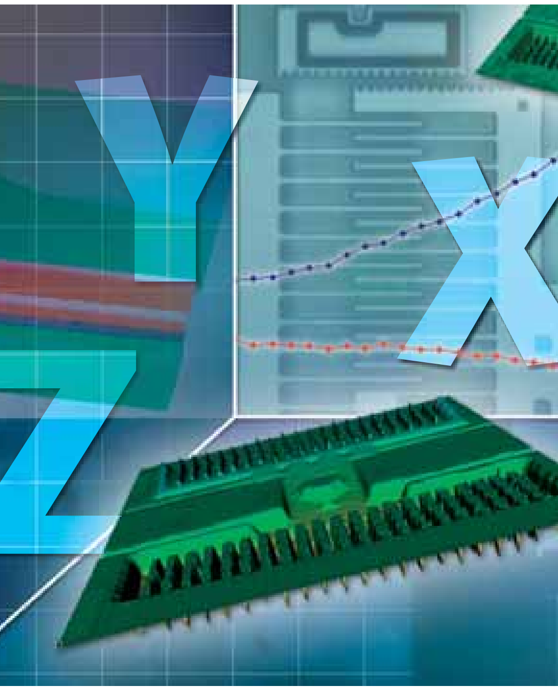
Polytec

MSA-500
Micro System Analyzer

Measuring 3-D Dynamics and Topography of MEMS and Microstructures

Complete 3-D Characterization



Static and dynamic analysis and visualization are a critical part of the test and development process for microstructures such as MEMS devices (Micro-Electro-Mechanical Systems). They are indispensable for validating FE calculations, determining cross-talk effects and measuring surface deformation. The MSA-500 Micro System Analyzer was designed to combine several measurement techniques into a convenient "All-in-One" solution for characterizing surface metrology and measuring in-plane and out-of-plane motions. This instrument delivers increased measurement flexibility and precision, adapting to the needs of today's and tomorrow's microstructures. When incorporated in the MEMS design and test cycle, the Micro System Analyzer provides precise 3-D dynamic and static response data that increases device performance while reducing development and manufacturing costs through enhanced and shortened design cycles, simplified trouble shooting and improved yield.

Non-Contact Measurements on Microstructures

As a consequence of MEMS wide spread usage, static and dynamic analysis of MEMS microstructures is vital to assuring design and production quality. MEMS devices are critical components in automotive, aerospace, consumer, telecommunication, optical, and medical applications. Standardized MEMS testing is essential for both packaged and unpackaged devices (single die and wafer-level testing). The Micro System Analyzer can be adapted to many different measurement scenarios and is easily mounted onto manual or fully automated probe stations.
It is a versatile instrument for MEMS R&D as well as for routine quality control measurements.

Polytec's Award-Winning Micro System Analyzer

The superior performance of the MSA-500 is a direct result of Polytec's many years of expertise and leadership in vibrometry and topography. Three different technologies utilize light for non-contact measurement of three-dimensional shape and motion in microstructures:

- Laser-Doppler vibrometry for fast, broadband, out-of-plane dynamics
- Stroboscopic video microscopy for in-plane motion
- White light interferometry for high resolution topography

By integrating these technologies into a compact, robust and reliable all-in-one measurement head, the MSA became the acknowledged worldwide standard for developing and characterizing MEMS dynamics. Used in the leading R&D labs, the instrument was recognized by two awards: the 2005 Sensor Innovation Award and the Photonics Circle of Excellence Award for the development of microscope-based scanning vibrometry.

For more information and to learn how the Micro System Analyzer works, visit www.polytec.com/microsystems and view or order a comprehensive video about microstructure characterization.

The All-in-One Solution

Three Technologies Integrated into One System

Polytec's Micro System Analyzer combines three highly sophisticated measuring techniques in one instrument permitting a comprehensive investigation of a microstructure without moving the device to another test station.

- Static characterization of the topography by scanning white-light interferometry, appropriate for rough and smooth surfaces with sub-nanometer vertical resolution and a horizontal resolution in the sub-micrometer range (see page 6)
- Real-time dynamic characterization of "out-of-plane" vibrations by laser-Doppler vibrometry at frequencies up to 24 MHz with a displacement resolution in the picometer range (see page 8)
- Dynamic characterization of "in-plane" movements by stroboscopic video microscopy up to 1 MHz with a displacement resolution in the nanometer range (see page 10)

The combination of all three techniques makes the MSA-500 a universal tool for:

- Obtaining 3-D profiles and determining surface and form parameters
- Identification, visualization and measurement of system resonances and transient responses
- Detailed information about amplitude and phase

Designed For Both R&D and Production

The data obtained can be used to improve FEM (Finite Element Method) calculations for microstructures. With a better FEM model, engineers can quickly optimize devices and improve their performance, thus accelerating the development time. The MSA-500 can easily be adapted to probe stations for automated or semi-automated measurements.

In addition, the MSA's fast measurement cycle makes the instrument perfect for production quality control or routine sample testing of MEMS devices. As designed, the MSA-500 is not only tailored for R&D applications but can also be used for routine measurements such as those in quality assurance.

Technology Integration Delivers Faster and More Accurate Results

By combining three measurement principles, Polytec has made the complete characterization of microstructures faster and easier. Just by turning objectives, without removing the sample device, you can switch between the different measurement techniques. This allows a powerful synergy between techniques. For example, out-of-plane vibrometry can enable a rapid determination of all in-plane resonance frequencies through cross-coupled residual out-of-plane motions. This improved efficiency is especially important when integrating the measurement system into automated processes for MEMS production environments.

Solutions for R&D and Production Applications

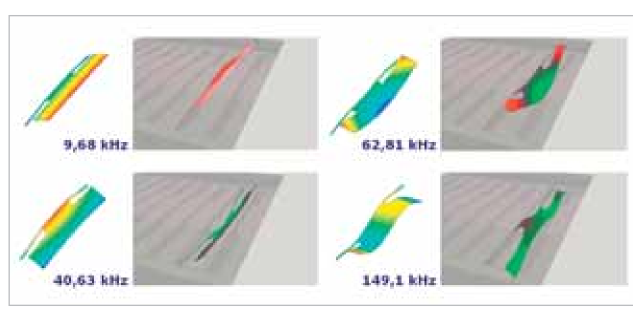
MEMS devices such as micro-sensors and micro-actuators are found in guidance systems, automobiles, aircraft, computers, entertainment systems and medical devices. Both R&D and production engineers must develop new devices quickly, precisely and cost effectively. Polytec's innovative Micro System Analyzer enables high-resolution surface profiling as well as the systematic testing of the dynamic mechanical response to important electrical and physical inputs.

Validate Simulation Models

MEMS researchers use various engineering tools to take a design from concept to simulation, prototyping and testing. Simulation models are validated and fine-tuned through comparisons with precise experimental data which reveal the mechanical response of the MEMS structure to electrical and physical inputs. The MSA helps acquire reliable measurement data where parameters can be extracted to validate the models. By using light as the probe, the measurement procedure has virtually no influence on the MEMS device. The diameter of the laser beam is in the range of a few microns, so that even very small structures can be tested.

Optimize MEMS Functionality

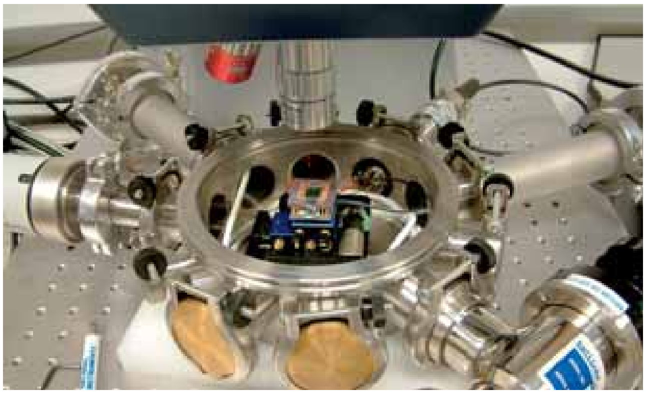
Measuring the response behavior of a device allows its functionality to be optimized. As an example, the damping behavior of micro mirrors is crucial for their performance. Real-time response measurements can be made using the MSA's time domain option to characterize the actuation dynamics of the mirror when switched from one tilt state to another.



