

# The LaserTRACER – Calibration and Testing with Sub-Micron accuracy

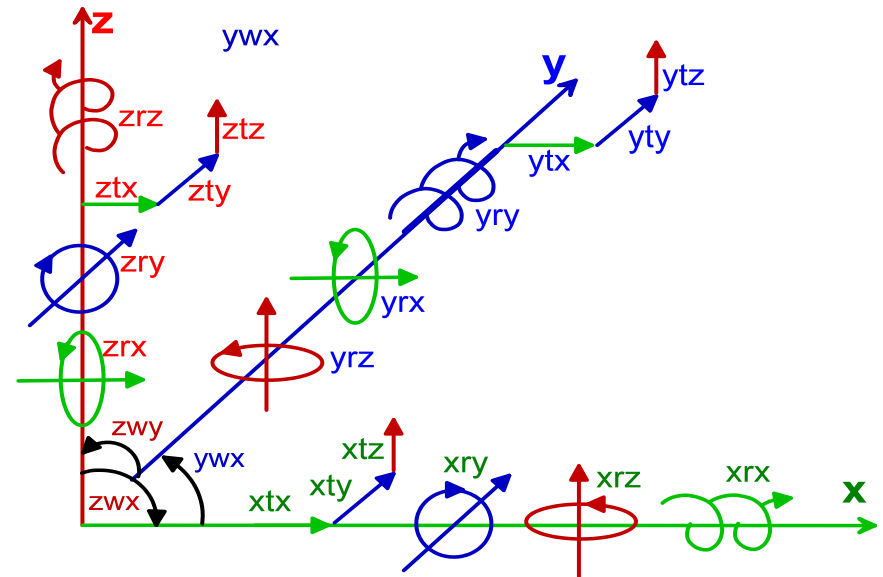
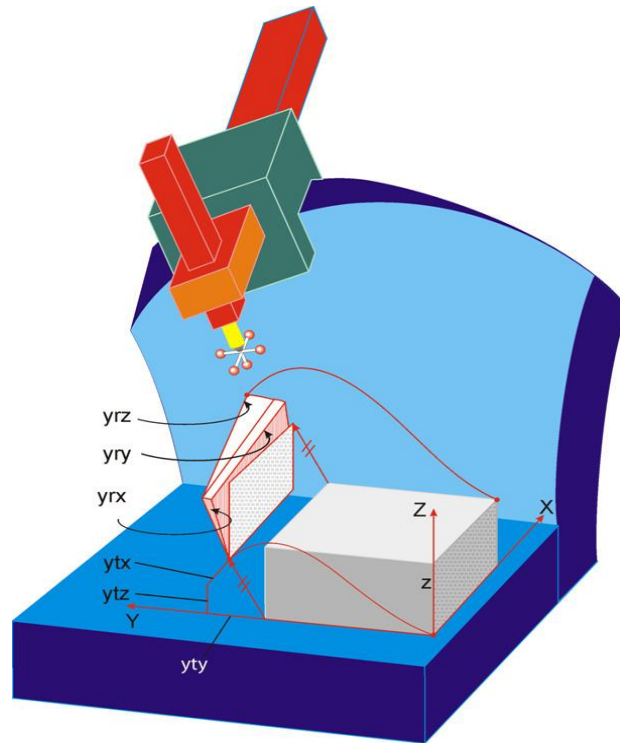
- ▷ Accuracy for measuring machines and machine tools and
- ▷ The LaserTRACER
- ▷ The Etalon solution
- ▷ TRAC-CAL® for Error Mapping and Compensation
- ▷ TRAC-CHECK® for Accuracy Testing
- ▷ Our customers



# Accuracy for CMMs and Machine Tools

- ▶ For CMM and machine tools accuracy is a key performance feature
- ▶ Highest accuracy cannot be achieved economically without numerical compensation
- ▶ Full error compensation is used for CMM since 15 years successfully, now it is available also in the machine tool world
- ▶ Classical methods for error mapping are time consuming and need operators with years of experience

