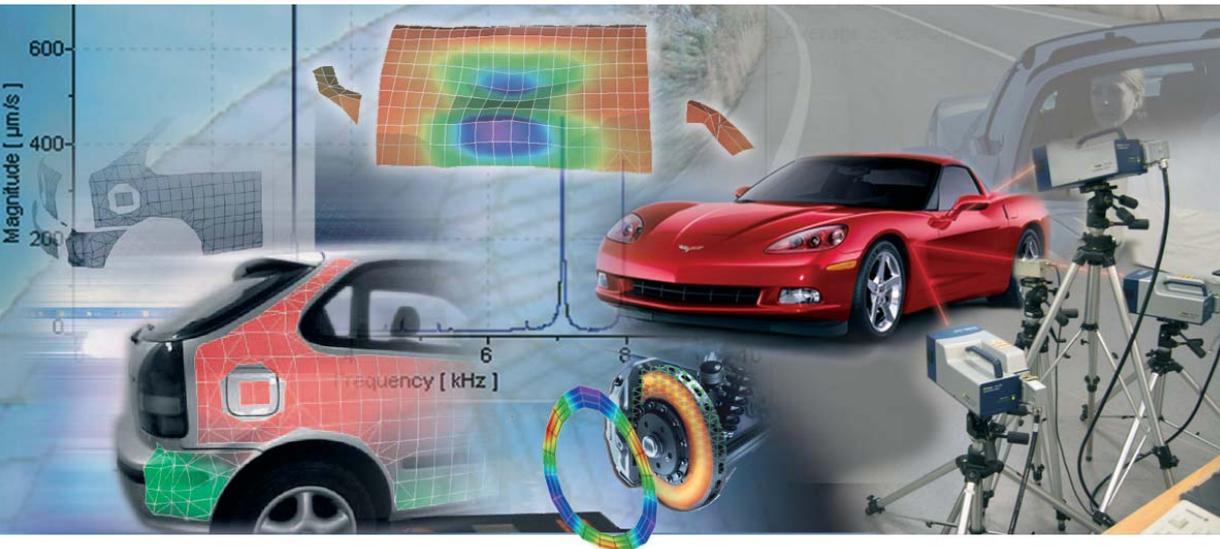


# Application Note *VIB-C-02*



## AUTOMOTIVE APPLICATIONS

- Experimental modal analysis
- Measurements on engine valve train assemblies
- Brake development
- Acoustic optimization of vehicle components
- Axle vibrations, bending and torsional modes
- Quality testing and industrial process control

## LASER VIBROMETRY AND THE AUTOMOTIVE INDUSTRY

*Laser vibrometry is firmly established as the automotive industry's gold-standard for non-contact vibration measurement. It's advantages are many including zero-mass loading, high precision and sensitivity, fast set-up, ease of operation and long standoff distance. By combining a single-point laser vibrometer with 2-D fast-scan mirrors, vibrations can be characterized over an entire surface. This exciting test and measurement procedure is revolutionizing design development and experimental modal analysis in the automotive industry. Polytec's comprehensive line of products and services provide an optimal solution for almost every automotive vibration measurement application.*

### Non-Contact Measurement Technology Improves Product Quality

Optimization of vibration and acoustic characteristics has become a high priority in product development labs. Specifically, the automotive industry views the dynamic and acoustic properties of a car as among its most important qualities affecting customer perception and sales. This demand for improvement is reflected in a continual stream of new analysis tools and sophisticated vibration measurement technology.

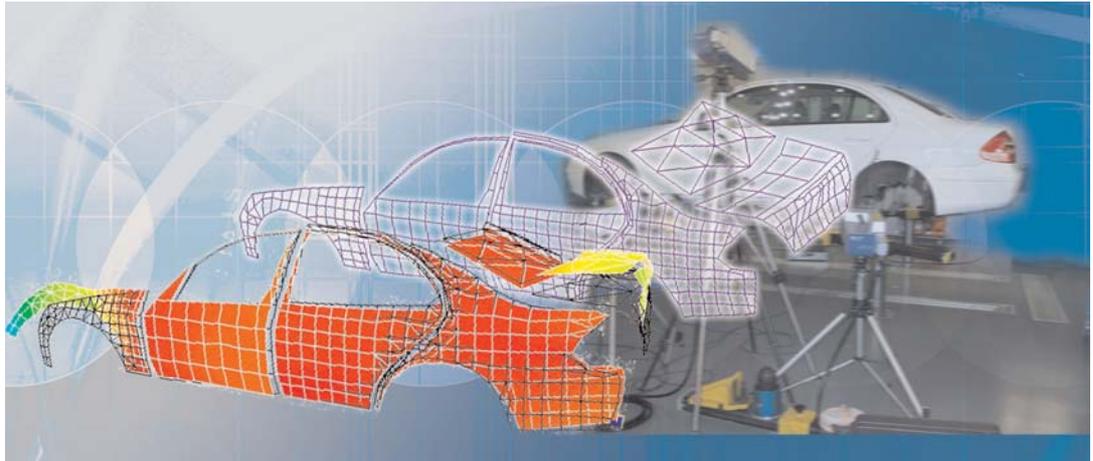
Recently developed, Laser Doppler Vibrometry is the current Gold Standard for experimental vibration and modal analysis. Not only does this technology offer high throughput, accuracy and a user-friendly interface for simple measurements; but it can be extended to the most difficult measurement tasks, such as red-hot, complex or microscopic structures.

