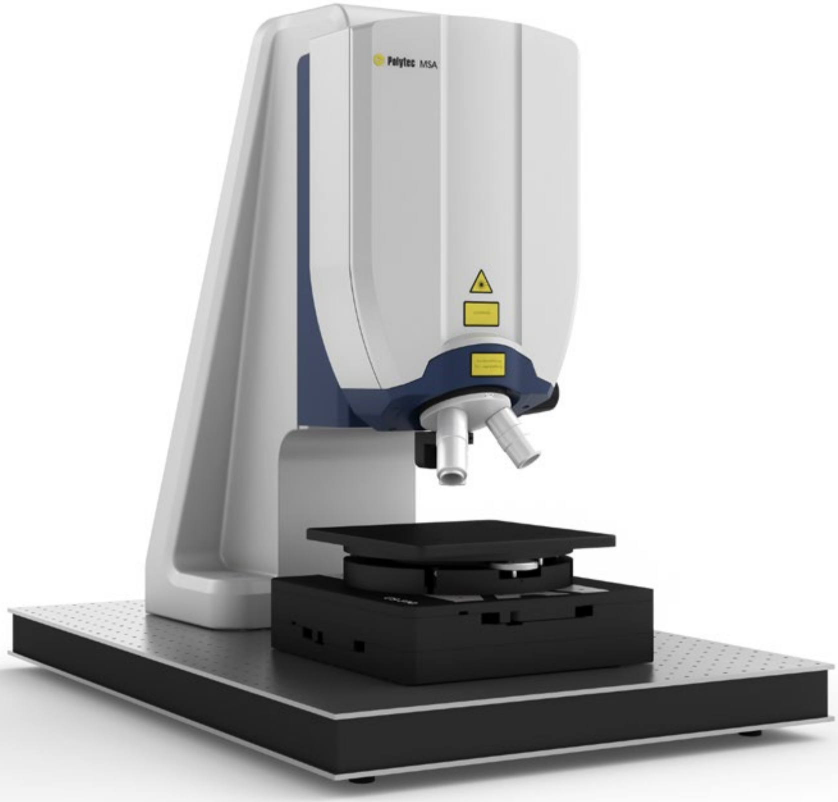
Visualization of dynamic response and static characterization are key to testing and developing MEMS devices. They are indispensable for validating FE calculations, determining cross-talk effects and measuring surface deformation.

The MSA-600 Micro System Analyzer is the all-in-one optical measurement workstation for characterizing surface topography as well as in-plane and out-of-plane motions.

The high-performance laser Doppler vibrometer delivers fast, real-time response measurement with sub-pm displacement resolution. The integrated stroboscopic video microscope enables the straightforward characterization and live-animation of in-plane motion. And the white-light interferometer option provides millions of 3D surface data in seconds.

Complemented by its straightforward operation and intuitive user interface, the MSA-600 is your powerful optical measurement solution in MEMS R&D and QC.



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Highlights

- All-in-one optical measurement workstation
- True real-time response measurements without post-processing
- Unparalleled sub-pm displacement resolution
- Fast measurement and visualization of deflection shapes
- Straightforward and intuitive operation
- Automated system for easy integration into probe stations

MSA-600 Micro System Analyzer

Measuring 3D dynamics and topography of MEMS and microsystems

Preliminary datasheet

Technical data

MSA-600 system configurations	
Basic configuration	Out-of-plane vibration measurement up to 2.5 MHz
Options	
Bandwidth extension	Out-of-plane vibration measurement up to 25 MHz
Differential measurement	Differential out-of-plane measurement
Planar motion analysis	In-plane-motion analysis
Topography measurement	Topography measurement

