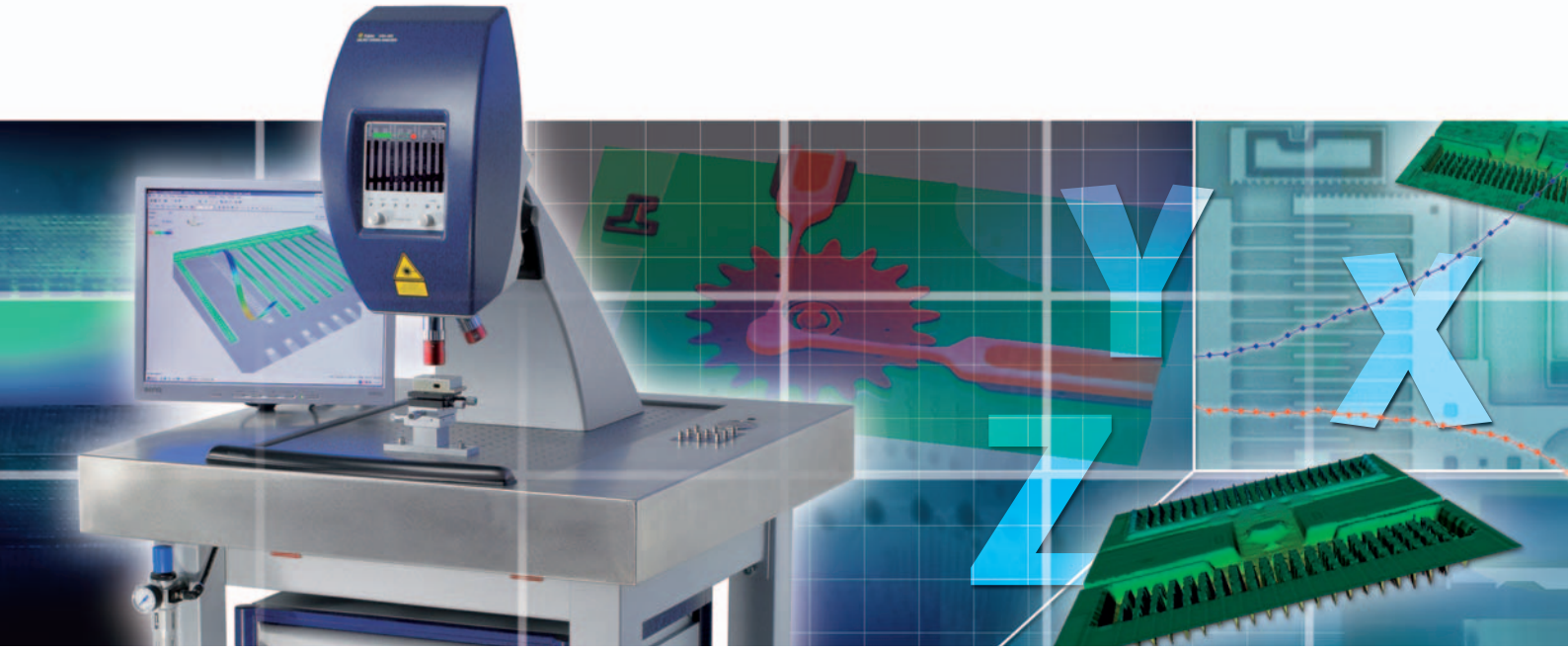
Polytec

MSA-400 Micro System Analyzer

Measuring 3-D MEMS Dynamics and Topography



Scanning Laser-Doppler Vibrometry
Stroboscopic Video Microscopy
White Light Interferometry
All-in-One Integration

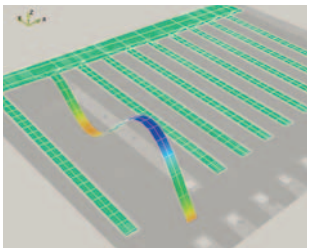
Complete 3-D Characterization

Measuring 3-D MEMS Dynamics and Topography

The MSA-400 Micro System Analyzer is the premier measurement technology for the analysis and visualization of structural vibrations and surface topography in micro structures such as MEMS (Micro-Electro-Mechanical Systems) devices. By fully integrating a microscope with Scanning Laser-Doppler Vibrometry, Stroboscopic Video Microscopy and White Light Interferometry, the MSA-400 is designed with an all-in-one combination of technologies that clarifies real microstructural response and topography. Incorporated in the MEMS design and test cycle, the MSA-400 provides precise 3-D dynamic and static response data that simplifies troubleshooting, enhances and shortens design cycles, improves yield and performance, and reduces product cost.

Non-Contact Measurements on Microstructures

The MSA-400 Micro System Analyzer series was developed expressly for dynamic and static analysis of microstructures such as MEMS (or MOEMS) devices. These devices find numerous applications in the automotive, medical, bio-chemical and aeronautic industries. As a consequence of this wide spread usage, standardized MEMS testing is essential for both packaged and unpackaged devices (single die and wafer-level testing). For wafer-level testing, the MSA-400 can easily be mounted onto manual or fully automated probe stations.

