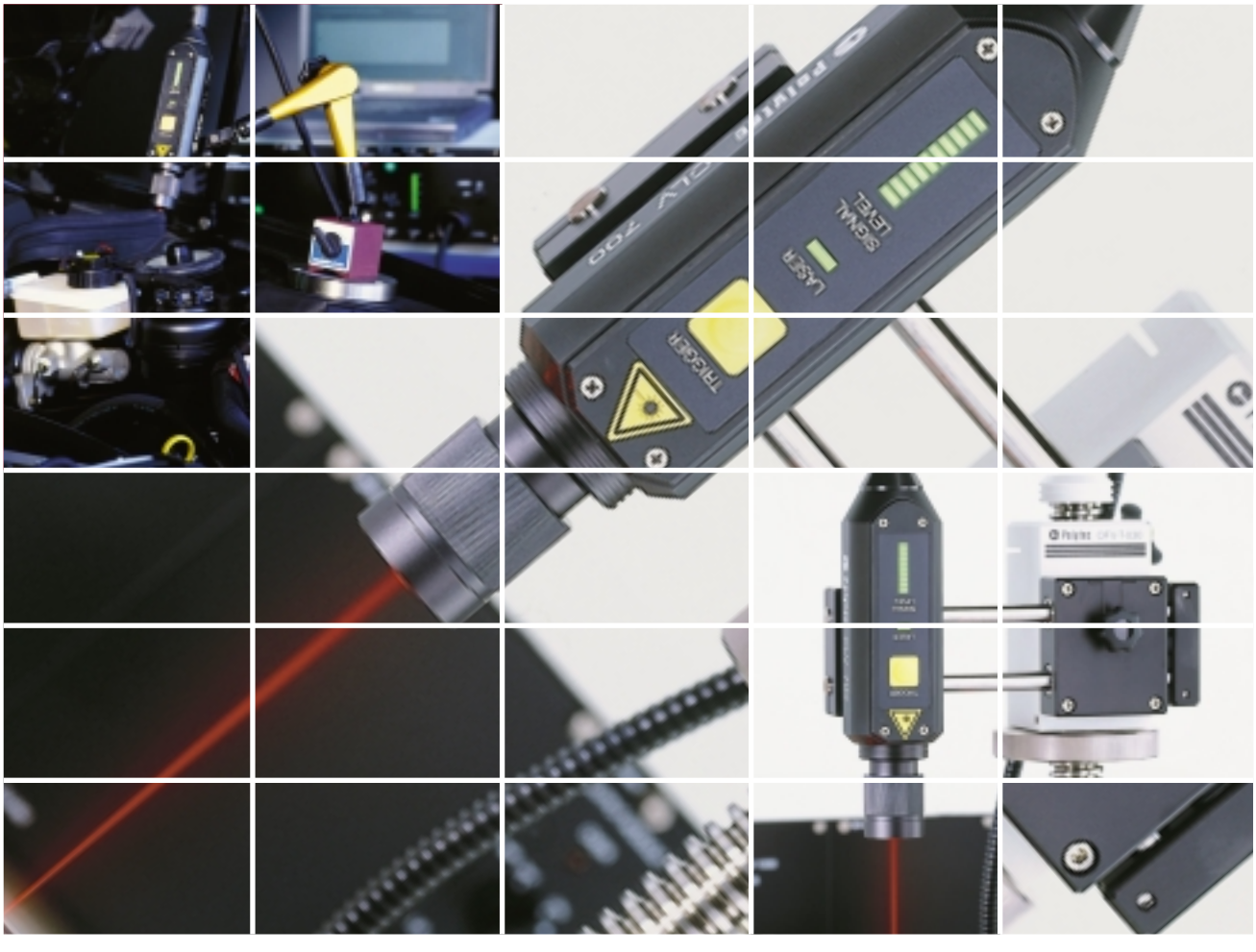
CLV –
Compact Laser Vibrometer



High Performance
Vibration Measurements
For Industrial Needs

Non-Contact Vibration Measurement

Laser Doppler vibrometers (LDVs) are optical instruments employing laser technology to measure velocity and displacement of points on a vibrating object.

As the laser beam can be focussed down to a few µm, measurements are possible on very tiny structures such as micro-electro-mechanical systems (MEMS), data storage components or ultrasonic bonding wires.

Unlike conventional transducers such as accelerometers, LDVs are completely non-invasive and are not affected by the properties of the test surface and/or by environmental conditions such as temperature or pressure.

LDVs are widely used by research engineers in the automotive, computer, micromechanics and other industries. The development of many modern products would have been impossible without the contribution of Polytec's LDV technology.

LDVs are also an ideal tool for on-line testing of products during the manufacturing process. Up until now, the physical size and sophistication of LDVs has limited the wider use of such systems in production lines. The new range of Polytec Industrial Vibrometers, such as the CLV (described in this brochure) overcomes these limitations.

Polytec is the world leading supplier of LDV systems covering the entire spectrum of laser vibrometry from low-cost systems for production testing, through turn-key scanning vibrometers for vibration mapping of entire areas.