# Geometry deviations of a Cartesian Machine

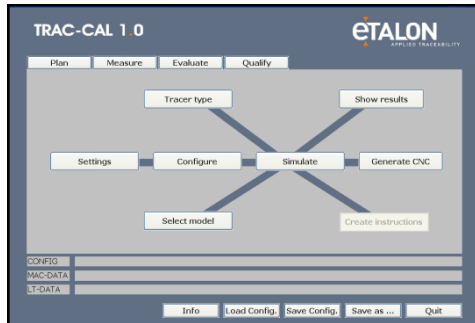


Notation according to VDI 2617-3

Source: PTB

# The ETALON solution

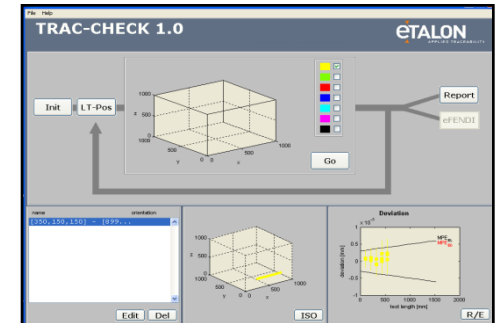
## TRAC-CAL<sup>®</sup>



## LaserTRACER



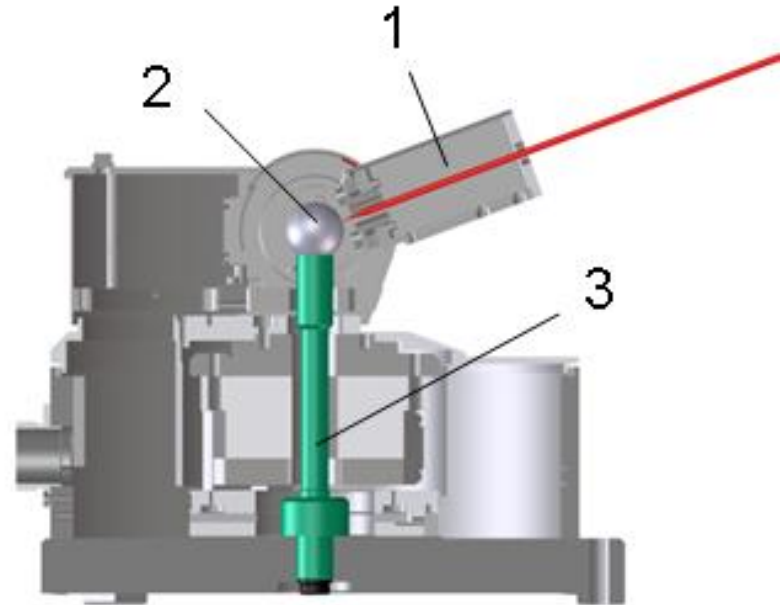
## TRAC-CHECK<sup>®</sup>



**Error mapping and  
compensation**

**Testing and qualification**

## The LaserTRACER



- ▷ Interferometer with  $0,001 \mu\text{m}$  resolution (1)
- ▷ Patented reference sphere (2) with form deviation  $< 0,050 \mu\text{m}$
- ▷ Environmental compensation for temperature, pressure, humidity



Length measurement uncertainty:  $U = 0.2 \mu\text{m} + 0.3 \mu\text{m}/\text{m}$

# Specifications



## Weights and dimensions

Weight LaserTRACER approx. 15 kg

Weight controller approx. 10 kg

Height LaserTRACER 200 mm

## Operating range

Angular range elevation axis  $- 20^\circ$  up to  $+ 85^\circ$

Angular range azimuth axis  $\pm 200^\circ$

Measuring range 0.2 m up to 15 m

## Accuracy

Frequency stability laser 24 h  $2 \cdot 10^{-8}$

Stability of the reference sphere  $\pm 0.1 \mu\text{m}$

Resolution interferometer  $0,001 \mu\text{m}$

Uncertainty (k=2)  $0.2 \mu\text{m} + 0.3 \mu\text{m}/\text{m}$

# Interfaces for conventional Laser Tracker



For highest accuracy requirement the Etalon LaserTRACER is the first choice due to it's exceptional technology.

For machines with axis length of several meters the use of a conventional LaserTracker can be adequate.

