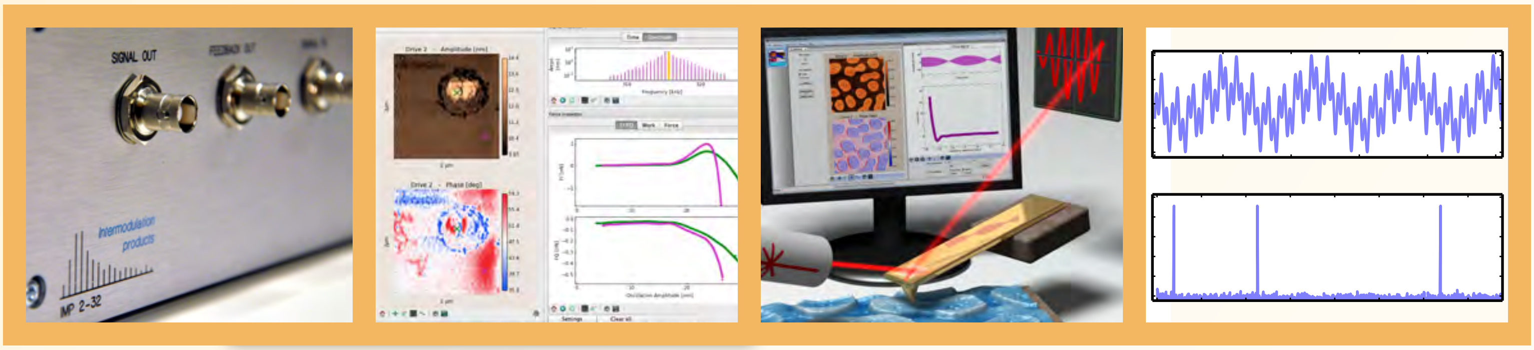
Multifrequency Lockin Analyzer

The ultimate multifrequency measurement tool

- 40 non-interfering lockin amplifiers in one instrument
- More than 100 dB of spurious free dynamic range
- Complete application software suite for quantitative AFM



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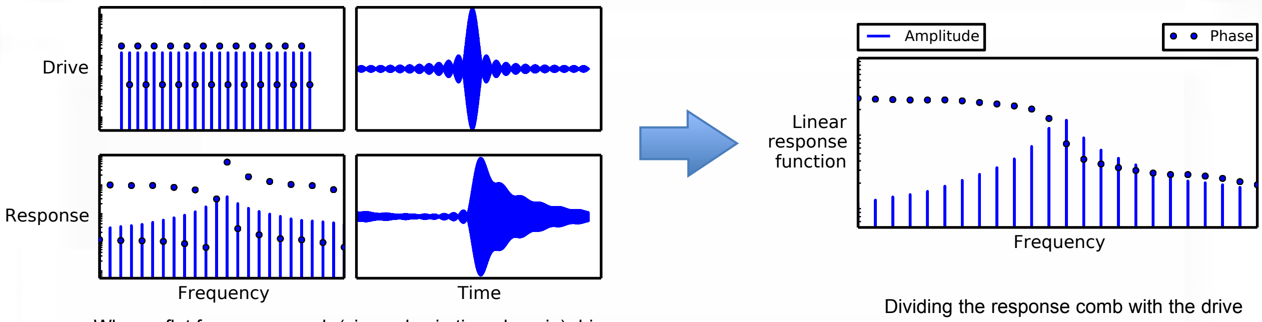
The Multifrequency Lockin Analyzer

Since its emergence in the 1940's [1] lockin measurement technique has become the standard method of small signal, low noise detection. Extension of the lockin technique to multiple frequencies gives much more information about the system-under-test in the time allotted for measurement.

Starting from the basic math and physics of lockin measurement, Intermodulation Products has completely re-designed the digital lockin to enable simultaneous measurement in multiple frequency bands without interference or cross-talk between the bands. The result is a an entirely new type of lockin instrument which is highly configurable and very well suited to application in many areas of science and technology [2].

Multifrequency measurement

Weather you are probing linear or nonlinear response it is important to carefully choose the frequencies of a multi-frequency lockin measurement. Fourier leakage or interference between frequency bands can be completely eliminated if the frequencies and measurement time are chosen to be integer multiples of one base frequency *Δf*, the reference oscillation. All tones in the **frequency comb** are orthogonal when the measurement time is and integer multiple of *T =1/Δf*.