Advantages of CLVs

- Adds no mass loading or stiffness which could alter the results on small, lightweight or soft objects.
- High spatial resolution.
- Works on virtually any surface including tight radii, or edges where it would be impossible to mount an accelerometer.
- Much higher linearity and accuracy than conventional transducers.
- Superior bandwidth and dynamic range.
- Calibration independent of stand-off distance, surface reflectivity and material properties.
- CLV works on any surface material:
  Mechanical transducers are usually mounted using a magnetic base requiring a metallic surface.
  When applied to plastics and soft surfaces the result depends upon the clamping pressure with which the contact transducer is applied.
- Reduced testing time per specimen. Laser easily repositioned.
- CLV operates in virtually any condition:
  – On hot parts where conventional transducers cannot be applied.
  – On oil soaked surfaces.
  – Through glass windows or fluids for measuring components requiring special test conditions.
  – On difficult to access surfaces.
- Unlike conventional sensors no special transducer handling system is required resulting in lower installation costs.

CLV Compact Laser Vibrometer

The Compact Laser Vibrometer is a non-contact transducer for vibration measurements in production lines and research and development (R&D) applications. The CLV system comprises a laser module with a ruggedized sensor head for operation in almost any environment, plus a highly modular electronics cabinet for processing and demodulation of the signal. The output is an analog vibration output signal proportional to the surface velocity or displacement of the test object.

For the electronics cabinet, a series of different plug-in modules are available, which can be tailored around specific applications ranging from measurements in the acoustics frequency range to high frequency/high velocity testing on ultrasonic transducers.

For R&D use and very demanding production applications a series of digital demodulator plug-in modules is available. These modules are characterized by low noise, high sensitivity and unique calibration accuracies.

CLV Features

- Compact, lightweight sensor head for easy positioning of laser, with a small footprint for simple integration into test systems. While not as miniature as Polytec's fiberoptic sensor heads, the CLV achieves a compromise between their small size and the high optical sensitivity of larger units.
- Sensor head is ruggedized and includes a watertight IP-64 housing.
- Sensor head and fiber cable are insensitive to misalignment, shock and vibration.
- Modular electronics: Saves costs and achieves higher performance with signal demodulation modules tailored to the specific application.
- Impressive specifications: Plug-in modules cover frequencies ranging from DC to 350 kHz and velocities up to 1.25 m/s. The CLV has excellent velocity resolution – an important feature for measurements of very small vibration levels, e.g. on ball bearings and micro devices.
- Digital demodulation: The best CLV performance is achieved by (optional) digital signal demodulation resulting in an even lower noise level, higher linearity and calibration errors close to zero.

What can the CLV do for you?

Do you need to replace the traditional vibration transducers in your lab or on the production line by an easier-to-use and more reliable method?

Are you running into trouble because your new product has a non-metallic surface prohibiting the use of magnetic-base accelerometers?

Are the costs for an accelerometer handling system or an acoustic test chamber to be installed on your new planned production line too high?

Has one of your customers specified the use of non-contact methods for vibration monitoring?

Are you testing turbo chargers or other components in an oil soaked environment, making the use of contact type transducers difficult?

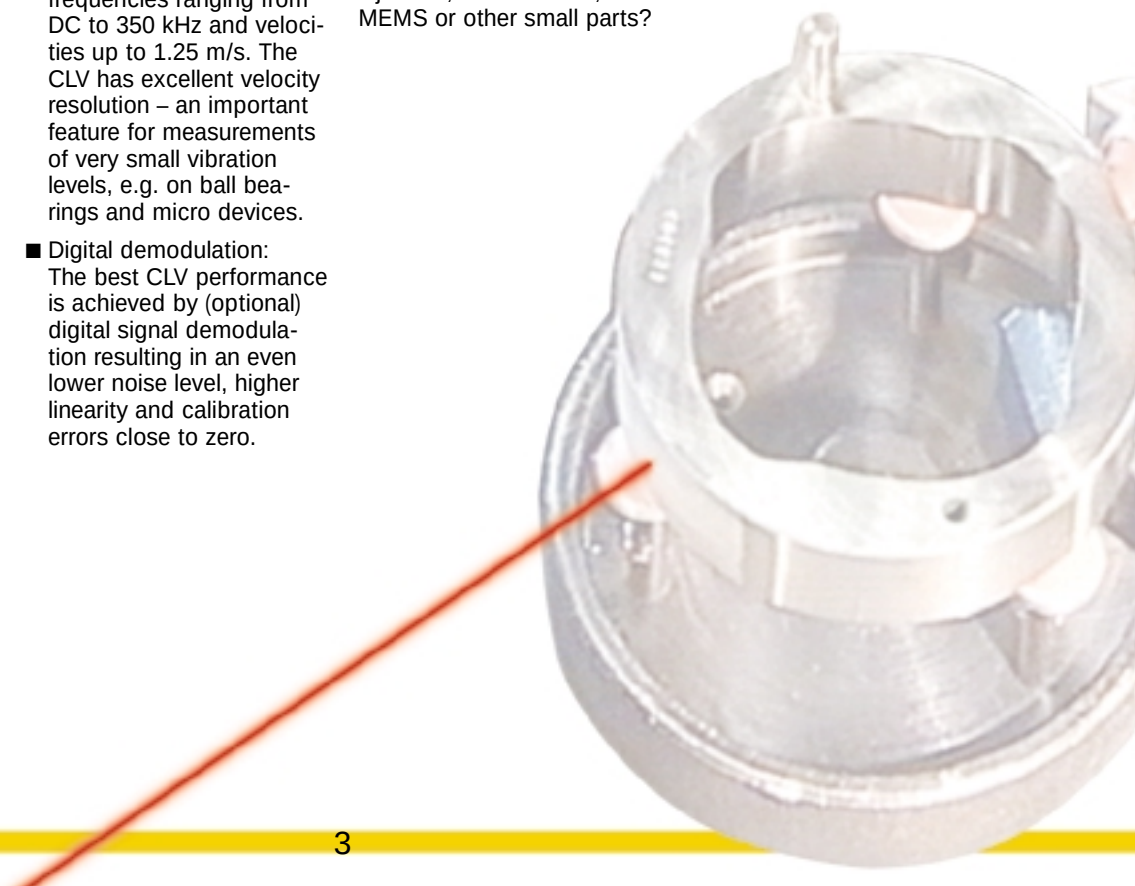
Do you need to set-up a production test rig for fuel injectors, ABS sensors, MEMS or other small parts?

