# APPLICATION NOTE

QPlus AFM on NaCl (001) at low oscillation amplitudes using Matrix 4 AFM PLL with TipGuard

Date: 14.03.2018
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Instrument Configuration
LT STM
Matrix 4 with new AFM PLL

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Improved QPlus AFM sensors

- **Newest Generation of Giessibl sensors**

- **Integrated electrodes**

- **New high precision manufacturing**

- **Higher Q-factor $\approx$ 90.000 at T=5K**

- **Better reliability**

(a) 2 Å 0 4 nm
(b) 7 Hz -12 3 Å
(c)
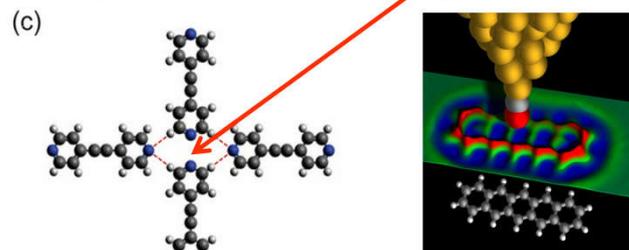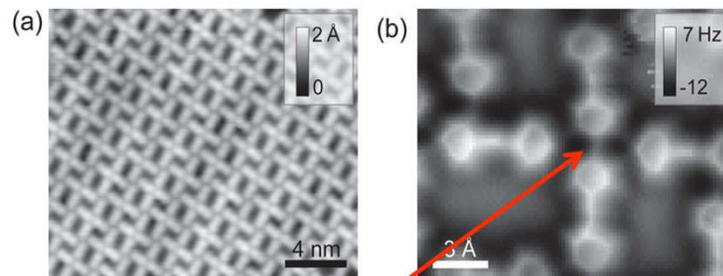
Sampsa K. Hämäläinen et al.: Phys. Rev. Lett. 113, 186102
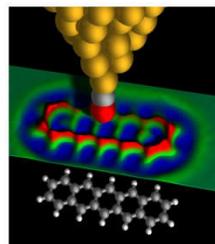
Schematic of CO functionalized tip

T = 5K
Q = 86280

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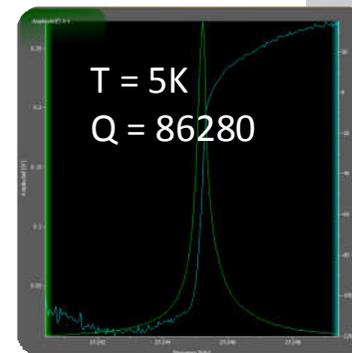
The new Matrix 4 – High Performance QPlus

- **More compact**

- **Better usability and accessibility**

- **Full 64bit Software**

- **Software coarse motor control**

- **Full Matrix integration for ease of use**
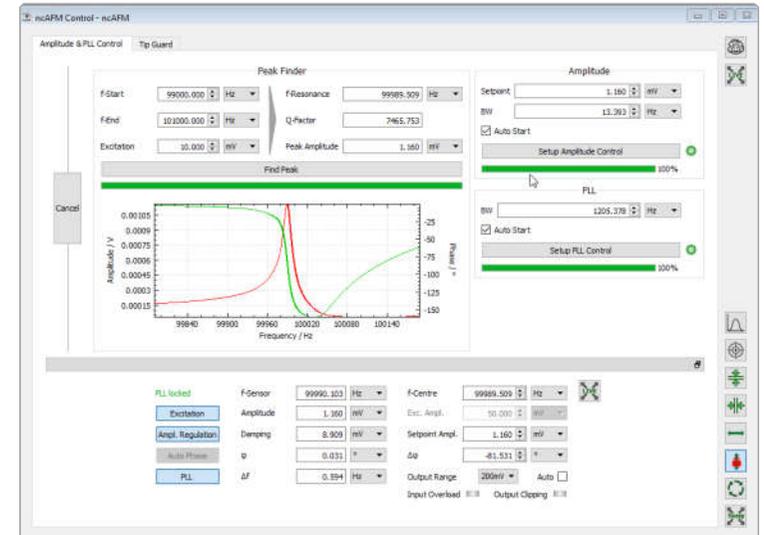
- **Highest performance QPlus AFM hardware powered by**
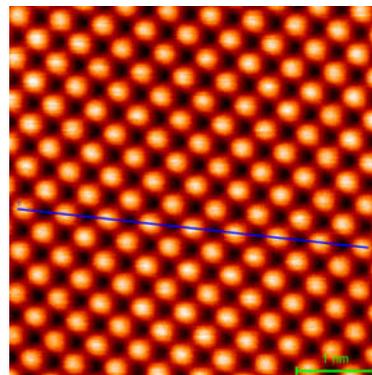
NaCl (001)

- **TipGuard** *phase & amplitude tip protection*

- **Oscillation Autofinder** *robust swarm technology algorithm*

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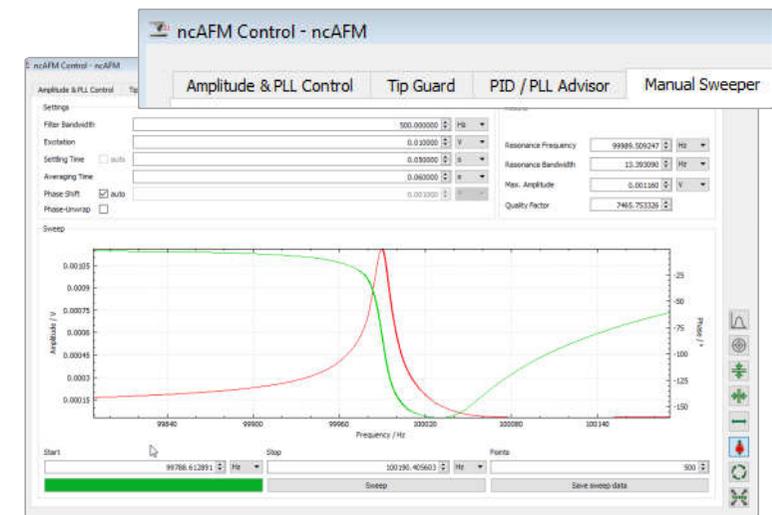
NaCl(001) with new AFM Control Unit and LT STM
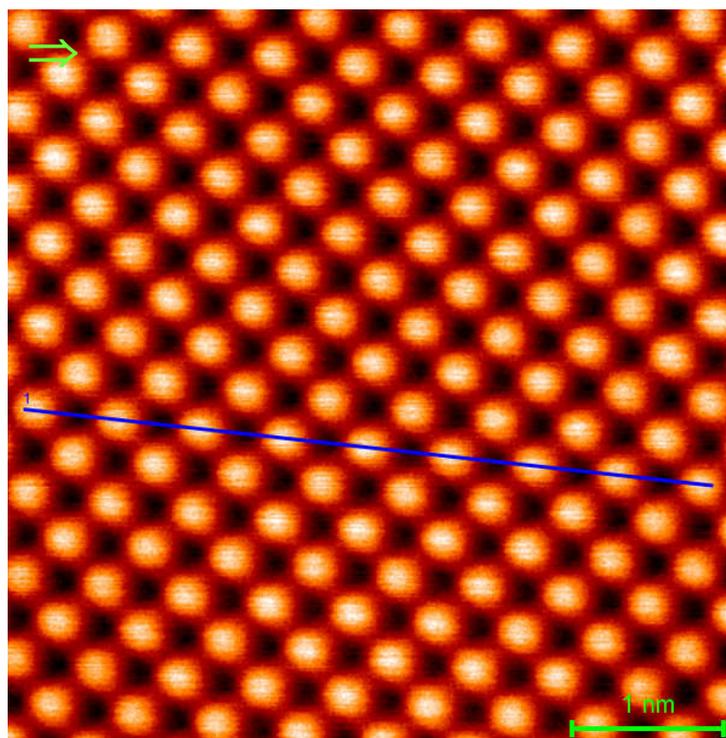
linewise slope subtract
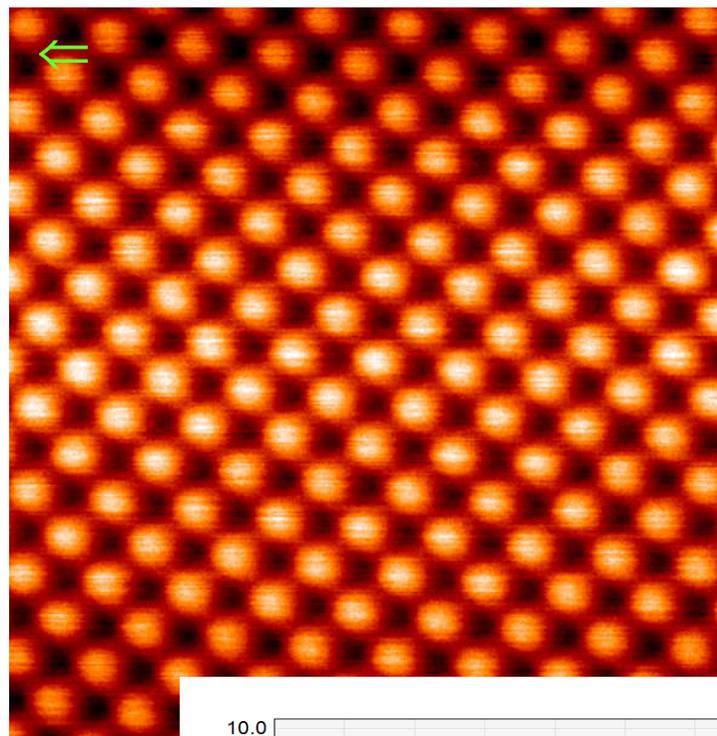
plane subtract