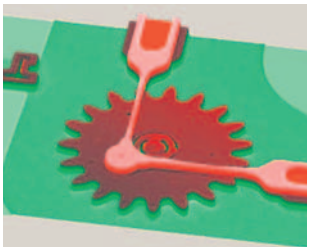


Characterize Out-of-Plane Vibrations

By Scanning Laser-Doppler Vibrometry

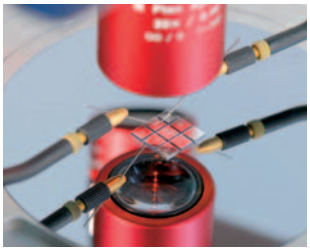
Measure In-Plane Motion and Vibration

By Stroboscopic Video Microscopy



Determine Surface Topography

By White Light Interferometry



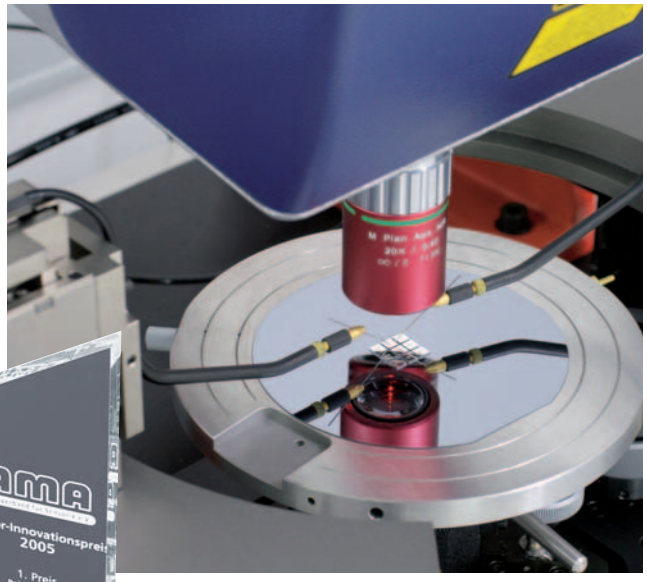
Test Wafers and Individual Die

By Combining Polytec's MSA-400 with a MEMS Probe Station

CONTENTS

For more info visit
www.polytec.com/int/microsystems

The All-in-One Solution



Polytec's Award-Winning Micro System Analyzer

The MSA-400 Micro System Analyzer uses 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; and white light interferometry for high resolution topography. These technologies are integrated into a compact, robust and reliable all-in-one measurement head. This outstanding degree of innovation has been recognized by the 2005 Sensor Innovation Award, following the Photonics Circle of Excellence Award for the development of microscope scanning vibrometry.

Superior Dynamic Characterization Compared to Single Technology Solutions

The combination of two complementary measurement techniques for investigating the vibrational behavior of small structures provides superior performance. For example, it can quickly identify, visualize and measure system resonances and transient responses, enhancing overall measurement productivity. This improved efficiency is especially important when integrating the measurement system into automated processes for MEMS production environments. Single technology solutions like ESPI, white light interferometry, and phase shifting interferometry give a much more limited view of small structure response.

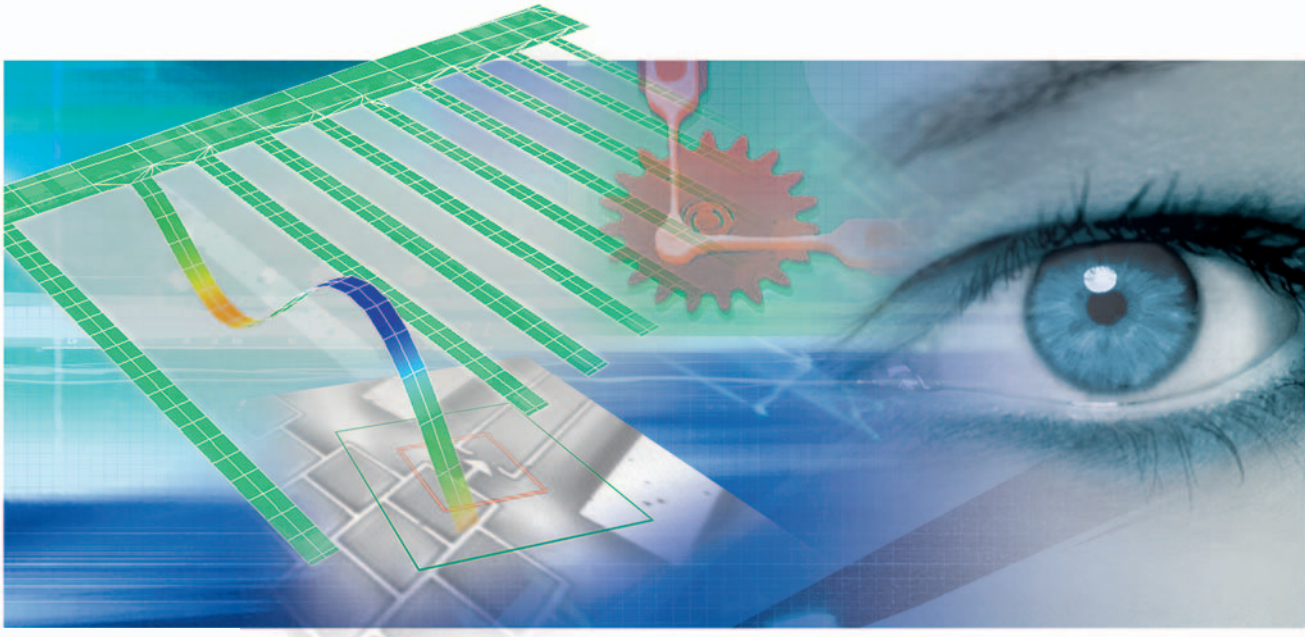
Finds All Mechanical Resonances Without A-Priori Information

