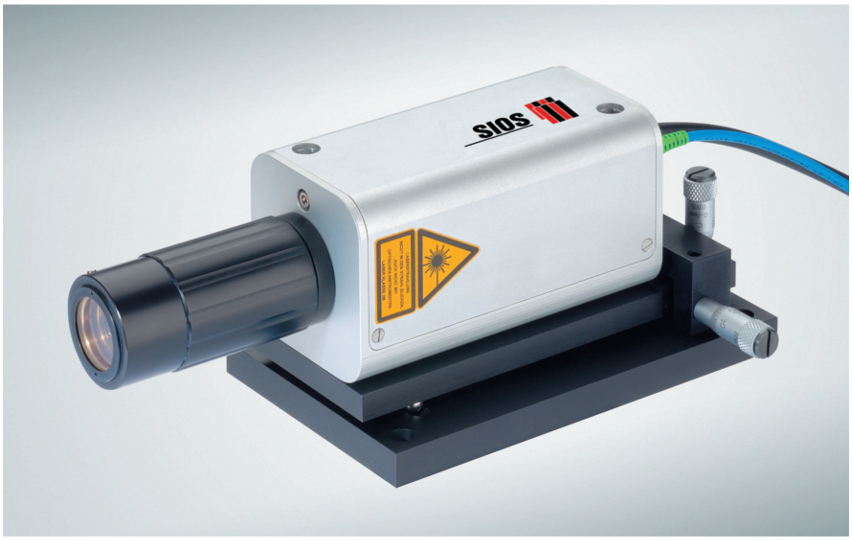
Precise, non-contact and flexible – the new laserinterferometric vibrometer

Mechanically coupled sensors have traditionally been used to measure vibrations. However, the general, continuing trend toward miniaturization is placing entirely new demands on measuring systems that have to measure the motion of objects through a wide frequency range and down to sub-nanometer resolution. This is where laserinterferometric vibrometers are used for the non-contact, reaction-free measurement of macroscopic and microscopic objects at frequencies from 0 to 2 MHz and resolutions in the subnanometer range. These systems are ideally suitable for applications in which the vibrations of hard-to-reach objects have to be analyzed.



Series LSV laserinterferometric vibrometer

The design of a laserinterferometric vibrometer is based on that of a Michelson interferometer, in which a beam of coherent light is split into two partial optical beams: a reference beam and a measuring beam. The reference beam has a fixed length. The measuring beam is focused on the surface to be measured, its length changes as a result of the motion of the object measured. After the measuring beam has been reflected from the object measured, the two returning partial beams interfere with one another. Their phase difference is proportional to the displacement of the object measured, and is thus the measured variable. This measurement can also be traced back to international length standards because the laser frequency serves as a linear scale.

Optimized for optically rough surfaces

Laserinterferometric vibrometers are interferometers that have been optimized for measuring optically rough surfaces. Their most important feature, which distinguishes them from other length measuring interferometers, is that they have a lens that focuses the measuring beam on the measuring location. Reflection from an optically rough surface creates a speckle pattern. The sensor head is designed to ensure a good signal-to-noise ratio, even when such a speckle pattern occurs. However, the focusing of the measuring beam limits the measuring range to a few mm as a function of the reflectivity of the surface. However, this is not usually a problem in vibration measurement because the vibration amplitudes measured are usually smaller. Normal displacement measurements can also be made in the available measuring range.

Helium-neon lasers are used as the light source for length and vibration measurement because their characteristics, such as coherence and frequency stability, are crucial for metrology. The measuring head in series LSV vibrometers is coupled via fiber-optic cable in order to keep the head relatively small and free from thermal radiation. The reference mirror in the sensor head can be modulated in order to simplify calibration and improve performance. The new feature of the series LSV is the use of a zoom objective to focus the measuring beam instead of the previously conventional, fixed focal length lens. This enables the distance between measuring head and measuring point to be freely selected between 20 cm and 2 meters. This allows a great deal of flexibility in the measuring set-up, so the measuring instrument can be used for a range of different applications.

