



Precision redefined

Simultaneous length and angle measurement with the Triple beam laser interferometer SP 5000 TR

- **II** Faster and more reliable measurement results
- **II** Reduction in measurement uncertainty
- II Improved reproducibility
- **II** Time saving in the measuring process

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PRECISION IN MEASUREMENT

Length • Angle • Straightness • Vibration • Temperature





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The challenge

Precision is a decisive factor in modern industry and research.

In many high-tech industries such as mechanical engineering, semiconductor production and optics, the requirements for measurement uncertainty and process control are becoming increasingly demanding.

Progressive miniaturization and the need to manufacture components of all sizes with the highest precision require state-of-the-art measurement technology.

However, many conventional measurement systems are unable to keep pace with these developments.

Pure length measurement without simultaneous angle measurement is no longer state of the art.

If tilting occurs during the measurement and is not recorded correctly, this leads to measurement deviations.

I am convinced that the dynamic and synchronous recording of length and angle values offers considerable added value.

All measured values are recorded quickly, environmental influences are also minimized. 🕊

For maximum precision and innovation

Deus Dour

Dr. Denis Dontsov. CEO. SIOS Meßtechnik GmbH

Typical challenges of precise length and angle measurements

- **I** Loss of time due to time-shifted measurements Length and angle measurements are often carried out separately, which is not only time-consuming, but also leads to unknown deviations in the overall result under changing ambient conditions.
- **II** Thermal influences on measurements

Static and slow measured value recordings lead to drifts and poor measurement data quality in the event of thermal changes in the measurement setup.

|| Lack of space in production environments

Complex measurement technology often requires a lot of space and is difficult to integrate into existing processes.

Limited resolution

Many systems do not achieve the precision required to reliably detect even the smallest deviations.

In this white paper we show you, how you can use the SP 5000 TR triple beam laser interferometer to optimize your measurement results with maximum precision.

Reliable, efficient, at the highest technological level

To meet these challenges, our development team has designed the **triple beam laser** interferometer SP 5000 TR.

By simultaneously measuring length and angles with maximum reliability, it sets new standards in measurement technology.

It enables a significant reduction of the measurement uncertainty, improves reproducibility and saves an enormous amount of time in the measuring process.

Thermal influences in the laser interferometric length and angle measurement

In industrial and scientific applications, measuring equipment rarely consists of a single material. Granite, stainless steel, titanium, invar, aluminum, ceramic and glass are the materials that are very often found in various combinations and compositions in a measuring setup. These have different linear expansion coefficients and thermal conductivities. They react to temperature changes with different time constants.

Users often only know the general measuring room class or the average temperature stability over 24 hours. Short-term temperature fluctuations or the day-night behavior of a measuring room are often not taken into account, which leads to unexpected measurement deviations.

If length and angle measurements are carried out at different times, temperature changes can significantly distort the results. A reliable analysis of all measurement data is made more difficult.

Conclusion: A fast and simultaneous acquisition of several degrees of freedom enables a coherent analysis of measurement deviations. As a result, the influences of temperature fluctuations on various measured variables can be reduced, as these are measured simultaneously.



Materials	Coefficient of linear expansion α by 20 °C / α in 10 ⁻⁶ K ⁻¹	Thermal conductivity in W/(m⋅K)
Aluminium	24 to 26	~ 220
Stainless steel	10 to 16	~ 20
Granit	5 to 7	~ 3
Invar	0.5 to 1.2	~ 13

The SP 5000 TR triple beam interferometer was developed to record length, pitch and yaw angle measurements* simultaneously, well correlated and consistently.

The high level of data synchronization enables dynamic measurements that minimize drift effects and accelerate measurement processes. In addition, the external triggering allows the measured values to be recorded "on the fly" at object speeds of up to **3 m/s**.

As space is often a limiting resource in measuring environments, the SP 5000 TR has been designed to be particularly compact. The fiber optic coupling of the laser interferometer ensures maximum precision in a spacesaving design.

If measured values are to be offset against each other, the achievable resolution plays a decisive role.

For example, a length measurement with a target measurement uncertainty of 10 nm and an Abbe offset of 100 mm requires an angular resolution of at least 0.1 µrad.

The **SP 5000 TR** fulfills these requirements and enables high-precision measurements in various application areas.



