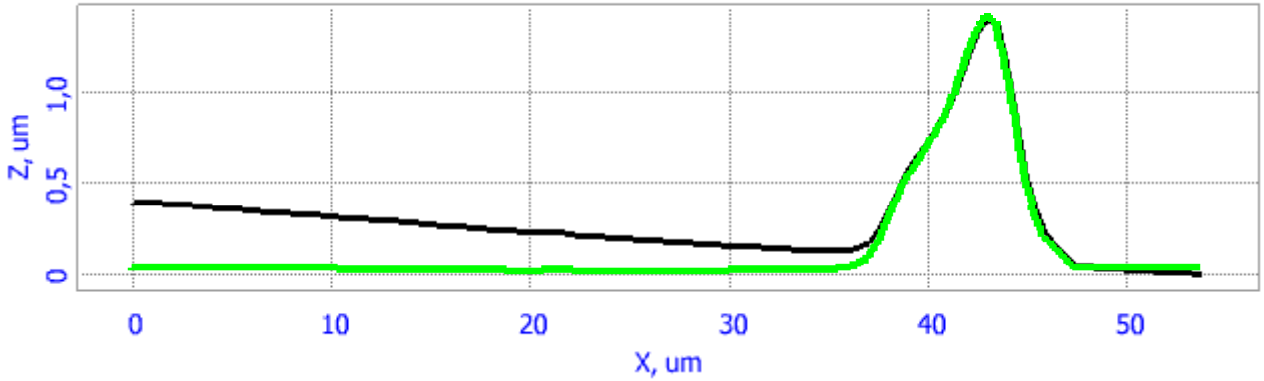
Высокие объекты на плоской подложке



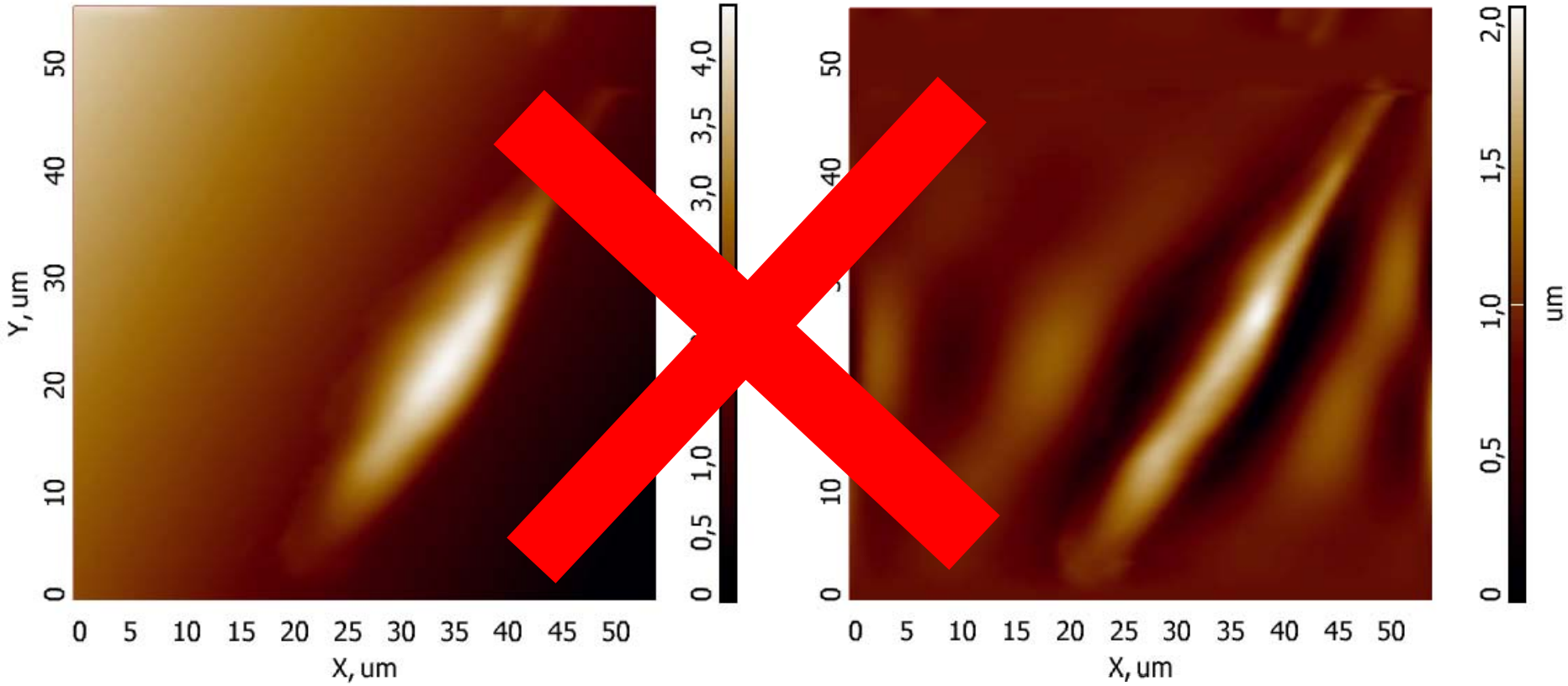
Сканы с высокими объектами





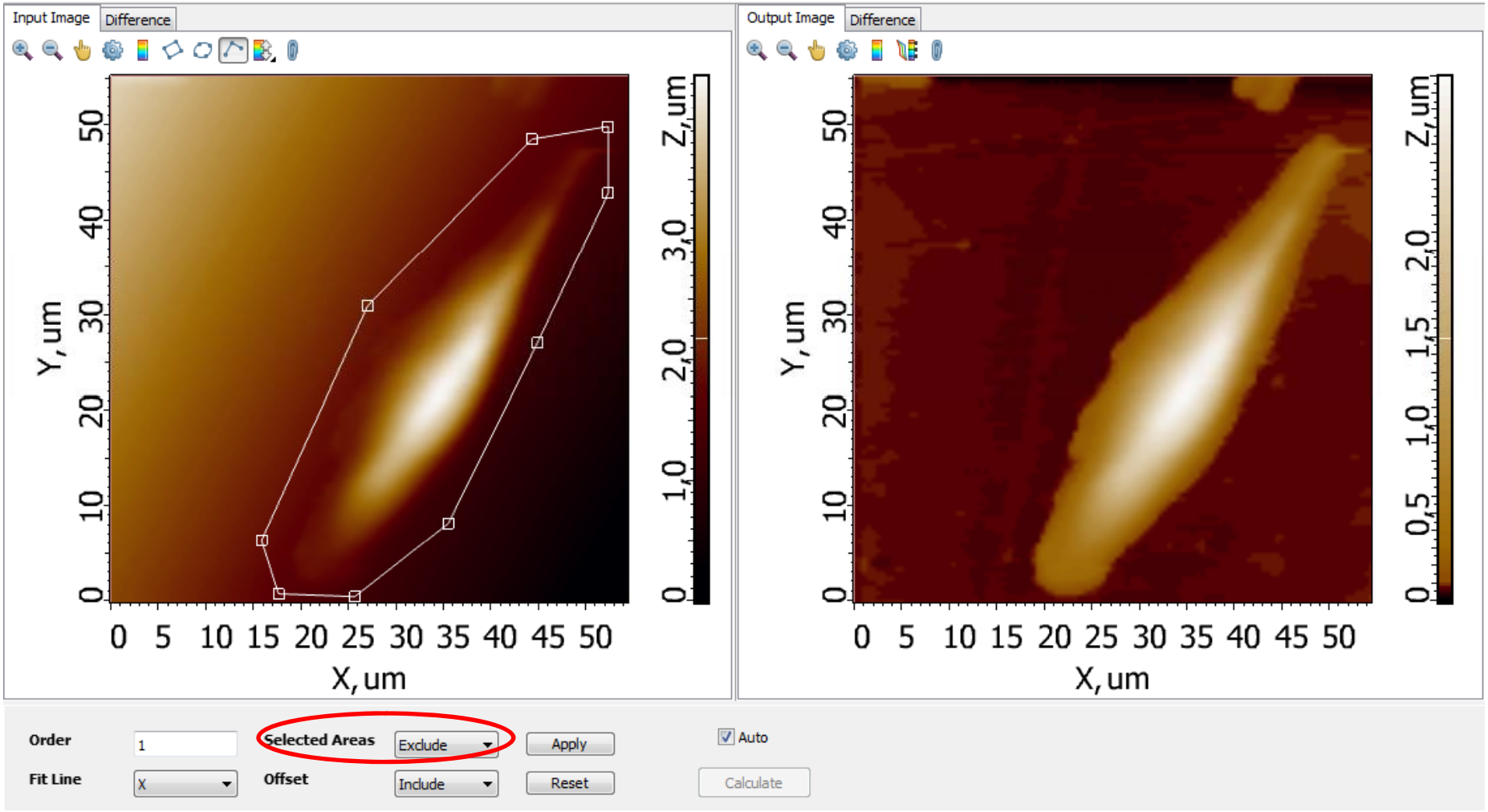


Коррекция полиномом высокого порядка

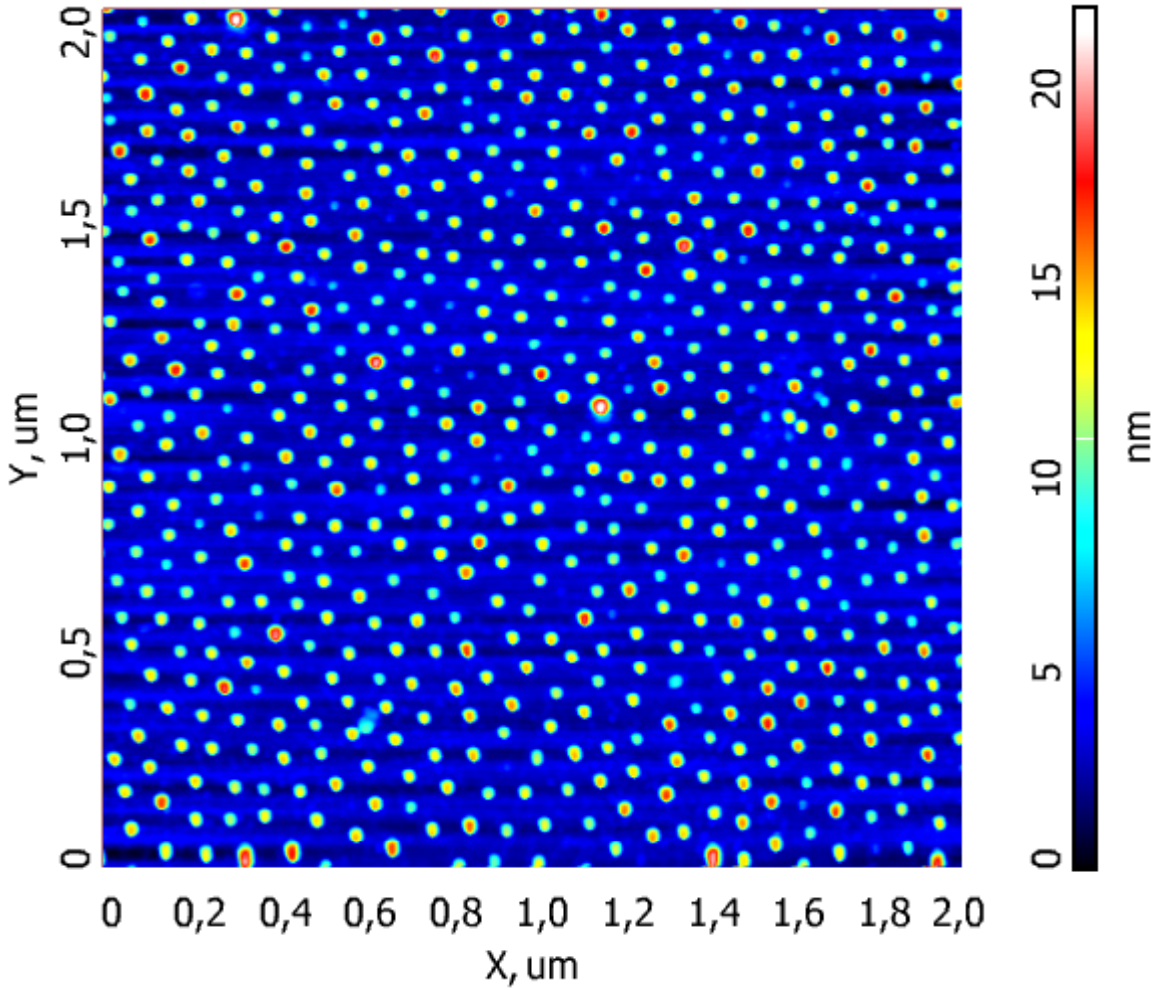


$$f(x) = A + Bx + Cx^2 + Dx^3 + Ex^4 + Fx^5 + Gx^6 + Hx^7$$

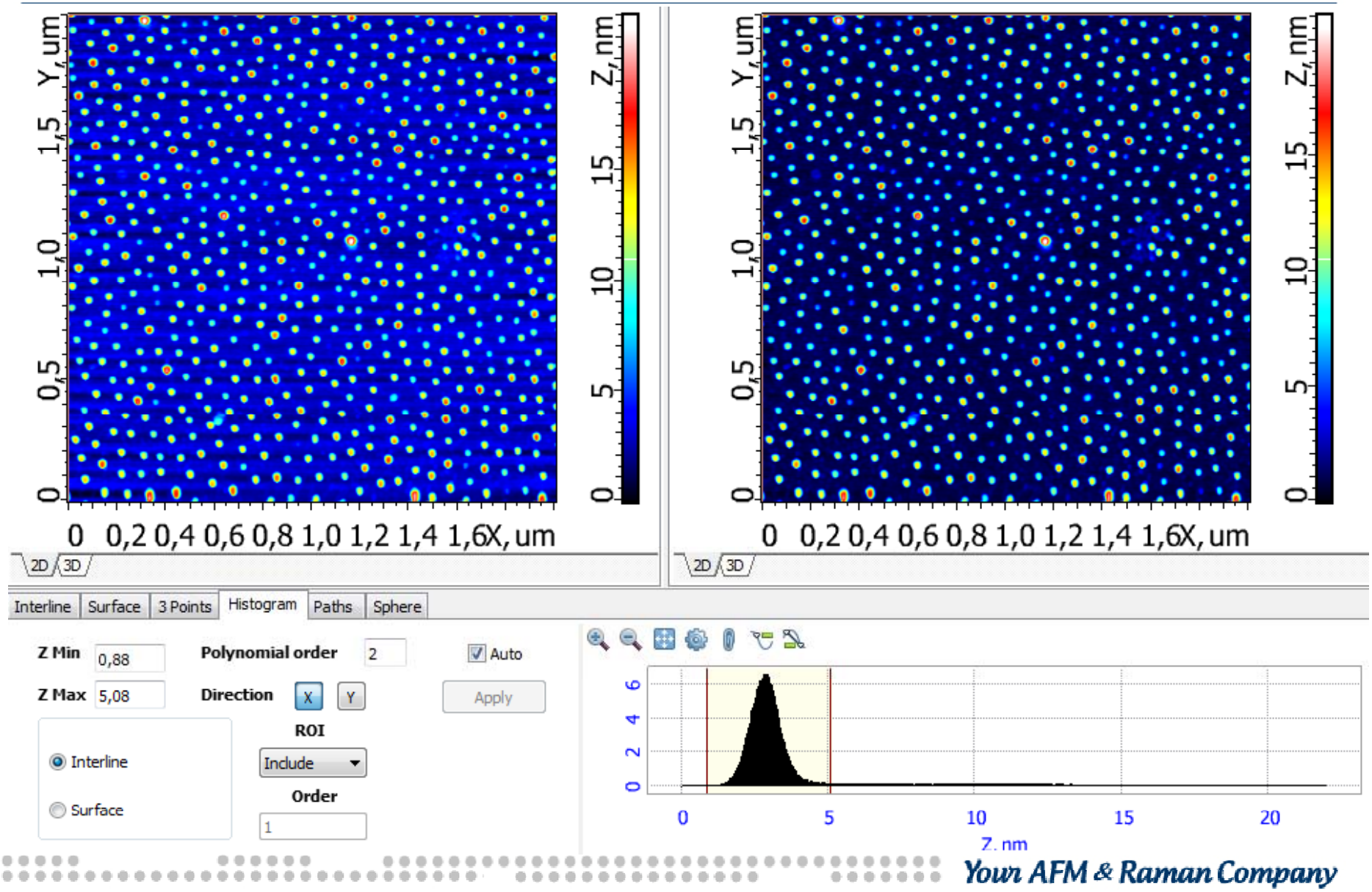
Fit Lines by Area



Множество объектов на плоской подложке



Fit Lines by Histogram



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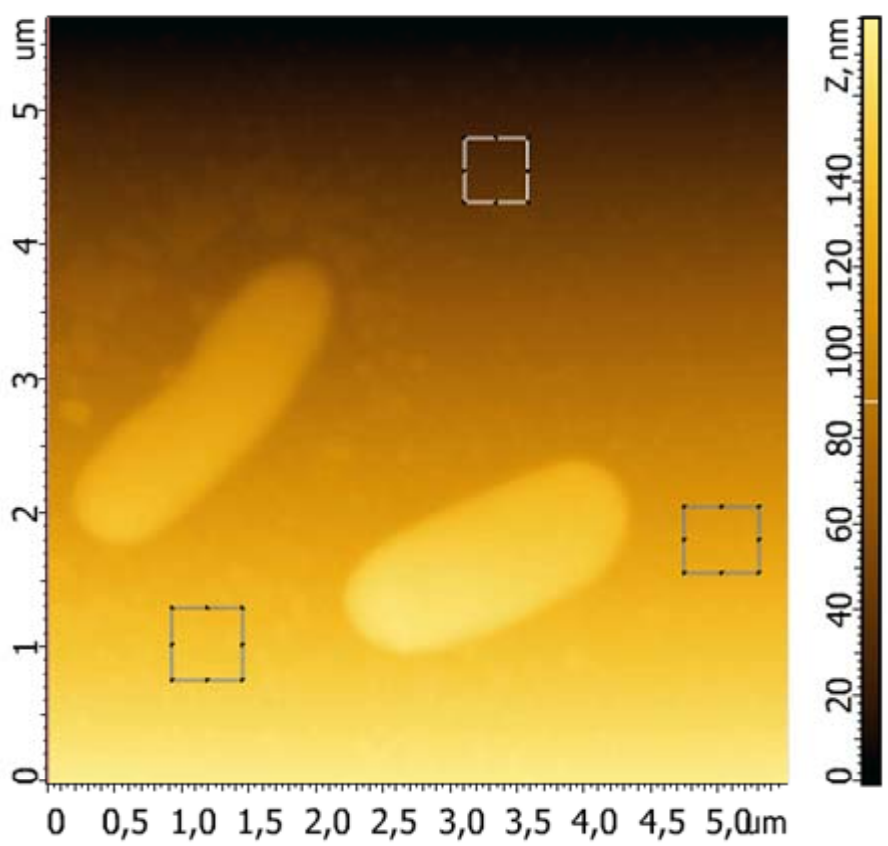
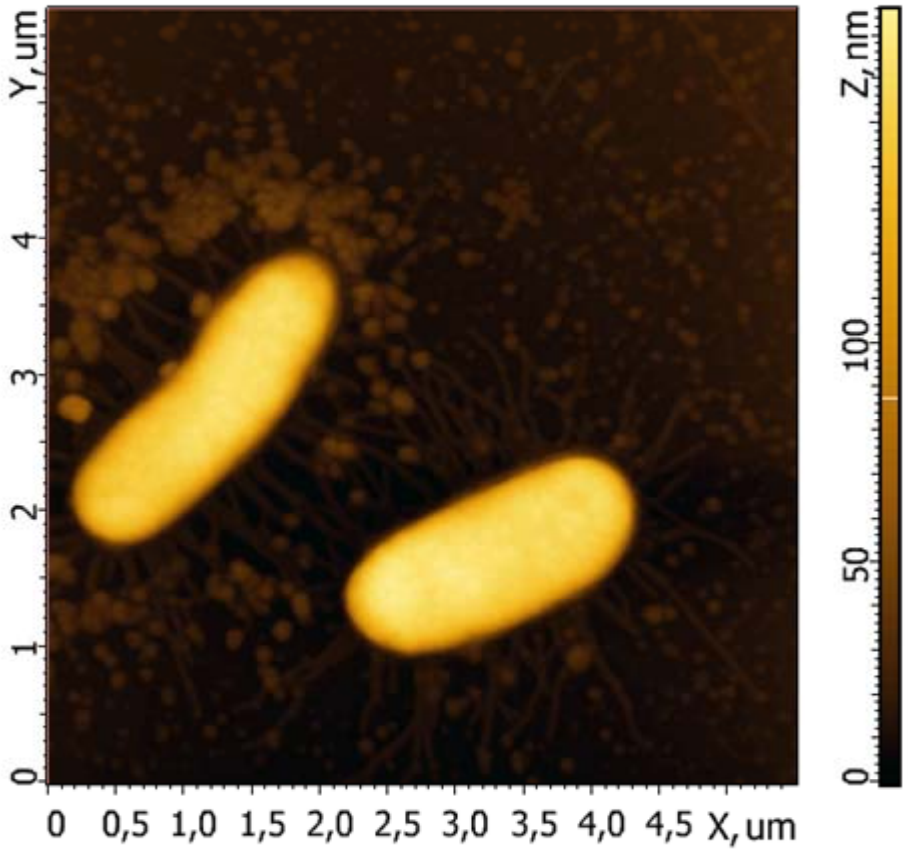
Three Points Leveling





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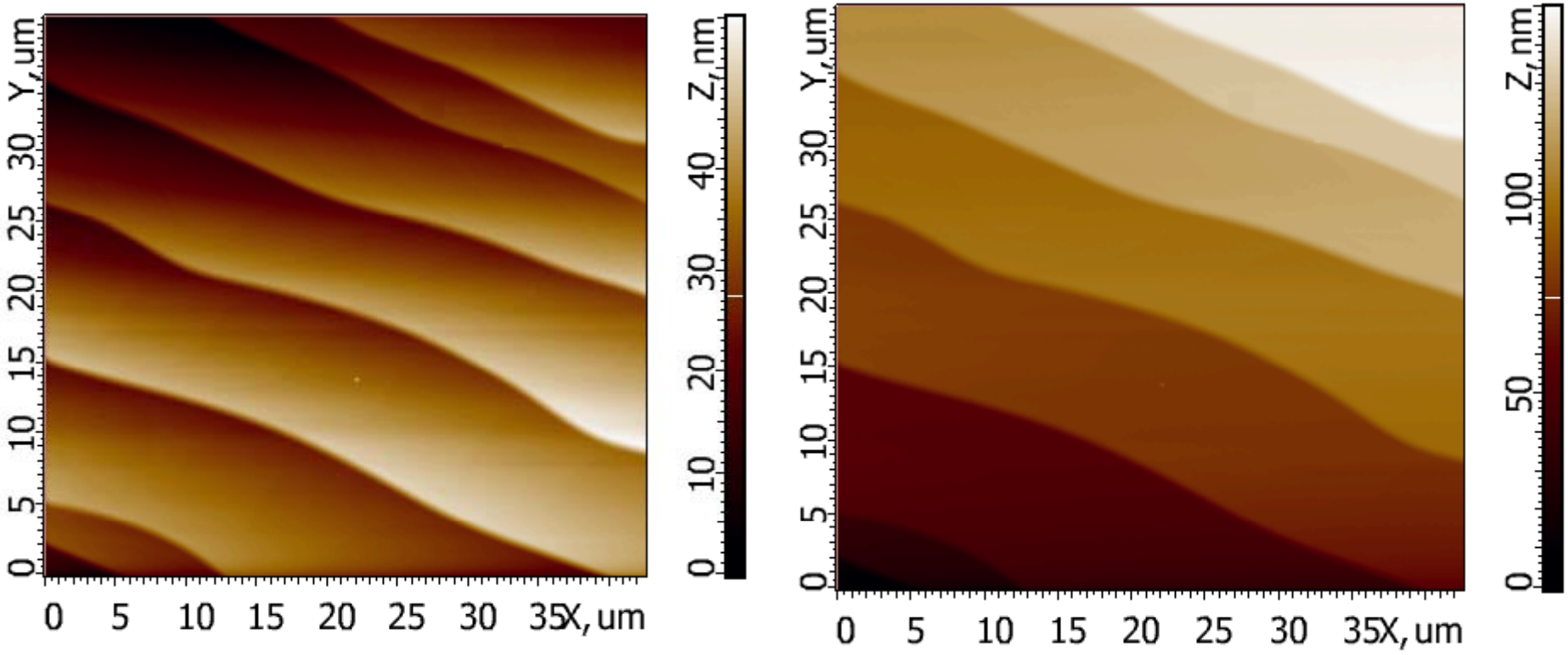
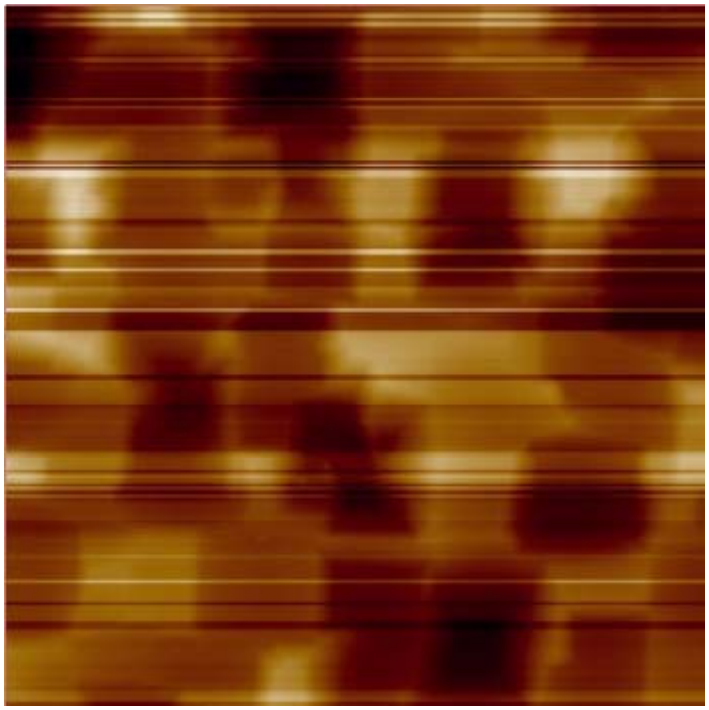
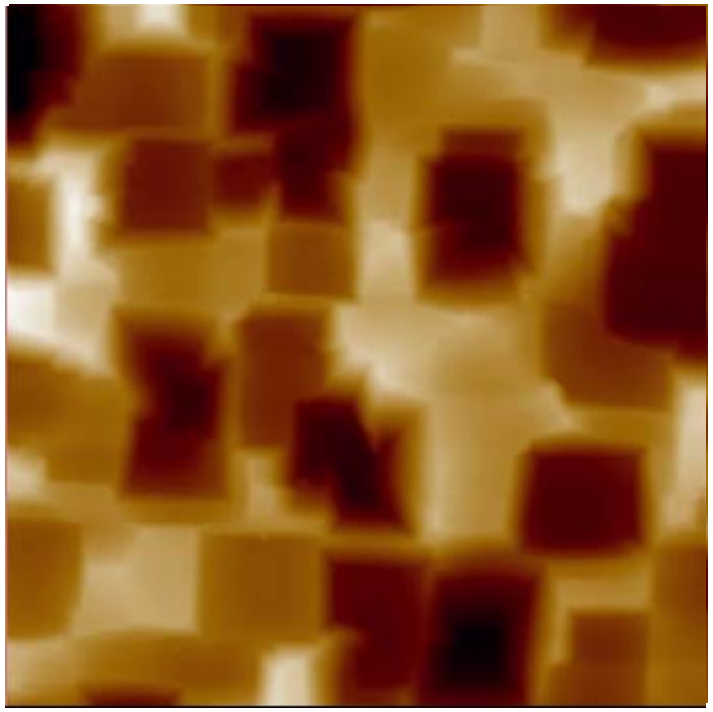
Facet Leveling