Using wide-band excitation, the highly sensitive Laser-Doppler technique can rapidly find all mechanical resonances (in-plane and out-of-plane) without a-priori information (for details please see page 7; a pure machine vision system could only measure at user-defined, discrete frequency points with single-frequency excitation). 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.

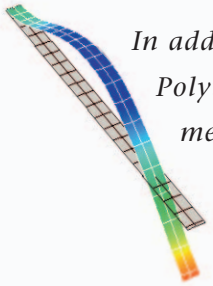
Convincing Benefits

- 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, measurement ready within minutes
- Increased productivity through short measurement cycle
- Accelerates product development, troubleshooting and time-to-market

Superior Integration of Technologies



In addition to its unique capability to measure MEMS and micro system dynamics, Polytec's MSA-400 Micro System Analyzer can also perform high resolution topography measurements on MEMS and micro-components.



Scanning Laser-Doppler Vibrometry for the Measurement of Out-of-Plane Vibrations

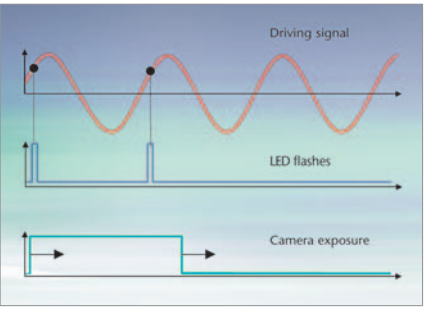
Instrumental in the development of resonant micro-electromechanical systems, the Laser-Doppler Vibrometer (LDV) is a very precise optical transducer for determining the vibration velocity and displacement at a sample point. It works by sensing the frequency shift of back scattered light from a moving surface.
To learn more about laser-Doppler vibrometry, please visit **www.polytec.com/int/vib-university.**

By moving the measurement point to predefined positions, a Scanning LDV provides the full picture of a device's out-of-plane vibrational behavior. There are no discrete frequencies at which measurements must be performed. Instead, frequency data over the instrument's bandwidth is available within milliseconds per sample point. Vibrometry enables the analysis of non-ideal or non-linear systems. Other unique features include the ability to make direct differential measurements between two sample points, to acquire data with picometer displacement resolution and to capture frequency response up to 20 MHz. The intuitive PSV 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 FRF (frequency response function) and ODS (operational deflection shape) 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.

See pages 14 and 15 for more details.

Features & Benefits

- Full-field vibration mapping and broadband, out-of-plane frequency response information
- Displays frequency-domain and time-domain data, simplifying transient response analysis
- High density sample grids with up to 512 x 512 user-defined measurement points
- Versatile data import and export interfaces to validate FE models
- Submicron laser probe spot for measuring very small structures and details
- Laser dimmer for optimized measurement conditions



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 moving objects can be sharply frozen in time to capture the objects' exact position. Short light pulses synchronized with the objects motion capture the position at precise phase angles. 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 an 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. Once set, these multi-band measurements are processed automatically around the selected resonances.

See pages 14 and 15 for more details.

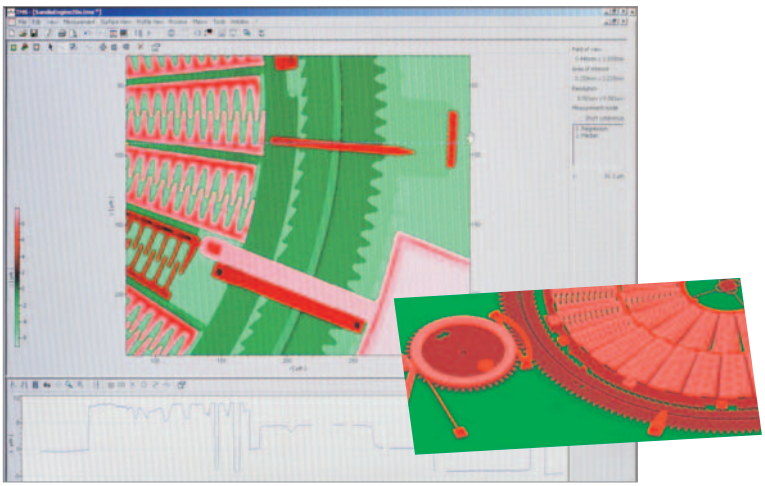
Features & Benefits

- Stroboscopic video measurement of in-plane motion with frequencies up to 1 MHz
- Time-domain displacement measurements with nanometer resolution
- Integrated signal generator for step response, ring down and Bode plot measurements
- Time-saving, automatic multi-band processing

