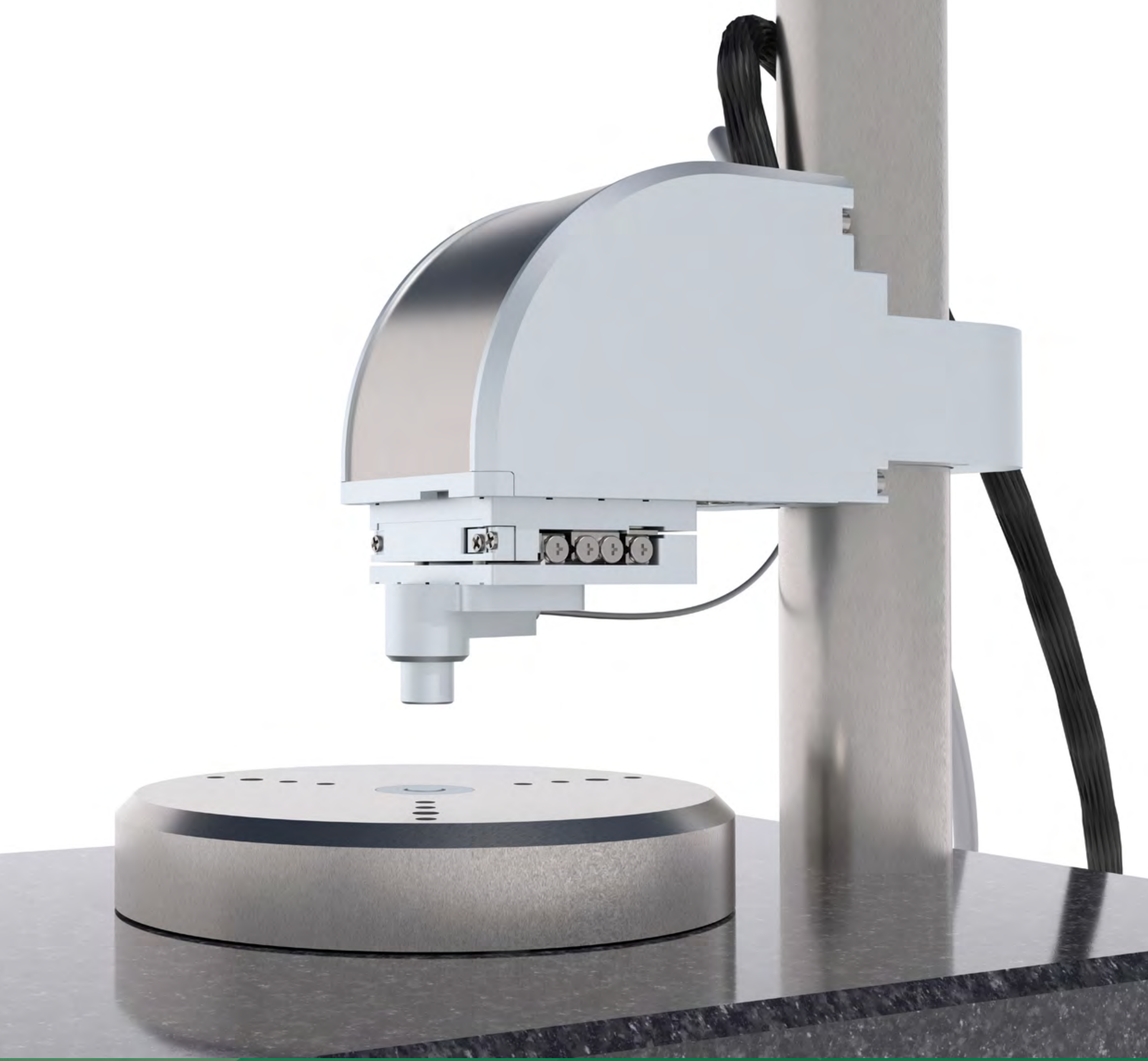


PICOSCALE

Vibrometer

SmarAct | metrology

Scanning Vibrometry

Overview

The **PICO**SCALE *Vibrometer* is a turnkey solution for measuring the vibrations of micromechanical structures with sizes ranging from a few µm to several cm. Applications include the testing of MEMS, sensors, miniature loudspeakers, as well as bearings and actuators. Equipped with an integrated confocal microscope and capable of measuring up to 1 million pixels, it is ideal for visualizing vibration modes with high spatial and temporal resolution. The system can accurately measure both out-of-plane and in-plane vibrational modes, providing comprehensive insights into the dynamic behavior of microstructures.