* Roll angles can also be measured with the RAS 175 accessory as an optiony

No loss of time due to time-delayed measurements

Simultaneous recording of length and angle ensures a consistent data basis and reduces measurement errors.

Minimized thermal influences Fast data acquisition and high synchronicity enable precise correction of drift effects.

<u>Space-saving</u> integration

The compact design and fiber optic coupling enable use even in confined production environments.

<u>Highest</u> resolution for reliable results Extremely fine angular resolution and minimal measurement uncertainty precise measurement results, even with demanding applications.



Triple beam laser interferometer SP 5000 TR

Triple beam interferometers are precision length measuring devices that combine three interferometers in one device. All three measuring channels are fed by a light source with the same, highly stable laser frequency. This means that three length values can be measured simultaneously with nanometer accuracy. The pitch and yaw angles can be determined with high resolution and precision from the difference between two length values and the calibrated beam distance. Optionally, roll angle measurement can be integrated via additional sensors. The interferometer system has a modular design and can therefore be adapted to a wide variety of measurement tasks.

The fiber optic coupling of the sensor head and the integrated beam direction detection support easy handling and precise adjustment.

The design of the **SP 5000 TR triple beam laser interferometer** is compact and robust. This makes it ideal for high-precision measurements in industry and research.

OEM versions, also for use in a vacuum, are available on request.

Yaw angle



Ideal for

- Quality assurance
- Calibration
- Development
- Science/Research

High-precision length measurement without Abbe error

Precise length measurement poses a particular challenge if the measuring reflector cannot be positioned in alignment with the axis of movement. This offset leads to the so-called Abbe error, which can significantly affect the measurement uncertainty.

The illustration shows that it is generally not geometrically possible to place the measuring axis of the interferometer directly in the drive axis of the guideway to be measured. The distance between the drive axis and the measuring axis in conjunction with the tilt of the reflector therefore leads to a measurement deviation that can be very large under certain circumstances and often remains unknown.

With the **triple beam laser interferometer** SP 5000 TR it is possible to compensate the **Abbe error** by calculation.

The triple beam technology enables the simultaneous acquisition of length and angle values with maximum precision. As a result, the measurement deviations caused by the Abbe offset can be massively reduced.



Length measurement at close range without misalignment

In addition to the Abbe error, the second geometric error that occurs during measurement is the alignment error. This is length-dependent and is specified as a relative value µm/m. At the same time, however, it is difficult to recognize, especially with short measuring distances.

The calculation examples listed in the **table** show which errors can occur with a purely visual alignment of a laser beam. If the beam on the measuring mirror shifts by 0.5 mm from the beginning to the end of the measuring distance, an error of 0.5 µm/m (example 1). If the same displacement is observed at 50 mm, the **error** is linearly greater and very high at **50 µm/m** (example 2).





 $\Delta l_{cos} = l_m \cdot [1 - cos(\phi)]$

	Example 1 without help
Visible beam shift	0.5 mm
Length of the linear axes	500 mm
Angle	3.4 arcmin
	(1 mrad)
Alignment error	0.5 µm/m



The triple beam laser interferometer **SP 5000 TR** offers a user-friendly solution for the **alignment error**, as the system has an integrated alignment aid that facilitates the fine adjustment of the laser beam. A target cross in the software conveniently indicates whether the measurement axis matches the direction of movement, making this error influence negligible.



 I_m = Measurement of the displacement φ = Angle

 \checkmark $\langle \checkmark \rangle$ Example 2 with alignment aid with alignment aid without help 0.5 mm 10 µm 20 µm 500 mm 50 mm 50 mm 0.14 arcmin 34.4 arcmin 0.68 arcmin (0.04 mrad) (0.2 mrad) (10 mrad) 0.0008 µm/m 0.02 µm/m 50 µm/m

Case Study 4

Dynamic angle measurement with a lightweight reflector

Measurements in dynamic applications often require lightweight measuring equipment so that these movements are not influenced by their own weight. This applies in particular to fast, complex movements such as those that occur in research and industrial production.

In combination with the specially developed lightweight reflector, the SP 5000 TR triple beam laser interferometer offers a tailor-made solution for these requirements. The lightweight reflector minimizes mass inertia and therefore enables fast and precise measurements even with highly dynamic movements.

Possible applications

Highly dynamic applications

The SP 5000 TR can measure precise angle changes even with fast movements of 3 m/s.

