PRECISION IN MEASUREMENT

SIOS Meßtechnik GmbH

Anwendungen von Mehrstrahl-Interferometern für hochgenaue Messungen und Kalibrierungen

Dr. Ilko Rahneberg

Technischer Leiter

What is Calibration?

In the ideal world

is nothing to calibrate.

In the real world

everything has deviations.

What is Calibration?

Calibration is a measuring procedure

for determining and documenting

the deviation of an device or artefact

measured against a higher-order standard.

What is Calibration?

Calibration is a measuring procedure for determining and documenting the deviation of an device or artefact measured against a higher-order standard.

device or artefact

higher-order standard

SIOS Calibration Interferometers

1-DOF / 3-DOF / 6-DOF

SP 5000 NG

Single-beam laser interfero-meter measurement system for high-precision fast length measurement

SP 5000 TR

Triple-beam laser interfero-meter for simultaneous and precise length, pitch and yaw angle measurement

SP 15000 C5

5-DOF laser interferometer for high-precision simultaneous measurement and calibration of length, pitch angle, yaw angle, horizontal and vertical straightness

SIOS Calibration Interferometer

Advantages

1. high resolution < 1 nm
2. high dynamic up to 3 m/s, 12.5 MHz
3. high synchronous less than 0.2 ns
4. simultaneous measurement of position, pitch, yaw and straightness
5. very compact design
6. easy to align

SIOS Calibration Interferometer

SP 5000 NG

Multiple Beam Systems Development Chain

SP 2000 TR

Triple beam interferometer

SP 5000 TR

Triple beam interferometer with alignment unit

SP 15000 C5

Multiple beam 5 DOF measuring interferometer

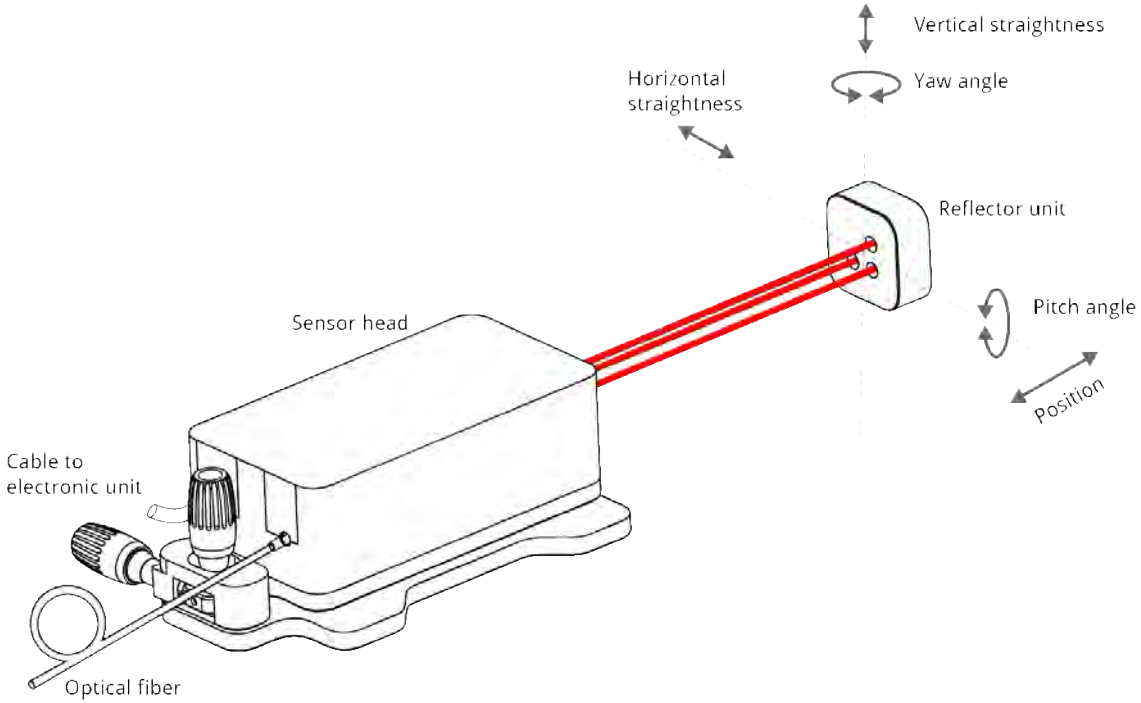
SP 15000 C6 NG

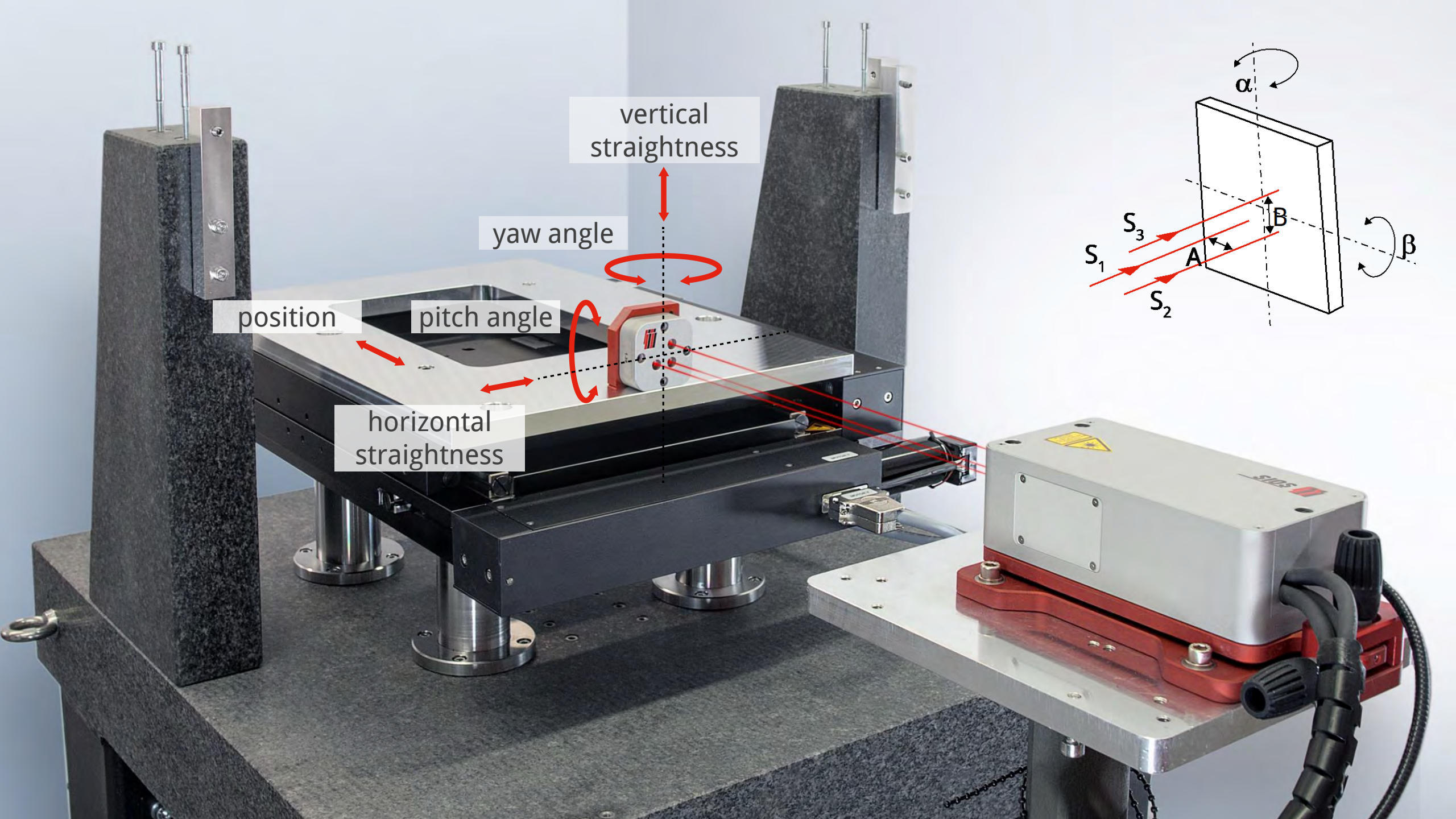
Multiple beam 6 DOF measuring interferometer

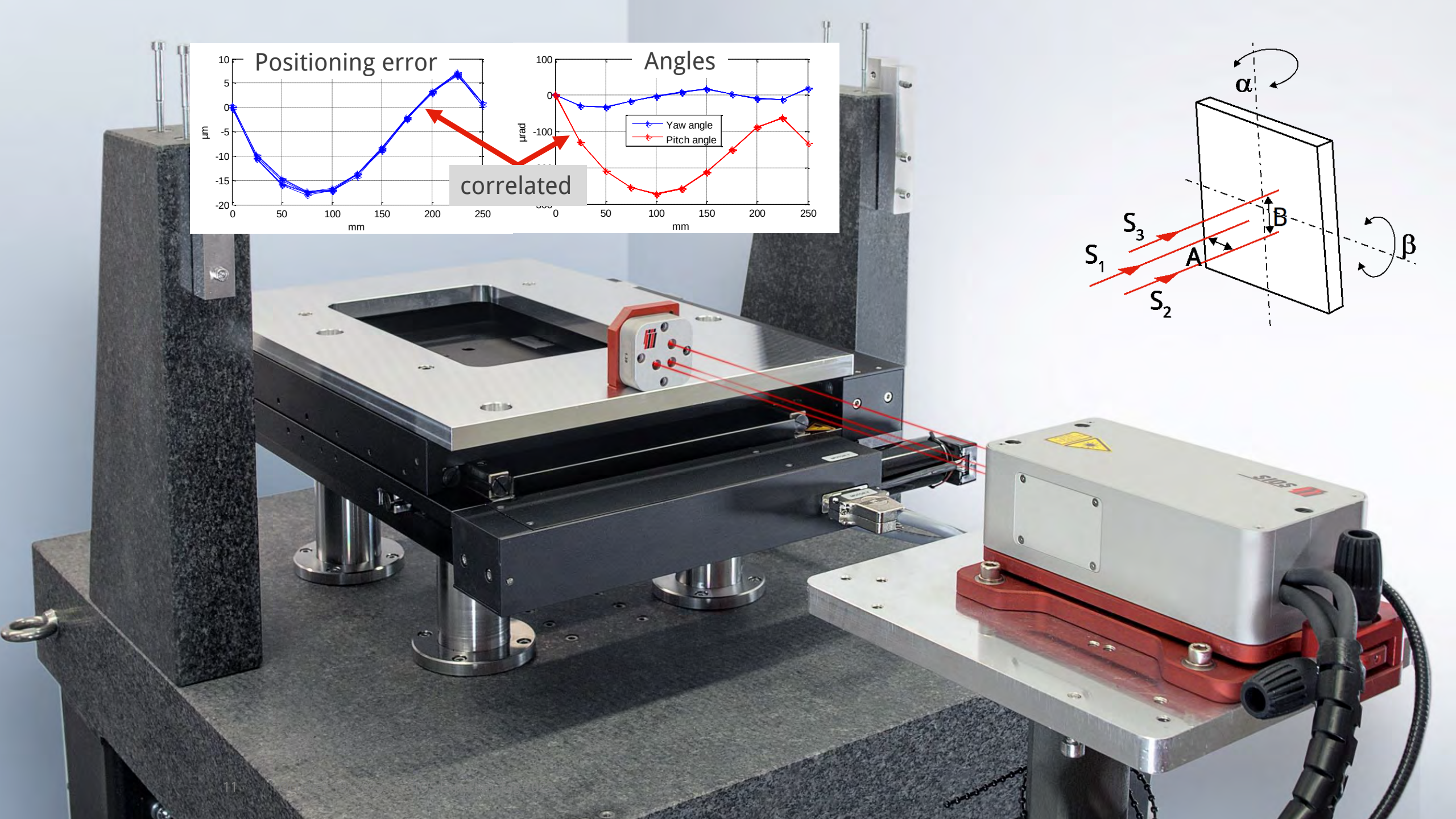
Triple-beam Laser Interferometers

Simultaneous measurements of lengths and angles

SP 5000 TR




vertical straightness
yaw angle
position
pitch angle
horizontal straightness
α
S3
S1
S2
A
B
β

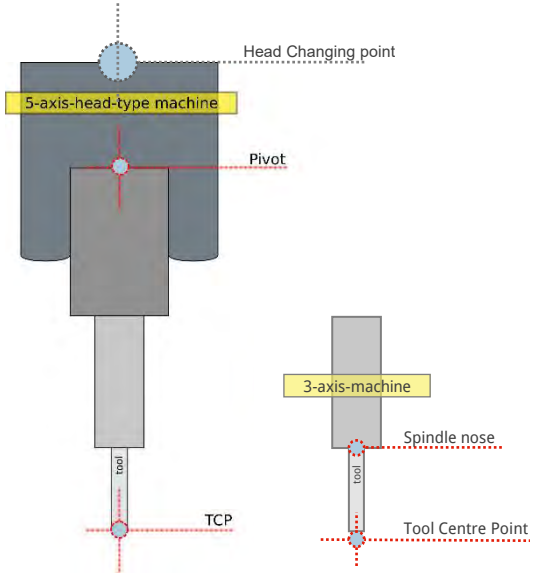

Positioning error
µm
mm
correlated
Angles
µrad
Yaw angle
Pitch angle
mm
α
β
S1
S2
S3
A
B

Basics of Geometric Error Calibrations

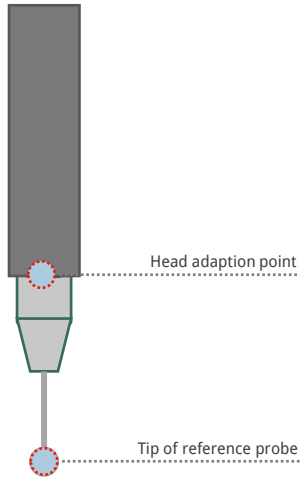
Reference point of error map

- The reference point for compensation is determined by control or user.
- The distance from the reflector to the reference point is used for the Abbe-Error correction.
- The translational deviations are location-dependent (errors can/must be recalculated to the reference point). The rotational deviations are location-independent but necessary for Abbe-Error correction.