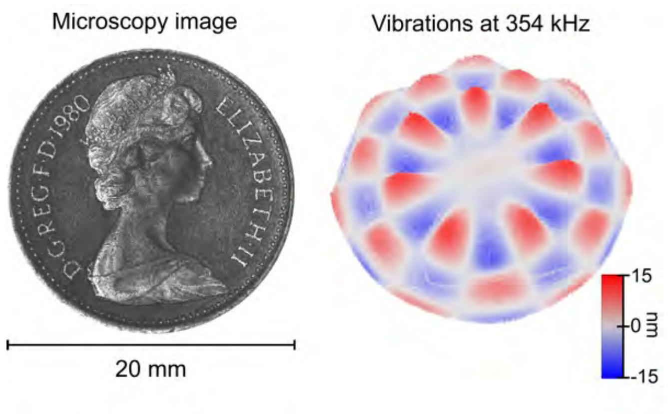
Sensor Head

Exchangeable objectives

Megapixel Imaging with the PICOSCALE *Vibrometer*

Vibration measurements at up to one megapixel can be performed with the **PICO**SCALE *Vibrometer*, the solution for the modal analysis at high spatial and temporal resolution for samples such as MEMS, sensors and actuators.

- Contactless measurement of vibrations with a resolution of below 1 pm
- Very high spectral resolution of 1 Hz for 1 s data recordings and 0.1 Hz for 10 s data recordings
- Up to 10 MHz sample rate to investigate vibrations up to 5 MHz
- Integrated confocal microscope with an optical resolution down to 2 µm
- Modal analysis of encapsulated MEMS
- Turn-key instrument complete with shaker stage and software



Higher order bending modes can result in complex vibrational patterns. For a full modal analysis, the measurement laser of the **PICO**SCALE *Vibrometer* is scanned over the sample to record microscopy and vibration images simultaneously.

> *In a collaborative work between the American University of Sharjah, UAE and SmarAct Metrology, we used PicoScale Vibrometer to analyze the in-plane and out-of-plane motions of an electrostatic MEMS resonator, comprising a microcantilever beam electrically actuated via a side electrode. The optical measurements showed interesting nonlinear dynamic aspects of the resonator's motion in terms of bifurcation and hysteresis. These nonlinear features can be exploited for sensing applications.*
>
> **- Prof. M. Ghommem,**
> **American University of Sharjah, United Arab Emirates**

System Components

1. Innovative Sensor Head

- Integrated Michelson interferometer
- Confocal optical design
- Various microscope objectives available down to 2 μm lateral resolution

2. Closed-Loop 3D Positioning System

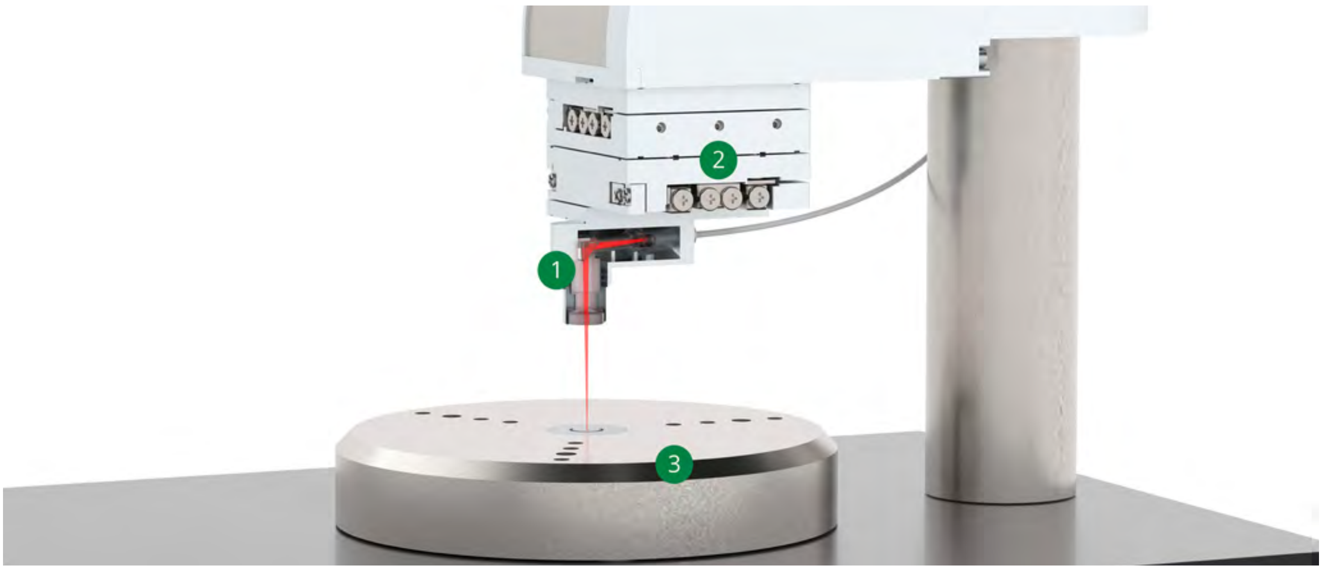
- Closed-loop piezo positioners withnm resolution
- Variable scan range of 30 mm x 30 mm
- 50 nm repeatability
- Easy integration in custom setups through 1” post mount
- UHV compatible upon request