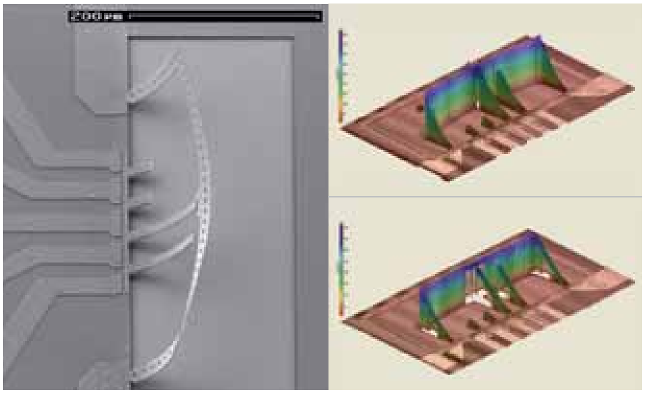
FEM simulation and vibration analysis of micro mirrors (IZM)

Improve MEMS Reliability

It is very important to determine reliability under mechanical excitation (wire bonding, environmental vibration and shock), radiation, temperature, humidity and pressure by targeting the device inside an environmental or vacuum chamber. The Micro System Analyzer has a stand-off distance that allows the researcher to characterize the static and dynamic behavior under specific environmental conditions. For topography measurements, a special long distance objective is available which allows measurements through the glass of a vacuum or pressure chamber.



MEMS measurement in a vacuum chamber (NPL)



MEMS flow sensor (UCL Microelectronics Laboratory)

Sort MEMS for Critical Applications

Stress on the membrane of a MEMS pressure sensor can adversely affect the expected lifetime of the device. Since stress shifts the vibrational frequency spectrum, devices where a high lifetime is required can be selected from production runs by examination of their dynamic spectrum using an MSA.

Determine Key Manufacturing Parameters

The MSA has been successfully used to experimentally determine parameters which are relevant to manufacturing. Information about current process parameters and their impact on dimensions and material parameters of the MEMS devices is needed to control the manufacturing process. For instance, when Silicon-on-Insulator (SOI) technology is used to build three-dimensional surface micro-machined sensors and actuators, topographic analysis using Polytec's MSA-500 is critical to their development.

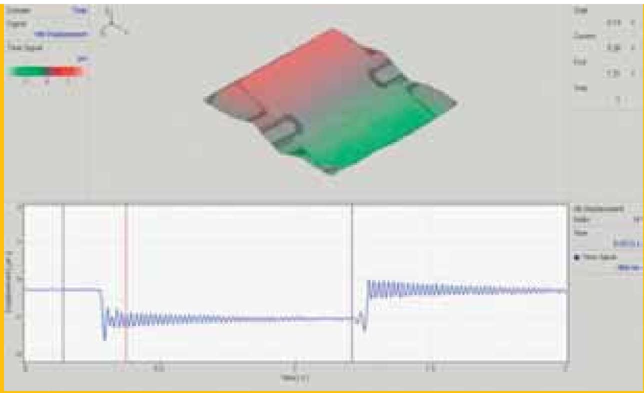
Enables Production Testing

Wafer-level testing can save money by the early characterization and selection of devices prior to packaging. For this task, the MSA can easily be integrated into automated and semi-automated probe stations. The MSA's fast measurement speed allows a high throughput and is an important tool to monitor the manufacturing process. For example, the thickness of the pressure sensor membrane can be determined by analyzing the membrane's frequency spectrum.
Another example is the measurement of stress which affects the lifetime of the MEMS device, thereby allowing the qualification of the expected service life.

Significant Benefits for R&D and Production Applications

- Rapid identification and visualization of both system resonances and static topography
- Integrated microscope optics with optimized optical path for best lateral resolution and highest image quality
- Easy integration with MEMS/wafer probe stations
- Simple and intuitive operation, ready to measure in a few minutes
- Increased productivity through a short measurement cycle
- Accelerates product development, troubleshooting and time-to-market

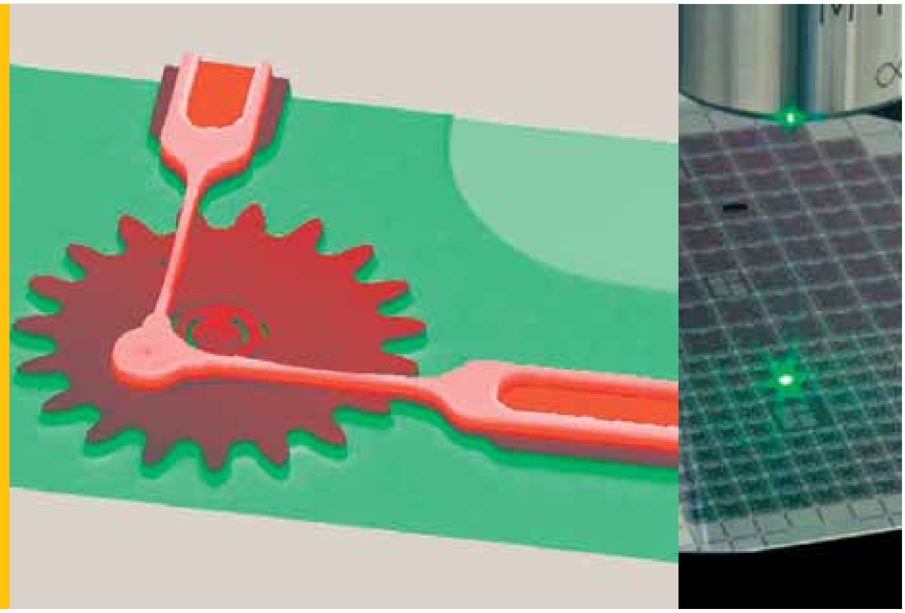
Semi-automatic probe station for production testing of pressure sensors (Melexis)



Real-time response measurement on a micro mirror (Applied MEMS)

Surface Metrology

When designing or manufacturing micro systems, structured functional surfaces require precise verification of surface topography to assure quality and performance. Due to its excellent spatial resolution in both in-plane and out-of-plane directions, the Micro System Analyzer's topography measurement unit is ideally suited for the 3-D profile analysis of microstructures.



Simple Measurements

Measuring and evaluating the results are easy even for inexperienced users: simply place the sample, focus the microscope, define the vertical scanning range and exposure time, and start the measurement. A high resolution X-Y-Z mapping will be generated by shifting an interference objective with nanometer precision with respect to the sample. The interference microscope images both the specimen and reference flat on the camera, thus detecting the interference pattern. The topography of the sample is then shown in 2-D or 3-D view on the PC screen and can be evaluated manually or automatically.

Determine Key Parameters

Many shape, surface and profile parameters are available including:

- Flatness
- Waviness
- Height
- Parallelism
- Angles
- Roughness
- Curvatures
- Volumes

High Performance

- Rapid, non-contact 3-D topography measurement on rough (scattering) or smooth (specular) surfaces
- Sub-nanometer resolution in vertical direction
- High resolution in the horizontal direction due to the mega-pixel camera
- Good reflectivity on silicon devices due to the green LED light source
- Smart Surface Scanning technique adapts to different contrast levels. This allows the investigation of even "difficult to measure" surfaces

Flexible Evaluation

- Powerful TMS analysis software
- Easily find defects through 2-D and 3-D presentations with video overlay
- User-selectable data processing method: envelope evaluation (for rough surfaces) or phase evaluation (even more accurate, for smooth surfaces)
- Special masking techniques allow a detailed analysis of certain portions of the surface

Powerful Tools and Options

- Automation and customization of routine measurements, evaluation and export functions can be done by visual C# add-ons. Large surfaces can be characterized by stitching several measurements together
- Data can be exported as ASCII files to 3rd party software applications for evaluation, CAD comparison or reverse engineering purposes