A = 500pm
Δf_{set} = -5.81Hz
Q=30k
f_{res}=27kHz
BW_A=10Hz
BW_{PLL}=82Hz

- **Constant Δf topography imaged with QPlus™ sensor (Giessbl single prongue).**

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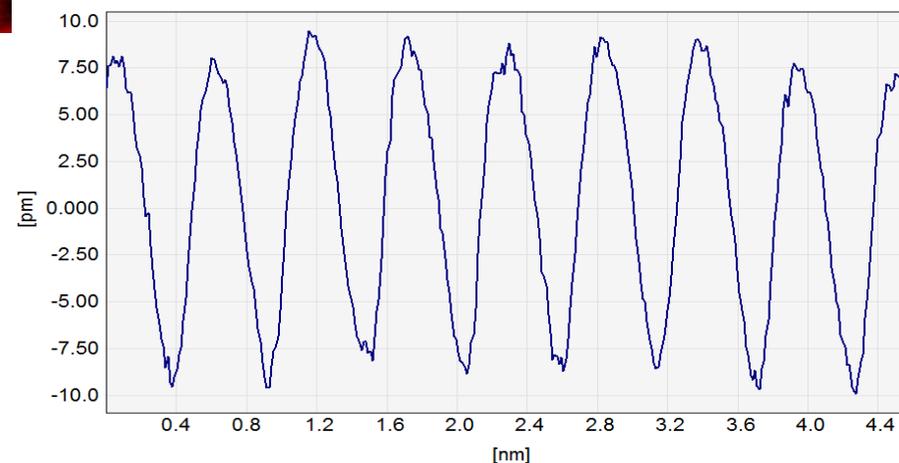
NaCl(001): Defect/Adsorbate imaging
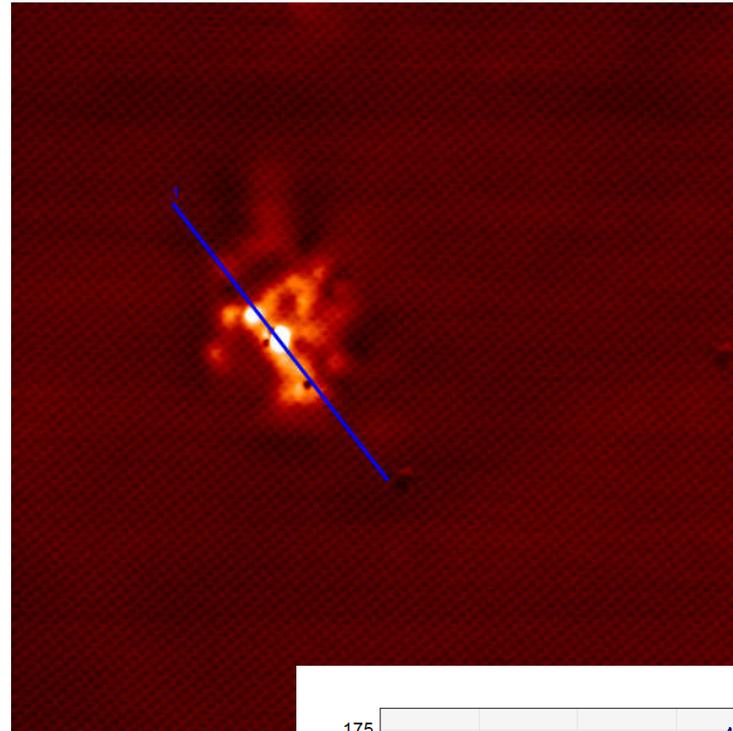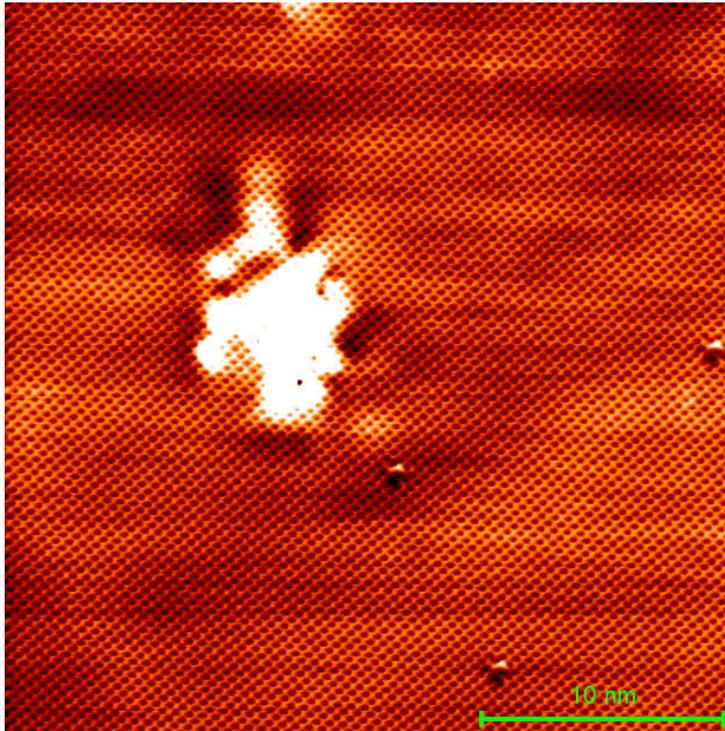
A = 500pm
Δf_{set} = -9.5Hz
Q=30k
f_{res}=27kHz
BW_A=10Hz
BW_{PLL}=82Hz

- **Constant Δf topgraphy imaged with defect or adsorbate**
- **Stable imaging even on charged defect region**

