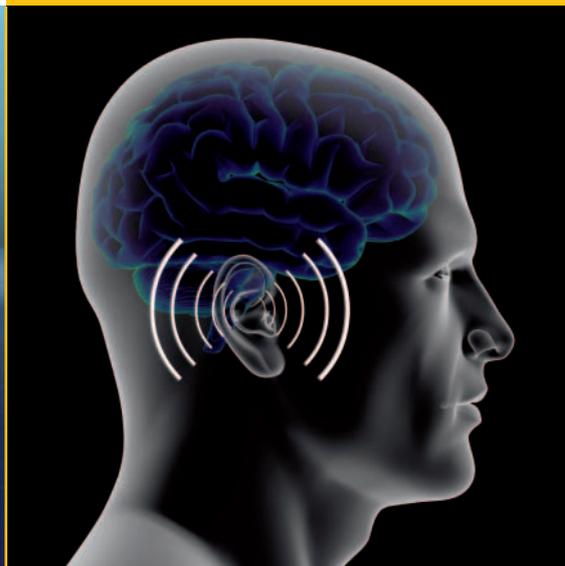


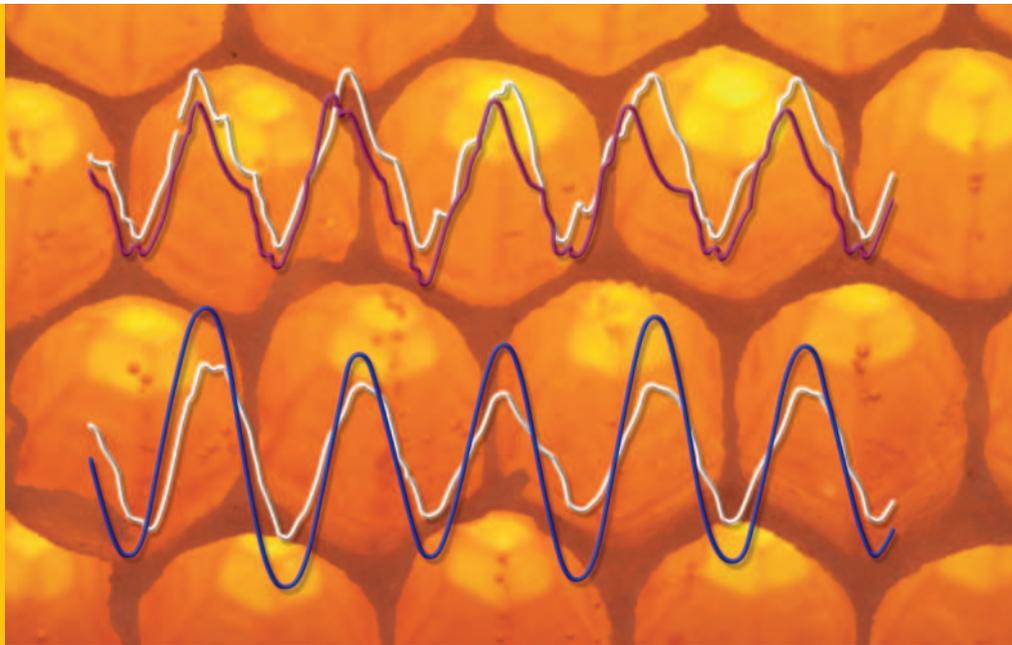
# Vibrations Everywhere in Nature

Applications of Optical Measurement Systems  
in Biology, Medicine and Health Care

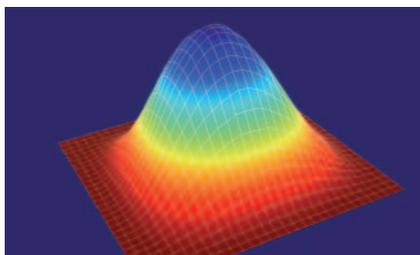


# Why Should We Measure Vibrations and Surface Topography?

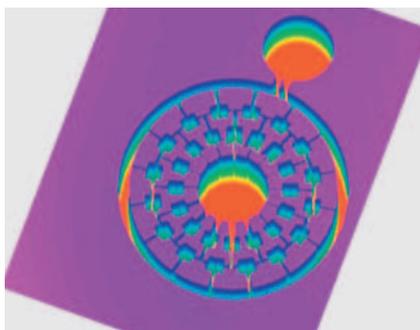
Perhaps the most important reason is to understand the biological and physiological structures and the mechanisms that interact with them. Polytec's laser vibrometers and optical surface metrology help improve our knowledge about living objects and medical devices. The data can be used for computer modelling, and the results used to enhance the design of bionic structures or therapeutic processes.