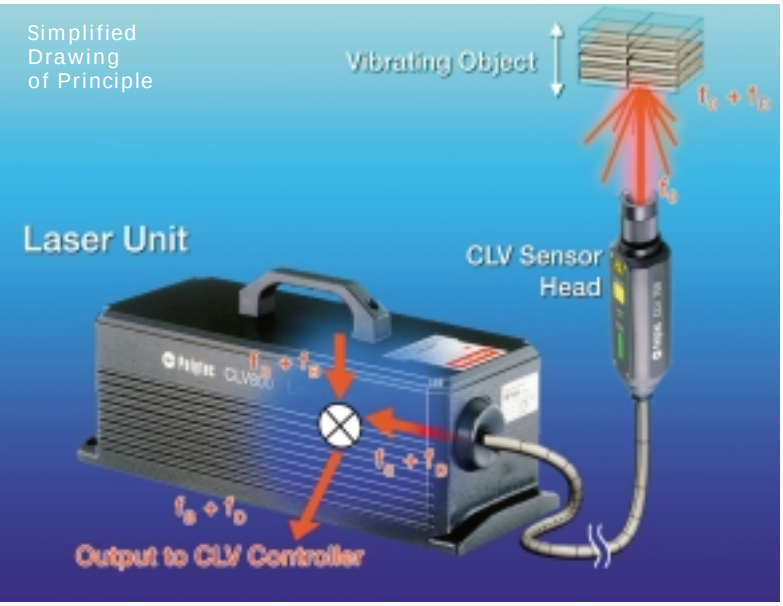
The non-contact CLV laser vibrometer is the ideal solution for all these tasks.

In the laboratory the CLV can be installed and set-up within minutes, targeted on your test object at any distance from 110 mm to more than 10 m. The small sensor head is easily repositioned for measurement of many test points in a fraction of the time needed for mounting and removing accelerometers.

On the production line the CLV installs at a safe distance from the test object, yet provides accurate and reliable data in a much shorter time than would be possible by using conventional sensors.

Our Polytec Noise Analysis (PNA) division will support you if data acquisition systems and software for evaluation of the vibration signal are needed.





Measurement Principle

Laser Doppler Vibrometers work according to the principle of laser interferometry. The laser beam, with a certain frequency f_0, strikes a point on the vibrating object. Light reflected from that point travels back to the sensor head. The back-scattered light is shifted in frequency (Doppler effect). This frequency shift f_D is proportional to the velocity of the vibrating object.

$$f_D = 2\ |v|\ /\lambda$$

To distinguish between movement towards and away from the sensor head an offset frequency f_B is added onto the backscattered light. The resulting frequency seen by the photo detector becomes $f = f_B + f_D$, where the sign in this equation depends upon the direction of movement of the object.

The frequency on the photo diode, f, is linked to the vibration velocity by the simple relationship

$$f = f_B + 2\ v\ /\lambda$$

λ is the wavelength of the HeNe laser utilized in the LDV system. Unlike laser diodes that are sensitive to ambient conditions, the wavelength of a HeNe laser is a highly stable physical constant (0.6328 µm). This is why no calibration of the laser interferometer itself is necessary.

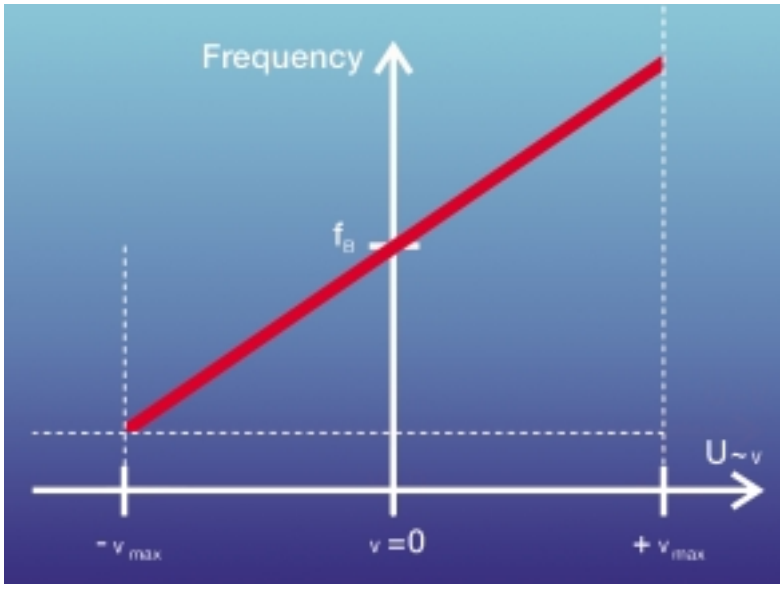
This technique is well proven and used in more than 4000 LDVs manufactured by Polytec so far.