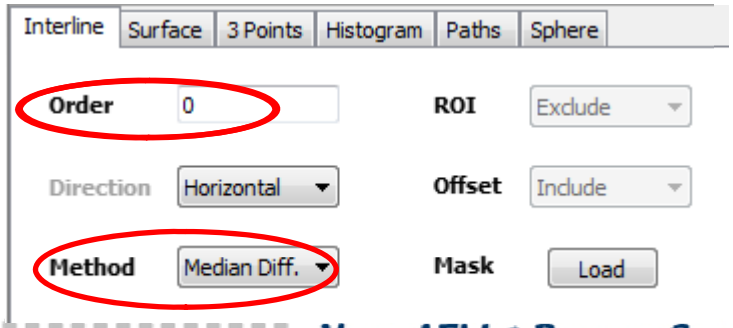


$$\nabla f(x,y) \rightarrow min$$

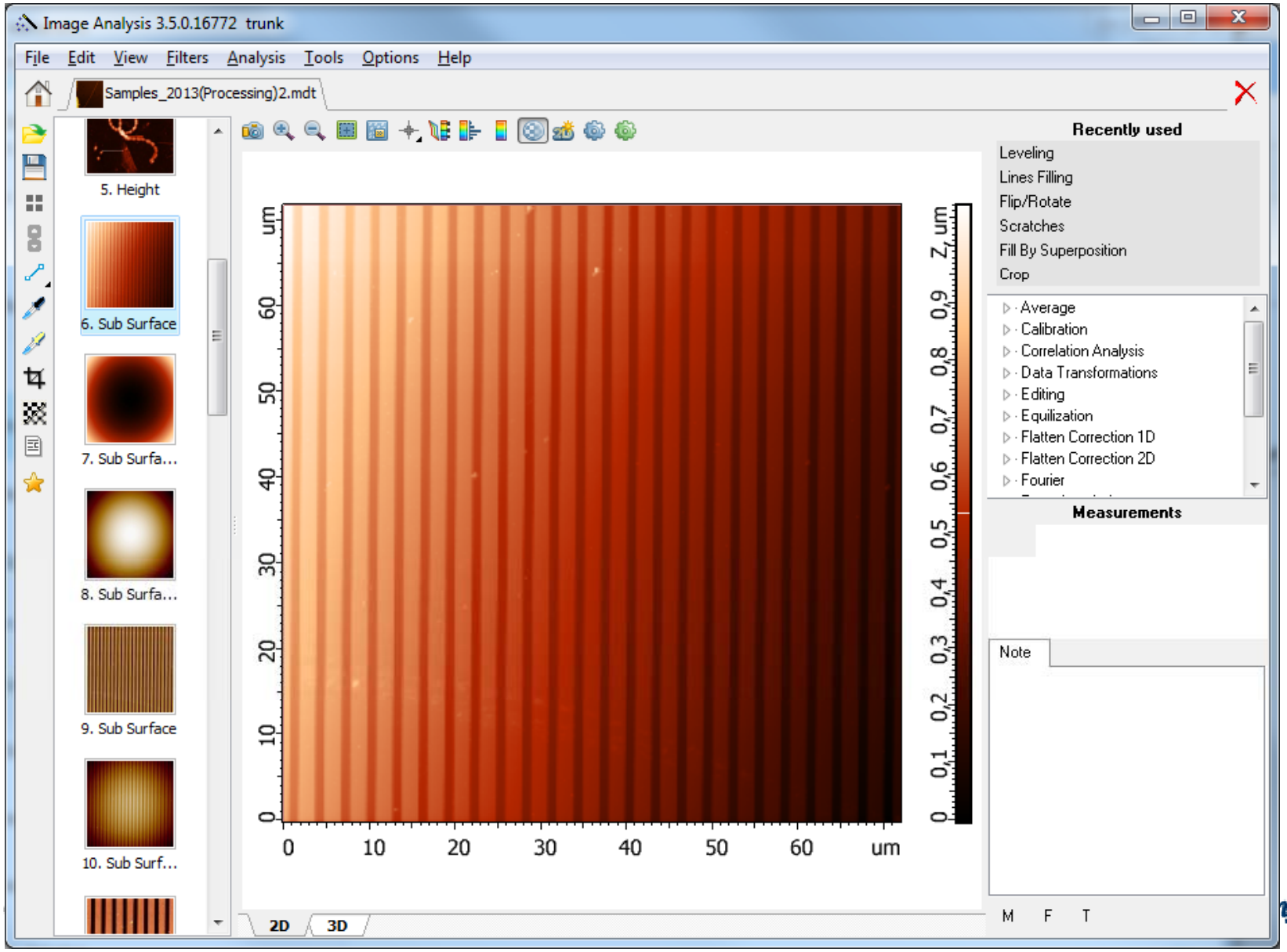
Line Correction



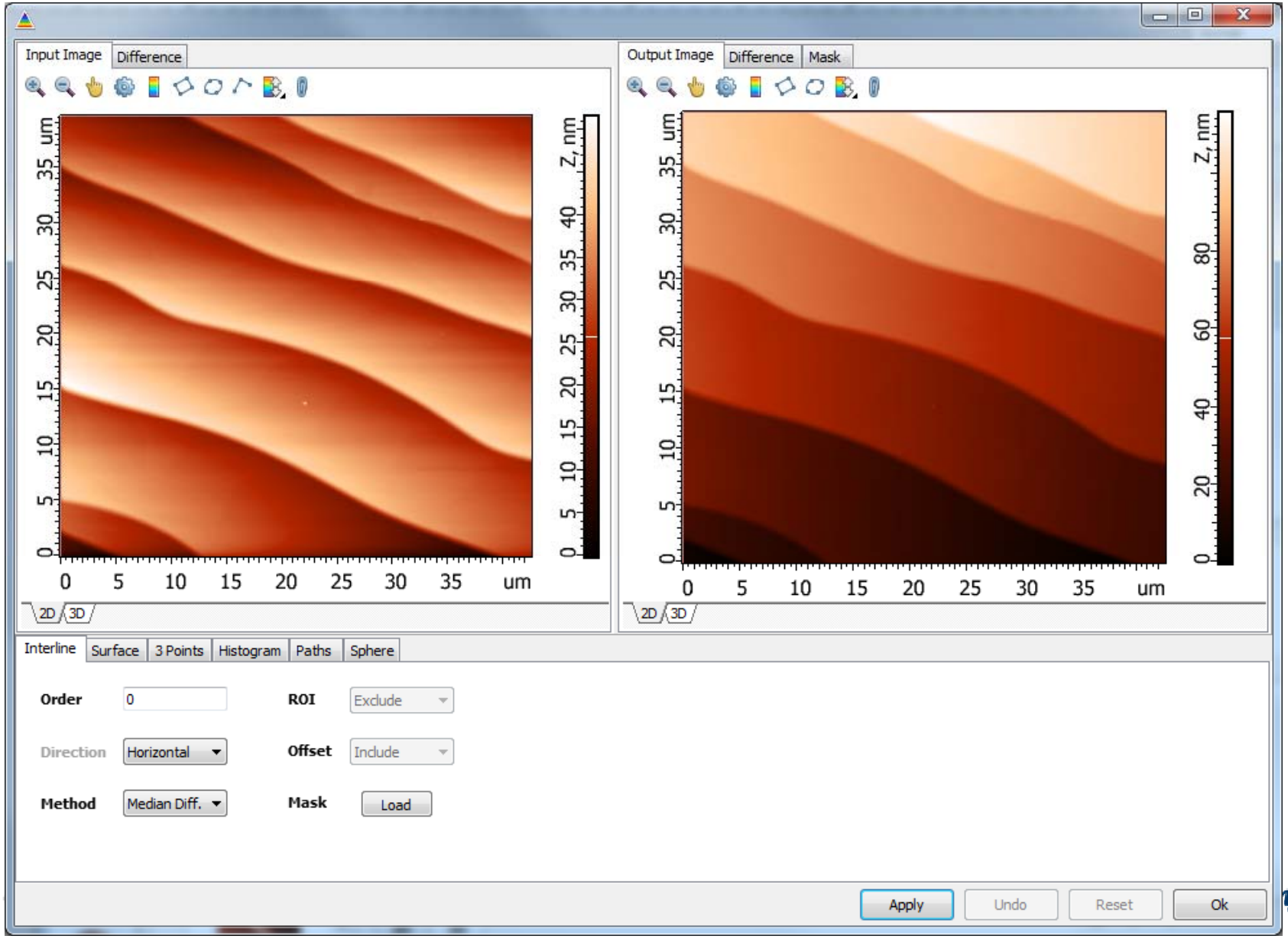




Интерфейс Image Analysis 3.5



Интерфейс модуля Leveling



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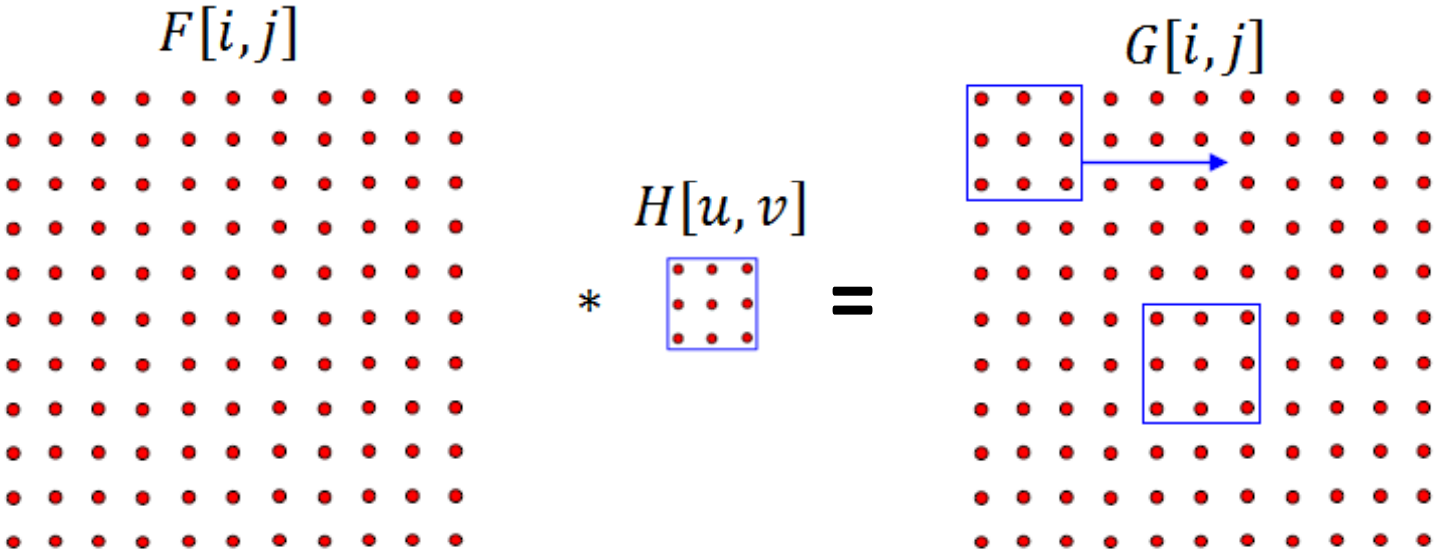
Фильтрация
АСМ изображений