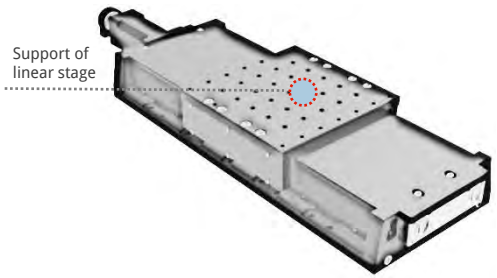
Machine tool



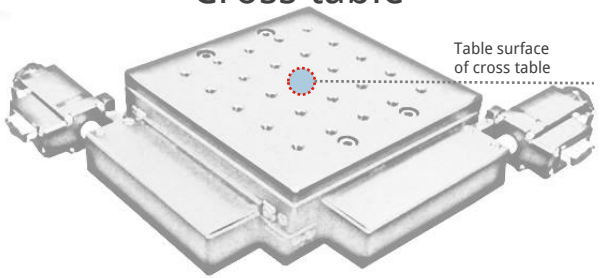
CMM



Linear stage

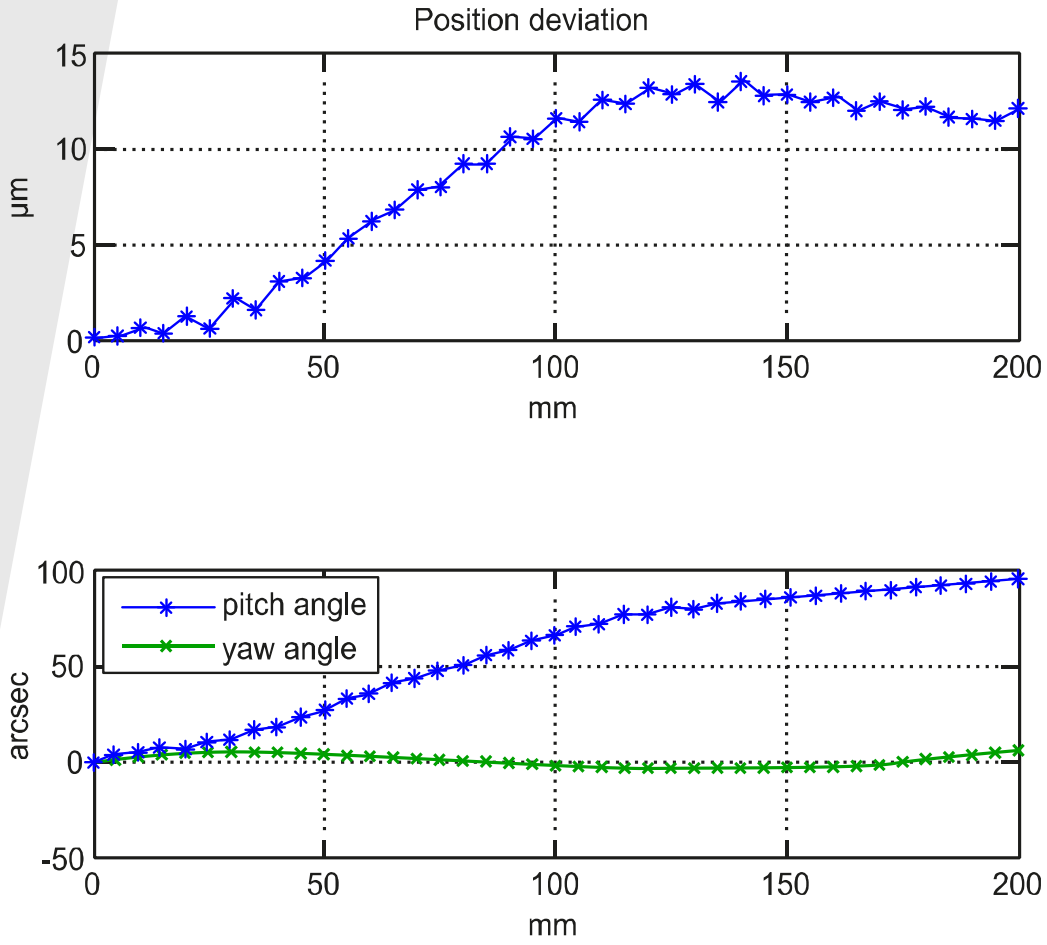


Cross table



Calibration Interferometer for 3 DOF

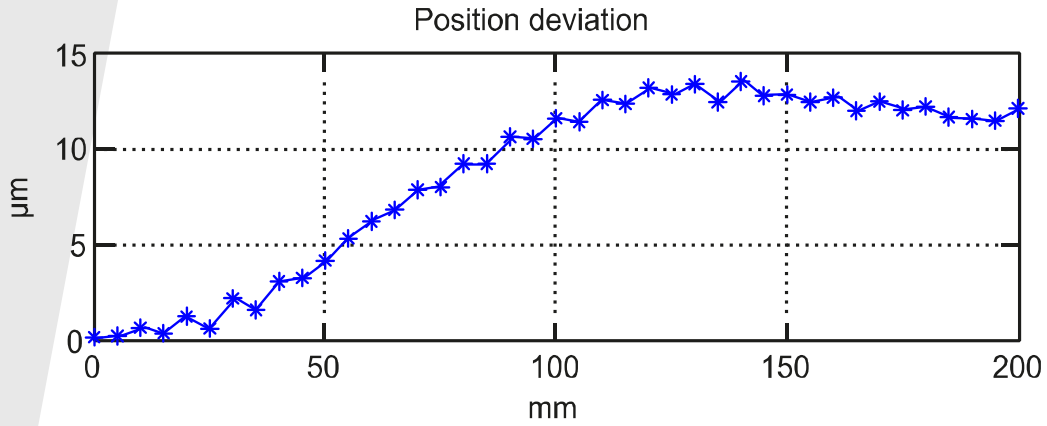
Synchronous measurement of position, pitch and yaw

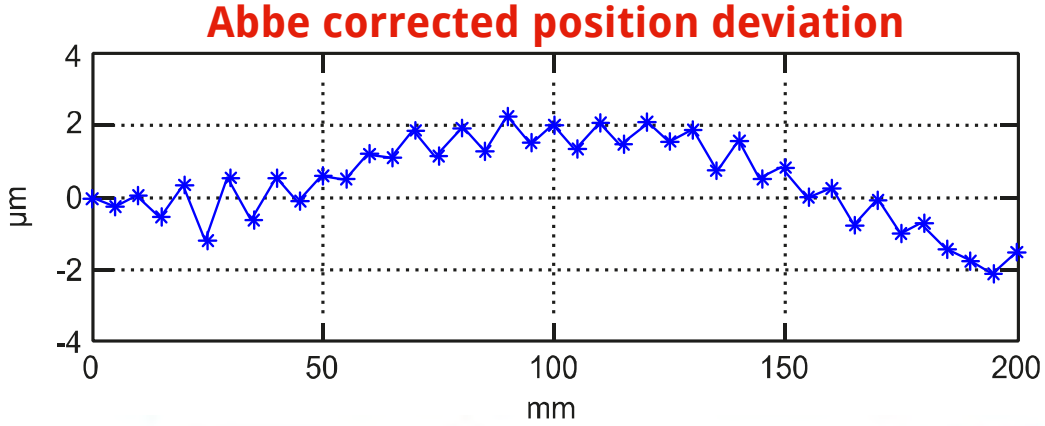


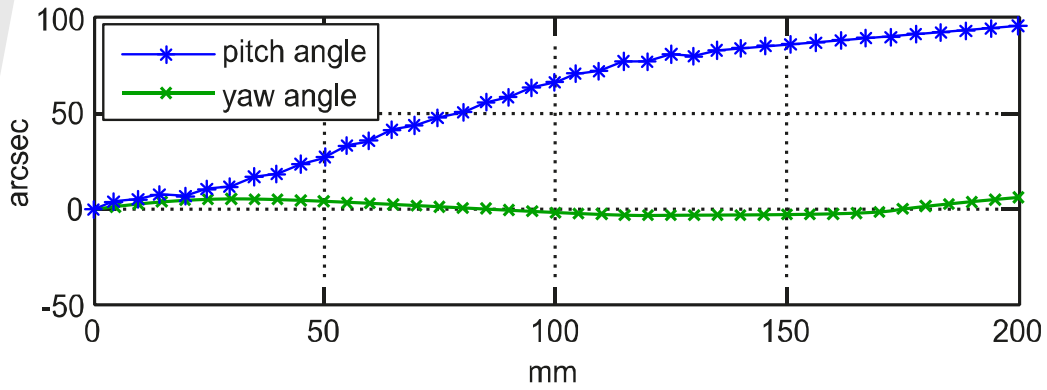
Triple-beam laser interferometer SP 5000 TR

