Zurich Instruments

Suivie de résonance: méthodes à fréquences multiples

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Application Scientist, Zurich Instruments AG

Atelier ANF KFM, December 2nd 2016

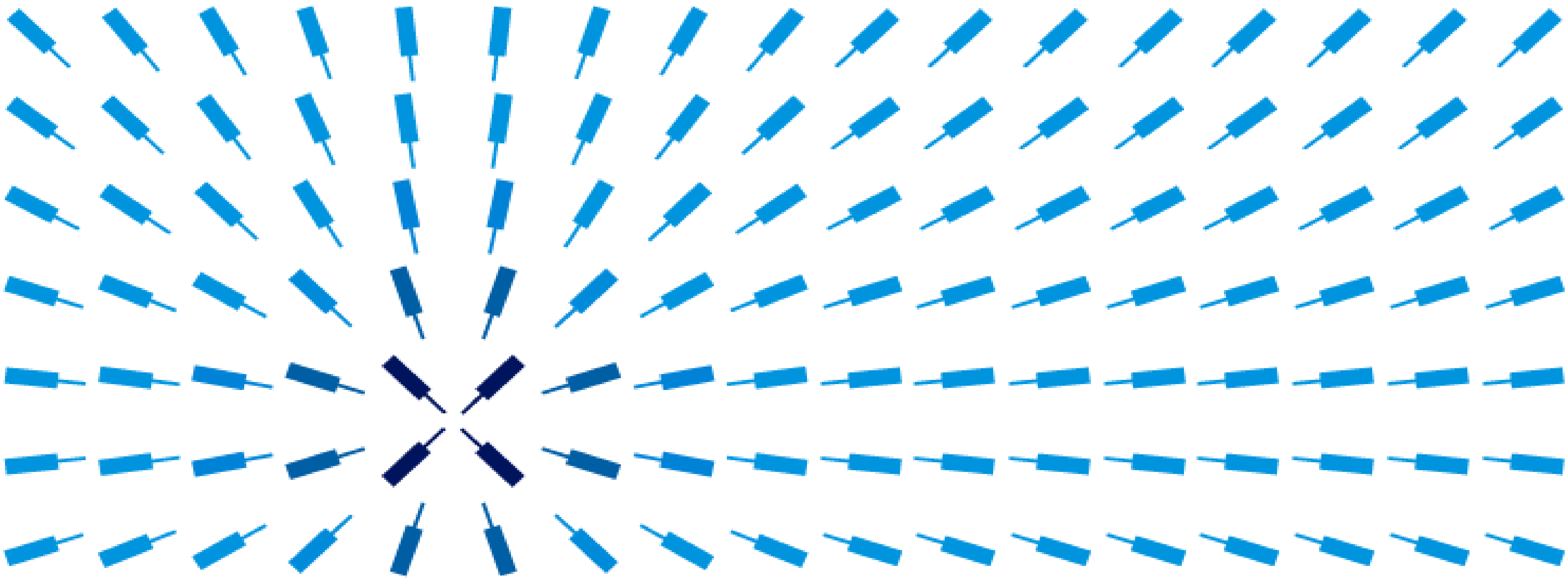
Sommaire

1. Un peu de traitement du signal pour le SPM
   - Détection synchrone pour le champs proche
   - Génération et acquisition d'image à n fréquences

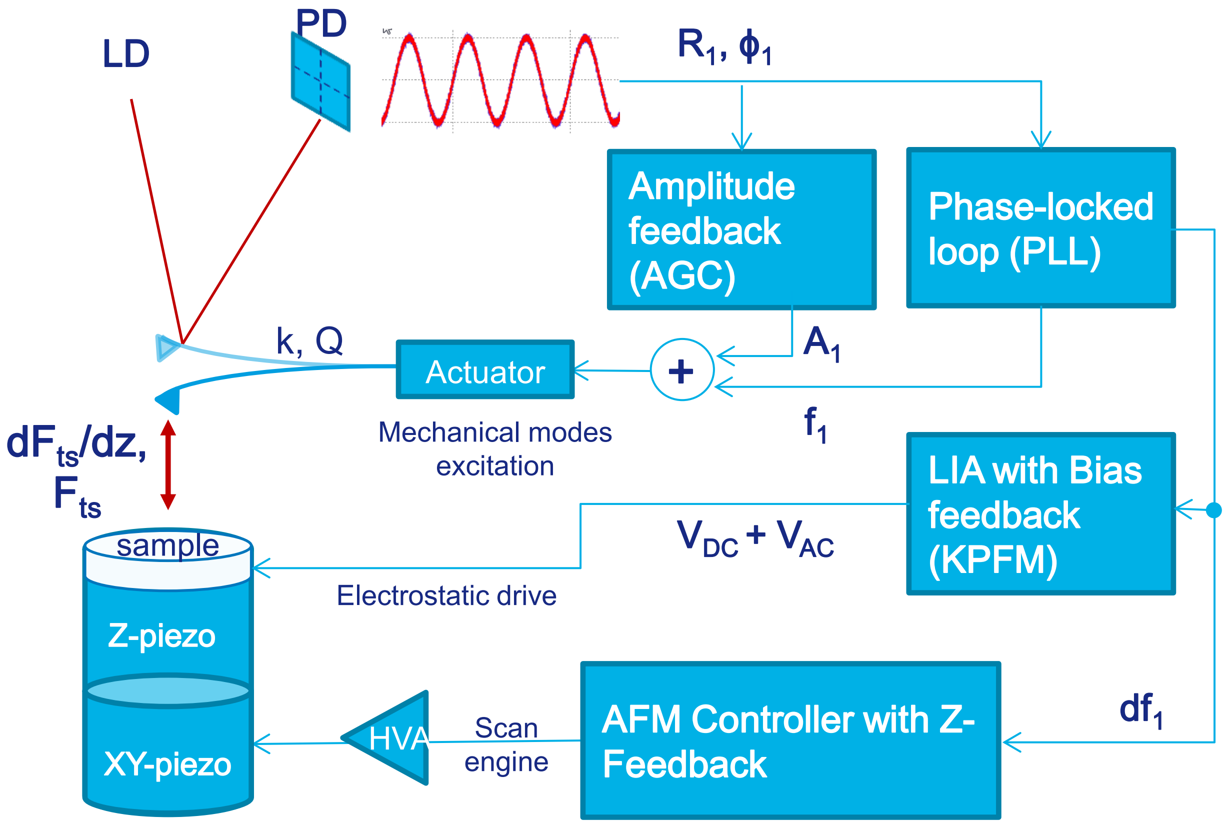
2. Méthode 'Dual Frequency Resonance Tracking' (DFRT)
   - Principe
   - Exemple

3. Suivie de résonance de contact à 1 ou 2 PLL
   - Variation sur le même thème
   - La DFRT apppliquée au KPFM

1. Un peu de traitement du signal pour le SPM



Multifrequency & mutliple feedback loops in SPM



Most common AFM modes:

- Contact Modes (DC deflection)
- Tapping Modes (AC Modulation & Amplitude demodulation)
- Non-Contact Modes (FM-AFM, measure dissipation or drive and conservative forces or freq shift)

Many variations:

- Electrostatic modes (EFM, KPFM, SSRM, …)
- Magnetic modes (MFM, MRFM)
- Resonance Contact modes (PFM, DFRT, …) for nanomechanics
- Spectroscopic modes (Force volume)

HF2LI – Multiple detection and excitation

Detection | Drive | Measurements

From PD - Dual Input for tandem or lateral deflection

Mechanical excitation (f0, f1,…)

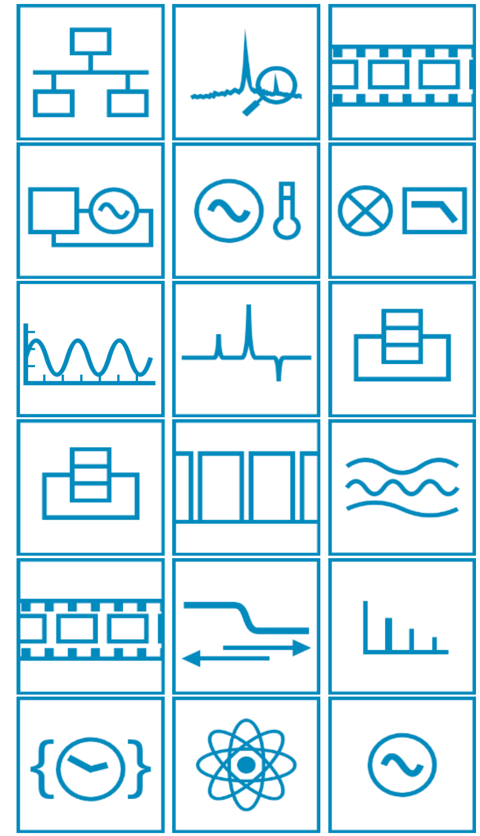
Electrostatic excitation (AC+DC)

To SPM Controller

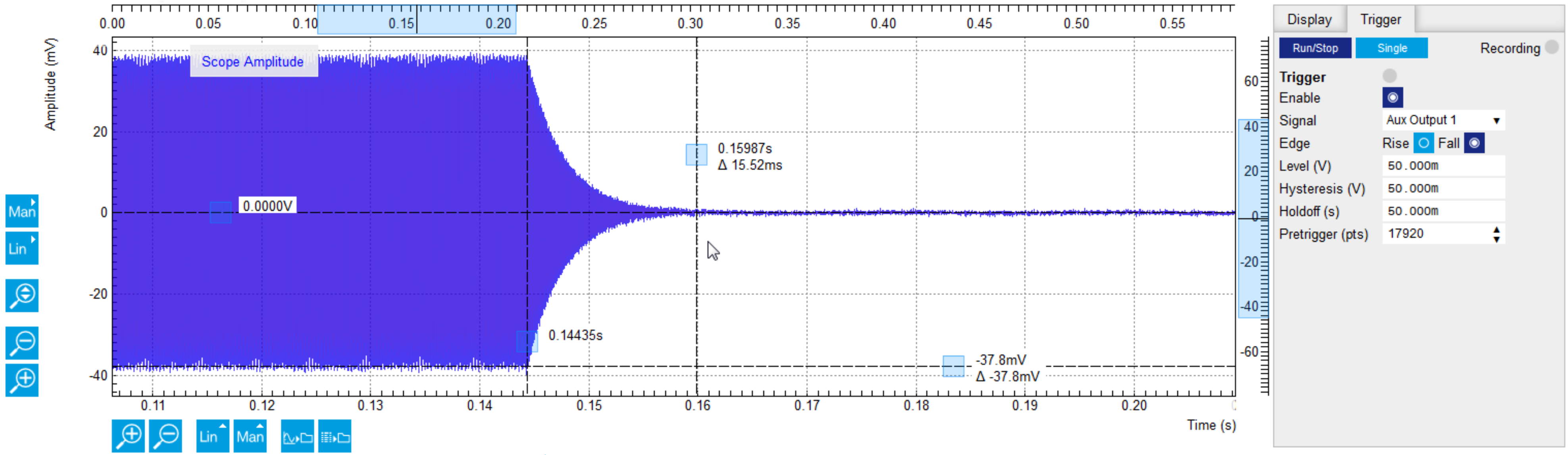
Complete dynamic signal generations & detections

Time and Frequency Domain Analysis

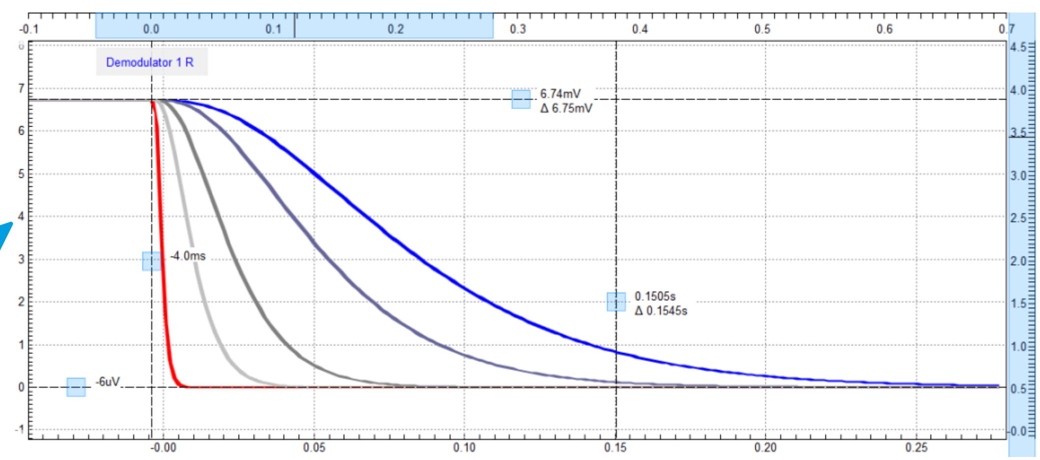
All digital Solution	Digitized samples A/D	Demodulated signal after down conversion ⊗
Time domain t	Oscilloscope Digitizer Function Generator	Multiple Demods Numerical and Plotter Tools Software Trigger
Frequency domain f	Raw FFT Analyzer Frequency Tracking	Frequency Response Analyzer (FRA) Zoom FFT