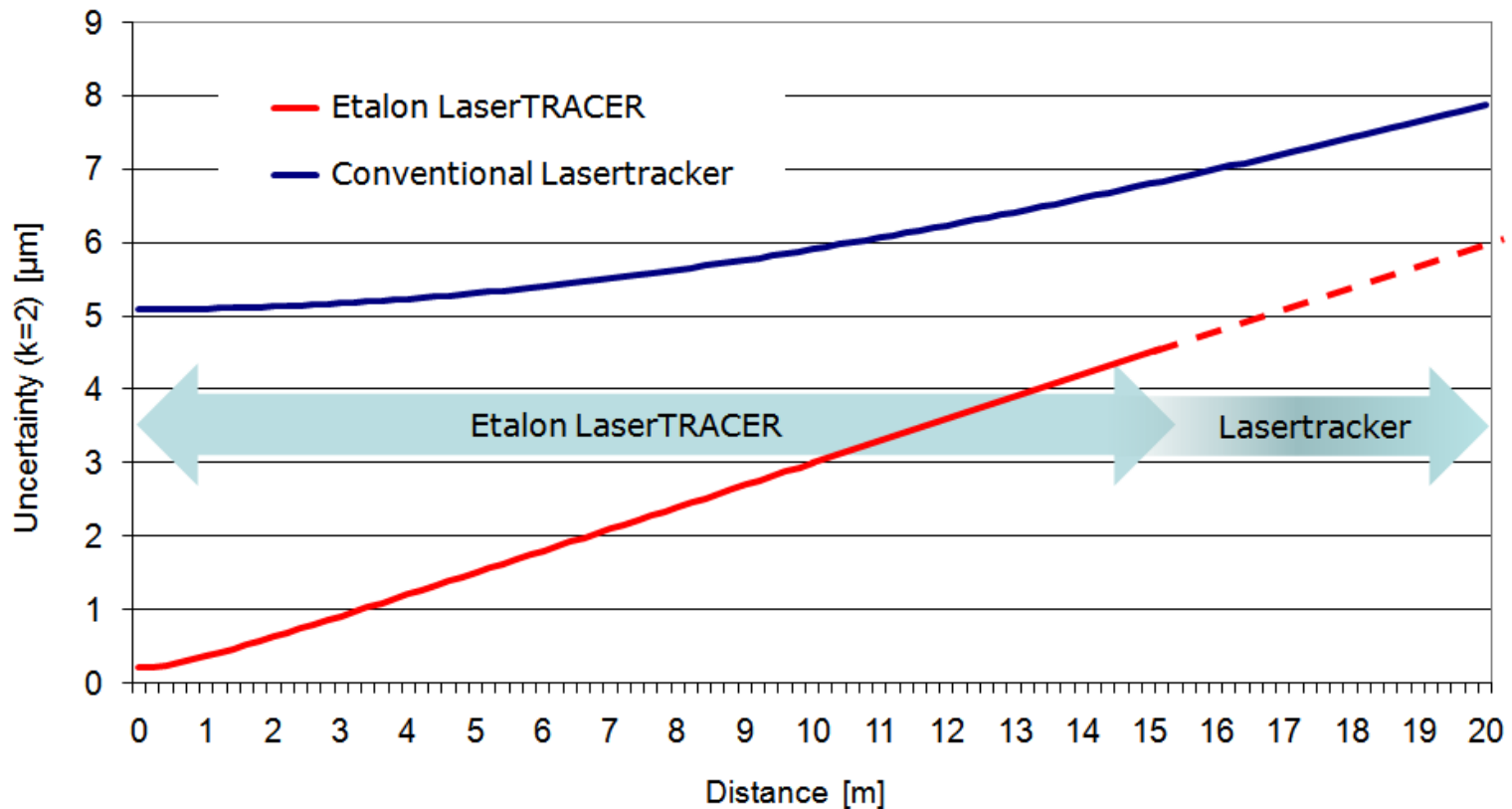
ETALON offers for it's software solutions interfaces for Laser Tracker from

- ▷ Leica
- ▷ Faro

# Comparison of accuracy for distance measurements

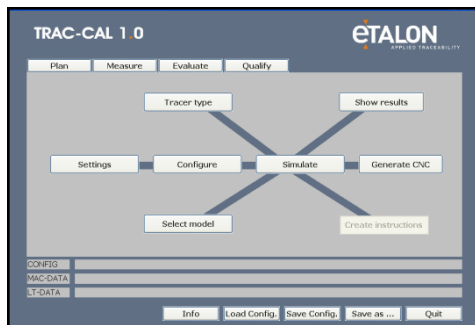
## LaserTRACER vs Lasertracker

$$U_{(k=2)} = \sqrt{u_{\text{Rotation}} + u_{\text{Reflector}} + u_{\text{Cosinus}} + u_{\text{Resolution}} + u_{\text{Refraktion}}}$$