Special Enhancements

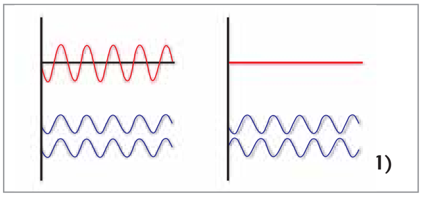
- Wafer-level and automatic measurements are available using the MSA integrated with commercially available probe stations
- Special objective lenses allow measurements in pressure or temperature chambers
- For enhanced capabilities, additional software packages are available

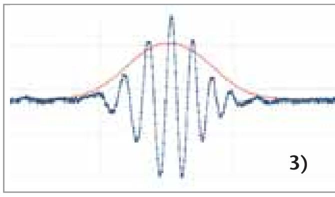
How it Works

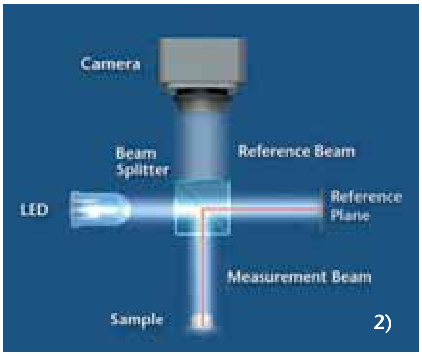
If two monochromatic, coherent light sources are superimposed, then, depending on the phase of the two waves relative to each other, you get either constructive or destructive interference (Fig. 1). The superposition of two light waves and the interference produced can be verified experimentally by using a Michelson interferometer where the light is split into two beams using a beam splitter (Fig. 2).
Part of the light is directed onto a reference surface, for example a coplanar mirror, and the other part onto the surface of the object under investigation. The light is reflected from both the reference and from the test surface and, depending on the path length differences, you will obtain fringe patterns of constructive or destructive interference, which can detected by a camera.

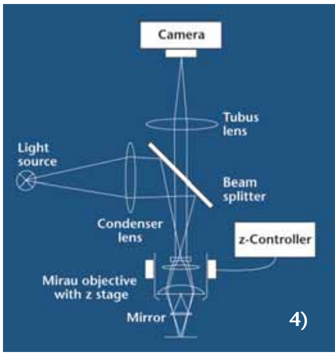
If the surface of the work-piece, however, is not joined or has large steps, the order number of the fringes is lost and the result becomes ambiguous. These obstacles can be overcome by using a broadband "white light" light source (actually the line width is narrow enough to give the light source a color, e.g. for a green LED). White light contains many different wavelengths and, therefore, interference only occurs within a small range and has the form of a correlogram as it is shown in Fig. 3. By moving the reference mirror, the reflections from every point run through the intensity variation of such a correlogram, which has its maximum, when the distance of the mirror is exactly the same as the distance of the surface. After the measurement cycle the correlograms are analyzed and a true topographical representation of the surface can be re-constructed.

For more information visit www.topmap.info



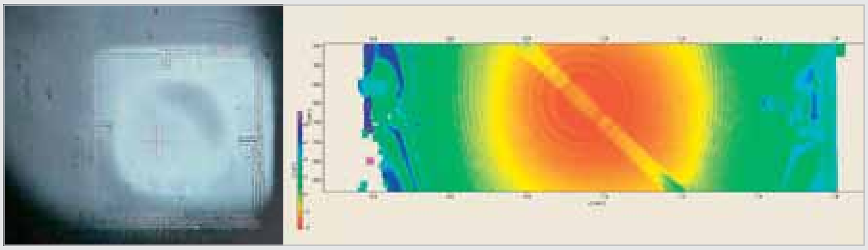






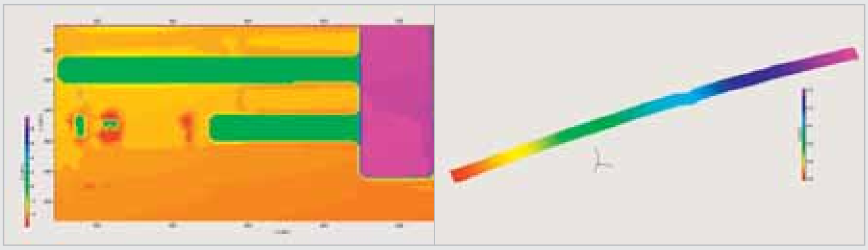
Applications

The Micro System Analyzer offers high performance analysis options suitable for characterizing most microstructure surfaces.

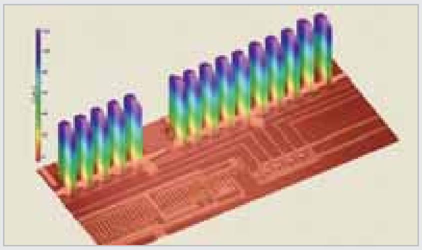


Topography of automotive pressure sensors (Melexis)

Measurement on a micro gearwheel (Sandia)



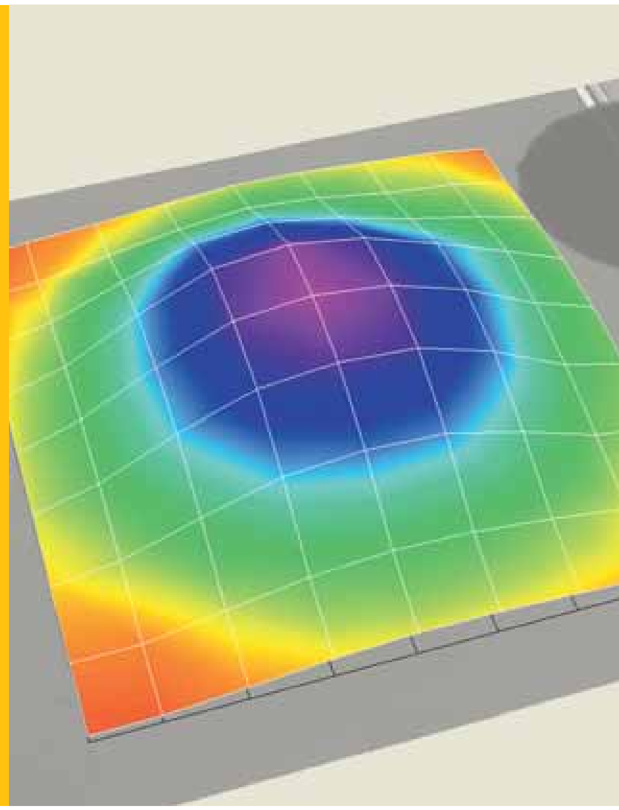
Surface topography and beam curl of a cantilever

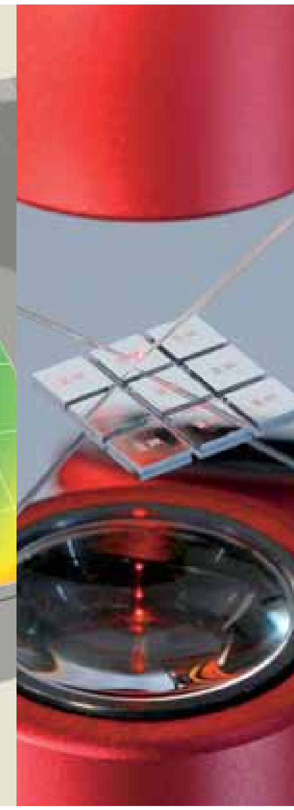


Displacement measurement on a flow micro sensor (UCL Microelectronics Laboratory)

Scanning Laser Vibrometry

Scanning laser-Doppler vibrometry allows non-contact measurements in real time for the characterization of out-of-plane vibrational behavior and for determining the vibration velocity and displacement at any sample point. Unique features include the ability to acquire data with picometer displacement resolution, to capture frequency response up to 24 MHz, and to analyze non-ideal or non-linear systems.





Just "Point and Scan" in Real Time

A Scanning Vibrometer is easy and intuitive to operate. The complete characterization of a surface requires just a few minutes to set up the system, define the scan grid manually or automatically, and then begin the measurement. The vibrometer automatically moves to each point on the scan grid and measures the response. When the scan is complete, the appropriate frequencies can be chosen and the animation of the deflection shape in several convenient 2-D and 3-D presentation modes can be done.