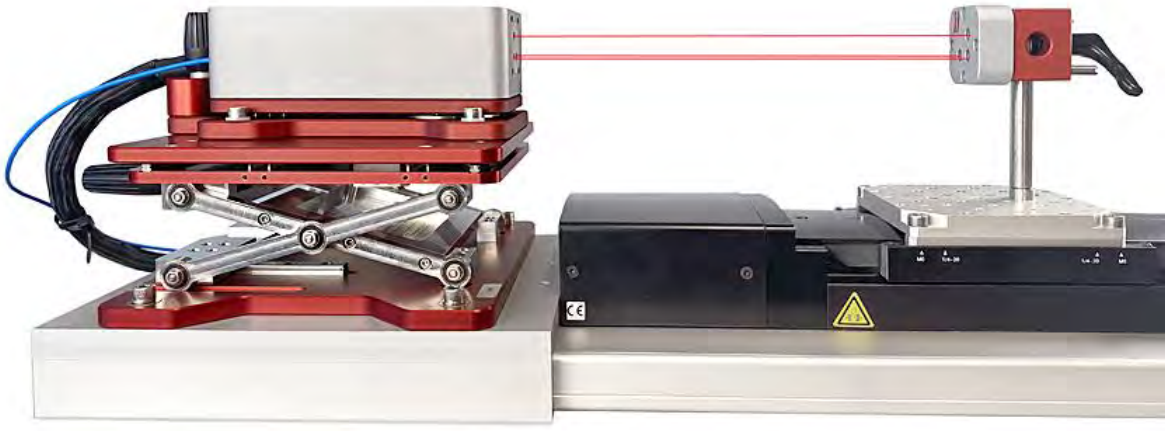
Calibration Interferometer for 3 DOF

Synchronous measurement of position, pitch and yaw







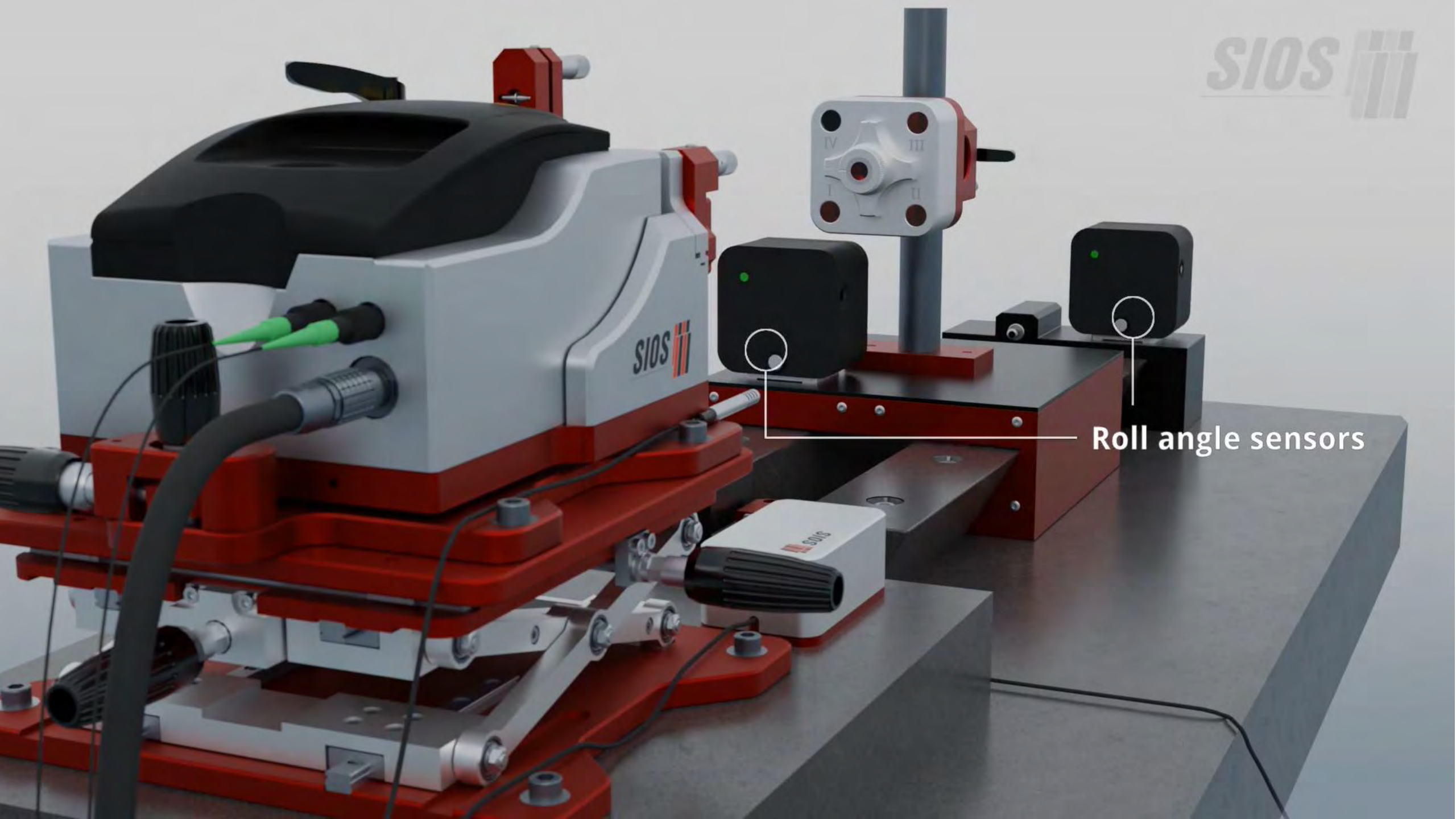


Triple-beam laser interferometer SP 5000 TR

SIOS

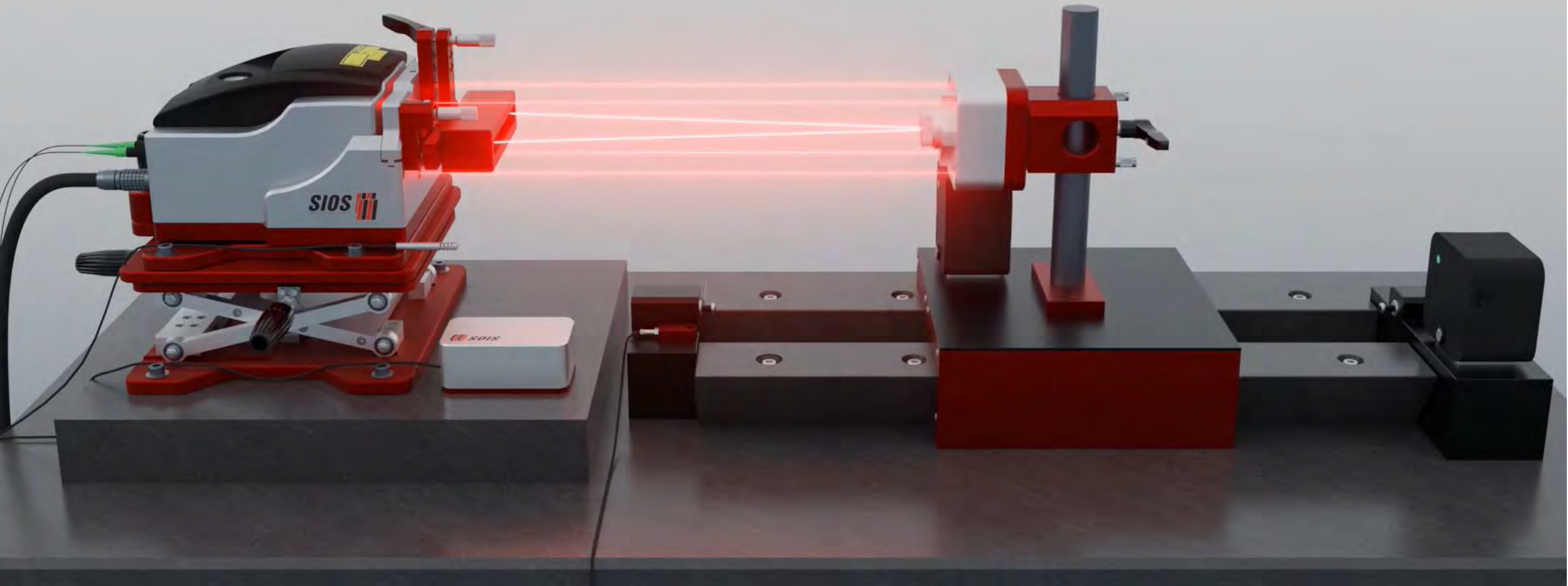
Calibration laser interferometer

SP 15000 C5


Roll angle sensors

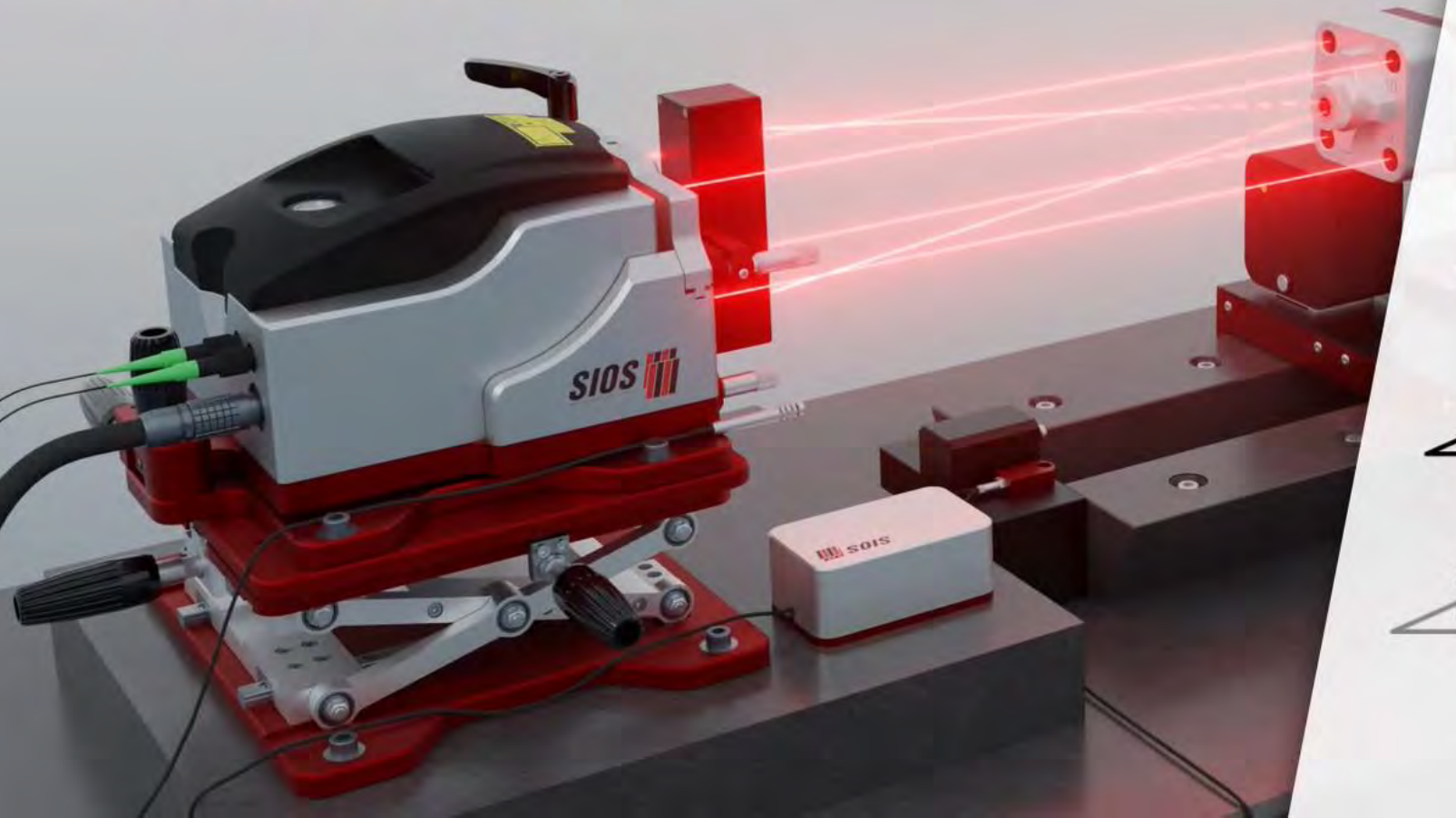
High-precision simultaneous measurement and calibration of up to 6 DoF

XTX: + 47.36838 mm	
XRY: + 3.75 µrad	**XRX:** + 0.71 µrad
XRZ: - 6.32 µrad	**XTY:** + 0.28 µm



Calibration laser interferometer

SP 15000 C5



SIOS

up to **5 m** and more

20 pm

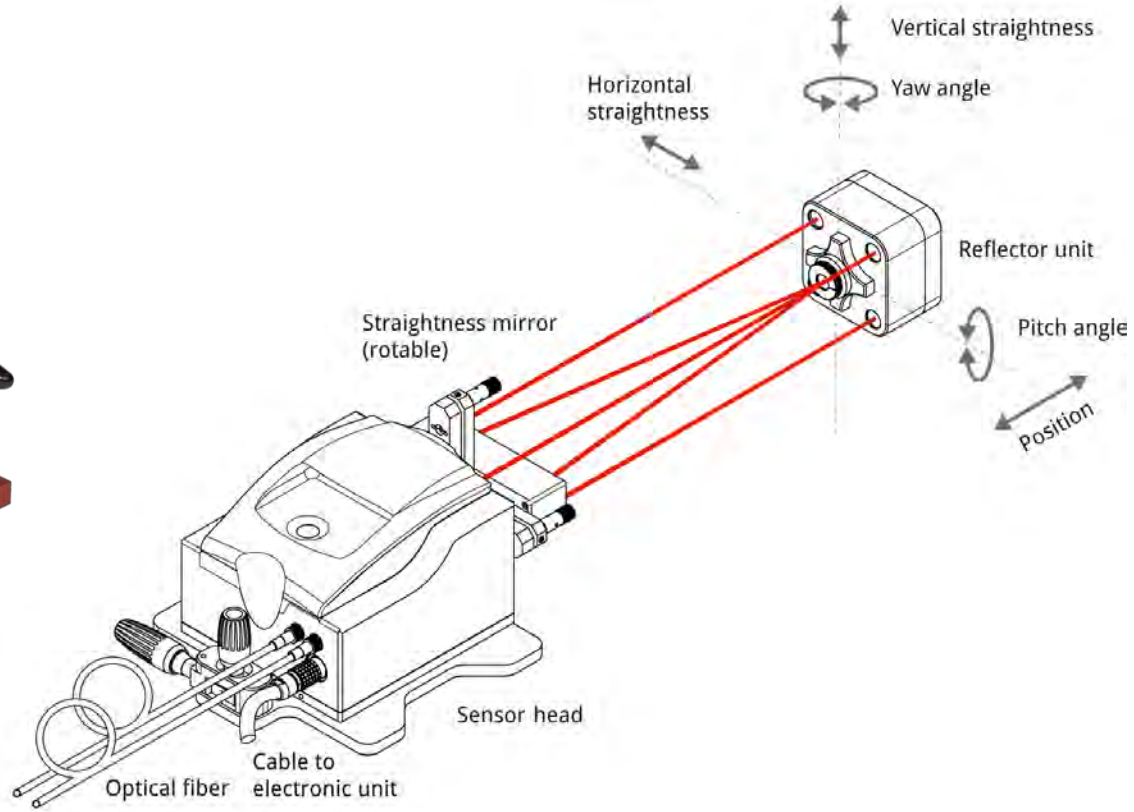
0.1 µm/m

±12.5° with reflector
±1.5' with plane-mirror

0.002 arcsec

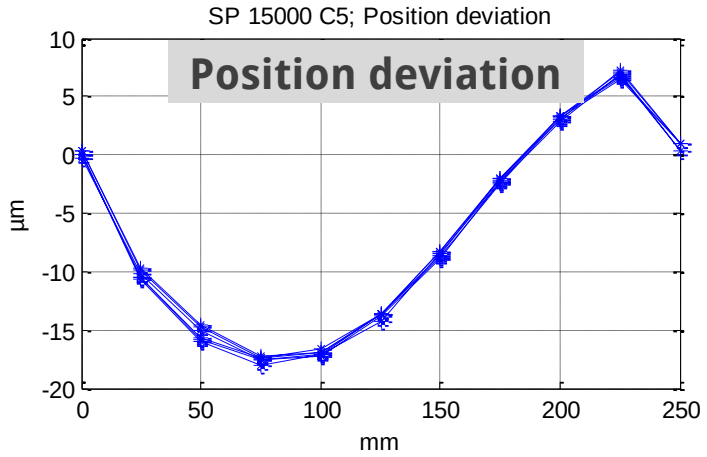
Calibration Interferometer for up to 6 DoF