White Light Interferometry for the Acquisition of Topography Data

Dynamic MEMS performance is directly linked to the production process parameters that determine the device geometry. With an integrated topography system, the MSA-400 does the full job. A data set with a high spatial resolution and precise Z values for all points is fed into a powerful analysis tool to determine shape, curvature, flatness and roughness. By shifting an interference objective with nanometer precision with respect to the sample, a high resolution X-Y-Z mapping is generated. The objective focuses the interference pattern on to the camera. The user can select the type of data processing, like envelope or phase evaluation, as well as various filtering and masking techniques. For even more capabilities the complementary TMS Report Software package is available.

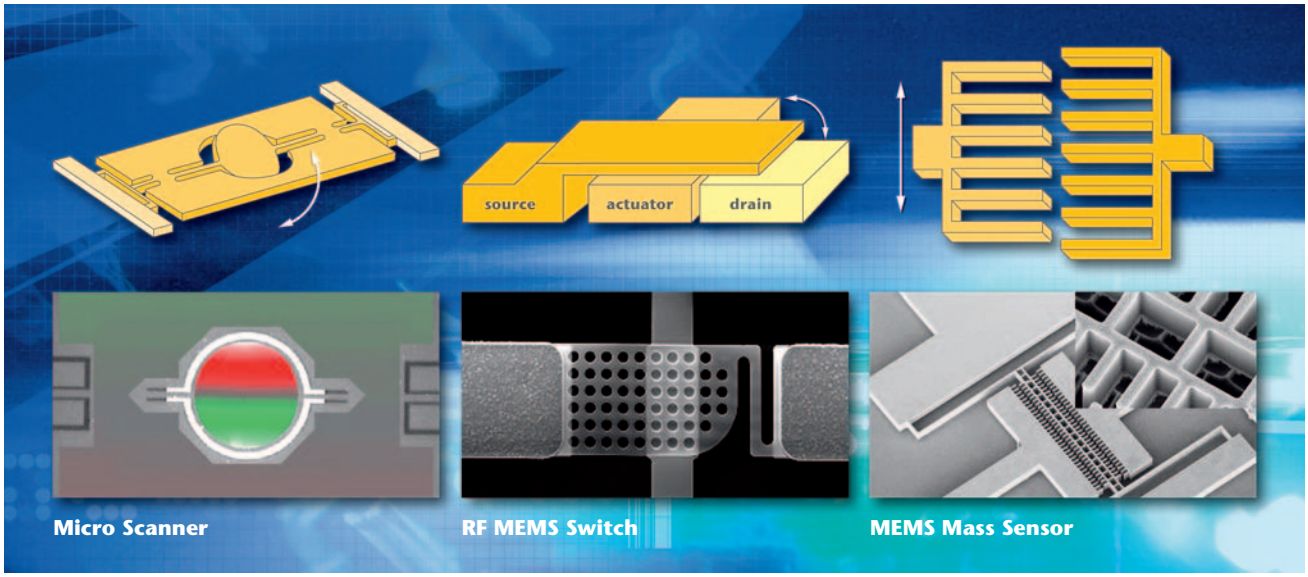
See pages 14 and 16 for performance details.



Features & Benefits

- Rapid, non-contact 3-D topography measurement with sub-nanometer resolution
- Determination of structure heights and shape on both rough and specular surfaces
- Overlay technique copes with different contrast levels and material mixes
- Powerful TMS software for topography and surface characterization
- 2-D and 3-D presentation with video overlay

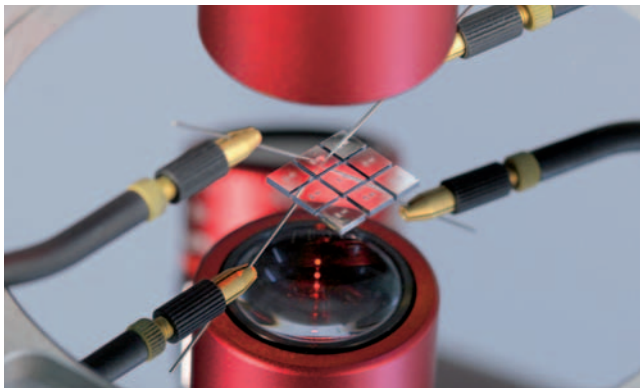
Successful MEMS Applications



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

Application Examples

Many MEMS devices have moving parts which may be measured with a MSA-400 Micro System Analyzer. Some candidate devices are accelerometers, gyroscopes, RF MEMS, optical network components (MOEMS), micro mirrors and video displays.