Integrated Vibration Excitation

An internal generator using Polytec software control provides a calibrated vibration excitation of the test object. The internal generator allows excitations with an arbitrary waveform and with a wide range of different excitation patterns. In addition to the internal generator, an external excitation source can be used with the MSA-500.

Intuitive Data Analysis and Evaluation

Frequency data over the instrument's whole bandwidth is available, without the need to know discrete frequencies in advance. The intuitive software package has a full featured analyzer for time domain, FFT, Zoom FFT, averaging and peak hold measurements using a wide range of excitation wave forms. Data visualization includes full frequency response function (FRF) and operational deflection shape (ODS) capabilities with impressive 3-D animations. Post processing and further evaluation of data is greatly enhanced by an open programming interface, versatile data export to modal analysis packages (UFF, ASCII, binary) and a powerful built-in signal processor.

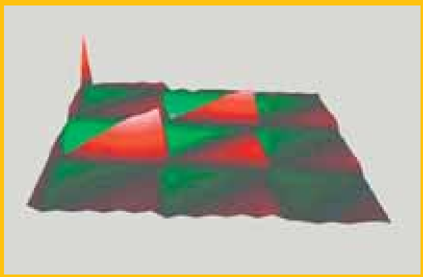
Features and Benefits

- Non contact, zero mass loading and no change of stiffness to the sample under test
- Full-field vibration mapping and broadband, out-of-plane frequency response information in real time
- Displays frequency-domain and time-domain data, simplifying transient response analysis
- Versatile vibration and geometry data import and export interfaces to validate FE models
- Autofocus and Geometry Scan widen the vertical measurement range and allow a complete 3-D view of the vibrations
- Submicron-sized laser spot probes microstructures and detailed features
- Laser dimmer for optimized measurement conditions
- All results are suitable for QC/QA purposes because they can be referred to calibration standards

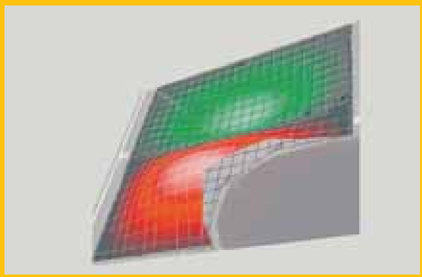
Polytec

Applications

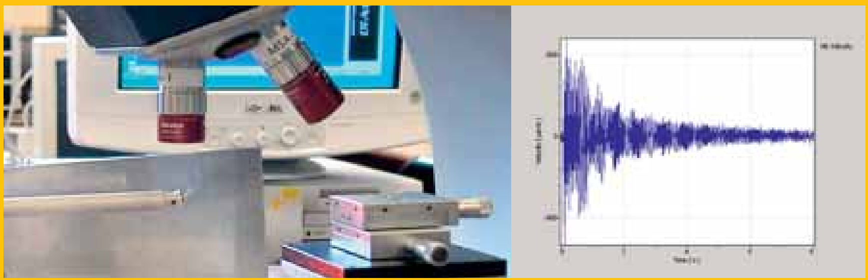
Dynamic Characterization of a MEMS nanopositioner (MIT)



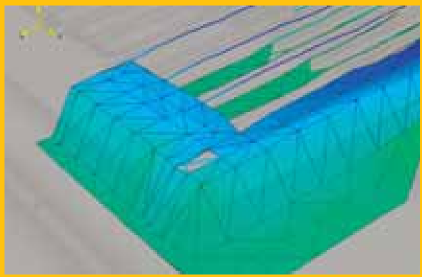
Deflection shapes and static tilt angles of a micro mirror array



ODS of an automotive pressure sensor (Melexis)



Frequency response of a cricket's sensor hair (Univ. of Reading)



Geometry scan of a cantilever structure

Autofocus and Geometry Scan

Many customers prefer to use the MSA-500 versions which include the Autofocus and Geometry Scan options. These features allow the system to focus the measurement beam automatically on different heights of the sample, and thus to avoid measurements outside the focal range. In addition, a special laser auto-focus technique measures precise 3-D geometries of the sample that automatically match to the grid points of the vibration measurements. This allows a 3-D visualization and a correlation between 3-D geometry and vibrations with a complete frequency spectrum, thus enabling dynamic-model refinement and modal analysis verification.

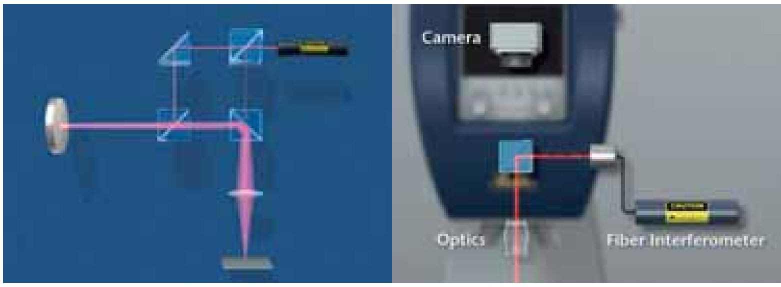
Flexibility for New Challenges

- Broad bandwidth capability – DC to 24 MHz
- Large velocity range – up to 10 m/s
- Displacement resolution in the picometer range
  Geometry Scan Unit measures real geometry of test sample
- High sample grid density with up to 512 x 512 auto-positioned, user-defined measurement points
- The D-versions of the MSA allow differential measurements between two points choosing a reference point on the sample itself

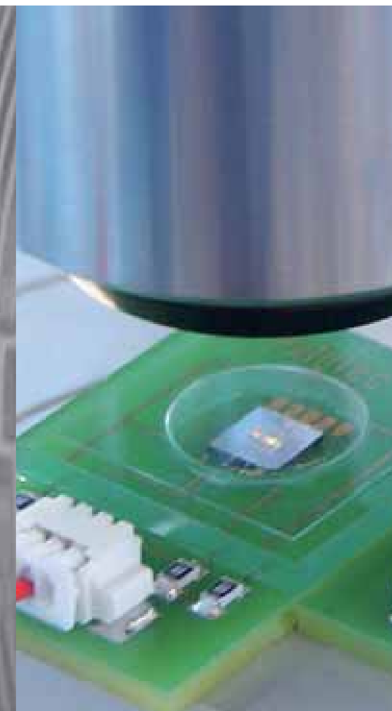
How it Works

The laser-Doppler vibrometer is a precision optical transducer for determining the vibration velocity and displacement at a measurement position. It works by sensing the frequency shift of back scattered light from a moving surface. The object scatters or reflects light from the laser beam and the Doppler frequency shift is used to measure the component of velocity which lies along the axis of the laser beam.

More Info: www.polytec.com/vib-university



Stroboscopic Video Microscopy for In-Plane Motion Detection



To precisely measure the high frequency, in-plane motion of the device under test, a stroboscopic technique is applied. Using stroboscopic illumination and digital imaging, motions of fast periodically moving objects can be sharply frozen in time to capture the exact position of a region of interest (ROI) on the specimen.

Simple Measurement Process

The measurement procedure is quite simple: The ROI is defined and an excitation signal selected. The internal signal generator or an external signal excites the component with either a single frequency or a broad band signal with up to 1 MHz bandwidth. In addition, investigations of repeatable transient phenomena are possible such as relaxations or step response following pulse excitations. Once set, even multi-band measurements are processed automatically around selected resonances. Differential measurements between two ROIs are possible as well.
Thus, influences from the environment can be reduced.

Internal Excitation

A precisely defined electrical signal for excitation of the test object is provided by an integrated signal generator remotely controlled by the Polytec software. This allows excitations over a wide range of different functions. In addition, the MSA-500 allows external excitation of the sample as well.

Software

The video sequences of the specimen are analyzed using a sophisticated proprietary measurement algorithm in the software. It allows the visualization of measurements of displacements, system resonances, transient responses, phase variations, amplitudes, Bode plot graphs and further analysis with a displacement resolution of 1 nm.