Large angle measuring ranges

With a measuring range of ±12.5°, the system offers the flexibility to fully capture even complex motion sequences.

Sub-microrad resolution

A resolution of 0.01 µrad ensures extremely fine detection of the smallest angle changes.

Lightweight construction

Weighing only **25** g, the lightweight reflector has hardly any influence on the measurement setup.



Lens attachment Sensor head **SP 5000 TR**

High-resolution dynamic angle measurement on optical surfaces

Optical quality surfaces with poor reflective properties that tilt pose a particular challenge for precise measurements.

The SP 5000 TR triple beam laser interferometer in

combination with a lens attachment offers a precise and reliable solution. The lens attachment enables measurement on surfaces such as e.g. aluminum and ensures reliable angle measurement, even with fast movements.

Possible applications

Highly dynamic movements

The lens attachment enables precise measurements even with rapid tilting movements of optical surfaces with poor reflective properties.

Sub-microrad resolution

With a resolution of 0.01 µrad, even the smallest changes in angle can be detected.

Optimum beam guidance

The lens attachment ensures ideal focusing and reflection of the laser beam, minimizing measurement errors.



Highly stable long-term, length and angle measurement

Laser interferometers that work according to the differential principle are used when particularly high demands are placed on the stability of measured values over long periods of time. The measuring and reference beams are arranged in such a way that the distance between them is minimized.

The **SP 5000 DI/TR** laser interferometer as a differential version of the three-beam interferometer is the right choice for this.

Possible applications

Highly stable measuring arrangements

The influence of the dead path of the measurement is completely eliminated by the differential principle, as is the movement of the sensor relative to the measurement setup.

Long-term stability

The system offers maximum measurement stability, even for measurements that have to be carried out over hours or days.



Highly stable length and angle measurement in a vacuum

Measurements in vacuum require special consideration paid to the materials used and on cleanliness during the manufacturing of the sensor. The design must be such that air inclusions in the sensor head are avoided and low outgassing of the materials is achieved.

Another problem is the handling of the sensor when it is inserted into the vacuum chamber. For this reason, solutions have been developed that allow the sensor to be separated from the feedthrough during servicing, thus minimizing installation work.

The specially adapted **SP 5000 TR triple beam laser interferometer** for vacuum applications up to 1×10^{-7} mbar with all specific requirements can be assembled on request.



Possible applications

Vacuum-optimized materials

The aluminum, stainless steel or Invar design ensures stability and reliability in a vacuum.

Highest precision

By measuring in a vacuum, the ambient influences on the measurement are eliminated, which currently represents the limit of the minimum achievable measurement uncertainty.

Fast acceptance measurements in the production of linear axes

Precise and fast acceptance measurements are essential in the modern production of linear axes. Particularly with high cycle times, measurements must be performed dynamically, simultaneously and with maximum precision in order to capture all relevant degrees of freedom of an axis.

The **triple beam laser interferometer SP 5000 TR** in combination with the InfasAXIS software offers an optimal solution for this. This system enables the simultaneous recording of all relevant parameters of a linear axis in real time.

Possible applications:

Simultaneous measurements

Detection of all relevant degrees of freedom for the position in the axis direction.

High cycle times

Optimized for fast production cycles with measuring speeds of up to 3 m/s.

Standard-compliant measurements

InfasAXIS certificates in accordance with VDI/ISO standards guarantee the highest quality of acceptance measurements.

Length and angle measurement in difficult-to-reach measurement setups

With fiber optic-coupled sensors, the measurement setup can be complicated by geometric conditions. The **SP 5000 TR** has various additional equipment, such as components for reducing the beam distances for very small measurement objects or for beam deflection. This means that even hard-to-reach areas can be reached without the need for a complex special design.

On request, the **SP 5000 TR triple beam laser interferometer** can be specially adapted for any location in order to provide the optimum solution for a wide range of measuring tasks.



Possible applications:

Measurements under restricted access conditions

The deflection optics allow precise alignment of the laser beam, even if the measuring location is spatially limited or difficult to reach.

Compensation of offset errors

The combination of length and angle measurement reliably corrects the Abbe error.