Useful for MEMS design, development, troubleshooting and production testing, the MSA-400 Micro System Analyzer provides data for

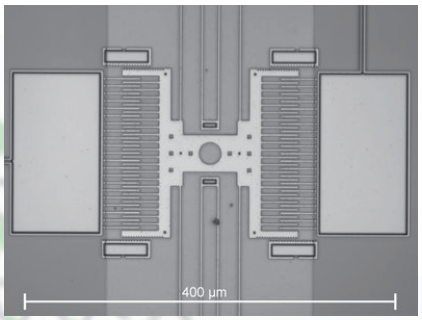
- Characterizing out-of-plane and in-plane motion of MEMS devices
- Continuous frequency domain measurements for device performance analysis
- Microstructure failure analysis and reliability testing
- Testing and refining of simulation models
- Transient behavior analysis using time-domain
- Identification of in-plane resonances through out-of-plane coupling
- Step response and ring down measurements to determine actuator settling times
- Wafer-level MEMS motion analysis using a probe station
- Bode plot graphs and analysis

Measurements on a MEMS Comb Drive

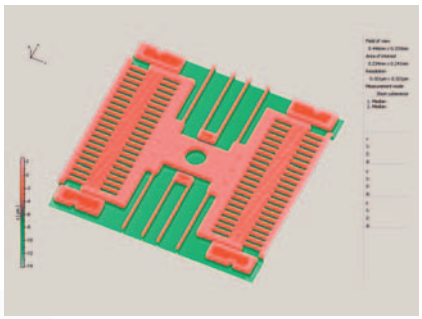
Electrostatic comb drives are actuators where two interdigitated comb structures can be moved together or apart by applying voltage to either of the two comb electrodes. Although the drive is designed for in-plane motion, the amount of residual out-of-plane motion is easily measured by laser vibrometry, giving a measure of the success of the design and manufacturing processes.

The comb drive shown in Figure A was examined first using the MSA-400's scanning white light interferometer. The geometry data output is presented in Figure B. Then the out-of-plane vibration measurements were made using the laser-Doppler vibrometer mode (Figure C, out-of-plane vibration spectrum; Figure D, out-of-plane deflection shape). The real-time measurement capability allows any suitable broadband waveform source to drive the device.

Focusing on the resonance frequency determined by laser vibrometry, in-plane measurements were made on the same comb drive using the stroboscopic system. An in-plane vibration spectrum (Bode plot) can be determined from stepped sine measurements (Figure E), and the motion can be visualized as a continuous video (screenshot in Figure F).



A



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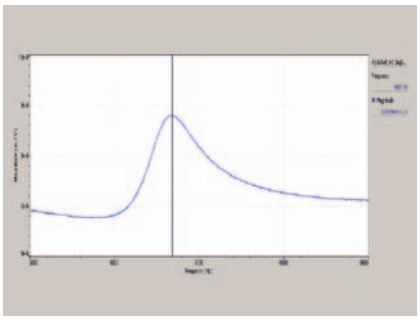

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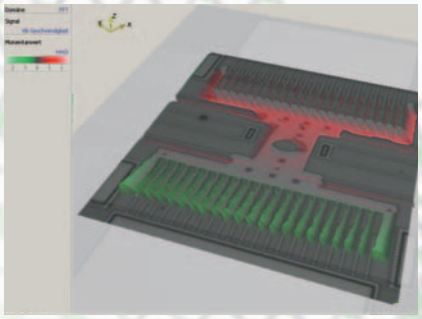

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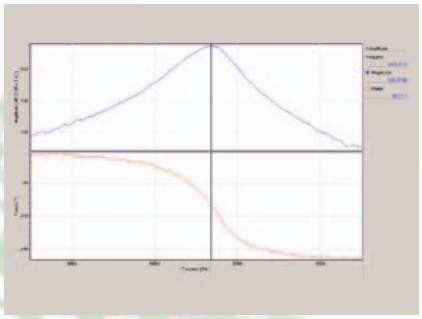
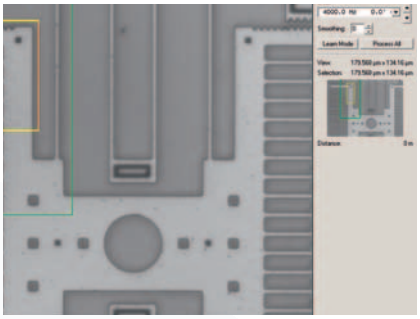


E



F

For more information and application examples please visit www.polytec.com/int/microsystems

The System and its Parts

The MSA-400 system is configured to optimally meet the data measurement requirements of your application. The system comprises an Optical Unit and a Processing Unit including the Data Management System (DMS), Junction Box and MSA Software. For out-of-plane vibration measurements a Fiber Interferometer and a Vibrometer Controller are added.

Components of MSA Optical Unit

The MSA Optical Unit is offered in six configurations which allow individual or combined in-plane measurements, out-of-plane measurements or topography measurements. Depending on system type, the optical unit comprises the MSA-400 measurement microscope head with microscope optics as well as a single point (Polytec OFV-551) or differential (Polytec OFV-552) fiber-optic interferometer.

In all configurations, the MSA-400 Sensor Head has optimized microscope optics, an integrated LED illumination unit and a progressive scan video camera which provides a live video stream for the DMS.

