MSV-400 *Microscope Scanning Vibrometer*

POLYTEC MICROSCOPE SYSTEMS

- MSV-050 Manual Microscope Adapter
- MSV-100 Remote Controlled Microscope Adapter
- **MSV-400 Microscope Scanning Vibrometer**
- PMA-400 Planar Motion Analyzer
- MMA-400 Micro Motion Analyzer

MEASURING MICRO VIBRATIONS

The MSV-400 Microscope Scanning Vibrometer is the successor to the award-winning MSV-300 for full-field vibration analysis of very small objects such as MEMS optical switches. Based on the laser Doppler principle, a HeNe laser maps the vibrational response of the structure with a lateral resolution of down to 1 µm. MSV-400 can achieve picometer vibration resolution and up to 20 MHz bandwidth.

MEMS and Microstructure Vibration Analysis

The MSV-400 Microscope Scanning Vibrometer 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 industries. 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 MSV-400 is the ideal tool for a quick and accurate motion analysis of MEMS devices. For wafer-level testing, the MSV-400 can easily be mounted onto manual or fully automated probe-stations.

Key Features

- Full-field vibration mapping through the optics of a microscope
- Frequency-domain and time-domain measurements
- Full out-of-plane frequency response information
- Frequency range from 0 Hz up to 1 MHz (20 MHz optional)
- High resolution video imaging for animated visualization of time-domain and frequency-domain data
- Picometer displacement resolution (optional) for out-of-plane motions
- Microscopic laser spot size (e.g. 1 µm for 40X lens)
- Compatible with most popular CCD port equipped microscopes
- Modular design is easily upgraded to an MMA-400 Micro Motion Analyzer
- Scripting control for automation

Benefits of Laser-Doppler Vibrometry

Only Laser Doppler Vibrometry (LDV) provides the full picture of a device's out-of-plane vibrational behavior. Measurements do not have to be performed at discrete frequencies. Instead, vibration data is available resulting from any excitation waveform over the full bandwidth of the Vibrometer. LDV enables the analysis of non-ideal or non-linear systems.

MSV-400 – The System

A MSV-400 Microscope Scanning Vibrometer system consists of the optical scanning system, an OFV-551 Fiber-Optic Interferometer, the OFV-5000 Vibrometer Controller and the Data Management System (DMS), a workstation with A/D-converter and software.

A dual beam-splitter module (OFV-072) is mounted onto the microscope and the optical fiber is coupled into the optical path via the micro-scanning module (OFV-073). The latter employs an external unit to control two ultra-precise piezo-stages for scanning the laser beam through the microscope's optics. Simultaneously a progressive scan camera (VCT-101) provides a live video stream for the DMS. The laser is moved, not the object. A steady, live video image during the whole measurement is the benefit.

Two Versions

The MSV-400 Microscope Scanning Vibrometer is available in a standard version MSV-400-M2 and a high-frequency version MSV-400-M2-20. In both cases a high-end Polytec OFV-5000 Vibrometer Controller is used for the demodulation of the velocity and the displacement signals. The MSV-400-M2, with an upper frequency limit of 1 MHz, has both digital and analog velocity decoders. The MSV-400-M2-20 comes with either a high frequency (HF) velocity decoder with an upper frequency limit of 10 MHz or a HF displacement decoder with an upper frequency limit of 20 MHz.

Hardware and Software

The MSV Data Management System (DMS) consists of a Windows® 2000 based PC (XP on request) in an industrial housing, hardware for scanner control, video and data acquisition, as well as the MSV-400 software suite.

The standard version PC (PSV-W-400-M2) contains an IEEE 1394 Fire-Wire adapter, an internal signal generator board, a dual-channel D/A-converter for the scanning control and a 1 MHz-bandwidth 2-channel A/D conversion board for data acquisition. A PC-based digital demodulation with down to 1 pm displacement resolution is available as an option. A 2-channel data acquisition board as well as an external or internal signal generator with 40 MHz band-width are used for the high-frequency version PSV-W-400-M2-20.

The system software comes with the same out-standing features as the PSV-400 system for macroscopic scanning. Advanced Point Selection (APS) Professional software for defining scan points on the test object in any density combi-nation and coordinate system (polar, cartesian, hexagonal or arbitrary) is a standard feature of the MSV-400 system. Up to 40,000 measure-ment points deliver in-depth information about the device. The results are animated directly on the video image in 3D.

Modular Features and Upgrades

Of course, the OFV-551 Fiber-Optic Interfero-meter can be used as a single point vibrometer together with the OFV-5000 Controller when it is disconnected from the optical microscope scanning system.