Signal demodulation

The purpose of signal demodulation electronics is to convert the frequency f seen by the photo detector into a voltage U proportional to the vibration velocity v as shown below.

One must keep in mind that the CLV system can measure vibration frequencies from a few Hz to hundreds of kHz. Velocities can be as small as 0.1 µm/s up to 1.25 m/s. A standard frequency-to-voltage converter simply cannot cover this broad range. The quality of the dedicated CLV demodulation electronics defines the accuracy, linearity, sensitivity and signal-to-noise ratio of the system.

Polytec has always been aware that signal processing is one of the most sensitive parts of any LDV system. A series of high performance plug-in signal demodulators have been developed for the CLV. Many are optimized for applications with respect to frequency/velocity ranges.



Analog and Digital

Until now, all real-time LDV systems have used analog signal processing electronics. Polytec is proud to introduce digital signal demodulation (optional) for the CLV system. The key advantages of digital compared to analog demodulation are:

- Outstanding linearity and accuracy with nearly immeasurable calibration errors.
- Higher resolution/lower noise floor.
- Absolutely linear phase response.
- No aging/drift effects, extending intervals between calibrations.
- Analog and digital (S/P-DIF standard) output signals.

With the digital S/P-DIF output no analog data acquisition system is needed. Any PC sound card, mini-disk recorder etc. with S/P-DIF input may be used for acquiring the data. Although the digital CLV modules are higher priced than the analog versions, the S/P-DIF interface can easily save the high cost of a data acquisition board or FFT analyzer.

The digital CLV demodulator is an excellent choice for R&D work and for applications requiring the highest resolution, e.g. non-repetitive run-out (NRRO) measurements on bearings, spindles etc.
For less demanding standard applications, the analog CLV demodulators are the more cost effective solution.

CLV Calibration

Calibration of measurement equipment has become an important issue in recent years. Polytec is closely cooperating with Germany's Bureau of Standards (PTB) to establish calibration methods for LDVs.

The LDV sensor head's output is related to the laser wavelength, which is an accurately known physical standard. Hence there is no need for calibration of the LDV optics.

The CLVs analog signal processing electronics drift very little over many years of use.

But Polytec recommends regular service and recalibration every two years. More frequent calibration can be provided to meet company Q.A. procedure requirements.

The CLV Sensor Head

The CLV-700 sensor head is permanently connected to the internal or external CLV laser unit via an armored 3 m fiber-optic cable (up to 10 m optional). It is available with three different lens systems, which should be selected according to the specific application.

The variable focus lens system with f= 25 mm (vf-25, short range) or f= 40 mm (vf-40, long range) lens should be selected for laboratory use. With a variable focus lens the laser beam can be focused onto the object at any standoff distance ranging from 0.11 m to more than 10 m.

The fixed focus version (ff) has an extra long depth of field and is mainly intended for permanent installations on a production line. The sensor head should be installed at a 316 mm distance from the test object. It has a larger spot size that is less sensitive to surface finish variations on production components.

CLV Laser Units

The CLV laser unit incorporates a HeNe laser with power supply and interferometer optics. The interfero-

meter and power supply component connects via a 3 m long armored fiber optic cable to the CLV-700 sensor head. Cable extensions up to 10 m can be ordered. It is available either as a plug-in module for the CLV-1000 mainframe (model CLV-810-xx including CLV-700) or as an external component in an IP-64 safe die-cast protection housing (model CLV-800-xx including CLV-700). The external CLV-800-xx housing is recommended for production applications requiring longer distances between the sensor head and CLV controller. The electrical connection cable between the CLV-1000 and external laser unit can be as long as 20 m. For laboratory work the space saving internal laser unit plug-in module CLV-810-xx may be considered more appropriate.

Input Module

The input module amplifies the signal received from the sensor head. It also features a range coupled “tracking filter” which is a very efficient electronic device for bridging short drop-outs in the vibration signal. A signal level bar-graph indicator on the front panel of each input module provides information about the intensity of the return signal from the test object.
The input module must be chosen based on the selected decoder module.