Out-of-Plane Vibrometry Combined with In-Plane Stroboscopy

The combination of two complementary measurement techniques to investigate the vibrational behavior of small structures provides superior performance. The highly sensitive laser-Doppler technique can rapidly find all mechanical resonances (in-plane and out-of-plane) without a-priori information if broad-bandwidth excitation is applied. In a second step, the stroboscopic video microscopy technique is used to obtain accurate amplitude and phase information of in-plane resonances identified by laser vibrometry. So even narrow unknown resonance peaks can be found in a frequency response spectrum within a broad frequency range without a time consuming search.

How it Works

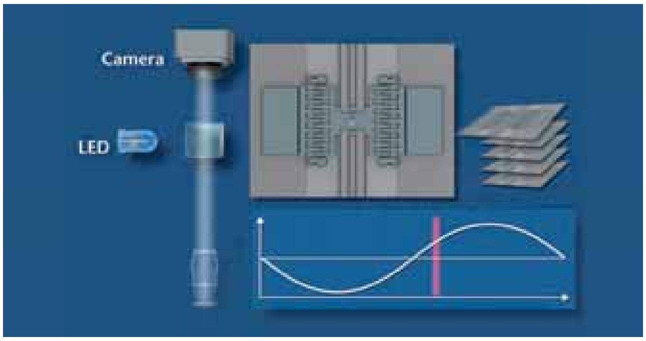
The stroboscopic video microscopy for in-plane motion detection employs a special kind of stroboscopic technique: short light pulses synchronized with the objects motion capture the position at precise phase angles. During the illumination time the motion is frozen. By shifting the timing of these pulses by phase angle increments, the motion of a moving object can be sampled and reconstructed.

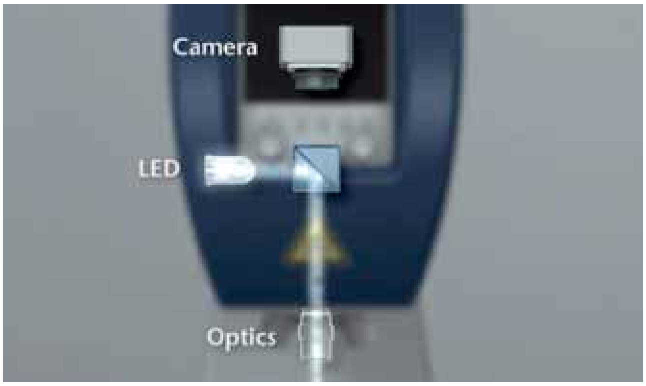
This technology is superior to common high speed video stroboscopy systems, as the flash duration is adapted to the actual vibration frequency. The image quality is thus independent from the frame rate of the camera.

The internal signal generator periodically excites the component with a sine or a pulse signal. A "pattern generator" uses a green LED to generate ultra-short flashes of light (<80 ns) synchronously with the phase position of the excitation signal. This means that a high degree of phase accuracy is attained, even with high frequency excitation. The electronic camera shutter in turn is synchronized with the excitation. It remains open until enough light at the same phase of the periodic motion has been collected.

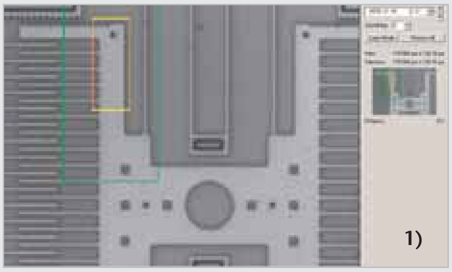
This procedure guarantees a high degree of measurement accuracy and a visual real-time analysis in live mode. The system is set to operate on predefined frequency bands selected from out-of-plane vibration measurements.

For more information visit www.polytec.com/vib-university





Applications


1)


2)


3)

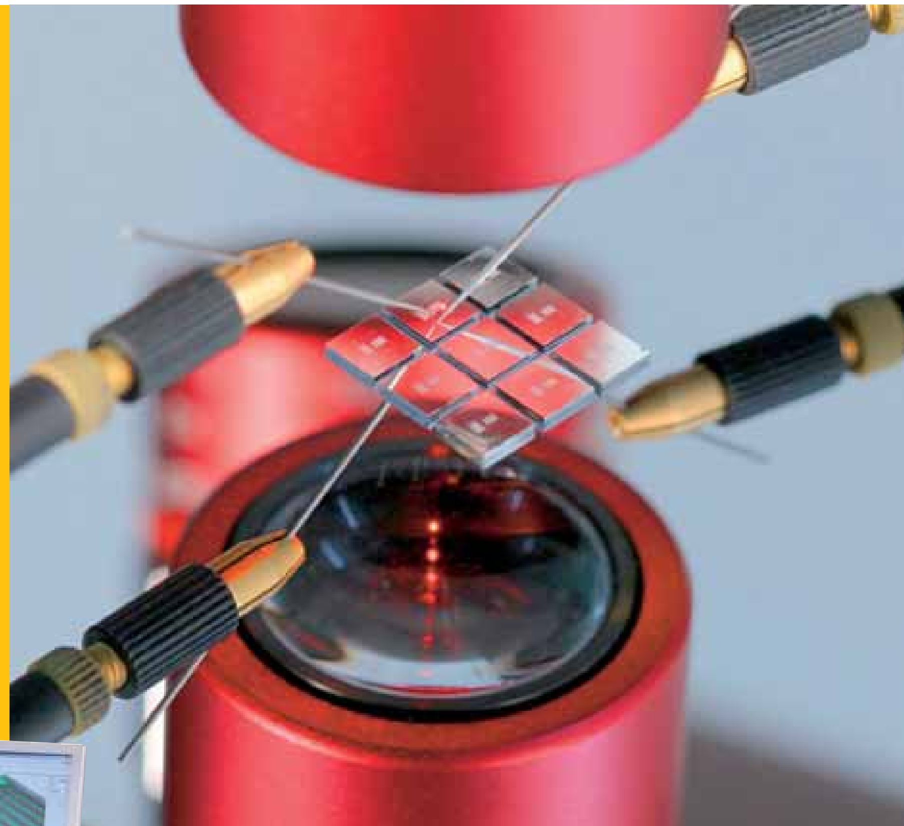
In-plane motion (1) and vibration spectrum (Bode plot) (2) of a MEMS comb drive (3)

MEMS torsional actuator (Sandia)

MEMS mass sensor (UCSB)

The System and its Parts

The MSA-500 Micro System Analyzer can be configured to cover many operating modes and measurement ranges needed to characterize microstructures. The configurations table (page 14) helps to match the appropriate system with the application.



MSA-500 Processing Unit mounted in A-CAB-BAS System Cabinet

Flexible and Upgradeable Configurations

Polytec provides systems for either single-task or combined measurements. For out-of-plane vibration measurements, the system can be configured for either single beam or differential operation. Differential systems can perform both single and differential beam measurements. In addition to the standard 1 MHz version, there is a 24 MHz option which features both high frequency data acquisition and a high frequency wave form generator. The main advantage of the MSA-500 is the “three-in-one“ solution. However, if a feature is not needed, the MSA can be delivered as “two-in-one“ or even as singular version. Singular and “two-in-one“ systems can be upgraded later to add new capabilities when needed (see figure on page 13).

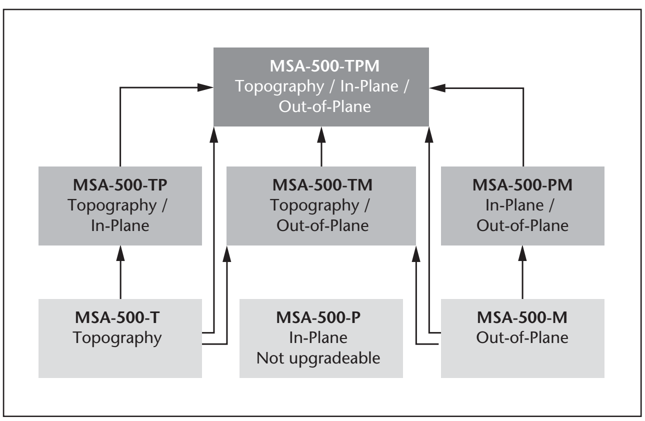
Positioning Equipment and Accessories

The MSA-500 Sensor Head can be mounted to either a stand provided by Polytec or to a commercially available probe station. Polytec stands are available with vibration isolated workstations or can be installed on user supplied optical tables. Please see page 17 for stands provided by Polytec and page 15 for dimensions of the Sensor Head.