To get an idea about the scope of the medical applications that our customers are finding for Polytec vibrometers, please visit the National Institutes of Health Archive entering either "Polytec" or "vibrometer" as the search criteria. You will be amazed at what you find!  
[www.pubmedcentral.nih.gov](http://www.pubmedcentral.nih.gov)



Vibration shape of a membrane



3-D Surface profile of a lab-on-a-chip device

## What is Laser Vibrometry?

Laser vibrometry is a non-contact technology based on the Doppler effect – sensing the frequency shift of back scattered laser light from a moving surface. Laser Doppler Vibrometers can accurately measure vibrations without contact at frequencies up to 1.2 GHz. Alternative methods usually can't be used because they load or interact with the system, have limited bandwidth and spatial resolution or can't be scanned across a surface. The same is even more true for vibrations on the surface of liquid materials or in very small and light structures, such as can be found in many areas of biology and medicine.

[www.polytec.com/vib-university](http://www.polytec.com/vib-university)

## What is Surface Metrology?

Polytec's scanning white-light interferometers are based on the Twyman-Green interferometer principle. These non-contact optical instruments can measure surface heights on 3-D structures with profiles varying between a few micrometers to some centimeters. All surface features ranging from gradual slopes to vertical steps, with rough or smooth finishes, can be characterized with excellent precision. [www.topmap.info](http://www.topmap.info)

## Applications in Biology and Medicine

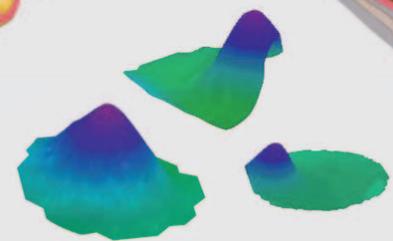
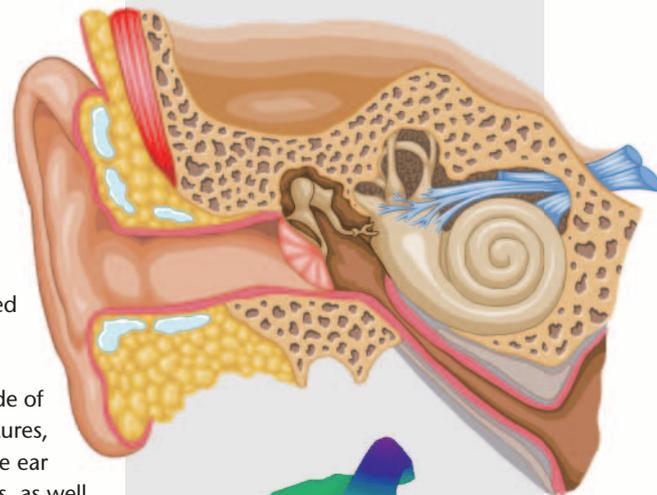
Laser vibrometers have proven to be indispensable instruments in hearing diagnostics and research, enabling the understanding of critical structural and functional relationships of the ear. Laser vibrometers have also been used for measurements on medical implants, for monitoring surgical procedures, for physiological measurements and other biomechanical research (pages 3 and 4). Further applications in medical technology for Polytec vibrometers or white-light interferometers include the development, proving and quality assessment of medical devices such as dental and surgical instruments, nebulizers and medical imaging systems, as well as many safety and health care devices (pages 5 and 6). In biology, Polytec vibrometers are prominent in insect communication and bio-mimicry studies. Other applications include measuring honeycomb vibrations in beehives (see image above), communication and orientation of mammals, fruit quality assessment and many others (page 7).  
**For more information please read further and visit [www.polytec.com/biomedical](http://www.polytec.com/biomedical).**



### Laser Tympanometry

Laser vibrometry is also used to acquire vibrational information about the response of the tympanic membrane in case of any pathologic changes in the middle ear. The technology gives access to full-field vibration down to microscopic detail and represents a standard in the research of the dynamics of the middle ear and the inner ear.