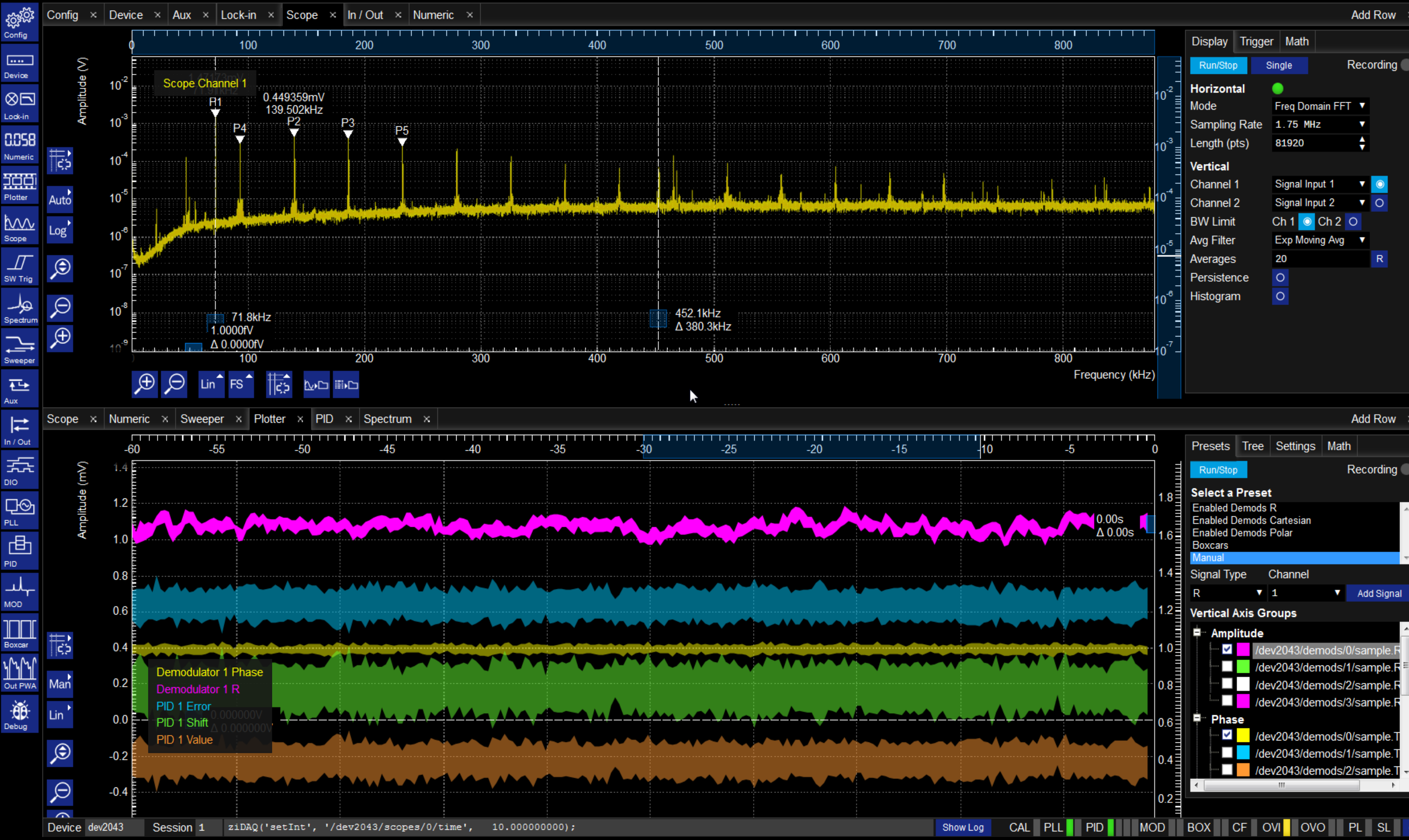


LabOne example: Oscilloscope and Trigger



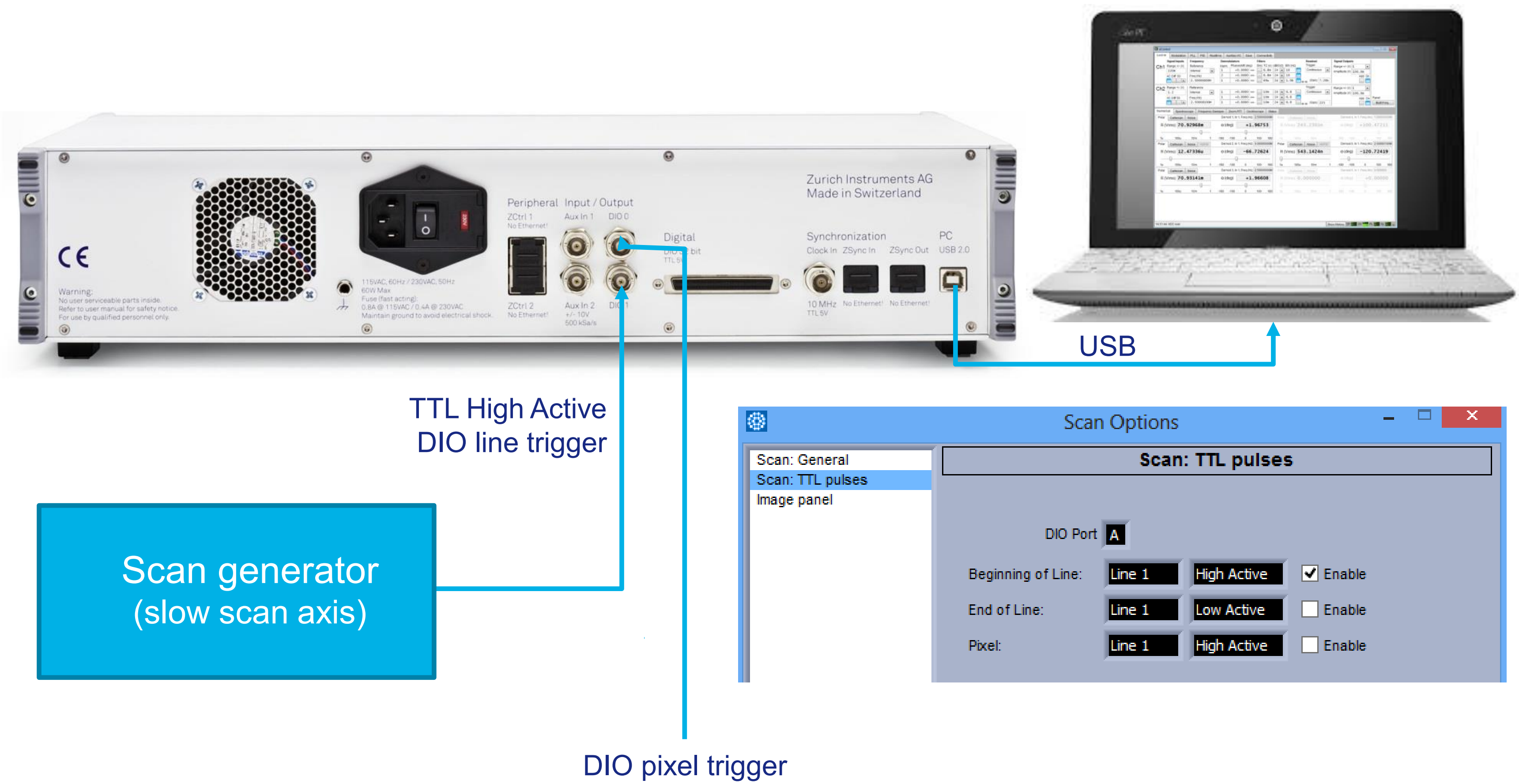
- 65kSa scope memory (extendable to 20MSa)
- trigger on any internal or external signal
- ring-down of transient phenomena





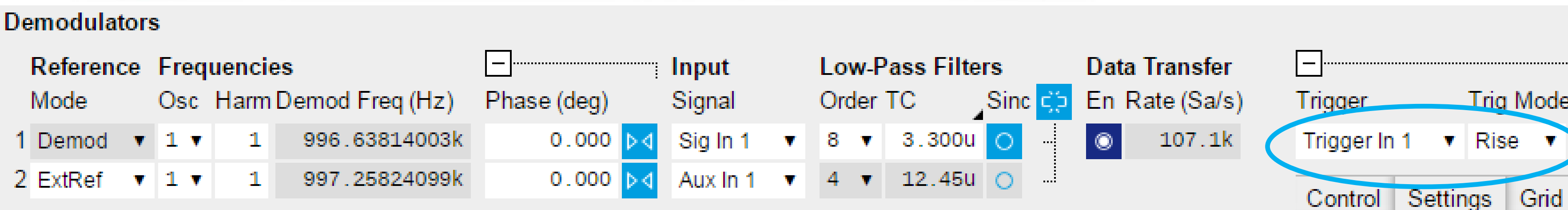
Config
Device
Aux
Lock-in
Scope
In / Out
Numeric
Add Row
Display
Trigger
Math
Run/Stop
Single
Recording
Horizontal
Mode
Freq Domain FFT
Sampling Rate
1.75 MHz
Length (pts)
81920
Vertical
Channel 1
Signal Input 1
Channel 2
Signal Input 2
BW Limit
Ch 1
Ch 2
Avg Filter
Exp Moving Avg
Averages
20
Persistence
Histogram
Scope Channel 1
Amplitude (V)
Frequency (kHz)
0.449359mV
139.502kHz
P1
P2
P3
P4
P5
71.8kHz
1.0000fV
Δ 0.0000fV
452.1kHz
Δ 380.3kHz
Auto
Log
Lin
FS
Sweeper
Plotter
PID
Spectrum
Presets
Tree
Settings
Select a Preset
Enabled Demods R
Enabled Demods Cartesian
Enabled Demods Polar
Boxcars
Manual
Signal Type
Channel
R
1
Add Signal
Vertical Axis Groups
Amplitude
/dev2043/demods/0/sample.R
/dev2043/demods/1/sample.R
/dev2043/demods/2/sample.R
/dev2043/demods/3/sample.R
Phase
/dev2043/demods/0/sample.T
/dev2043/demods/1/sample.T
/dev2043/demods/2/sample.T
Amplitude (mV)
Demodulator 1 Phase
Demodulator 1 R
PID 1 Error
PID 1 Shift
PID 1 Value
0.00s
Δ 0.00s
Man
Numeric
SW Trig
DIO
PLL
MOD
Boxcar
Out PWA
Debug
Device
dev2043
Session
1
ziDAQ('setInt', '/dev2043/scopes/0/time', 10.000000000);
Show Log
CAL
PLL
PID
MOD
BOX
CF
OVI
OVO
PL
SL

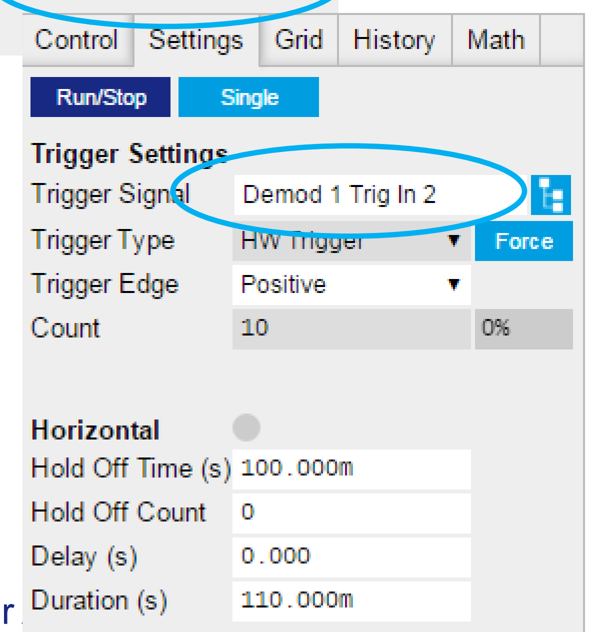
HF2LI – Back panel and data synchronization



All reference inputs and scan engine synchronization
Save more SPM image than # of Aux Out available!