An automated X-Y translation stage enables sequential measurements of objects that are larger in size than the respective measurement field. The measurement data can be easily combined into one single data set (stitching).

The MSA electronics can be mounted in a convenient 19'' System Cabinet that houses the Vibrometer Controller, Data Management System, Junction Box and cabling. System Cabinets keep the electronic components separated from the work surface to reduce the influence of ambient noise on the test specimen.

Different types of focus blocks are provided for Z adjustment of the measurement head relative to the measurement sample. A 50 mm focus block is included in all systems.



MSA-500 Micro Motion Analyzer mounted on the A-STD-TAB Workstation

MSA-500 Micro System Analyzer and MEMS/Wafer Probe Stations

The mounting holes of the MSA-500 are equivalent to a Mitutoyo FS70-L-S (short base) back plate. Thus, it can be attached to most of the commercially available probe stations which have the same array of mounting holes. Furthermore, by using a special long-focal length lens, the MSA can even be integrated with a vacuum, pressure or temperature chamber.

For more information about accessories, please see the technical specifications (page 17) or contact your local Polytec sales/application engineer.

Configurations

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Model	Measurement Modes				
	Out-of-Plane Vibration			In-Plane Motion	Topography
	Single Beam	Differential	24 MHz		
MSA-500-M2	•				
MSA-500-M2-D	•	•			
MSA-500-M2-20	•		•		
MSA-500-M2-20-D	•	•	•		
MSA-500-P				•	
MSA-500-PM2	•			•	
MSA-500-PM2-D	•	•		•	
MSA-500-PM2-20	•		•	•	
MSA-500-PM2-20-D	•	•	•	•	
MSA-500-T					•
MSA-500-TM2	•				•
MSA-500-TM2-D	•	•			•
MSA-500-TM2-20	•		•		•
MSA-500-TM2-20-D	•	•	•		•
MSA-500-TP				•	•
MSA-500-TPM2	•			•	•
MSA-500-TPM2-D	•	•		•	•
MSA-500-TPM2-20	•		•	•	•
MSA-500-TPM2-20-D	•	•	•	•	•

Technical Data

Compliance with Standards	
Electrical safety	IEC/EN 61010-1:2002-08
EMC	IEC/EN 61326-1:2006-10; Emission: Limit Class A, IEC/EN 61000-3-2 and 61000-3-3 Immunity: IEC/EN 61000-4-2 to 61000-4-6 and IEC/EN 61000-4-11
Laser safety	IEC/EN 60825-1:2003-10 (CFR 1040.10, CFR 1040.11)

System Components

Housing and Power			
Component [(1)]	MSA-I-500 Sensor Head	MSA-E-500 Junction Box	MSA-W-402 Data Management System
Power	via MSA-E-500 Junction Box	100 VAC … 240 VAC ±10%, 50/60 Hz; max. 60 W	100 VAC … 240 VAC ±10%, 50/60 Hz; max. 350 W
Dimensions [W x L x H]	See figure	450 mm x 360 mm x 150 mm (17.7 in x 14.2 in x 5.9 in)	450 mm x 550 mm x 190 mm (17.7 in x 21.7 in x 7.5 in)
Weight	10.4 kg (22.9 lbs)	~8 kg (~17.6 lbs)	~18 kg (~39.7 lbs)
Operating temperature	+5 °C … +40 °C (41 °F … 104 °F)		
Storage temperature	–10 °C … +65 °C (14 °F … 149 °F)		
Relative humidity	Max. 80%, non-condensing		

[(1)] OFV-5000 Vibrometer Controller and OFV-551/552 Fiber-Optic Interferometers are also needed for out-of-plane measurements: see separate data sheets availabe on www.polytec.com/vibrometers

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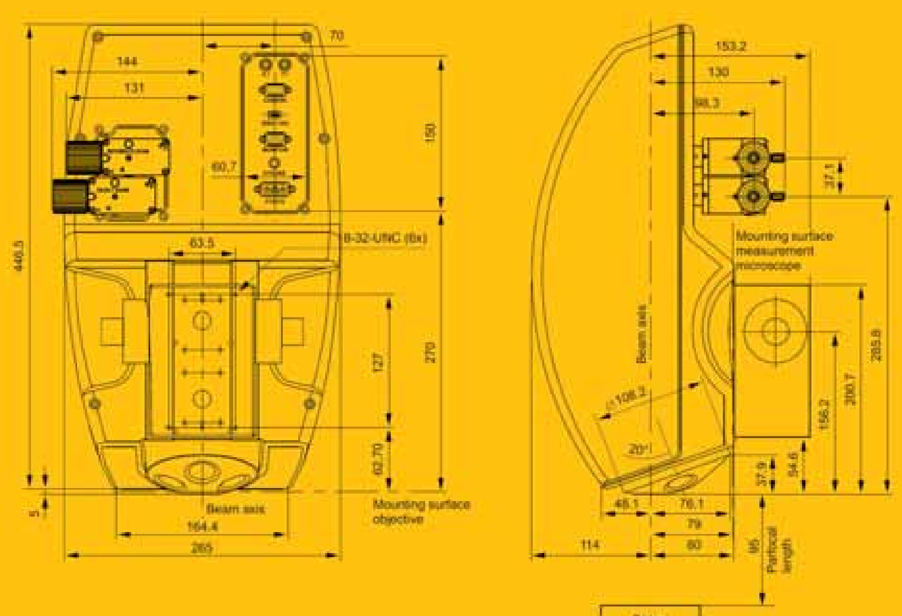
MSA-O-500 Optical Units	
MSA-O-500-P MSA-O-500-TP [1]	Measurement Microscope Head with video stroboscopic video system for in-plane motion analysis
MSA-O-500-S MSA-O-500-TS [1]	Measurement Microscope Head with one pair of scanning mirrors for scanning vibrometer measurements and video stroboscope system for in-plane motion analysis
	OFV-551 Fiber-Optic Interferometer (see separate data sheet)
MSA-O-500-D MSA-O-500-TD [1]	Measurement Microscope Head with video stroboscope system for in-plane motion analysis and two pairs of scanning mirrors: One for scanning vibrometer measurements and one for the stationary reference beam. The reference beam is positioned using 2 controls on the front panel.
	OFV-552 Dual-Fiber Interferometer with reference mirror (see separate data sheet)

All versions include a turret equipped with a long stand-off objective lens with 10X magnification.
[1] For topography measurements, equipped with an additional piezo-objective positioning stage and interference objective

OFV-5000 Vibrometer Controller			
Version	Standard Configurations	High Frequency Configurations MSA-500-…-M2-20	
	MSA-500-…-M2 (1 MHz)	HF Velocity	HF Displacement
Decoder combination (please see decoder data sheets for details)	VD-09: Wide-bandwidth velocity decoder VD-06: High precision digital velocity decoder	VD-09: Wide-bandwidth velocity decoder VD-05: 10 MHz velocity decoder	VD-09: Wide-bandwidth velocity decoder DD-300: 24 MHz displacement decoder

For alternative decoder configurations please contact your Polytec sales engineer.



