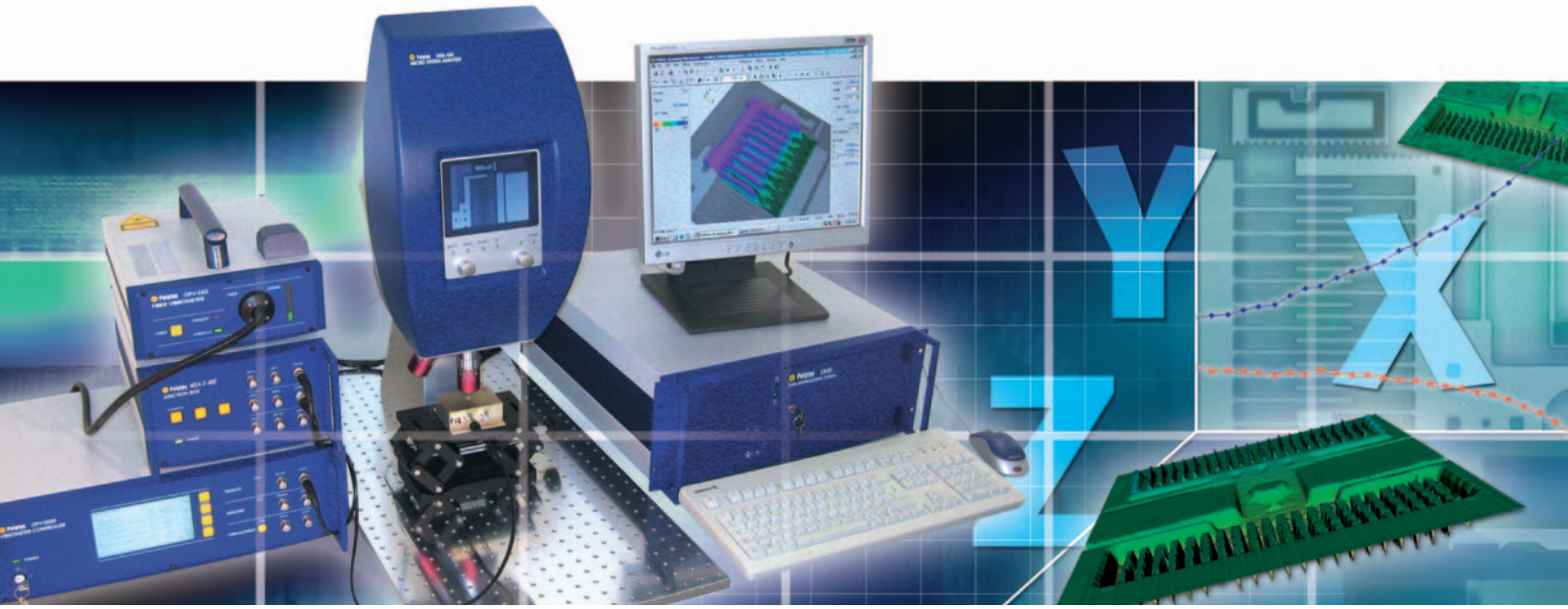
Polytec

MSA-400 Micro System Analyzer



Measuring 3-D
Micro Motions

Measuring 3-D Micro Motions

The MSA-400 Micro System Analyzer is a powerful new tool for precise 3-D dynamic characterization of MEMS and MOEMS microstructures. By fully integrating a microscope with delivery optics for Scanning Laser-Doppler Vibrometry and Stroboscopic Video Microscopy, the MSA increases displacement sensitivity, provides a diffraction-limited laser spot and reduces spurious reflections. This optimal system for micro motion analysis opens the world of microstructures to a clearer understanding.

A Superior Integration of Measurement Technologies

The MSA-400 Micro System Analyzer finds and measures resonances of micro mechanical structures moving in all three dimensions. The MSA-400 integrates Laser-Doppler Vibrometry (LDV) for the fast broadband out-of-plane (OOP) vibrational characterization and Stroboscopic Video Microscopy for the in-plane (IP) examination of MEMS devices in one compact, robust and reliable all-in-one measurement head.