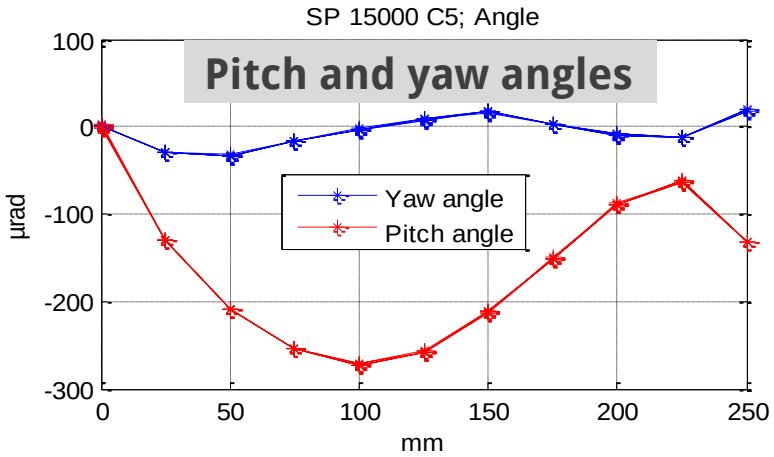
SP 15000 C5

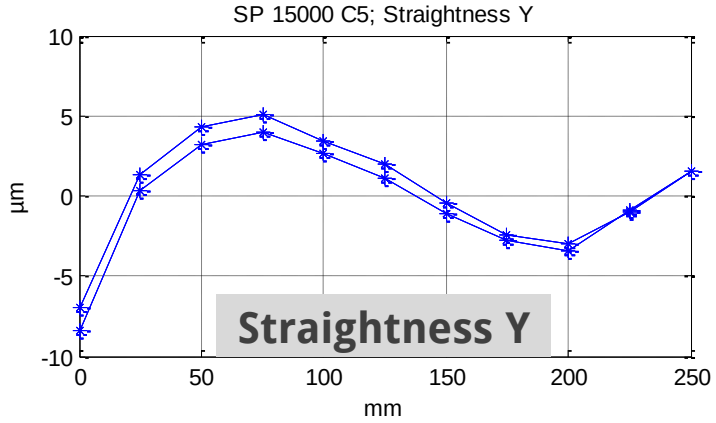


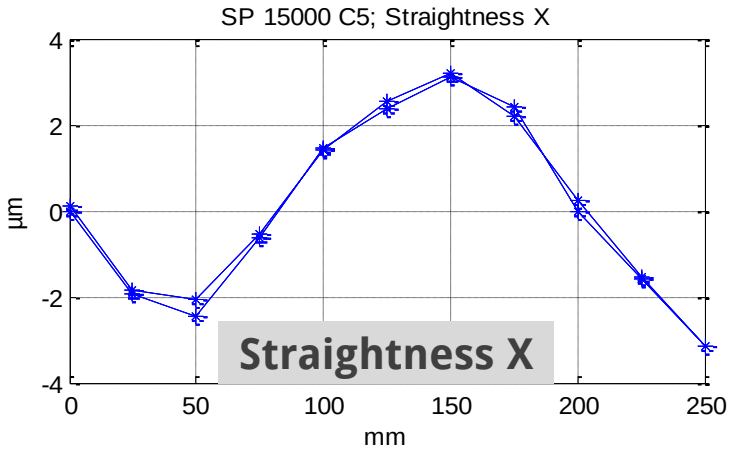
Calibration Interferometer for up to 6 DoF

Direct measurements of the straightness by interferometer SP 15000 C5





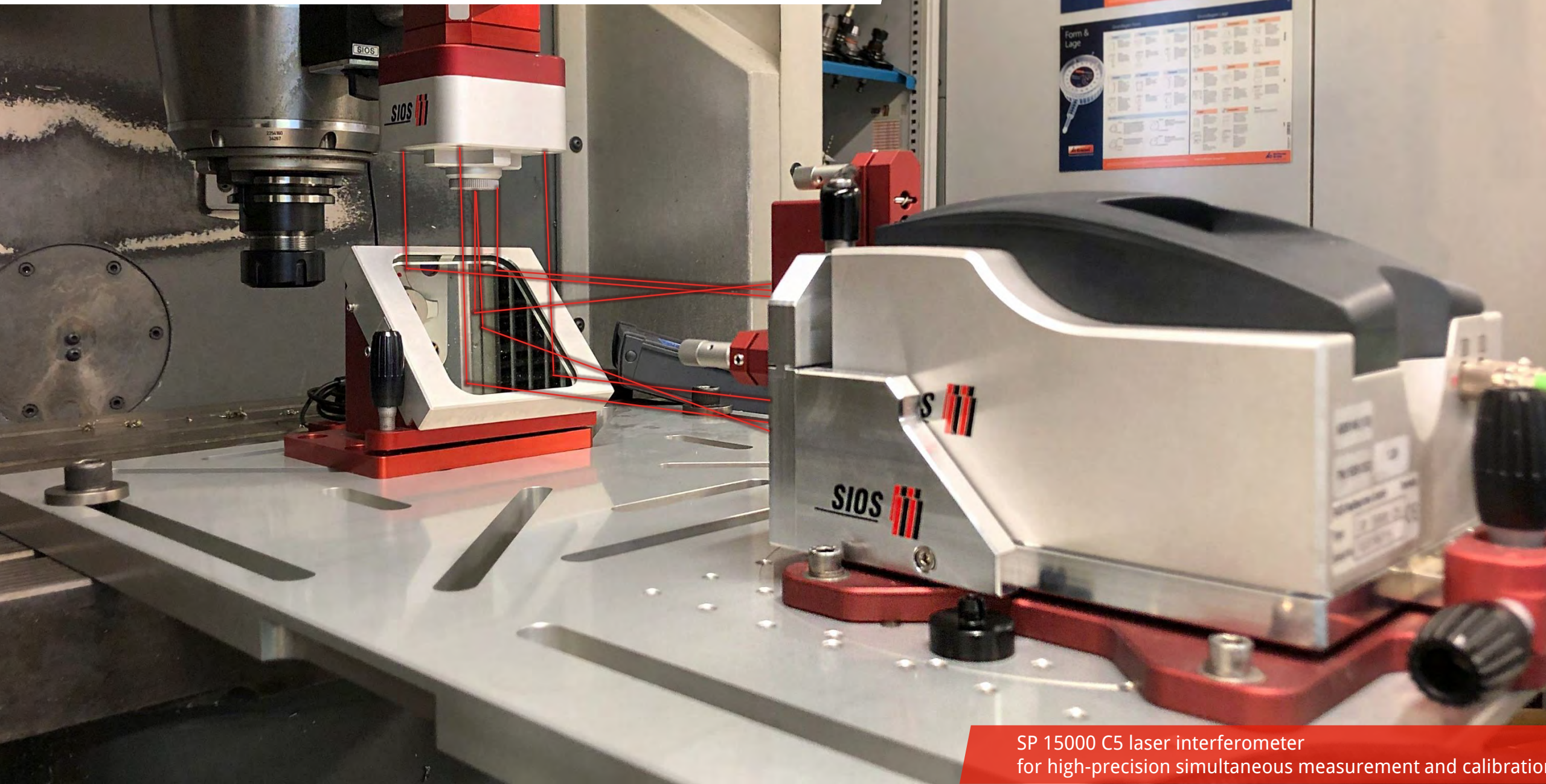




Y-axis calibration - vertical straightness - ytz / EZY

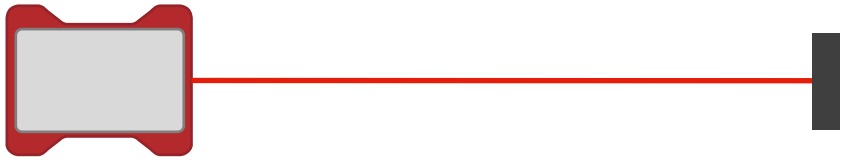
SP 15000 C5 laser interferometer
for high-precision simultaneous measurement and calibratio

Z-axis calibration - vertical straightness - zty / EYZ

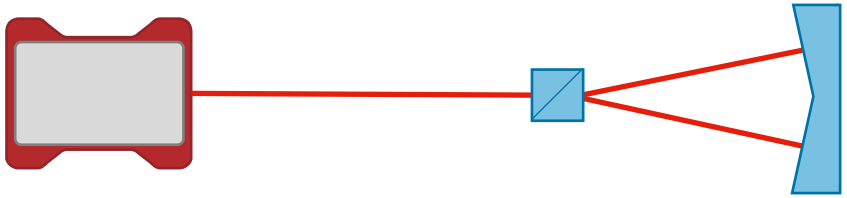


SP 15000 C5 laser interferometer
for high-precision simultaneous measurement and calibratio

