AFM experiments with single molecules II

Ernst Meyer

Department of Physics, University of Basel, Switzerland

Outline

- Friction force microscopy and contact resonance force microscopy
- Submolecular resolution and single molecule pulling
- Pendulum AFM on superconductors: The influence of electronic friction
- Pendulum AFM on $NbSe_2$ (charge density wave)

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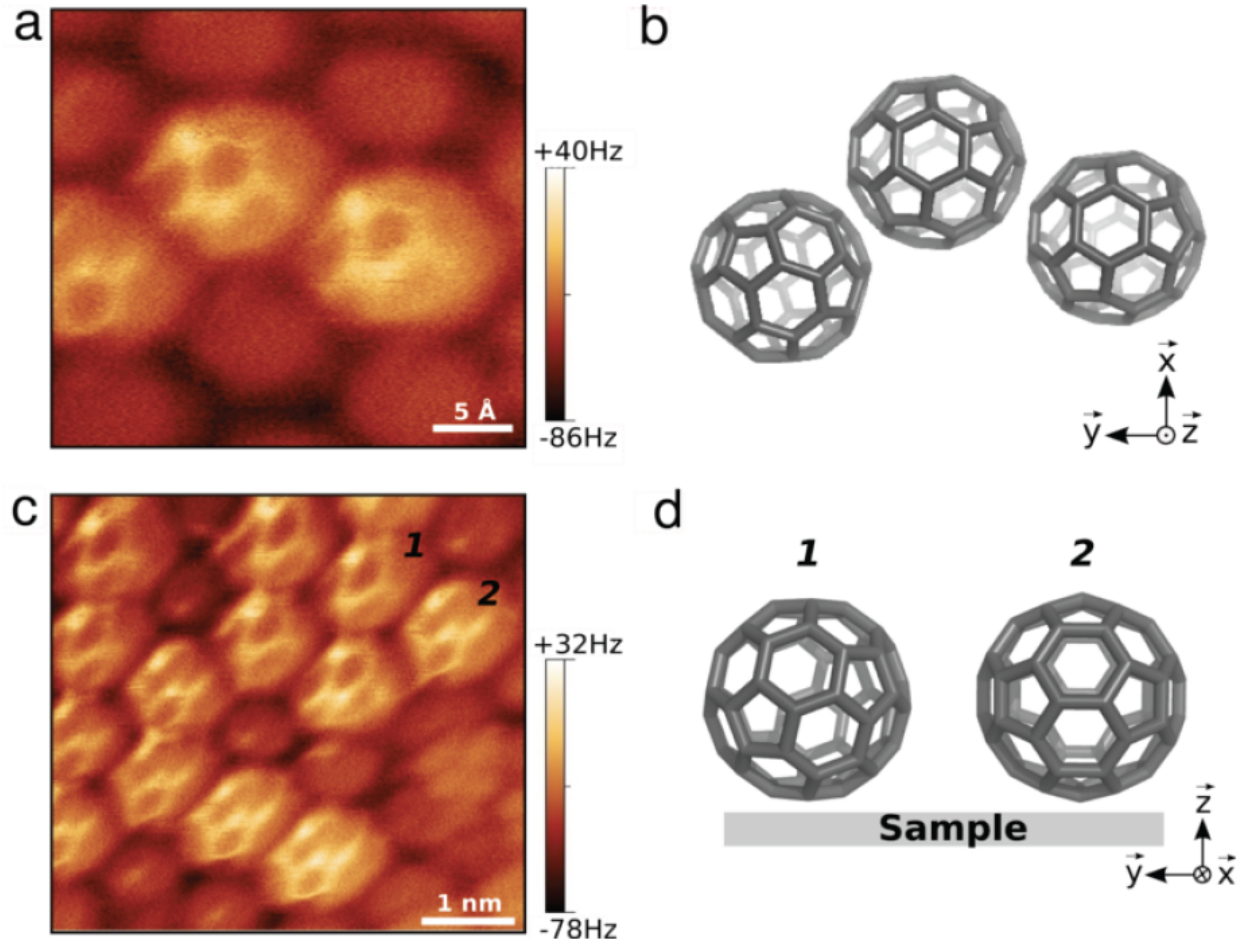
Orientation of C60 determined by frequency shift images (constant current mode)



R. Pawlak, S. Kawai, S. Fremy,, T. Glatzel, and E. Meyer, ACS Nano 2011, 5, 6349–6354.

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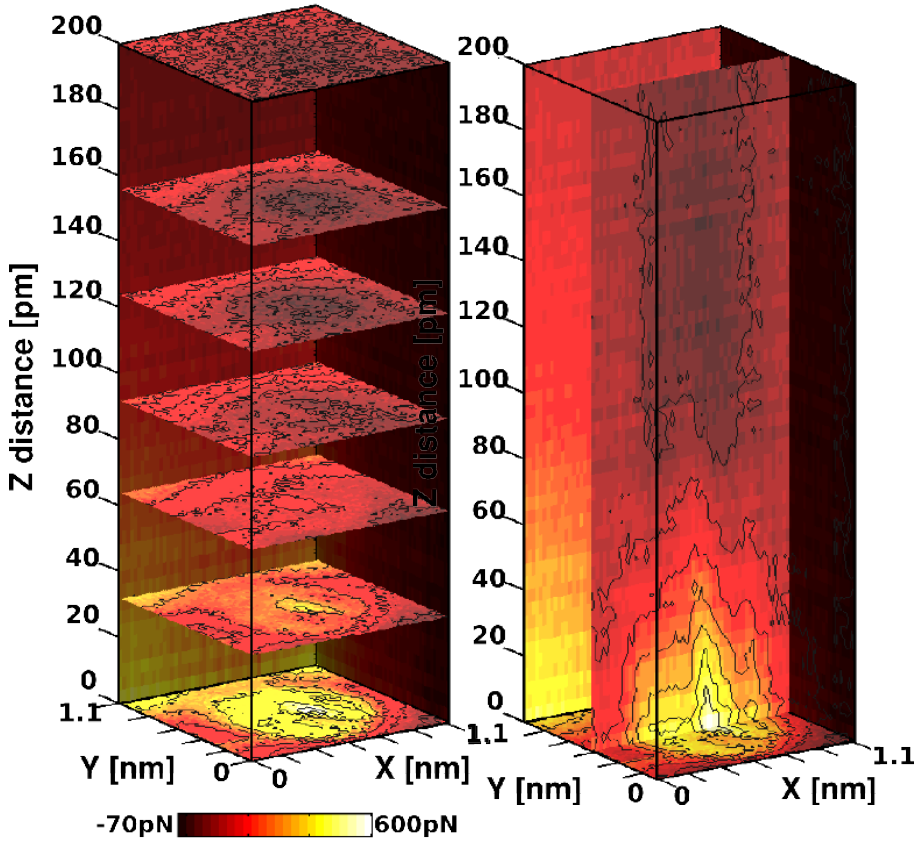
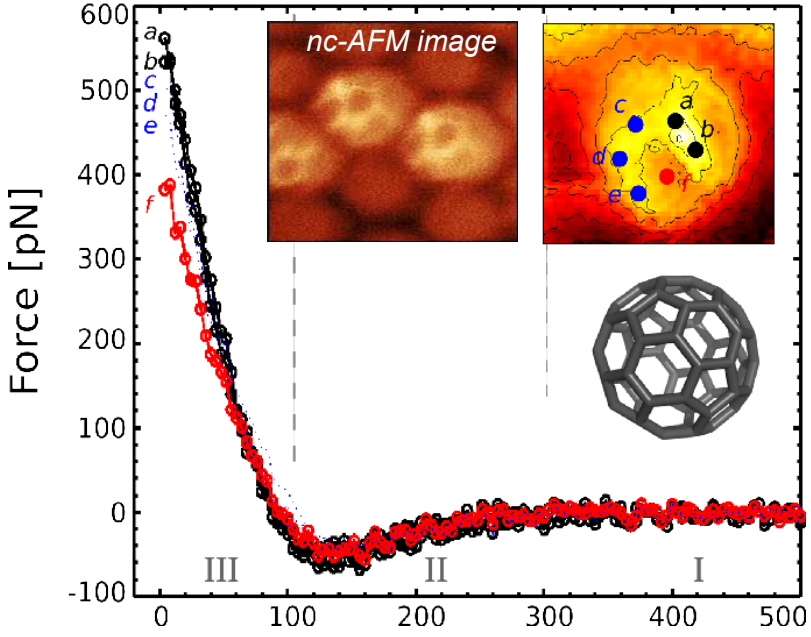
High Resolution Imaging of C_{60} Molecules