When a flat frequency comb (sinc pulse in time domain) drives an AFM cantilever free from the surface, the response comb is multiplied by the cantilevers transfer function.

Dividing the response comb with the drive comb gives the linear response function of the cantilever resonance.

Probing nonlinear response with a frequency comb is particularly advantageous. **Intermodulation** or frequency mixing of multiple tones in a drive comb generates many new frequencies in the response at integer multiples of *Δf*. Measuring multiple amplitude and phase response at mixing frequencies is a powerful new paradigm for understanding nonlinear systems [3].

User Interface

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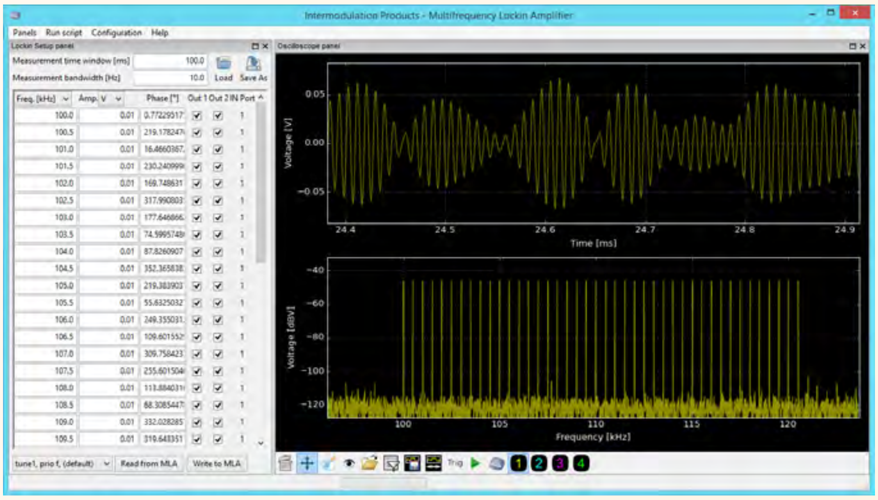
You can control the MLA™, record measurement data, plot data and save data, using its Graphical User Interface (GUI). Many measurements can be configured and performed with mouse clicks in the GUI. The GUI itself can be programmed from the script panel where you can run simple Python scripts.

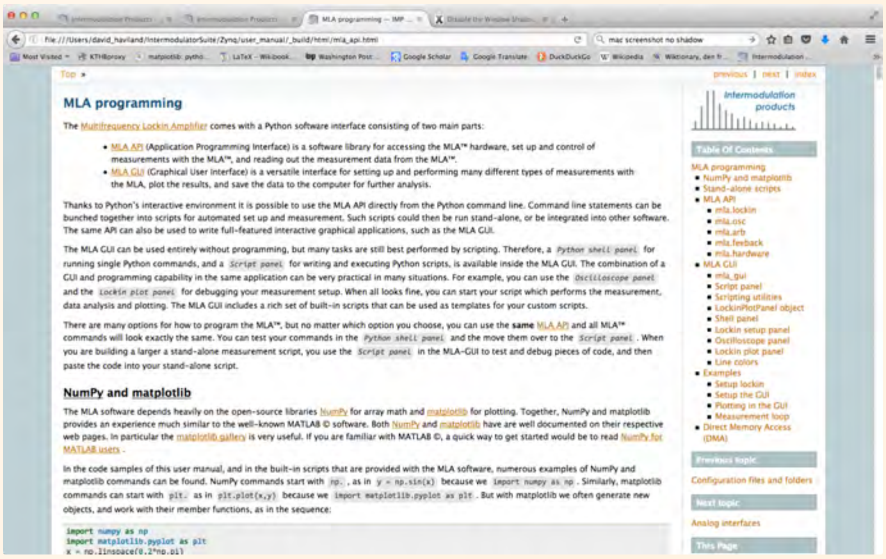
With as many as 40 frequencies, tuning and manual configuration of a measurement becomes cumbersome. Setting up a measurement is most easily done from the Python scripting interface. Novice users can start by modifying example scripts. Advanced users will become familiar the Application Programming Interface, creating their own applications with complete control of low-level operations in the MLA™.