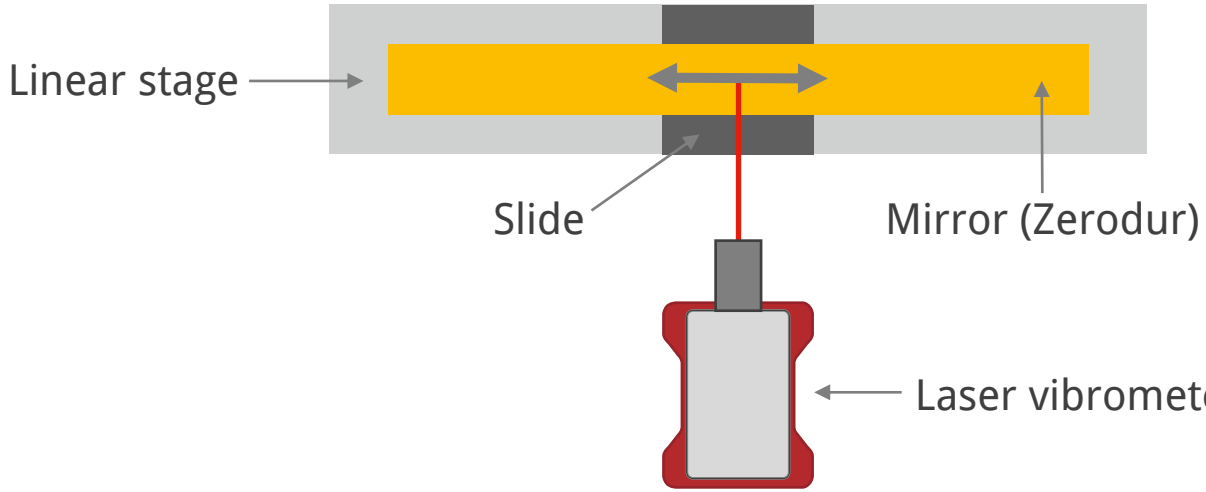
Straightness Measurements



measurements of beam position

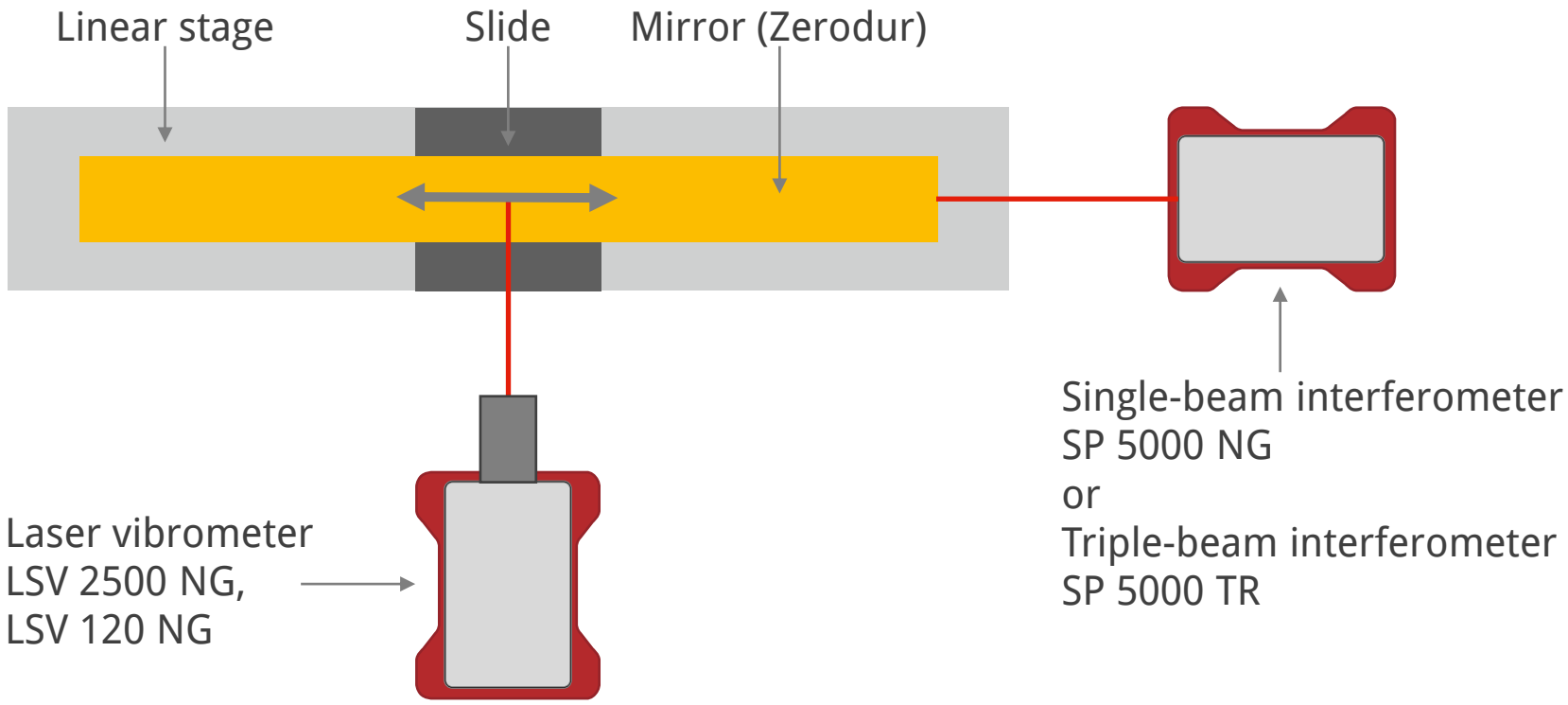


interferometric measurements



measurements of reference artefact

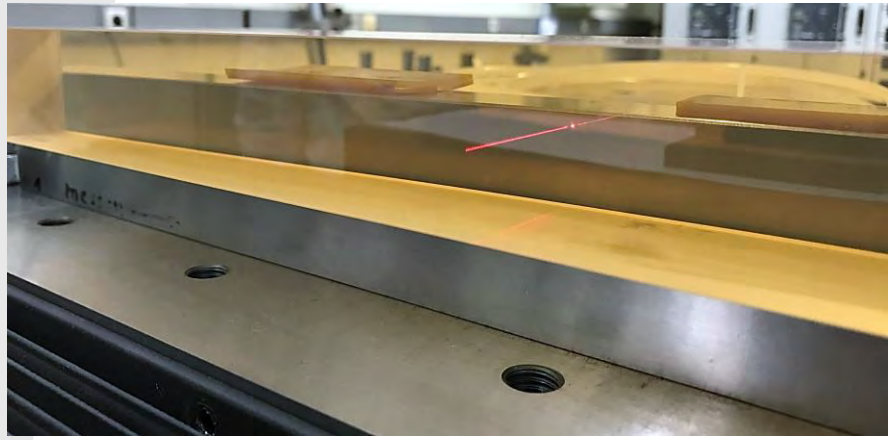
Direct Straightness Measurements

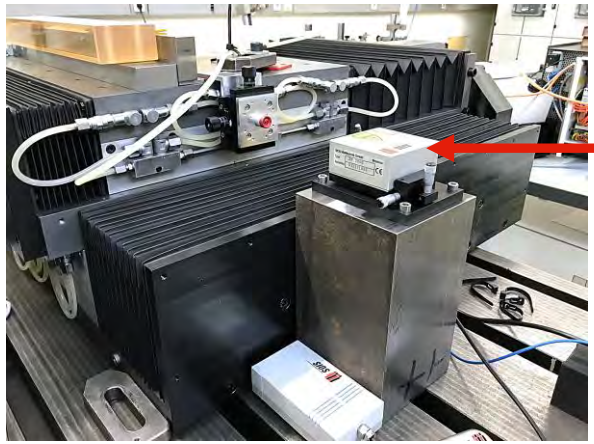


The mirror works as a straightness artefact. The laser vibrometer scans the surface and the standard interferometer gives the position.

Direct Straightness Measurements

Application in a shop floor



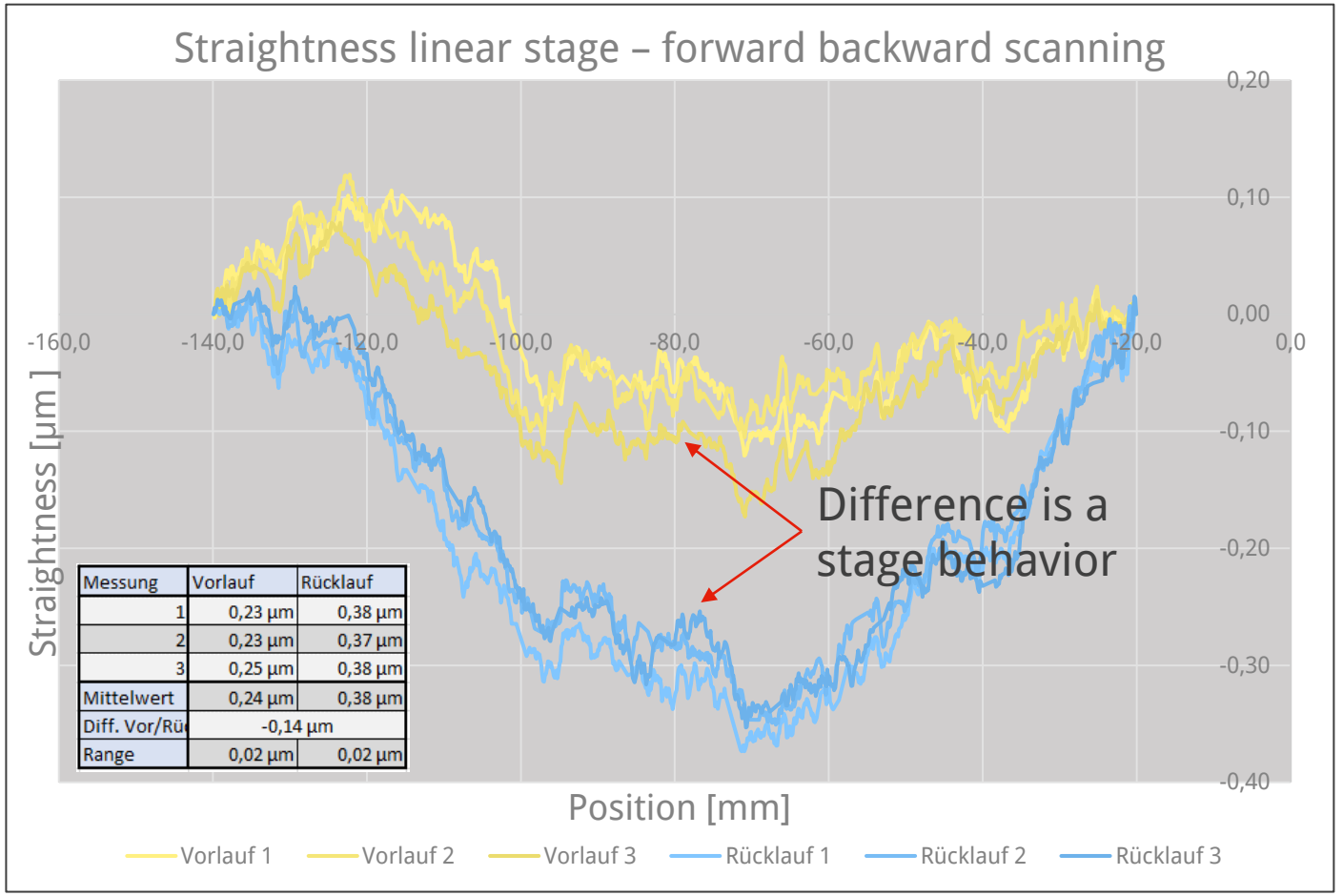


Interferometer

Vibrometer

Direct Straightness Measurements

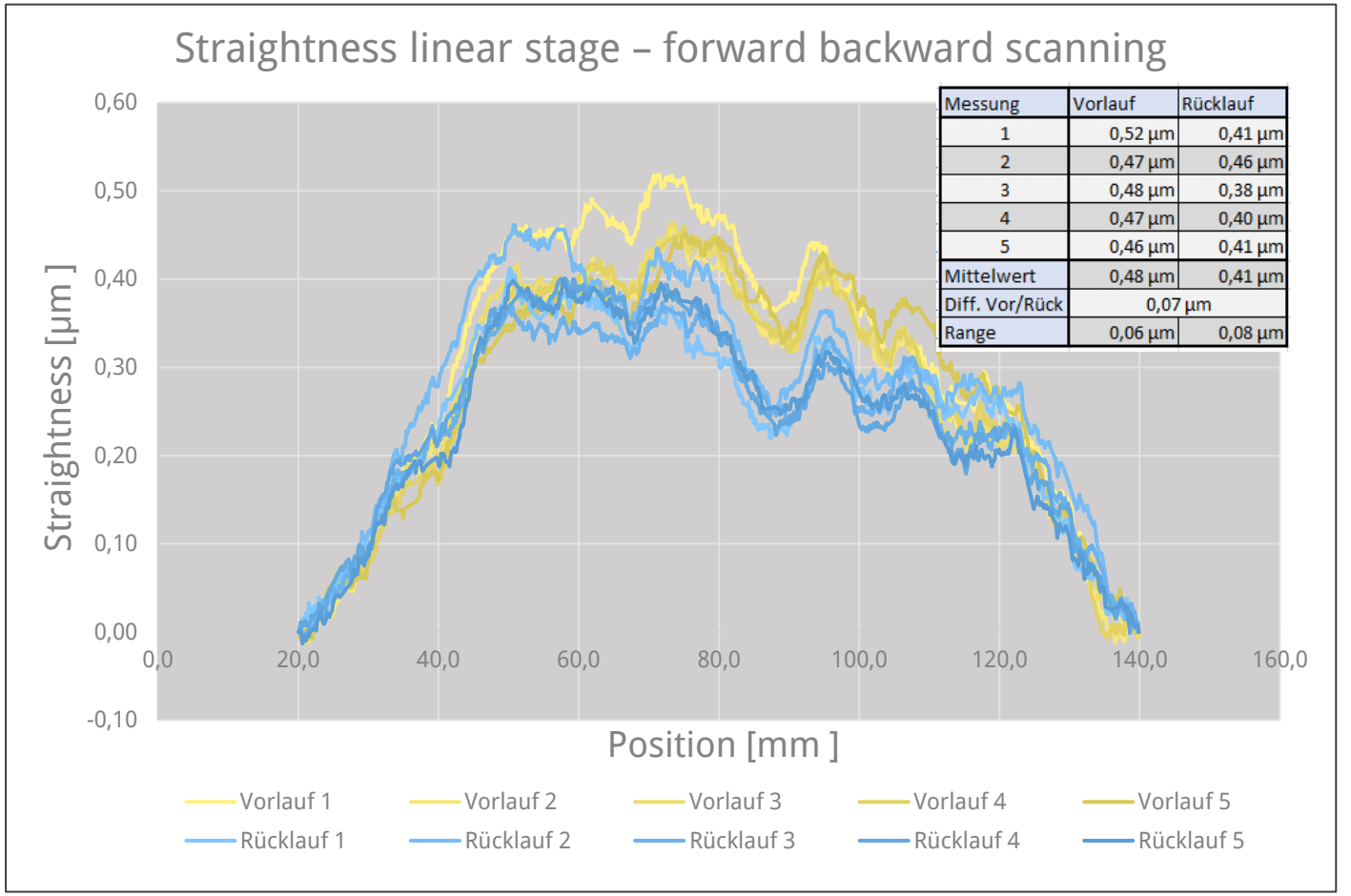
Result (I)



Messung	Vorlauf	Rücklauf
1	0,23 µm	0,38 µm
2	0,23 µm	0,37 µm
3	0,25 µm	0,38 µm
Mittelwert	0,24 µm	0,38 µm
Diff. Vor/Rü	-0,14 µm	
Range	0,02 µm	0,02 µm