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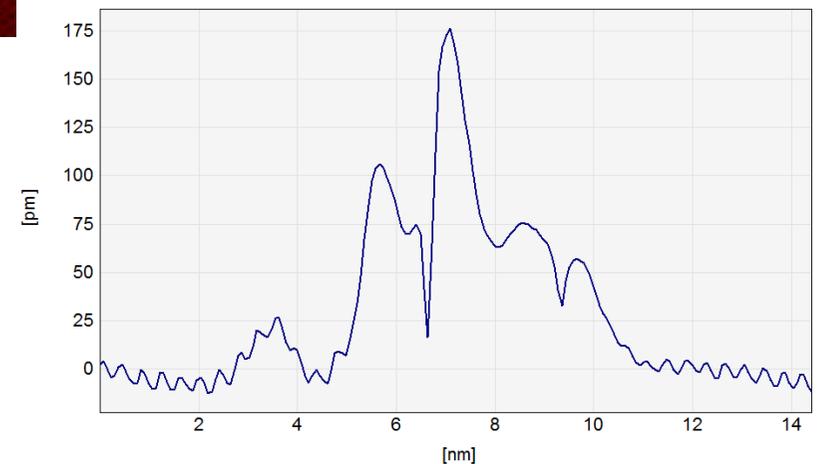
# NaCl(001): Defect/Adsorbate imaging
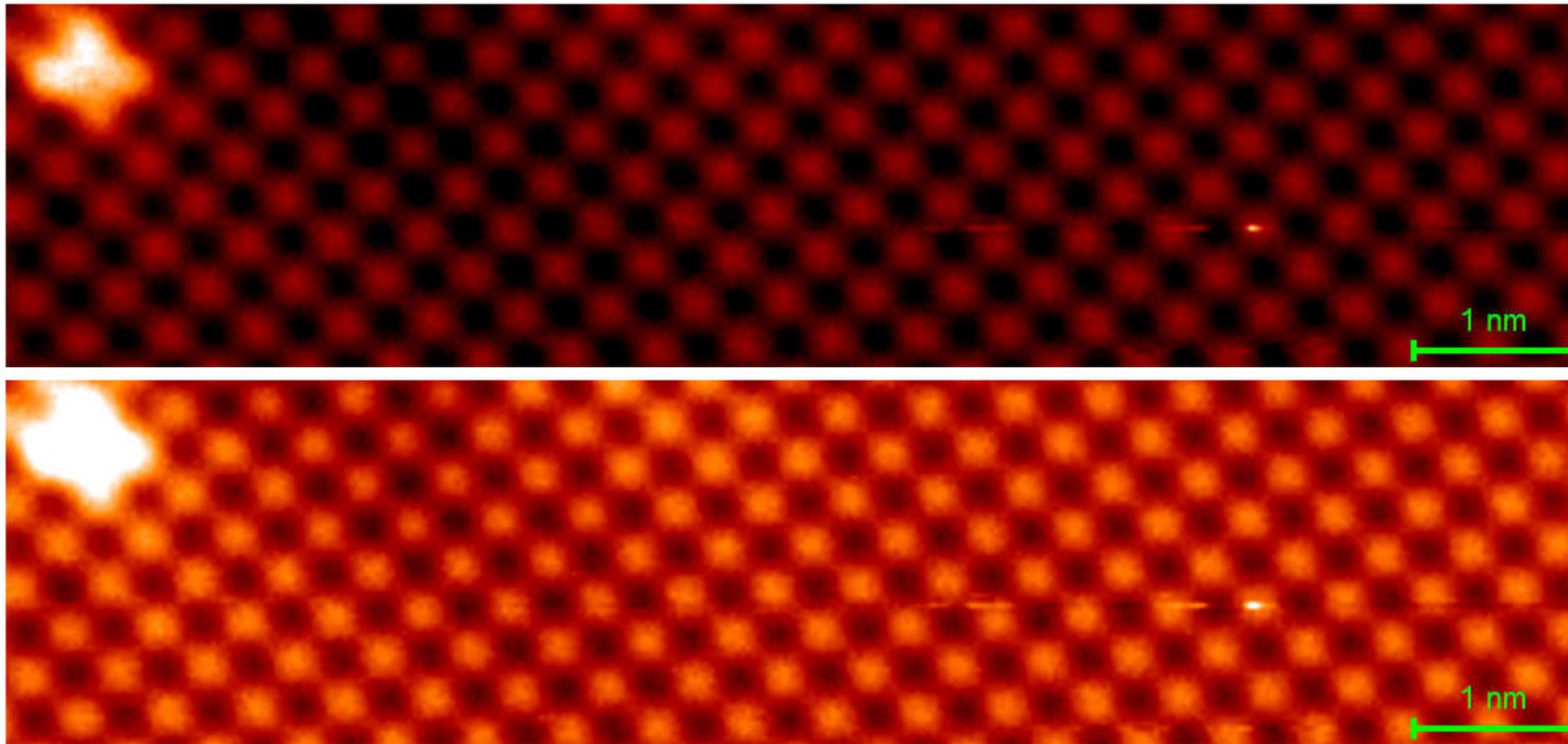
$A = 500\,pm$
$\Delta f_{set} = -8.5\,Hz$
$Q = 30k$
$f_{res} = 27\,kHz$
$BW_A = 10\,Hz$
$BW_{PLL} = 82\,Hz$

- **Constant Δf topography imaged with defect or adsorbate**
- **Local charges usually destabilize the feedback loop. Here the image runs without any distortions.**

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Constant Δf imaging at various amplitudes – **500pm**
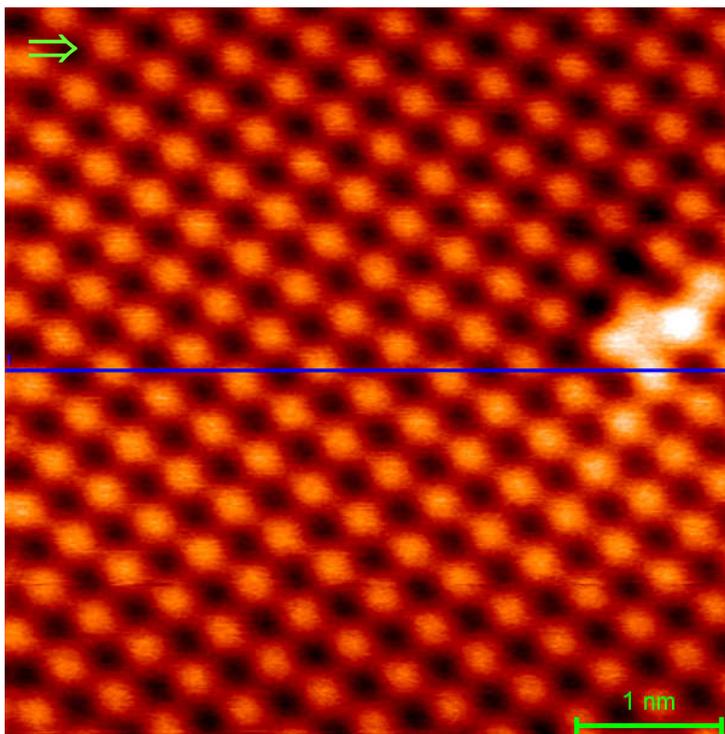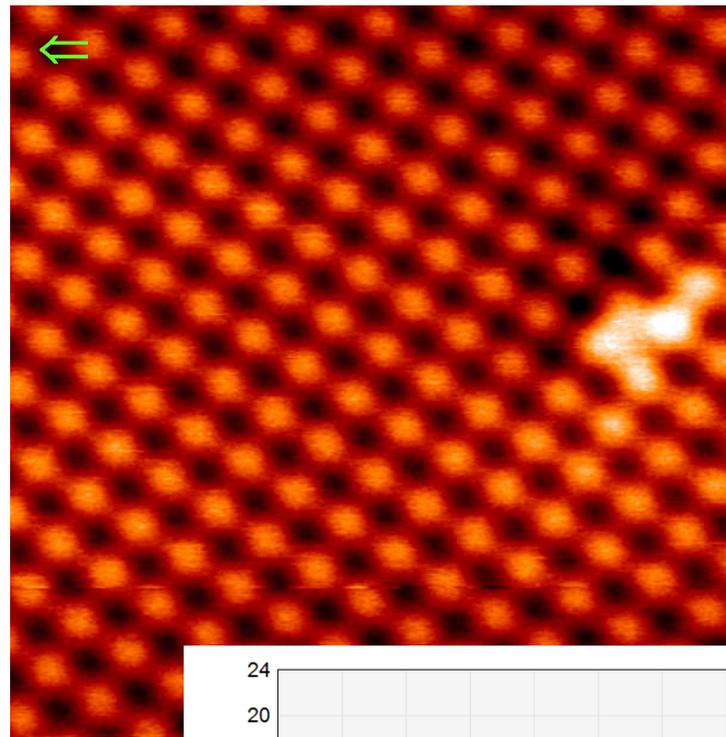
$A = 500pm$
$\Delta f_{set} = -3.07Hz$
$Q = 55k$
$f_{res} = 27kHz$
$BW_A = 4Hz$
$BW_{PLL} = 36Hz$