# The ETALON solution

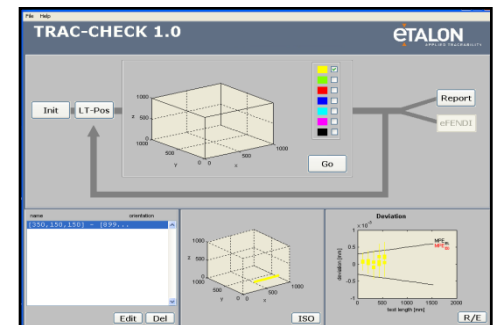
## TRAC-CAL<sup>®</sup>



## LaserTRACER



## TRAC-CHECK<sup>®</sup>

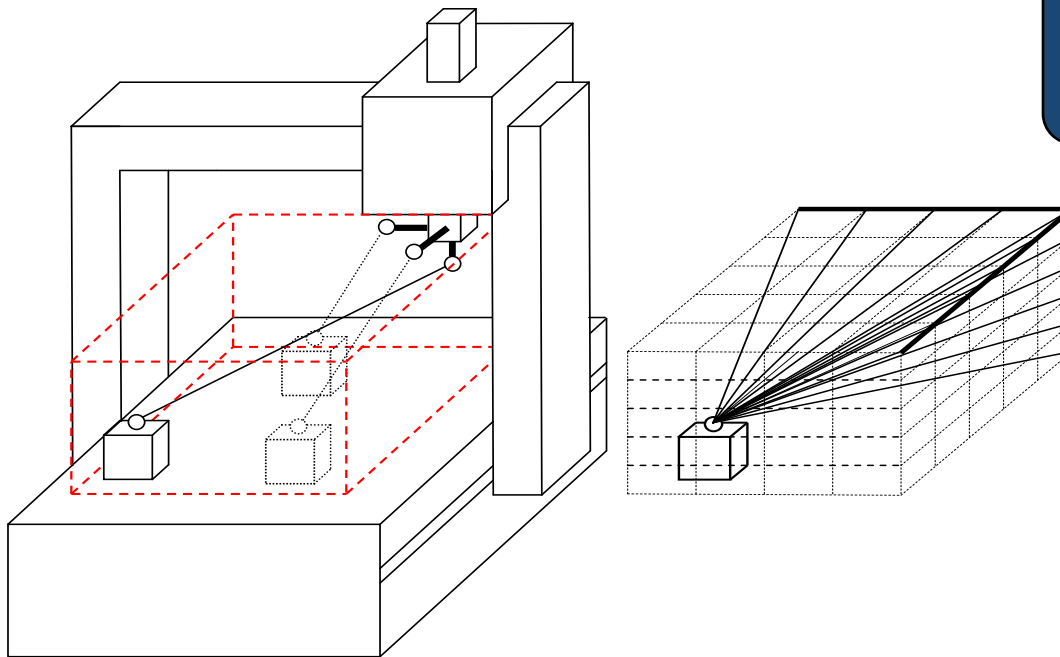


**Error mapping and  
compensation**

**Testing and qualification**

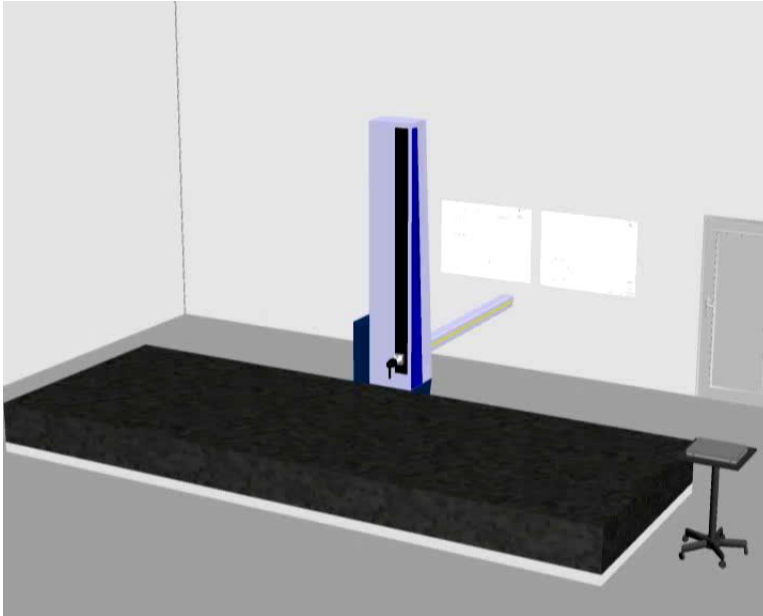
## The Principle:

“GPS-  
Principles”  
for machine  
calibration



- ▶ Interferometrical length measurement from 4-6 positions
- ▶ **Evaluation of all errors entirely based on length information**
- ▶ Position of LaserTRACER position and dead path need not be known

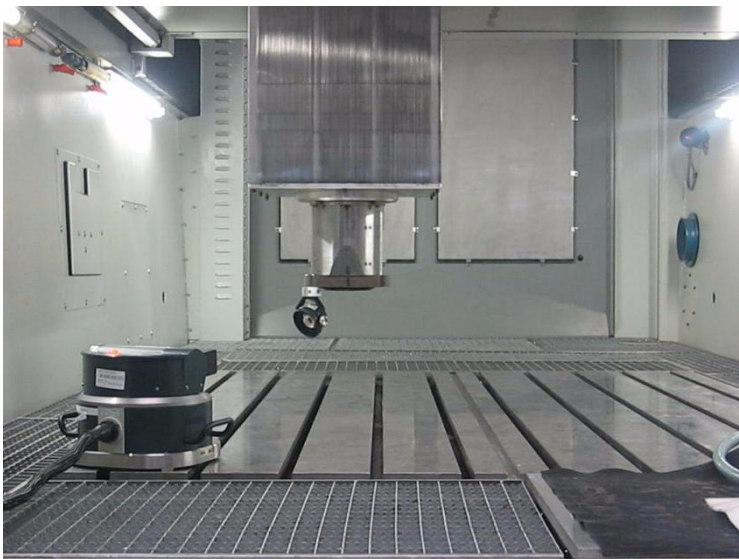
## How TRAC-CAL works in practice



Open Animation:



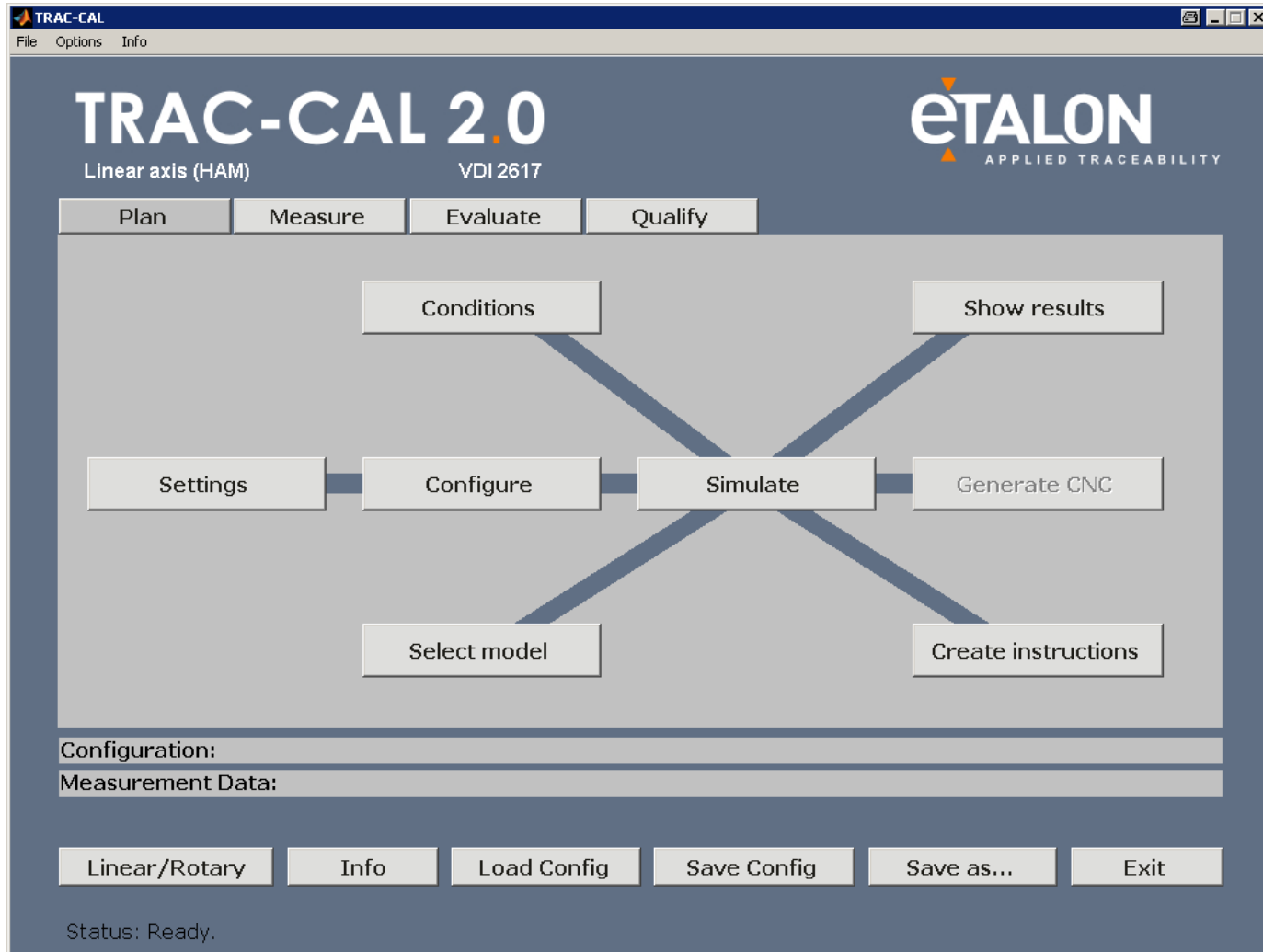
## How TRAC-CAL works in