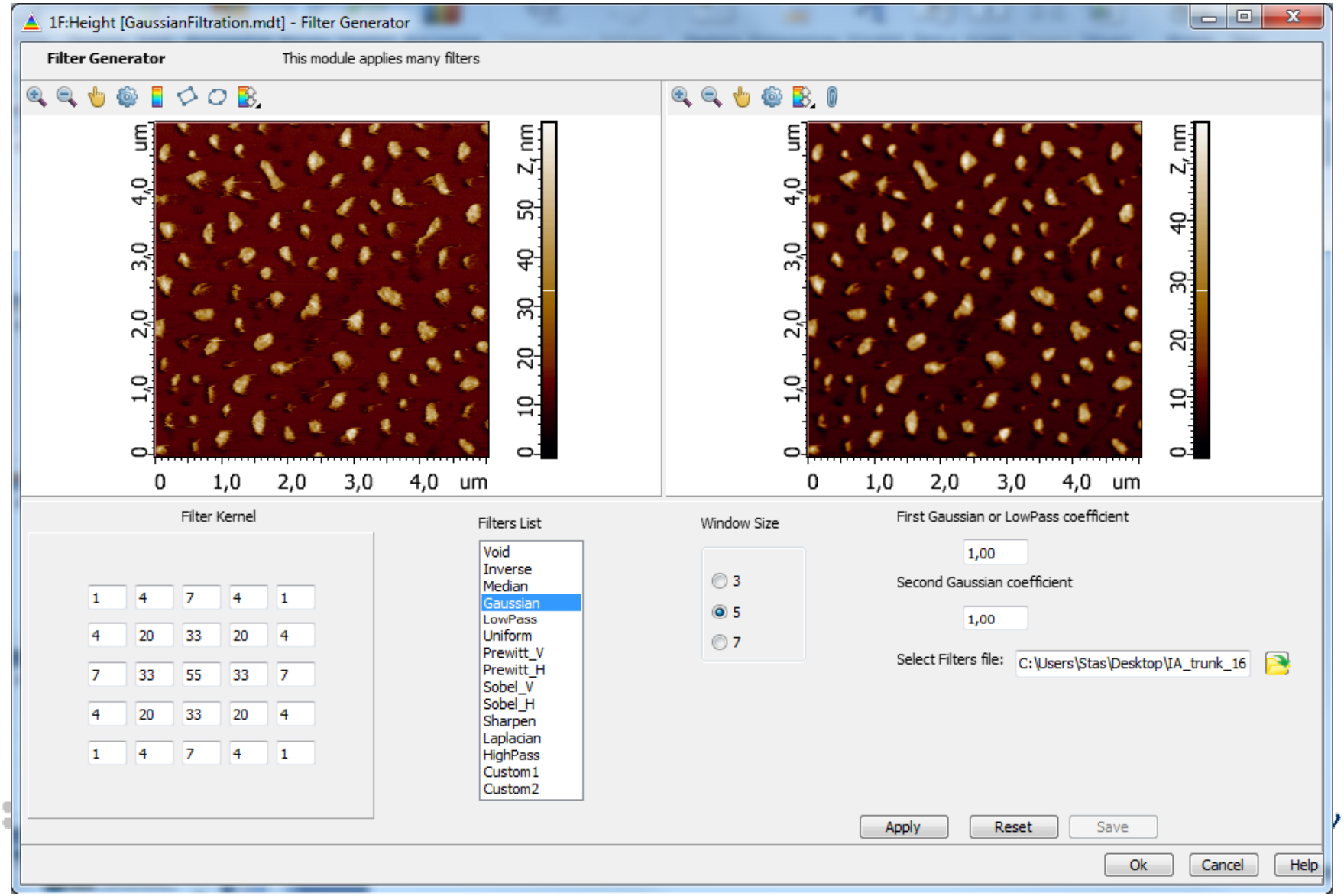
Пространственная оконная фильтрация

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



Окно генератора фильтров

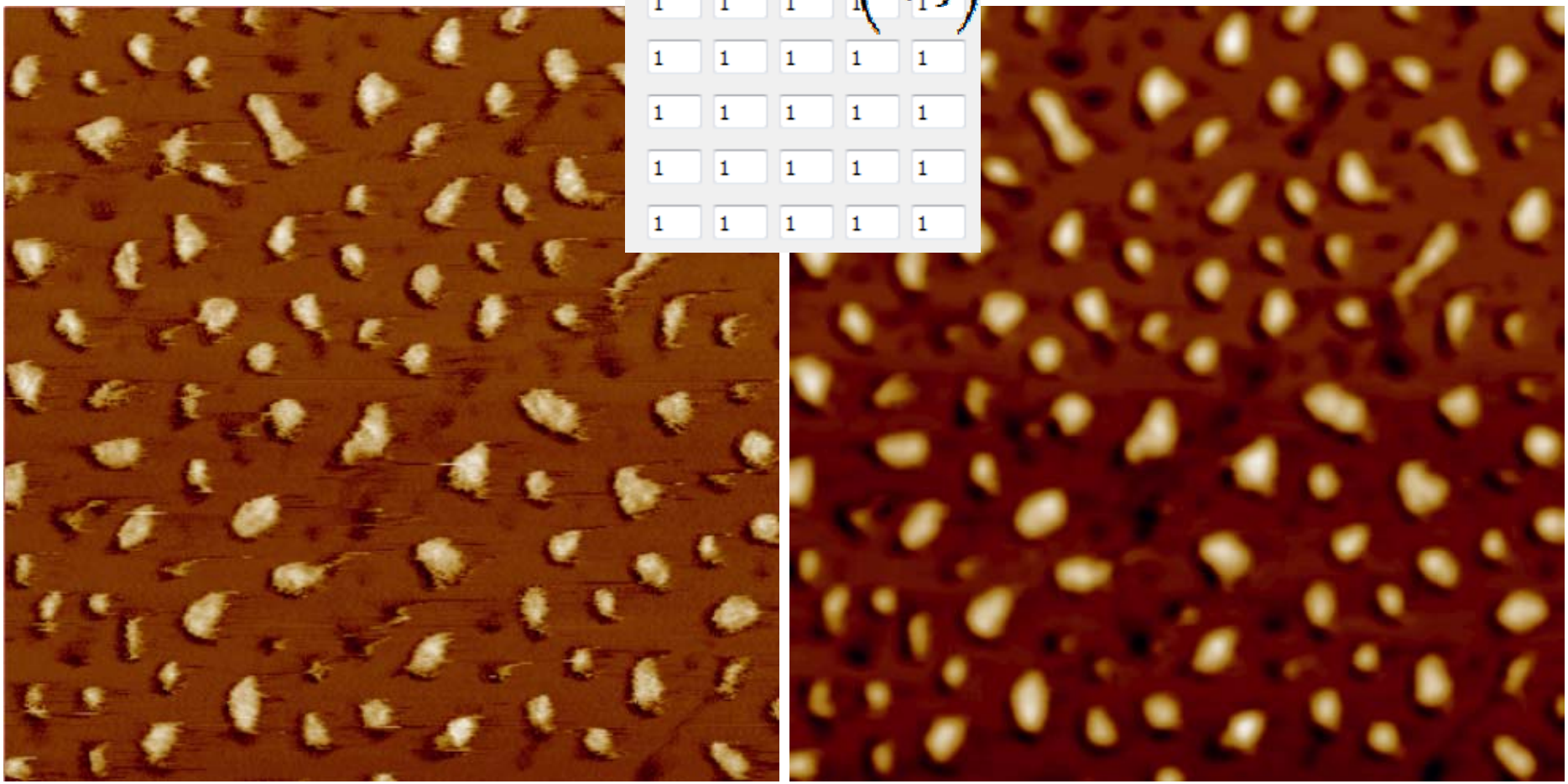
Editing → Filter Generator



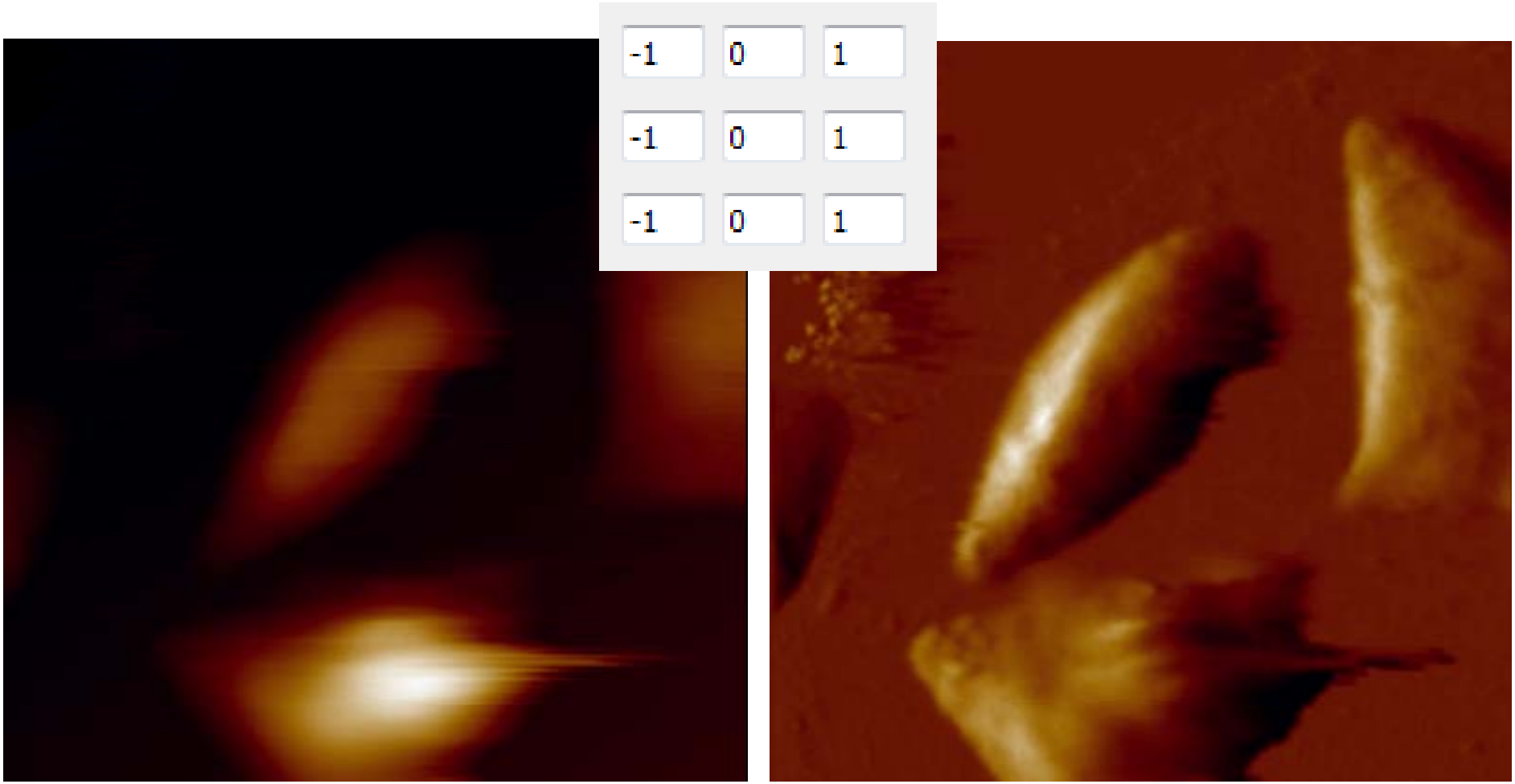
Усредняющие фильтры

$$\left(\frac{1}{9}\right)$$

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



Высокочастотная фильтрация



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Filter Generator

Uniform

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

Gaussian

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

Prewitt vertical

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

Prewitt horisontal

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

Sharpen

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

Sobel Vertical

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