local mechanical properties

3D-force field above a single C_{60}

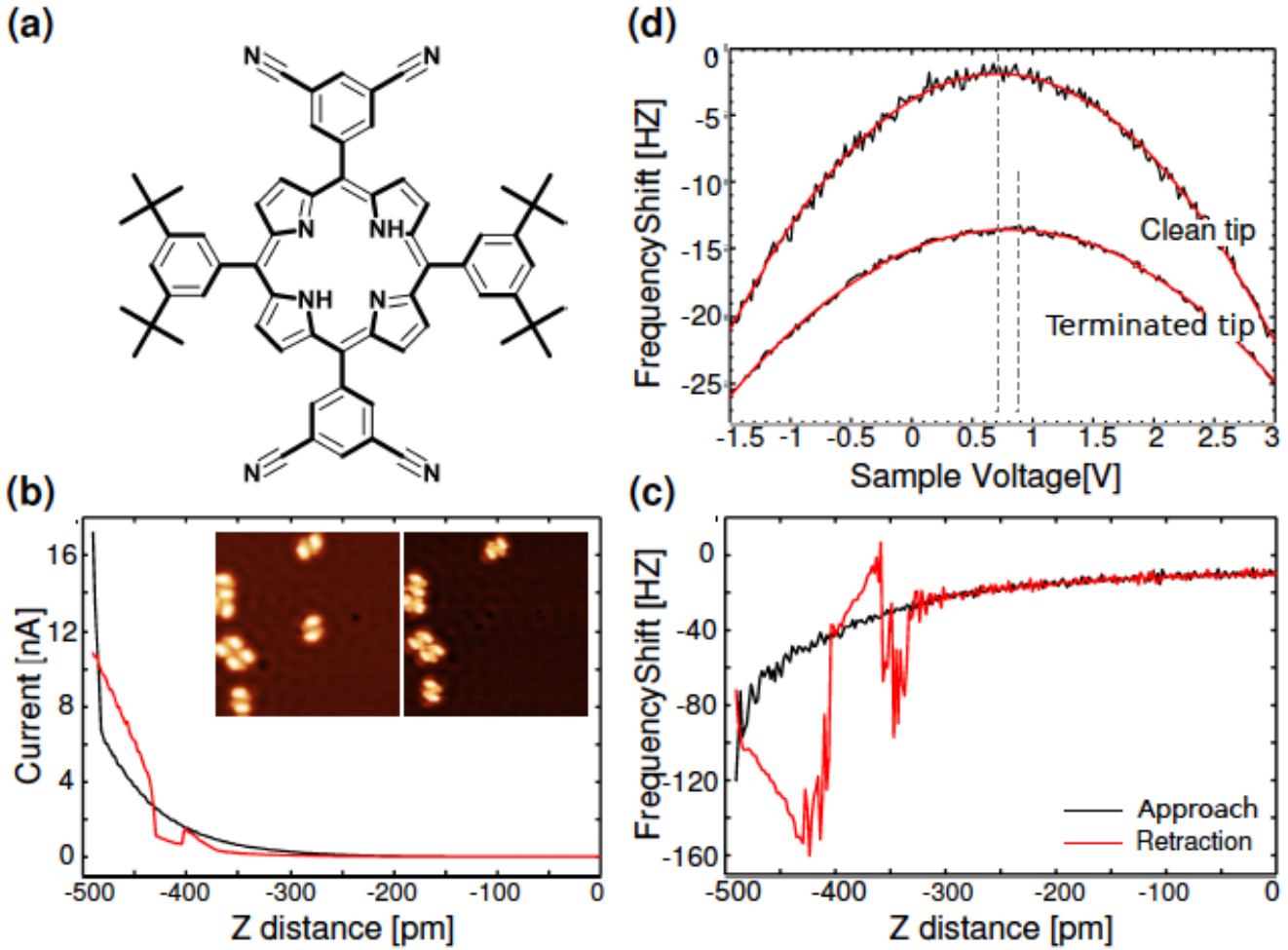




Site-specific tip-sample force variations above the C_{60} structure detected with 3D-spectroscopy
-9N/m to -7N/m on carbon sites
-4N/m on center of carbon ring

R. Pawlak et al., ACS Nano 5, 6349-6354, (2011).

Molecule terminated tip



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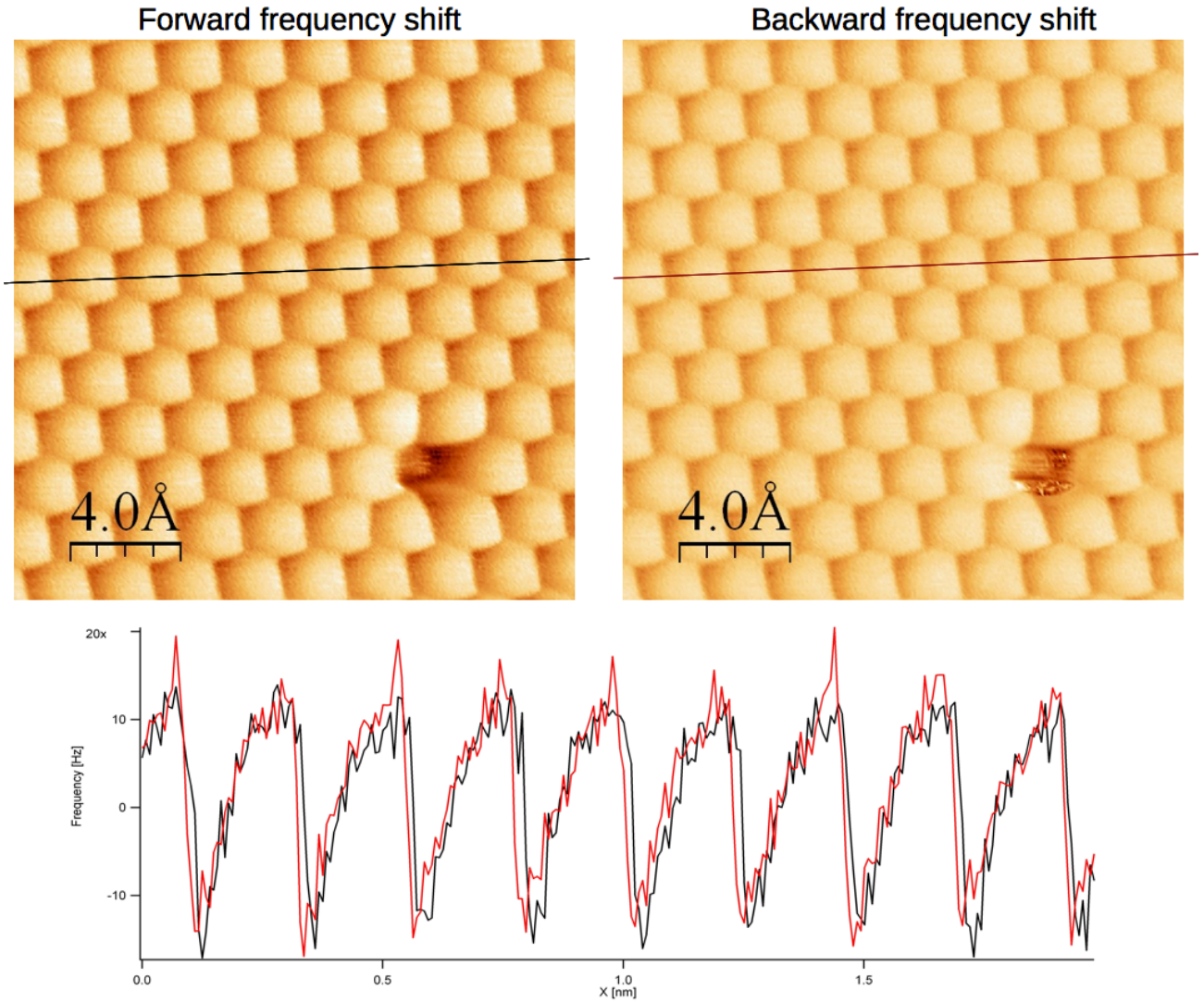
Friction loop traced with a single molecules attached to the tip