practice



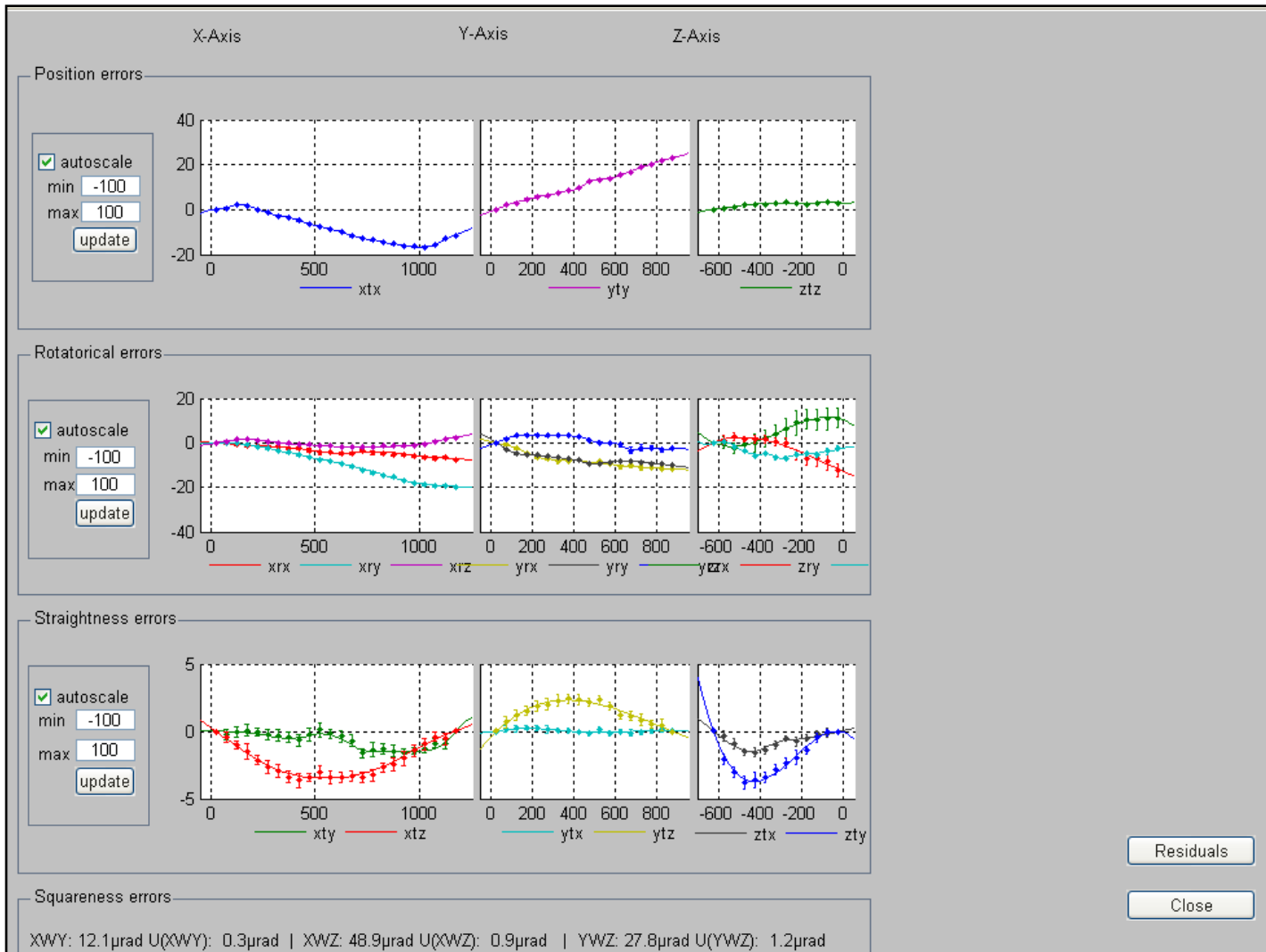
Open Film:



# Software for error mapping

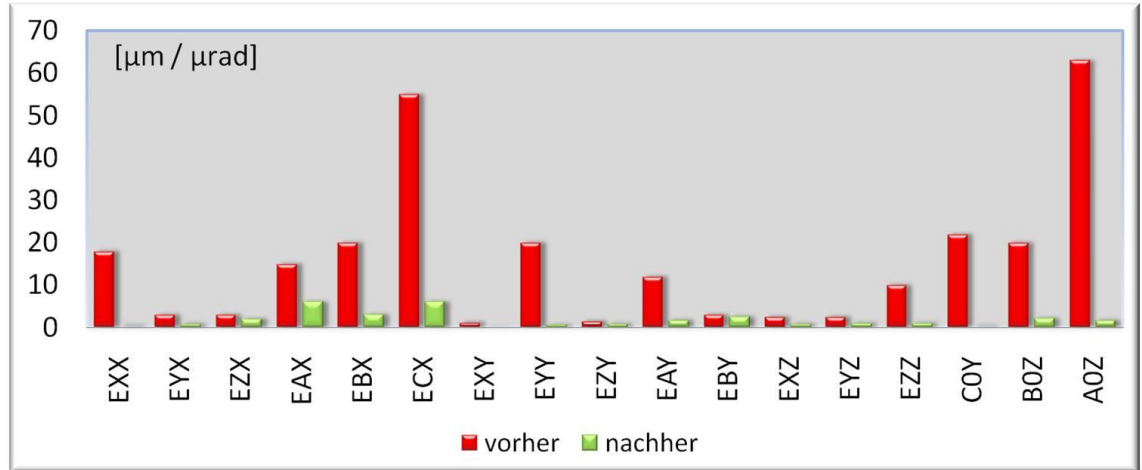


# Evaluation of parametric errors

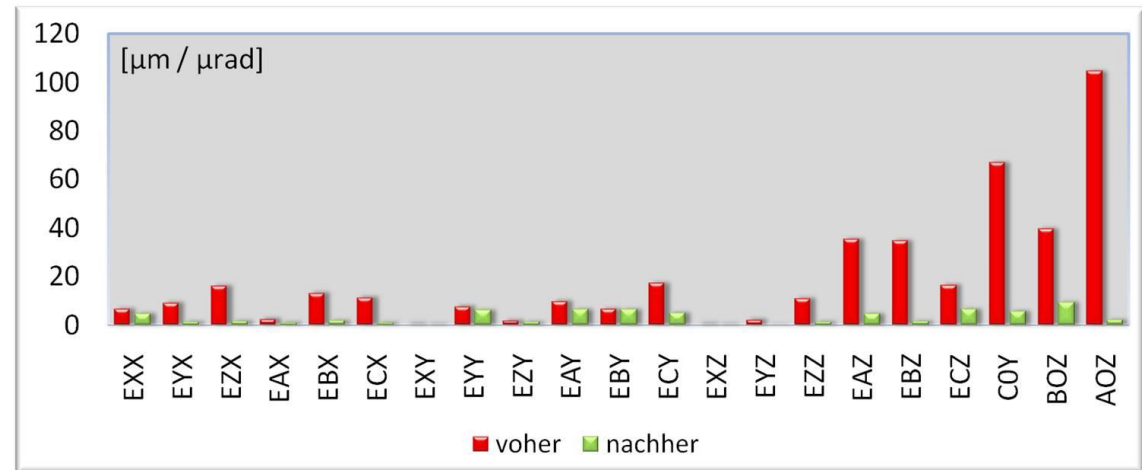


# Comparison before and after compensation

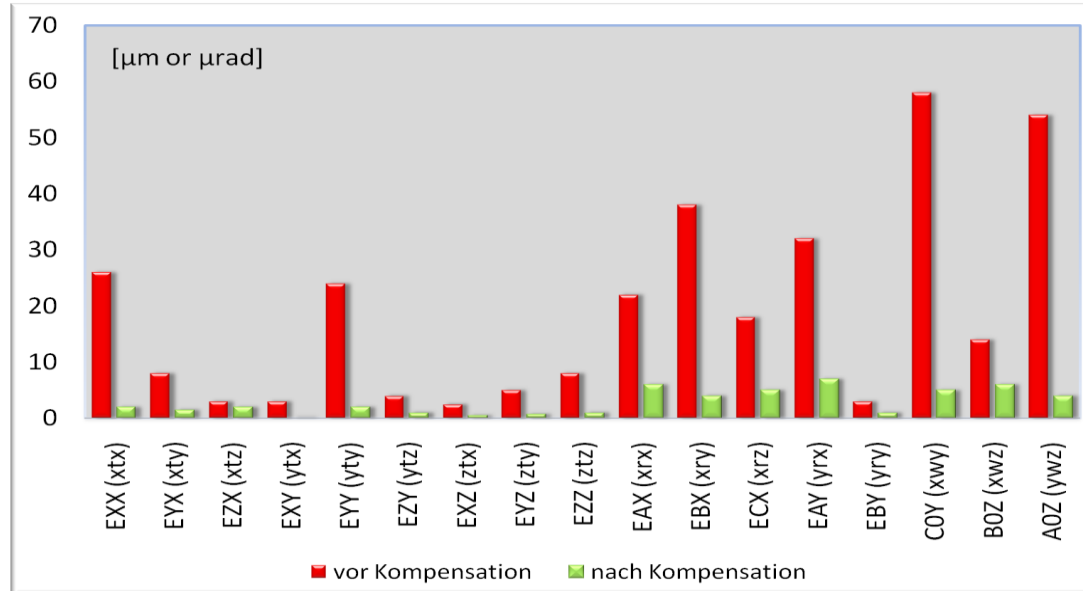
Vertical Machining center



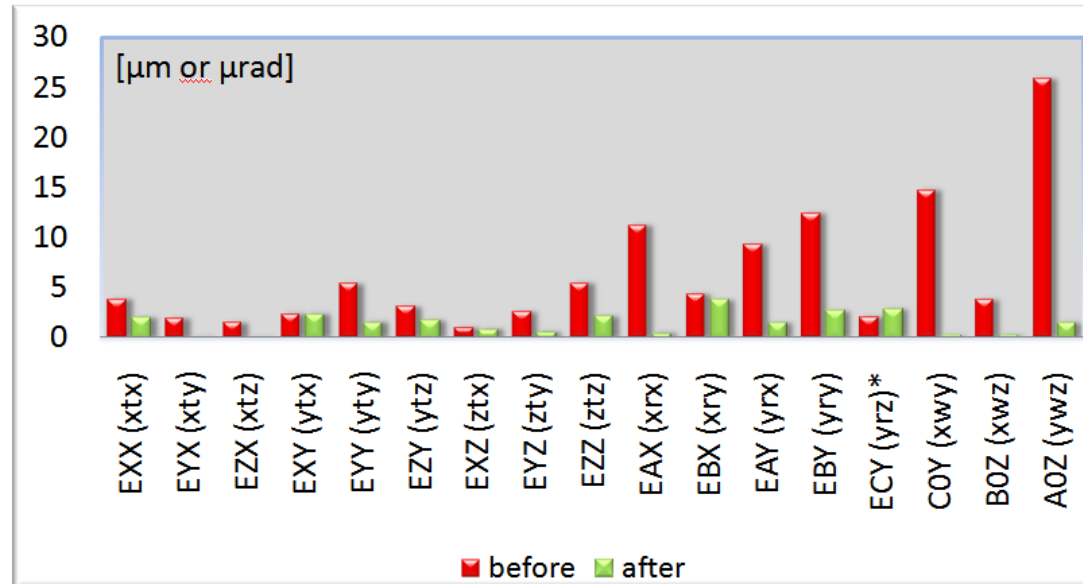
Horizontal Mill  
(Siemens controller)