The combination of these two complementary measurement techniques for investigating the vibrational behavior of small structures provides superior performance compared to single-technology solutions like ESPI, white light interferometry or phase shifting interferometry. The quick measurement cycle for identifying, measuring and visualizing system resonances and for measuring transient processes allows a greatly enhanced productivity in comparison to those alternative approaches. This is especially important when integrating the measurement system into automated processes as in MEMS production environments.

The highly sensitive Laser-Doppler technique is used to find all mechanical resonances rapidly without a-priori information about the device using wide-band excitation (a pure machine vision system can 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 the resonances found with the Vibrometer technique.

Facilitates MEMS Vibration and Motion Analysis

The MSA-400 Micro System Analyzer series was developed expressly for the vibrational analysis of MEMS (Micro-Electro-Mechanical Systems) devices and other microstructures. These devices find numerous applications in the automotive, medical, bio-chemical and aeronautic industry. As a consequence there is a huge demand for standardized MEMS testing for both packaged and unpackaged devices (single die and wafer-level testing).

Polytec's MSA-400 is the ideal tool for a quick and accurate motion analysis of MEMS devices. For wafer-level testing, the MSA-400 can easily be mounted onto manual or fully automated probe stations.

Benefits of Laser-Doppler Vibrometry

Laser-Doppler Vibrometry (LDV) provides the full picture of a device's out-of-plane vibrational behavior. There are no discrete frequencies at which measurements have to be performed. Instead, frequency data over the continuous bandwidth is available within milliseconds per sample point. LDV enables the analysis of non-ideal or non-linear systems.

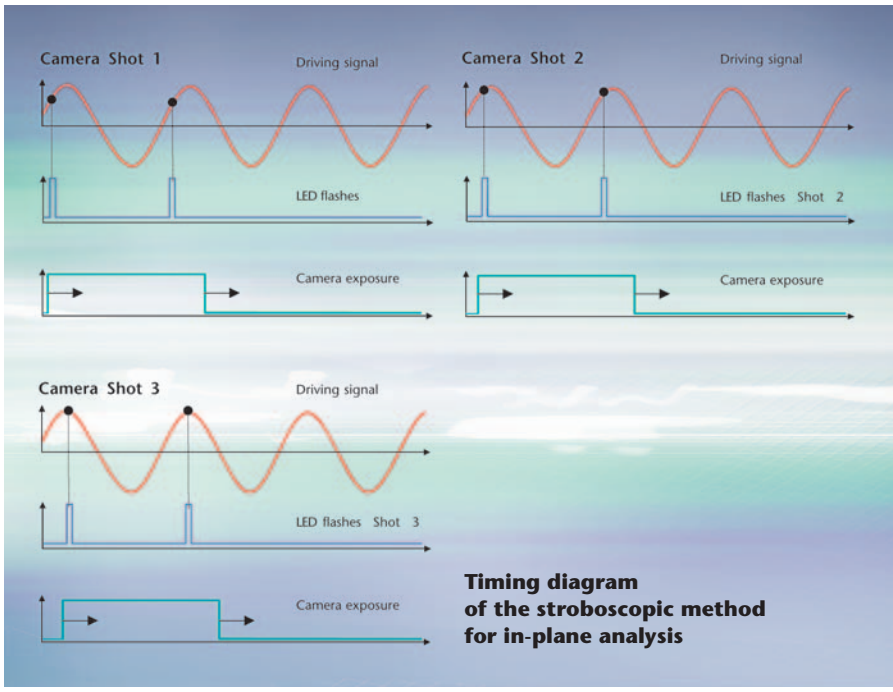
Other unique features include the opportunity to make direct differential measurements between two locations, acquire data with picometer displacement resolution and at frequencies up to 20 MHz.