3. Shaker Stage

- Mechanical excitation of samples by a fast piezo-based shaker stage
- High bandwidth of up to 1.5 MHz
- Open-loop operation
- Available for out-of-plane and in-plane direction

Controller

- Class 1 IR laser coupled to the sensor head with fiber optics
- Configurable lock-in amplifier for the direct imaging of bending modes
- Vibration data can be processed in the time or frequency domain
- Outputs available for the electrical excitation of samples
- Synchronization with external excitation sources with a phase-locked-loop (PLL)



Software

The **PICO**SCALE *Vibrometer* is delivered with two programs that can be operated in parallel:

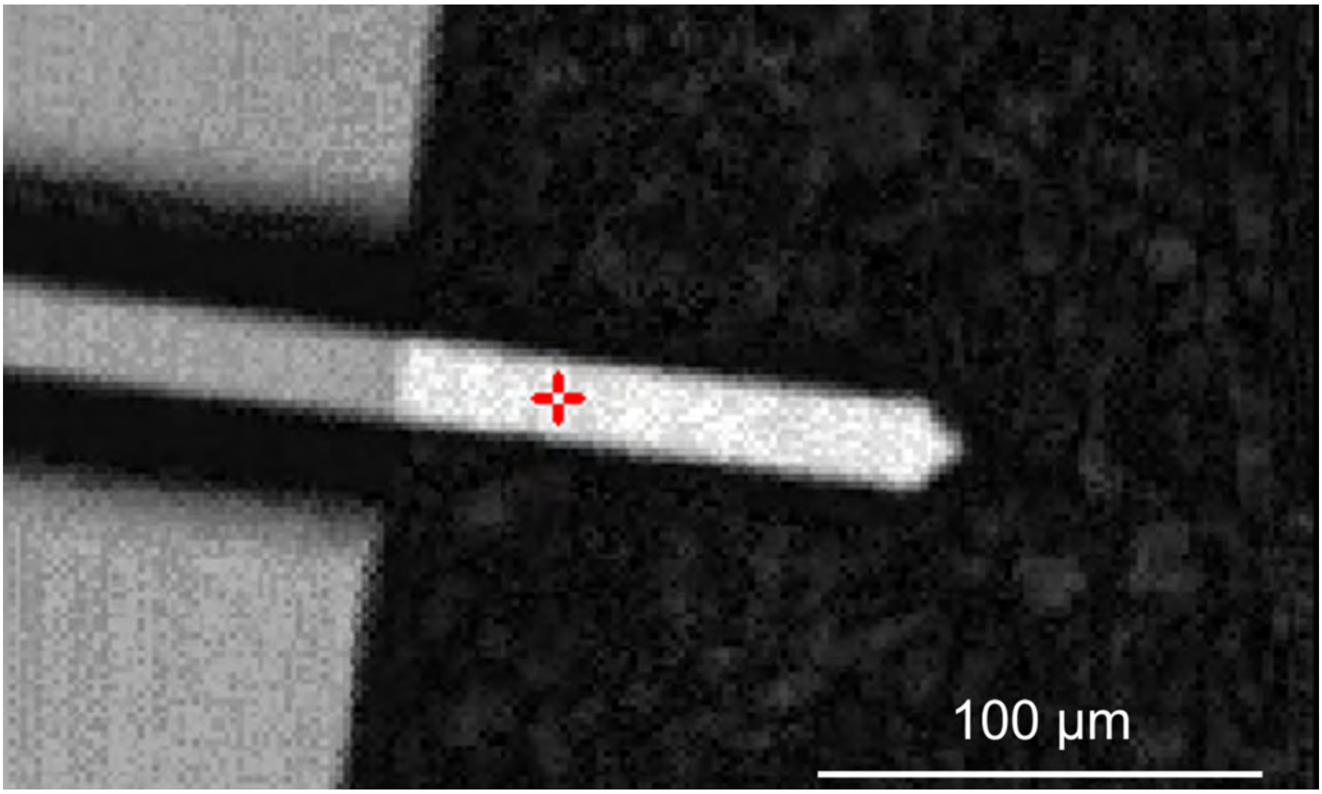
- Intuitive operation of the vibrometer with the Control software
- Extensive data analysis with the View software