Sobel horisontal

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

Laplacian

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

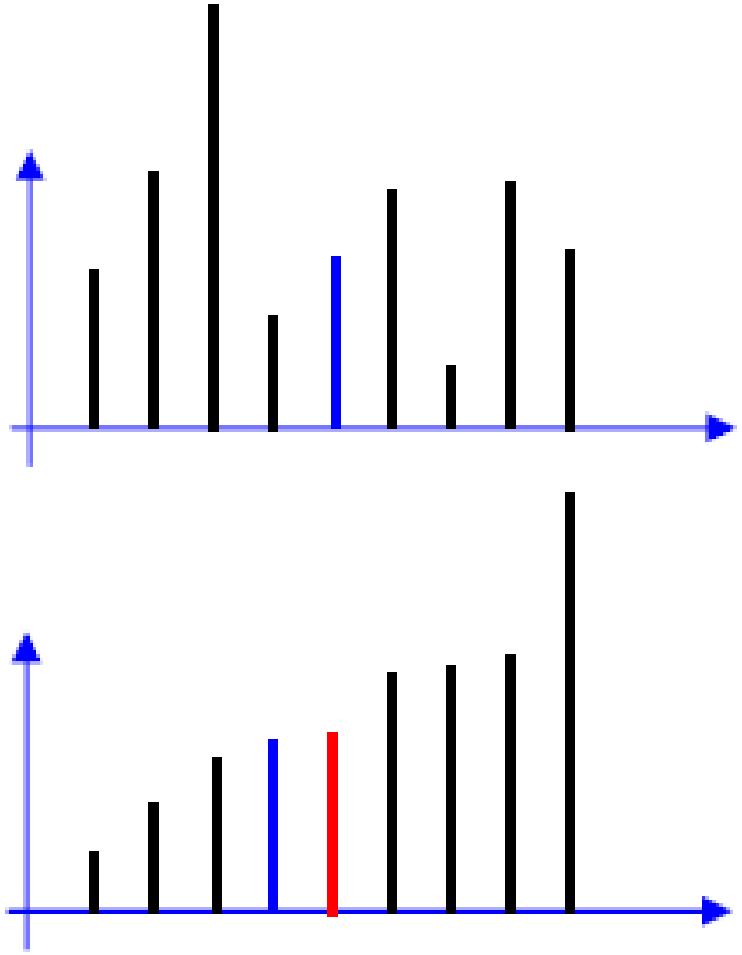
High Pass

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

Custom

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

Медианная фильтрация



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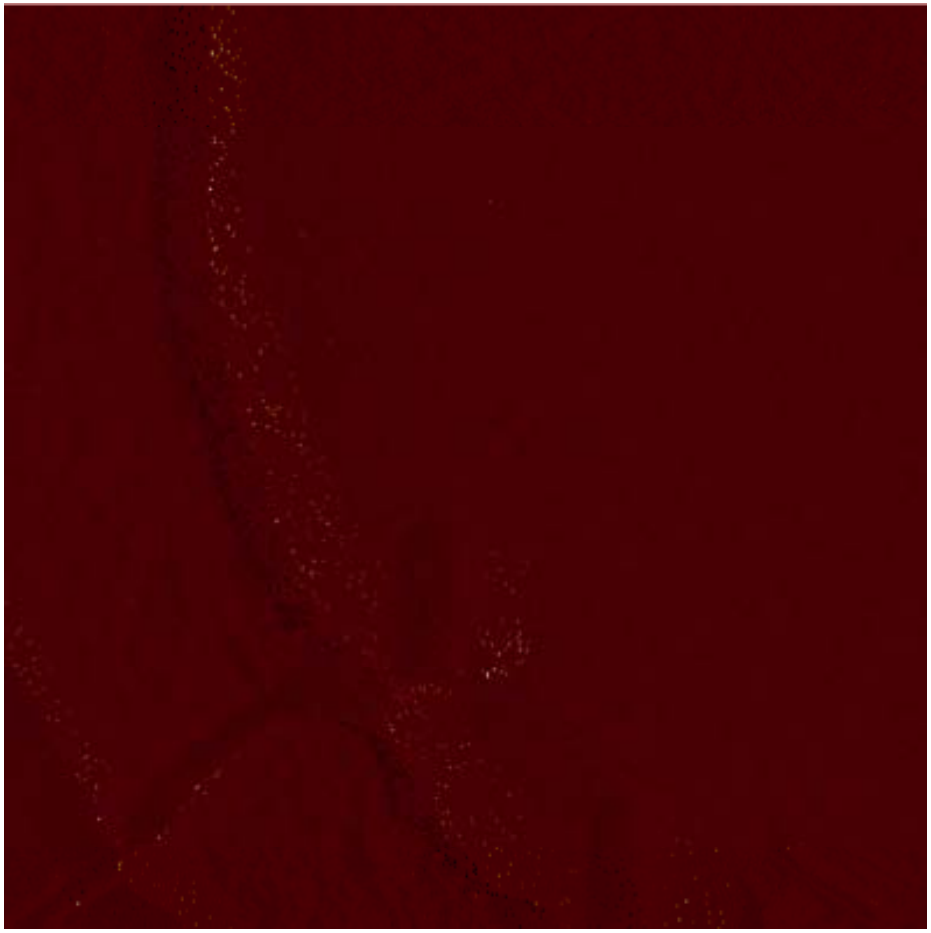
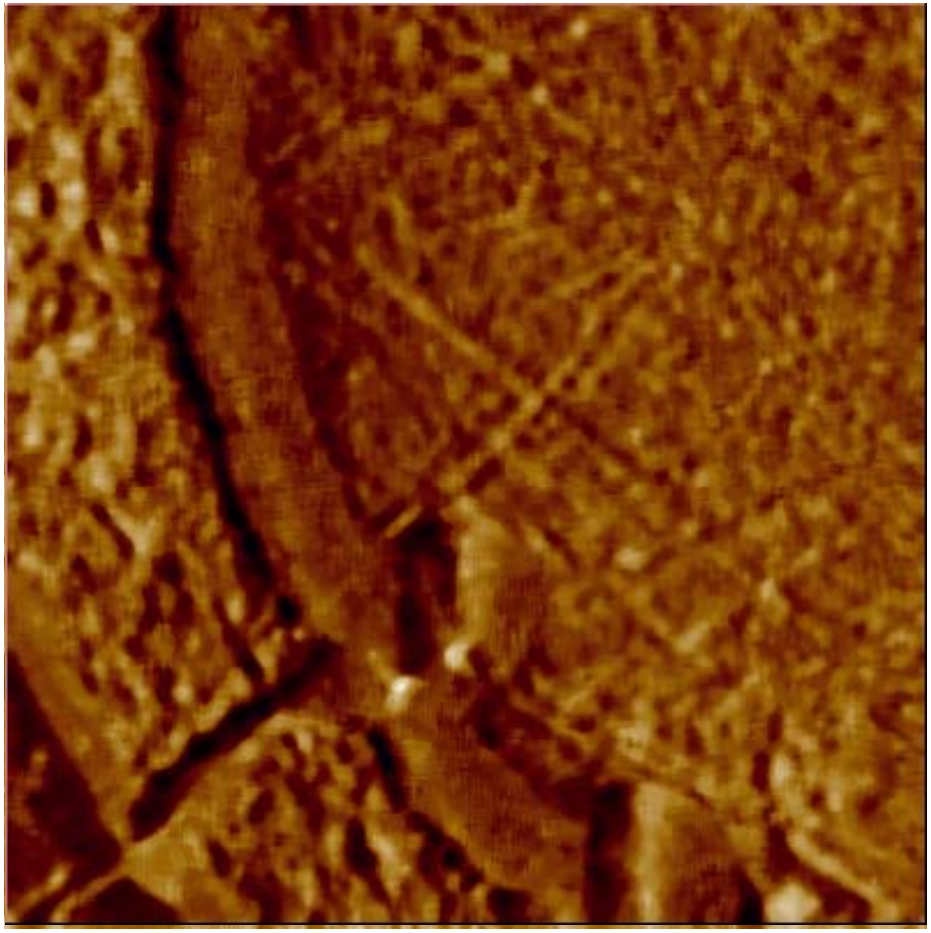
Медианная фильтрация



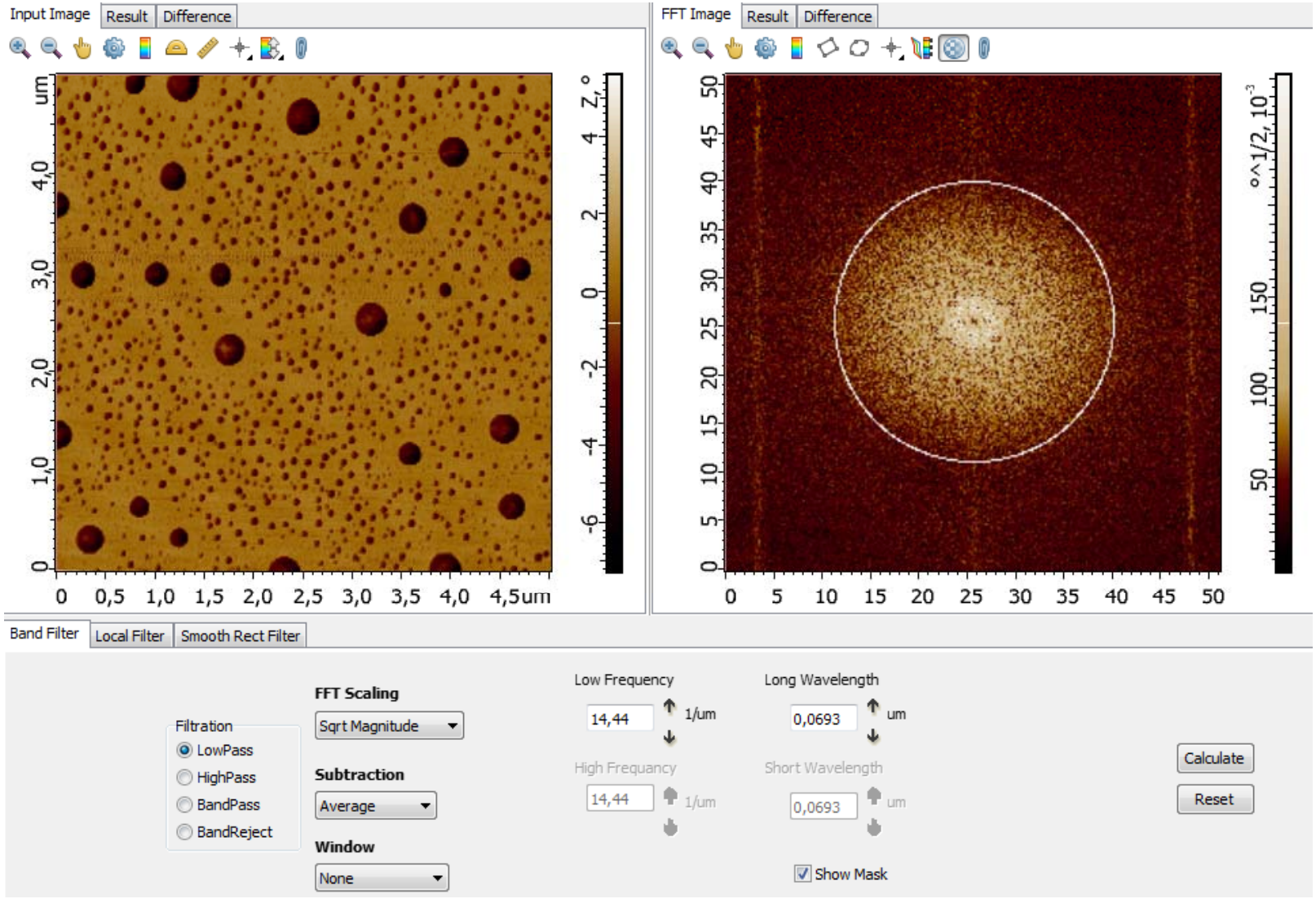


Фурье фильтрация

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

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

Fourier-> FFT Filtration



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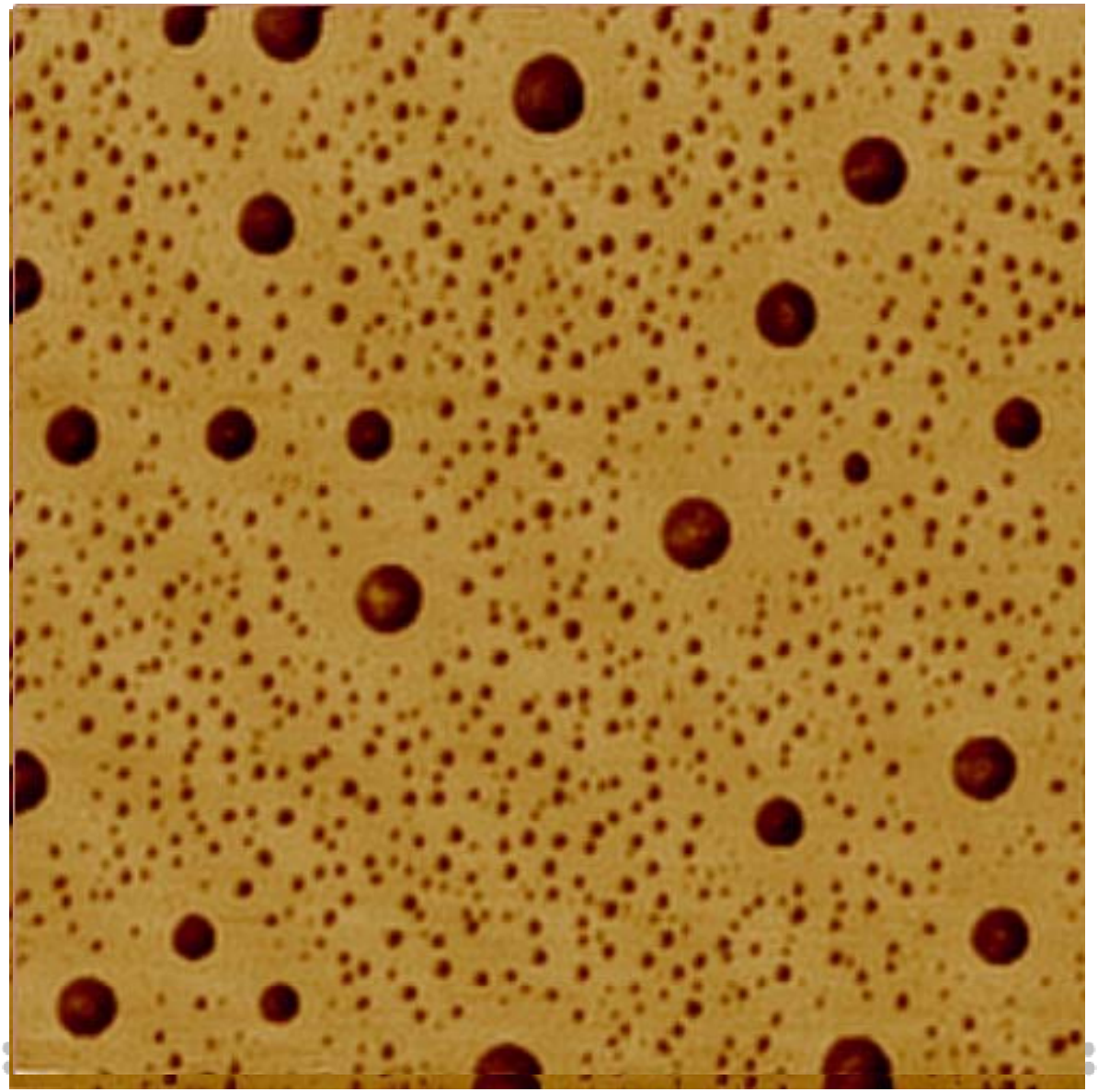
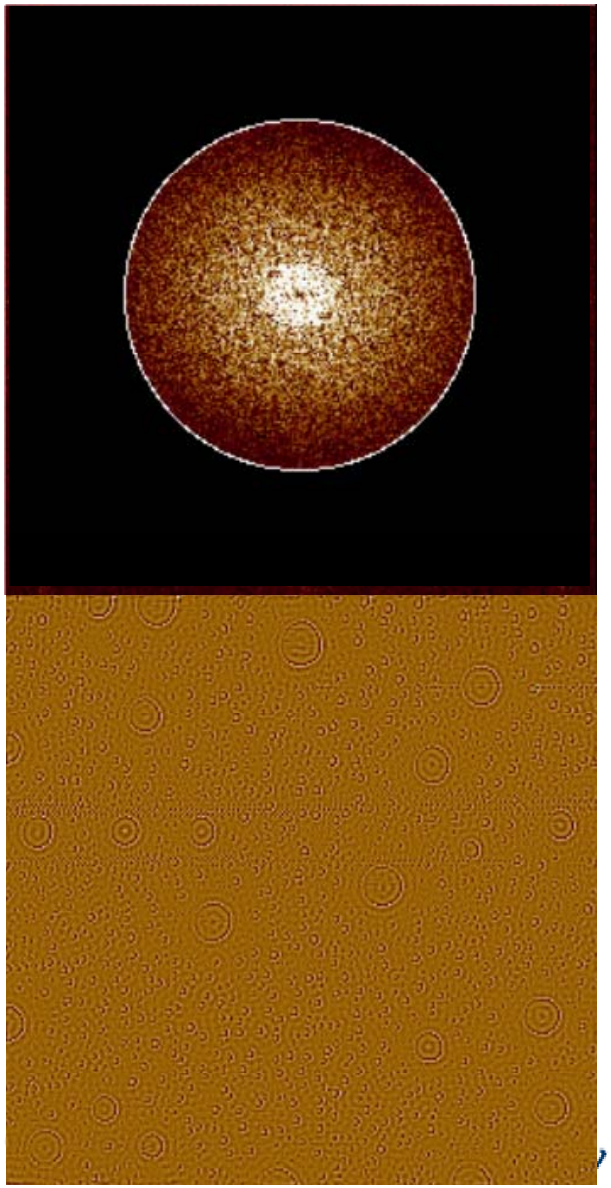
Low Pass FFT