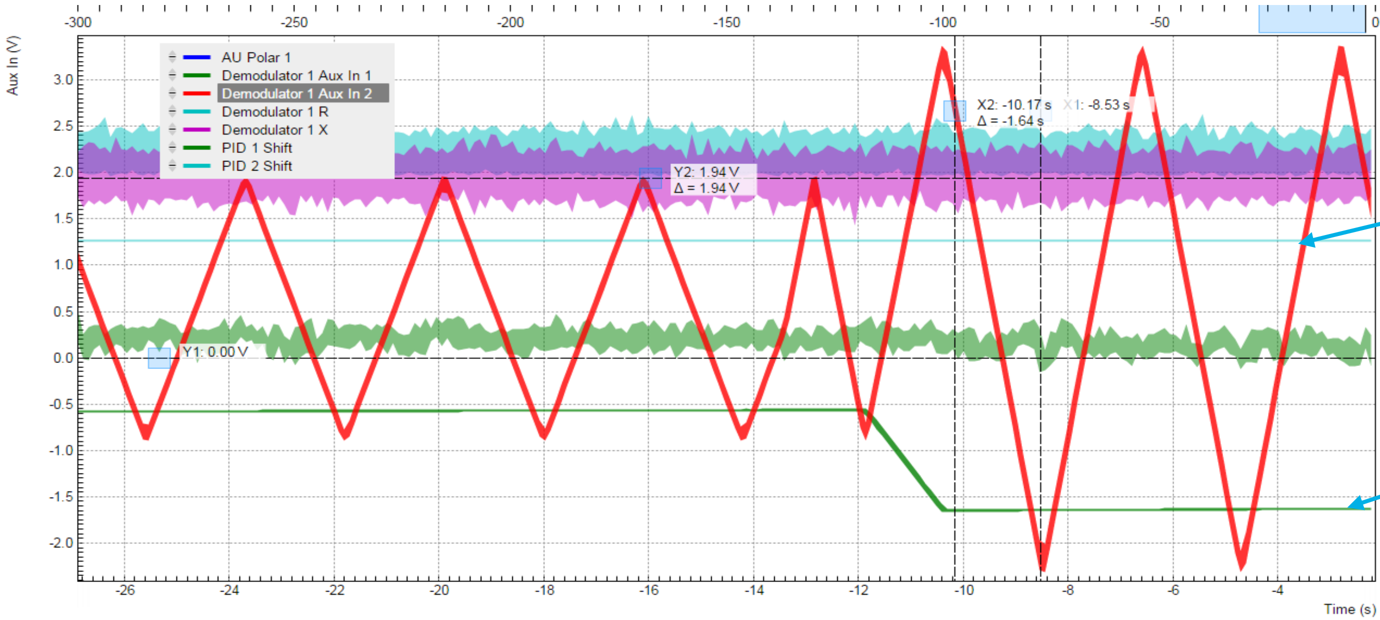
HF2LI – Back panel and data synchronization





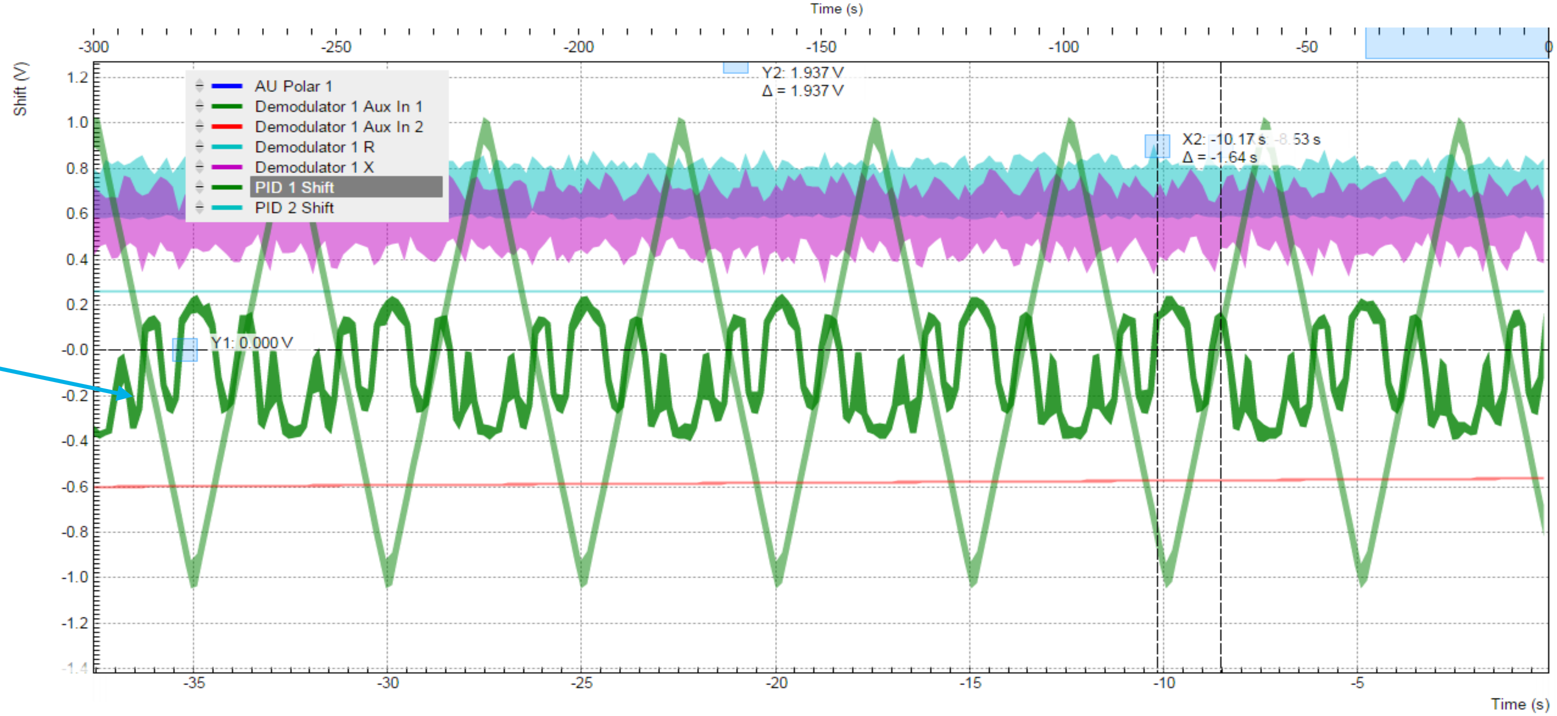
Software (SW) Trigger: data capture of all internal signals upon any trigger conditions

Scan synchronisation for mapping applications



X fast scan axis
Aux In1

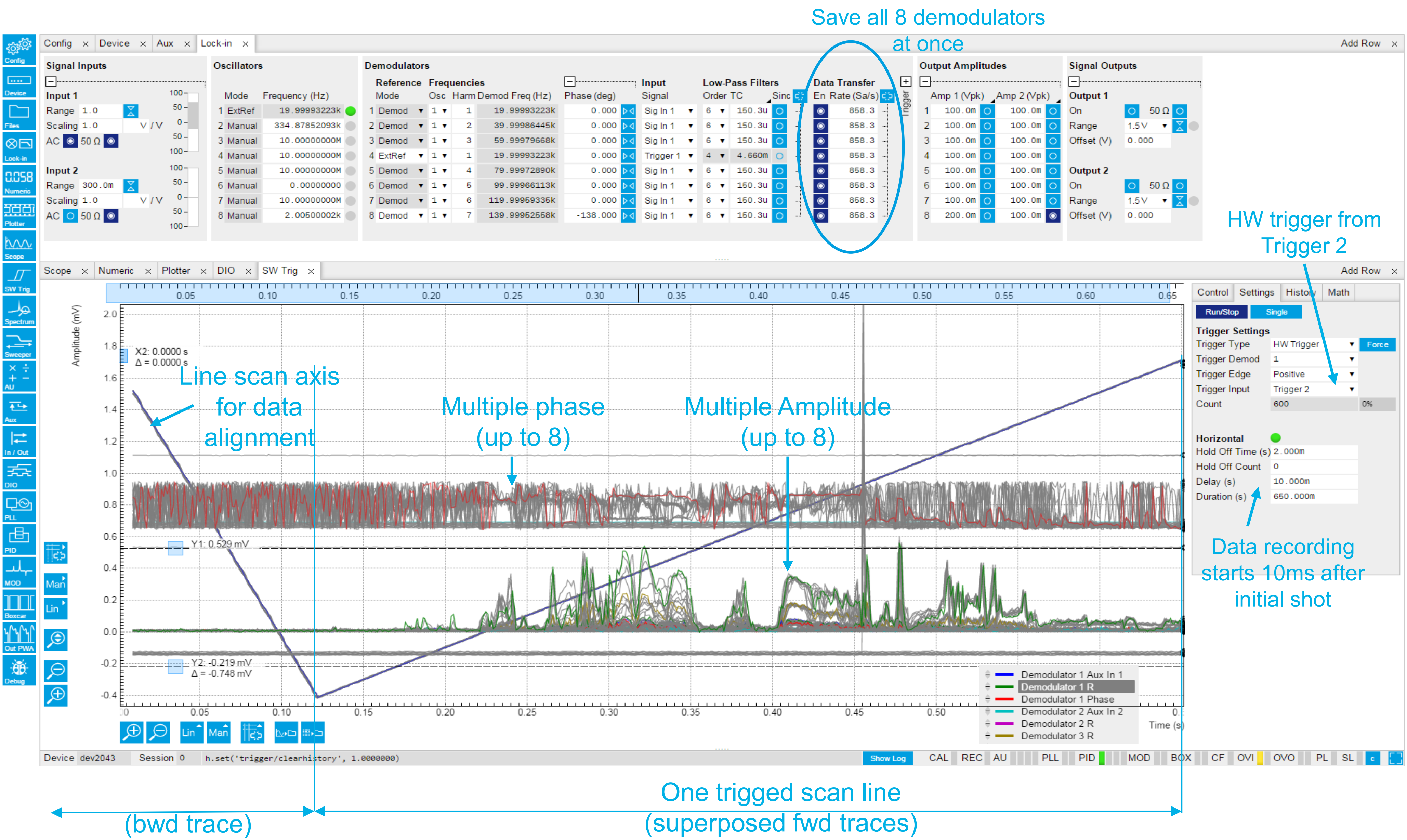
Y slow scan axis
Aux In2



Line scan

ZI Applications
www.zhinst.com

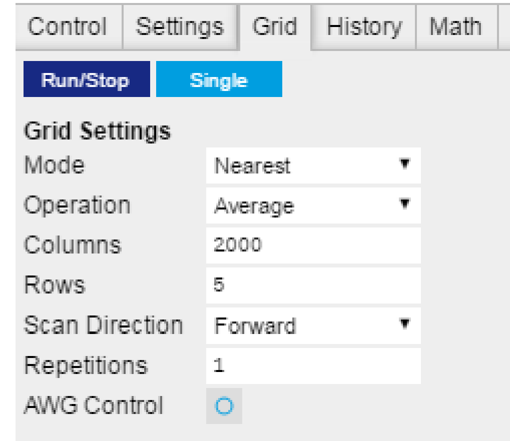
Mapping applications: Multichannel SW trigger

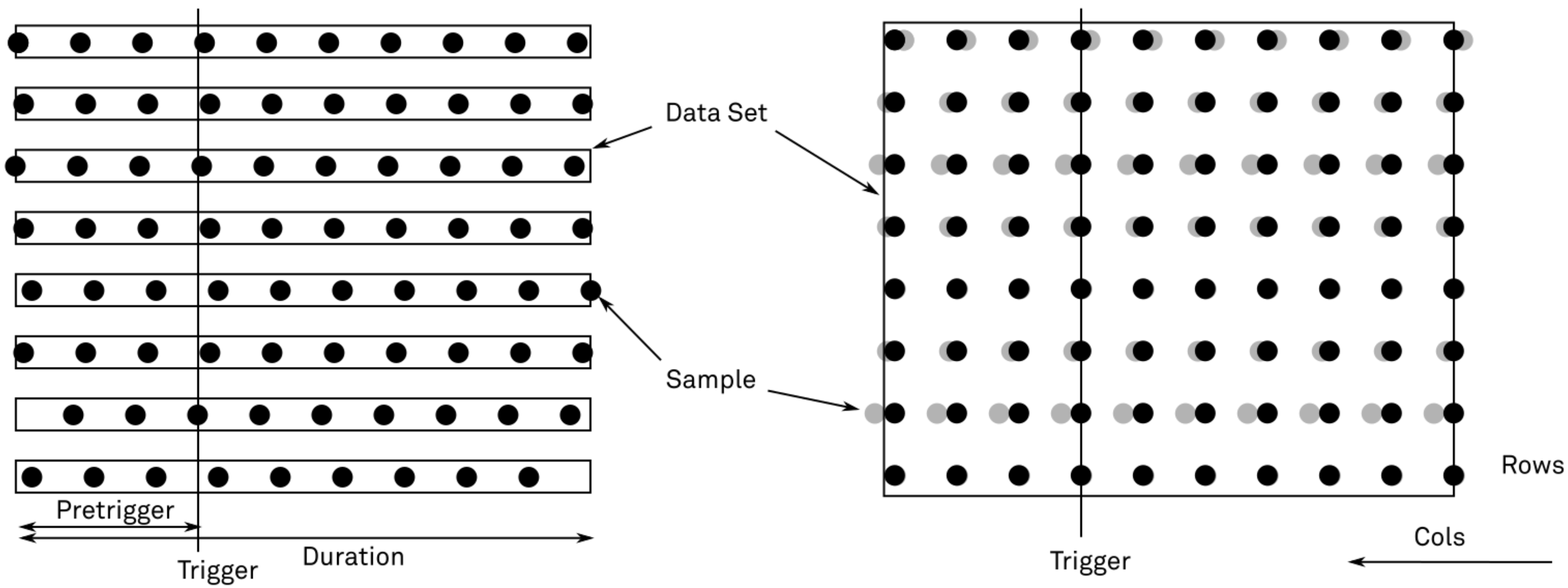


Mapping applications: image reconstruction

Grid alignment:

1. DIO trigger for line (and pixel trigger)
2. Data alignment on a user-defined grid
3. Matrix data file saved with number of rows and columns