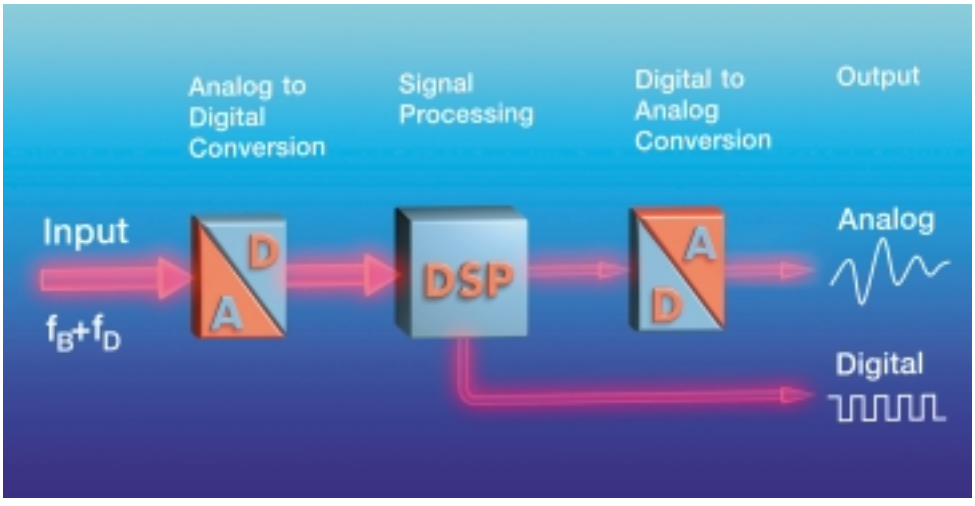
Input Module	Maximum Velocity	Suited for Decoder
CLV-M100	100 mm/s	CLV-M010
CLV-M200	1,250 mm/s	CLV-M020/CLV-M030
CLV-M300	500 mm/s	CLV-M050/CLV-M060

For handheld operation the “Trigger” button on the head may be used to trigger the data acquisition of an FFT analyzer or other data recording equipment.

Decoder Module

There are four analog and two digital decoder modules to choose from. In most combinations the decoder module must be combined with an input module and an output module. The CLV-M040 20 kHz “Combi” decoder module is the most cost-

effective module as it already incorporates the input module on the same board. The digital decoder module CLV-M050 does not necessarily require an output module.
For each of the decoder modules the required velocity range is selected by a rotary switch on the front panel.



Decoder Module		Velocity Ranges	Max. Velocity (0 – peak)	Frequency Range	Resolution	Recommended Input Modules	Recommended Output Modules
CLV-M010		1 mm/s/V 5 mm/s/V	10 mm/s 50 mm/s	0.5 Hz – 20 kHz 0.5 Hz – 50 kHz	0.2 µm/s 0.5 µm/s	CLV-M100	CLV-M001 CLV-M003
CLV-M020		5 mm/s/V 25 mm/s/V	50 mm/s 250 mm/s	0.5 Hz – 50 kHz	0.5 µm/s 0.8 µm/s	CLV-M200	CLV-M001 CLV-M003
CLV-M030		5 mm/s/V 25 mm/s/V 125 mm/s/V	50 mm/s 250 mm/s 1,250 mm/s	0.5 Hz – 250 kHz	0.5 µm/s 1.5 µm/s 2 µm/s	CLV-M200	CLV-M002
CLV-M040		1 mm/s/V 5 mm/s/V	10 mm/s 50 mm/s	10 Hz – 20 kHz 0.5 Hz – 20 kHz	2 µm/s 2 µm/s	Not needed	CLV-M004 CLV-M003
CLV-M050	digital	2 mm/s/V 10 mm/s/V 50 mm/s/V	20 mm/s 100 mm/s 500 mm/s	0 Hz – 75 kHz	0.1 µm/s 0.2 µm/s 0.5 µm/s	CLV-M300	CLV-M001 CLV-M003 (*1)
CLV-M060	digital	2 mm/s/V 10 mm/s/V 50 mm/s/V	20 mm/s 100 mm/s 500 mm/s	0 Hz – 350 kHz	0.2 µm/s 0.4 µm/s 1 µm/s	CLV-M300	CLV-M001 CLV-M002

*1: An output module is only needed when time domain viewing of the results with reduced bandwidth is required

The digital decoder modules CLV-M050 and CLV-M060 feature 3 different output formats summarized in the table below. The S/P-DIF digital output can be connected directly to the digital input of any data recorder, mini-disk or PC sound card, saving the cost of an expensive data acquisition system.

Output Type		Resolution	Max. Frequency	Propagation Delay	Installed in CLV-M050	CLV-M060
Analog I	digital	16 Bits	50 kHz	11 µs	X	
Analog II	digital	16 Bits	350 kHz	11 µs		X
Digital S/P-DIF	digital	24 Bits	22 kHz	1.1 ms	X	

CLV Mainframe

The CLV-1000 modular main frame incorporates the line power supply for all CLV components and provides space for installation of the various modules, including the power supply/ interferometer component of the internal laser unit. The total space available is 9 slots and cannot be exceeded. The internal laser unit occupies 3 slots whereas all other modules needed 1 slot each. Please refer to the example configuration on page 10.

To measure at two different positions simultaneously, the CLV can be configured as a dual-channel vibrometer in one single housing, using the CLV-2000 main frame. Separate input, decoder, output and extension modules are required for each channel. The total space available for modules is again 9 slots. The CLV-2000 main frame is only compatible with the external laser units CLV-800.xx, of which two are required.