	Key Specifications	
Vibrometry	Resolution* [pm]	< 1
	Bandwidth** [MHz]	5
	Maximum Sampling Rate	10 MHz
Microscopy	Optical Lateral Resolution*** [µm]	2 - 7
	Optical Axial Resolution*** [µm]	7 - 90
	Working Distance*** [mm]	1.5 - 10
	Maximum Image Size [mm]	30 x 30
	Minimum Pixel Size [µm]	1
	Maximum Number of Pixels	1000 x 1000
Dimensions	Controller	2 units of each 33 x 27 x 7.2 cm (W x L x H), combined weight 7.6 kg
	Instrument Mount	Granite stone 15 x 20 x 4 cm (W x L x H) with stainless steel post 2.5 x 15 cm (Ø x H), combined weight 4.3 kg
	Shaker Stage	8 x 1.5 cm (Ø x H), weight 0.5 kg

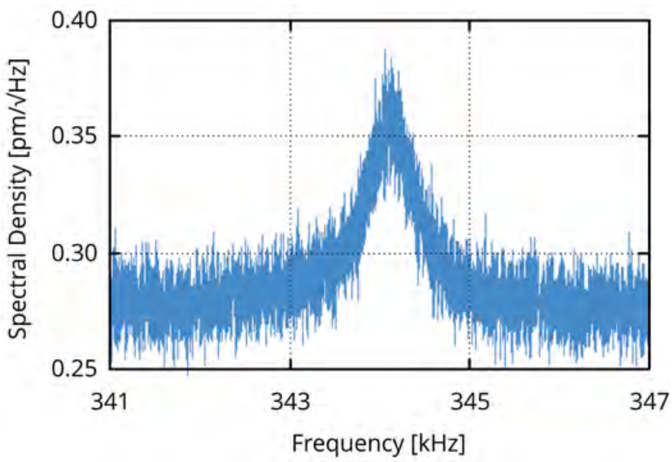
* *When analyzing displacements in the frequency domain*
** *Sampling rate is 10 MHz*
*** *Depending on the selected sensor head*