Raw Data (plane subtract only)
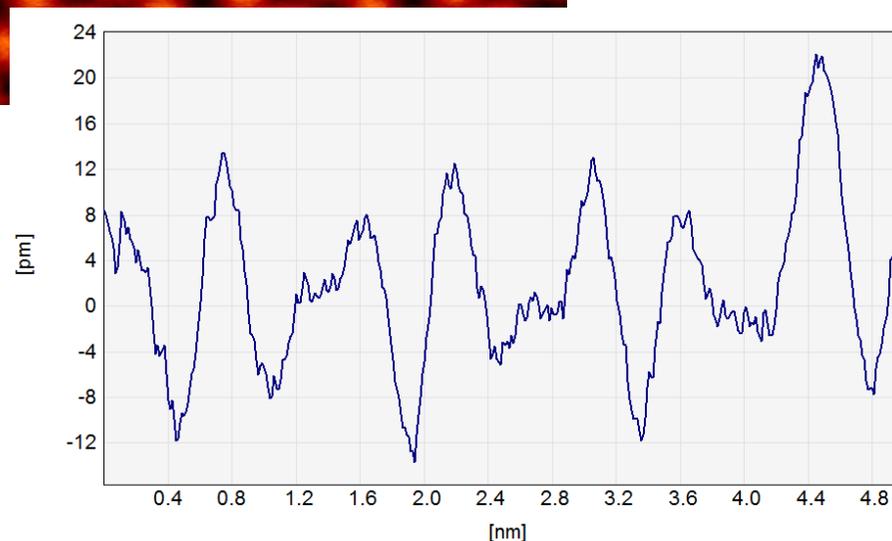
- **Constant Δf topography imaged with defect or adsorbate imaged at large amplitude with best S/N at 500pm oscillation amplitude.**


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Constant Δf imaging at various amplitudes – **100pm**
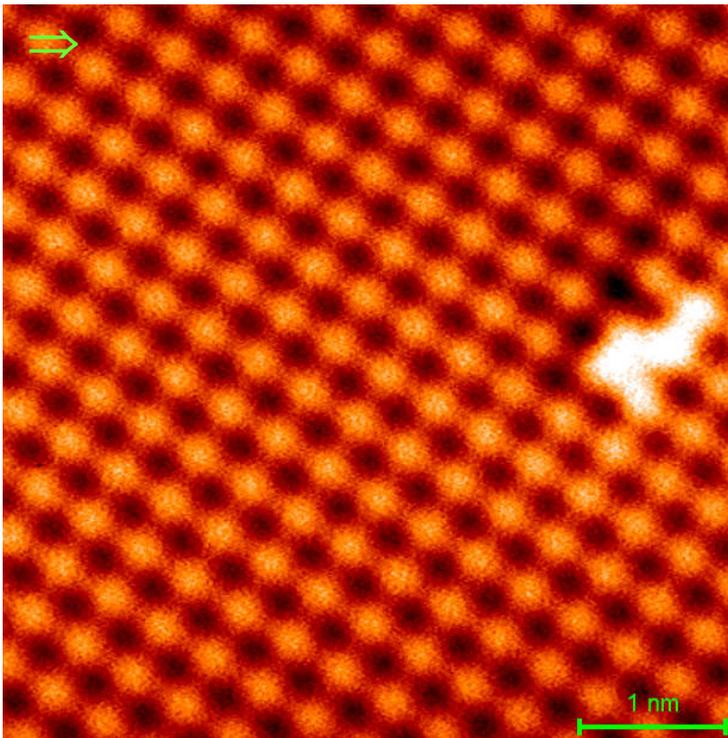
Raw Data (plane subtract only)
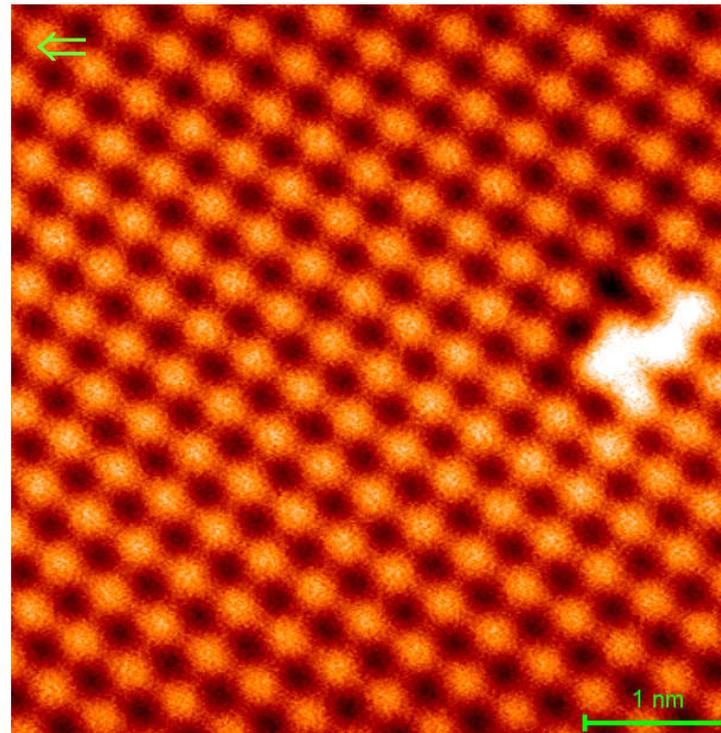
$A = 100pm$
$\Delta f_{set} = -5.0Hz$
$Q = 55k$
$f_{res} = 27kHz$
$BW_A = 4Hz$
$BW_{PLL} = 36Hz$
Tip Guard on

- **Constant Δf topography imaged with defect or adsorbate**
- **Imaged at 100pm oscillation amplitude.**