Metrological specifications		
Out-of-plane measurement		
	Measuring principle	**Laser Doppler vibrometry**
Version	MSA-600-M (standard)	MSA-600-V (with bandwidth extension)
Max. frequency	2.5 MHz	25 MHz
Number of ranges	13 velocity ranges	13 velocity ranges
Max. velocity	0.001 m/s ... 10 m/s, range dependent	0.001 m/s ... 10 m/s, range dependent
Velocity resolution, average value[1]	0.005 (µm/s)/√Hz ... 1 (µm/s)/√Hz, range and frequency dependent	0.005 (µm/s)/√Hz ... 2 (µm/s)/√Hz, range and frequency dependent
Displacement resolution	50 fm/√Hz	50 fm/√Hz
In-plane measurement		
	Measuring principle	**Stroboscopic video microscopy**
Version	MSA-600 with planar motion analysis option	
Frequency range	1 Hz ... 2.5 MHz	
Max. velocity	> 0.1 m/s ... 10 m/s (magnification dependent)	
Objective magnification[2]	1x ... 100x	
Displacement amplitude resolution[3]	5 nm	
Time resolution	100 ns (strobe exposure time); max. strobe jitter ±40 ns	
System output	Displacement data, bode diagram, step-response plots, decay plots, trajectory plots	

[1] Averaging is performed over the maximum bandwidth f_{max} of the respective range.

[2] Objective specifications, as specified in table below.

[3] Frequency noise floor for 512 shots per frequency on vibration isolated table.

Metrological specifications		
Topography measurement		
Version	MSA-600 with topography measurement option	
Vertical measurement range	250 µm	
Nominal sampling increment	80 nm	
Method of evaluation [4]	smooth surface	rough surface
Resolution (RMS) [5]	45 pm	1.2 nm
Resolution of single measurement (RMS)	300 pm	14 nm
Repeatability [6]	500 pm	20 nm
Average flatness deviation [7]	< 5 nm	< 50 nm
Measurement performance on a traceable calibrated standard (PTB Type A1 (ISO 5436-1)		
Repeatability [8]	0.07 %	
Extended measurement uncertainty [9]	0.35 %	

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

[5] 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 Resolutionsingle correspond to single measurements.

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

[7] Mean value of the flatness (according to ISO 1101), see (6).

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

[9] 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.

Optical specifications	
MSA-I-600 Sensor Head	
Laser wavelength	532 nm
Laser safety class	class 3R (< 5 mW visible output)
Light source wavelength	470 nm
Light source safety class	class 2 LED product (< 20 mW visible output)
Camera	Full-field progressive scan camera
Camera resolution	1732 x 1200 pixel
Camera frame rate	max. 56 fps

Bright field objectives	Magnification	Working distance (WD) mm	Spot diameter (1/e²) µm	Field of view mm x mm
A-MOB-001X	1	13	46	10.0 x 7.0
A-MOB-002X	2	34	23	5.1 x 3.5
A-MOB-005X	5	34	9.3	2.0 x 1.4
A-MOB-010X	10	33.5	4.6	1.0 x 0.7
A-MOB-010B-LD	10	48.9	4.6	1.0 x 0.7
A-MOB-020X	20	20	2.3	0.51 x 0.35
A-MOB-050X	50	13	1.4	0.20 x 0.14
A-MOB-100X	100	6	0.8	0.10 x 0.07

Interference objectives	Magnification	Working distance (WD) mm	Type	Field of view mm x mm
A-IOB-02X5-B	2.5	10.3	Michelson	4.0 x 2.8
A-IOB-005X-B	5	9.3		2.0 x 1.4
A-IOB-010X-B	10	7.4	Mirau	1.0 x 0.7
A-IOB-020X-B	20	4.7		0.51 x 0.35
A-IOB-050X-B	50	3.4		0.20 x 0.14
A-IOB-100X-B	100	2		0.10 x 0.07