MSA-400 Sensor Head on MSA-A-450 Standard Stand

When performing in-plane measurements, the LED unit is used for stroboscopic illumination of the device, allowing video acquisition of high frequency motions. For topography measurements, the LED provides illumination for the interference objective and the Z-stage provides scanning to enable white light interferometry to measure the surface profile.

In configurations needing out-of-plane capability, the setup is supplemented with fiber connectors for the interferometer, beamsplitters, and scanning units with ultra-precise piezo stages for scanning the laser beams through the microscope's optics. The laser is moved, not the object. A steady, live video image during the whole measurement is the benefit.

MSA-400 Processing Unit mounted in MSA-A-010 System Cabinet

Components of MSA Processing Unit

The MSA-400 Processing Unit comprises the Data Management System with MSA Software, the MSA-E-401 Junction Box and, in system configurations that include vibrometry, the Polytec OFV-5000 Vibrometer Controller.

The MSA Software comprises the different programs for data acquisition and evaluation:

- Polytec Scanning Vibrometer (PSV) Software for out-of-plane measurements offers quick and easy setups, simple data acquisition and outstanding 3-D data visualization.
- Planar Motion Analysis (PMA) Software similarly controls the in-plane measurement process and provides a dynamic visualization.
- Topography Measurement System (TMS) Software for data acquisition, analysis, 2-D and 3-D data representation including profile cuts.

Please see pages 11 – 16 for more details

Positioning Equipment and Accessories

The MSA-400 Sensor Head can be mounted to 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 13 for stands provided by Polytec and page 11 for dimensions of the Sensor Head.

The MSA Processing Unit can be mounted in the convenient 19'' MSA-A-010 System Cabinet that houses the Vibrometer Controller, Data Management System, Junction Box and cabling, or likewise in the MSA-A-020 System Cabinet Extension. Both versions 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 object.

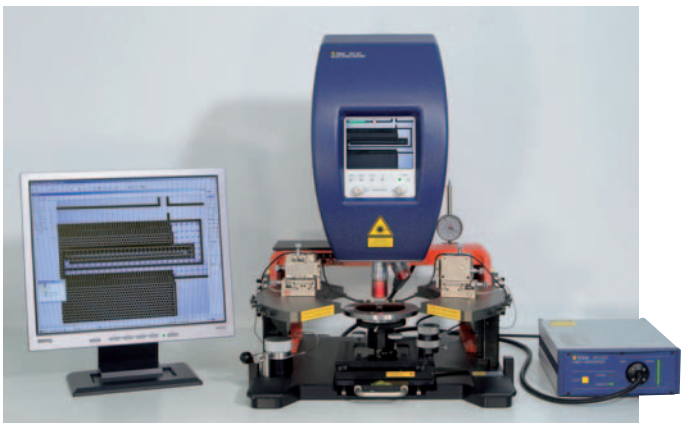
For more information about accessories, please contact your local Polytec sales/application engineer.

MSA-400 Micro Motion Analyzer mounted on the MSA-A-460 Workstation

MSA-400 Micro System Analyzer and MEMS/Wafer Probe Stations

The mounting holes of the MSA-400 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. Please ask your Polytec sales/application engineer for details.



Configurations

The MSA-400 Micro System Analyzer can be configured to cover many operating modes and measurement ranges needed to characterize microstructures. The following table helps to match the appropriate system to the application. 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 1.5 MHz version, there is a 20 MHz option which features both high frequency data acquisition and a high frequency wave form generator.

Model	Measurement Modes				
	Out-of-Plane Vibration			In-Plane Motion	Topography
	Single Beam	Differential	20 MHz		
MSA-400-M2	•				
MSA-400-M2-D	•	•			
MSA-400-M2-20	•		•		
MSA-400-M2-20-D	•	•	•		
MSA-400-P				•	
MSA-400-PM2	•			•	
MSA-400-PM2-D	•	•		•	
MSA-400-PM2-20	•		•	•	
MSA-400-PM2-20-D	•	•	•	•	
MSA-400-T					•
MSA-400-TM2	•				•
MSA-400-TM2-D	•	•			•
MSA-400-TM2-20	•		•		•
MSA-400-TM2-20-D	•	•	•		•
MSA-400-TP				•	•
MSA-400-TPM2	•			•	•
MSA-400-TPM2-D	•	•		•	•
MSA-400-TPM2-20	•		•	•	•
MSA-400-TPM2-20-D	•	•	•	•	•