- **Matrix TipGuard activated**

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Constant Δf imaging at various amplitudes – **50pm**
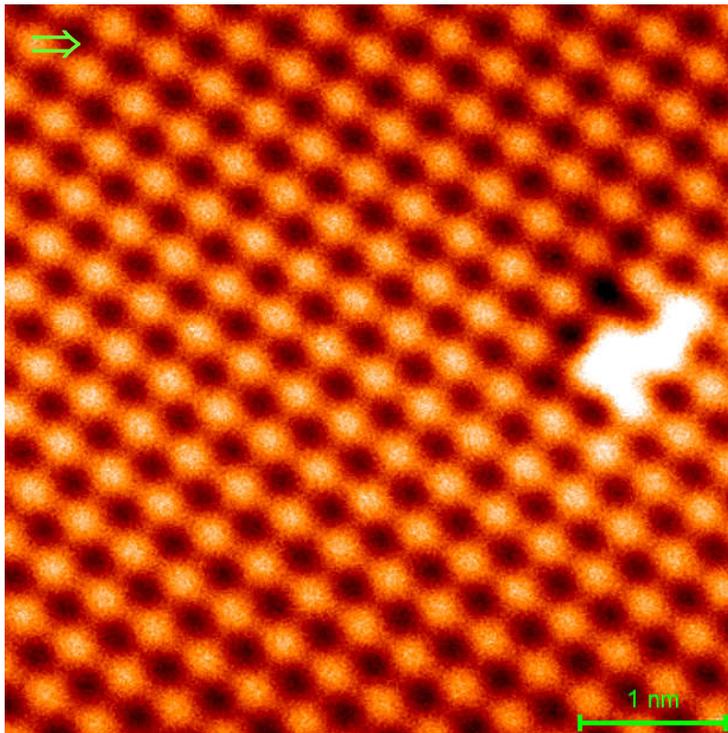
Raw Data (plane subtract only)
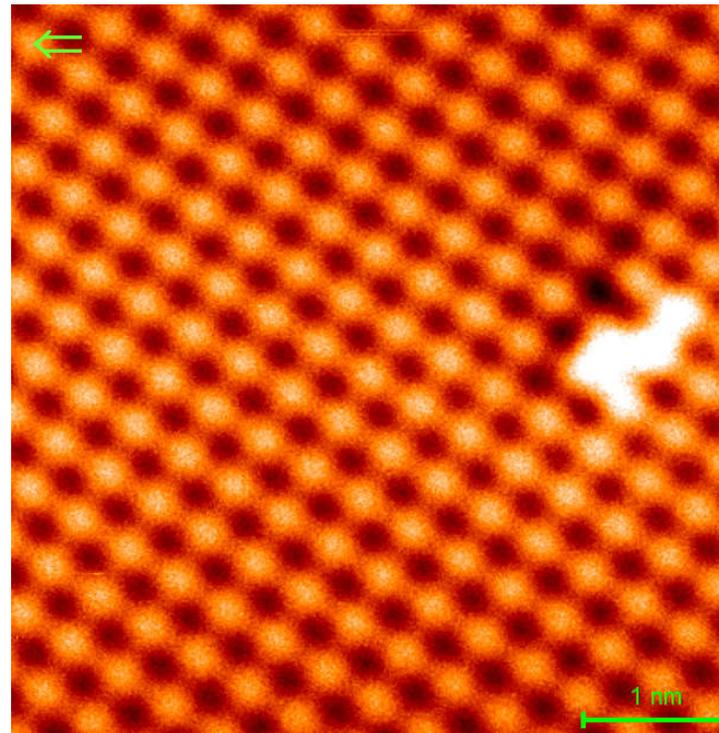
A = 50pm
Δf_{set} = -5.25Hz
Q=55k
f_{res}=27kHz
BW_A=4Hz
BW_{PLL}=36Hz
Tip Guard on

- **Constant Δf topography imaged with defect or adsorbate**
- **Imaged at 50pm oscillation amplitude**

- **Matrix TipGuard activated**

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Constant Δf imaging at various amplitudes – **25pm**
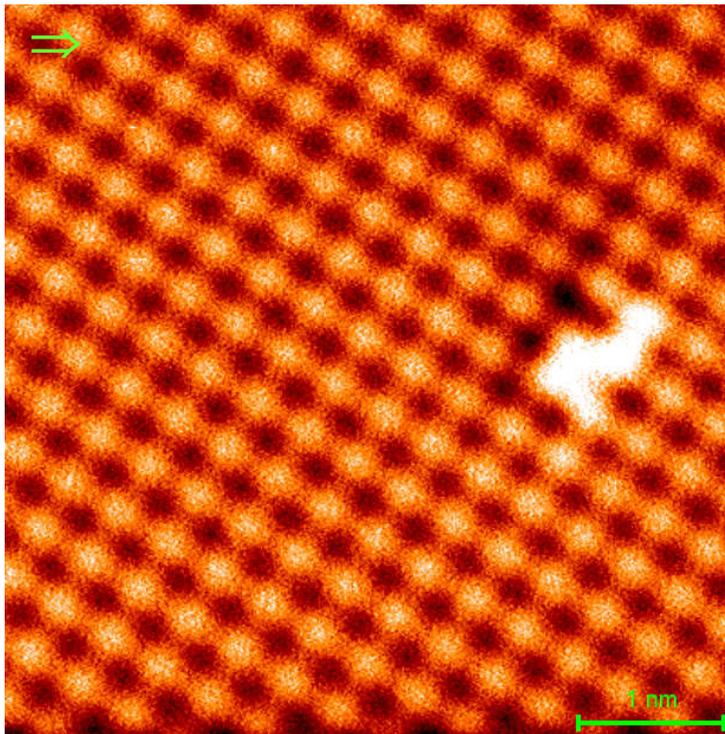
Raw Data (plane subtract only)
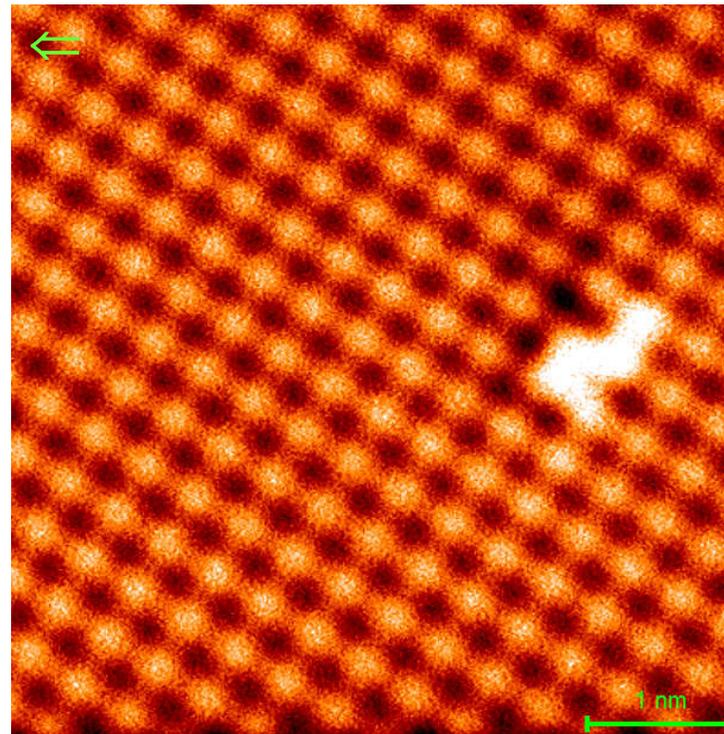
$A = 25pm$
$\Delta f_{set} = -5.25Hz$
$Q = 55k$
$f_{res} = 27kHz$
$BW_A = 2Hz$
$BW_{PLL} = 25Hz$
Tip Guard on

- **Constant Δf topography imaged with defect or adsorbate**
- **Imaged at 25pm oscillation amplitude**