General specifications

Component	MSA-I-600 Sensor Head	MSA-F-600 Front-End	MSA-W-600 Data Management System	MSA-E-600 Controller
Power	via MSA-F-600 Front End	100 ... 240 VAC ± 10%, 50/60 Hz max. 100 VA	100... 240 VAC ± 10%, 50/60 Hz max. 525 VA	100... 240 VAC ± 10%, 50/60 Hz max. 450 VA
Dimensions [W x L x H]	see figure	485 x 150 x 380 mm (19", 84 TE/3 HE)	485 x 190 x 550 mm (19", 84 TE/4 HE)	499 x 177 x 373 mm (19", 98 TE/4 HE)
Weight	12.6 kg	9.0 kg	18.0 kg	12.0 kg
Operating temperature	18 ... 30 °C (64.4 ... 86 °F)	+5...+40 °C (41...104 °F)		
Storage temperature	–10 ... + 65 °C (14 ... 149 °F)	–10 ... + 65 °C (14 ... 149 °F)		
Relative humidity	max. 80%, non-condensing			

Compliance with standards

Electrical safety	IEC/EN 61010-1
EMC	IEC/EN 61326-1 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 (CFR 1040.10, CFR 1040.11)
Expanded uncertainty of measurement	SEMI MS4-0416 and MS2-113

Options and accessories

Please refer to the document “Accessories for stand-based instruments”

Software features

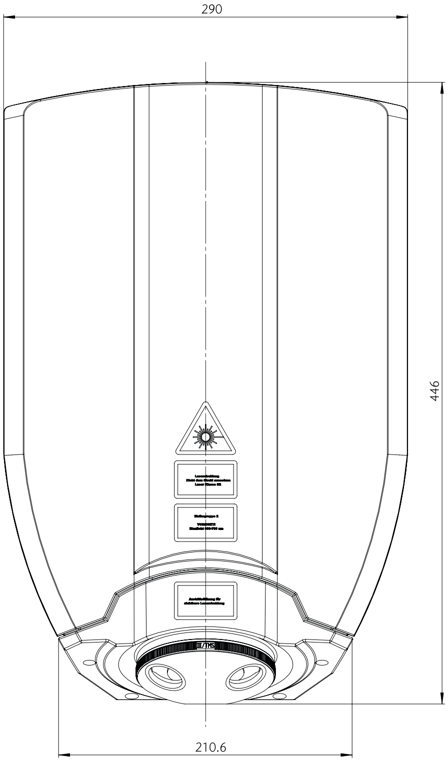
Out-of-plane measurement	
Data acquisition	
Video display	Live, full field, black & white video image of test object directly incorporated into user interface for interactive scan set up and beam positioning. Digital zoom into live video image.
Laser positioning	Visible laser moves with cursor on live 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 import	Geometry import from UFF or ME'scope format.
Autofocus 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 [1].
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.
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-600 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
FFT lines	6,400 standard; 12,800 optional; 819,200 optional
Window functions	Rectangular, Hamming, Hanning, Flat top, Blackman Harris, Bartlett, Exponential

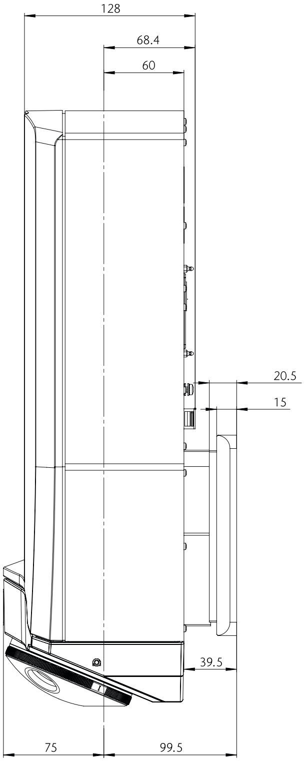
[1] Requires portal stand with automatic z-stage.

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 and PolyWave 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), H1, H2, auto power, cross power, coherence, averaged RMS over frequency. 3rd octave analysis, ESD, PSD.
Polytec Signal Processor	The Polytec Signal Processor is the user interface to the PolyMath library included in the PSV software. Easy-to-use spreadsheet for post processing of scan data.
Automated processing	Software can be fully automated.