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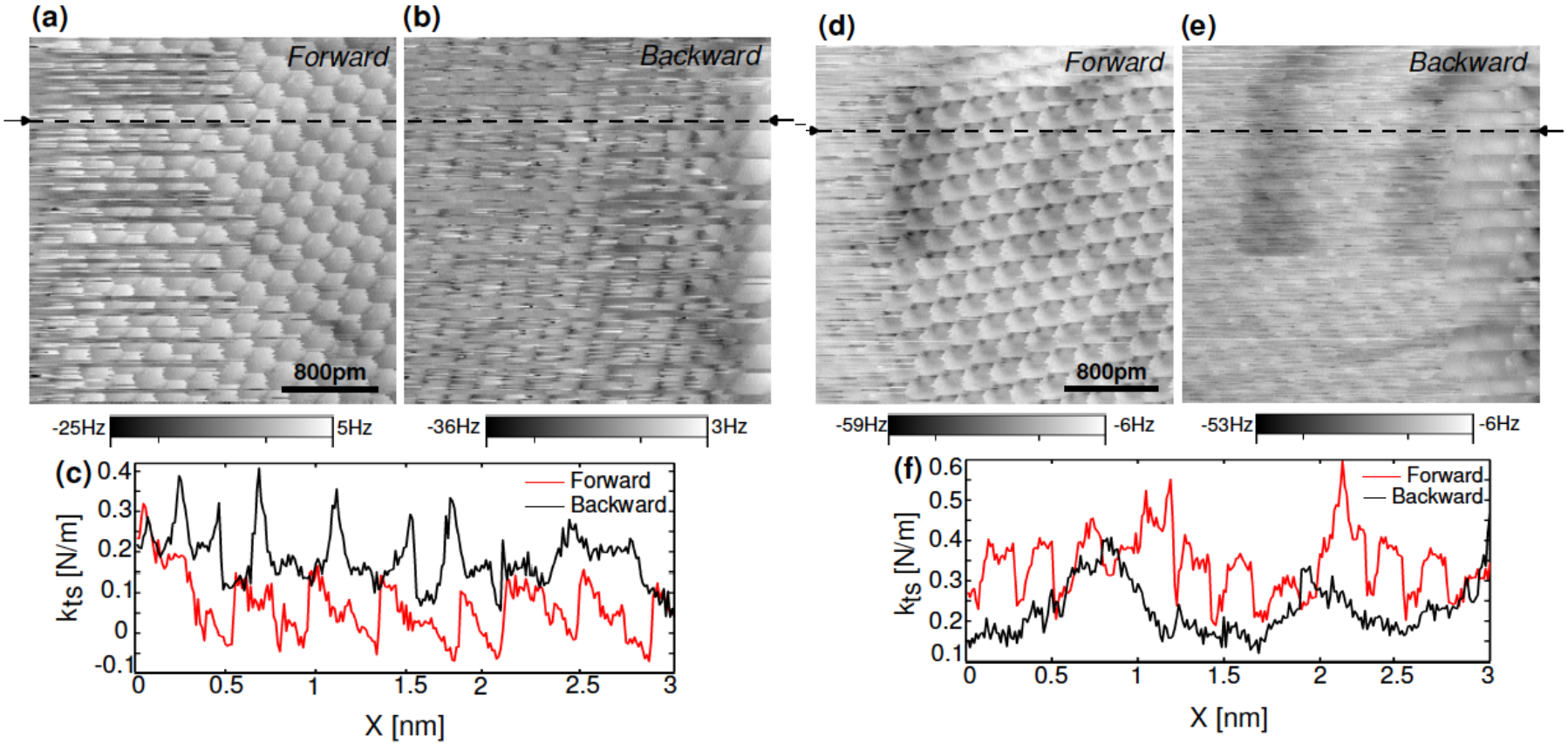
Sliding at different angles