- **Matrix TipGuard activated**

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Constant Δf imaging at various amplitudes – **10pm**
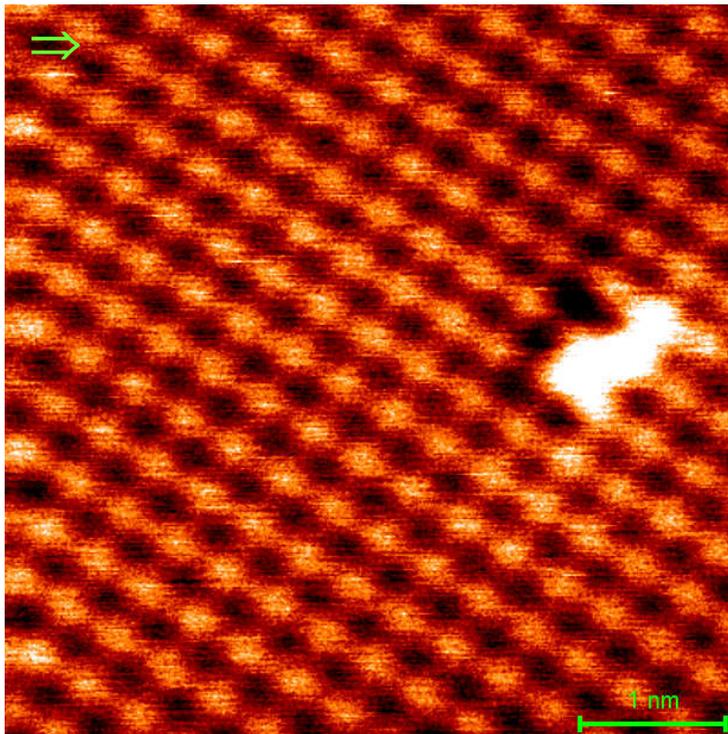
Raw Data (plane subtract only)
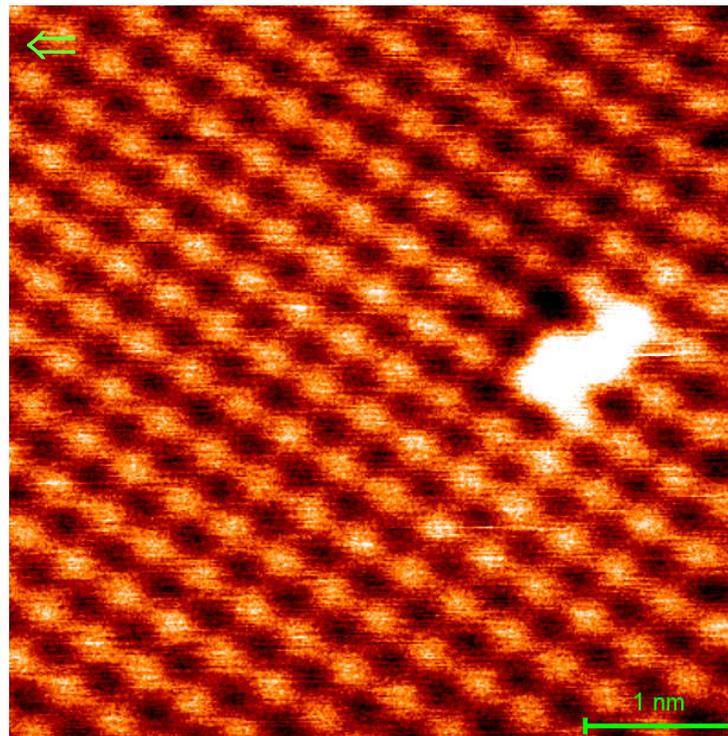
A = 10pm
Δf_{set} = -5.25Hz
Q=55k
f_{res}=27kHz
BW_A=2Hz
BW_{PLL}=25Hz
Tip Guard on

- **Constant Δf topography imaged with defect or adsorbate**
- **Imaged at 10pm oscillation amplitude**

- **Matrix TipGuard activated**

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Constant Δf imaging at various amplitudes – **5pm and 3pm**

External lab distortions
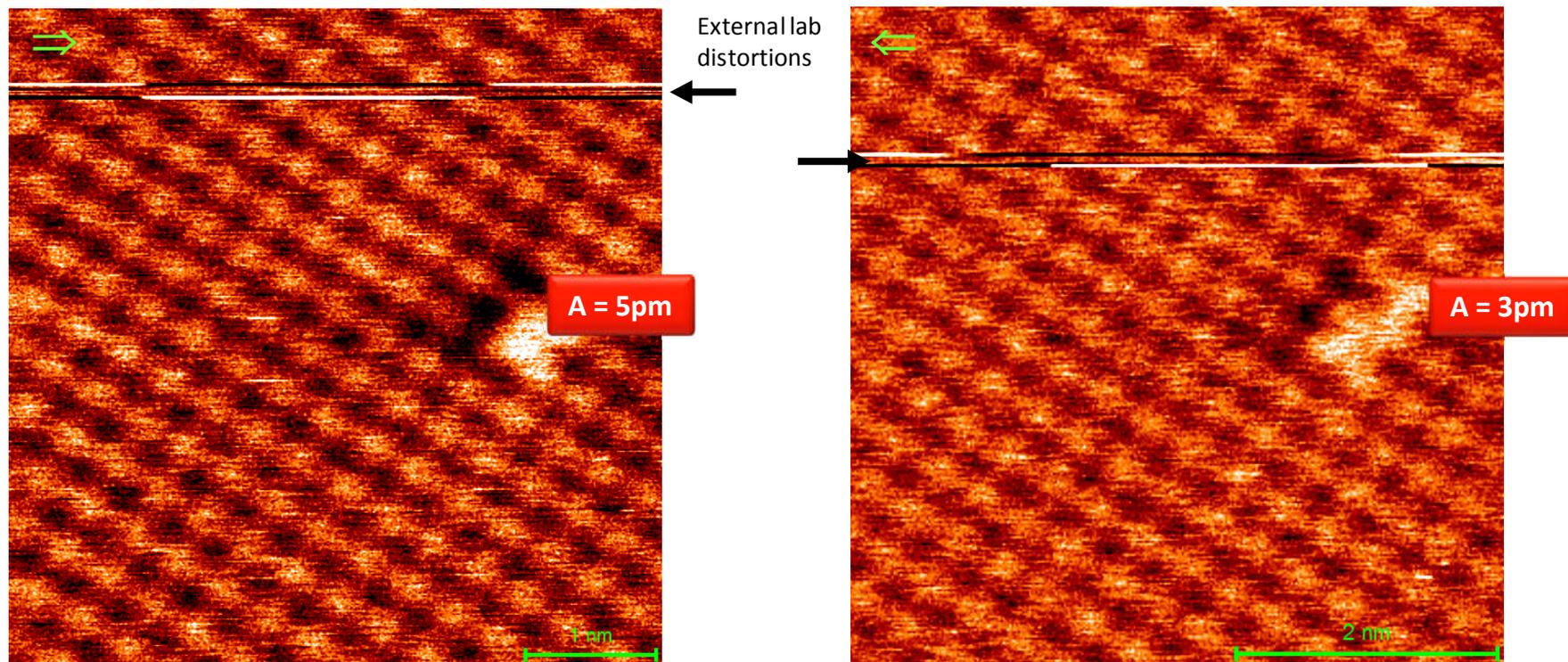
A = 5pm

A = 3pm

Raw Data (linewise slope subtract)

A = 5pm
Δf_{set}= -5.25Hz
Q=55k
f_{res}=27kHz
BW_A=2Hz
BW_{PLL}=25Hz

A = 3pm
Δf_{set}= -5.25Hz
Q=55k
f_{res}=27kHz
BW_A=2Hz
BW_{PLL}=25Hz

- **Constant Δf topography imaged with defect or adsorbate**
- **Imaged at smallest oscillation amplitudes**

