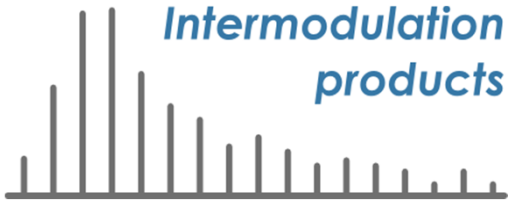
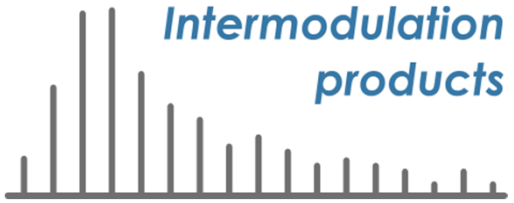


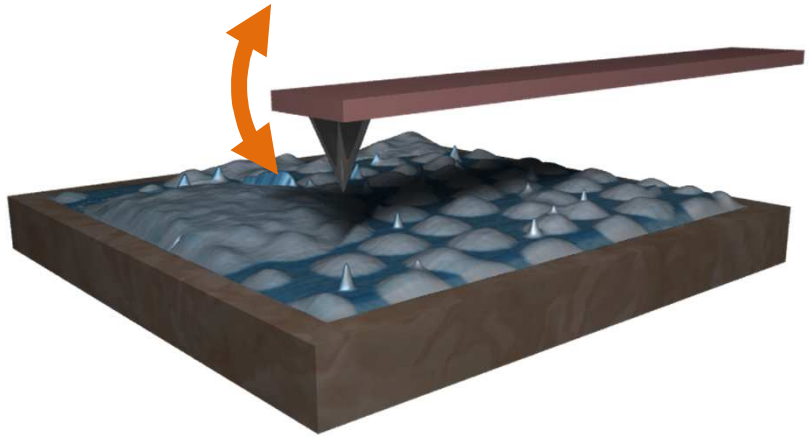
Intermodulation atomic force microscopy

A novel nonlinear dynamics approach to atomic force microscopy

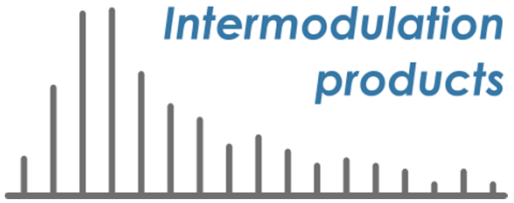
Intermodulation AFM



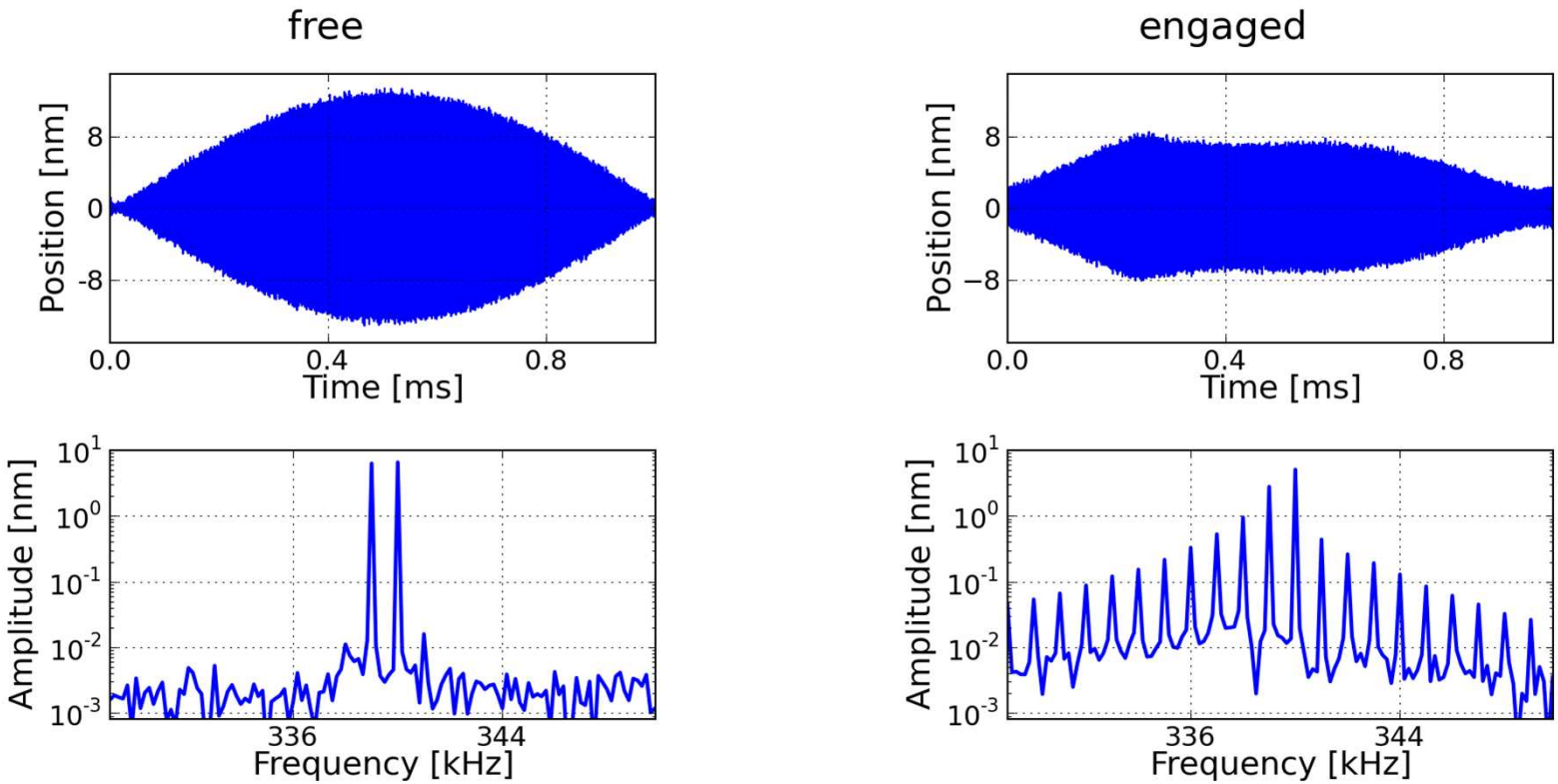
- Dynamic multifrequency AFM method
- Utilization of nonlinear frequency mixing
- Increased number of information channels
- High signal-to-noise ratio
- Various analysis methods



Intermodulation



- Cantilever driven with two pure drive tones close to resonance
- Nonlinear tip-surface force creates new components in the spectrum (**Intermodulation products**)

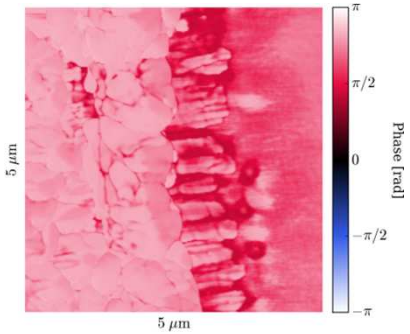


IMAFM imaging

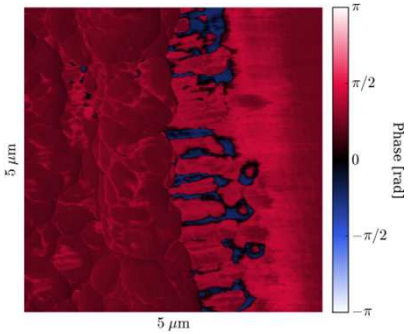
Intermodulation products

Each intermodulation product has amplitude and phase which can be used for imaging