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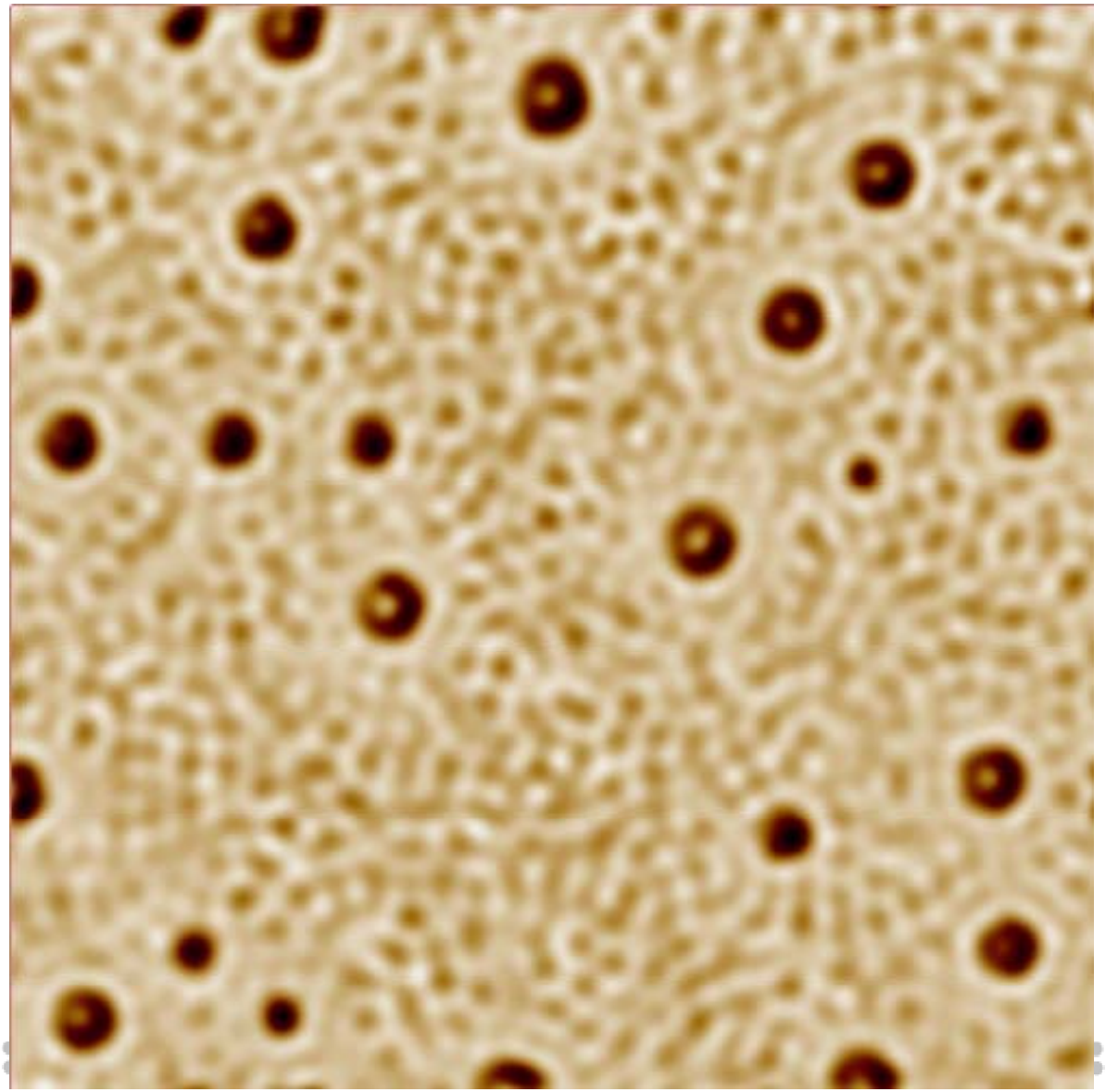
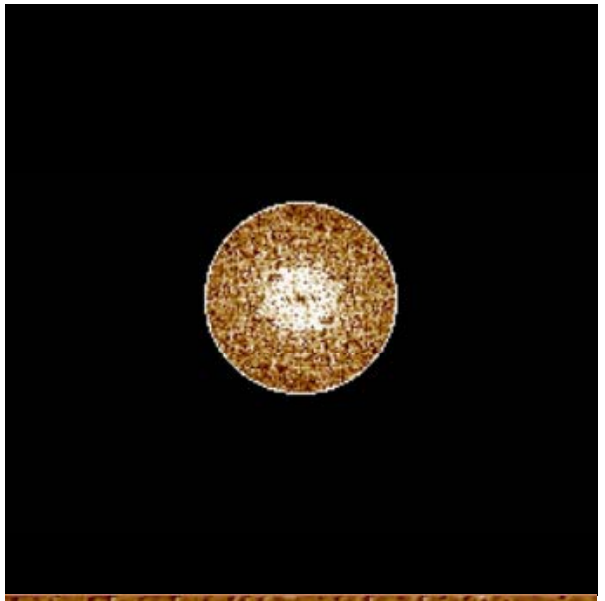
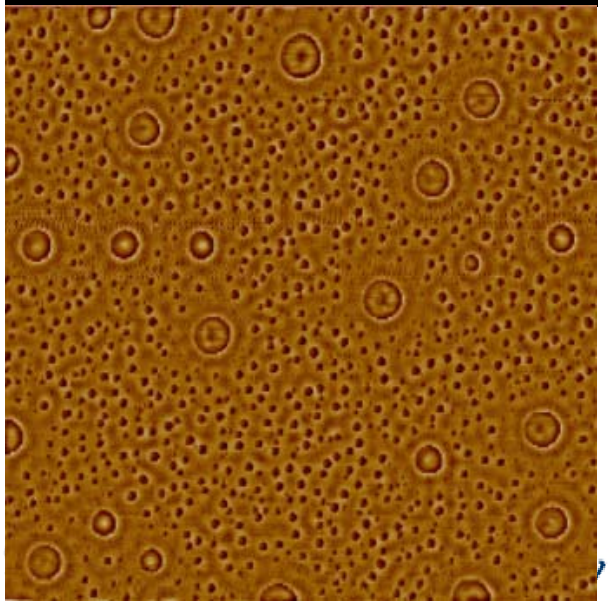
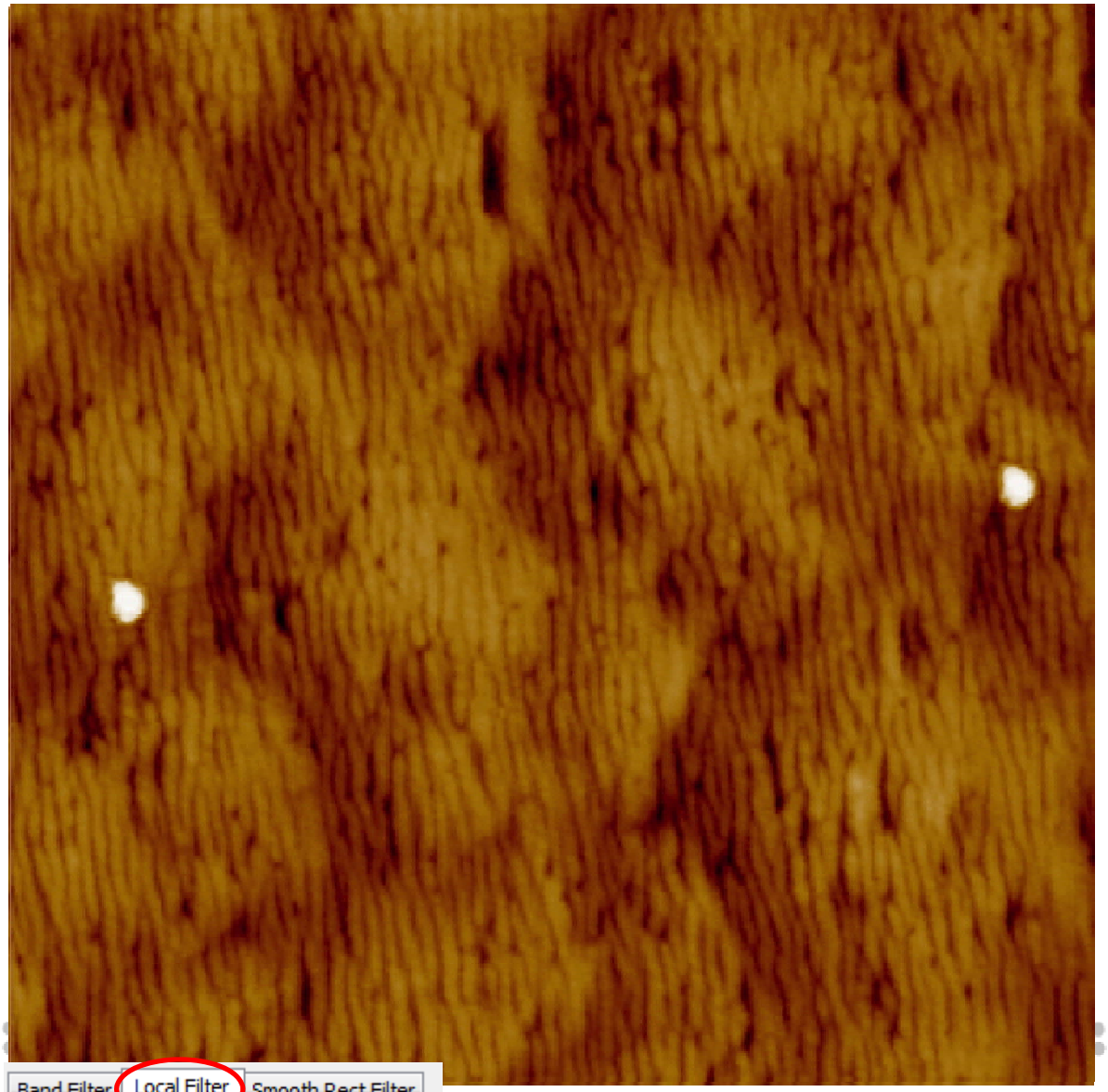
Low Pass FFT

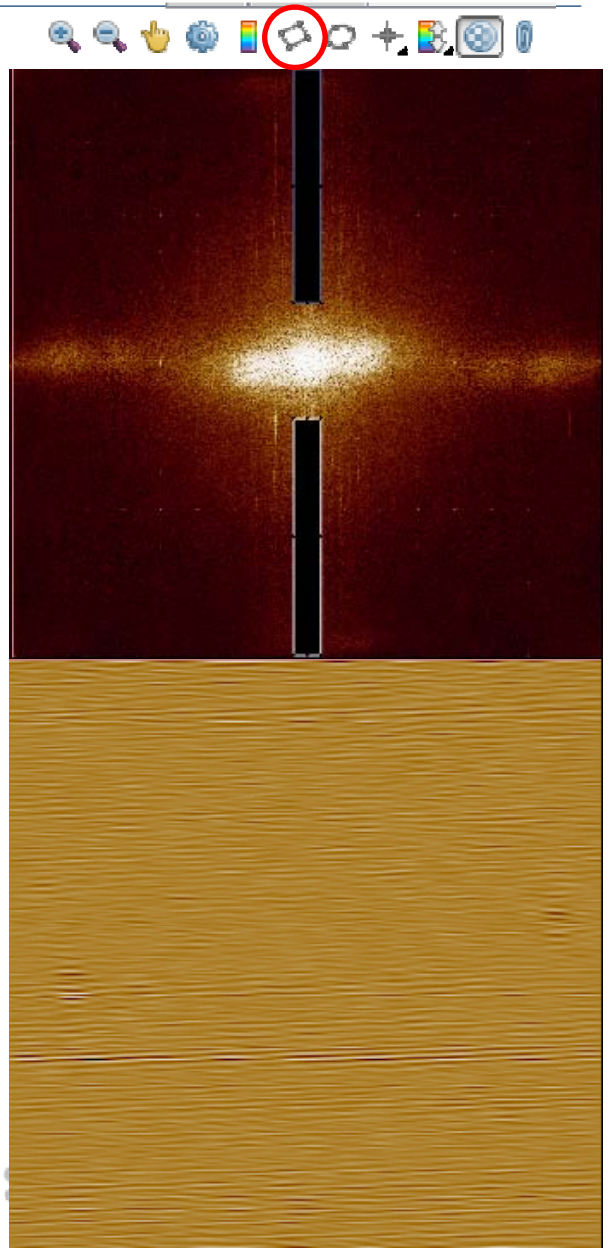






Local Filter FFT





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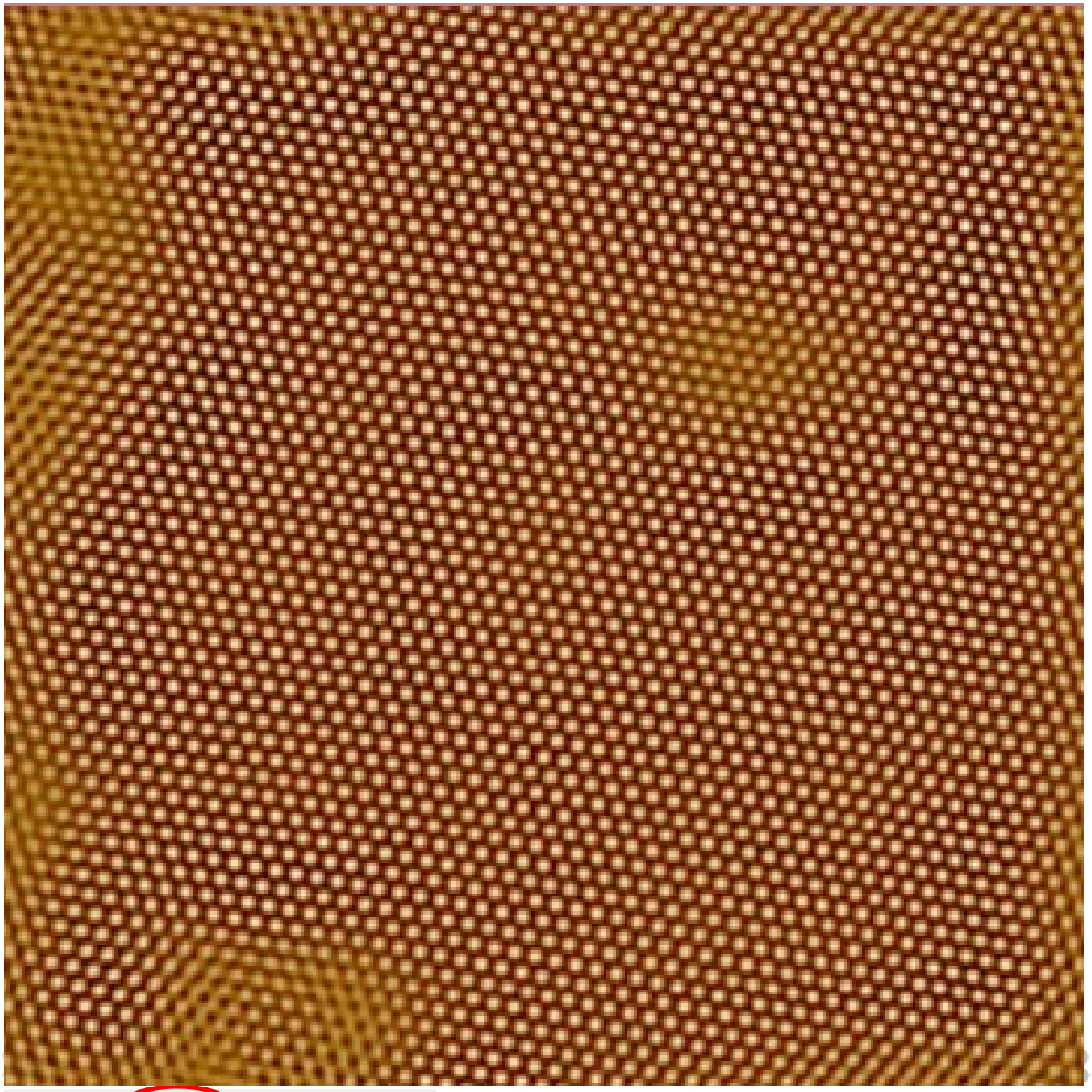
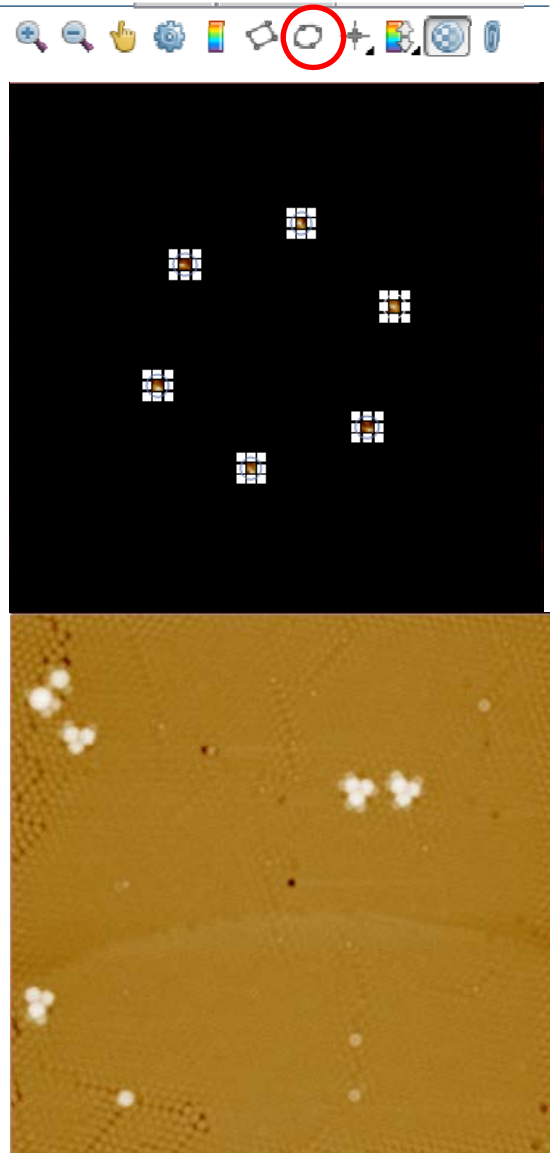
Local Filter FFT