0deg

45deg

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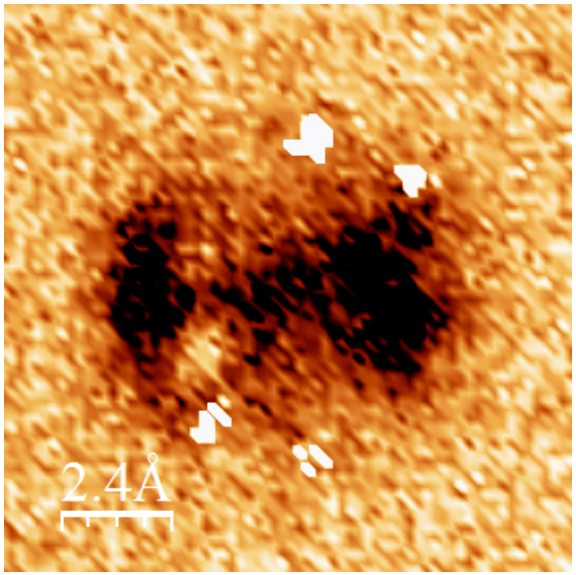
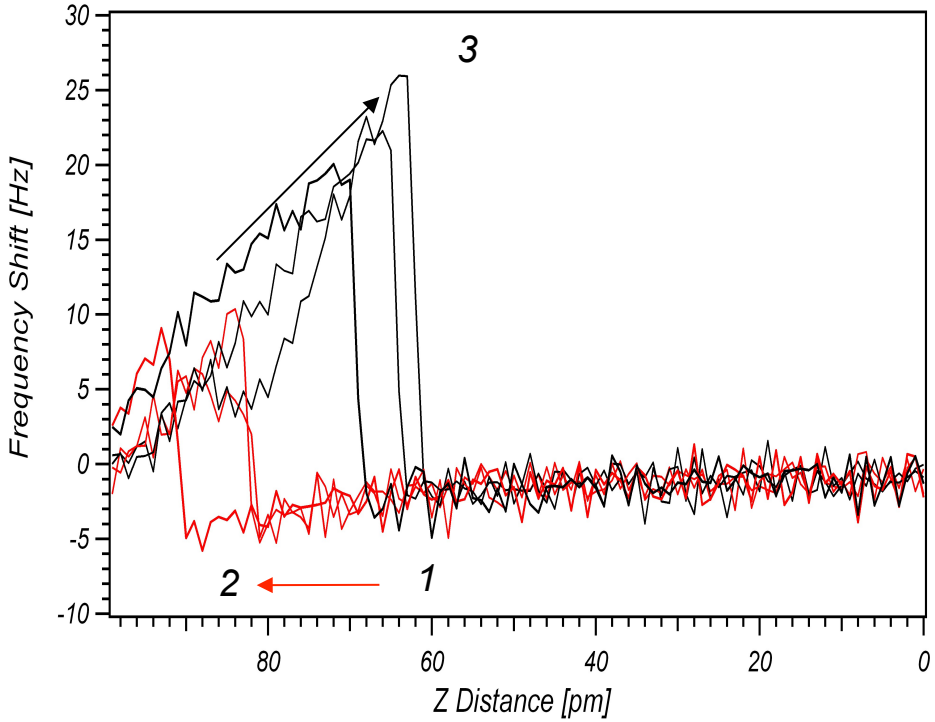
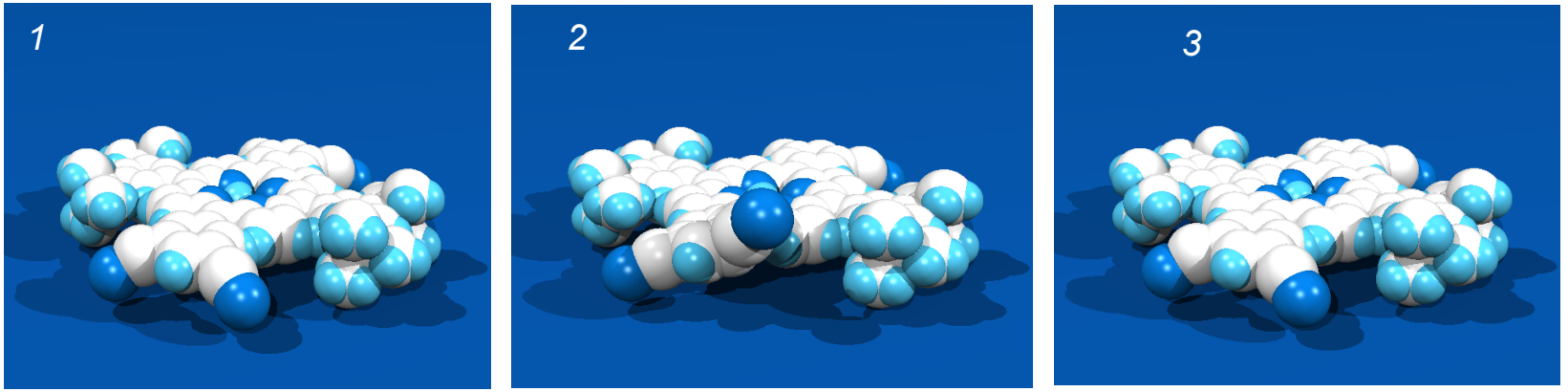
3d-force spectroscopy: Observations of localized instabilities



Three-dimensional
Force Field Spectroscopy



Origin of the hysteresis



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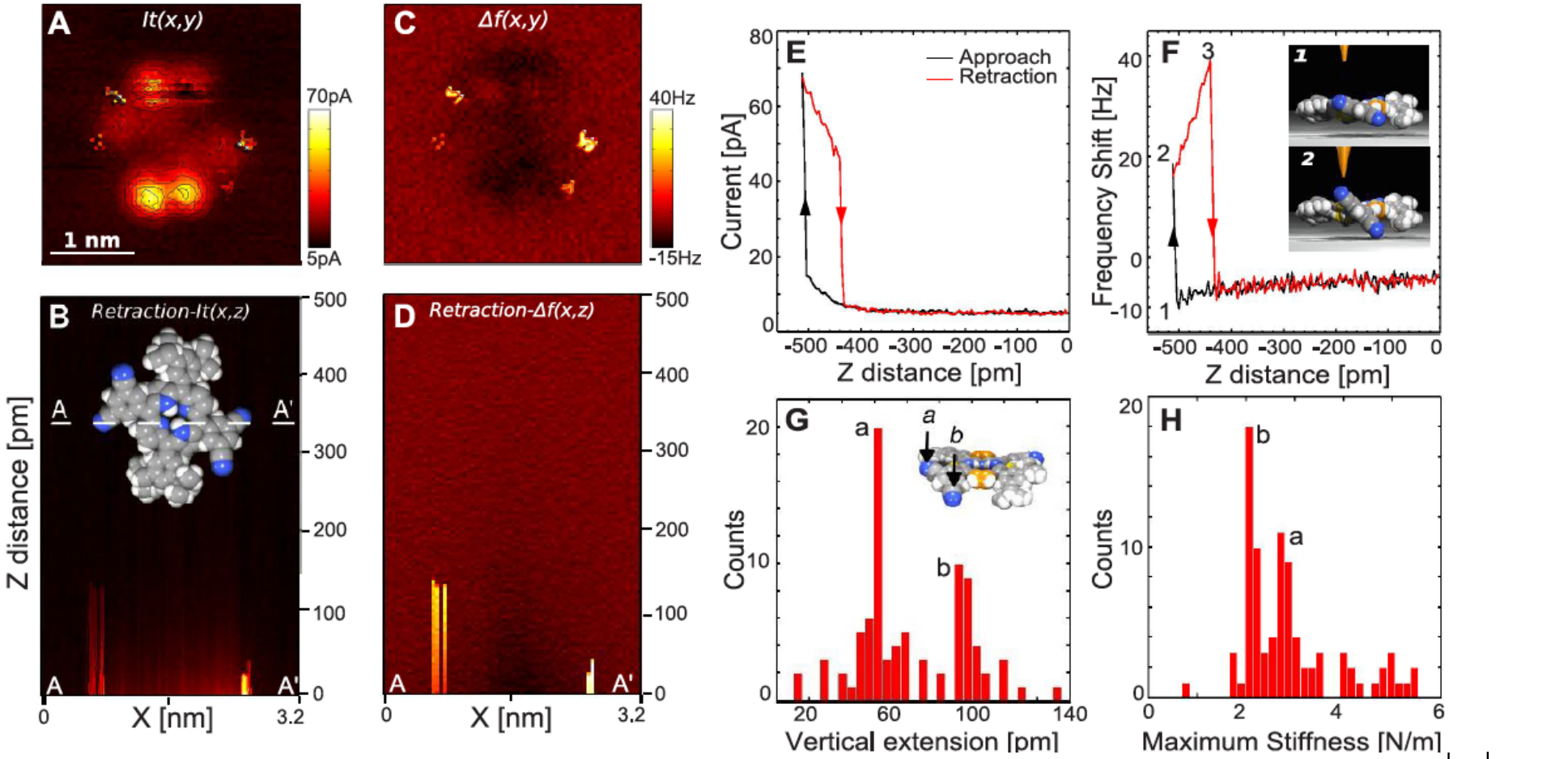
Spectroscopy on Molecules