For more information about Scanning Vibrometers please see back page.



Full-field scanning measurements of the tympanic membrane. Left: normal; center: stapes fixation; right: perforation of tympanic membrane. (courtesy H. Mojallal, MHH Hannover, Germany)

## Applications in Hearing

State-of-the-art laser vibrometers are indispensable to those actively involved in the design, development, quality control, calibration and certification of middle-ear implants. They provide ease of use and unsurpassed accuracy and resolution, greatly advancing our understanding of hearing mechanics.



“Regarding our fundamental research on biophysical processes in the cochlea, there is no other measurement technology providing appropriate sensitivity and a resolution below 1 pm”

**Prof. Anthony W. Gummer**  
[www.uni-tuebingen.de/cochlea](http://www.uni-tuebingen.de/cochlea)



“Laser vibrometers are critical to understand structure/function relationships of the ear”

**Prof. Sunil Puria**  
[www.stanford.edu/people/puria](http://www.stanford.edu/people/puria)

Laser Vibrometry is an established technique used throughout the hearing research community. Dynamic measurements are made of temporal bones, cochlear structures, ear models, hearing aids, middle ear prostheses, implants and devices, as well as the monitoring of ear implant surgery.

### We Can “See” How the Patient Hears

Measurements on the eardrum allow us to investigate the micromechanical function of the inner ear. The active amplification process inside the cochlea, can be assessed non-invasively by the highly sensitive vibrometer. We can “see” how well or poorly the patient hears. This could have important applications in screening infants for dysfunctional hearing.

### Biomechanics of the Human Middle Ear

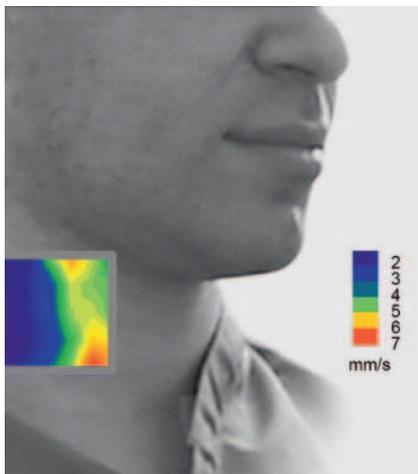
One reason for the enhanced understanding has been the use of non-contact laser vibrometers to measure motions of the middle ear both in-vitro and in-vivo. Measurements can be used to diagnose

pathologies, such as luxations of the ossicles, otosclerosis or dysfunctions of middle-ear implants and prostheses. Studies result in enhanced biocomputational models of the middle ear and the related sound transmission.

# Applications in Biomechanics



Biomechanics includes bioengineering, the research and analysis of the mechanics of living organisms and the application of engineering principles to and from biological systems. Vibrometers are an invaluable tool used for applications as diverse as physiological diagnostics, vibration measurements on artificial heart valves, mechanical properties of tendons, analysis of vibrations while bone drilling or medical laser ablation, detection of bone crack propagation, biodynamic response to hand tool vibration, for generating FE models of bones, and many more.



## Measuring Physiology and Biometrics from a Distance

Laser-Doppler vibrometers are widely used in industrial and engineering applications but their use for measuring system-level physiology is fairly recent. However, a large variety of internal sounds, pulses and vibrations can be detected simply by directing the laser beam at the body. Multiple investigators in the Washington University School of Medicine and School of Engineering have contributed to the development of a dedicated instrument that supports acquisition of vibrometer data on a

largely autonomous basis, with targeting, tracking and focusing of the instrument controlled using computer vision methods. Data are analyzed in near real time. Advanced measurements are supported in multiple response systems, especially cardio-respiratory and muscle activities.