Detailed user and programming manual

The MLA comes with an extensively cross-referenced HTML user and programming manual. The manual covers fundamentals of multifrequency measurement, as well as specific details about how the MLA tunes the frequency comb. Programmers will find detailed documentation built in to the code as Python doc-strings, also included in the cross-linked HTML manual with extensive example scripts.

MLA™ programming is built around Scientific Python, based on the open-sources modules Numpy and Matplotlib for numerical analysis and plotting respectively. There are numerous other Python modules, for everything from numerical integration to digital signal processing. Programming the MLA™ and analyzing the measurement data is seamlessly done with the ever-growing number of open source Python modules.



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MLA Specifications

Features

Two high speed output ports
DAC resolution: 16 bits
DAC sampling frequency: up to 250 MSPS
Arbitrary waveform generation
Digital DC offset correction

2+2 high speed input ports
ADC resolution: 14 bit and 16 bit
Sampling frequency: up to 250 MSPS and 62.5 MSPS
Sample in time mode (raw), or frequency mode (lockin)
The frequency mode analyzes up to 40 frequencies simultaneously, in real time.

Sample memory: up to 384 Msamples

Four auxiliary output ports, 16 bit, up to 800 kSPS. Useful for AFM feedback and in custom experiments, for example voltage bias or temperature control.

6 configurable input/output trigger ports for 3.3V or 5V.

52 auxiliary digital ports for custom expansion.

System performance

(combined performance of output and input ports)

Analog bandwidth: 0-50 MHz
(DC-coupled, AC-coupling possible)

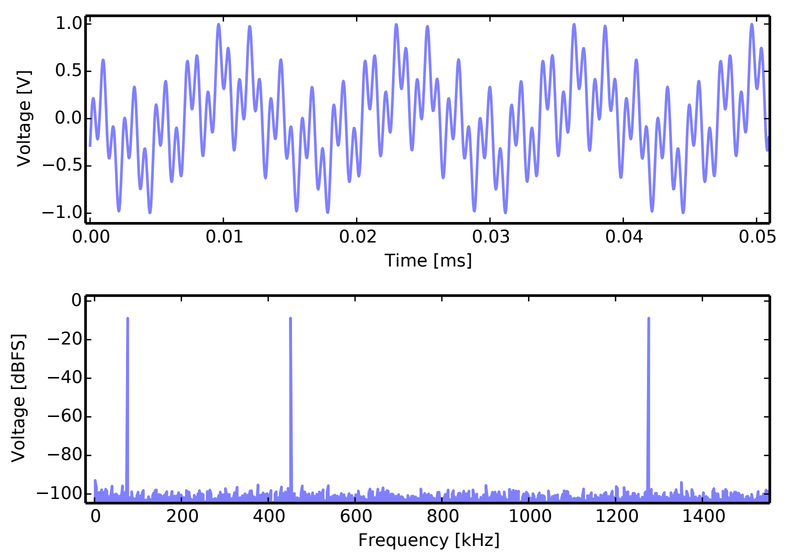
Lockin bandwidth: 1 mHz - 30 kHz

Frequency resolution: down to 3 μHz

Voltage range: -2 V to +2 V
(extra gain- or attenuation stages available)

SFDR*: >100dB
(when output signals are DC-5 MHz)

*SFDR (Spurious Free Dynamic Range) - amplitude ratio of the maximum signal, to the largest spurious signal over the entire instrument bandwidth, including harmonic overtones and intermodulation distortion.



Noise performance of the MLA. The output port is driving three tones at typical cantilever eigenmode frequencies. The input signal is directly sampled and Fourier transformed. The sampling frequency was 25 MSPS and the signal was sampled during 1 ms.

References

[1] R. H. Dicke, Rev. Sci. Instrum. 17, 268 (1946)
[2] E. A. Tholén, et al., Rev. Sci. Instr. 82, 026109 (2011)
[3] C. Hutter, D. Platz, E. A. Tholén, T. H. Hansson and D. B. Haviland. Phys. Rev. Lett. 104, 050801 (2010)

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