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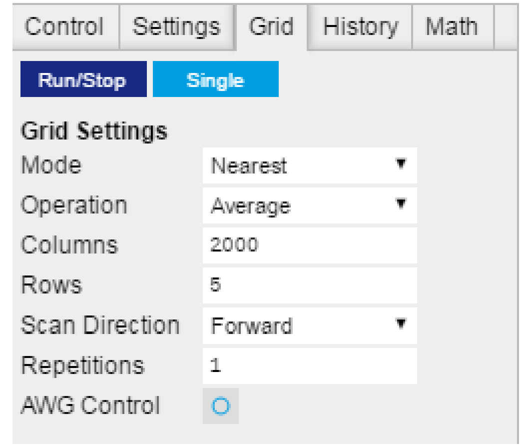
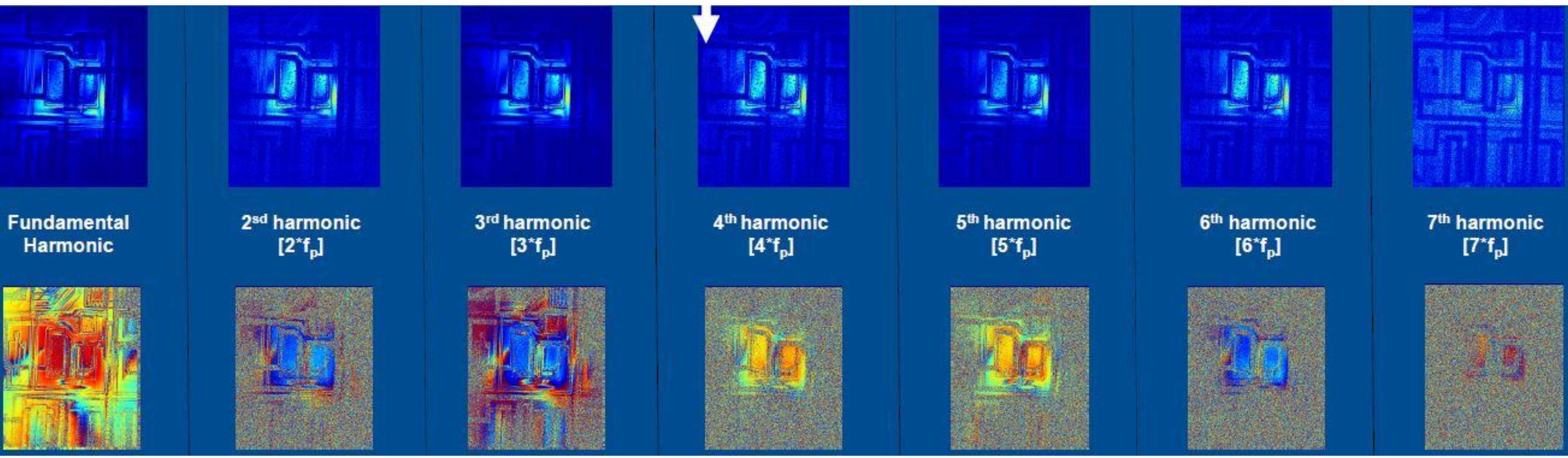
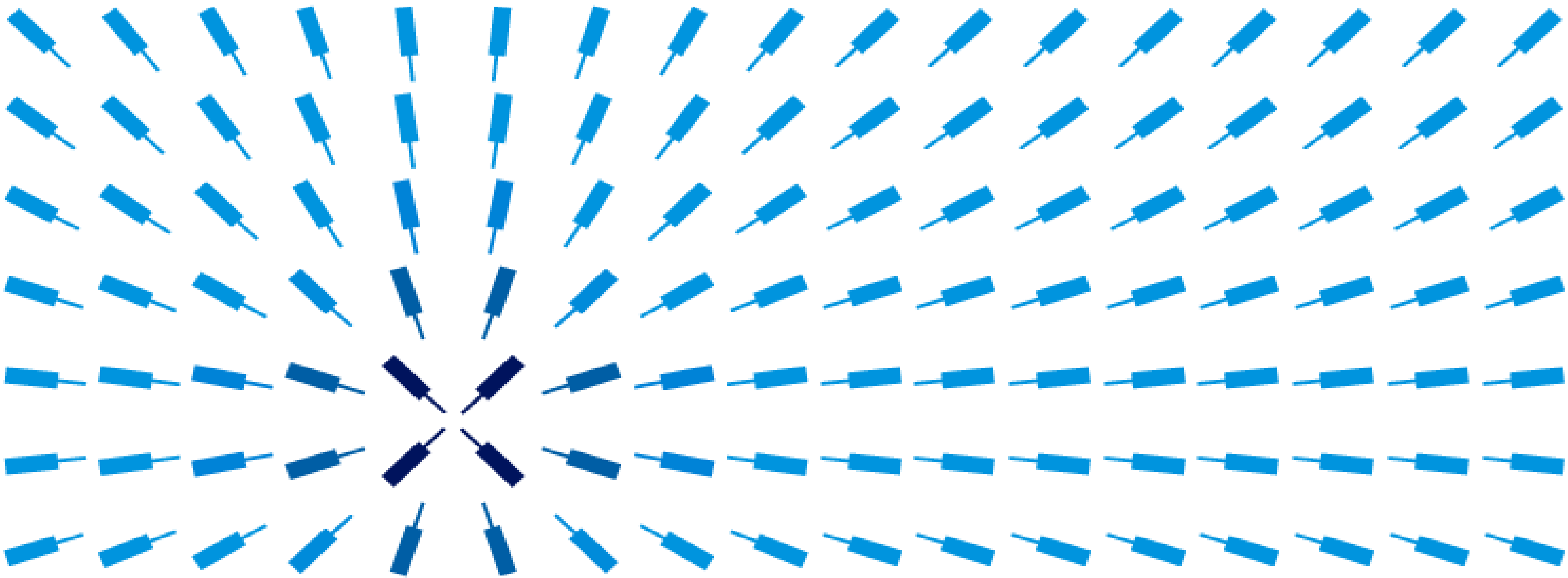


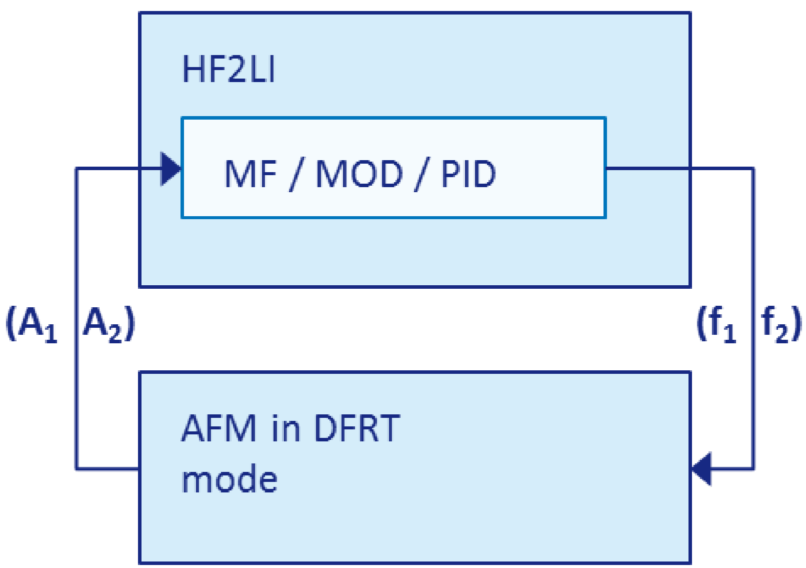


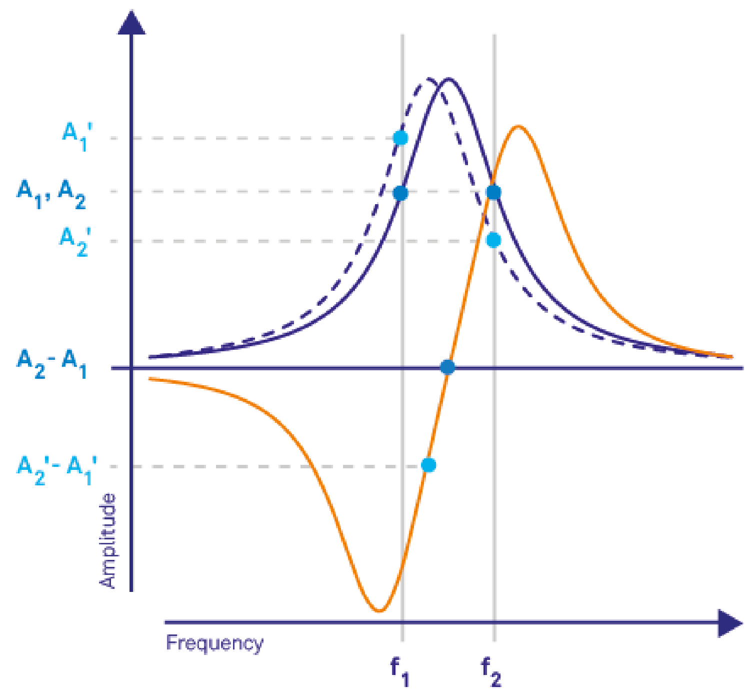
2. Méthode ‘Dual Frequency Resonance Tracking’ (DFRT)



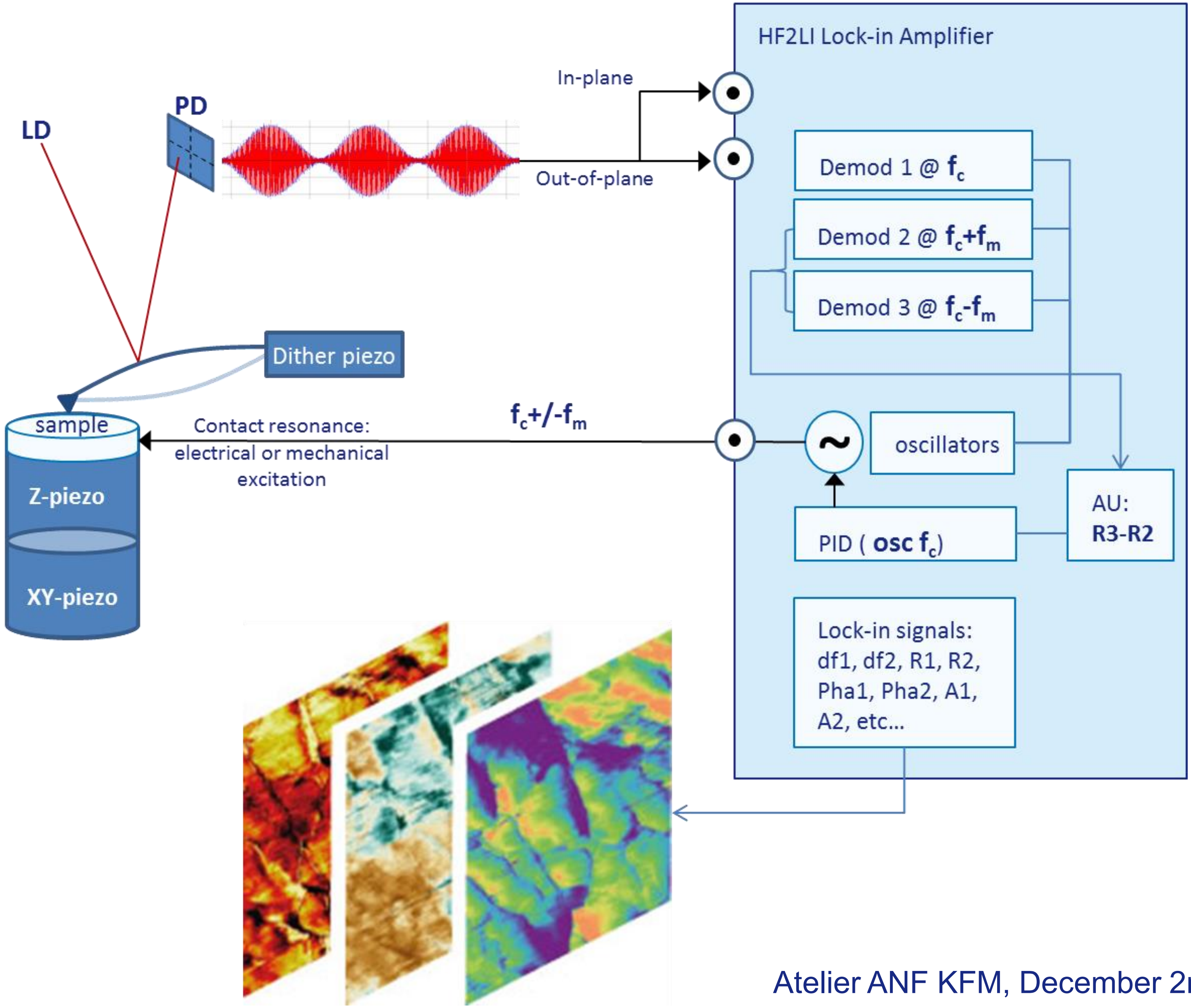
Dual Frequency Resonance Tracking (DFRT)

1. Bimodal excitation @ f_c+/-f_m (just around the resonance)
2. Both sides of the resonance amplitude are measured simultaneously.
3. The difference of amplitude exhibits a linear dependance with a set-point of 0 at resonance.