Application Examples

Single Point Measurements

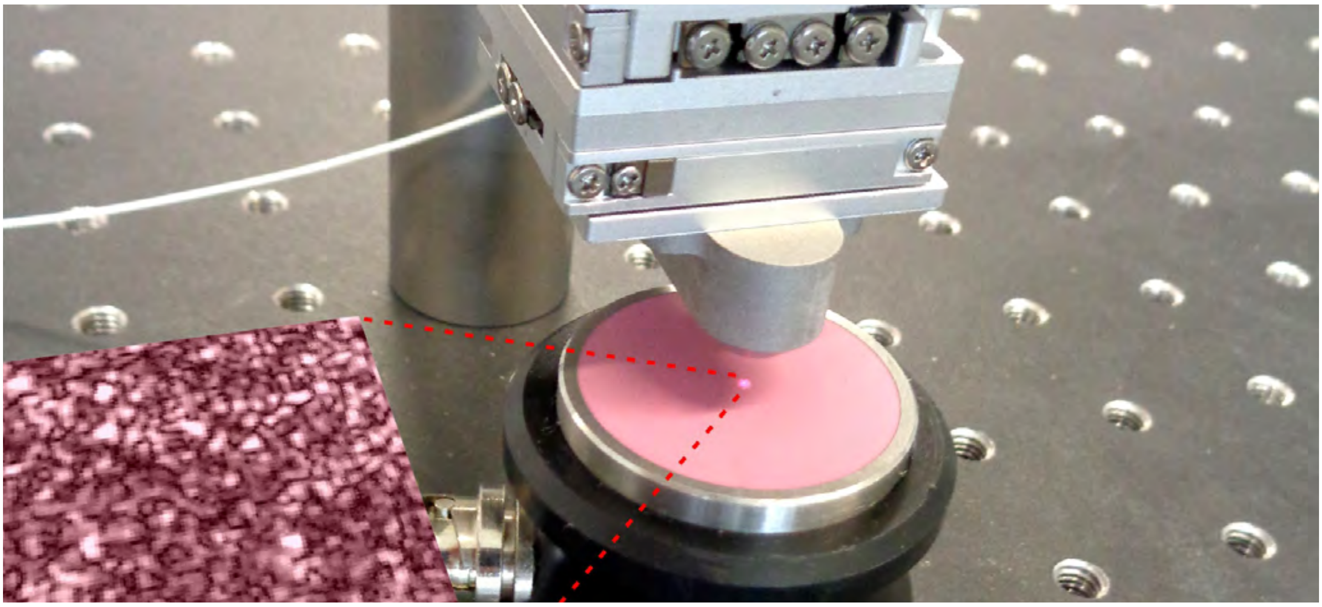


- Measuring out-of-plane vibrations with interferometry
- Easy selection of measurement points with integrated optical microscope
- High resolution and bandwidth

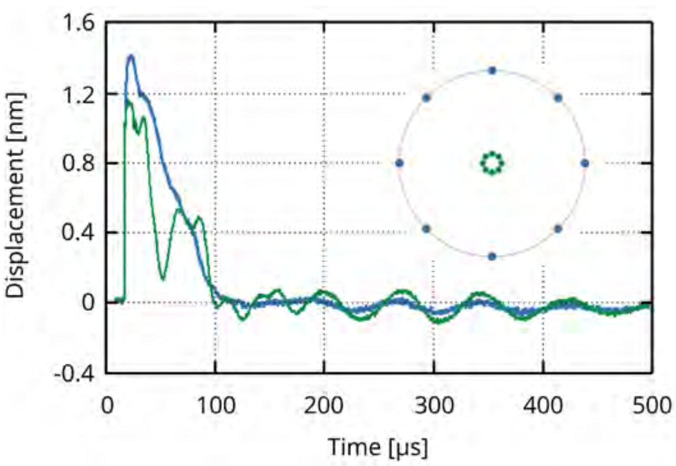


The amplitude spectrum of a micro cantilever was measured at the indicated position. Although the cantilever was not actively excited, the high resolution of the interferometric measurements still allows to detect the thermal fluctuations, in this case 0.36 pm at 344 kHz.