Benefits

- Increased productivity through short measurement cycle
- Very fast identification and visualization of all OOP and IP system resonances
- Integrated microscope optics with optimized optical path for best lateral resolution and highest image quality
- Simple and intuitive operation, measurement ready within minutes
- Easy integration in MEMS probe stations

Features

- Measures in-plane (IP) and out-of-plane (OOP) motions of micro structures
- Displays frequency and time domain data
- On-line live-video monitoring of the measurement processes, no distracting fringes in the video image
- Measurement probe uses sub micron laser spot (e.g. 0.7 µm for 50X lens)
- Scripting control for automation
- Out-of-plane motion:
  - FFT spectrum within milliseconds
  - 0 Hz to 1 MHz, standard
  - 0 Hz to 20 MHz, optional
  - Analysis of transient processes
  - Picometer resolution
  - Resolution magnification independent
- In-plane motion:
  - 0.001 Hz to 2 MHz
  - Various analysis modes like Bode plots and displacement-over-time plots
  - Standard export formats for measurement data, graphics and animations

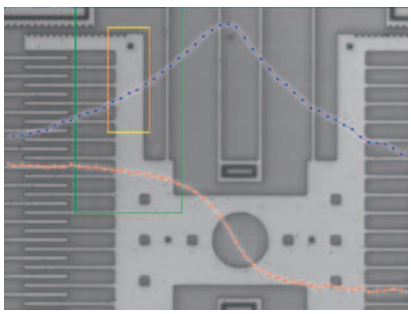


Timing diagram of the stroboscopic method for in-plane analysis

Combined with Stroboscopic Video Microscopy

A stroboscopic technique is applied to measure precisely the high frequency in-plane motions of the device under test. 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 at phase angle increments, the motion of a moving object can be sampled and reconstructed. Ordinary video techniques can not be used since fast moving objects will produce blur patterns based on their motion.



Courtesy Sandia National Laboratories

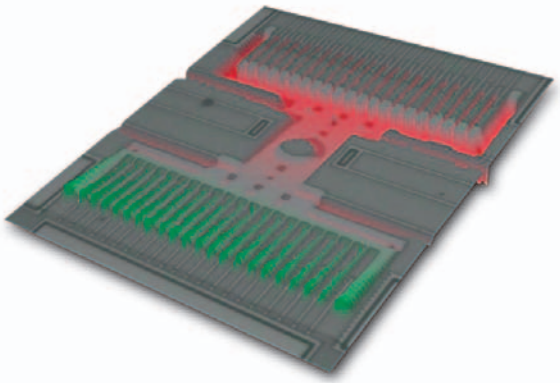
The System

The internal signal generator periodically excites the component with a sine or a pulse signal. A so-called "pattern generator" uses a LED to generate ultra-short flashes of light (< 50 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. The power of the LED generally allows sufficient illumination with only a few flashes. This procedure guarantees a high degree of measurement accuracy and a visual real-time analysis in live mode.

Applications

- Vibration and general out-of-plane and in-plane motion measurement of MEMS
- Continuous frequency domain measurements for device performance analysis
- Microstructure failure analysis and reliability testing
- Measurements of transient behavior using time mode
- Identification of in-plane resonances through out-of-plane coupling
- Ring down measurements to determine actuator settling times
- Wafer-level MEMS motion testing using probe station
- Measurement of Bode plots



MSA-400 – The System

The MSA system comprises an optical part (MSA Optical Unit with microscope optics, fiber interferometer) and the MSA Processing Unit (Data Management System with software, junction box, vibrometer controller).

Components of MSA Optical Unit

The MSA Optical Unit depends on the overall system configuration and is offered in three different variants which either allow exclusively in-plane measurements, out-of-plane measurements combined with in-plane or differential out-of-plane measurements combined with in-plane. Depending on system type the Optical Unit comprises the MSA Measurement Microscope Head with included microscope optics as well as a single point (Polytec OFV-551) or differential (Polytec OFV-552) fiber-optic interferometer.

In all configurations the MSA Measurement Microscope Head is made up of the optimized microscope optics with an integrated LED illumination unit and a progressive scan video camera which provides a live video stream for the DMS. When performing in-plane measurements the LED unit is used for the stroboscopic illumination of the device, thus allowing to acquire video data of high frequency motions.

In the configurations with 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.

Components of MSA Processing Unit

As in the case of the MSA Optical unit the MSA Processing Unit depends on the overall system configuration and comprises the Data Management System with software, the MSA-E-400 junction box and, in case of the OOP system configurations, the Polytec OFV-5000 Vibrometer Controller.