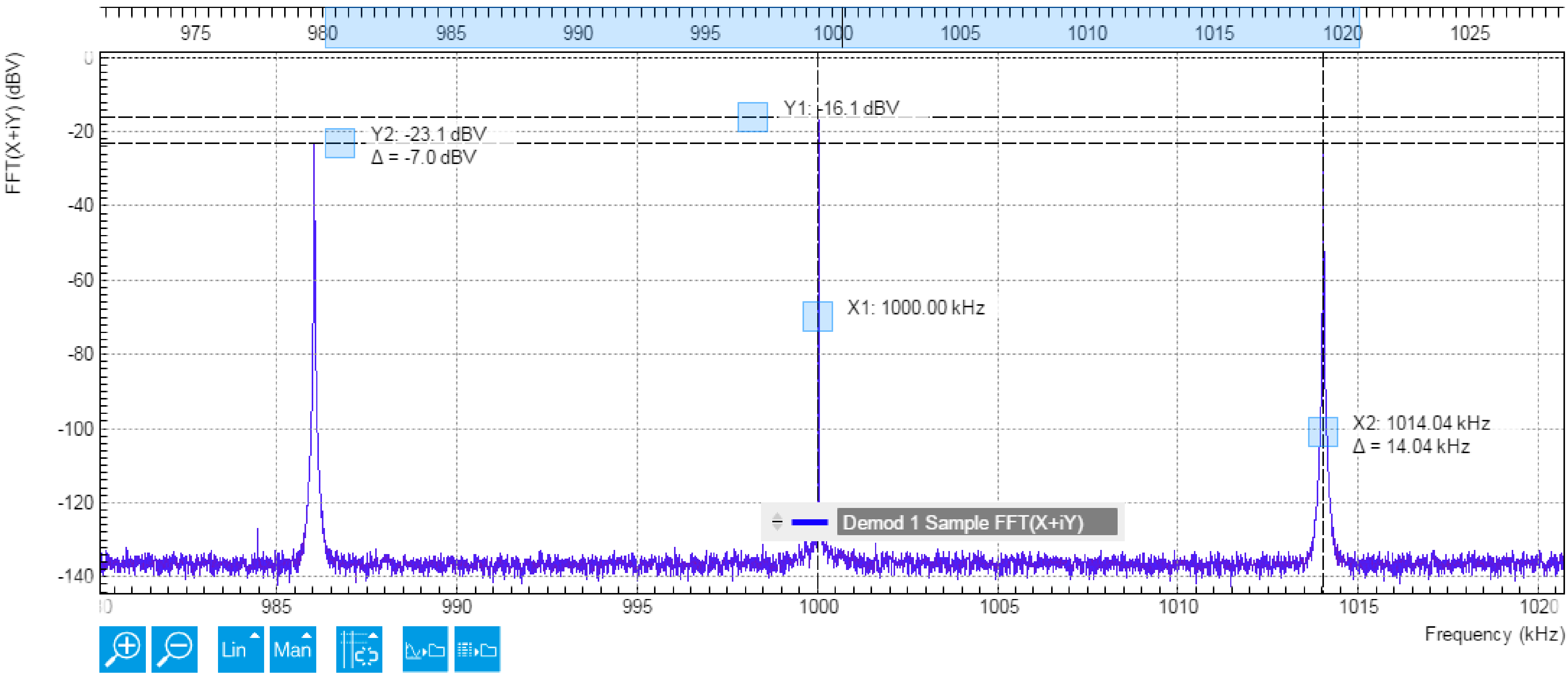




How it works in practice

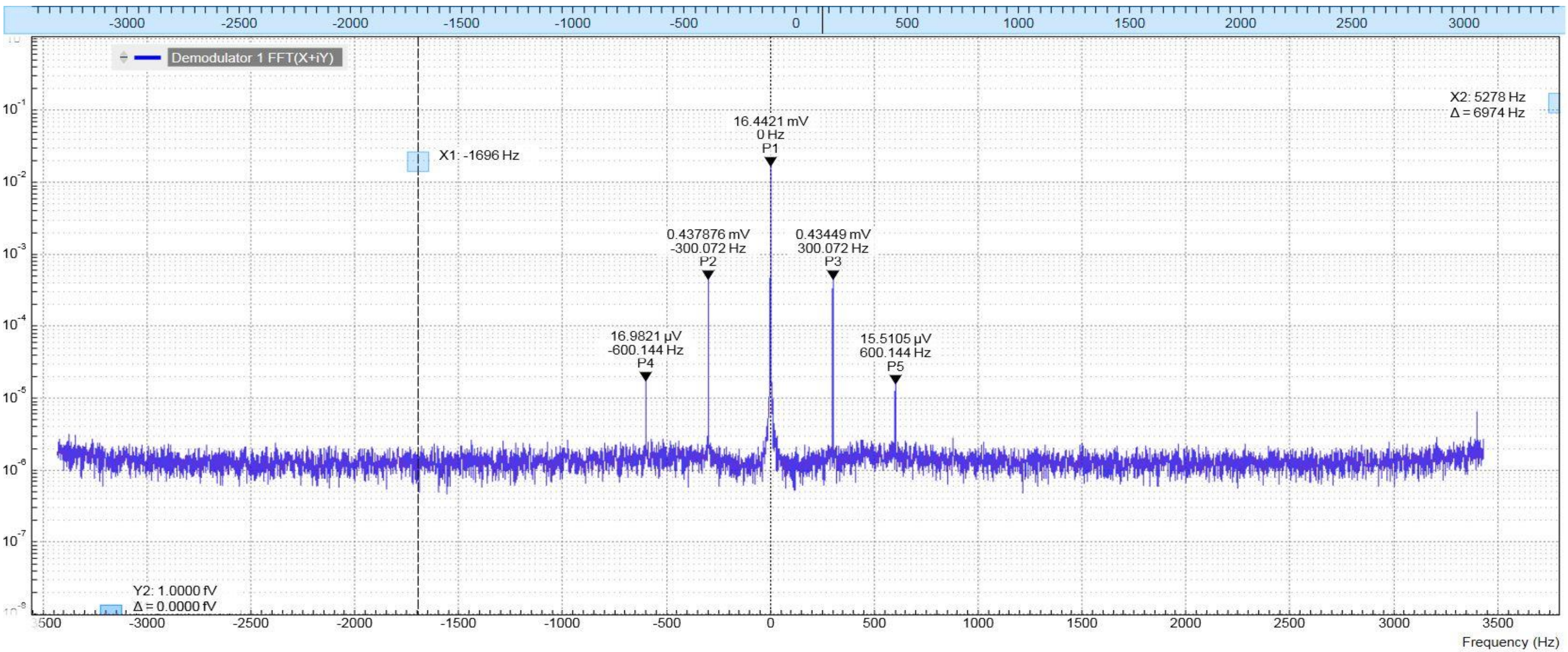


AM Modulation: frequency domain



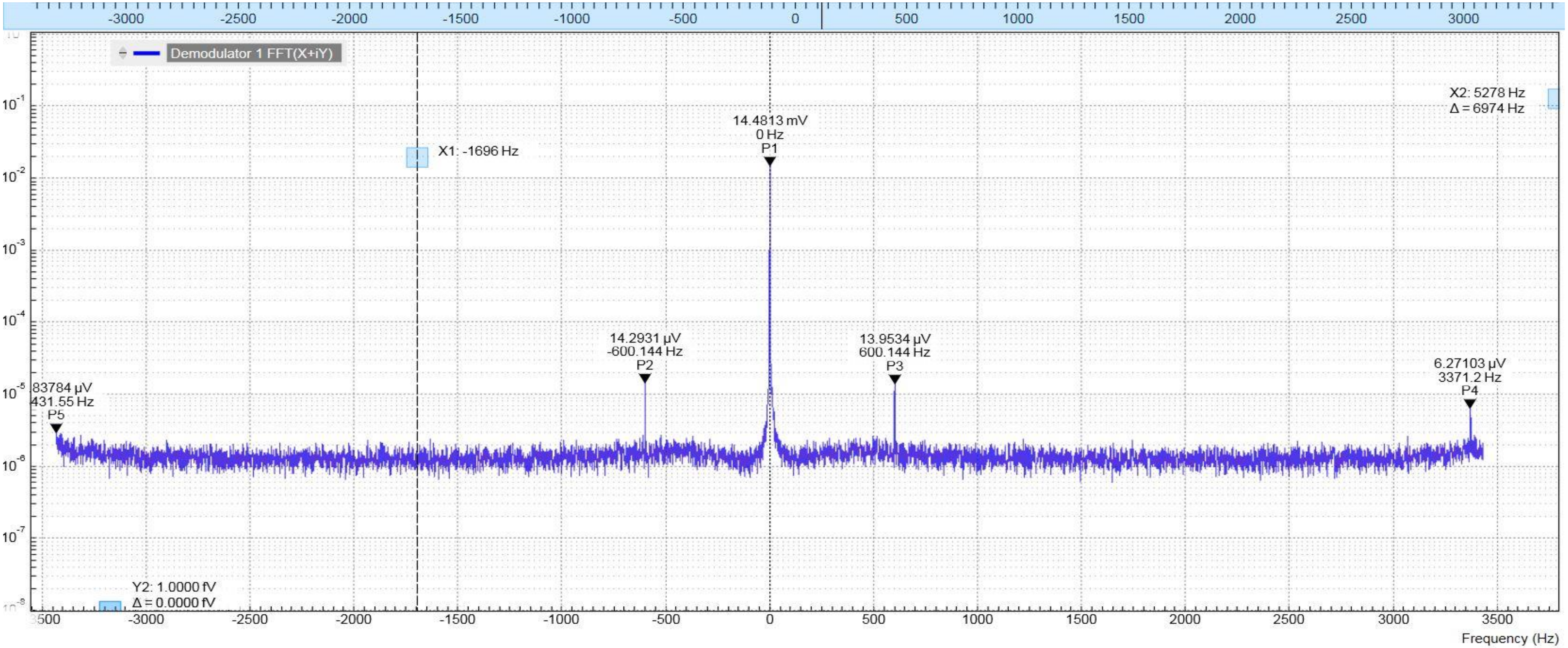
Amplitude Modulation can be with or without carrier suppression

Feedback on bias OFF



V_{DC} = 1V
V_{ac} @ 300Hz

Feedback on bias ON



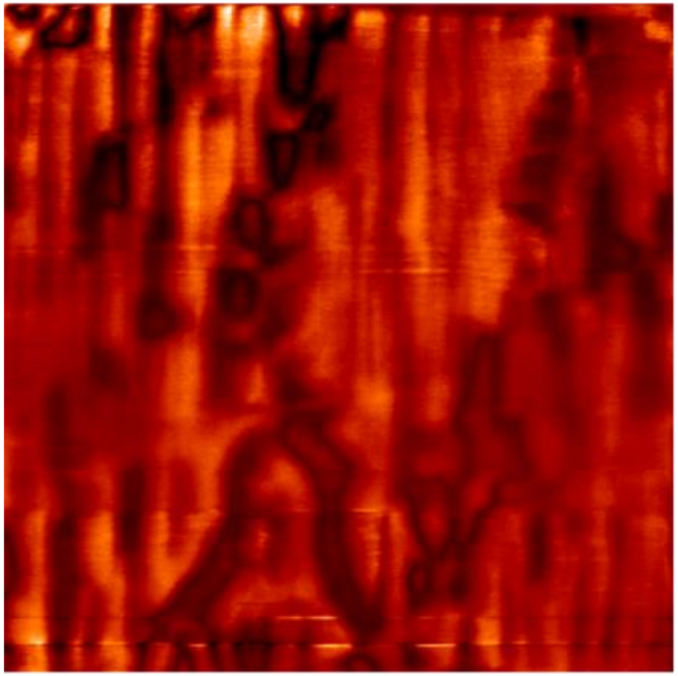
$V_{DC} = V_{cpd}$

V_{ac} @ 300Hz

2ω component not affected by cpd (as expected)