Output Module

A voltage proportional to the vibrational velocity is available from the output module. This signal may be connected directly to an external data acquisition system for further processing via a BNC connector.

The output module provides final amplification and filtering of the vibration signal. For industrial environments we recommend applying a high-pass filter to suppress ambient environmental vibrations. The low pass filters are useful for reducing the bandwidth for time domain viewing of the signal or when performing rms measurements.

The filters are selected via a rotary switch on the front panel. An LED indicates if the maximum output voltage is exceeded and a higher velocity range should be chosen.

For the digital decoder module CLV-M050, an output module is optional, and not always necessary.

Output Module	Low-pass Filters	High-pass Filters	Recommended for Decoder Module	Remarks
CLV-M001	5/20/50 kHz/off	–	CLV-M010/CLV-M020 CLV-M050	Low pass filter only
CLV-M002	5/20/100 kHz/off	100 Hz/off	CLV-M010/CLV-M020 CLV-M030/CLV-M060	High and low pass filter
CLV-M003	5/15/30 kHz/off	10 Hz	CLV-M010/CLV-M020 CLV-M050	For acoustic applications
CLV-M004	–	–	CLV-M040	Unfiltered module

Extension modules & accessories see page 10 – 11

Specifications of CLV laser units with CLV-700 sensor head

Available Models			
Model	Description	Standoff Distance	Spot Diameter
CLV-800-ff	External laser unit, fixed focus sensor	316 mm	160 µm @ 316 mm
CLV-810-ff	Internal laser unit, fixed focus sensor		
CLV-800-vf25	External laser unit, variable focus sensor, f=25mm	0.11 – 10 m	85 µm @ 316 mm
CLV-810-vf25	Internal laser unit, variable focus sensor, f=25mm		285 µm @ 1 m
CLV-800-vf40	External laser unit, variable focus sensor, f=40mm	0.2 – 10 m	45 µm @ 316 mm
CLV-810-vf40	Internal laser unit, variable focus sensor, f=40mm		180 µm @ 1 m

CLV-800 External Laser Unit	
Protection rating	IP64
Operating temperature	+0°C...+45°C (32°F...113°F)
Weight	6 kg
Dimensions	340 mm x 130 mm x 115 mm

CLV-700 Sensor Head	
Laser type	HeNe, < 1 mW
Laser safety class	II
Protection rating	IP64
Operating temperature	+0°C...+45°C (32°F...113°F)
Weight	0.5 kg
Dimensions	174 mm x 48 mm x 38.8 mm (ff version) 202 mm x 48 mm x 38.8 mm (vf version)

General Specifications CLV-1000 and CLV-2000

General	
Mains	Voltage 100...240 VAC ±10%
Power consumption	Max. 80 VA
Operating temperature	+5°C...+40°C (32°F...104°F)
Weight	Ca. 6 kg depending on modules installed
Dimensions	450 mm x 355 mm x 134 mm
Recommended calibration interval	Every 2 Years

Extension Modules

A series of optional modules can be added to extend the capabilities of the CLV system:

Ultrasonic Integrator Modules

Provides a direct displacement output for measurements on wire bonders, piezo transducers and other high frequency devices. Frequency components below 10 kHz are suppressed making the output insensitive to environmental vibrations.

Acoustics Integrator Module

Low frequency integrator for achieving a direct displacement output in addition to the velocity output signal.

Remote Control Module

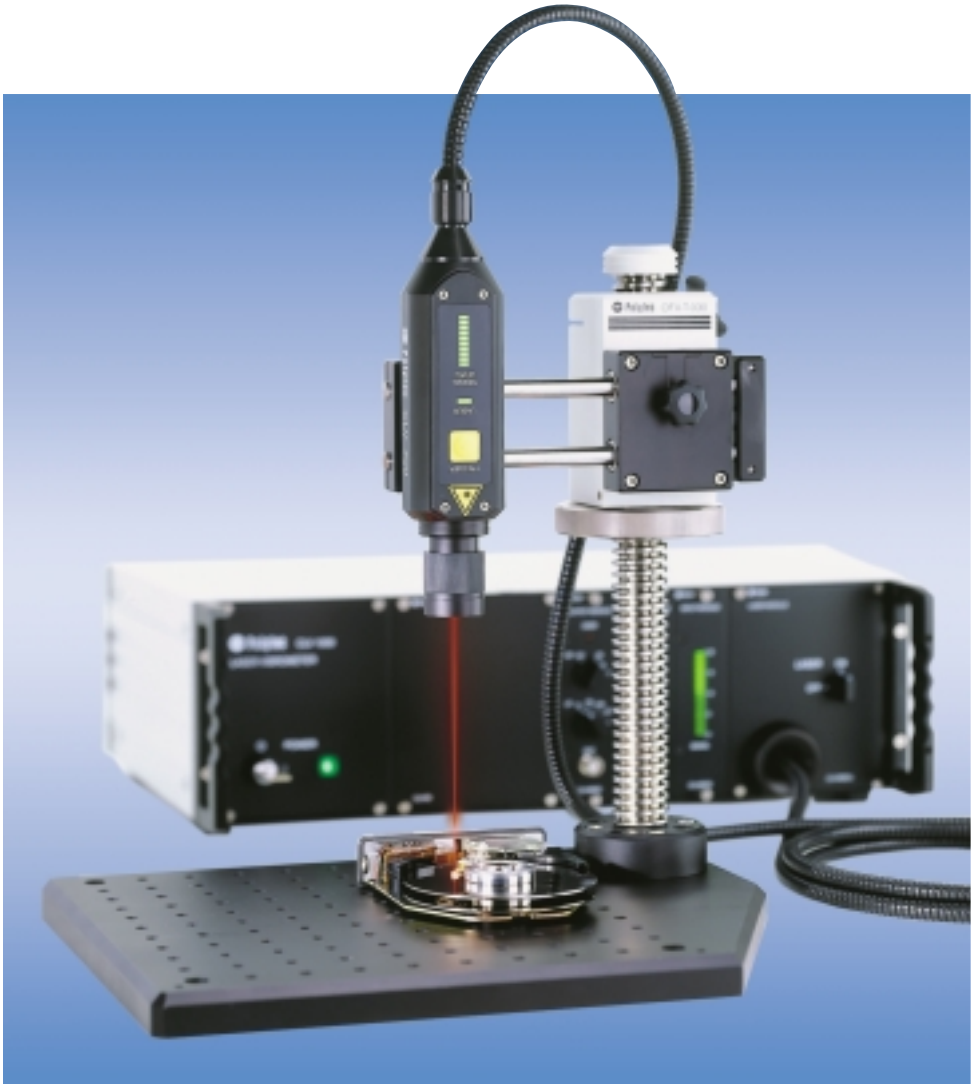
For setting velocity ranges and filters on the CLV system remotely controlled via an RS-232 serial interface. The CLV-M000.RC remote control module is not compatible with the dual-channel CLV-2000 system.