### Advantages of Laser Vibrometry

- Precise, non-contact measurement process with zero-mass loading
- Increases productivity by eliminating slow, tedious steps associated with traditional contact-based measurements (accelerometers)
- Wide frequency bandwidth
- Works with a variety of material properties such as soft, filigree, jagged or hot structures
- Long standoff distance simplifies measurements on inaccessible or environmentally difficult structures
- Works well with structures sized from large 747 aircraft to small MEMS devices
- Large measurement grid with more than 250,000 points
- 3-D measurement data for modal analysis and FEM verification
- Optional 3-D geometry scan unit

Polytec GmbH  
 Laser Measurement Systems  
 Application Note  
 VIB-C-02  
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## Experimental Modal Analysis

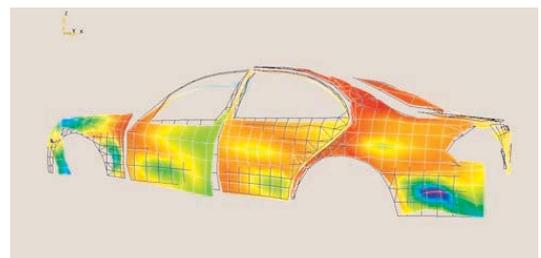
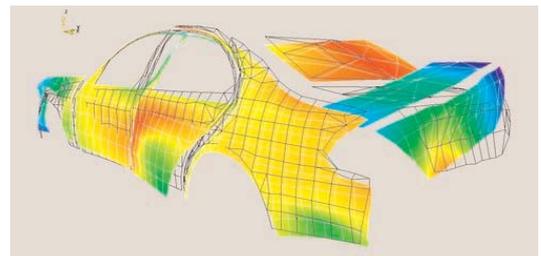


Mathematically calculating and predicting the vibration characteristics of automotive components and systems is a standard CAD process in today's automotive development environment. Computer simulation makes a significant contribution towards speeding the introduction of new products, improving vehicle safety and enhancing the quality and comfort of new automobiles. Since a real object's material properties are often different from "text" book examples, the reliability of critical mathematical simulations comes from direct comparison with experimental data.

Laser vibrometers are an accepted and proven method to acquire vibration data across a wide range of metrology applications. In comparison to traditional contact accelerometers, they offer several decisive advantages, such as substantially greater bandwidth, very high displacement resolution ( $< 1 \text{ pm}$ ), zero-mass loading (non-reactive) and dramatically increased productivity due simple first-time setup, fast measurement, rapid visualization of results and easy repeat product measurement. Scanning Vibrometers (PSV-400 & PSV-400-3D) measure entire surfaces and map the out-of-plane vibration or the complete 3-D vector response across the test object.

The Laser Scanning Vibrometer is perfect for measuring structure motion that is driven by broadband mechanical excitation such as an electro-dynamic shaker. Using this arrangement, engineers can perform experimental modal analysis where the Scanning Vibrometer acquires data from each sample point across the structure in quick succession. During data acquisition, the vibrometer system calculates the Frequency Response Function (FRF) between the driving for-

ce and the measured response as determined by the vibrometer signal (velocity) for every sample point in the specified frequency range. Using the PSV software, the deflection shapes in the frequency or time domain can be calculated, then animated and finally superimposed on the geometry model or video image of the structure. Data acquisition and software system are MIMO capable allowing the measurement data to be prepared for a principal component analysis.