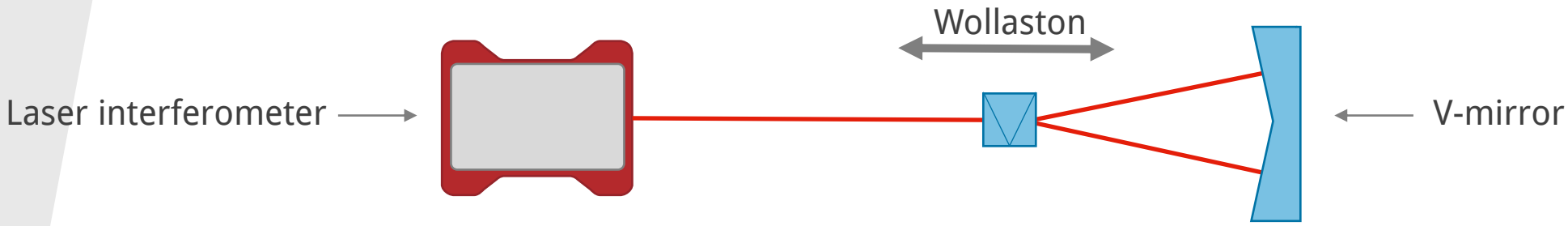
Direct Straightness Measurements

Result (II)



Messung	Vorlauf	Rücklauf
1	0,52 µm	0,41 µm
2	0,47 µm	0,46 µm
3	0,48 µm	0,38 µm
4	0,47 µm	0,40 µm
5	0,46 µm	0,41 µm
Mittelwert	0,48 µm	0,41 µm
Diff. Vor/Rück	0,07 µm	
Range	0,06 µm	0,08 µm

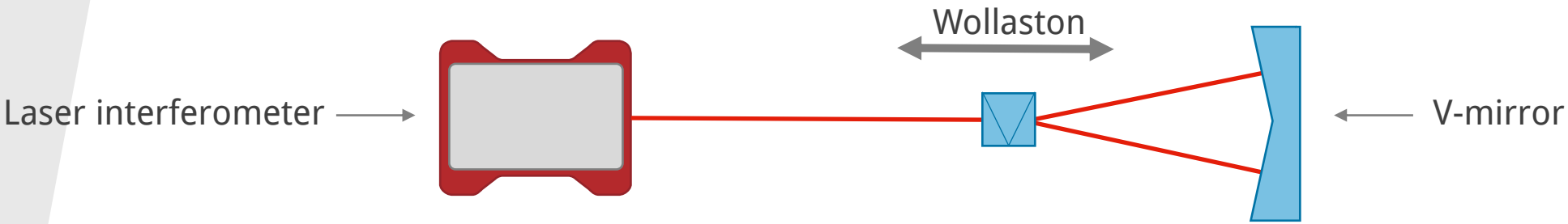
Interferometric Straightness Measurement

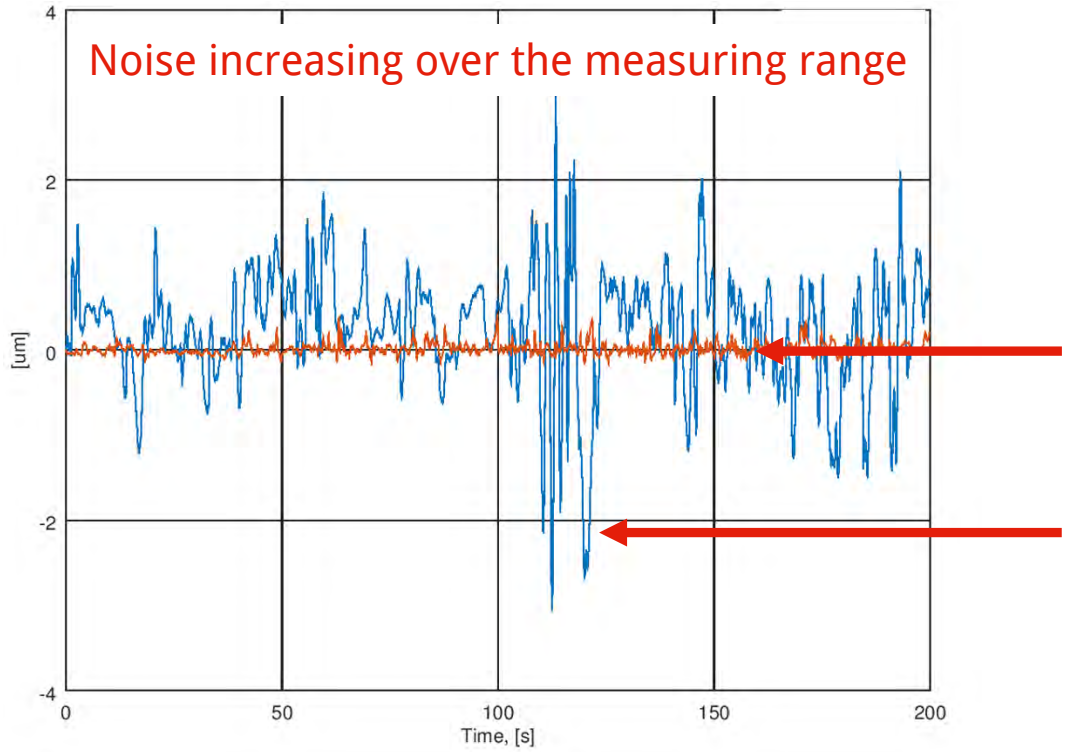


Important points

- laser noise caused by power supply or functional irregularities
- inhomogeneity of the environment
- changes of the laser wavelength due the refractive index of air
- electronic noise of the photoreceiver
- nonlinearities of the signal demodulation
- optics geometry
- setup stability

Interferometric Straightness Measurement



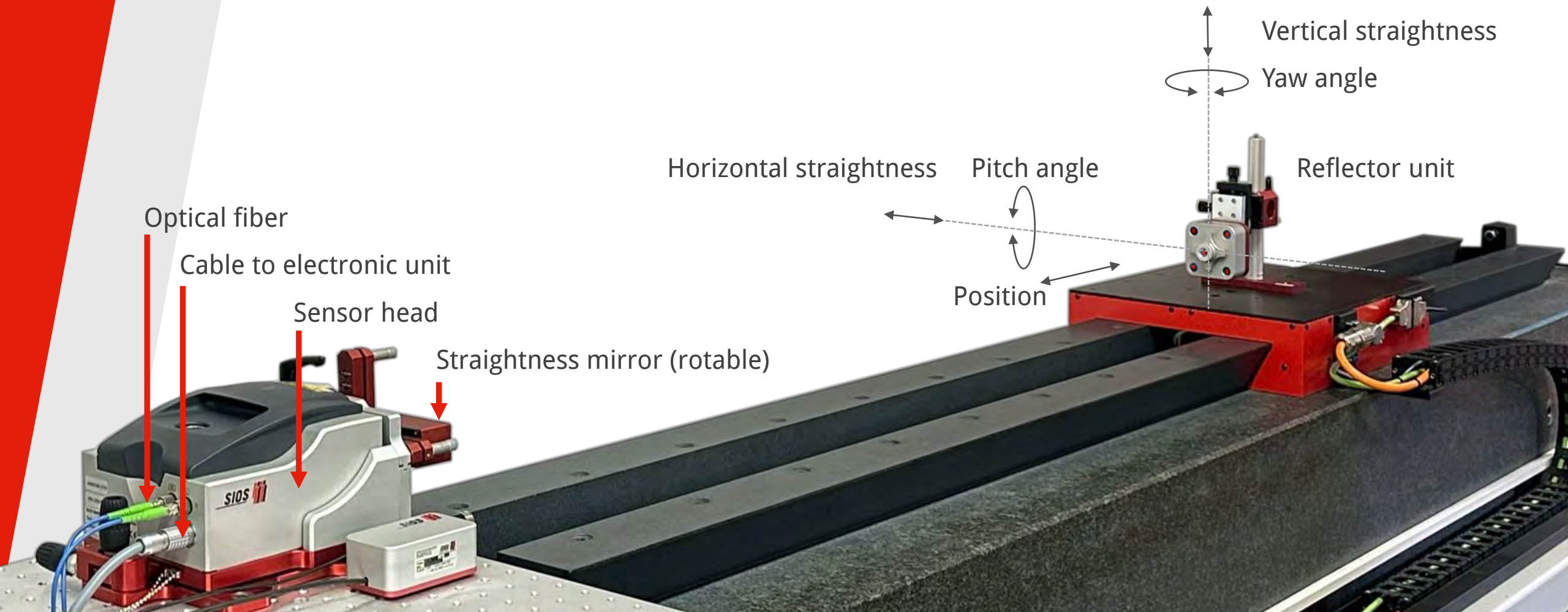


Short range, 300 mm,
production room, without housing

Long range, 1300 mm,
production room, without housing

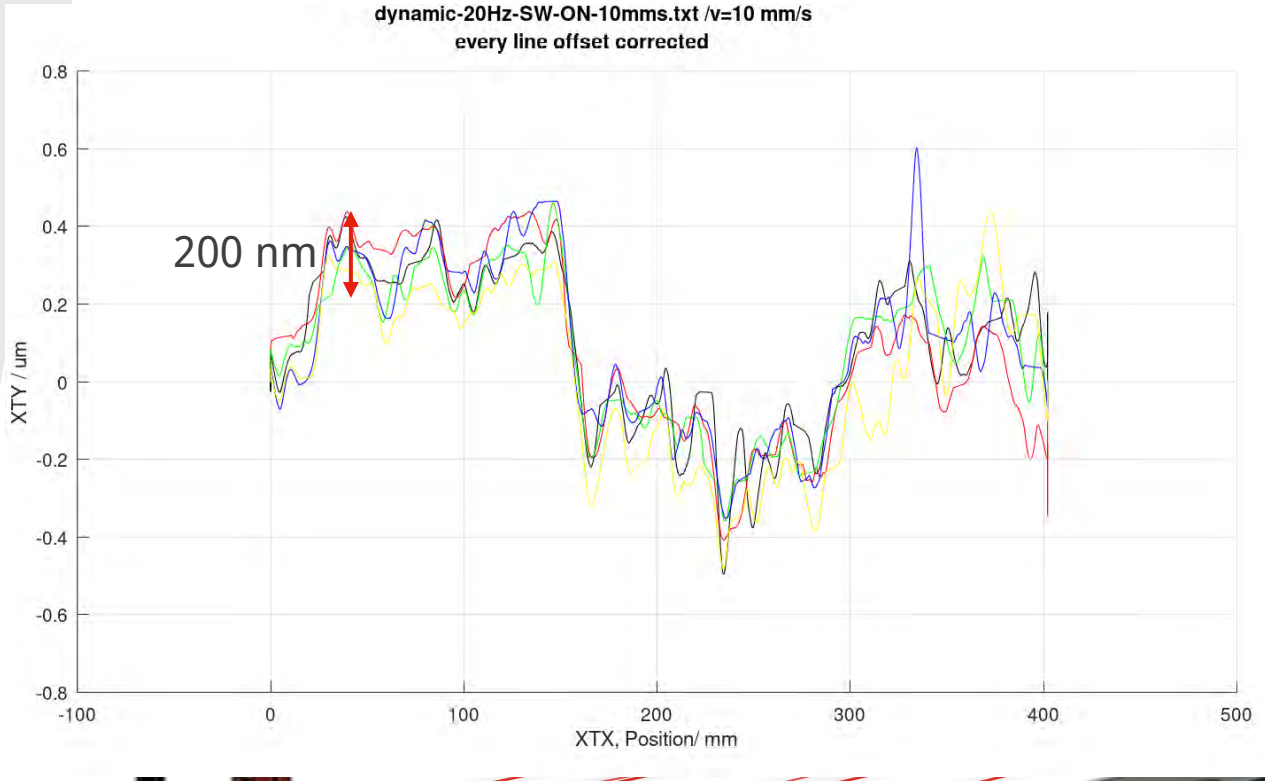
Simultaneous displacement and straightness measurement