“A large variety of internal sounds, pulses and vibrations can be detected”  
**Prof. John W. Rohrbaugh,**  
Washington University  
School of Medicine,  
St. Louis, MO



## Dynamic Analysis and Modeling of Bones

Recently, Finite Element Methods (FEM) have been used in biomechanics to investigate and model components for medical applications. For example, to assist with bone surgery, various approaches to generate realistic bone models from computer tomography data are being evaluated. The 3-D Scanning Vibrometer was used for the first time to determine

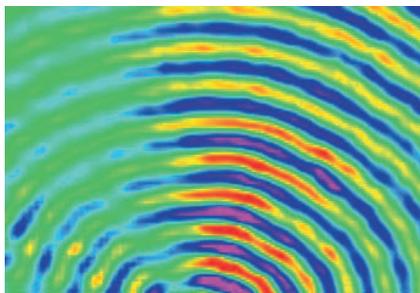
the modal parameters of a pelvic bone and provided spatial vibration modes with an accuracy and resolution that has not been available until now.

**Martin Quickert, Michael Werner, Sandra Scherer; Fraunhofer Institute for Machine Tools and Forming Technology IWU, Dresden, Germany**

# Medical Applications



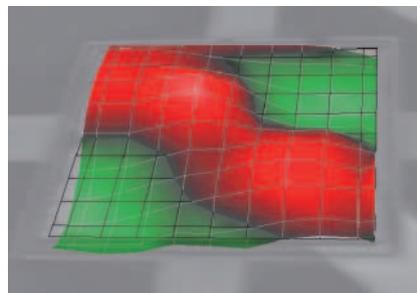
Applications in medical technology include development and quality assessment of medical instruments like micro fluidic devices, dental descalers, surgical instruments, and medical imaging devices. Further, there are many medical, safety and health care devices like inhalers, respirators and tooth brushes that have been investigated using Polytec vibrometers and white-light interferometers.



## High Frequency and High-Power Medical Ultrasound

Laser vibrometry is the ideal tool for characterizing and visualizing the behavior of ultrasonic transducers e.g. for use in lithotripsy, thrombolysis, sonography, disintegrators or nebulizers, or for high intensity focused ultrasound or low-power high resolution ultrasound imaging. Data for the verification of simulation models are quickly and easily created, enabling short development cycles. Polytec provides sophisticated tools for measuring high frequencies up to 1.2 GHz and velocity amplitudes of more than 100 m/s.

[www.polytec.com/u/hf](http://www.polytec.com/u/hf)



## Vibrational Analysis of Ultrasonic Transducers for Medical Imaging

Piezoelectric Micromachined Ultrasonic Transducers (pMUTs) are being used to push the limits of real-time 3-D medical ultrasonic imaging in areas such as intravascular ultrasound and intracardiac echocardiography. Measurement of these devices at high speed (~10 MHz frequency) and high resolution (<1  $\mu\text{m}$  displacement) were made possible by the Polytec's Micro System Analyzer and revealed a wealth of information about pMUT performance.

Derrick R. Chou, John B. Castellucci, Olaf T. von Ramm; Duke University; David E. Dausch, RTI International; Durham, NC

## 100 % Quality Control of Membrane Nebulizers

At PARI Pharma GmbH, a leading German manufacturer of aerosol generation systems, the quality of manufactured nebulizer systems is 100 % tested and affirmed using a Compact Laser Vibrometer to validate the vibration characteristics of the membrane generating the aerosol. This measurement system guarantees precise, reproducible delivery of the medication dose.

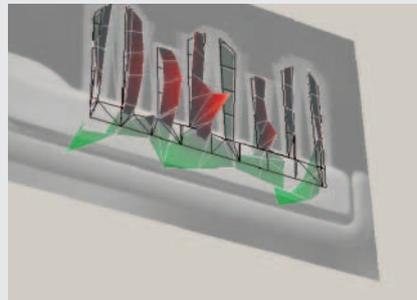
Philipp Holzmann, PARI Pharma GmbH, Gräfelfing, Germany





### Improving Efficacy in Dental Ultrasonics

Visualizing the motion of ultrasonic dental descalers is challenging due to their high frequency vibrations, small associated displacement amplitudes and multi-axis vibration. Laser vibrometry has made it possible to study, in detail, the vibration patterns of dental ultrasonic descaling



equipment, and to determine the most effective designs. The Scanning Vibrometer has found further application for measuring the response of endosonic files, ultrasonic retrograde tips and even powered toothbrushes.