For differential measurements through the microscope, the optical scanning system can be extended with a second beam splitter and a manual optical 2-axis positioning system. For these differential measurements an OFV-552 Dual-Fiber Interferometer must be used instead of the OFV-551. By adding in-plane capability through integration of the PMA-400 Planar Motion Analyzer, the MSV-400 can be upgraded to a complete MMA-400 Micro Motion Analyzer and a full 3-D characterization becomes possible.

For measurements on devices sensitive to high light intensities an optional laser dimmer is avai-lable for all Fiber-Optic Interferometers.

Application Areas

- Vibration 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

Application Examples

MEMS Mirror

Applied MEMS Inc. has developed a MEMS mirror device for use in optical bar code scanners. The micro-mirror is completely manufactured from single-crystal silicon. It is electrostatically actuated and offers a large rotation angle of at least ± 14°.

This mirror device was extensively tested using a Polytec MSV Microscope Scanning Vibrometer. The purpose of these tests was to measure the various resonant modes and to confirm that the mirror maintains optical planarity while undergoing electrostatic actuation. Modelling analysis on the mirror has shown that the single axis mirror may be operated in a dual axis mode, which has been confirmed by the laser measurements (Figure 1): There is a primary rotational mode about the x-axis (left) and a secondary rotational mode about the y-axis (right).
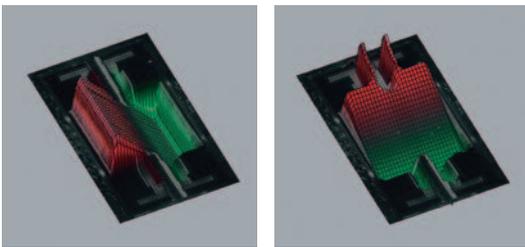

Figure 1: vibration modes of micro mirror

MEMS Acceleration Sensor

The MEMS acceleration sensor displayed in Figure 2 has been developed for frequency selective acceleration measurements.

It comprises a large number of cantilever arms of different lengths. Naturally the resonance frequency for each lever will be different as well. When experiencing shock or vibration only certain levers will vibrate depending upon their resonance frequency.

A Polytec MSV system was used to measure the resonance frequencies of the individual levers and for the presentation of the out-of-plane operational deflection shape.
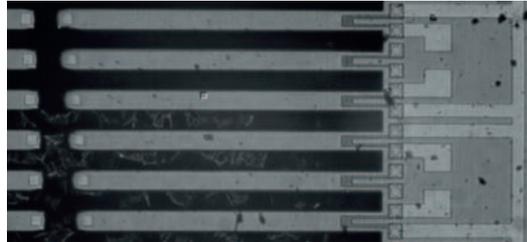

Figure 2: MEMS acceleration sensor

The micro sensor itself is placed under a standard microscope and is mechanically excited by a small piezo actuator. A broadband periodic chirp signal from a signal generator is applied to the actuator for excitation of all frequencies, with the same energy. The generator signal is looped back into the acquisition channel and, thus, is providing the reference phase.

In Figure 3, a frame from a live video image shows the geometry mesh used to measure the ODS of the cantilevers. The analysis is performed on three example cantilevers although the sample contained more than thirty. The scan-point grid for each lever is defined rapidly with a freehand tool on the video image.
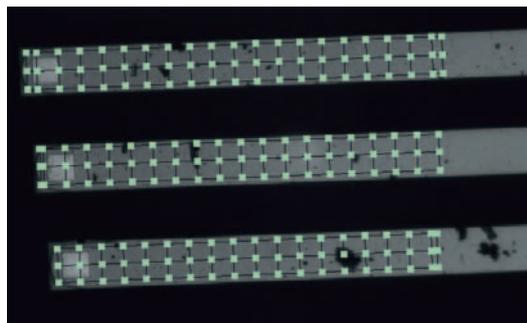

Figure 3: Geometry mesh on the cantilevers

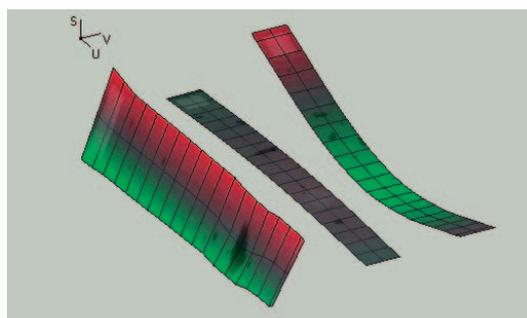A snapshot from the 3-D ODS-animation of the a tilt mode (± 2 nm) is displayed in Figure 4:

Figure 4: ODS animation of the cantilever

MSV-400 Technical Data

MSV-400 System Configurations	
MSV-400-M2	Standard Configuration, Bandwidth 1 MHz, 2 MHz optional
MSV-400-M2-20 (A)	HF Configuration with high frequency velocity decoder, Bandwidth 10 MHz
MSV-400-M2-20 (B)	HF Configuration with high frequency displacement decoder, Bandwidth 20 MHz

MSV-100 Microscope Scan Unit	
Optical sensor head	Standard: OFV-551 single-fiber (see separate datasheet) Optional: OFV-552 dual-fiber with reference mirror
Laser safety class	<1 mW visible output (Class 2)
Beam diameter	10 µm with 4X microscope lens ~ 1 µm with 40X microscope lens
Scanners	Closed loop, dual-piezo scan stage
Scanner resolution	> 200 x 200 points within field of view
Video camera	digital progressive scan camera (1.3 Mpixel) with FireWire interface (IEEE 1394)
Viewing field	Approx. 2.5 mm x 1.75 mm with 4X lens Approx. 100 µm x 70 µm with 100X lens
Scan field	1.75 x 1.75 mm with 4X lens 70 x 70 µm with 100X lens
Connection to microscope	Via CCD port (C-mount)
Recommended Microscopes	Mitutoyo FS70 Series Zeiss Axioskop 2Mat Series Olympus BX2M Series Leica DMLM Series **Please ask your Polytec representative for further recommendations**

OFV-5000 Vibrometer Controller			
Decoder configuration	MSV-400-M2	MSV-400-M2-20 (A)	MSV-400-M2-20 (B)
	VD-02 Wide-bandwidth velocity decoder	VD-02 Wide-bandwidth velocity decoder	VD-02 Wide-bandwidth velocity decoder
	VD-06 High Precision digital velocity decoder	VD-05 10 MHz velocity decoder	DD-300 20 MHz displacement decoder
	Please see decoder datasheets for details		
Velocity resolution	down to 0.02 µm s^{-1} √Hz, range and frequency dependent	down to 0.15 µm s^{-1} √Hz, range and frequency dependent	
Displacement resolution	< 0.1 pm/√Hz at 100% reflectivity (MSV-400-M2 with PSV-S-VDD , MSV-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 and provides piezo driver for scanner and amplifier for excitation signals
Input signals	Variable gain 0.1 V ... ±31.6 V analog inputs for vibrometer and reference signal, TTL inputs for trigger and gate
Piezo controller	2 channel
Power Amplifier	Built-in amplifier, differential output, 10 V / 50 mA peak amplitude

OFV-551 / OFV 552 Vibrometer Optics Specifications	
Laser wavelength	633 nm, visible red laser beam
Laser protection class	Class 2 He-Ne laser, < 1 mW, eye-safe
Available fiber lengths	1000 mm (OFV-551), 2000 mm, 3000 mm (OFV-552)
Light Intensity control	Optional laser power dimmer
Coherence Properties	
Sensor head	Maxima of Visibility
OFV-551	$135 \text{ mm}^1 + n \cdot 204 \text{ mm}$; n = 0; 1; 2; ...
OFV-552[2]	$0 \text{ mm} + n \cdot 204 \text{ mm}$
OFV-552[3]	$63 \text{ mm} + n \cdot 204 \text{ mm}$

[1] also 33 mm on request [2] differential measurement [3] single point measurement

Data Management System	
Computer	Industrial PC with 3 GHz CPU (or higher)
RAM	1 GB
Hard drive	120 GB
Data backup and storage	Combined DVD (4x) and CD (16x) recorder
Live video board	High end graphics board with VIVO
Piezo control board	16 bit DAC
ADC and Generator boards	See separate section below
Data link	Ethernet LAN
Operating system	Microsoft Windows® 2000 (XP on request)

Data Acquisition	MSV-400-M2	MSV-400-M2-20
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- or post-trigger	
Gate	Additional input for gated measurements, MSV-400-M2 only	
FFT frequency range	DC ... 1 MHz, DC ... 2 MHz optional	DC … 40 MHz
Specimen excitation	Internal signal generator up to 500 kHz	Internal signal generator up to 40 MHz
	Software for control of Agilent model 33120A arbitrary waveform generator	
Waveforms	Wide range of waveforms including sine, periodic chirp, white noise, random signals, sweep and arbitrary signals.	

Software: 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 RS232-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
Gate input	Gate-input for intermittent scan control
Scan data validity check	Data quality check at all scanned points. In Signal Enhancement (SE) mode MSV-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 Averaging
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: 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), H1, H2, 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

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