System Components

MSA-500 Optics	
Camera	Progressive scan camera, 1.4 Mpixel (1392 x 1040), IEEE 1394 FireWire interface
Light source	Long-lifetime LED, 525 nm wavelength, coherence length ~8 µm
Laser safety class [1]	Class 2 (<1 mW visible output)
Beam diameter [1]	(FWHM) ~0.9 µm (with 50X objective lens)
Scanner [1]	Regulated double piezo scanner, resolution: 512 x 512 points within field of view
Piezo [2]	Piezo-objective translation stage; travel range: max. 250 µm
Parfocal distance	95 mm

Bright Field Objectives for Vibration Measurements [3]					
Objective	**Magnification**	**Stand-off distance[4] (mm)**	**Field of view (mm x mm)**	**Pixel resolution (µm)**	**Vertical resolution (MSAGeo)[5] (µm)**
Standard	10X	≥33.5	0.90 x 0.67	0.645	0.500
Optional					
	2X	34	4.5 x 3.35	3.23	[6]
	2.5X	32.5	3.6 x 2.7	2.58	[6]
	3.6X	53	2.5 x 1.86	1.79	3.100
	5X	≥34	1.8 x 1.34	1.29	1.500
	10X (long distance)[7]	48.9	0.90 x 0.67	0.645	[6]
	20X	≥20	0.45 x 0.335	0.322	0.125
	50X	≥13	0.18 x 0.134	0.129	0.030
	100X	≥6	0.09 x 0.067	0.064	0.025

Objectives for Topography Measurements [2]					
Objective	**Magnification**	**Stand-off distance[4] (mm)**	**Field of view (mm x mm)**	**Pixel resolution (µm)**	**Numeric aperture NA[8]**
Standard (Mirau)	10X	7.4	0.90 x 0.67	0.645	0.30
Optional					
Michelson objectives	2.5X	10.3	3.59 x 2.68	2.58	0.075
	4X	>30	2.24 x 1.68	1.61	0.1
	5X	9.3	1.8 x 1.34	1.29	0.13
Mirau objectives	20X	4.7	0.45 x 0.335	0.323	0.40
	50X	3.7	0.18 x 0.134	0.129	0.55
	100X	2.0	0.09 x 0.067	0.065	0.7

(1) Only systems including scanning vibrometer
(2) Only systems including topography measurement
(3) Only systems including scanning vibrometer and/or in-plane motion measurement
(4) The stand-off distance results from the parfocal length (95 mm) minus the length of the objective mounted. For the exact values please ask you local Polytec sales/application engineer.
(5) Vertical resolution during geometry measurement with MSAGeo Option. Standard deviation (root mean square = RMS) of the measurement values of 169 measurement points, measured on a plane plate
(6) Not recommended
(7) For the long distance objective, the parfocal distance is 135 mm. The front window can be removed in order to measure e.g. through a vacuum prober window of 6 mm thickness
(8) Optical resolution can be calculated by 0.61· λ/aperture = 0.32 / (aperture [µm])

MSA-E-500 Junction Box	
Functions	– Connects Vibrometer Controller and Data Management System – Provides piezo driver for scanner, amplifier for excitation signals and current-source output for Piezo Focus control – Includes microscope strobe controller for generating the LED strobe signal and synchronization with the excitation signal of the structure
Digital interfaces	RS-232, USB, and Focus Control
Input signals	±200 mV… ±10 V analog inputs for vibrometer and reference signal, TTL inputs for trigger and gate [1]
Output signals	Analog voltage outputs for specimen excitation, TTL outputs SYNC and AUX (output for special applications, programmable)
Excitation booster	Built-in amplifier, differential output, 10 V / 50 mA peak amplitude

(1) not for 24 MHz configurations

MSA-W-402 Data Management System		
Computer	Industrial PC, min. Intel Core 2, 2.8 GHz, 4 GB RAM, 700 GB HDD	
Graphics	High end graphics board	
ADC/generator boards	See separate section below	
IEEE 1394 FireWire adapter	For acquisition of the video signal from the progressive scan camera (see Optics section, page 12)	
Data link	Ethernet LAN	
Operating system	Microsoft Windows® XP (Windows® Vista 64-bit on request)	
Hardware for Out-of-Plane Data Acquisition		
Version	Standard Configurations MSA-500-…-M2	High Frequency Configurations MSA-500-…-M2-20
Input channels	2 (4, with PSV-S-VDD option)	2
Resolution	effective 12...16 bit (depending on bandwidth)	12 bit
Input voltage range	±200 mV ... ±10 V	±200 mV ... ±10 V
Trigger	External or analog, pre- and post-trigger	External or analog, pre- and post-trigger
Gate	Additional input for gated measurements	–
FFT frequency range	DC ... 1 MHz; DC ... 2 MHz (optional)	DC … 40 MHz
Specimen excitation	Internal signal generator, up to 40 MHz, output voltage max. ±10 V with adjustable offset	
Hardware for In-Plane Data Acquisition		
Camera	Progressive scan camera, 1.4 Mpixel (1392 x 1040), IEEE 1394 FireWire interface	
Strobe generation	Pattern generator board for producing strobe pulses for the object illumination	
Specimen excitation	Internal signal generator, up to 1 MHz, output voltage max. ±10 V with adjustable offset	

For performance and resolution see Performance Specifications section on page 14.

Optional Accessories		
A-STD-BAS **Base Stand**	Base Stand for installation on optical tables. Dimensions: 342 mm x 430 mm x 350 mm (13.5 in x 16.9 in x 13.8 in) Weight: ~8 kg (~17.6 lbs)	
A-STD-BBO **Standard Stand**	Standard Stand with passive or active vibration damping. Available with metric or inch hole-patterns. Dimensions: 500 mm x 750 mm x 590 mm (19.7 in x 29.5 in x 23.2 in) Weight: ~70 kg (~154 lbs)	
A-STD-TAB **Workstation**	Includes the stand, monitor arm, BNC connectors and active air vibration damping. Available with metric or inch hole-patterns. Dimensions: 900 mm x 900 mm x 1325 mm (35.4 in x 35.4 in x 52.2 in) Desk top height: 910 mm (35.8 in) Weight: ~175 kg (~386 lbs) Compressed air supply: 6.5 bar … 12 bar; flow rate: max. 1120 l/min	
A-CAB-BAS **System Cabinet** **A-CAB-EXT** **System Cabinet Extension**	19’’ housing for the Data Management System, Vibrometer Controller and Junction Box. Slides under the A-STD-TAB. Dimensions: 555 mm x 630 mm x 555 mm (21.9 in x 24.8 in x 21.9 in) Weight: ~65 kg (~143 lbs) A-CAB-EXT Extension (right): convenient stand alone solution. Provides additional workspace for equipment separated from the optical table.	

Performance Specifications

Out-of-Plane Measurements				
Version	Standard Configurations MSA-500-…-M2		HF Configurations MSA-500-…-M2-20	
	Standard	with PSV-S-VDD [1]	HF Velocity	HF Displacement
Max. vibration frequency	1 MHz (2 MHz) [2]	2 MHz	10 MHz	24 MHz
Max. displacement	–	arbitrary	–	±75 nm
Displacement resolution	–	<0.4 pm/√Hz	–	<0.1 pm/√Hz [3]
Max. vibration peak velocity	up to ±10 m/s, depending on decoder and decoder configuration			
Velocity resolution (rms) [4]	<1 µm/s			

[1] With PSV-S-VDD digital demodulation (optional)

[2] With PSV-S-BW2M bandwidth extension (optional)

[3] At 100% reflectivity

[4] The resolution limits of the OFV-5000 Vibrometer Controller are changed in conjunction with the vibrometer scanner
The resolution is defined as the root mean square of the signal amplitude (rms) at which the signal-to-noise ratio is 0 dB in a 10 Hz spectral bandwidth (RBW).