To determine the modal parameters (eigen frequency, modal attenuation and natural vibration shapes) the measured FRF matrix can be further evaluated with commercially-available modal analysis software packages. To facilitate this data exchange, the PSV software makes appropriate data export functions available.

*See also Polytec Application Note VIB-C-01*



Scanning vibrometry has several advantages over contact transducers for performing a modal test:

Photo courtesy CEVAA/France

- Measurements are simple and fast even with very high sample-point density.
- Zero mass loading does not influence structure being tested
- Significantly reduced setup time, minimal instrumenting of the test structure with accelerometers
- FEM models can be verified using FRF data with high spatial resolution.
- Fully automatic measurement
- MIMO modal testing with parallel control of up to 3 shakers

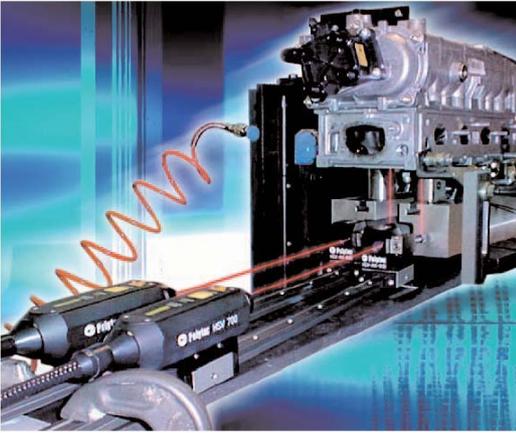
## Measurements on Engine Valve Train Assemblies

Combustion and the associated engine valve train movement are highly dynamic processes where extremely high speeds and accelerations can occur.

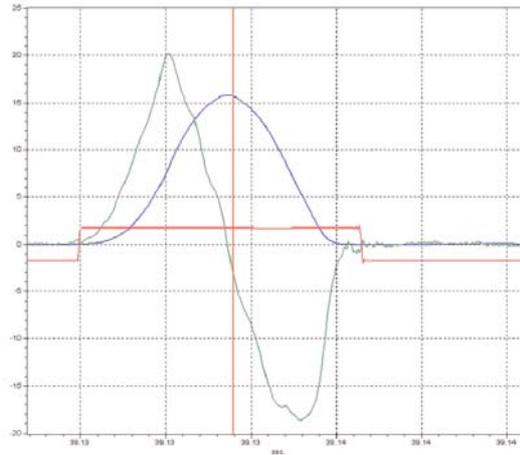
One measurement challenge is to separate the valve disc or valve tappet motion from the superimposed whole body displacement of the cylinder head. Another challenge is to measure the large movements with high displacement resolution so the small, undesirable deviations from the planned path are obvious and highlight effects such as bounce/rebound.

A differential, high speed vibrometer is an excellent measurement solution and can provide accurate valve motion graphs perfect for optimizing the combustion process, fuel consumption, engine performance and service life. In a normal measurement configuration, the reference beam is directed at the cylinder head and the measurement beam at the valve, then the optical signals are subtracted from each other.

The measurement usually takes place on a valve train assembly test stand with an externally driven valve train assembly.



The measurement range of up to 30 m/s even allows measurements on high performance Formula 1 drive systems. The process of valve closure is of particular importance to the development of engine valve trains. By characterizing before, during and after the valve mates with the valve seat, one can study the spring-mass system of the valve arrangement. Poorly designed valve



trains can lead to undesirable acoustic effects, poor fuel consumption as well as reduced engine life. The highly dynamic valve closure is analyzed in terms of velocity; often indicating that the natural resonance of the valve unit itself affects the closing behavior.