Band Filter | Local Filter | Smooth Rect Filter

Your AFM & Raman Company

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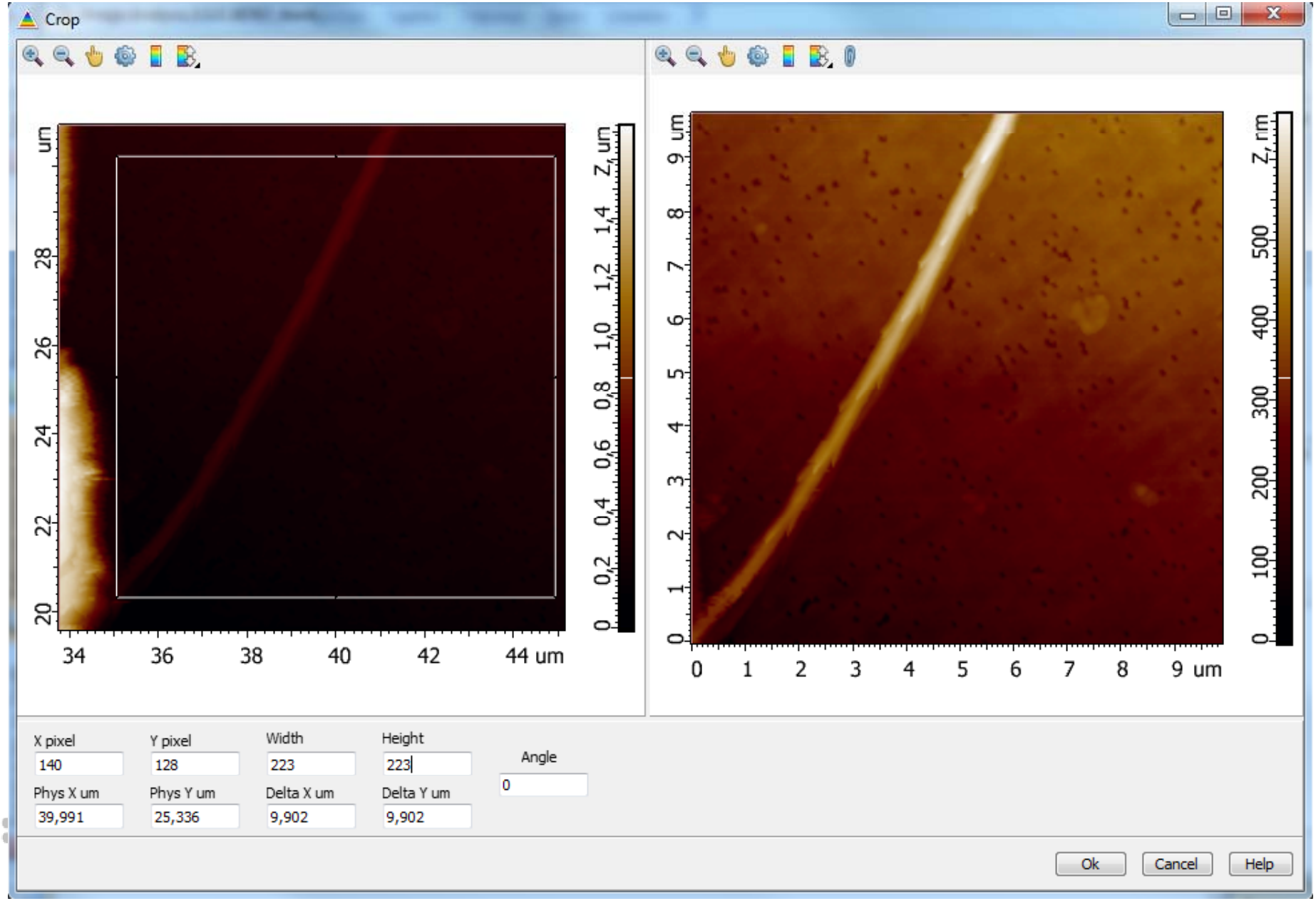
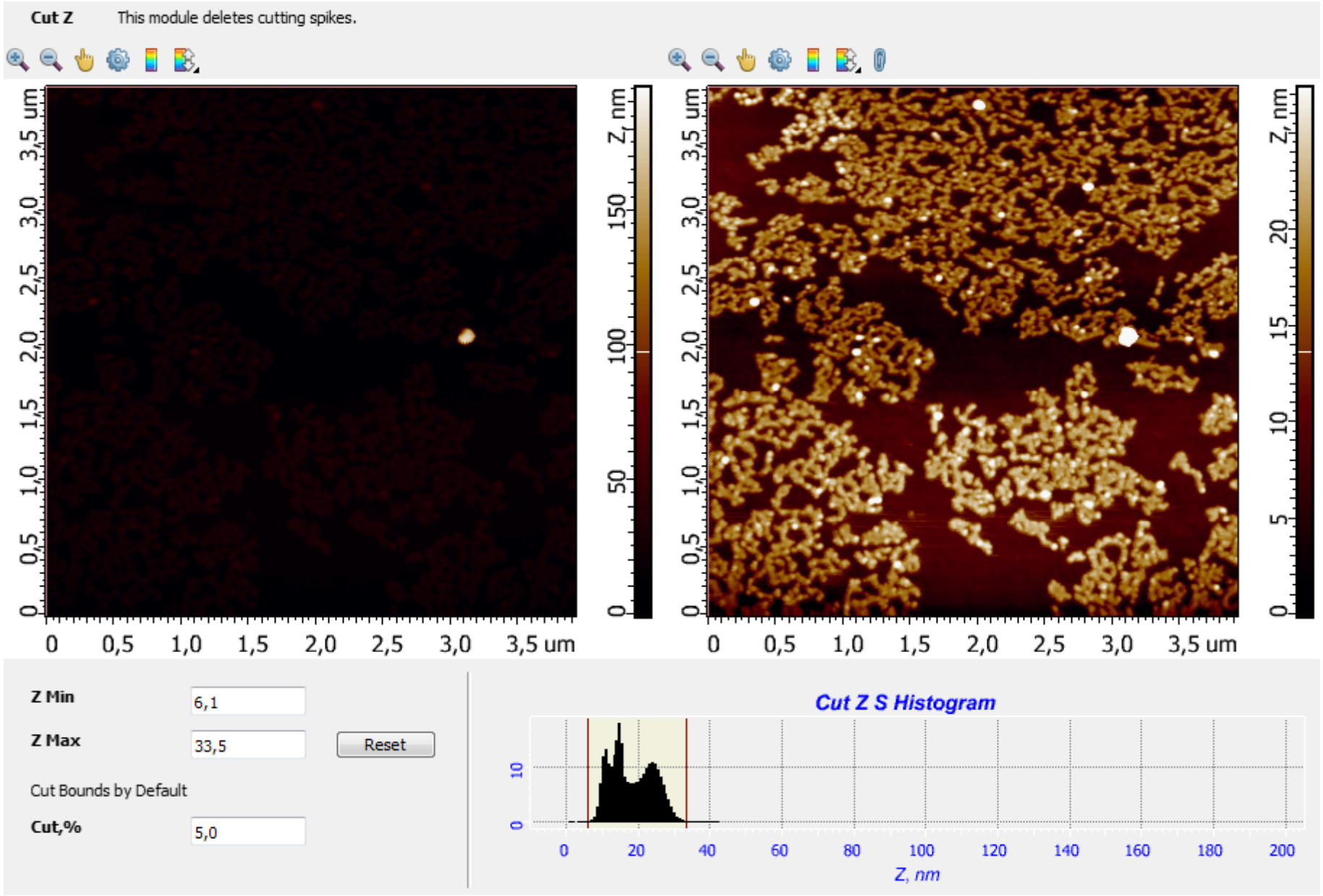
«Ретушь»
АСМ изображений

Data Transformations -> Crop



Editing -> Cut Peaks



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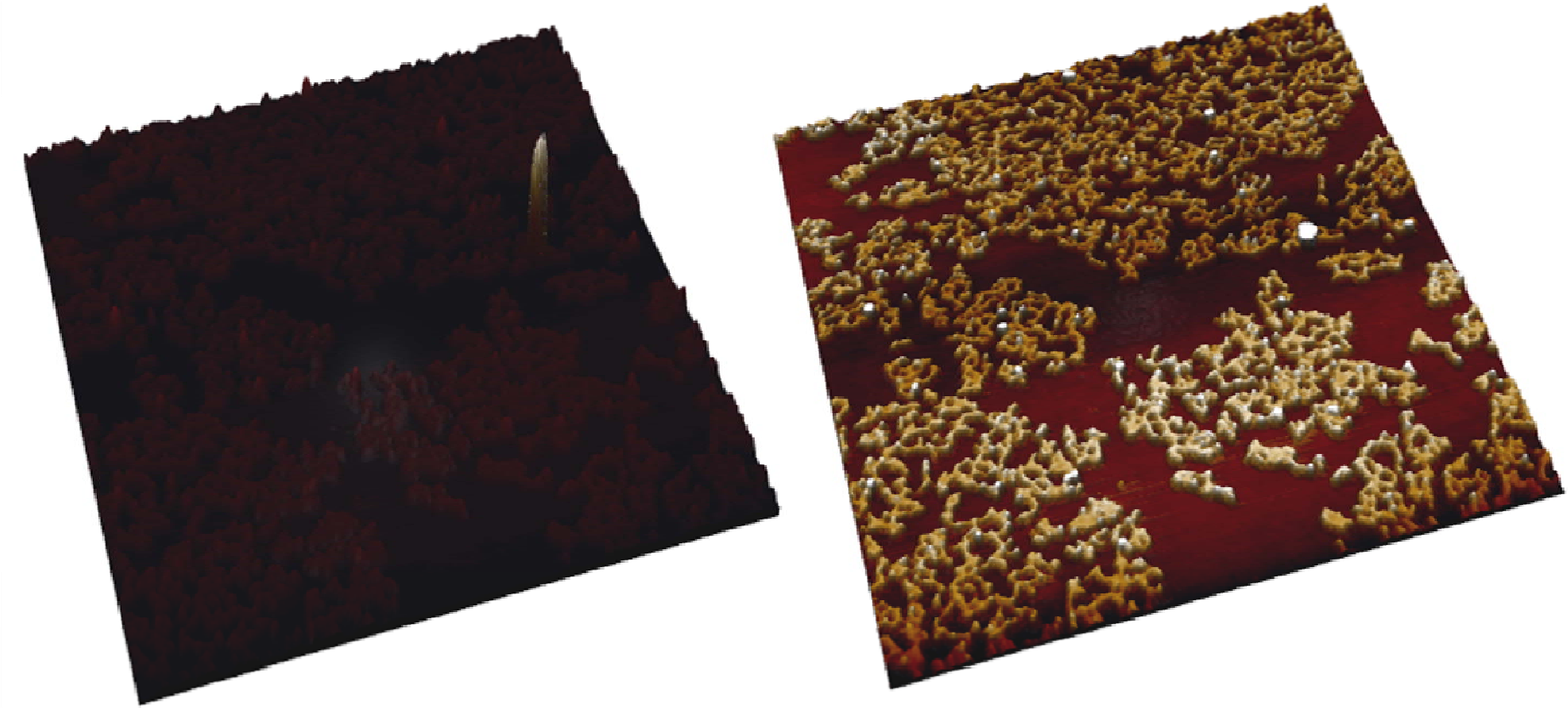
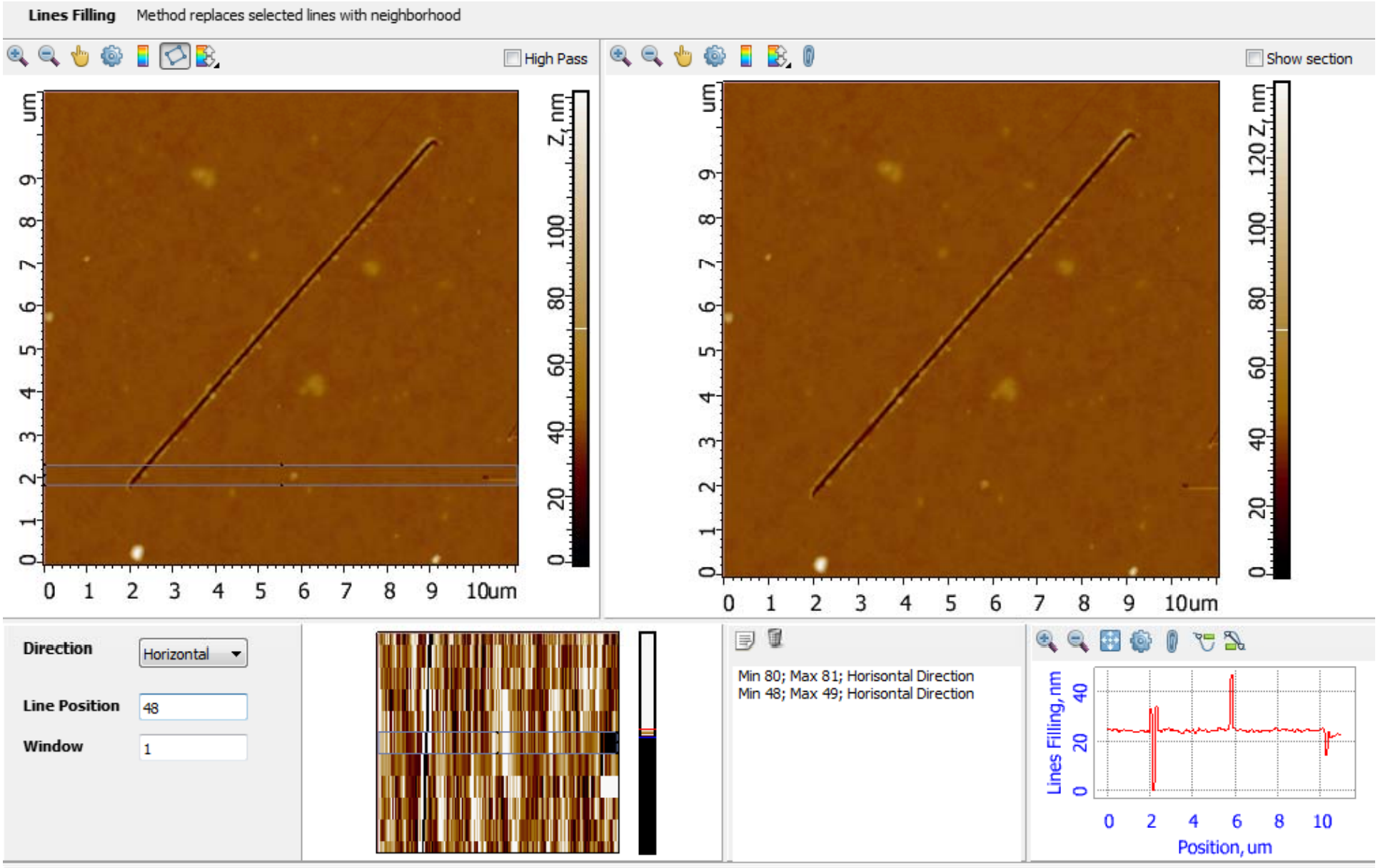
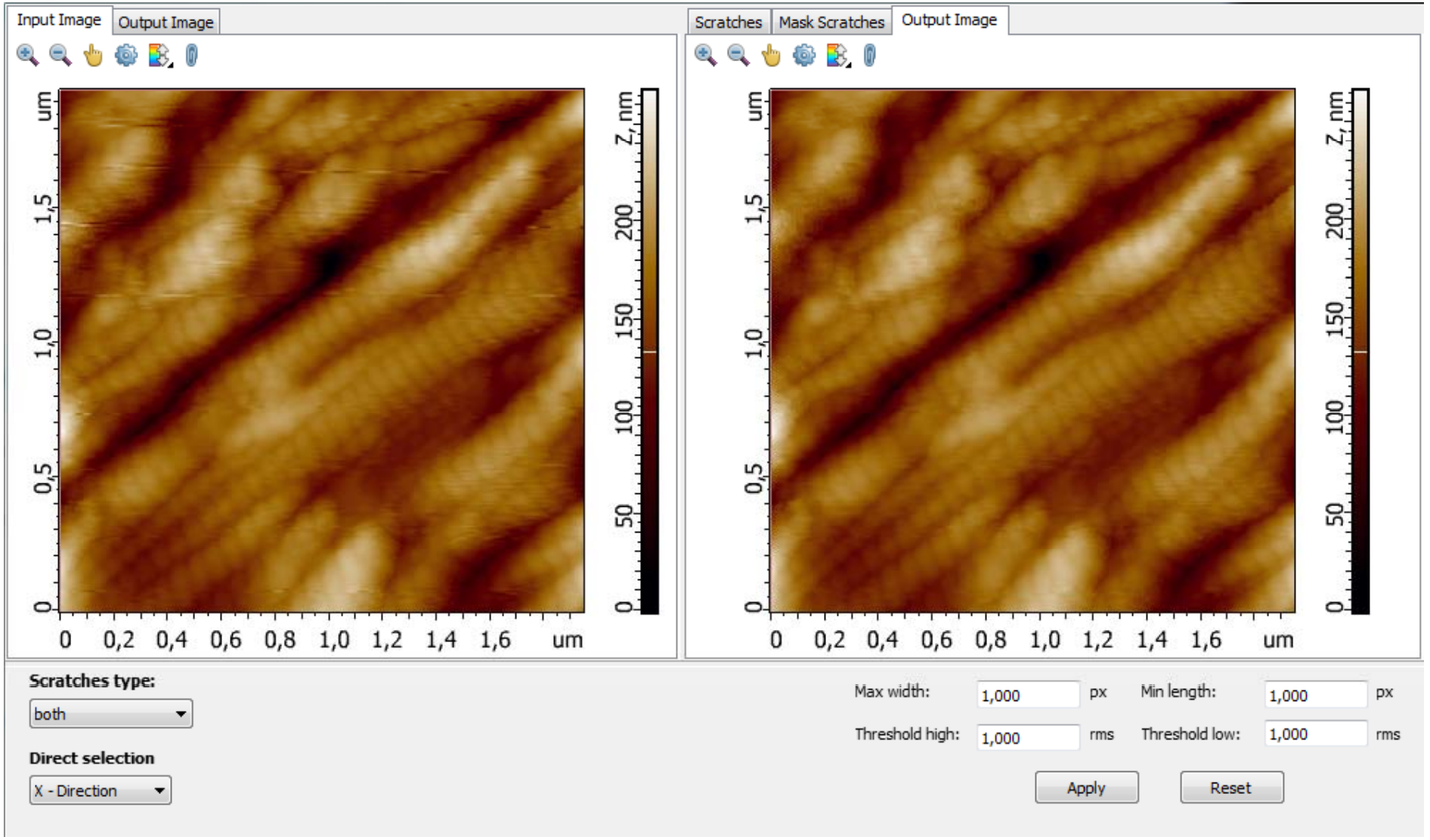
Editing -> Cut Peaks