R. Pawlak et al., ACS Nano, 6, 6318{6324, (2012).

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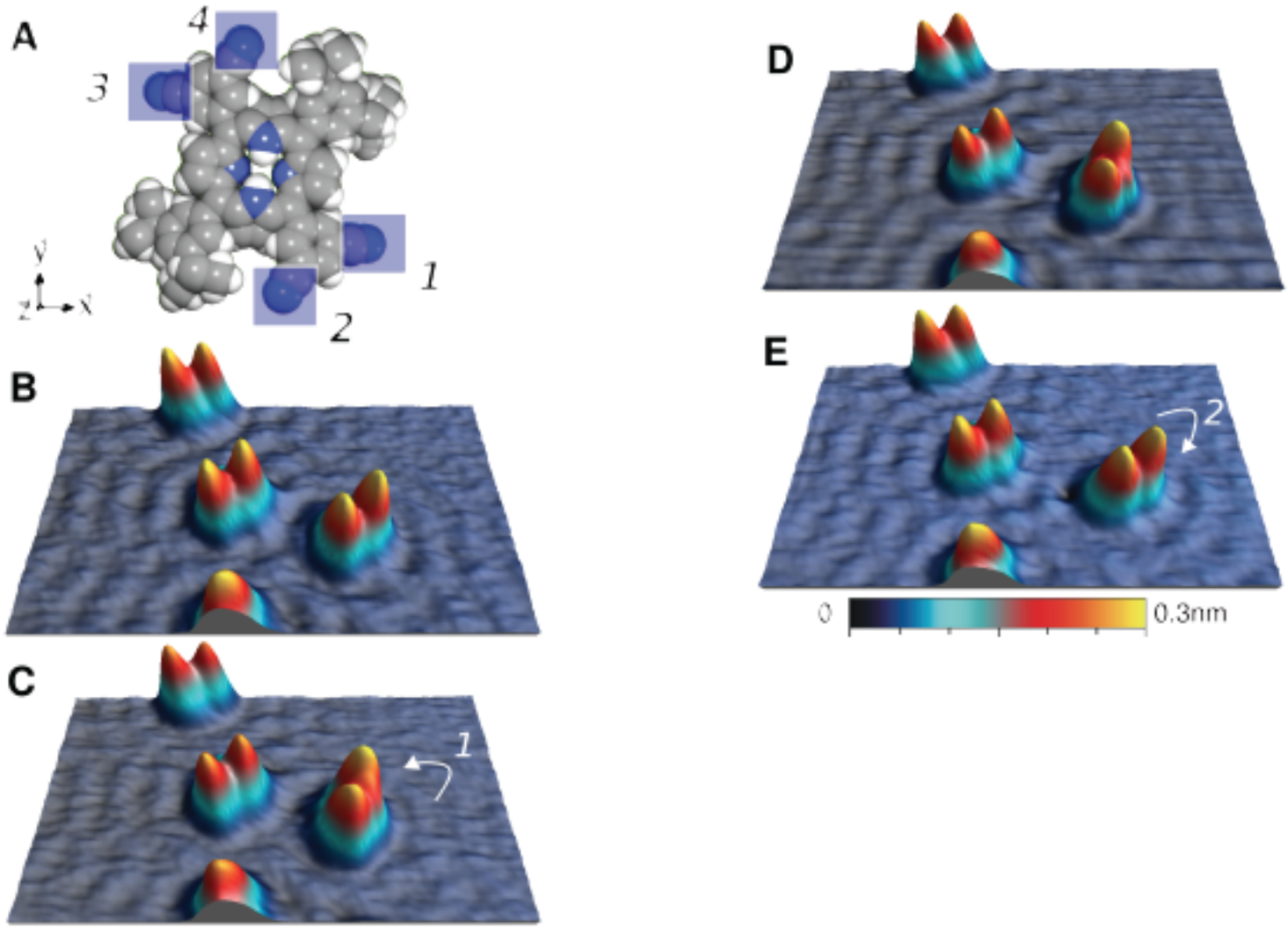
Controlled rotation of porphyrin molecules



N-Atoms can be targeted by z-spectroscopic curves to induce the rotation of the whole molecule
1 and 3 leads to anti-clock-wise rotation
2 and 4 lead to clock-wise rotation

R. Pawlak et al., ACS Nano, 6, 6318{6324, (2012).

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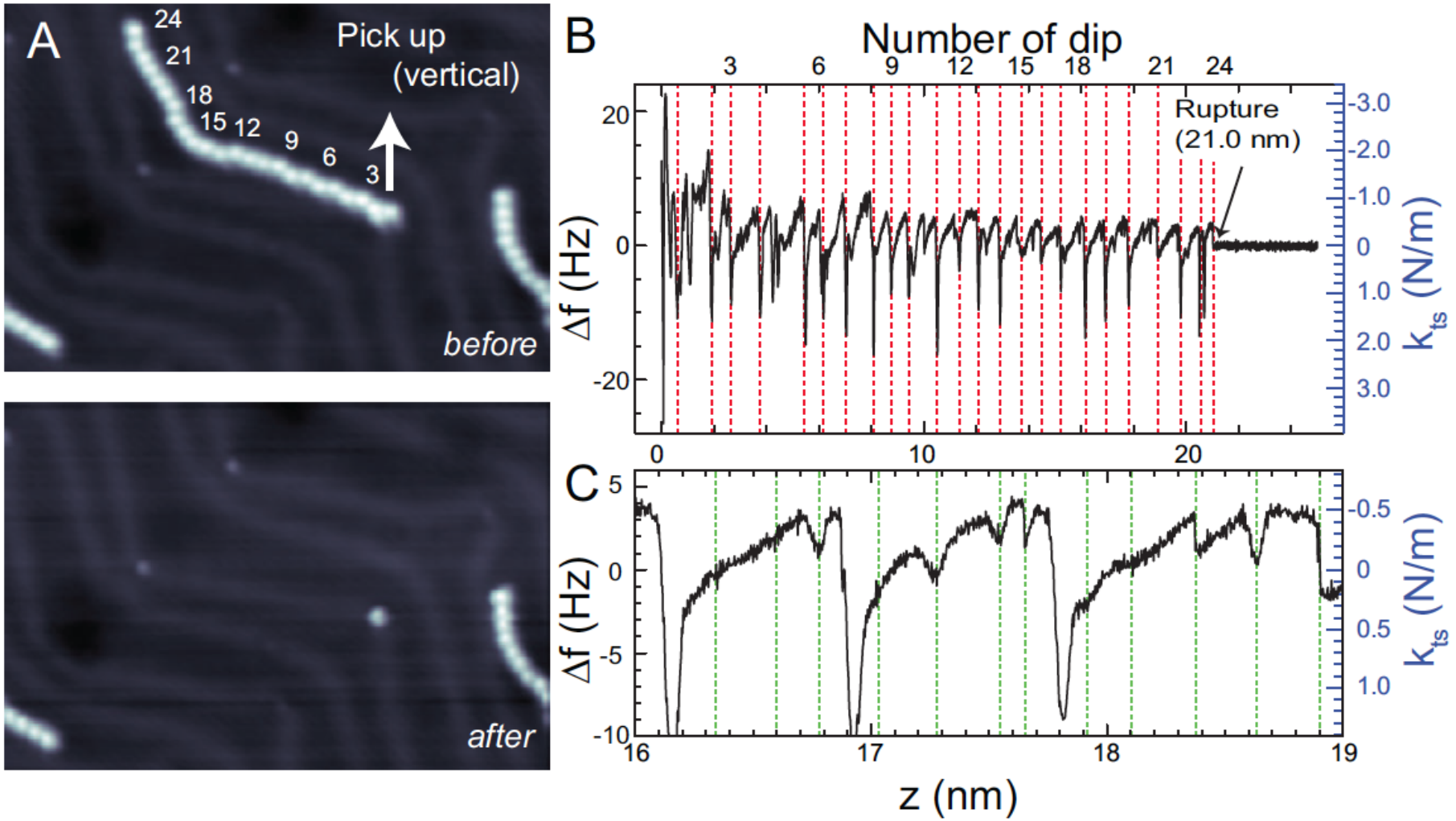
Pulling of single molecules by nc-AFM



Observation of b=0.845 periodicity: Detachment of molecular units substrucutres with a=0.27nm due to sliding over fcc-region of Au(111)