On the fly measurements



Simultaneous displacement and straightness measurement

On the fly measurements



SIOS Calibration Software

AXIS

Easy and fast

ISO & VDI compliant
axis calibration

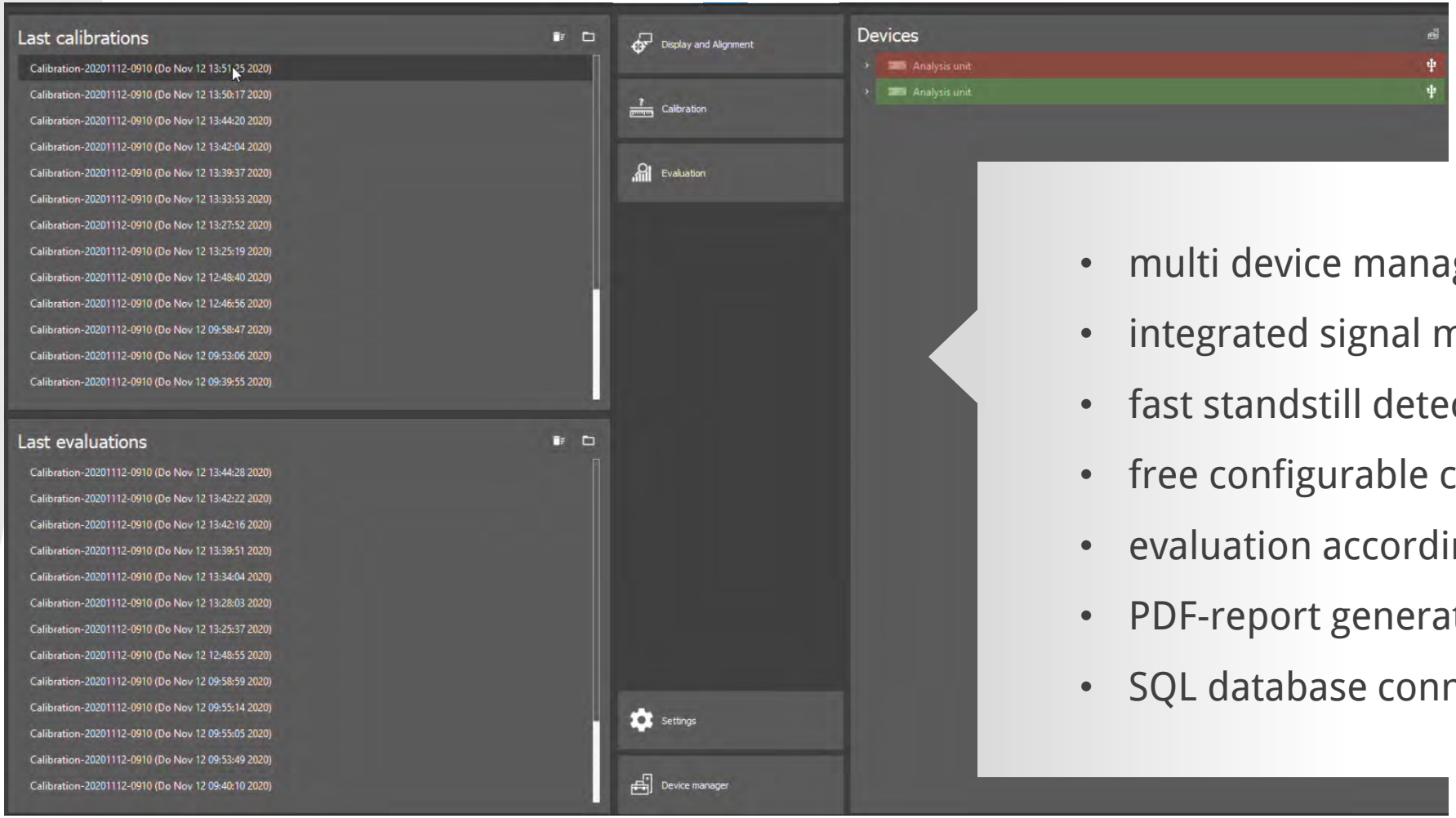
MTCAL

Mighty and complex

Volumetric error mapping
and control specific correction

SIOS Calibration Software

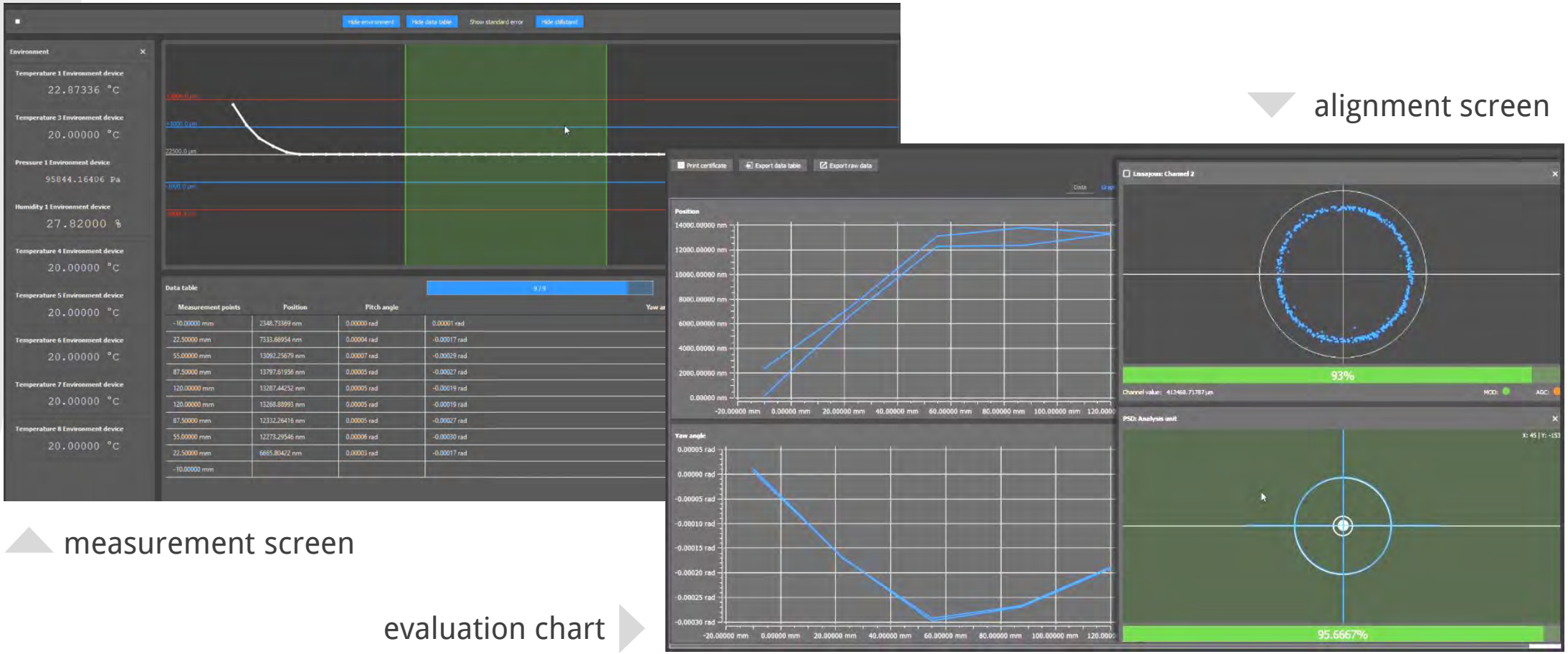
InfasAXIS



- multi device management
- integrated signal monitor
- fast standstill detection
- free configurable calibration
- evaluation according ISO & VDI
- PDF-report generator
- SQL database connector

SIOS Calibration Software

InfasAXIS



alignment screen

measurement screen

evaluation chart

Hide environment | Hide data table | Show standard error | Hide stillstand

Environment

Temperature 1 Environment device
22.87247 °C

Temperature 3 Environment device
20.00000 °C

Pressure 1 Environment device
95839.82031 Pa

Humidity 1 Environment device
27.85000 %

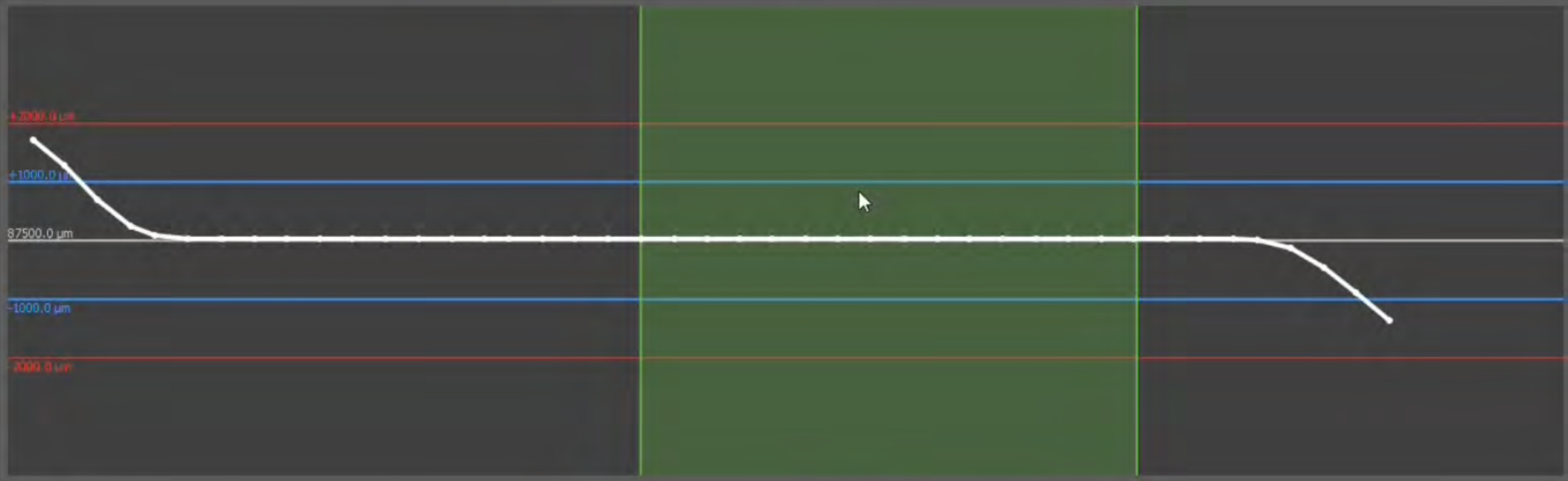
Temperature 4 Environment device
20.00000 °C

Temperature 5 Environment device
20.00000 °C

Temperature 6 Environment device
20.00000 °C

Temperature 7 Environment device
20.00000 °C

Temperature 8 Environment device
20.00000 °C



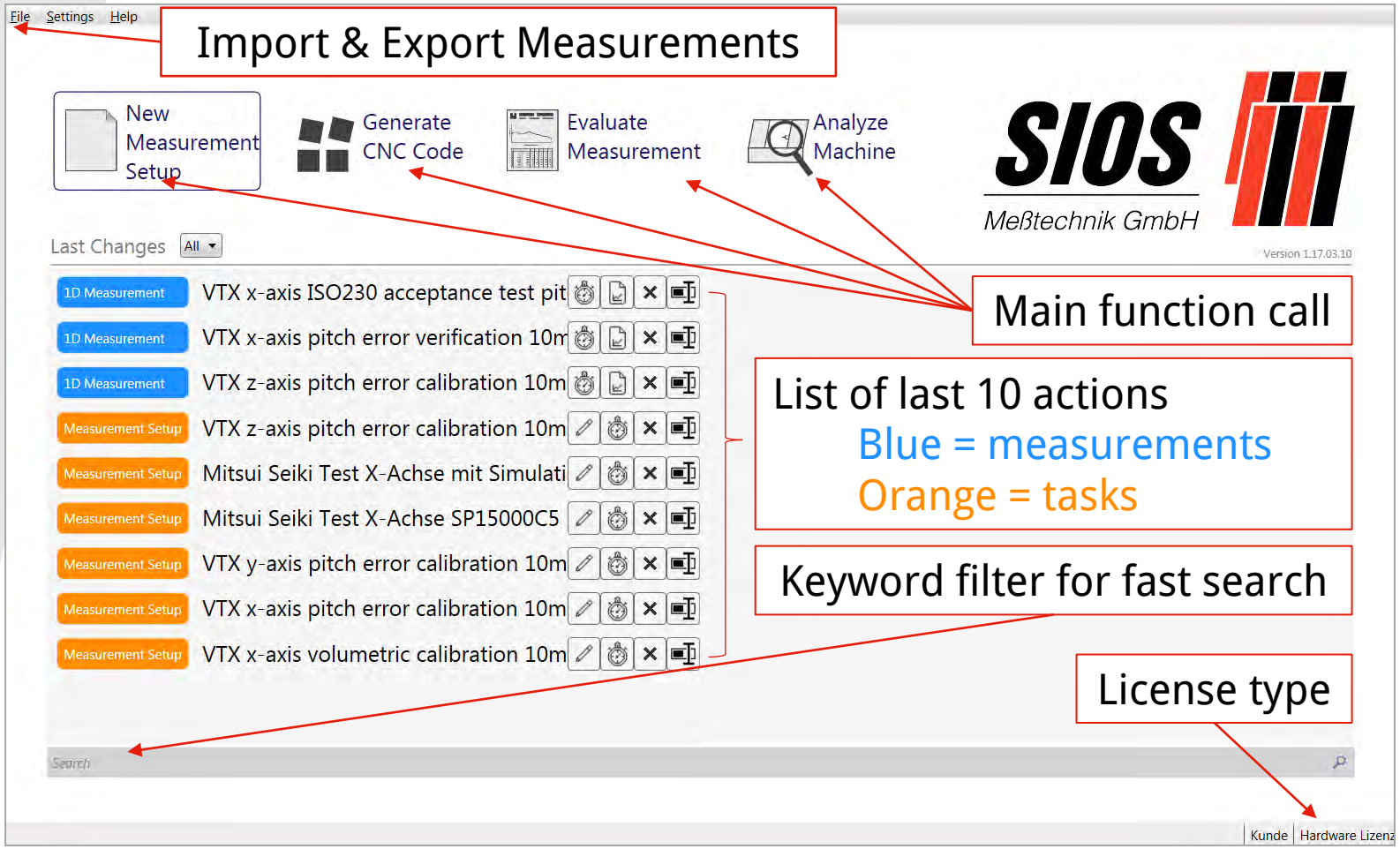
Data table

7 / 9

Measurement points	Position	Pitch angle	Yaw angle
-10.00000 mm	2348.73369 nm	0.00000 rad	0.00001 rad
22.50000 mm	7333.66954 nm	0.00004 rad	-0.00017 rad
55.00000 mm	13092.25679 nm	0.00007 rad	-0.00029 rad
87.50000 mm	13797.61956 nm	0.00005 rad	-0.00027 rad
120.00000 mm	13287.44252 nm	0.00005 rad	-0.00019 rad
120.00000 mm	13268.88993 nm	0.00005 rad	-0.00019 rad
87.50000 mm	12332.26416 nm	0.00005 rad	-0.00027 rad
55.00000 mm			
22.50000 mm			
-10.00000 mm			