In-Plane Measurements						
Vibration frequency range	1 Hz … 1 MHz					
Maximum velocity	> 0.1 m/s … 10 m/s (magnification dependent)					
In-plane amplitude and resolution performance:						
Microscope magnification	5X	10X	20X	40X	50X	100X
Max. peak-to-peak motion amplitude @ 2 kHz	1795 µm	897 µm	448 µm	224 µm	179 µm	89 µm
Displacement amplitude resolution [1]	1 nm					
Time resolution	100 ns (strobe exposure time); max. strobe jitter ±40 ns					
Uncertainty of phase angle	±0.0144° @ 1 kHz; ±0.144° @ 10 kHz; ±1.44° @ 100 kHz; ±14.4° @ 1 MHz					
System output	Displacement data, Bode diagram, step-response plots, ring-down plots, trajectory plots					

[1] Frequency noise floor for 512 shots per frequency (15 nm rms) on a vibration isolated table

Topography Measurements				
Z Dynamic range	250 µm (piezo objective translation stage)			
Measurement performance				
Sampling increment	10 nm		87 nm	
Evaluation procedure [1]	Smooth surface	Rough surface	Smooth surface	Rough surface
Resolution (RMS) [2]	35 pm	350 pm	45 pm	1.2 nm
$\text{Resolution}_{single}$ (RMS)	195 pm	3.65 nm	300 pm	14 nm
Repeatability [3]	250 pm	2.5 nm	500 pm	20 nm
Average flatness deviation [4]	550 pm	7.5 nm	2 nm	50 nm
Measurement performance on a traceable calibrated standard (PTB Type A1 (ISO 5436-1)				
Repeatability [5]				0.07%
Expanded uncertainty of measurement [6]				0.35%
Measurement time				
Calculation	Measurement time = (Z range + 6 µm) / (sampling increment x frame rate)			
Examples [7]	~1.2 min (10 nm sampling increment)		~8 s (87 nm sampling increment)	

[1] "Smooth surface": Evaluation of the correlogram phase. "Rough surface": Evaluation of the correlogram envelope

[2] Root mean square (RMS) of the signal amplitude at an averaging number of 50 measurements on a silver coated, parallel aligned plane mirror, measured under vibration-damped, temperature controlled conditions. Values for $\text{Resolution}_{single}$ correspond to single measurements

[3] Standard deviation of the measured flatness in a series of 100 measurements on a parallel plate (λ/20) slightly tilted

[4] Mean value of the flatness (according to ISO 1101), see [3]

[5] RMS deviation of 30 step height measurements, referred to a calibrated step height of nominal 50 µm

[6] 3x combined standard uncertainty + deviation of the nominal value at 30 consecutive measurements under repeating conditions. The combined standard uncertainty is the quadratic mean out of the uncertainty of the normal and the standard deviation of the measurement values.

[7] Conditions: Z range 15 µm, frame rate 30/s, without averaging

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Software Features

Out-of-Plane Measurements	
Data Acquisition	
Video display	Live, full field, black & white video image of test object directly incorporated into user interface for interactive scan set up and beam positioning. Digital zoom into live video image.
Laser positioning	Visible laser moves with cursor on live video image by clicking or dragging the mouse.
Defining scan geometry	Utilizing APS Professional mode for up to 512 x 512 points per object, of any shape. Measurement points are defined graphically over the live video image using a mouse. User can draw individual objects using polar, cartesian or hexagonal grids, or define single points. Define single points (optional): Single point geometry can be optimized by refining or coarsening the grid. Automatic generation of surface elements to connect scan points.
Scan geometry acquisition	Direct geometry scan data acquisition for the vibration measurement with MSAGeo Geometry Scan Option. Geometry import from UFF or ME'scope format.
Laser focusing	With MSAGeo option; automatic focusing of the laser at the current position of the specimen or during the scan; allowing for an optimized signal level at every scan position.
Sample positioning	Interactive control of X-Y positioning stage (optional) by using the mouse and absolute or relative displacements by precisely defined distances. Measurements at different positions can be acquired separately and combined for analysis and presentation.
Vibrometer control	All vibrometer parameters such as velocity range and tracking filter are software controlled via RS-232 interface.
Display	Simultaneous display of live video showing actual laser spot, entire scan area including scan points, and multiple analyzer displays of various signals (time traces and spectra).
Specimen excitation	Wide range of waveforms including sine, periodic chirp, white noise, random signals, sweep and arbitrary signals.
Acquired scan data	Entire spectrum acquired for all channels at all scan points.
FastScan	Fast acquisition mode (up to 50 points/s) for measurements at a single frequency. Bandwidth is definable. Complex and magnitude averaging and signal enhancement are available.
Time domain data (optional)	Time domain acquisition, time domain averaging, time domain animation.
Gate input	Gate input for intermittent scan control.
Scan data validity check	Data quality check at all scanned points in Signal Enhancement (SE) mode. MSA-500 checks the quality of data in each spectrum. The averaged spectrum is weighted toward those spectra with the best signal to noise ratio. Measured points are labeled: optimal (SE only), valid, or A/D overload.
Trigger	Auto or manual threshold, rising or falling edge, source: external or any measurement signal
Averaging	Complex or magnitude averaging of spectra, peak hold, time
Overlap FFT	Up to 75% for reduced averaging time
FFT lines	6,400 standard; 12,800 optional; 819,200 optional; Zoom FFT optional
Window functions	Rectangular, Hamming, Hanning, Flat top, Blackman Harris, Bartlett, Exponential
Data Processing and Analysis	
Data organisation	Support for project oriented workflow by a tree-style file browser for measurements, settings, macros, user defined waveforms, amplitude correction files. Context based actions on different file types.
Display	Color/gray, filled/unfilled contours and 3-D relief maps over stored video image (static or animated), averaged spectra over all scan points, individual spectra at each point as Bode or Nyquist plots, line profiles. Animation of video image for easy visualization of results. Data are scaled in velocity, acceleration or displacement. Logarithmic/linear axes
Data transfer	ASCII, Universal File Format (UFF), ME'scope binary data interface (optional). UFF and ME'scope data can be imported, analyzed and processed as user defined datasets and combined with measured data.
Graphics transfer	Graphic formats AVI (for animations), JPEG, BMP, TIFF, PNG, GIF.
Data processing	Complex spectral analysis provides the following quantities and functions for area and/or single-point data: magnitude, magnitude dB(A), phase, real, imaginary, frequency response function (FRF), H_1, H_2, auto power, cross power, coherence, averaged RMS over frequency. 3rd octave analysis, ESD, PSD.
Polytec Signal Processor	Integrated tool for signal processing in Presentation Mode with MS Excel-like usability.
Automated processing	Software can be fully automated.

Software Features

In-Plane Measurements	
Data Acquisition	
Working principle	In the Acquisition Mode, video sequences are sampled and analyzed using proprietary measurement algorithms.
Strobe illumination control	Control of the strobe pulses (interval, pulse length).
Data acquisition	Acquisition of the stroboscopic video image via FireWire interface and live view of object movement.
Specimen excitation	Integrated signal generator software for specimen excitation with sine and pulse signals with excitation frequencies up to 1 MHz. Support for arbitrary, user-provided excitation signals.

In-Plane Measurements	
Data Processing and Analysis	
Working principle	Motion analysis is performed interactively. Motion data based on pixel deviations are extracted and displayed as X, Y displacement values. Sub-pixel resolution enables motion measurements in the nanometer range.
Data organization	Support for project oriented workflow by a tree-style file browser for measurements and settings.
Live video display	The live video mode provides a steady, slow-motion image sequence of the test object's motion for visual characterization.
Display	– Displacements for individual frequencies and their differentiations as well as frequency spectrums – Bode plots for both – horizontal and vertical – motion can be viewed in a variety of different ways – All graphs can be examined using cursors, zoomed and panned. For each graph, different line and marker styles are selectable.
Data transfer	Graphs can be exported as image or ASCII file and sequences of images can be saved as AVI files.

Topography Measurements	
Data Acquisition	
Working principle	By shifting an interference objective with respect to the sample, a high resolution X-Y-Z mapping is generated. The interference pattern is captured with the video camera.
Measurement modes	– Short coherent measurement, measurement with envelope or with phase shift – Overlay technique for extended contrast range; individual Visual C# macros
Data acquisition	Acquisition of the video image via FireWire interface
Data Processing and Analysis	
Data organization	Support for project oriented workflow by a tree-style file browser for measurements and settings.
Post processing	Envelope or phase evaluation
Data evaluation	Linear regression; polynomial fit; subtracting; averaging; filters like median, erosion, high pass and low pass filter; masking functions
Data display	– Surface view: 2-D, 3-D presentation and isolines view, with video overlay – Profile view: profile sections; correlogram; roughness/waviness parameters; graphs/diagrams, geometrical data like angle, heights, radius etc.
Data transfer	Graphs can be exported in various common image graphic formats; measurement data can be exported as ASCII file.
Automated processing	Software can be fully automated.

Call or e-mail your local Polytec sales/application engineer for the latest information. Please see the address list for contact details.

More info: www.polytec.com/microsystems

You can also order your free Demo DVD on the Micro System Analyzer

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