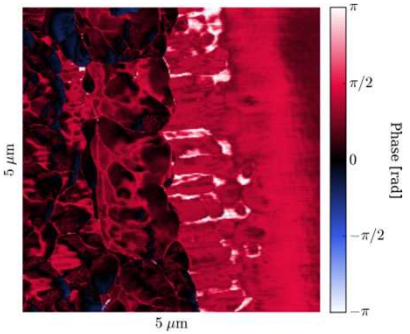
Drive 1



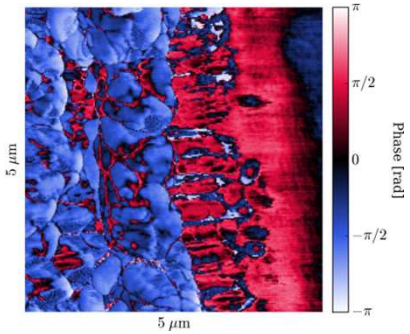
Drive 2



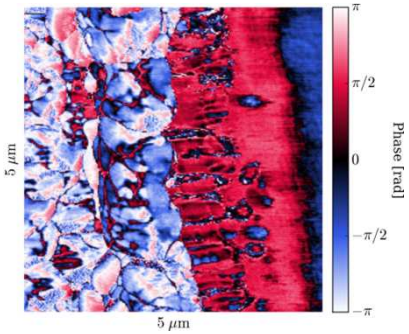
IMP 3L



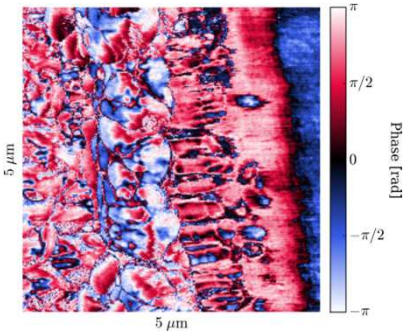
IMP 5L



IMP 7L

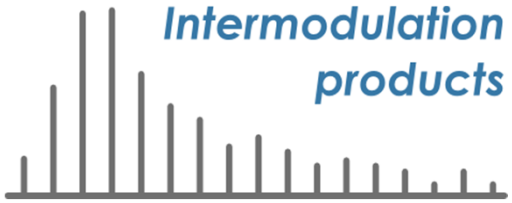


IMP 9L



Phase images on a stack of different metals

Force measurements

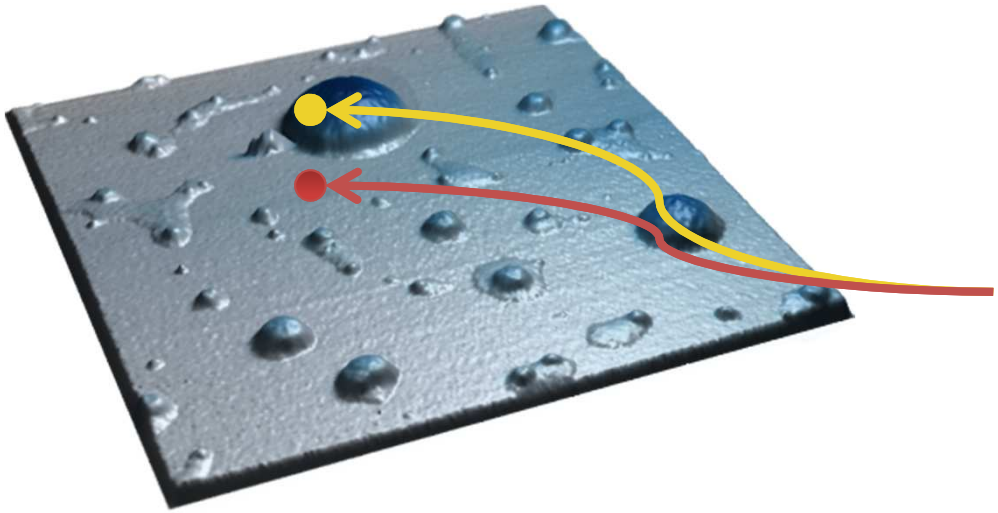


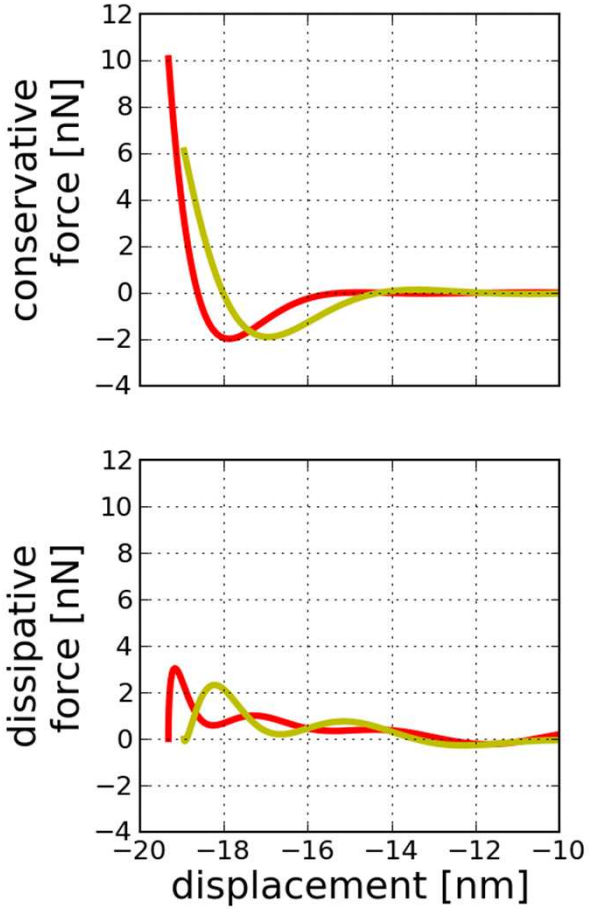
- Reconstruction of the tip-surface force by combining all measured IMP amplitudes and phses
- The force is approximated as a polynomial
- Conservative forces and position dependent viscosities are reconstructed separately
- Reconstruction at fixed probe height allows force reconstruction in every pixel of an image