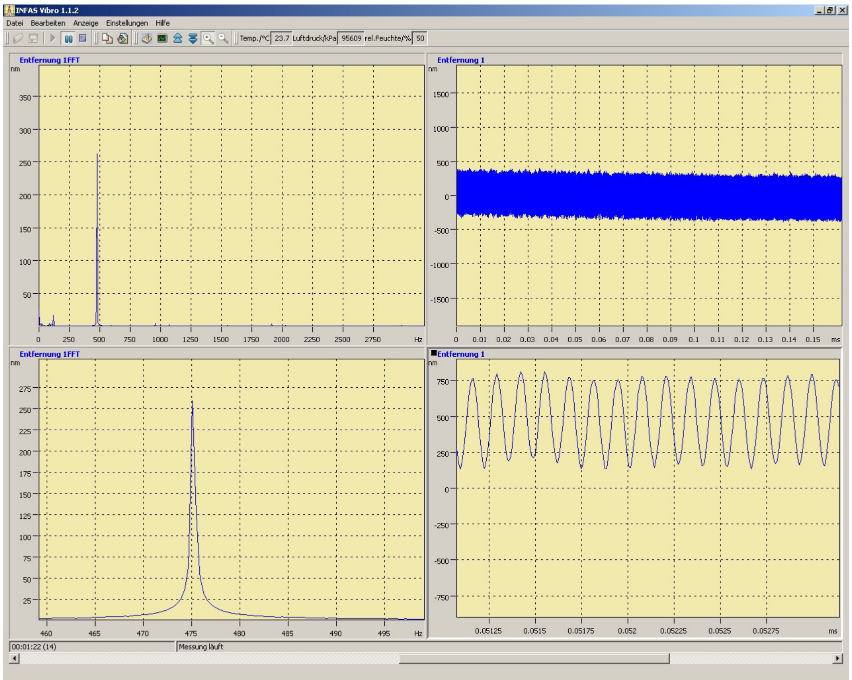
Design of the electronic evaluation unit

The He-Ne laser and the electronics for processing the interferometer signals received from the measuring head are housed in a 19 inch evaluation unit. The signals are processed and the reference mirror and the variable input amplifier are controlled by multiple microprocessors and very quickly programmable logic circuits. The evaluation unit has a modular structure, so the measuring system can be adapted flexibly to an application by the addition of various signal processing cards. The evaluation of two series LSV sensor heads can be housed in a 19 inch device.

The data capture can be synchronized with external events. This is achieved by using a trigger input with an extremely short delay time. This also enables the phase responses of an object to be measured at a known excitation.

The evaluation unit can be equipped with different interface cards to suit the intended purpose:

The high-speed evaluation card provides a USB and an RS232 interface for connection to a PC. There is also a trigger input for synchronizing the vibration measurement with an external excitation source. This evaluation card can be used to control both various functions of the vibrometer as well as signals with a maximum sampling frequency of 1 MHz (corresponds to a maximum possible signal frequency of 500 kHz) and a maximum data block length of 32768 values. The application programming interface (API) for communicating with this card is available for the user. A DLL, a



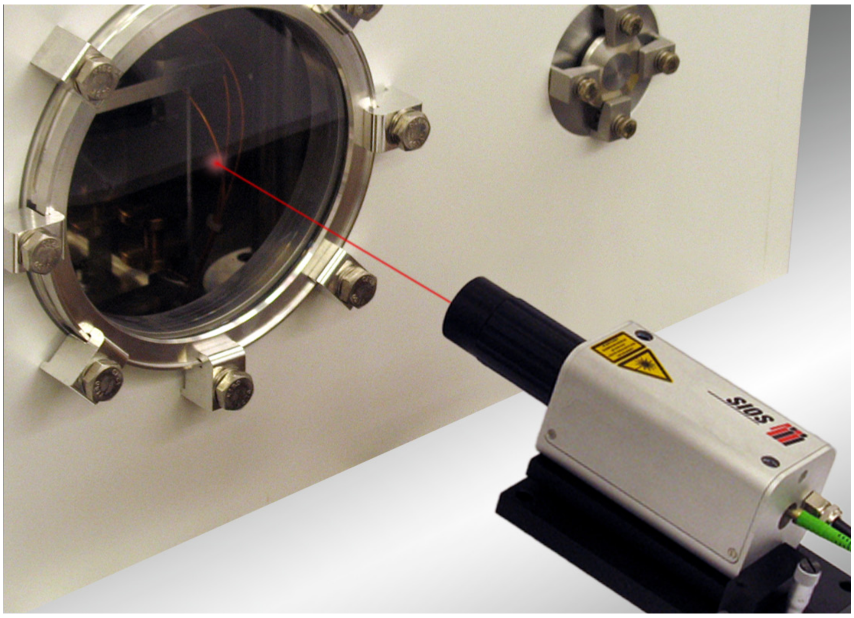
Measurement with the INFAS-Vibro software