Characterizing Ultrasonic Transducers According to the Norm ISO 24543



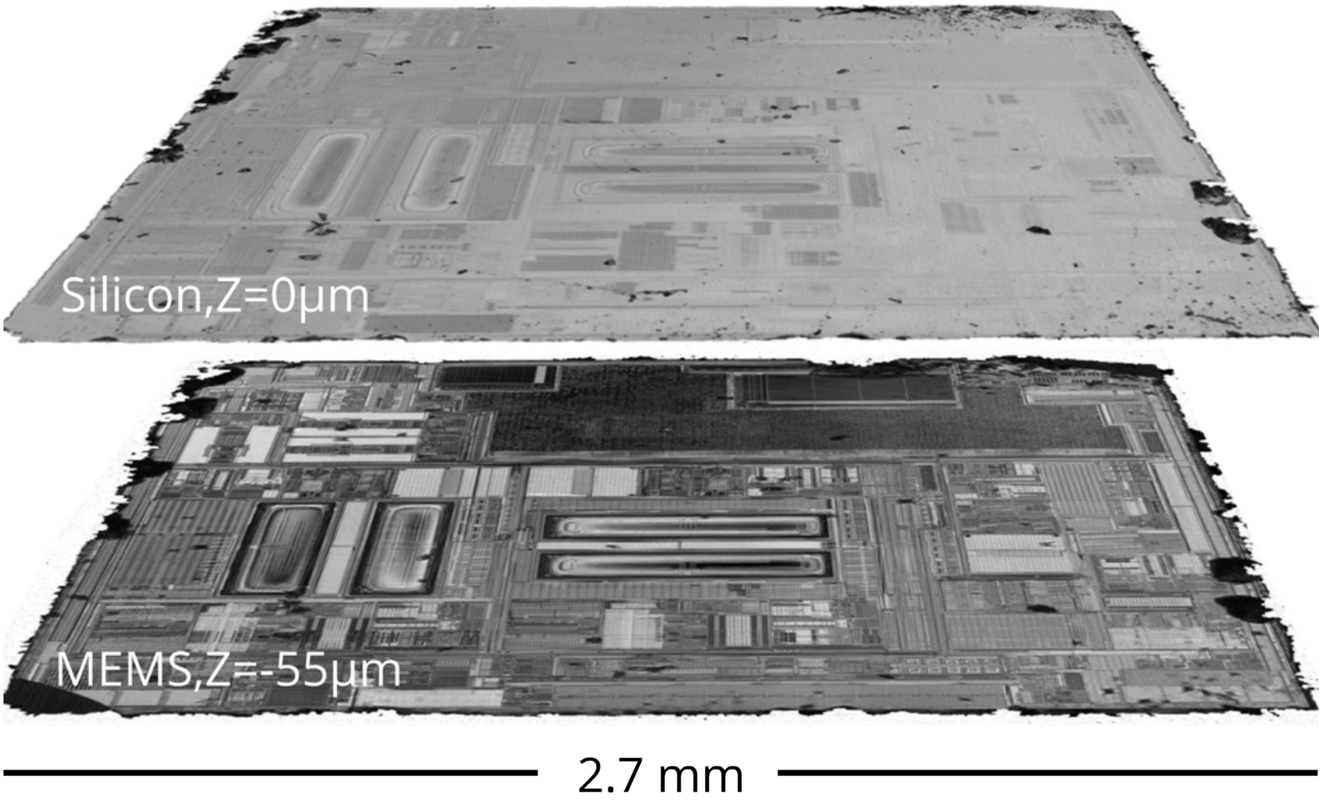
- Measuring sub-nm motion at multiple predefined points
- Sample excitation with external arbitrary waveform generator



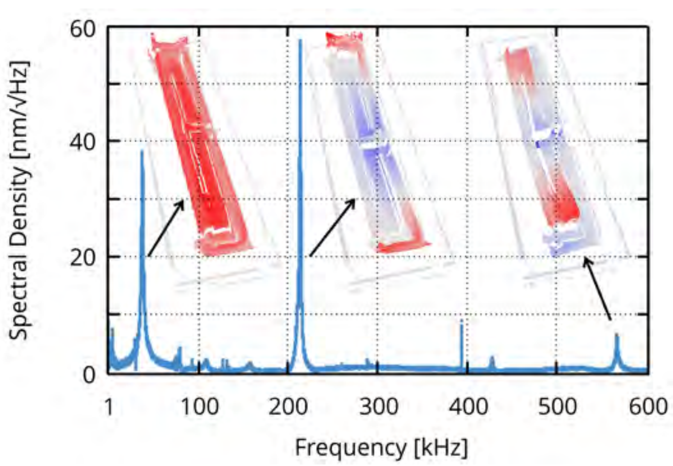
Measuring motion at a circular array of points on the surface of an ultrasonic transducer. The graphs show the averaged response from all measurements performed at 1.3 mm (green) and 10 mm (blue) from the transducer center. We thank Vallen Systeme GmbH for their support with this application example.

> *The* **PICO**SCALE *Vibrometer with its capabilities to perform megapixel modal analysis and confocal IR microscopy is an ideal tool for our MEMS development activities.*
>
> **- Dr. J. Volk, Nanosensors Lab in Budapest, Centre of Energy Research**