SIOS Calibration Software

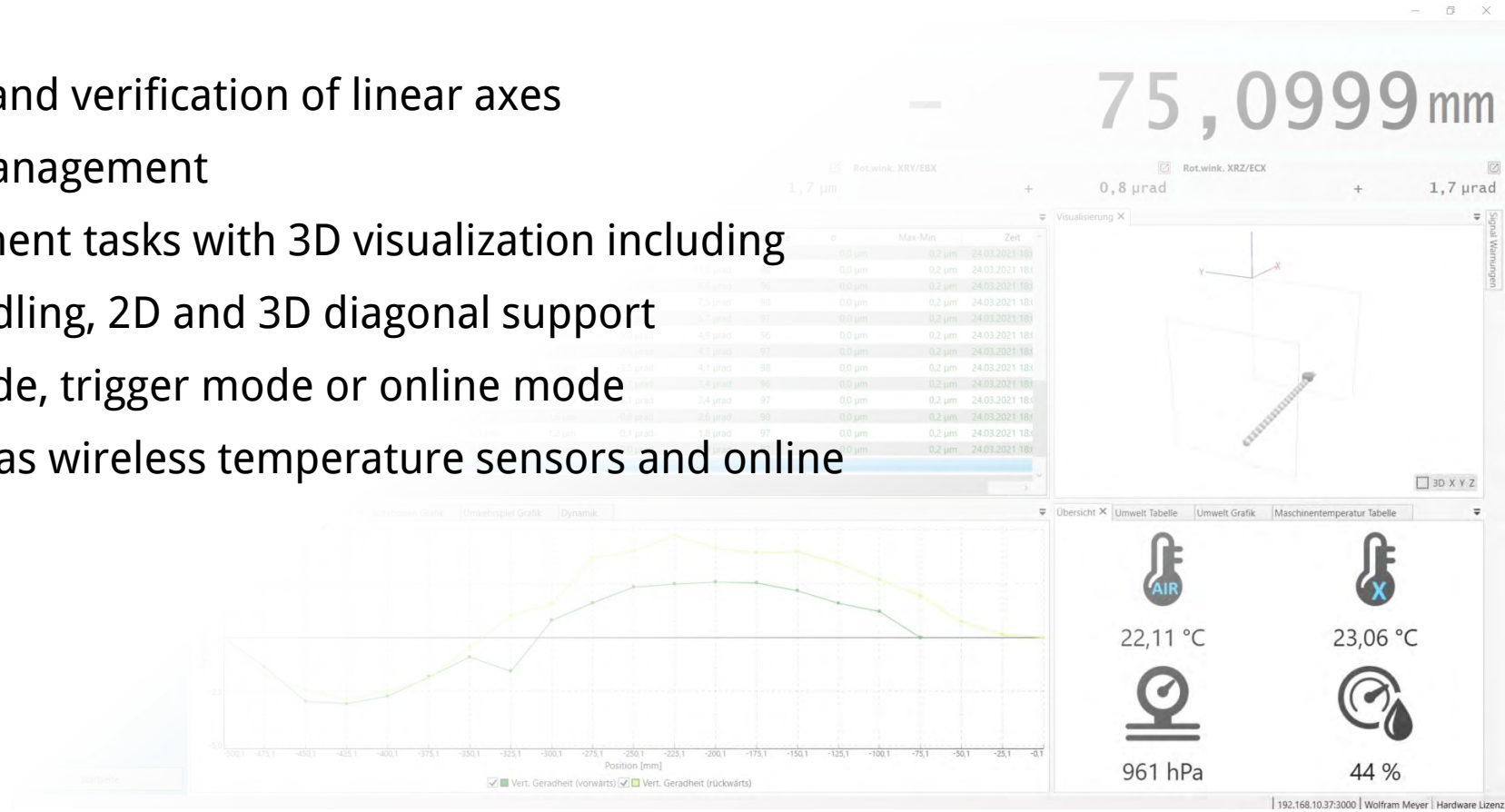
Desktop InfasMTCAL



SIOS Calibration Software

InfasMTCAL key feature

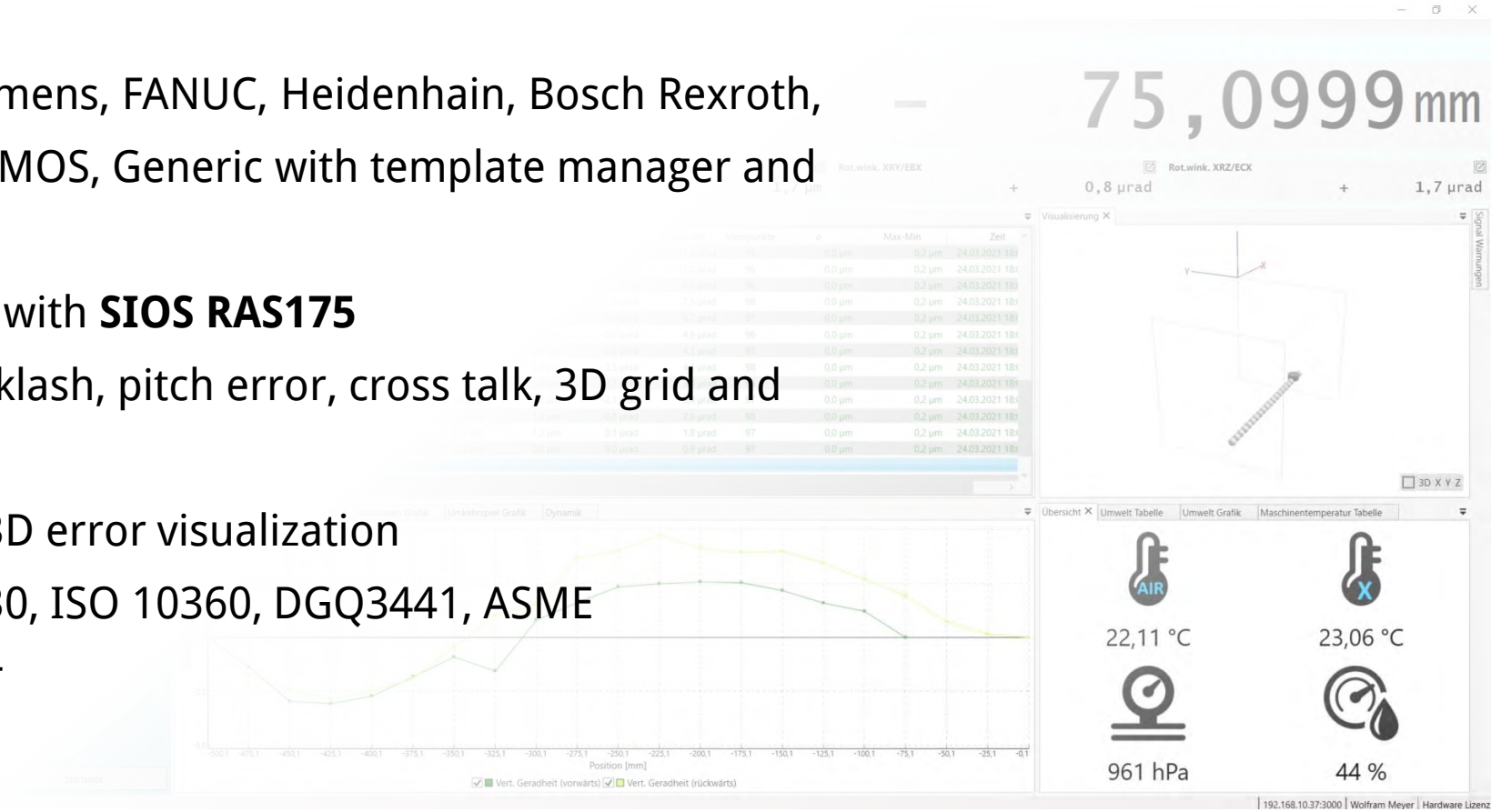
- calibration, error mapping and verification of linear axes
- device and machine tool management
- definition of axis measurement tasks with 3D visualization including mirror setups and sign handling, 2D and 3D diagonal support
- operation in dwell time mode, trigger mode or online mode
- supports wired and as well as wireless temperature sensors and online temperature compensation



SIOS Calibration Software

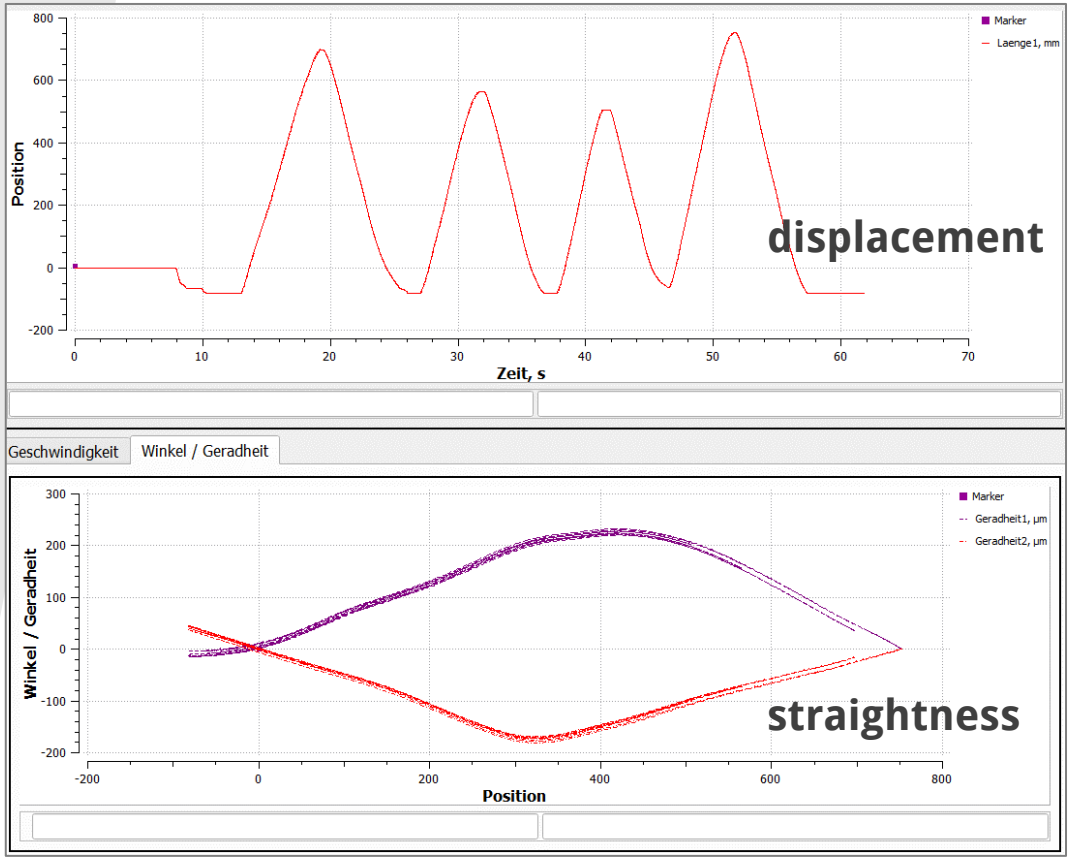
InfasMTCAL key feature

- CNC control support for Siemens, FANUC, Heidenhain, Bosch Rexroth, Fagor, Fidia, Mazak, I++, CMMOS, Generic with template manager and code generator
- supports roll measurement with **SIOS RAS175**
- creating error maps for backlash, pitch error, cross talk, 3D grid and volumetric compensation
- Abbe-Error correction and 3D error visualization
- evaluation according ISO 230, ISO 10360, DGQ3441, ASME
- calibration report generator



Software: InfasAlign

Indirect measurements of the straightness by interferometer



- move the sliding element by hand
- simultaneous measurement of angle and position
- direct relationship between the straightness of linear guide and position

SIOS Calibration Interferometer

Capabilities

1. high resolution < 1 nm
2. high dynamic up to 3 m/s, 12.5 MHz
3. high synchronous less than 0.2 ns
4. simultaneous measurement of
   position, pitch, yaw and straightness; and roll
   → Can be used for angular calibration (> 1°)
5. very compact design
6. easy to align
7. Triggering capability for dynamic measurements
8. High measurement frequencies for dynamic analysis
9. Traceable calibration

SIOS Meßtechnik GmbH

THANK YOU VERY MUCH FOR YOUR ATTENTION!

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