See also Polytec Application Note VIB-C-03

## Brake Development



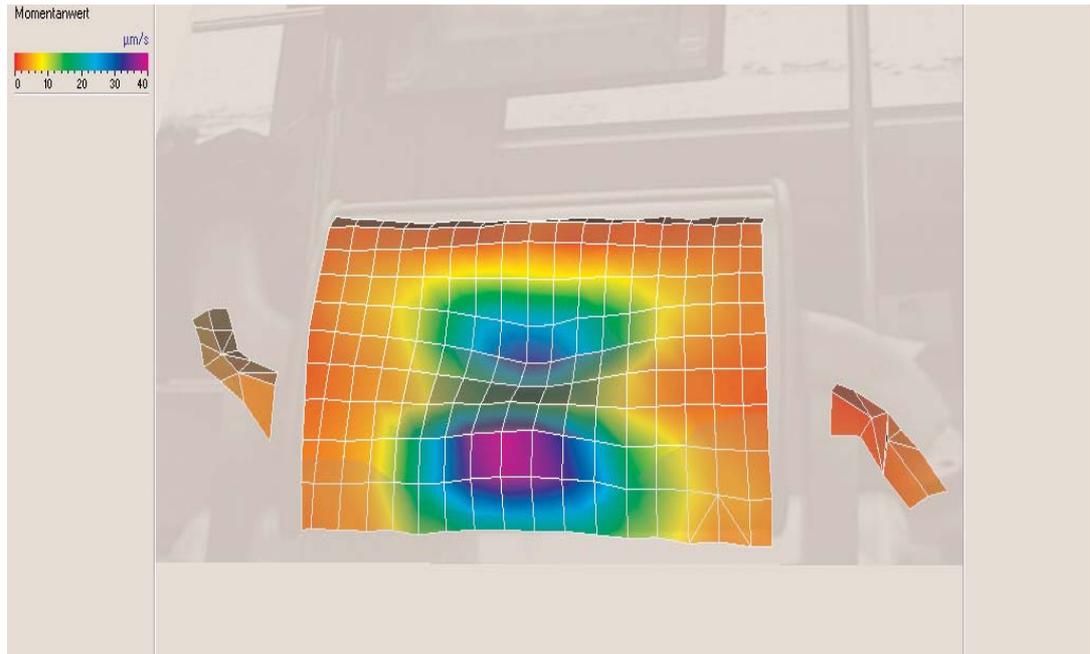
Polytec's innovative vibration measurement technology has helped provide important measurements for acoustic optimization of brake disk systems. Under certain operating conditions, the complex dynamics between the brake caliper, brake pads and brake disk can cause undesired audible squealing. The driver perceives the brake noise as a quality problem. Measurements with Polytec's 3-D scanning vibrometer acquire complete vibration vector data showing the spatial dynamics, making it possible to reveal the interaction between the primarily excited vibration modes on the disk plane and the acoustically relevant out-of-plane modes.



Measurements can be made on all of the brake subsystems, both at rest and rotating on the brake test stand.



## Acoustic Optimization of Vehicle Components



Another important application of laser scanning vibrometry is to measure the acoustically relevant vibration modes of automotive engines, auto bodies, drive trains, exhaust systems, steering systems, dashboards and other components.

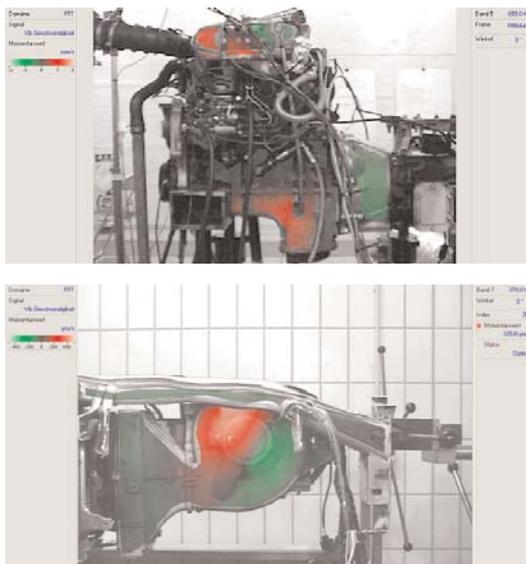
The fast, large field-of-view measurement procedure combined with the clear animated visualization of the measurement results superimposed on a video image immediately provide important indications of acoustically relevant zones on the object under investigation.

The process is so easy that testing on constructional modifications in real time can be accomplished. For example, if car panels are modified with insulation between consecutive measurements, the effects on the vibration characteristics can be immediately determined and displayed.

Deflection shape analysis using the laser scanning process is simple and ideally suited for acquiring data under steady state operating conditions. Transient conditions, such as shutting a door, can also be acquired and analyzed, providing the response can be duplicated.

Due to the sequential nature of the scanning process, a phase reference is required for every measurement point. This is acquired at the same time as the vibration response. Almost any measurement can be used as the phase reference. Some examples of useful phase references are the excitation force (modal test), the acceleration at a structural sample point or the signal from a static single-point vibrometer or a microphone signal (sound pressure level).

The results of a deflection shape study using the laser scanning process can be depicted graphically by animating over the video image or a 3-D measurement grid of the test structure. Generally, this process makes the analysis easier to understand.