S. Kawai et al., PNAS (2014)

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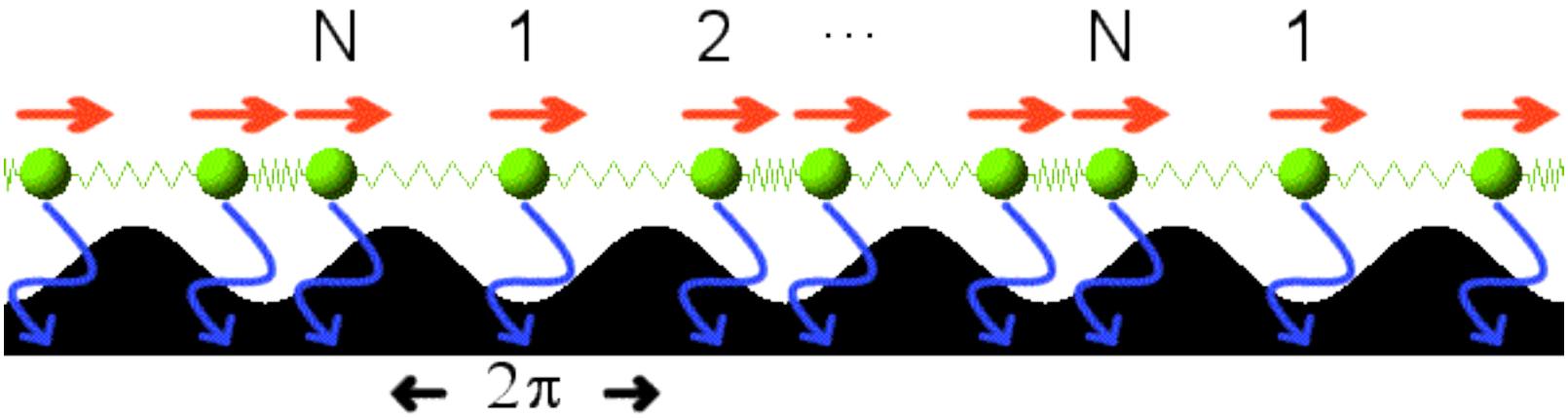
Frenkel Kontorova Model



F. Elmer
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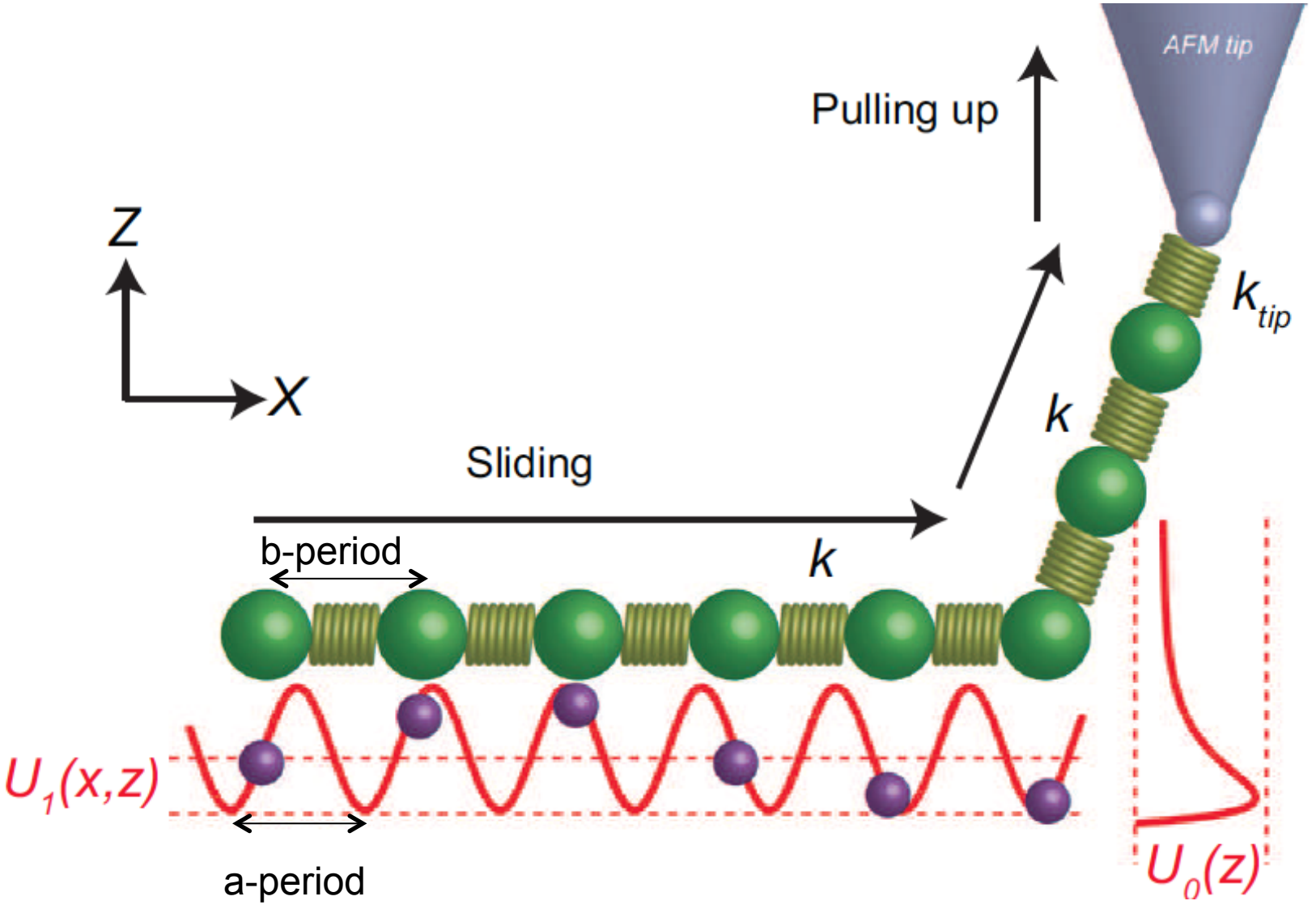
Pulling of single molecules by nc-AFM