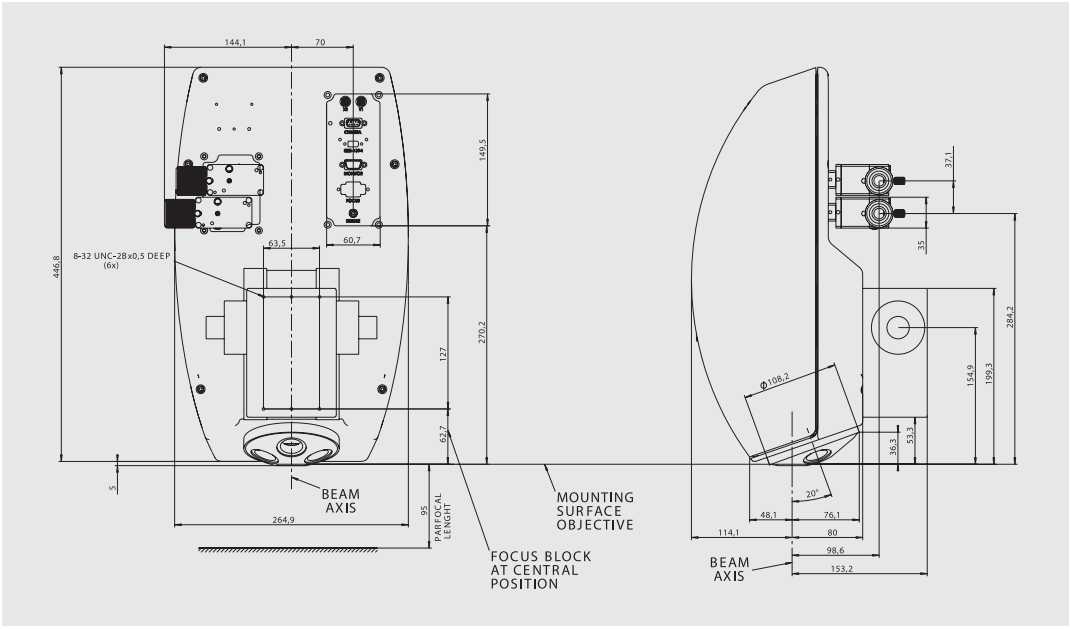
Technical Data

Compliance with Standards	
Electrical safety	IEC/EN 61010
EMC	IEC/EN 61326; Emission: FCC 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 (CFR 1040.10, CFR 1040.11)

System Components

Housing and Power			
Component [1]	MSA-I-400 Sensor Head	MSA-E-401 Junction Box	MSA-W-400 Data Management System
Power	via MSA-E-401 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 355 mm x 135 mm (17.7 in x 14.0 in x 5.3 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/int/LM-download



MSA-O-400 Optical Units	
MSA-O-400-P MSA-O-400-TP [1]	Measurement Microscope Head with video stroboscope system for in-plane motion analysis
MSA-O-400-S MSA-O-400-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-400-D MSA-O-400-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 standoff objective lens with 10X magnification.

[1] For topography measurements, equipped with an additional piezo-objective positioning stage and interference objective

System Components

Optics				
Camera	Progressive scan camera, 1.4 Mpixel (1392 x 1040), IEEE 1394 FireWire interface			
Light source	LED, 770 nm, coherence length 12 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			
Objectives for Vibration Measurements [3]				
	Magnification	Working distance (mm)	Field of view (µm x µm)	Optical resolution (µm)
MSA-A-M10X	10X	30.5	900 x 670	1.6
Optional objectives				
MSA-A-M2X	2X	34.0	4500 x 3350	8.5
MSA-A-M5X	5X	37.5	1800 x 1340	3.6
MSA-A-M20X	20X	20.0	450 x 335	1.2
MSA-A-M50X	50X	17.0	180 x 134	0.85
Objectives for Topography Measurements [2]				
	Magnification	Working distance (mm)	Field of view (µm x µm)	Optical resolution (µm)
MSA-A-I10X	10X	7.40	900 x 670	1.6
Optional objectives				
MSA-A-I2.5X	2.5X	10.3	3590 x 2630	6.3
MSA-A-I5X	5X	9.30	1800 x 1340	3.6
MSA-A-I20X	20X	4.70	450 x 335	1.2
MSA-A-I50X	50X	3.70	180 x 134	0.85

[1] Only systems including scanning vibrometer

[2] Only systems including topography measurement

[3] Only systems including scanning vibrometer and/or in-plane motion measurement

OFV-5000 Vibrometer Controller			
Version	Standard Configurations MSA-400-…-M2 (1.5 MHz)	High Frequency Configurations MSA-400-…-M2-20	
		HF Velocity	HF Displacement
Decoder configuration (please see decoder data sheets for details)	VD-02: Wide-bandwidth velocity decoder VD-06: High precision digital velocity decoder	VD-02: Wide-bandwidth velocity decoder VD-05: 10 MHz velocity decoder	VD-02: Wide-bandwidth velocity decoder DD-300: 20 MHz displacement decoder

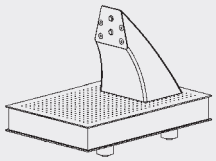
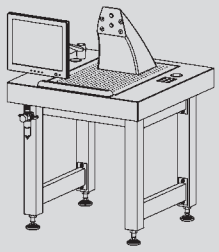
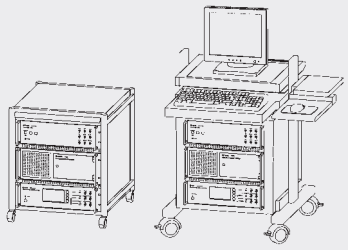
For performance and resolution see Performance Specifications section on page 14.