Force measurements

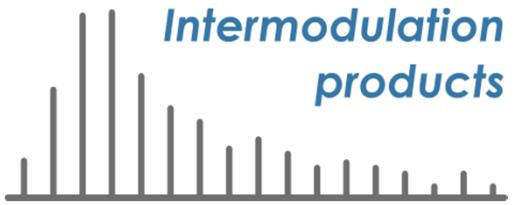
Intermodulation products

Force reconstruction on two points of blend of polystyrene and poly(acrylic acid)





Parameter maps

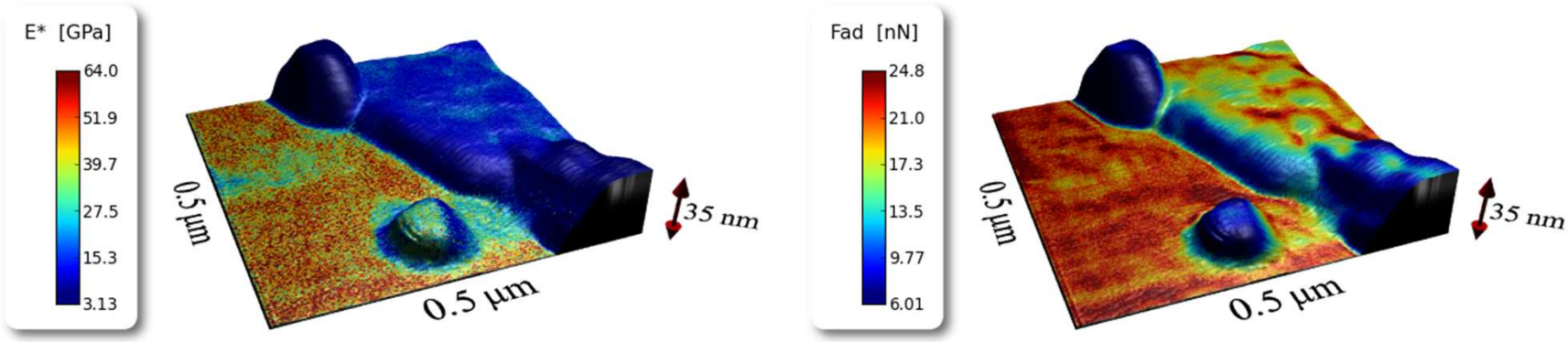


- Measured IMPs used to directly extract surface force parameters
- Any force model can be assumed
- Numerical solver extracts the model parameters that fit best the measured IMPs
- Generation of high resolution surface property maps

Parameter maps

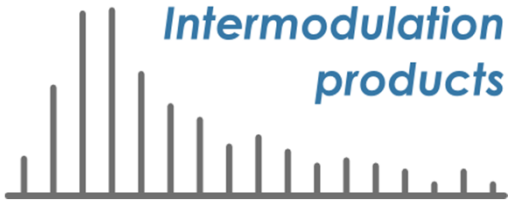
Intermodulation products

Extracted Young's modulus and adhesive force from a van-der-Waals DMT model



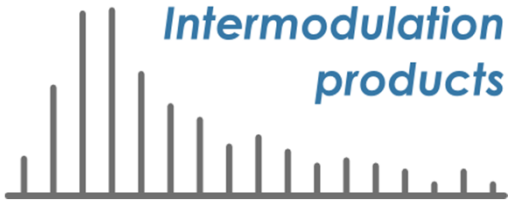
Sample courtesy of Eva Malmström (KTH) and Henrik Hillborg (ABB)

Summary



- IMAFM is a new dynamic multifrequency mode
- Increased tremendously the number of available information channels
- Surface force reconstruction in every pixel of an image
- High resolution parameter mapping with arbitrary force models
- Real-time intermodulation lockin analyzer available

References



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