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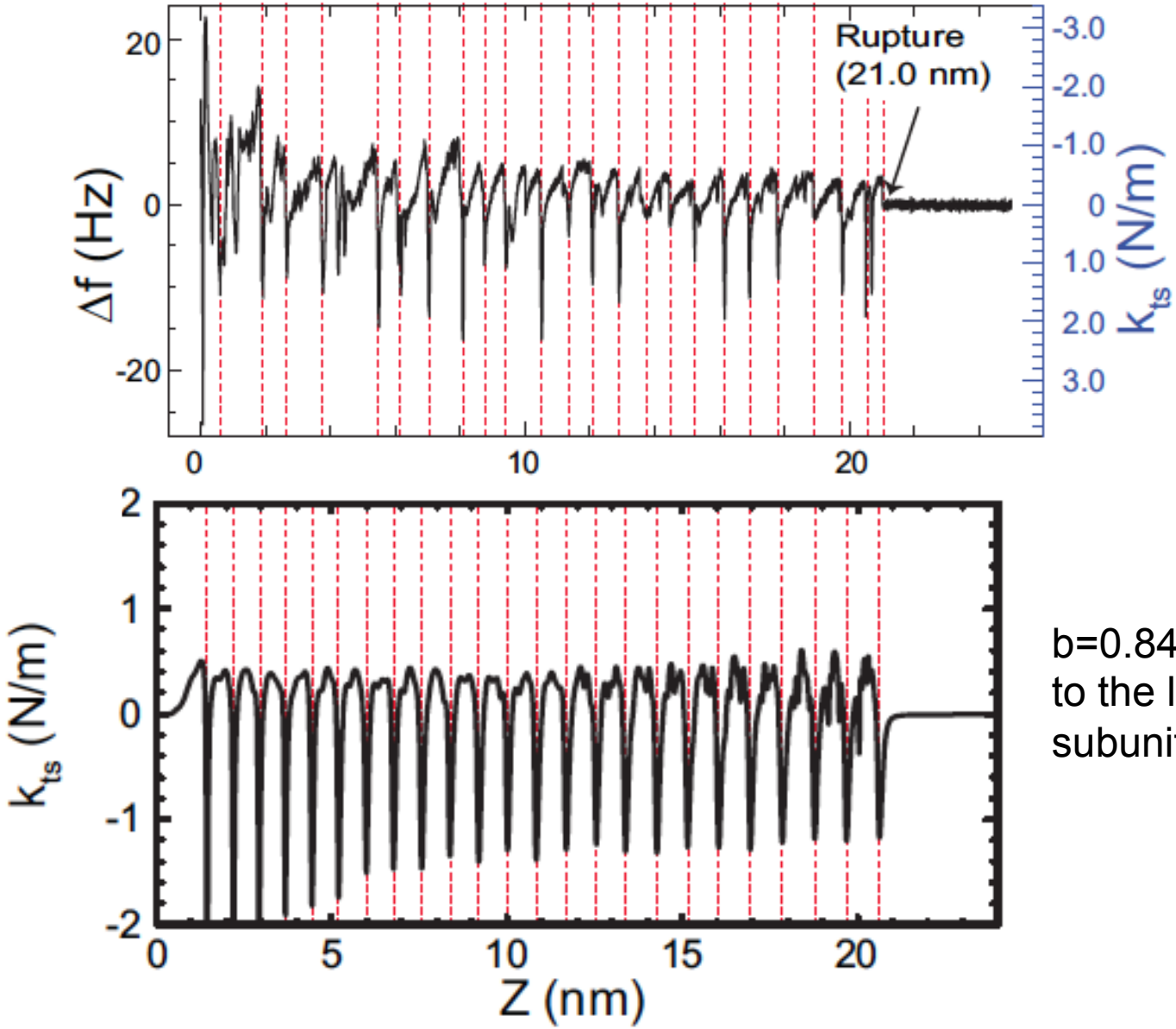
Comparison with Model: Observation of Detachment of molecules (b-periodicity)



b=0.845nm corresponds to to the length of one fluorene subunit

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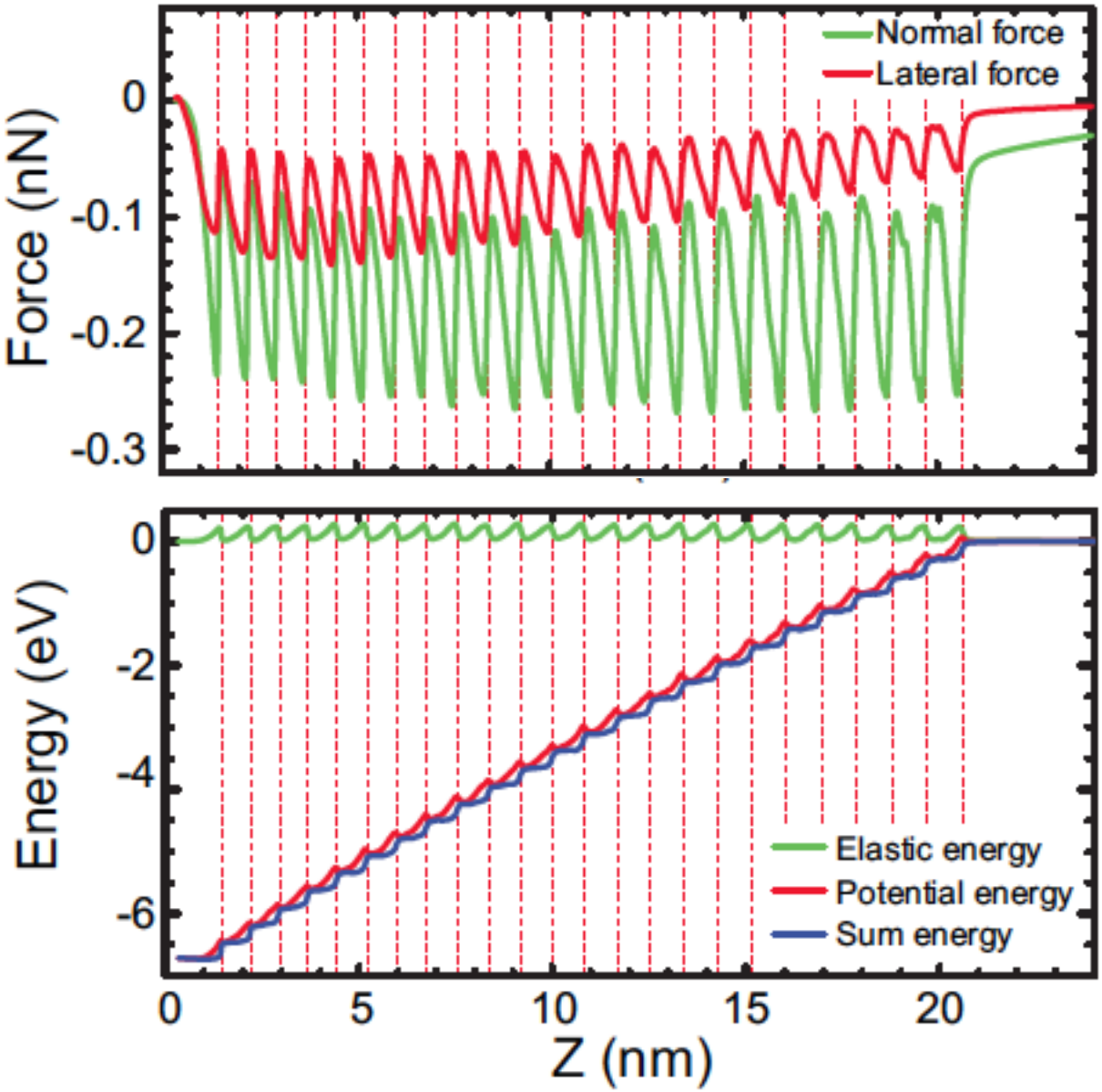
Corresponding forces and energies