Accessories

The right accessories for the SP 5000 TR triple beam laser interferometer



Triple reflector unit up to 6 m item number A039992



Deflecting mirror unit 90°

item number A040678



Triple reflector unit long-range up to 10 m item number A041318

90° deflection, sensor head

attachment

item number A043949

Roll angle measurement



Lightweight construction Triple reflector unit item number 039169



Reflector holder with ball joint item number A037044



Ball joint table

item number A034567



Environmental correction



Especially in industrial environments, measurements are not always carried out under ideal laboratory conditions or in optimized measuring rooms. However, monitoring the ambient conditions is of crucial importance (see information on page 6).









Adjustment table

item number A032051



DU-04 4.5" display Display unit item number A034568



SIOS offers you the equipment and software for seamless monitoring of your measuring room environment.

LCS-Temp – Mobile set for all-round monitoring of measuring rooms

The LCS-Temp standard set contains eight tem-

Measured value display with indication of the measuring room class

Technical data for the SP 5000 TR

The right software for the SP 5000 TR triple beam laser interferometer





Calibration software according to VDI/ISO standards

for the calibration of linear axes

Detection of position, pitch and yaw angles and straightness according to VDI/ISO standards



SignalMonitor

Freeware for aligning interferometers

Interferometer status and signal quality



API

SIOS API

Software library for customer software

Support and programming examples for all common programming languages



Software for calibration and volumetric compensation

Calibration, error analysis and verification

Application for linear axes, CMMs and machine tools

System parameter
Measuring range
Resolution
Angular measuring ranges
with reflector
with plane mirror (recommended distance ≤ 2 m
Angular resolution
Roll angle measurement (optional with RAS 175 W
Measuring range
Resolution
Measuring uncertainty under stable conditions:
Length measurement
Angle measurement
Roll angle measurement
Beam distances (horizontal and vertical)
Wavelength
Frequency stability of the HeNe laser
(after warm-up time)
Warm-up time of the HeNe laser
Operating temperature range
Max. displacement speed of measuring reflector
Geometric Data
Dimensions (L x W x H):
Sensor head with adjustable mount
Reflector
Electronic evaluation and supply unit EU
Roll angle sensor RAS 175 W (optional)
Electrical Data
Interfaces standard
other interfaces on request (/R)
Cable length between sensor head and
electronics unit
Power supply
Laser safety class according to EN 60825-1:2014
and ANSI Z136.1 (CDRH)
and ANSI Z136.1 (CDRH)

0 m bis ≥5 m (auf Anfrage 10 m)
20 pm*
±12.5° **
±430 µrad
0.01 µrad***
±17.5 mrad
0.4 µrad
0.15 μm/m
±0.04 % ± 0.04 µrad
±2.4 μrad ±0.5% (19°C – 21°C)
±2.4 μrad ±1.5% (15°C – 25°C)
12 mm
632.8 nm
2·10 ⁻⁸
10 20 min
15 30°C
3 m/s
[202 x 137 x 72] mm
[45 x 45 x 20] mm
[450 x 400 x 150] mm
[74 x 54 x 77] mm
RS232C, USB
3 m, optional 6 m bis 10 m
100 240 VAC / 47 63 Hz
2M

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Why SIOS Meßtechnik GmbH?

For more than 30 years, **SIOS Meßtechnik GmbH** has stood for pioneering innovations, maximum precision and outstanding quality in laser interferometry. Our highly developed measurement systems are used worldwide by industrial customers, research institutes and universities to make measurement processes more efficient and reliable.

Our success is based on the consistent further development of our technology and close cooperation with our customers.



By choosing SIOS, you not only get an innovative measuring system for simultaneous length and angle measurement, but also a reliable partner who speaks your language and understands your technical challenges. **(K**

Dr. Ilko Rahneberg CTO, SIOS Meßtechnik GmbH We develop and manufacture laser interferometric measurement technology and precision measuring instruments for calibration and nano measurement technology.



Our strengths at a glance:

Technological innovation:

We continuously invest in research and development in order to always be able to offer you the most modern solutions.

Customer-specific adaptations:

Standard solutions are often not enough. We develop measuring systems that are optimally adapted to your specific applications.

Highest manufacturing quality:

Made in Germany - our products are manufactured under the strictest quality controls at our site in Ilmenau.

Comprehensive support and advice:

We are at your disposal from the initial planning implementation through to after-sales service.



The simultaneous, precise length and angle measurement with the SP 5000 TR has piqued your interest?

Contact us for an individual consultation or a live demonstration of the three-beam laser interferometer.

Open contact form

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