Please read the full article at:

[www.polytec.com/infocus](http://www.polytec.com/infocus)

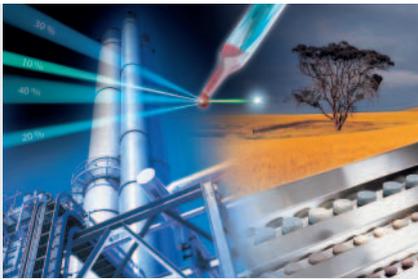
German: [www.polytec.de/infocus](http://www.polytec.de/infocus)



"Laser vibrometry has made it possible to determine the most effective designs"

**Dr. Simon Lea,**  
School of Dentistry,  
University of  
Birmingham, UK

[www.dentistry.bham.ac.uk/dentalultrasonics/](http://www.dentistry.bham.ac.uk/dentalultrasonics/)



### 100 % Quality Control of Tablets, Capsules and Pharmaceutical Substances

Near Infrared (NIR) spectroscopy is used for fast, reliable, and non-destructive measurements on pharmaceuticals to simultaneously control manufacturing processes and product quality, assuring that final product specifications and quality are met. Polytec spectrometers combine a high sampling rate with a flexible optical delivery method. Due to the extremely high measurement speed of these systems, each and every capsule or tablet produced can have its active ingredient content verified, thus, giving 100 % inspection and certification.

More Info · Contact:

[st@polytec.de](mailto:st@polytec.de) · [www.polytec.com/st](http://www.polytec.com/st)

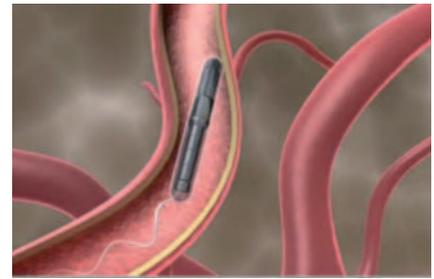
### Motors for Medical Nano-Robots

Remember the movie *Fantastic Voyage*? Now researchers are developing a motor for nanorobots with the help of Polytec's Micro System Analyzer. Its Australian creators hope their tiny motor will soon power medical nanorobots that can swim through tiny blood vessels into the brain. They made the microscopic motor using a piezoelectric material whose resonance frequencies and the associated mode shapes were determined by the use of a Micro System Analyzer.

Please find more information on

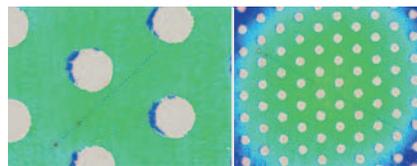
<http://mnrl.monash.edu> and

[www.youtube.com/watch?v=VRMEtCCDR\\_E](http://www.youtube.com/watch?v=VRMEtCCDR_E)



"Simple can be made small"

**Prof. James Friend,**  
MicroNanophysics Research  
Laboratory, Monash  
University, Melbourne



### Surface Metrology for Development and Quality Control of Medical Devices

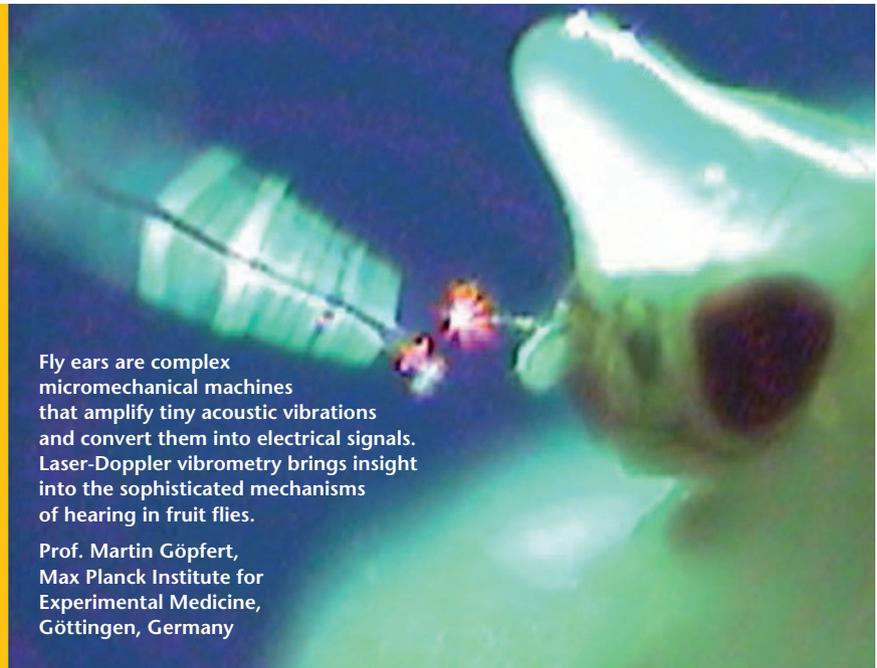
Polytec's White-Light Interferometers are well suited for non-contact 3-D surface characterization of medical devices.