Accessories

Positioning equipment

MSA-400 is compatible with most of the major probe stations. For a stand-alone operation a range of stands with vibration isolated tables or for subsequent installation on optical tables are provided. Please see page 12 for illustrations of the different stands provided by Polytec. 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 a probe station with the same mounting holes (e.g. SUSS MicroTec, Micromanipulator, etc; please ask your Polytec representative for details) or to a stand provided by Polytec.

Different types of focus blocks are provided for z-adjustment of the measurement head relative to the measurement object.

Configurations

MSA-400 System Configurations			
Package	**Description**	**Processing Unit**	**Optical Unit**
MSA-400-P	Planar Motion Analysis	MSA-P-400-P	MSA-O-400-P
MSA-400-M2	Scanning Vibrometer Standard Configuration, Bandwidth 1 MHz, 2 MHz optional	MSA-P-400-M2	MSA-O-400-S
MSA-400-M2-D	Differential Scanning Vibrometer Dual-fiber Configuration, Bandwidth 1 MHz, 2 MHz optional	MSA-P-400-M2	MSA-O-400-D
MSA-400-M2-20	20 MHz Scanning Vibrometer HF Configuration, Bandwidth 20 MHz	MSA-P-400-M2-20	MSA-O-400-S
MSA-400-M2-20-D	Differential 20 MHz Scanning Vibrometer Dual-Fiber HF Configuration, Bandwidth 20 MHz	MSA-P-400-M2-20	MSA-O-400-D
MSA-400-PM2	Scanning Vibrometer and Planar Motion Analysis IP & OOP-Configuration, OOP-Bandwidth 1 MHz, 2 MHz optional	MSA-P-400-PM2	MSA-O-400-S
MSA-400-PM2-D	Differential Scanning Vibrometer and Planar Motion Analysis IP & Dual-fiber OOP-Configuration, OOP-Bandwidth 1 MHz, 2 MHz optional	MSA-P-400-PM2	MSA-O-400-D
MSA-400-PM2-20	20 MHz Scanning Vibrometer and Planar Motion Analysis IP & HF OOP-Configuration, OOP-Bandwidth 20 MHz	MSA-P-400-PM2-20	MSA-O-400-S
MSA-400-PM2-20-D	Differential 20 MHz Scanning Vibrometer and Planar Motion Analysis IP & Dual-fiber HF OOP-Configuration, OOP-Bandwidth 20 MHz	MSA-P-400-PM2-20	MSA-O-400-D

The MSA-400 Micro System Analyzer is available in 9 different system configurations, covering different operating modes and measurement ranges.

Technical Data

Out-of-Plane Measurements	
Laser safety class	Class 2 (<1 mW visible output)
Beam diameter (FWHM)	~ 0.7 µm with 50X microscope lens
Scanners	Closed loop, dual-piezo scan stage
Scanner resolution	512 x 512 points within field of view
Video camera	1.3 Mpixel progressive scan camera, FireWire interface (IEEE 1394)
Scan & Viewing field (nominal)	9 mm x 6.7 mm with 1X lens 1800 µm x 1340 µm with 5X lens 450 µm x 335 µm with 20X lens 180 µm x 134 µm with 50X lens

In-Plane Measurements		
System output	Displacement data Bode diagram Step-response plots	Ring-down plots Trajectory plots
Frequency range	0.001 Hz to 2 MHz	
In-Plane Resolution and Amplitude Performance		
Microscope magnification	Displacement resolution (nm)	Max. peak-to-peak motion amplitude (in-plane, µm) @ 2 kHz
5X	38.7	1795
10X	19.4	897
20X	9.6	448
40X	4.8	224
50X	3.8	179
100X	1.9	89
Strobe exposure time (time resolution)	100 ns	
Max. strobe jitter	± 40 ns	
Precision of phase @1kHz	0.16 mrad (0.009°, resp.)	
Precision of phase @100kHz	0.016 rad (0.9°, resp.)	
Precision of phase @1MHz	0.16 rad (9°, resp.)	
Maximum velocity	> 0.1 m/s to 10 m/s (magnification dependent)	