How it looks like

Contact Resonance PFM image of 100nm BFO layer, 2x2um scan size

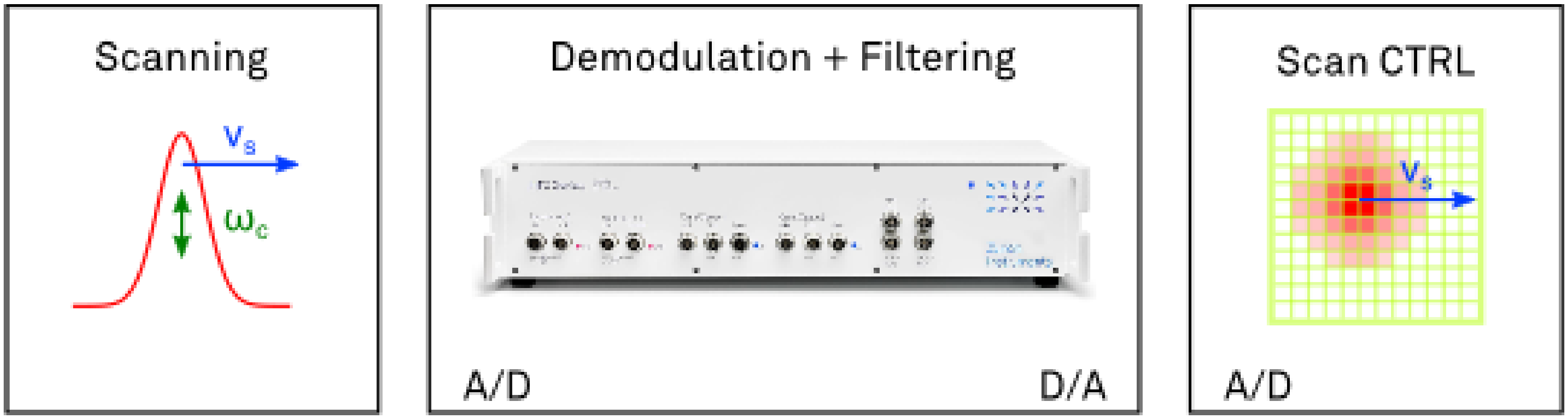


Piezoresponse Amplitude

Piezoresponse Phase

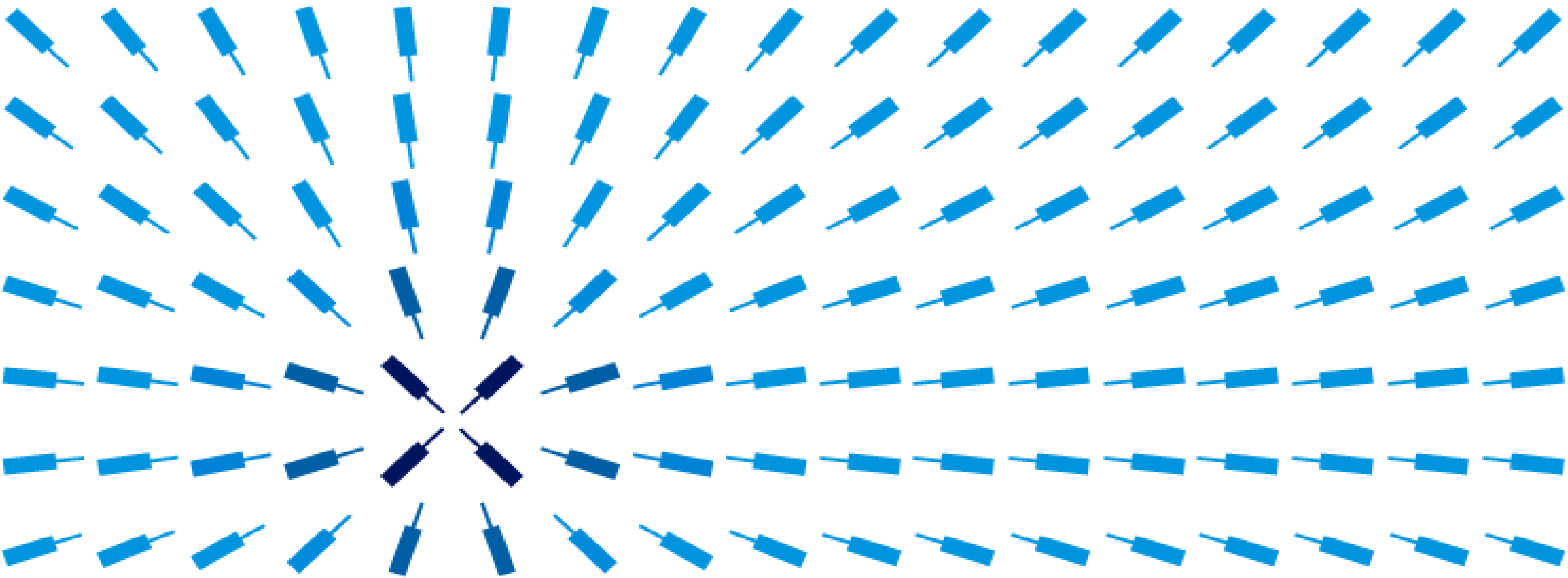
Image Courtesy of Igor Stolichtnov and Enrico Colla, Ceramic Lab, EPF Lausanne, Switzerland

Speed versus Resolution

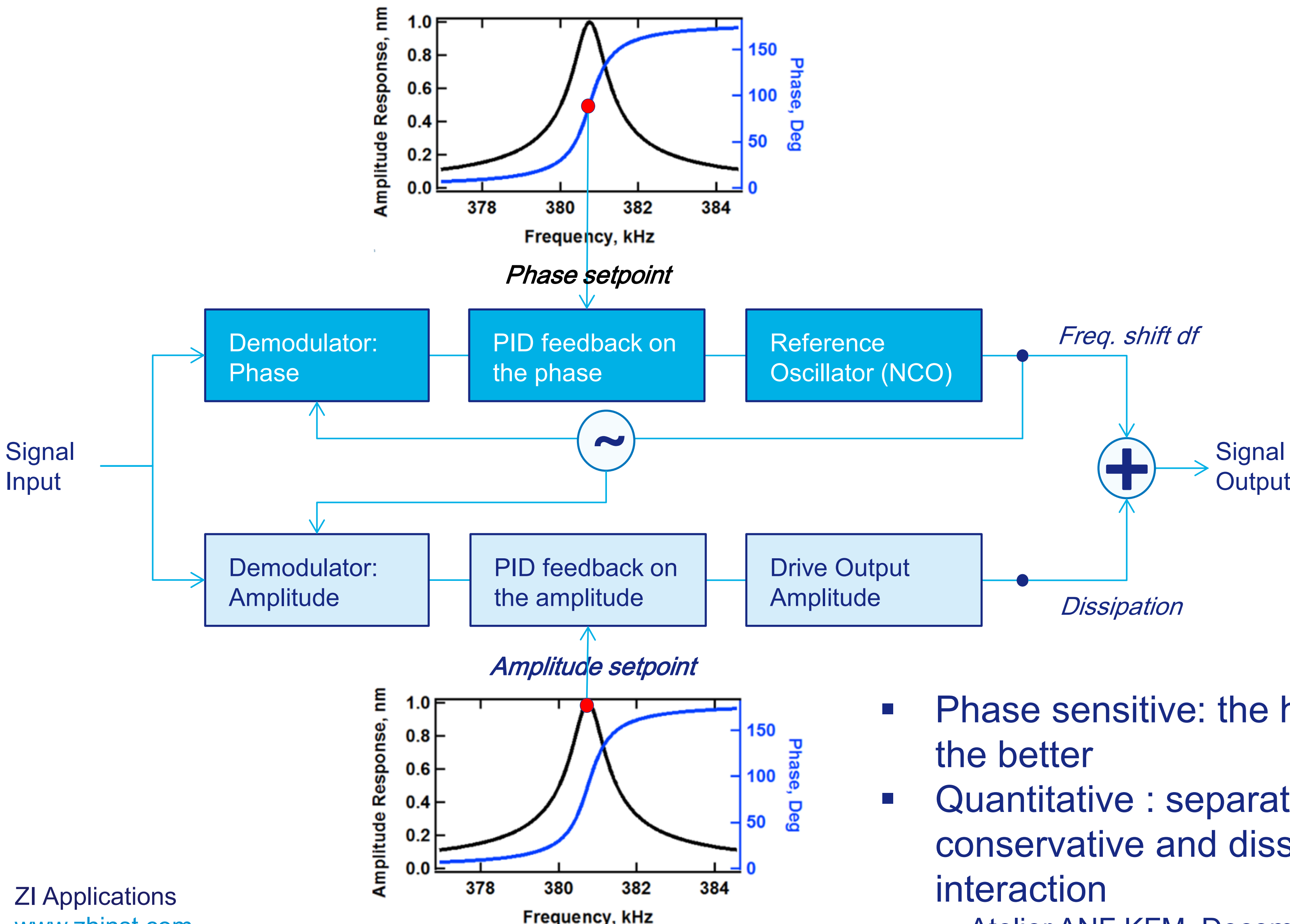


- **Pixel Dwell Time:** the less time per pixel, the faster the image
- Modulation always introduce some ‘blurring’ effect: challenge is to make it (and detect it) as small as possible with appropriate **filter settings**
- The higher the drive modulation, the more ‘disturbing’ side effect it produces

3. Suivie de résonance de contact à 1 ou 2 PLL



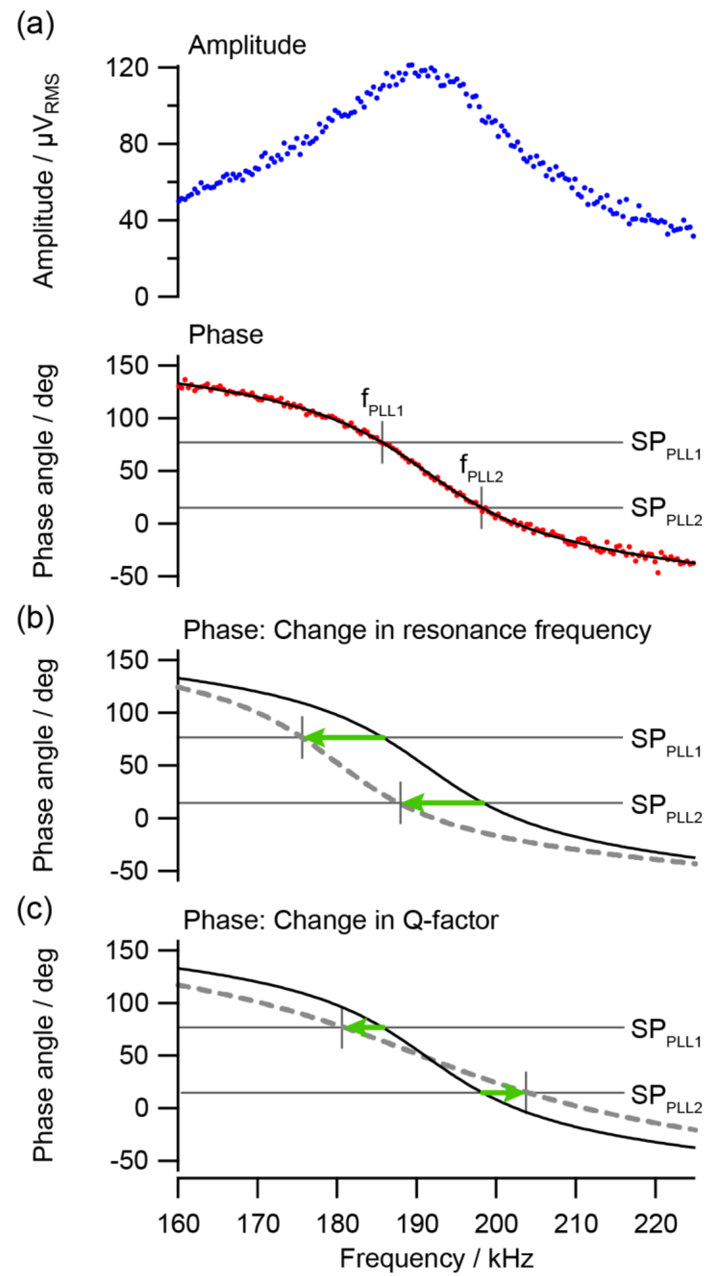
NC-AFM: Phase & Amplitude feedback loops



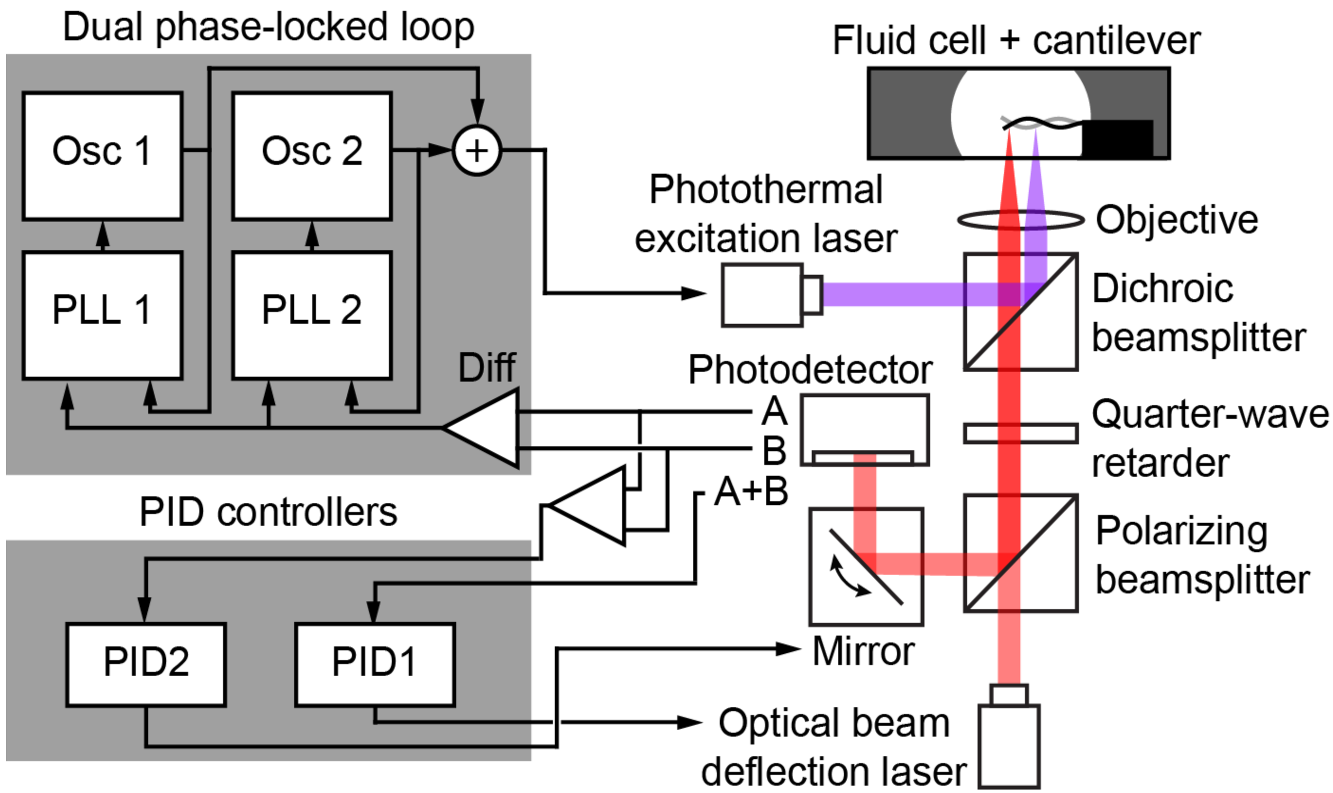
- Phase sensitive: the higher the Q, the better
- Quantitative : separation between conservative and dissipative interaction

Phase-Locked Loops

- DFRT doesn't provide info on Q factor (dissipation)
- Single PLL does not perform well with low Q
- Dual PLL operation for quantitative feedback even with low Q