For instance, the structure of tiny holes in the membrane of a drug nebulizer (see photo) can be monitored during production. 3-D topography and dimensions of cell clusters, dental implants, lab-on-a-chip systems and many other objects can be easily acquired. Polytec TopMap systems help determine critical parameters like flatness or waviness of various optical and mechanical parts of medical tools and machines.

More Info: [www.topmap.info](http://www.topmap.info)

# Applications in Biology

For nearly every living species on our planet there are corresponding biological applications of laser vibrometry. One of the most prominent is insect communication. Other bio applications include measuring echo location mechanics of mammals like bats or dolphins, communication between elephants, honeycomb vibrations in beehives, fruit quality, spider web motion, and the hearing mechanism in frogs, crickets, fruit flies, and other animals.



Fly ears are complex micromechanical machines that amplify tiny acoustic vibrations and convert them into electrical signals. Laser-Doppler vibrometry brings insight into the sophisticated mechanisms of hearing in fruit flies.

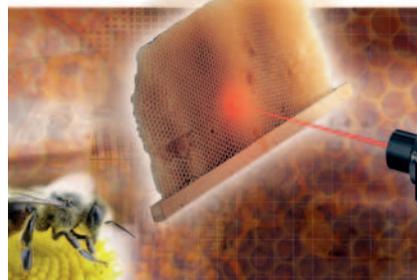
Prof. Martin Göpfert,  
Max Planck Institute for  
Experimental Medicine,  
Göttingen, Germany



## The Mechanics and Morphology of Hair-based Sensor Arrays

Crickets possess a hair array that can detect minute changes in air flow. It is one of the most sensitive sensory systems known in nature. By understanding how this highly sensitive biosensor works, we open the door to bio-mimicry, the manufacture of new sensors such as microelectromechanical systems (MEMS) technology, as substitutes for insect biology. The project already shows some very promising results.

Prof. George Jeronimidis,  
Dr. Emma Johnson,  
Centre for Biomimetics,  
University of Reading, Berkshire, UK



## Communication in Beehives

Social insects are excellent subjects for study. Understanding their mechanical systems and the evolution of differentiated, meaningful communication signals is important. The use of innovative laser vibrometry methods to measure signals and their transmission has shown how brilliantly the honeybees have utilized such signals to communicate.



“Vibrations of complex and lightweight structures like honeycombs can only be measured with non-contact equipment like laser vibrometers”

Prof. Jürgen Tautz,  
Biocenter, University of  
Wuerzburg, Germany



## The Origin of Sound-Processing Elements in Ensifera

The group of insects which include crickets is called Ensifera and produce sounds for communication. Their ears have evolved in their legs from the pre-existing vibratory organs. Through our study, we want to determine whether their auditory and vibratory senses share a common origin within their central nervous system. Non-contact laser vibrometry offers many advantages over contact methods of measuring vibrations.

Dr. Nataša Stritih, National Institute  
of Biology, Ljubljana, Slovenia

# Polytec Optical Measurement Systems

## Benefits for Bio-Medical Research and Testing

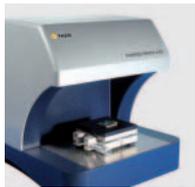
Laser vibrometry can sense the smallest of vibrations. It gathers data to display and characterize how mechanical motion takes place. It delivers a full picture either of single-point frequency responses or of full-field structural deflection shapes, by way of scanning vibrometry. Both Polytec's laser vibrometers and optical surface metrology help improve our knowledge about living objects as well as medical devices.