Integrator Module	Frequency Range	Displacement Range	Recommended for Decoder Modules
CLV-M000.I1	10 kHz to 250 kHz	1 µm/V (25 µm p-p)	CLV-M030
CLV-M000.I5	10 kHz to 250 kHz	5 µm/V (110 µm p-p)	CLV-M030
CLV-M000.IL	10 Hz to 20 kHz	100 µm/V (2.4 mm p-p)	All

Model number and space requirement example:

Main frame	CLV-1000	
Input module	CLV-M300	1 slot
Decoder module	CLV-M030	1 slot
Output module	CLV-M002	1 slot
Integrator module	CLV-M000.I1	1 slot
Integrator module	CLV-M000.IL	1 slot
Remote control	CLV-M000.RC	1 slot
Internal laser unit	CLV-810.vf25	3 slots
Total number of slots		9 slots
Model number	CLV-1332.I1.IL.RC with CLV-810.vf25	

CLV Accessories



Fiber Cable Extension CLV-FC-X

Extends the fiber cable length between laser unit and CLV-700 sensor head from 3 m (standard) up to a maximum of 10 m *(-X denotes the cable length).*

Electrical Cable Extension CLV-C-X

Extends the signal cable between external laser unit CLV-800-xx and CLV-1000/CLV-2000 main frame from 5 m (standard) up to a maximum of 20 m *(-X denotes the cable length).*

CLV-0000.CM Cable Reel

The cable reel is used to fix the cable and sensor head during transportation of CLV-1000 systems with internal laser unit.

Transportation Cases

A set of cases is available for the CLV systems.

OFV-T-030 Test Stand

Provides vertical and horizontal positioning of the CLV-700 sensor for testing small parts. Linear and angular micro-positioning stages may be added to the OFV-T-030 (ask for separate catalog).

CLV-039 Flexible Arm with Magnetic Base

Positions CLV-700 sensor head for measurements on machines, engines, shafts etc.

CLV Applications

Automotive

The CLV is widely used by NVH engineers for vibration measurements on automotive parts. In conjunction with the CLV-039 flexible positioner, the compact, and oil proof CLV-700 sensor head is easily installed under the hood for measurements on engine components, or under the car for testing exhaust systems or gear boxes. Inside the car, the small size of the CLV-700 sensor allows measurements in difficult to reach areas, such as on the instrument panel, under the seats etc. The CLV signal output is compatible with all standard data acquisition systems used in NVH labs.

For measurements on rotating components (brakes, tires, drive shafts, etc) velocities in excess of 1.25 m/s can easily occur. For such applications, Polytec vibrometers with higher speed range (e.g. OFV-3001/303 series vibrometers) are recommended.

Vibration measurements on the alternator of a running engine.

Production testing of electrical motors

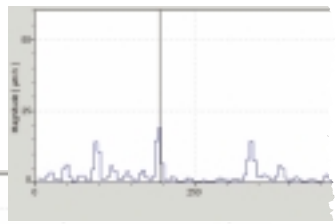
Major manufacturers of electrical motors are using CLV systems for non-contact, on-line production testing. Vibration measurements are performed on many different devices including starter, window/roof lifting, wiper and vacuum cleaner motors. Similar applications range from testing of compressors for refrigerators to measurements on washing machine production lines.