Dual Phase-Locked Loop

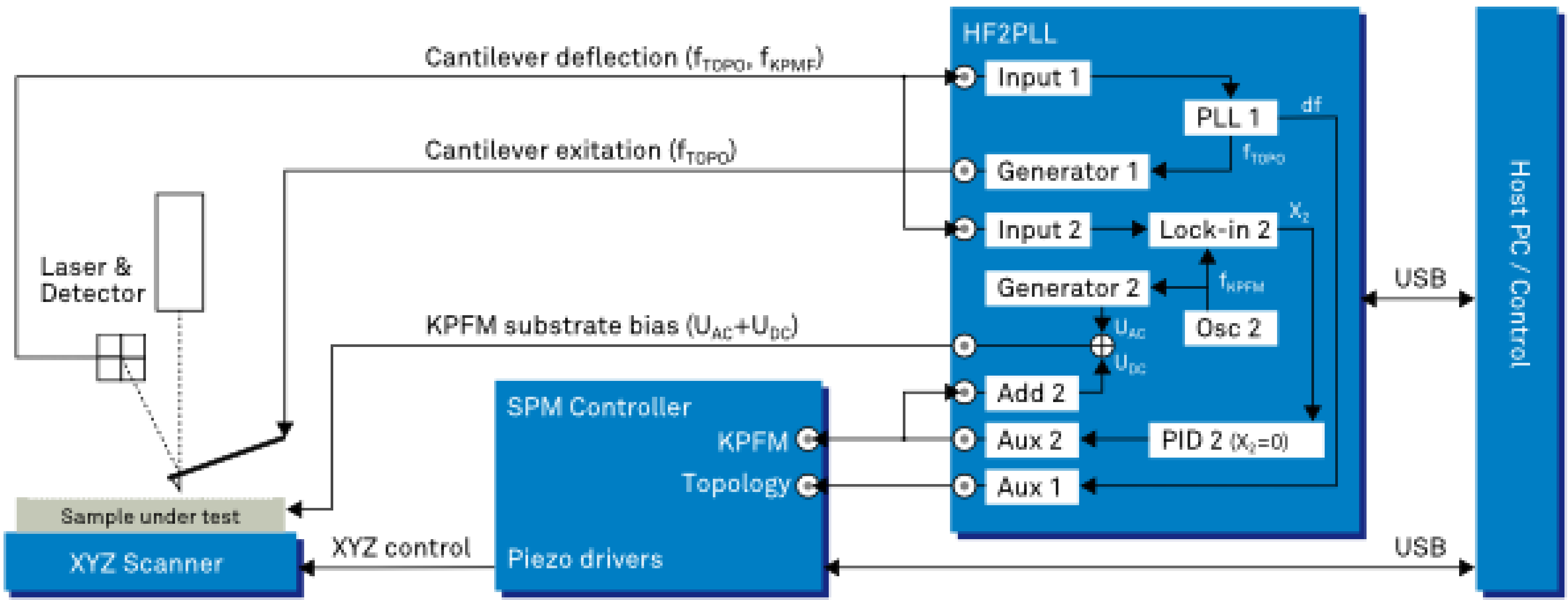


$$f_R \approx \frac{f_{PLL1} + f_{PLL2}}{2}$$

$$Q \approx \frac{f_R f_{PLL1}}{f_R^2 - f_{PLL1}^2} \tan\left(\frac{SP_{PLL1} - SP_{PLL2}}{2}\right)$$

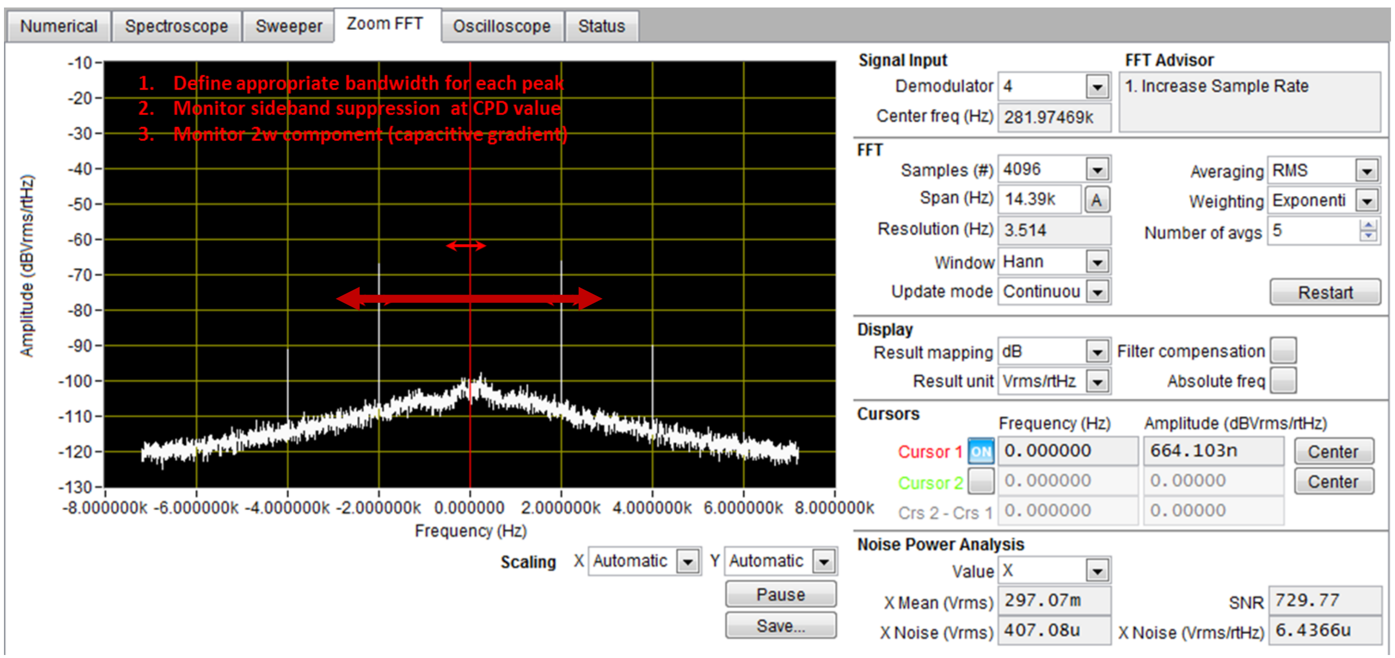
Kelvin Probe Microscopy: chose your mode

- Single-pass vs Mutli-pass
- AM-KPFM vs FM-KPFM
- Tandem vs Direct Sideband
- …



FM-KPFM: why using direct sideband detection ?

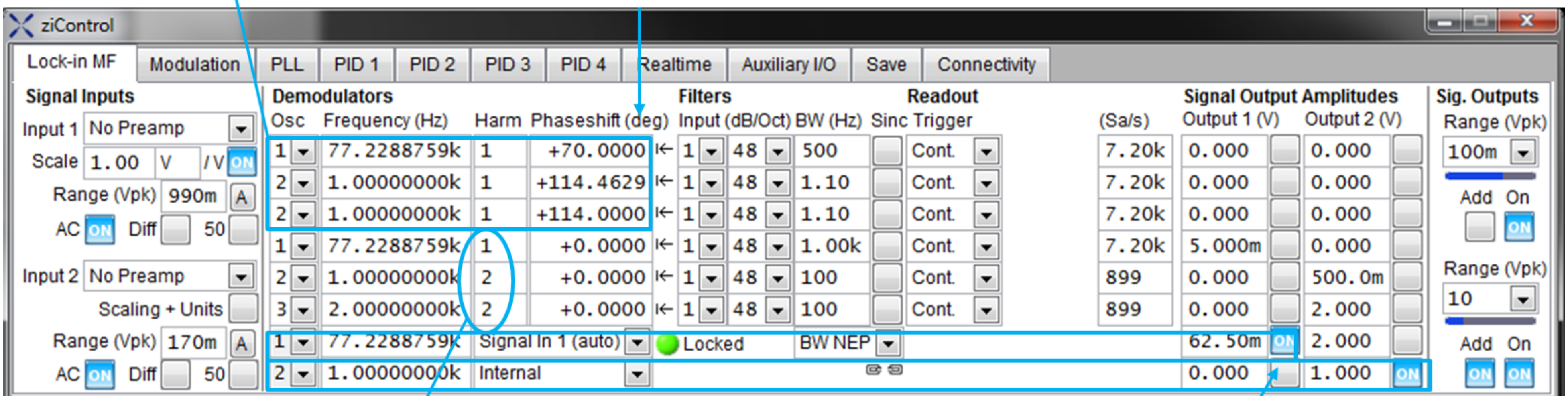
1. Faster bias modulation possible (independent of PLL BW)
2. Optimization of PLL settings for better resolution (narrow band) regardless of AC modulation
3. Potential increase of SNR for the Kelvin feedback since both sidebands are measured and added



FM-KPFM: benefit of using many demodulators

MOD1 takes first 3 demod. X(2) & X(3) will be max with the right phaseshift

All 6 demodulated signals on Input 1



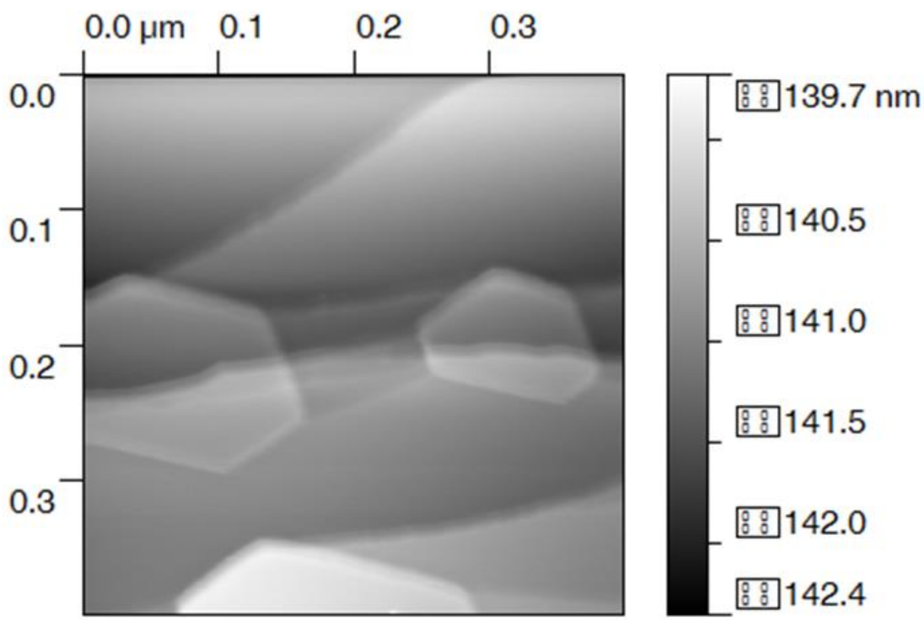
MOD2 can be used to measure second harmonic simultaneously (capacitive gradient of the force)

Mechanical excitation on Output 1 (PLL and AGC locked)

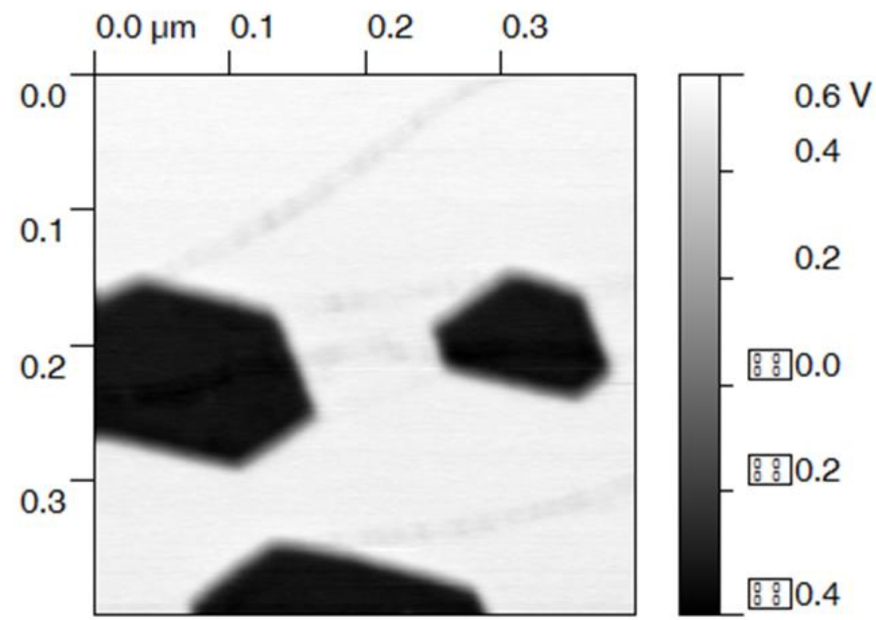
Electrostatic excitation on Output 2 AC+DC added (demodulated in MOD1)