Technical Data

Optical Units			
MSA-O-400-P	MSA-I-400-P IP Measurement Microscope Head with video stroboscope system for in-plane motion analysis. Including a turret equipped with 3 Mitutoyo long range lenses with 5X, 20X and 50X magnification.		
MSA-O-400-S	MSA-I-400-S IP & OOP Measurement Microscope Head with one pair of scanning mirrors for scanning vibrometer measurements and video stroboscope system for in-plane motion analysis. Including a turret equipped with 3 Mitutoyo long range lenses with 5X, 20X and 50X magnification.		
	OFV-551 Fiber-Optic Interferometer (see separate data sheet)		
MSA-O-400-D	MSA-I-400-D IP & OOP Measurement Microscope Head with 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. Video stroboscope system for in-plane motion analysis. Including a turret equipped with 3 Mitutoyo long range lenses with 5X, 20X and 50X magnification.		
	OFV-552 Dual-Fiber Interferometer with reference mirror (see separate data sheet)		

OFV-5000 Vibrometer Controller			
Decoder configuration	MSA-400-M2 (-D) MSA-400-PM2 (-D)	MSA-400-M2-20 (-D) MSA-400-PM2-20 (-D) Configuration A	MSA-400-M2-20 (-D) MSA-400-PM2-20 (-D) Configuration B
	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
	Please see decoder data sheets for details		
Velocity resolution	up to 0.02 µm s^{-1} √Hz, range and frequency dependent	up to 0.15 µm s^{-1} √Hz, range and frequency dependent	
Displacement resolution	< 0.1 pm/√Hz at 100 % reflectivity (MSA-400-M2 with PSV-S-VDD , MSA-400-M2-20 (B))		
Max. vibration frequency	1.5 MHz (2 MHz with PSV-S-VDD option)	10 MHz	20 MHz
Max. vibration peak velocity	± 10 m/s		
Remote control	Via RS-232 interface		

MSA-E-400 Junction Box	
Functions	– Connects Vibrometer Controller and Data Management System – Provides piezo driver for scanner and amplifier for excitation signals – Includes microscope strobe controller for generating the LED strobe signal and synchronization with the excitation signal of the structure
Input signals	Variable gain 0.1 V ... ± 31.6 V analog inputs for vibrometer and reference signal, TTL inputs for trigger and gate
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

Data Management System	
Computer	Industrial PC with 3.2 GHz CPU (or higher)
RAM	1 GB
Hard drive	120 GB
Data backup and storage	Combined DVD (8X) and CD (32x) recorder
Live video board	High end graphics board with VIVO
Piezo control board	Dual channel 16-bit D/A converter for scanner control
ADC and generator boards	See separate section below
IEEE 1394 FireWire adapter	For acquisition of the video signal from the VCT-101 progressive scan camera
Data link	Ethernet LAN
Operating system	Microsoft Windows XP (Windows 2000 on request)

Data Acquisition	MSA-400-M2, MSA-400-PM2	MSA-400-M2-20, MSA-400-PM2-20
Number of channels	2, simultaneously sampled	
Resolution	12 bits (up to 15 bit due to over sampling, depending on bandwidth)	
Range settings	± 100 mV … ± 31.6 V	± 200 mV … ± 10 V
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	
	Pattern generation board for generation of the strobe pulses for the object illumination	
Waveforms	Wide range of waveforms including sine, periodic chirp, white noise, random signals, sweep and arbitrary signals	

Technical Data

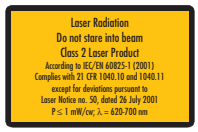
Data Acquisition MSA-400-P	
Specimen excitation	Pattern generation board for generation of the strobe pulses for the object illumination
	DAC waveform generator for excitation of the test device with frequencies up to 2 MHz on board. Output voltage of the generator (amplified in MSA-E-400 Junction Box) maximum ± 10 Volts with adjustable offset voltage.