Matlab library and corresponding VI modules support integration into independent applications.

The parallel interface card makes the demodulated interferometer signal available as a digital, parallel 32-bit word. The resolution (an LSB of this word) corresponds to approximately 0.078 nm. The parallel 32-bit value is available with a very low latency, and can be read out at a scanning rate of up to 4 MHz. This facilitates use of the full possible bandwidth of 2 MHz. In this case, the data block length depends only on the PC evaluation, and is not limited by the hardware. Typical fields of application for this interface are high-resolution frequency analyses of forced vibrations of micro-objects.

Vibration analysis systems often provide analog inputs for the sensors. The analog interface therefore has an analog output for integration into such systems. This enables conventional vibration sensors to be easily replaced by laserinterferometric vibrometers. The dynamic range of the series LSV vibrometer is far greater than the measuring range of conventional sensors, as is the analog resolution achievable with reasonable expenditure. The measuring range mapped at the analog output can therefore be selected in seven stages (± 0.63 µm to ± 2.6 mm) to adapt to different fields of application. This is normally done with a rotary knob on the front panel, but the range can also be switched by suitable software via the PC interface. An additional input for resetting/zero setting the analog signal further simplifies use. All in all, the analog interface card offers 16-bit resolution with a maximum output rate of 10 MHz.

Although the various interfaces available with the series LSV laserinterferometric vibrometer can be integrated into almost every measuring system, experience has shown that most of the applications involve stand-alone operation with PC software. The INFAS-Vibro software controls the vibrometer



Simple measurements made in high vacuum by placing the non-contact measuring vibrometer outside the vacuum chamber

via the USB or RS232 interface or via a DIO card from National Instruments (PCI-6534) used with the high-speed parallel interface of the vibrometer. The software enables vibration signals to be displayed, saved and preprocessed. Recording the raw signals enables the measurements to be analyzed offline without restriction. A configurable export in ASCII format data enables both raw and preprocessed signals to be further processed. For integration into independent applications, INFAS-Vibro can be controlled by a simple protocol via TCP-IP.

Analyzing and measuring mechanical vibrations without contact

Series LSV laserinterferometric vibrometers can be used in all fields of application in which mechanical vibrations have to be analyzed and measured without contact. Its main advantages in comparison to other vibration measurement methods are its non-contact and thus reaction-free mode of operation, the large measuring range with a distance resolution of less than one nanometer in the time range, which is increased by the FFT to less than 80 picometers in the frequency range, and, of course, the frequency range from 0 Hz to the current maximum of 2 MHz. The vibration spectra, natural frequencies and modes of vibration can also be determined. Multicoordinate measurements and differential measurements can be made with the aid of multiple systems.

A special version of the series LSV vibrometer which can work in vacuum is possible, but technically very complex. However, it is often possible to see the object to be measured through a window in the vacuum chamber, in which case the measurement can be made through the window by an externally placed measuring head. This makes it very easy to measure objects lying in a vacuum.

Conclusion

The laserinterferometric vibrometer is a valuable tool for all applications in which precise, non-contact measurement of object motion is required. The non-contact mode of operation provides a means of quickly analyzing objects in different positions without any mechanical influence by the sensor. The system is characterized by high precision and resolution, and a very wide frequency range. The adaptable measuring range facilitated by the zoom objective, the diverse interfaces of the evaluation electronics as well as the comprehensive software support make the series LSV vibrometer an important measuring instrument in production, quality assurance, and research and development.

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