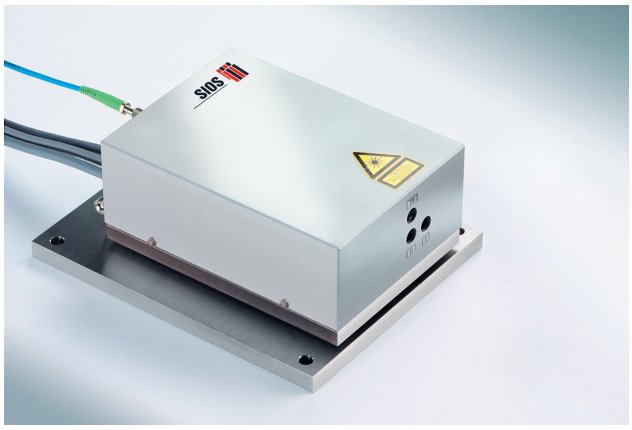
Triple-beam interferometer - Modern regarding function and design

SIMULTANEOUS LENGTH-ANGLE-MEASUREMENT UP TO 15 METRES FOR VARIOUS APPLICATIONS

The detection of several degrees of freedom of a movement is one of the specific measuring tasks with regard to the characterisation of positioning axes. The triple-beam interferometers allow the simultaneous measurement of length and angle deviations when positioning, now with a measurement range up to 15 metres.



1 Sensor head of the triple-beam interferometer ›SP 2000 TR‹

2 Long-Range triple-beam interferometer in a new design

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The interferometers with plane mirror reflector of the SIOS Meßtechnik GmbH are characterized by high precision, a wide dynamic range and easy handling. The measurements with these system are traceable and strictly linear with a linearity of less than ±1.5 nm. These interferometers manage with a single measurement beam per measuring axis. This beam is reflected back in itself from a reflective surface. For short measuring lengths up to 2 metres, a mirror is used as reflector. Thanks to a special optical arrangement in the interferometer, these systems work up to a tilt of the measuring mirror of ± 1.5 arcmin. This range is perfectly sufficient for the measurement of precision guides. Due to the relatively small tilt invariance, the second-level measurement errors often neglected are minimized. In doing so, the measuring mirror can also be shifted laterally, as it is the case with x-y-planar tables. In case of larger measuring lengths, these interferometers can be equipped with a tilt-invariant reflector.

The special design of the interferometers with a single measurement beam per measuring axis allows simple setup of Abbe-error-free measuring arrangements, trouble-free beam modifications, for example by an objective and a flexible realization of multi-beam interferometers, which can be used for a simultaneous detection of several movements. The triple-beam interferometers represent an advancement of the single axis interferometers with plane mirror reflector.

Simultaneous length-angle measurement with three beams

Triple-beam interferometers (Picture 1) are measuring systems that are supplied by one laser and evaluate three separate interferometer channels. Special attention was paid to a completely symmetrical optical design. Three length values can be recorded simultaneously with nanometric precision. From the difference of two length values Δs a time and the associated beam distance a, the angle α can be determined with highest precision according to the equation (1) (Picture 3). Synchronous data transfer of all measuring channels is given.

$$\tan \alpha = \Delta s / a \qquad (1)$$

Due to their extremely compact design, triple-beam interferometers for the high-precision length and angle measurement can be adapted to different measuring tasks without problems. The standard systems have an angle measurement range of ± 1.5 arc minutes and a length measurement range of 2 m. With length resolutions of 0.01 nm, angles with 0.002 arcsec are resolved. In order to measure greater lengths, the system can be extended by a compact and tilt-invariant reflector. With this reflector, tilting up to ± 12.5 ° is possible.

Extension of the measurement range to 15 metres

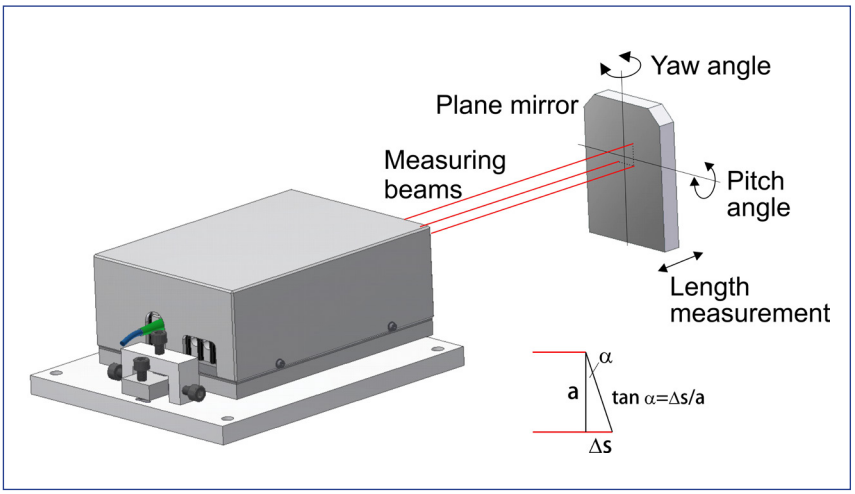
The triple-beam interferometers of the series ›SP 15000 TR‹ (Picture 2) allow measurements up to 15 metres and are designed for high-precision length and angle measurement at larger positioning axes, with which the simultaneous length and angle information must be recorded. In the presented measuring system, the beam distance is 50 mm. This results in an angle resolution of 0.04 arcsec with a length resolution of 10 nm. The actual system resolution of the interferometer is < 0.1 nm. When practically using the interferometer, this length resolution, which can only be achieved under stable environmental conditions, can rarely be achieved due to the air movements.

The measuring reflector is based on a combination of hollow reflectors. In this case, the maximum tilting angle of the reflectors is ±15° when the pivot point is in the centre of the reflector.

By providing a connection of the interferometer electronics with a position control, it is possible to determine the positioning and angle deviations in a single run by means of a quick data acquisition “on-the-fly”. The measuring and calibration process with a Long-Range interferometer can be synchronized with the positioning control of the plant. Extensive opportunities for electrically isolated triggering of the system such as

- Start/stop-triggering
- Triggering of the single measurement values
- Substitution of the sampling frequency

allow control of the measurement value recording. The measurement values are transmitted via a fast USB interface to a laptop or computer.



3 Measuring principle of the triple-beam interferometer

Applications

Areas of application of the triple-beam interferometers are laser interferometric measurements on guides, measuring tables, microscope stages and positioning tables, high-precision pitch and yaw angle measurements and corrections with two- or multi-coordinates measurements, calibration of high-precision axes on measuring machines and machine tools as well as alignment optimisation of high-precision components (optics, lithography).

Apart from the application examples mentioned so far, planar and spatial multi-coordinate measurements are possible as well by combining several interferometers. By further combining single- and multi-beam systems, up to 6 degrees of freedom can be measured simultaneously and can further be used for position control.

Conclusion

Triple-beam interferometers represent an advancement of the single axis interferometers with plane mirror reflector and are suitable for simultaneous and precise determination of position and tilting, for example regarding high-precision positioning or calibration tasks. The special design of the interferometers allows simple setup of Abbe-error-free measuring arrangements, trouble-free beam modifications, for example by an objective and a flexible realization of multi-beam interferometers, which can be used for a simultaneous detection of several movements.

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