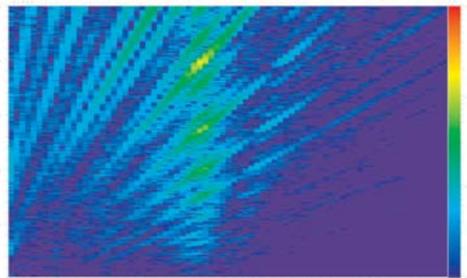
## Axle Vibrations, Bending and Torsional Modes



The ever present rotational movements of different components in a car are always the subject of intensive optimization efforts by product development groups. The non-uniform rotation induced by the discrete combustion process leads to torsional vibrations in the drive chain that are the cause of undesired vibration and noise emissions.

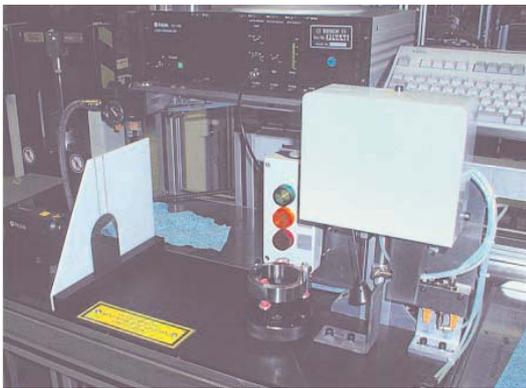
Rotational vibrometers with their non-contact measurement procedure allow a quick and easy examination of the torsional vibrations while the components of interest are in operation. In parallel to the rotational vibrations, the bending vibrations can be measured with the single point vibrometer.

See also Polytec Application Note VIB-C-04



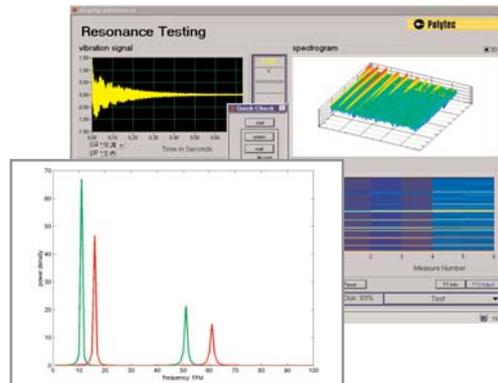
Images courtesy IAV GmbH, Chemnitz

## Quality Testing and Industrial Process Control



Outstanding product quality requires consistent quality assurance across the entire production process. Polytec's Acoustic Quality Control makes a decisive contribution to this effort by examining important acoustic signatures.

Acoustic quality control is a multipurpose, non-destructive process to assure the quality and reliability of products and manufacturing processes. It provides information on vibration characteristics which can show deviations in the produc-



tion process and the state of the test items. This permits an assessment of product reliability and a certification of the product.

In developing and realizing acoustic test systems, Polytec has primarily specialized in the application of laser vibrometers. In the car industry this process allows testing on engines, gear boxes, steering gears, cam rings, turbochargers, fuel pumps, etc.

Please visit [www.polytec.com/usa/automotive](http://www.polytec.com/usa/automotive) to learn more about vibrometers and automotive applications and to download Polytec Application Notes.

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

**Polytec-PI, S.A. (France)**  
32 rue Délizy  
93694 Pantin  
Tel. + 33 (0) 1 48 10 39 34  
Fax + 33 (0) 1 48 10 09 66  
info@polytec-pi.fr

**Lambda  
Photometrics Ltd.  
(Great Britain)**  
Lambda House, Batford Mill  
Harpenden, Herts AL5 5BZ  
Tel. + 44 (0) 1582 764334  
Fax + 44 (0) 1582 712084  
info@lambdaphoto.co.uk

**Polytec KK (Japan)**  
Hakusan High Tech Park  
1-18-2 Hakusan, Midori-ku  
Yokohama-shi, 226-0006  
Kanagawa-ken  
Tel. +81 (45) 938-4960  
Fax +81 (45) 938-4961  
info@polytec.co.jp

**Polytec, Inc. (USA)**  
North American Headquarters  
1342 Bell Avenue, Suite 3-A  
Tustin, CA 92780  
Tel. +1 714 850 1835  
Fax +1 714 850 1831  
info@polytec.com

Midwest Office  
3915 Research Park Dr.,  
#A12  
Ann Arbor, MI 48108  
Tel. +1 734 662 4900  
Fax +1 734 662 4451

East Coast Office  
25 South Street, Suite A  
Hopkinton, MA 01748  
Tel. +1 508 544 1224  
Fax +1 508 544 1225