The CLV can also replace microphone-based acoustic test methods. In the example shown below the motor is measured simultaneously at 2 points. One CLV system is checking the vibration level of the motor. The second CLV is looking for gear defects causing noise spikes. In such installations the CLV not only replaces an accelerometer and it's contacting system, it also eliminates the need for acoustic chambers required by microphones.

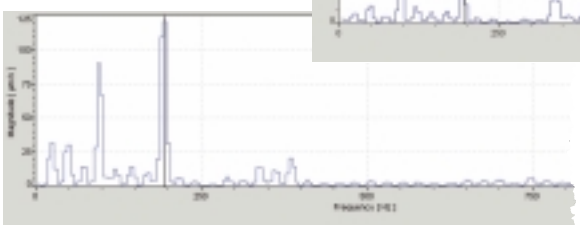
In many applications, the selection of the best measurement point on the compressor, motor etc. can be difficult and time consuming. The Polytec Scanning Vibrometer PSV-300 will scan the test object within seconds and provide reliable information about the best measurement position to aim the CLV for production monitoring. Polytec can provide a PSV-300 area scanning measurement service to it's customers on a consultancy basis.

PSV area scanning result shows best test positions on the motor.

Vibration spectrum of a good motor.



Vibration spectrum of a bad motor.



Quality monitoring of light bulbs

Automotive and household light bulbs are consumable products requiring regular replacement. Light bulbs used in airplanes and motorcycles are more critical and difficult/costly to replace, so must be more rugged, have much longer lifetimes and higher reliability. For assuring highest quality these bulbs are 100% tested on a vibration shaker or test-hit with a force hammer. The CLV laser vibrometer measures the vibration amplitude directly from the filament or the reflector.

Light bulb test rig for motorcycle bulbs manufactured by Polytec's PNA division: The bulb is mounted to a vibration shaker. The CLV-700 sensor with CLV-800 external laser unit measures the vibration amplitude of the bulb reflector.

Defect detection by Acoustic Analysis

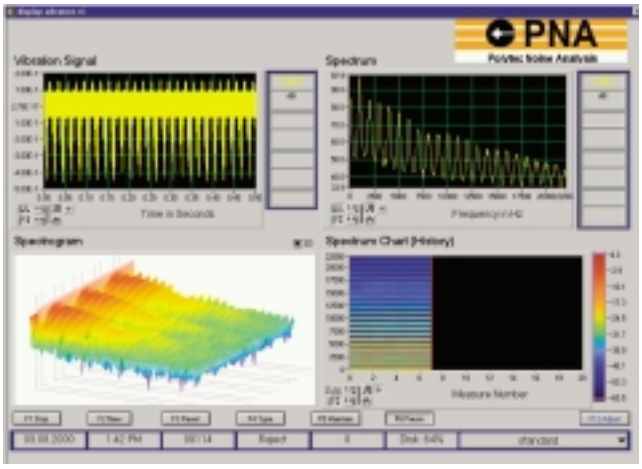
A crack in a camshaft ring can cause serious damage to the engine. A traditional test method involved a trained operator hitting every ring manually with a hammer and then listening to the sound of the ring. The reliability of this subjective method has been drastically improved by incorporating a CLV system for detecting the surface vibration with noise analysis software assessing part quality automatically.

Source:
Bosch/PNA video film

Acquiring the vibration data is only one part of the job. Equally important is the processing of the vibration signal with dedicated software to ensure that a reliable PASS/FAIL decision is made. Ideally, both the laser vibrometer and data processing system should be perfectly matched to each other and supplied by the same manufacturer. Polytec has recognized this and established a new division – Polytec Noise Analysis (PNA) – employing experienced experts in software, defect detection and quality monitoring. PNA provides customized data acquisition systems and software, optimized for operation with Polytec's CLV system.

Wire bonding applications

Wire bonding is a common technique for ultrasonic soldering of tiny wires to computer chip substrates. The quality of a bond strongly depends upon the vibration amplitude at the tip of the bonding tool (wedge or capillary). Polytec vibrometers are used for the development of wire bonding machinery as well as for checking and re-calibrating machines on-line in the semiconductor factories. Quality control engineers in wire bonding factories like the CLV-700 sensor because, with it's small size and low weight, it is so easy to install and position on the bonding machine. For wire bonding applications, the CLV controller should be equipped with the CLV-M000.I1 integrator option, which provides an output signal proportional to instantaneous displacement.



Customized screen layout for acoustic defect detection on camshaft rings. The CLV and PNA software not only "listen" to the quality of the sound, but are also monitoring the impact force of the hammer to obtain input/output energy values (response function).

Production line test stand for checking hard disc vibrations. Photo courtesy of PMDM Germany.

Resonance testing

Polytec laser vibrometers have been most successful for resonance testing on data storage devices, e.g. for suspensions of hard disk drives, pick-up lenses of CD recorders and DVD players, as well as for components in DAT and other tape recorders. Polytec vibrometers are routinely used for run-out measurements on hard disk drive ball and liquid bearings.

The combination of CLV-8x0-40-vf laser unit with CLV-1352 digital demodulation controller provides optimum parameters for this application. With a spot diameter of 45 µm, even the smallest components are accessible. The extremely low noise level of < 0.1 µm/s allows measurements of lowest vibration levels, e.g. for NRRO (non-repetitive run-out) testing of bearings.

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