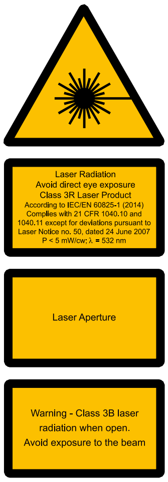
In-plane measurements	
Data acquisition	
Working principle	In the Acquisition Mode, video sequences are sampled and analyzed using proprietary measurement algorithms.
Strobe illumination control	Control of the strobe pulses (interval, pulse length).
Data acquisition	Acquisition of the stroboscopic video image 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 2.5 MHz. Support for arbitrary, user-provided excitation signals.
Data processing and analysis	
Working principle	Motion analysis is performed interactively. Motion data are based on image correlation and displayed as X, Y displacement values. Sub-pixel resolution enables in-plane motion measurements with resolution 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 spectra, step responses and decay (ring down). ■ Bode plots for both – horizontal and vertical – motion. ■ 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 ■ Smart Surface Scanning technique for extended contrast range
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: 2D, 3D 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.





All dimensions given in mm

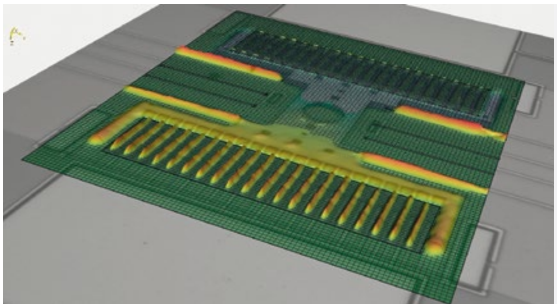


Laser Radiation
Avoid direct eye exposure
Class 3R Laser Product
According to IEC/EN 60825-1 (2014)
Complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice no. 50, dated 24 June 2007
P < 5 mW/cw; λ = 532 nm

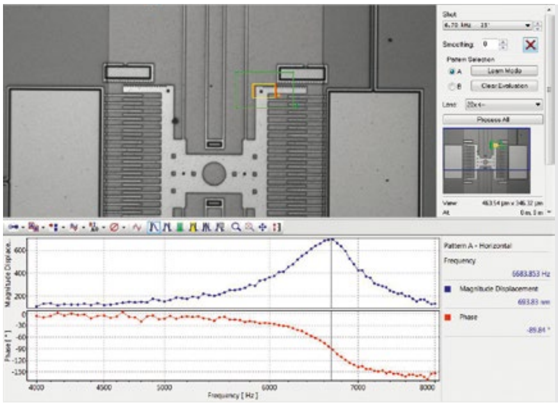
Laser Aperture

Warning - Class 3B laser radiation when open.
Avoid exposure to the beam

Comprehensive analysis of a MEMS electrostatic combdrive



Fast, real-time response measurement of the combdrive's out-of-plane dynamics reveals all system resonances. In addition, detect all in-plane modes with ultra-high sensitivity laser Doppler vibrometry measuring their minute parasitic out-of-plane contribution.



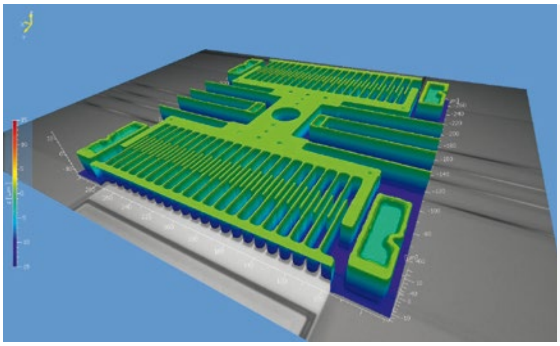
Pattern A - Horizontal

Frequency 6683.853 Hz

■ Magnitude Displacement 693.83 nm

■ Phase -89.84 °

Bode plot of the combdrive's principal in-plane driving mode. Visualize the device operation with live-mode animation.



High-resolution surface topography measurement revealing every detail of the device topography – even as fully automated measurements on wafer-level.

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