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High stability at 50pm - Image series 8h

- **Constant Δf topography imaging sequence showing stabillity of 50pm low amplitude imaging including Tip Guard**

Time →

Raw Data (plane subtract only)

A = 50pm
Δf_{set} = -5.15Hz
Q=55k
f_{res}=27kHz
BW_A=4Hz
BW_{PLL}=36Hz
Tip Guard on

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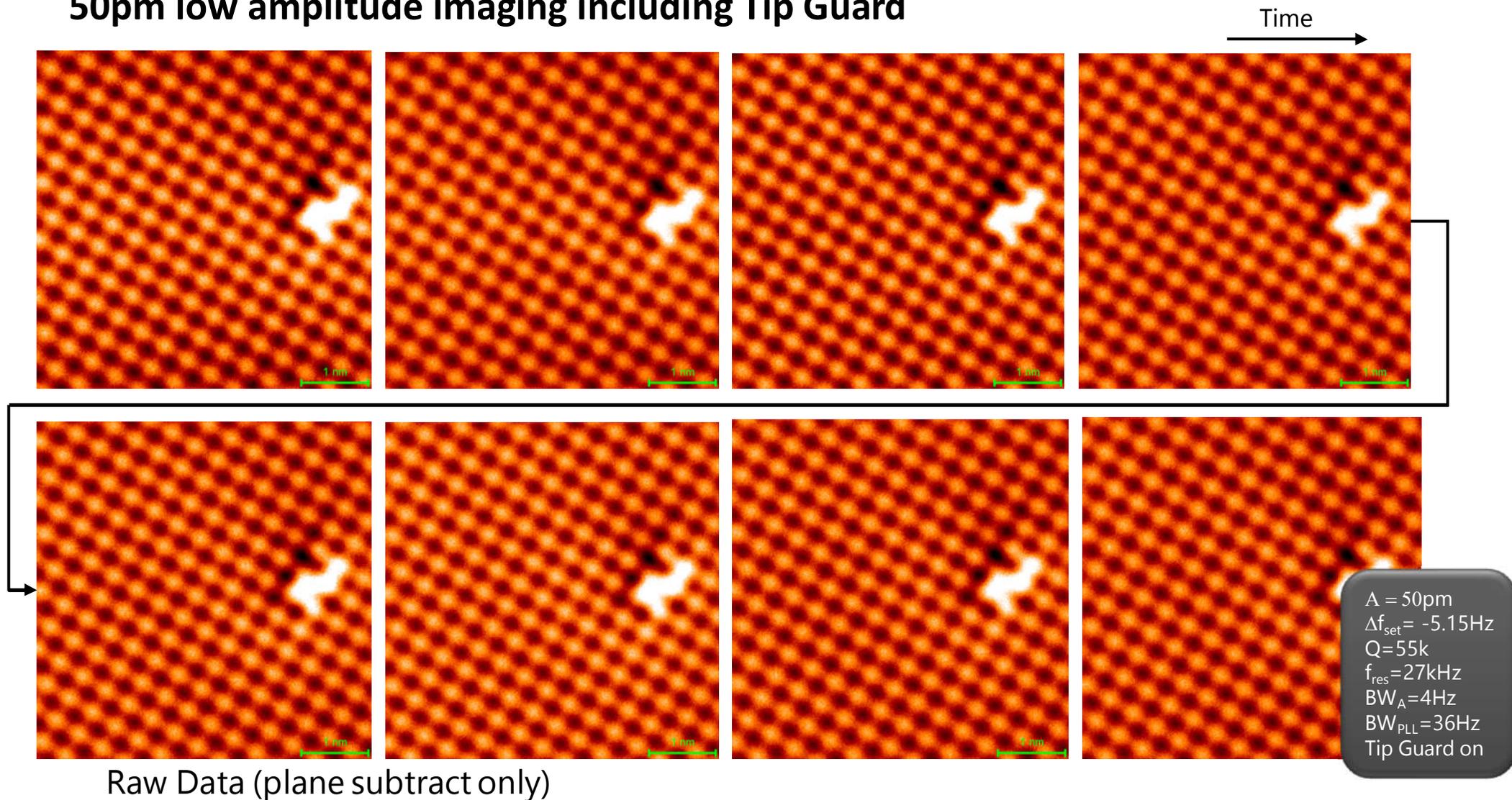
Comparison of line profiles
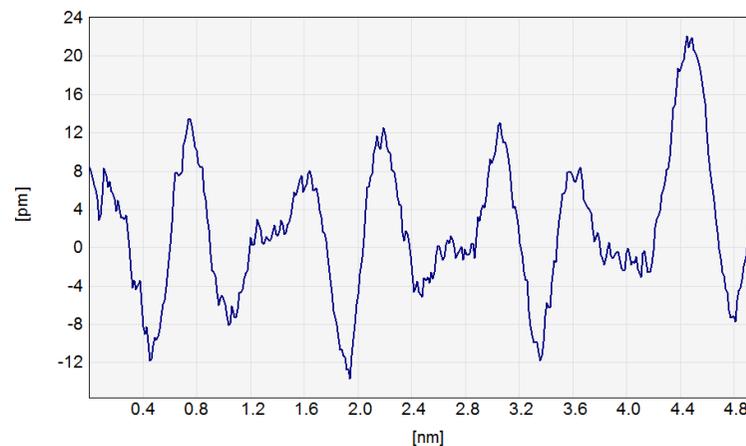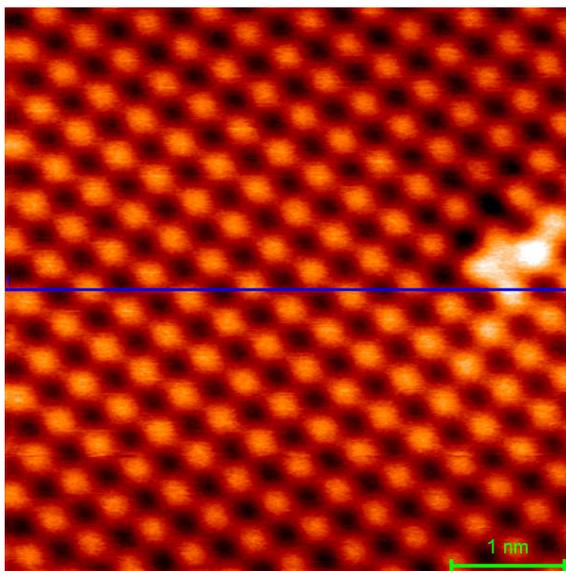
A = 500pm
Δf_{set}= -3.07Hz
Q=55k
f_{res}=27kHz
BW_A=4Hz
BW_{PLL}=36Hz
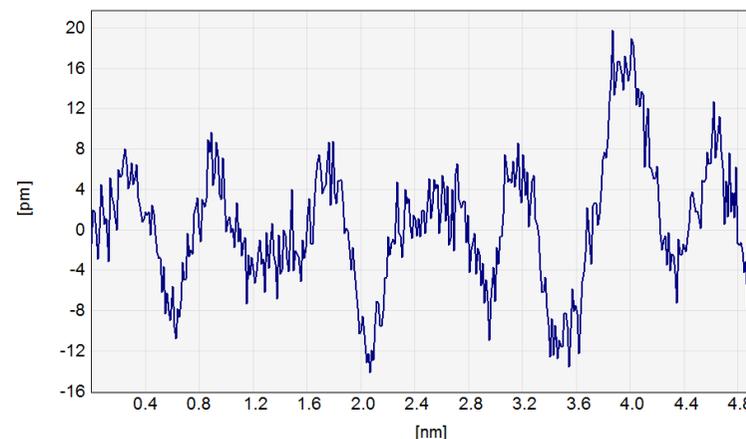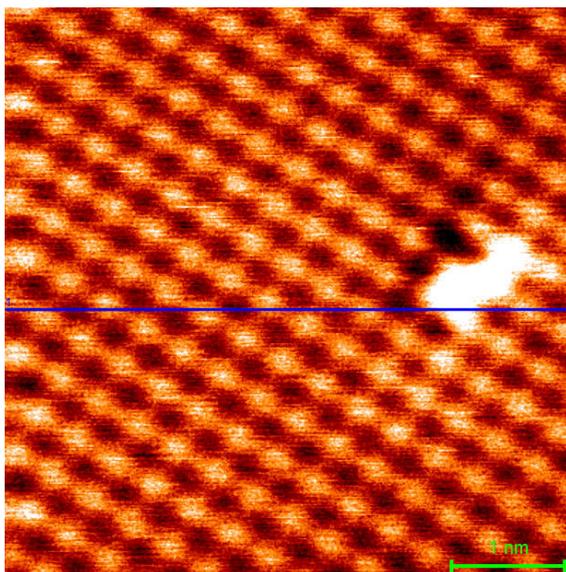
A = 10pm
Δf_{set}= -5.25Hz
Q=55k
f_{res}=27kHz
BW_A=2Hz
BW_{PLL}=25Hz
Tip Guard on