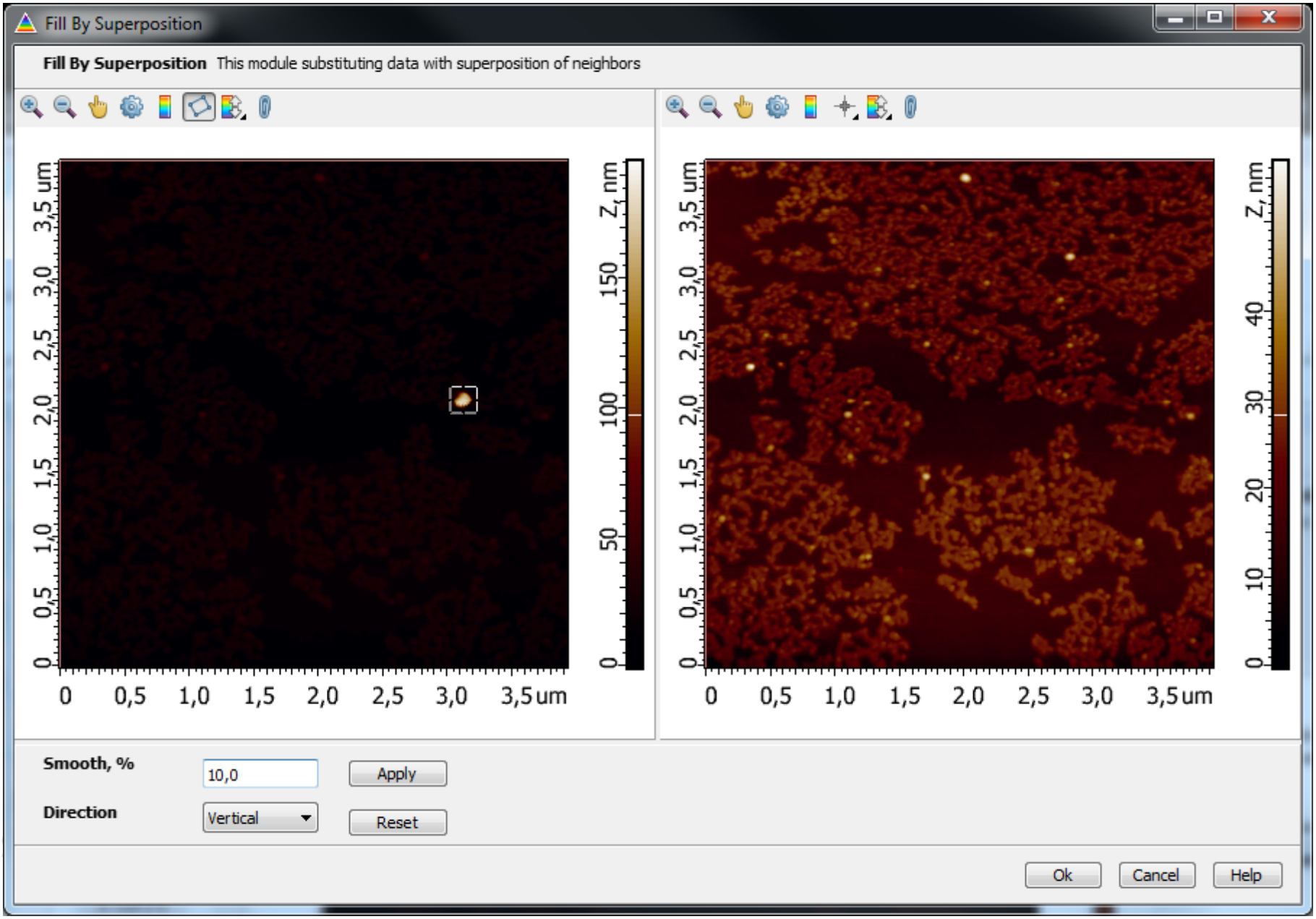
Editing -> Lines Filling



Editing -> Scratches



Editing -> Fill by Superposition



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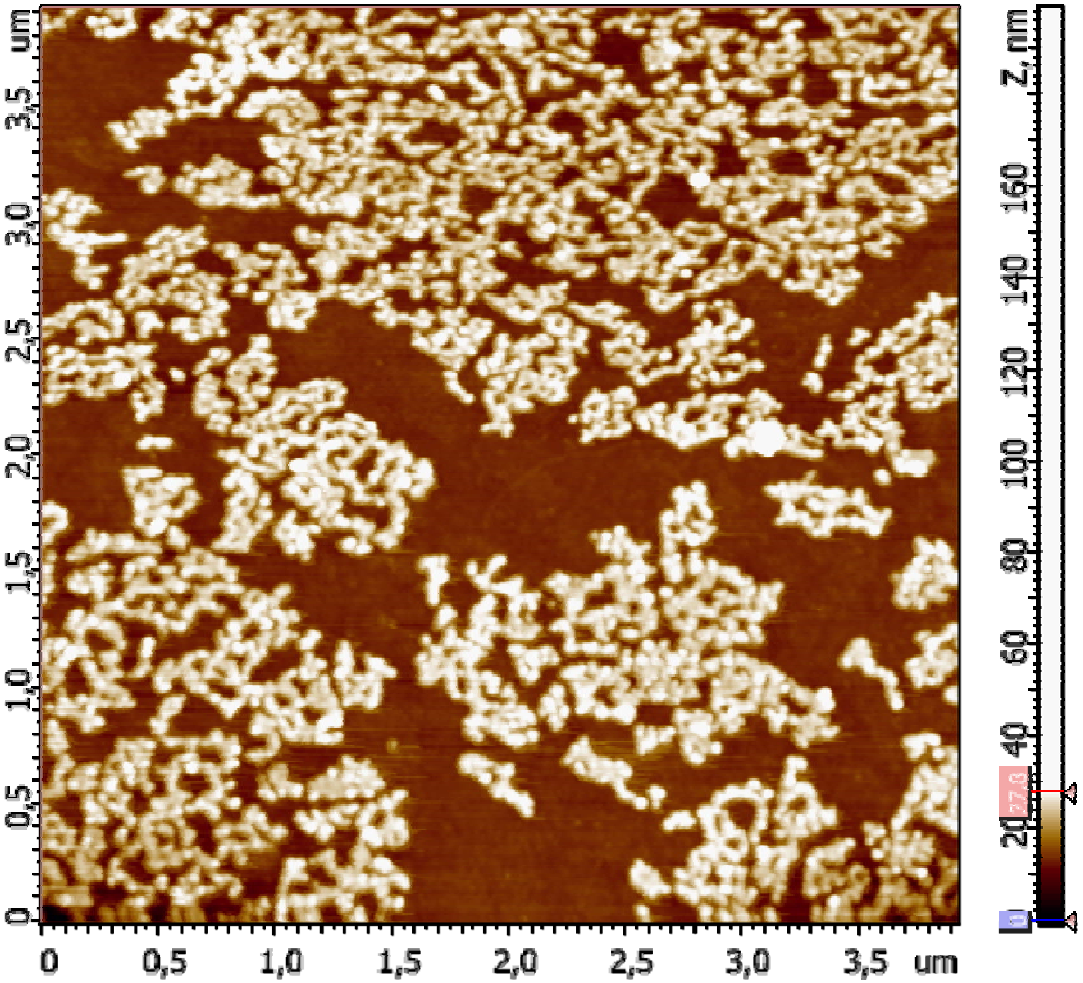
Представление АСМ изображений

Общие принципы

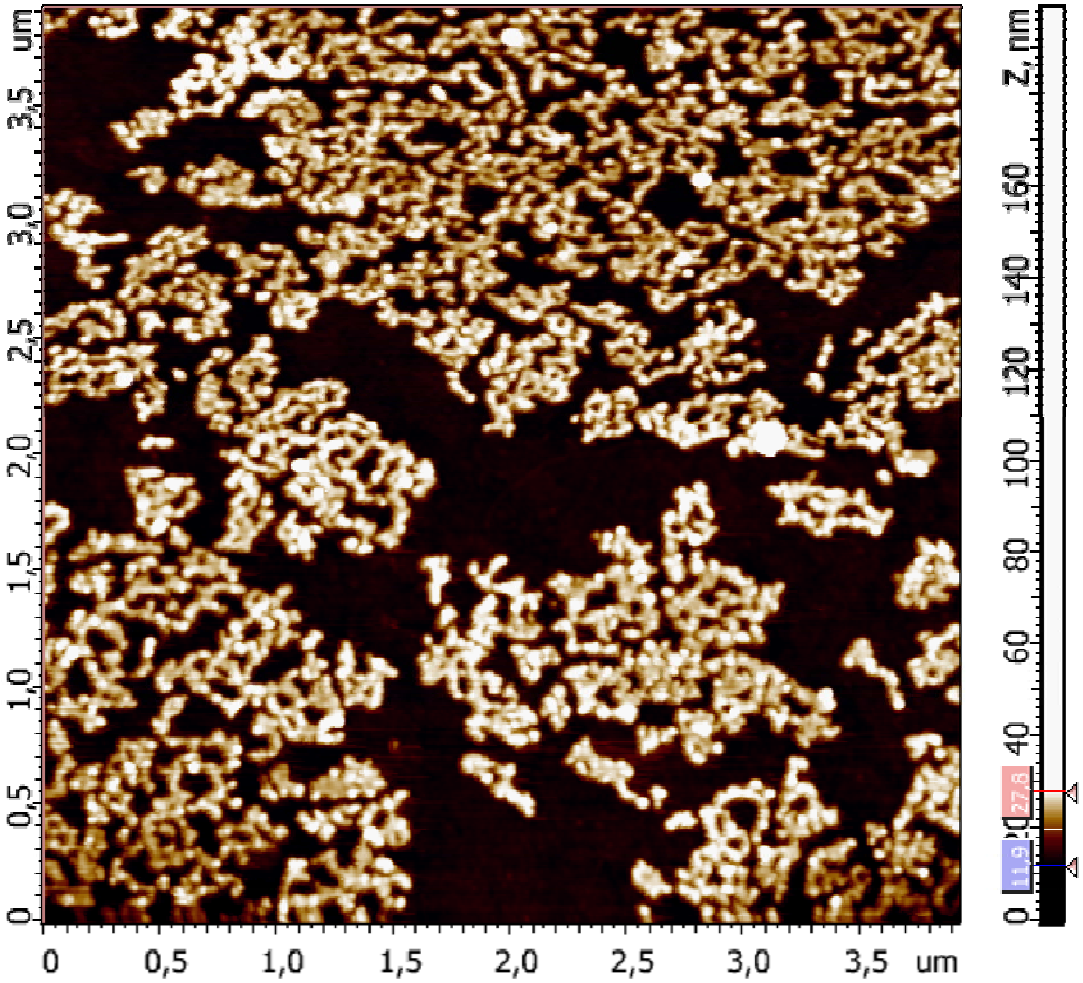
1. Изображение должно быть информативным

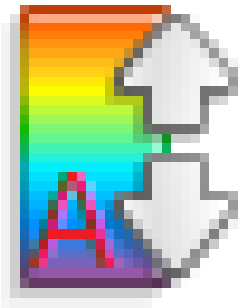
2. Изображение должно быть похоже на правду