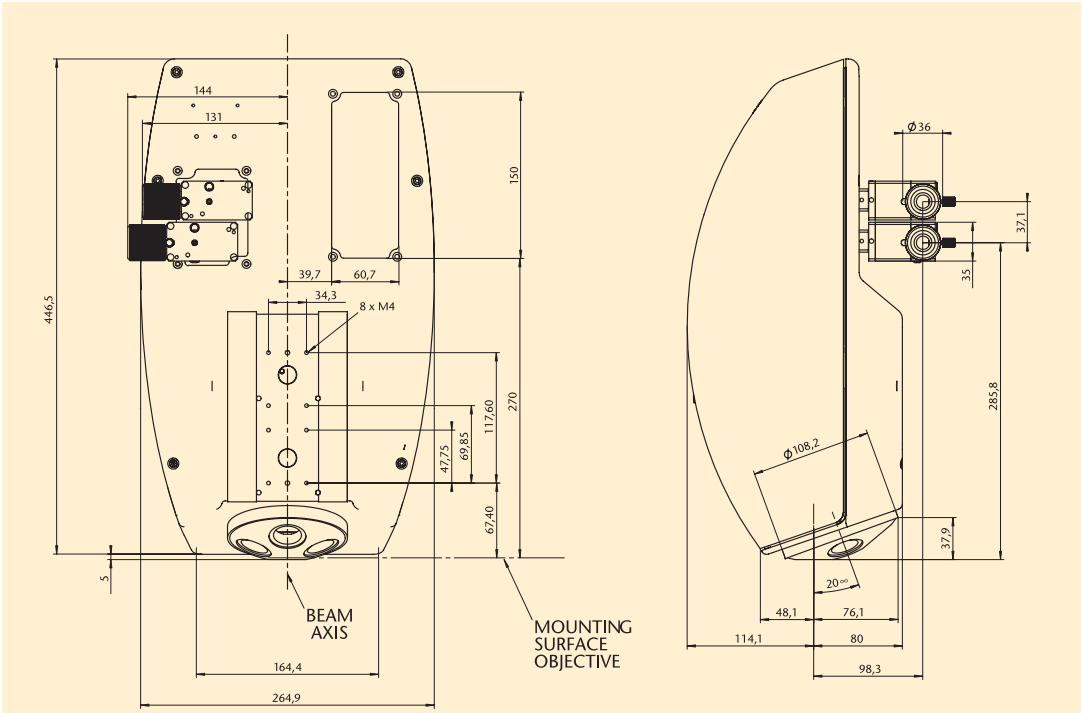
Software: Out-of-Plane Acquisition	
Video display	Live, full-field, black & white video image of test object directly incorporated into user interface for interactive scan set-up and beam positioning. Digital zoom into live video image
Laser positioning	Visible laser moves with cursor on live video image 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
Scan unit control	Laser beam position in the microscope is fully remote controlled via the mouse
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)
Acquired scan data	Entire spectrum acquired for all channels at all scan points
FastScan	Fast acquisition mode (up to 50 pts/s) for measurements at a single frequency. Bandwidth is definable
Time domain data	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

Software: Out-of-Plane Data Processing and Analysis	
Display	Color/gray, filled/unfilled contours and 3D-relief maps over stored CCD 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 (Vibrant)
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 Excel-like usability
Automated Processing	Software can be fully automated via Visual Basic Scripting

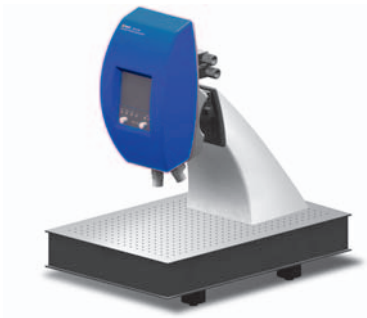
Software: In-Plane Acquisition	
Working principle	In the Acquisition Mode, video sequences are sampled and analyzed using proprietary measurement algorithms
Strobe illumination control	Control of the strobe pulses (interval, pulse length)
Data acquisition	Acquisition of the stroboscopic video image via Fire Wire 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 2 MHz

Software: In-Plane 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 better than 10 nm
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





Dimensions of MSA-I-400
Measurement Microscope



MSA-A-450
MSA on Standard Stand with passive air vibration damping

MSA-A-460
MSA on Workbench with Stand and active vibration damping

	Dimensions	Weight
MSA-A-450	500 mm x 750 mm x 110 mm	70 kg
MSA-A-460	900 mm x 900 mm x 910 mm	160 kg

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