Raw Data (plane subtract only)

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Force spectroscopy at various amplitudes
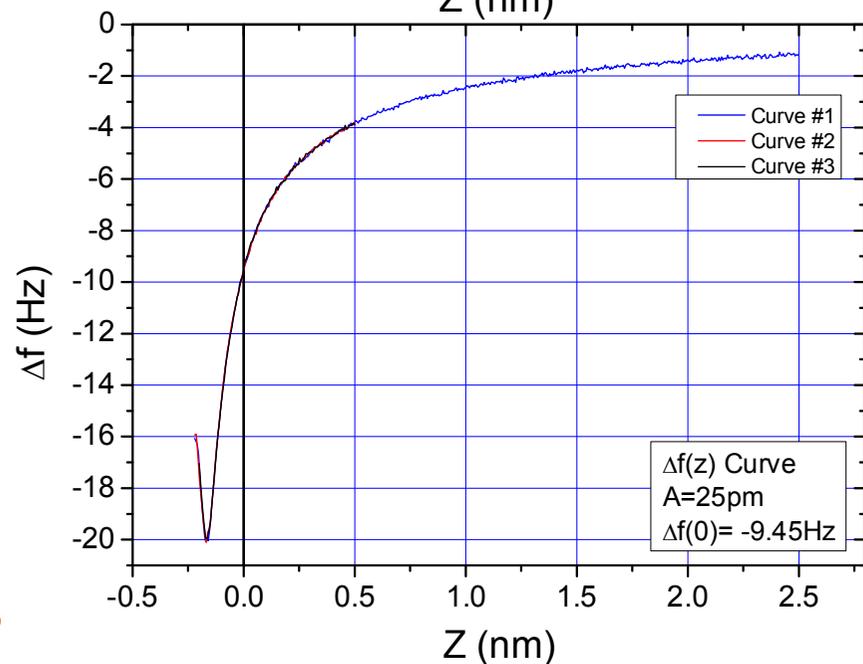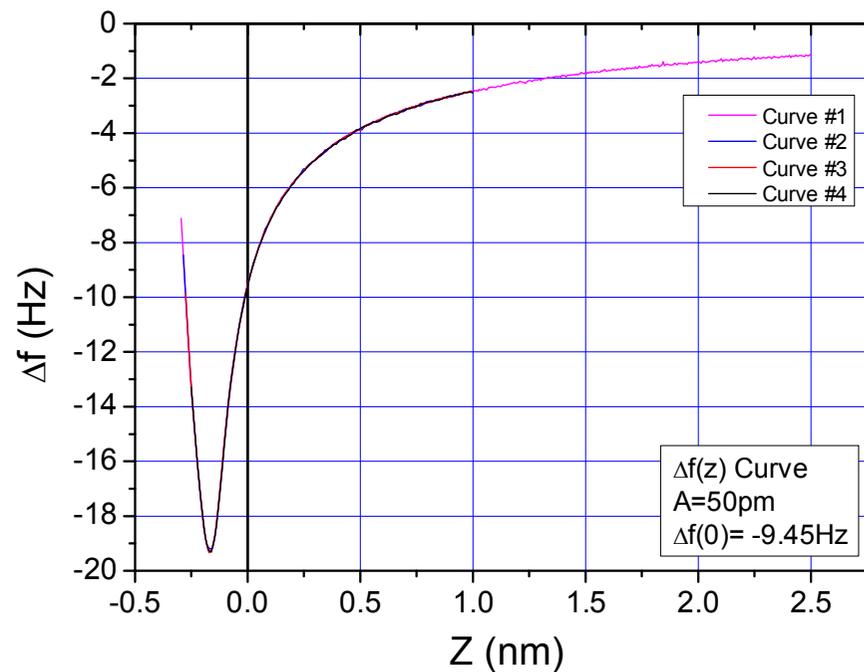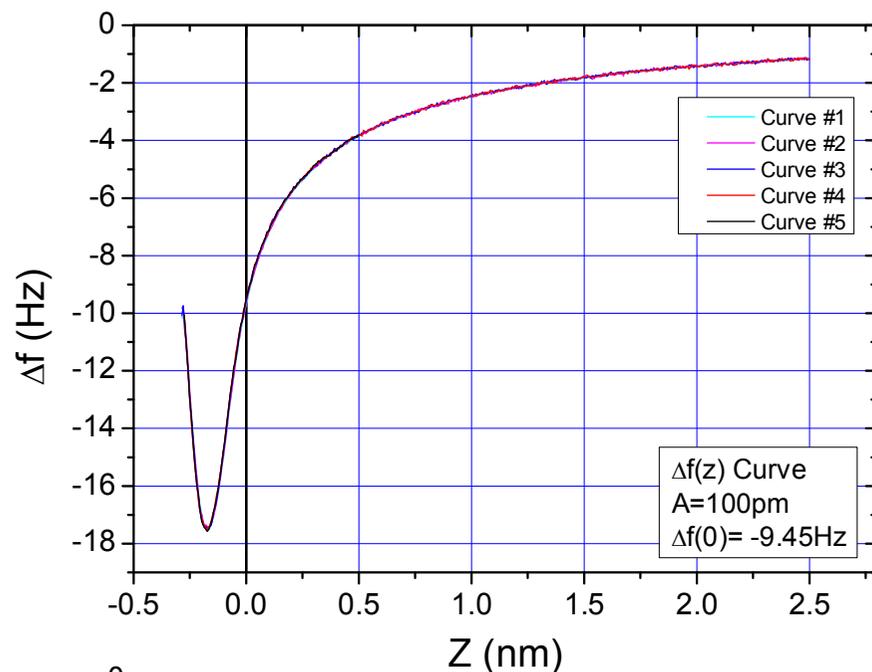
- **High reproducibility and low noise down to 25pm amplitude.**

Summary

- **LT STM with record proven scientific output on leading-edge QPlus AFM research**

- **AFM PLL based on Zürich Instruments electronics proving best S/N performance on the market**

- **Fully integrated with Matrix providing ease-of-use and *TipGuard* for stable imaging**

- **New manufacturing process for QPlus sensors with extremely high Q factor**

- **Oscillation amplitudes down to 3pm on NaCl(001)**

- **Impressive long-term imaging stability using *TipGuard***

- **Stable imaging even on charged defect regions**

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