### MSA-500 Micro System Analyzer

Besides scanning vibrometry for measuring out-of-plane vibrations of microscopic structures, the MSA includes also stroboscopic video

microscopy for in-plane motion and white light interferometry for high resolution topography. [www.polytec.com/microsystems](http://www.polytec.com/microsystems)



### TopMap Surface Metrology

Polytec's TopMap Topography Measuring Systems allow for non-contact, high-precision surface profile measurements and 3-D image analysis of

both small and large surfaces and structures, including soft materials in research, development and quality control. [www.topmap.info](http://www.topmap.info)



### UHF-120 Ultra High Frequency Vibrometer

The UHF-120 Vibrometer is designed to characterize mechanical motions at frequencies up to 1.2 GHz, enabling the precision examination of high frequency RF-MEMS and other components. In addition, the capability to resolve high velocities permits the characterization of high-intensity, focused ultrasound transducers. [www.polytec.com/uhf](http://www.polytec.com/uhf)

www.polytec.com/uhf

Polytec is a global enterprise with corporate facilities in Europe, North America and Asia. Our market-leading position is built on innovative technology, high-quality products, engineering excellence, expert technical advice and thousands of satisfied customers worldwide.



### CLV-2543 Compact Laser Vibrometer

The CLV-2534 is the most versatile instrument for the audiologist and the otologist. Designed as an all-in-one system, it comprises the laser

sensor head with integrated optics and video camera. For beam steering and integration with the clinical microscope, the sensor head is mounted onto the Micro Manipulator. The head is fiber-coupled to the CLV control unit containing the laser source and the latest digital demodulation electronics for low-noise measurement. It can resolve nanometer displacements with ease. [www.polytec.com/vibrometers](http://www.polytec.com/vibrometers)



### OFV-5000 Modular Vibrometer Systems

The OFV-5000 Controller is the core of Polytec's state-of-the-art laser vibrometer systems and can be equipped with specialized sensor heads.

For fundamental research on biophysical processes, there is no other measurement technology providing such sensitivity with displacement resolution below 1 pm. [www.polytec.com/vibrometers](http://www.polytec.com/vibrometers)



### PSV-400 and PSV-400-3D Scanning Vibrometers

Polytec's Scanning Vibrometers provide cutting edge measurement technology for the analysis and visualization of structural vibrations up

to 24 MHz. Entire surfaces can be rapidly scanned and automatically probed, with no mass loading or added stiffness. [www.polytec.com/psv](http://www.polytec.com/psv)

The full articles can be viewed and downloaded from [www.polytec.com/infocus](http://www.polytec.com/infocus) (German: [www.polytec.de/infocus](http://www.polytec.de/infocus)). For more information and advice, please contact your local sales/application engineer.

**Polytec GmbH (Germany)**  
Polytec-Platz 1-7  
76337 Waldbronn  
Tel. + 49 (0) 7243 604-0  
Fax + 49 (0) 7243 69944  
[info@polytec.de](mailto:info@polytec.de)

**Polytec France S.A.S.**  
32 rue Delizy  
93694 Pantin Cedex  
Tel. + 33 (0) 1 48 10 39 30  
Fax + 33 (0) 1 48 10 09 66  
[info@polytec.fr](mailto:info@polytec.fr)

**Polytec Ltd. (Great Britain)**  
Lambda House, Batford Mill  
Harpenden, Herts AL5 5BZ  
Tel. + 44 (0) 1582 711670  
Fax + 44 (0) 1582 712084  
[info@polytec-ltd.co.uk](mailto:info@polytec-ltd.co.uk)

**Polytec Japan**  
354 German Centre  
1-18-2 Hakusan, Midori-ku  
Yokohama, Kanagawa  
226-0006  
Tel. +81 (0) 45 938-4960  
Fax +81 (0) 45 938-4961  
[info@polytec.co.jp](mailto:info@polytec.co.jp)

**Polytec, Inc. (USA)**  
North American Headquarters  
16400 Bake Parkway  
Suites 150 & 200  
Irvine, CA 92618  
Tel. +1 949 943 3033  
Fax +1 949 679 0463  
[info@polytec.com](mailto:info@polytec.com)

Central Office  
1046 Baker Road  
Dexter, MI 48130  
Tel. +1 734 253 9428  
Fax +1 734 424 9304

East Coast Office  
25 South Street, Suite A  
Hopkinton, MA 01748  
Tel. +1 508 417 1040  
Fax +1 508 544 1225

[www.polytec.com](http://www.polytec.com)