Measuring MEMS through Silicon

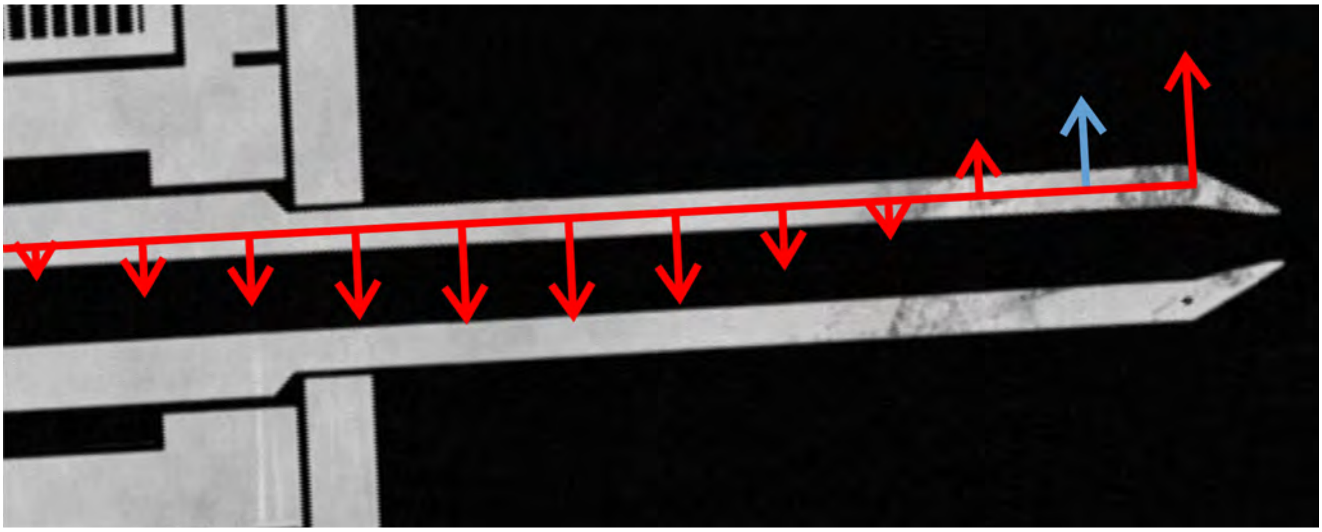


- Selective imaging of layers with infrared confocal microscopy
- Measuring through semi-transparent materials such as glass and silicon
- Semi-transparent structures themselves can still be measured when in focus

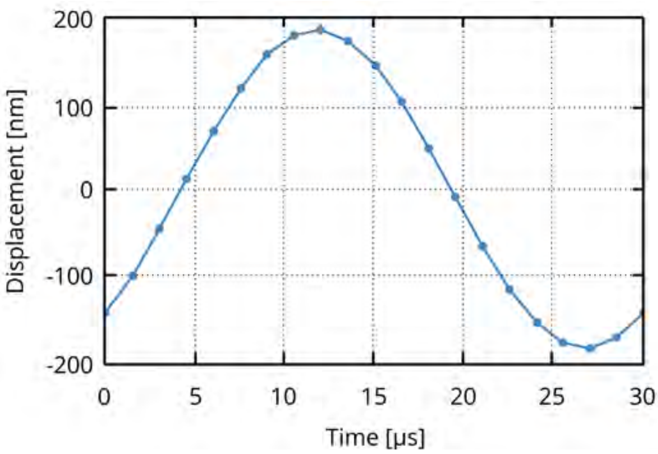


Measuring vibrations of MEMS through a packaging of silicon is made possible by confocal imaging with an IR light source. We thank InvenSense, a TDK Group Company, for their support with this application example.

Imaging Lateral Vibrations



- In-plane motion is imaged by recording a sequence of microscopy images that span exactly one vibration cycle (conceptually similar to stroboscopic imaging)
- In-plane vibrations down to 1 nm can be extracted through optical flow algorithms



Lateral vibrations are measured by recording a sequence of microscopy images. Of any moving part within the images the motion can be quantified with a tracking routine. Although this method is based on microscopy, and not on interferometry, the resolution is not limited by optical diffraction and can be as good as a few nm.

"For the development of our novel MEMS vibrometer, the ability to inspect and understand the dynamic behavior of the sensor's inertial core system is a crucial analysis method. With the help of the provided **PICO**SCALE*-based vibration analysis and their expertise in metrology, SmarAct strongly contributed to the sensor development. For future research, we are planning to keep up the excellent collaboration with SmarAct."*

- J. N. Haus, Braunschweig University of Technology, Germany

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SmarAct Metrology GmbH & Co. KG develops sophisticated equipment to serve high accuracy positioning and metrology applications in research and industry within fields such as optics, semiconductors and life sciences. Our broad product portfolio – from miniaturized interferometers and optical encoders for displacement measurements to powerful electrical nanoprobers for the characterization of smallest semiconductor technology nodes – is completed by turnkey scanning microscopes which can be used in vacuum, cryogenic or other harsh environments.

We maintain the complete production in house for a high level of customization so that we can always provide you the optimal individual or OEM solution. We also offer feasibility studies, measurement services and comprehensive support to accompany you along your projects.

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