MSA-E-401 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 20 MHz configurations

MSA-W-400 Data Management System		
Computer	Industrial PC, min. AMD Athlon™ XP3000+, 2,6 GHz, 1 GB RAM, 160 GB HDD	
Data backup/storage	Combined DVD (8X) and CD (32x) recorder and storage	
Live video board	High end graphics board with VIVO	
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® 2000 on request)	
Hardware for Out-of-Plane Data Acquisition		
Version	Standard Configurations MSA-400-…-M2	High Frequency Configurations MSA-400-…-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 2 MHz, output voltage max. ±10 V with adjustable offset	

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

Optional Accessories		
MSA-A-440 **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)	
MSA-A-450 **Standard Stand**	Standard Stand with passive air 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)	
MSA-A-460 **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	
MSA-A-010 **System Cabinet** **MSA-A-020** **System Cabinet Extension**	19'' housing for the Data Management System, Vibrometer Controller and Junction Box. Slides under the MSA-A-460. Dimensions: 555 mm x 630 mm x 555 mm (21.9 inx 24.8 in x 21.9 in) Weight: ~65 kg (~143 lbs) MSA-A-020 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-400-…-M2		HF Configurations MSA-400-…-M2-20	
	Standard	with PSV-S-VDD [1]	HF Velocity	HF Displacement
Max. vibration frequency	1.5 MHz (2 MHz) [2]	2 MHz	10 MHz	20 MHz
Max. displacement	–	arbitrary	–	± 75 nm
Displacement resolution	–	<0.4 pm/√Hz	–	<0.1 pm/√Hz [3]
Max. vibration peak velocity	± 10 m/s			
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), measured on 3M Scotchlite Tape™ (reflective film).

In-Plane Measurements						
Vibration frequency range	0.001 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 resolution [1]	1 nm					
Time resolution	100 ns (strobe exposure time); max. strobe jitter ±40 ns					
Precision of phase	0.16 mrad (0.009°) @ 1 kHz; 0.016 rad (0.9°) @ 100 kHz; 0.16 rad (9°) @ 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 [1]				
Sampling step size	10 nm		130 nm	
Evaluation procedure	Phase evaluation	Envelope evaluation	Phase evaluation	Envelope evaluation
Resolution (rms) [2]	28 pm	525 pm	50 pm	1.95 nm
$\text{Resolution}_{\text{single}}$ (rms) [2]	195 pm	3.65 nm	300 pm	14 nm
Repeatability [3]	175 pm	4 nm	300 pm	15 nm
Reproducibility [4]	300 pm	5 nm	2 nm	20 nm
Accuracy [5]	0.9 nm	16 nm	2.9 nm	62 nm
Measurement performance on a traceable calibrated standard [6]				
Repeatability (rms deviation of 20 step height measurements)				0.03 %
Accuracy (average deviation from calibrated step height + 3 x repeatability)				0.25 %
Measurement time				
Calculation	Measurement time = (Z range + 20 µm) / (sampling step size x frame rate)			
Examples [7]	~2 min		~10 s	

[1] Determined on a flat silver plated mirror, using a vibration-isolated table

[2] Root mean square (rms) of the signal amplitude at an averaging number of 50. $\text{Resolution}_{\text{single}}$ values correspond to single measurements

[3] Repeatability = max. peak-to-peak value of the difference between two subsequent measurements after applying noise filter

[4] Reproducibility = peak-to-peak amplitude of the residual waviness measured with slightly inclined mirror

[5] Accuracy = reproducibility + 3 x $\text{resolution}_{\text{single}}$

[6] Traceable calibrated PTB depth setting standard Type A1 (ISO 5436-1), sampling step size 130 nm, step height 50 µm

[7] Conditions: Z range 20 µm, frame rate 30/s, without averaging

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. Any object may be moved or stretched while grouped or ungrouped with other objects.
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
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-400 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; Zoom FFT optional
Window functions	Rectangular, Hamming, Hanning, Flat top, Blackman Harris, Bartlett, Exponential
Data Processing and Analysis	
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, ME'scope binary data interface (optional)
Graphics transfer	More than 20 different graphic formats (AVI, JPEG, BMP, TIFF...)
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
Polytec Signal Processor	Integrated tool for signal processing in Presentation Mode with MS Excel-like usability
Automated processing	Software can be fully automated via Visual Basic® compatible scripting.

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

Software Features

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.
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 (optional) – Overlay technique for extended contrast range; individual Visual Basic® macros
Data acquisition	Acquisition of the video image via FireWire interface
Data Processing and Analysis	
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, parallelism, 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 via Visual Basic® compatible scripting.

Polytec's Modular Vibrometer Family

Measuring vibration vectors in one, two or three dimensions, on either microscopic or macroscopic scale? For all types of vibration measurement tasks there is a customized solution with Polytec Vibrometers. All systems are based on the superior OFV-5000 Vibrometer Controller, a choice of powerful signal decoders, and high-performance sensor heads. Hence, modules can be changed and the systems can be upgraded to meet new measurement requirements.

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