FM-KPFM: example on Graphene flakes

Image of Graphene flakes on Cu (111) in FM-KPFM mode



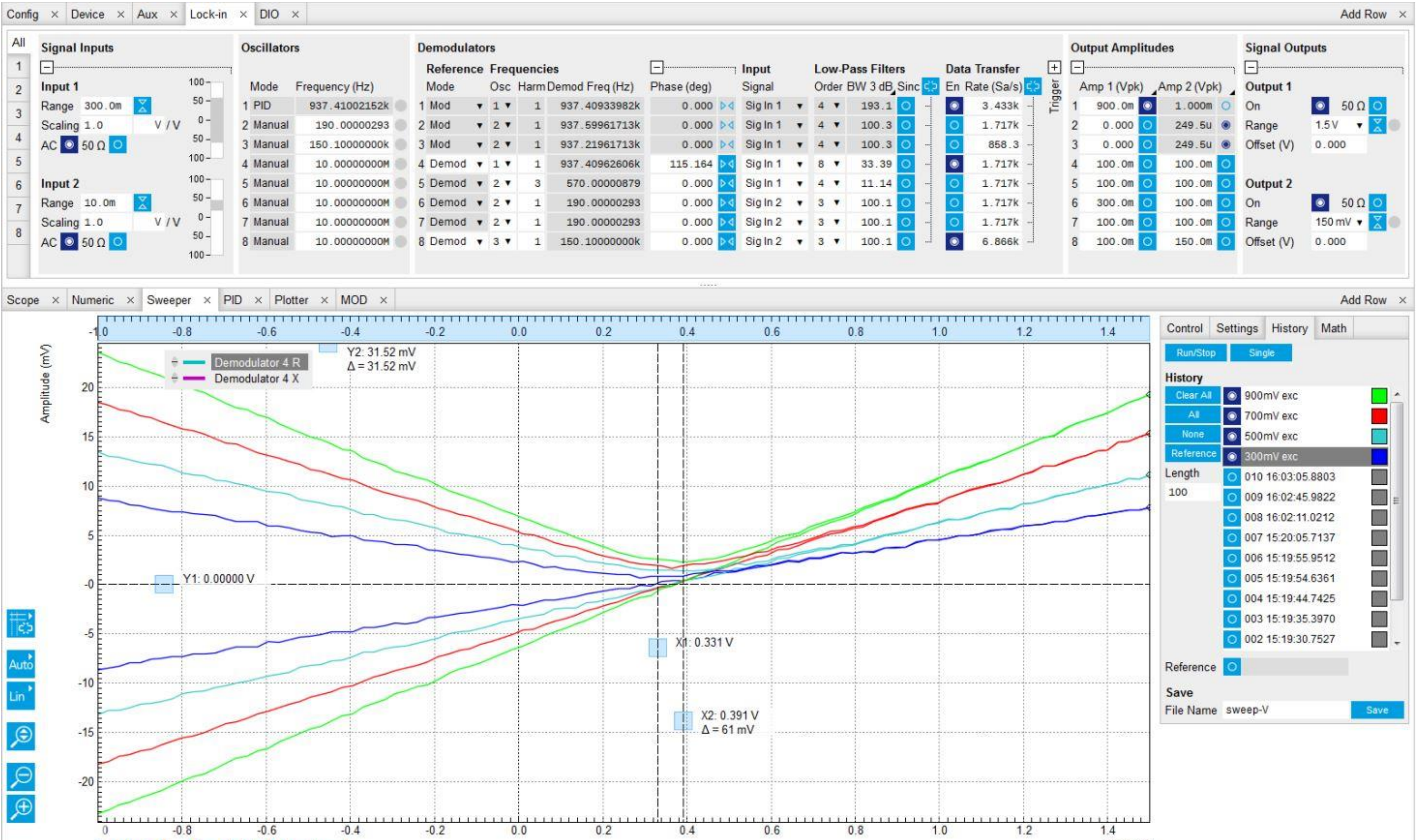
Topography (feedack on Z)



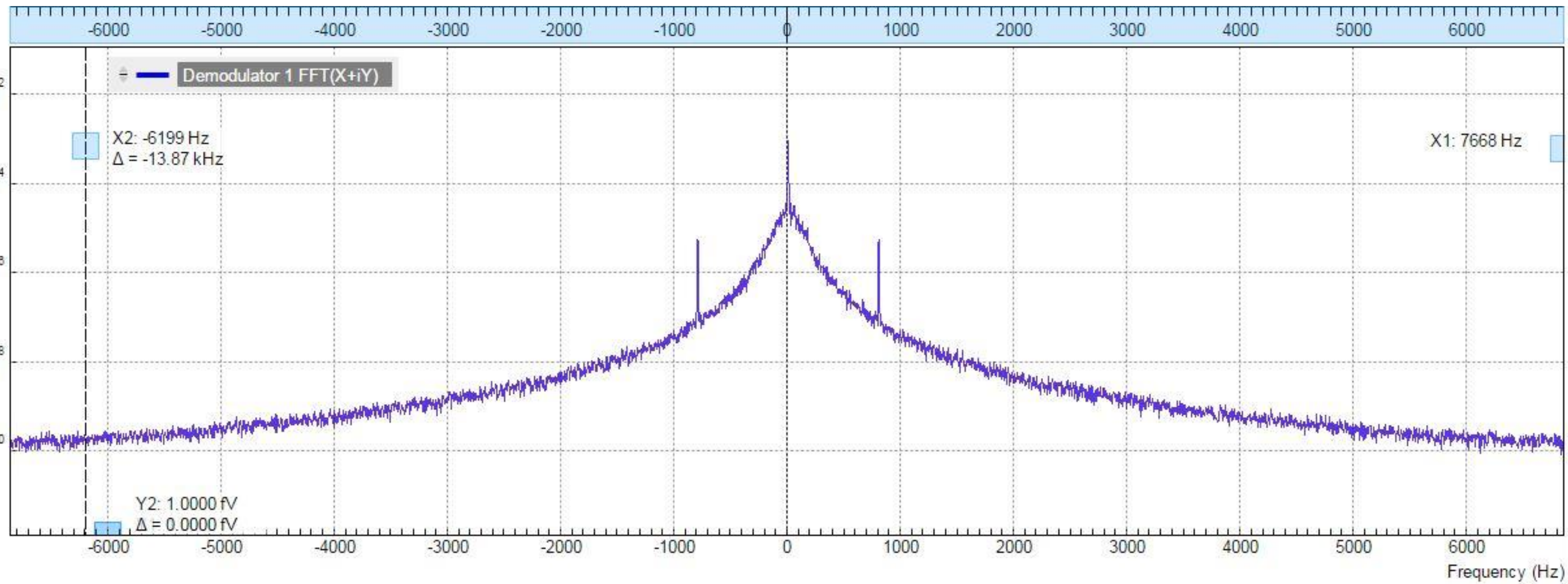
CPD (feedack on bias voltage)

Image courtesy of Thilo Glatzel and Ernst Meyer, Universität Basel, Switzerland

Why phase adjustement is important for KPFM ?



Combining DFRT & KPFM method ?

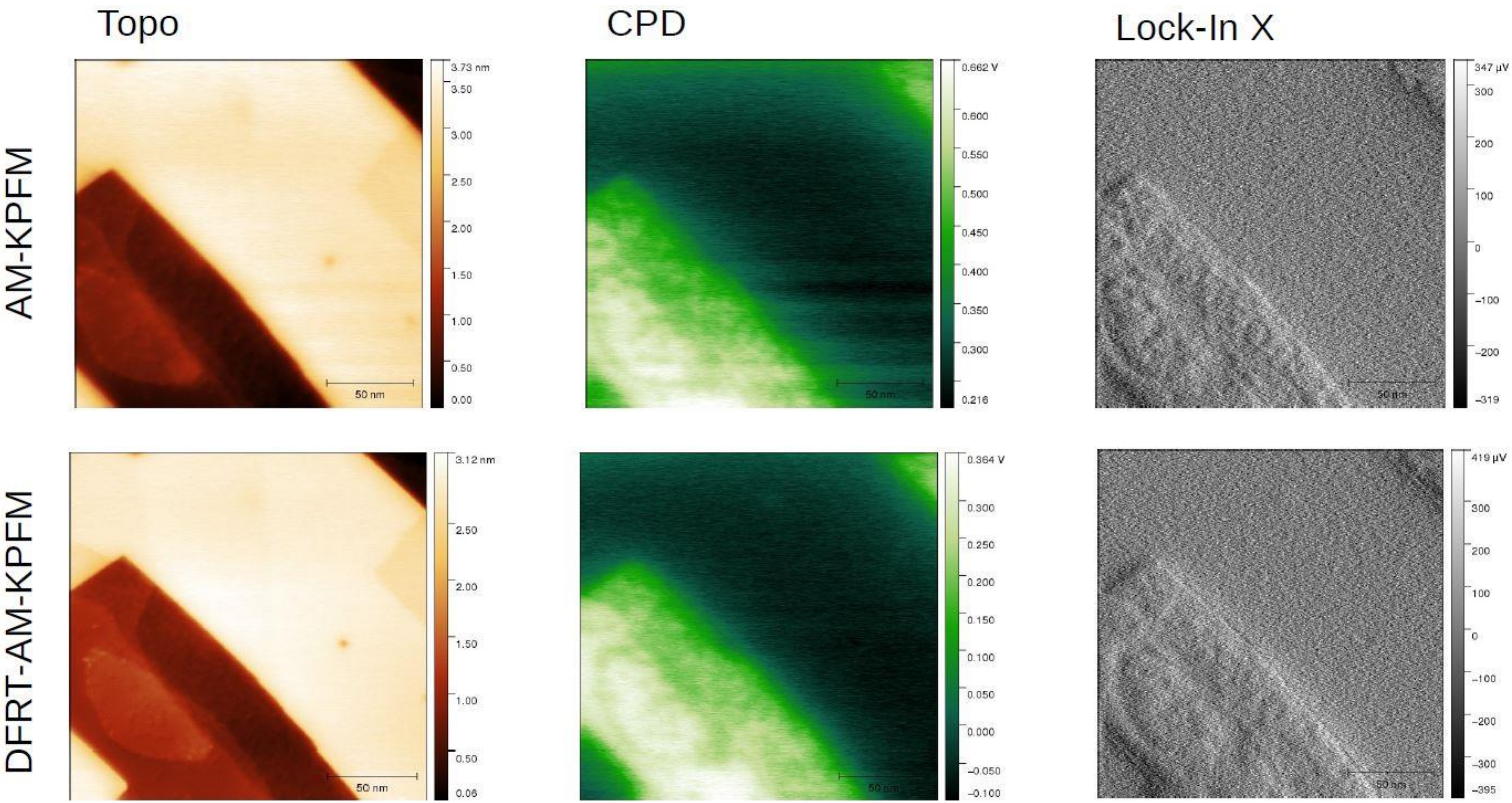


Second eigenmmode for bias modulation with mechanical frequency tracking

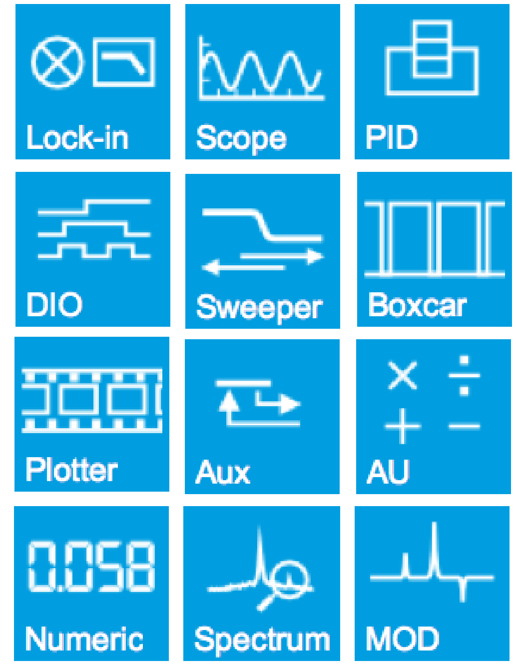
1. Carrier is electrostatically driven
2. Sidebands are mechanical modulated

More KPFM imaging...

Cu(111) on KBr - 300mV V_{ac} @ second eigenmode (f2)



Conclusion: The Benefit of Digital



- **Zurich Instruments integrates in one box**
  - Lock-in (6/8 demodulators)
  - Dual signal generator
  - Oscilloscope / Digitizer
  - FFT / Spectrum Analyzer
  - Boxcar Integrator
  - Frequency Sweeper
  - PLL / PID Controller

- **Most SPM modes available** with Basic HF2LI Lock-in configuration and upgradable later with options (PLL, PID, MOD,…).

- **Increase Demodulation Speed** and reduce pixel dwell time

More resources on ZI website & ZI blogs !

Zurich Instruments Blogs

Most Recent

< Older

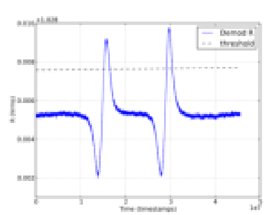
Synchronisation of HF2LI/UHFLI with External Scan Engines for Image Acquistion

on 10.09.2014 at 23:50 by Romain Stomp on Blog of Romain Stomp

Since a lock-in amplifier is most of all used for synchronous measurements, it comes at no surprise that many HF2 or UHF users want to synchronize saved demodulated sample with their scan generator either for mapping, scanning or imaging in [...]

Loading data saved from the LabOne UI in Python

on 05.08.2014 at 17:07 by Daniel on Blog of Daniel Wright



The LabOne User Interface can continuously save instrument data such as demodulator samples to hard disk as binary data in MAT (Matlab®) files or as plain text in CSV (comma separated value) files. Using MAT files, demodulator data can be recorded at full [...]

Basic vector network analyzer (VNA) measurements using the UHFLI

on 03.07.2014 at 15:43 by dragan on Blog of Dragan Lesic

Introduction This article describes how to measure reflection and transmission coefficients using a Zurich Instruments UHFLI Lock-in Amplifier and a directional coupler. Network analysis is a commonly performed in RF measurement. A network analyzer is an instrument that measures the network [...]

Processing Data in Different Applications with LabOne Net

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