Both normal and lateral forces vary during detachment 0.1-0.2nN

Stepwise increase of potential energy by 0.3ev

Oscillatory behaviour of elastic energy

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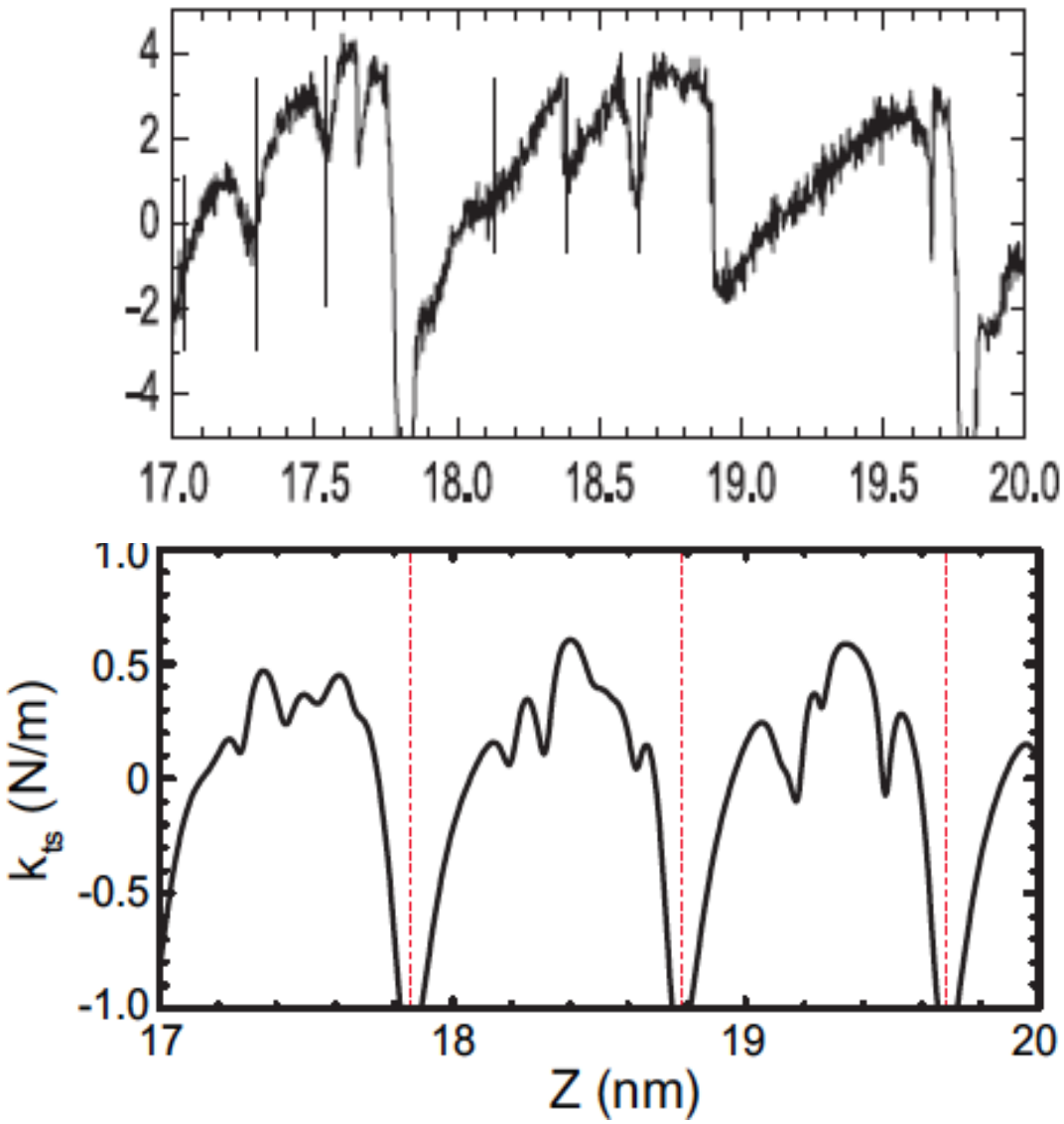
Substructure due to the substrate Au(111) (fcc-domain)



Rather irregular and small compared to detachment force gradients
(no stick slip, rather smooth sliding)

Probably due to incommensurability of substrate structure (a=0.288nm;0.249nm) and molecular length (b=0.345nm)

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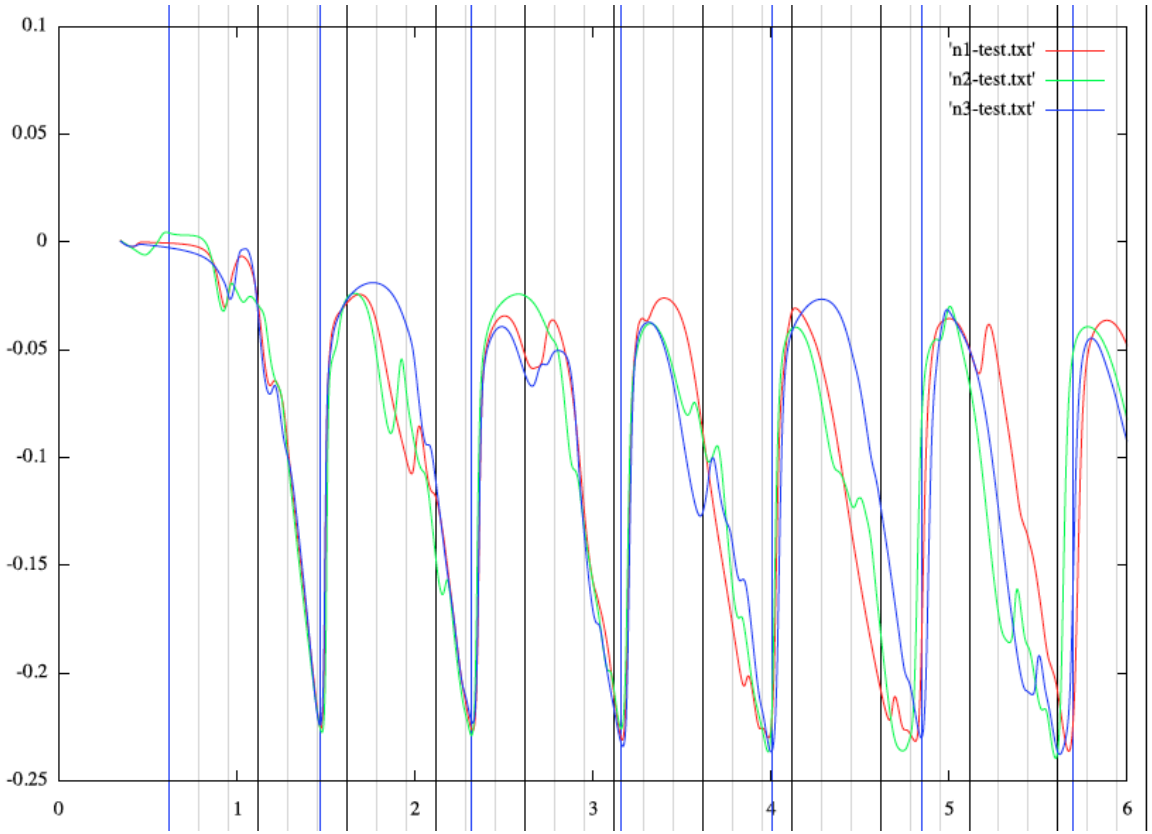
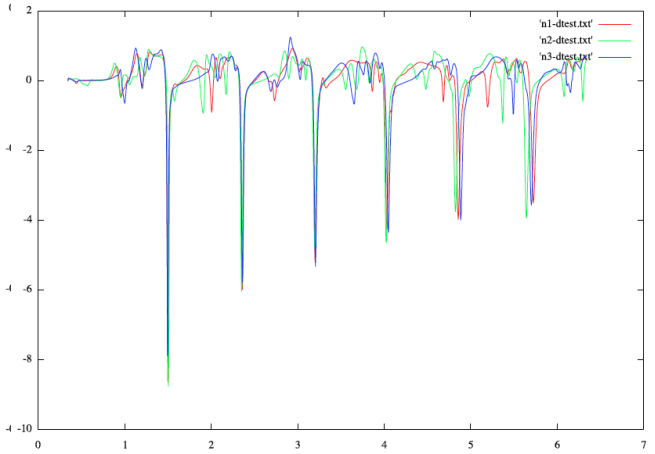
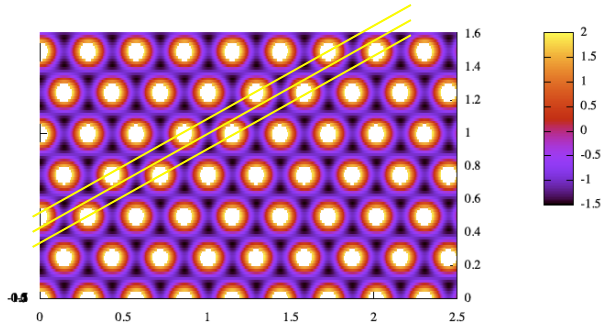
Forces for different paths (offset=0,a/8,a/3)







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