Режимы раскраски



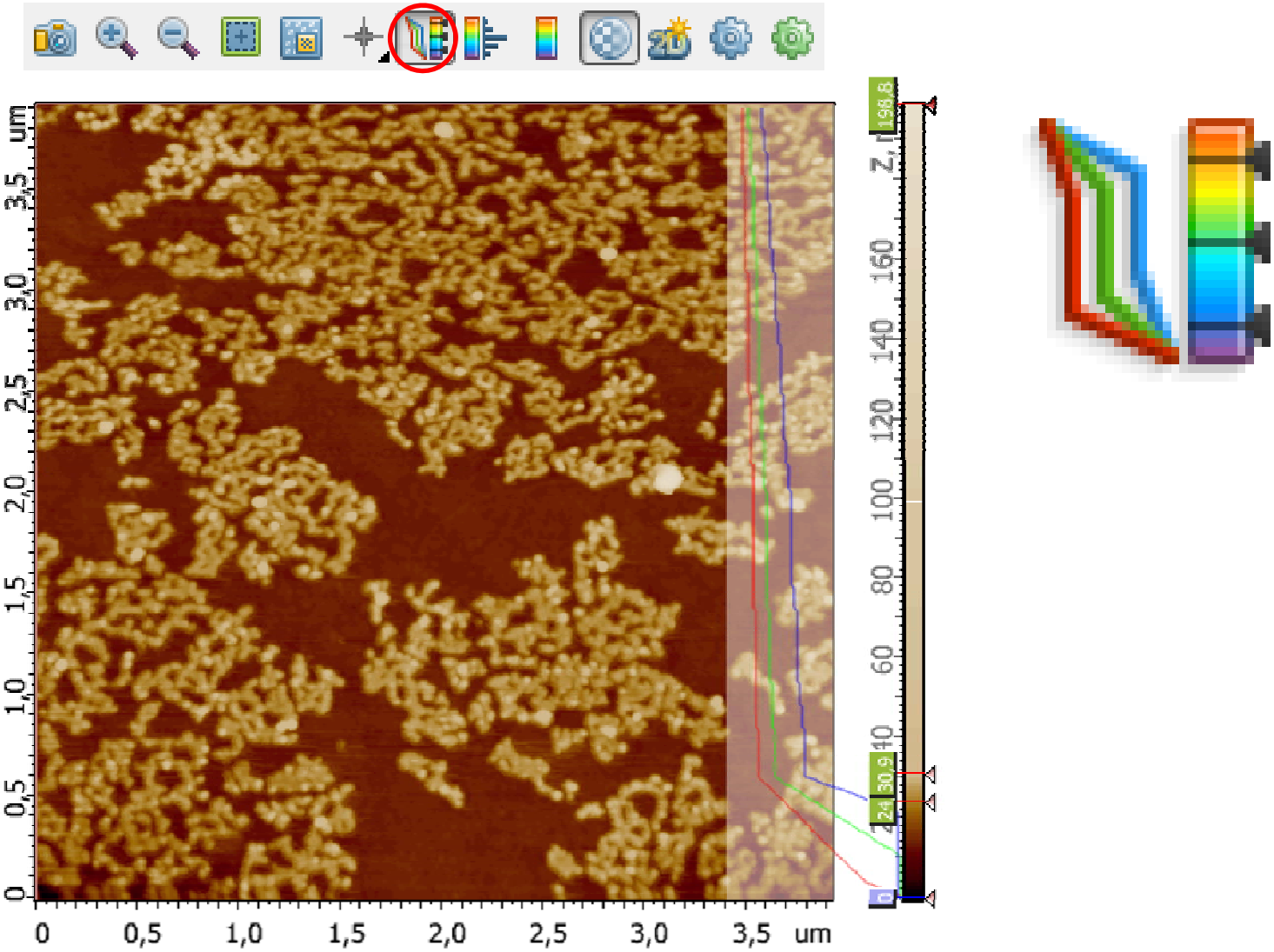
Режимы раскраски



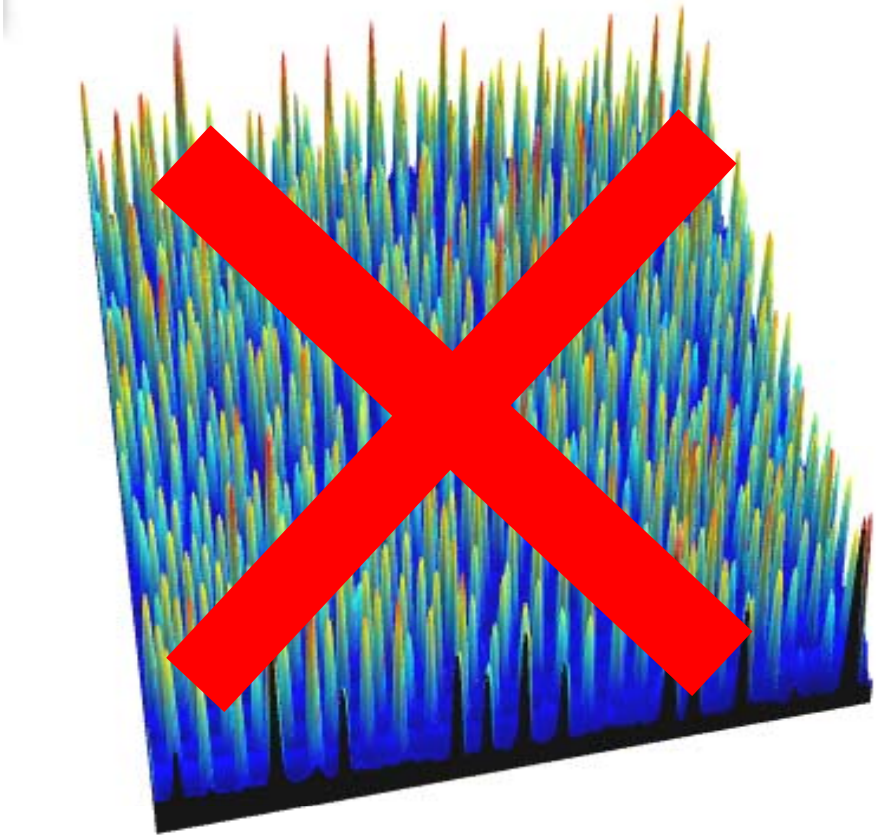


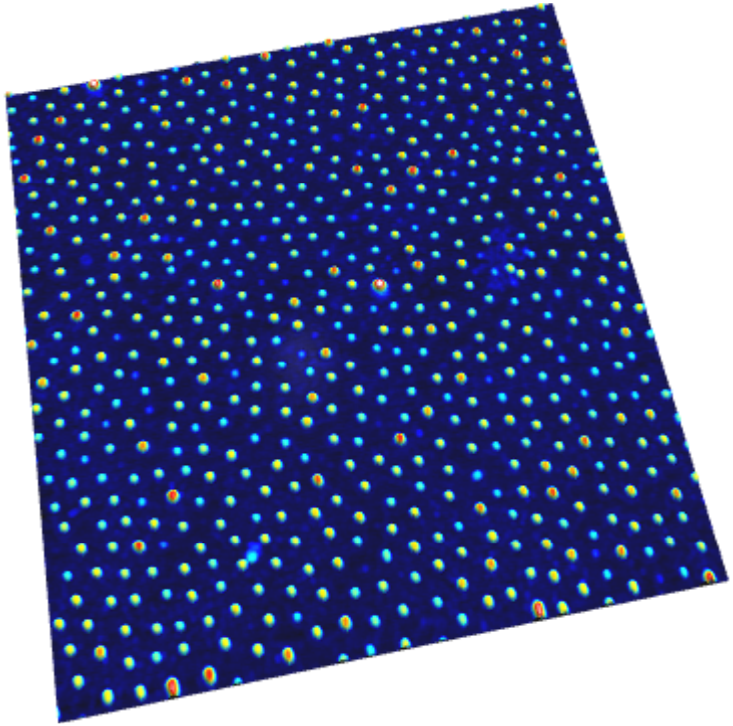
Settings-> 2D Settings -> Axes -> Histogram -> Auto Coloration Percent

Режимы раскраски

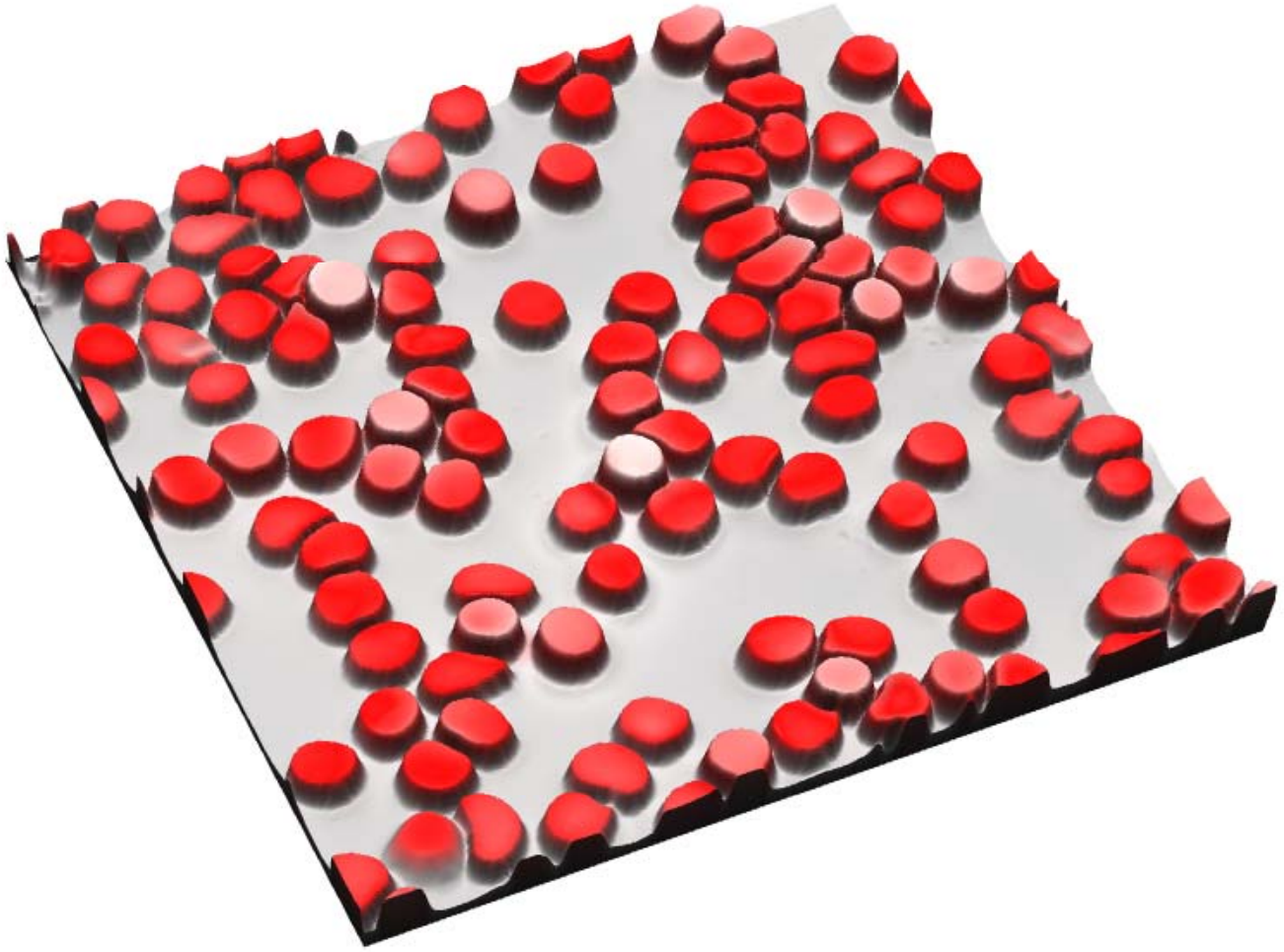


3D





3D



Восприятие (Perception)

BLOODY LETTERS

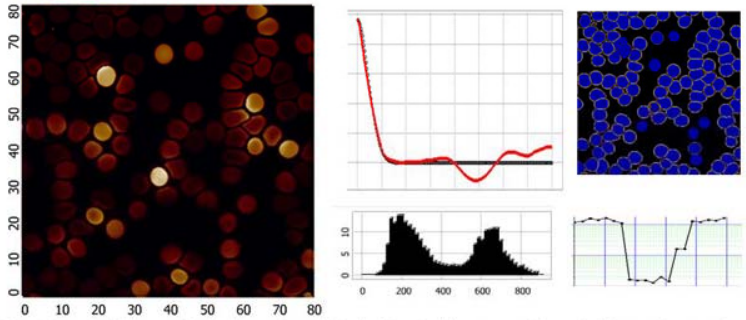


Figure 1. Though this image of blood cells may have a high scientific value, it is not eye-catching and will attract less attention.

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

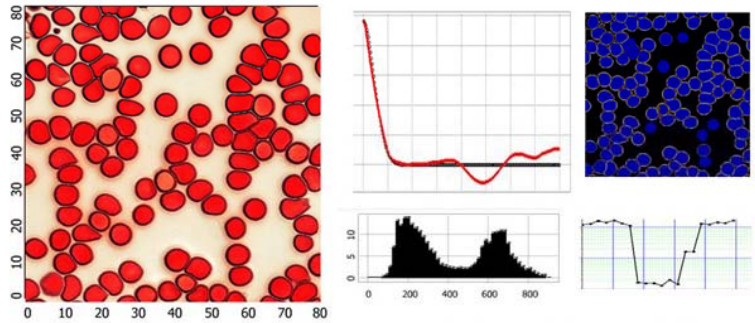


Figure 1. This is an example how simple steps for interception improvement make your publication more remarkable

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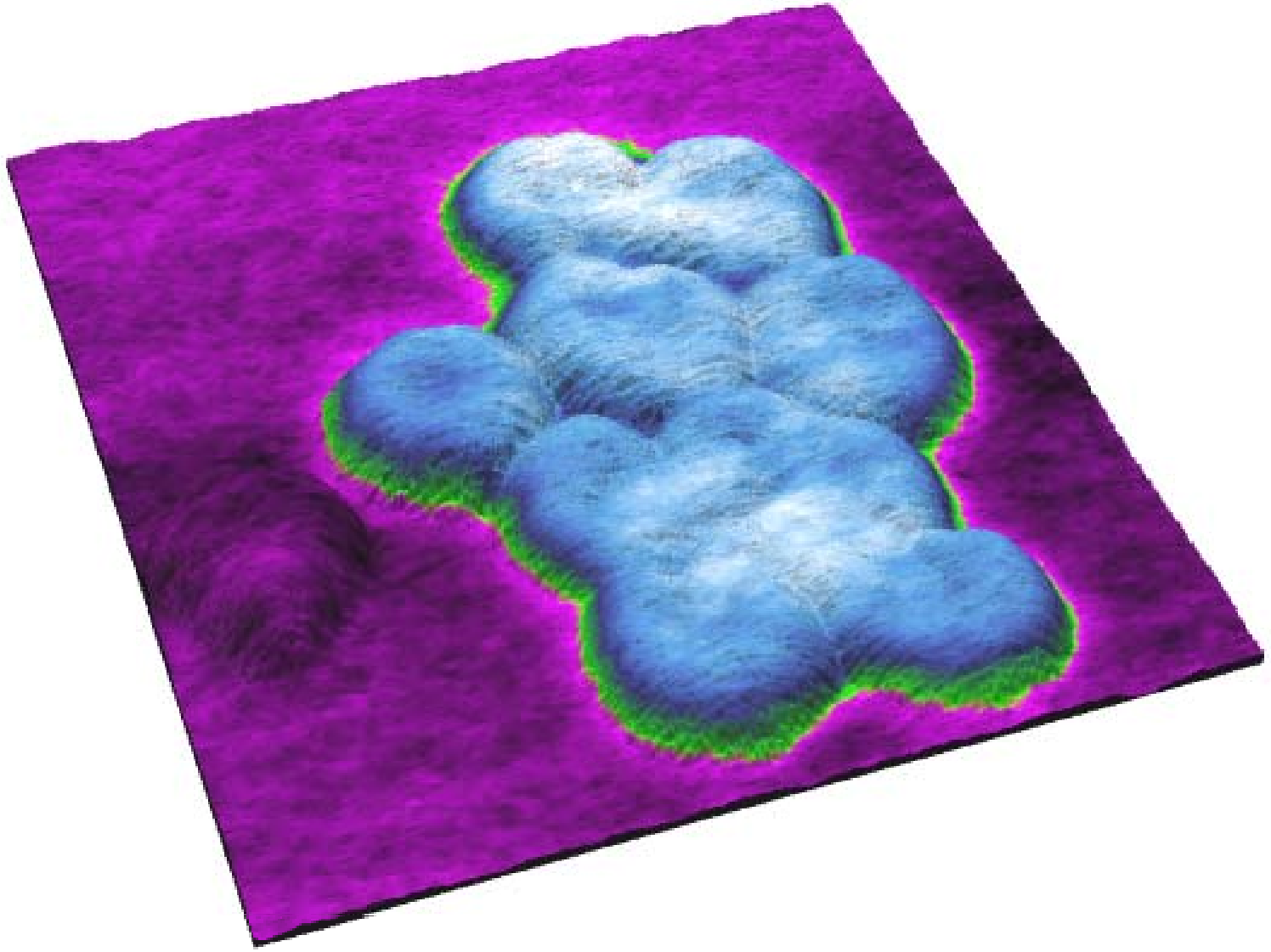
Наложение текстуры



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Заключение

1. Пробуйте различные подходы
2. Используйте априорную информацию (плоское должно быть плоским)
3. Не злоупотребляйте «мощностью» методов – всегда оценивайте разницу между исходником и результатом.
4. Картинка должна быть реалистичной
5. Красиво представленные данные воспринимаются лучше

Благодарности

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Dr. Valery Kuryavy
Dr. Viktor Novak
Dr. Alexander Kotlyar

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

Использованная литература:

В.Л. Миронов, **Основы сканирующей зондовой микроскопии** *(2004)*

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

www.ntmdt.com

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