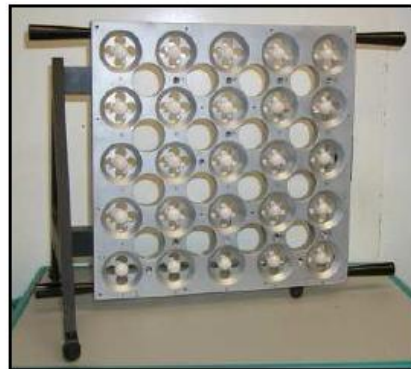
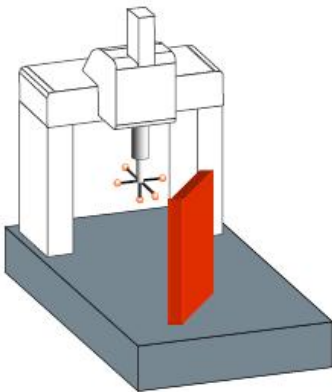
## Middle Class Vertical Mill (Fanuc controller)



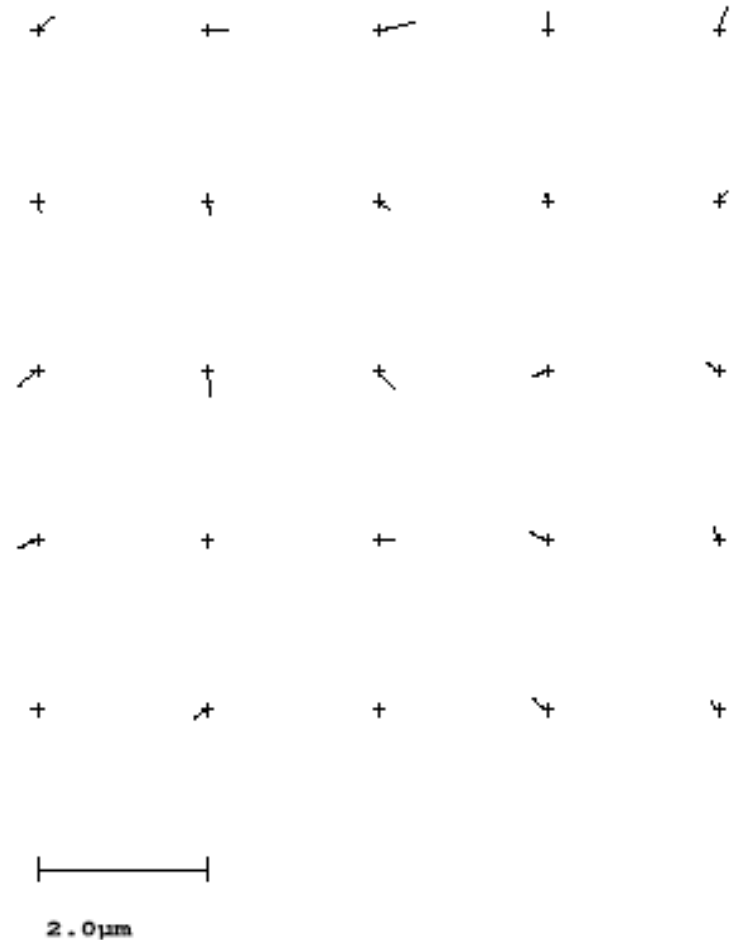
## High End Vertical Mill (Fanuc controller)



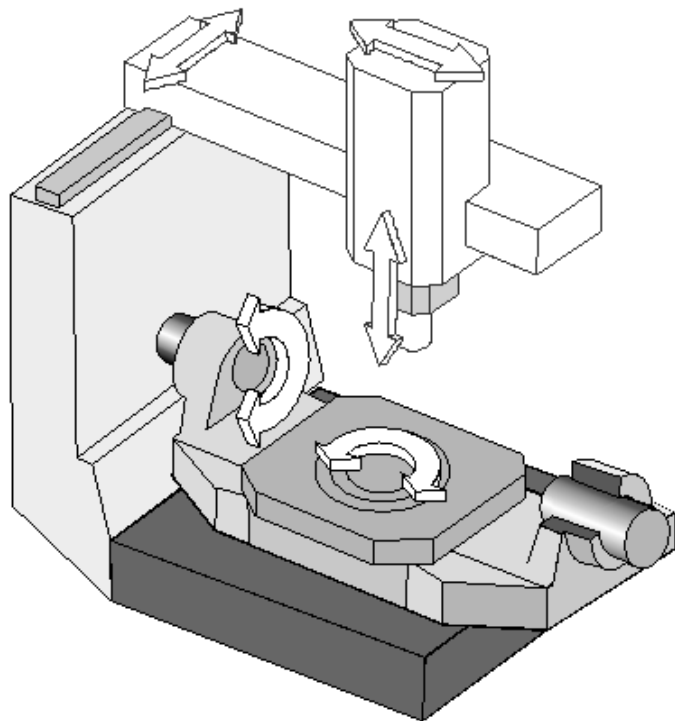
# Measurement of a Ball Plate (PTB calibration) on a high accuracy CMM after compensation with TRAC-CAL



- ▷ **Deviations <math>< 0.4 \mu\text{m}</math>**  
(smaller than calibration  
uncertainty of ball plate!)



## New: Calibration of rotary tables



### Determination of

- ▷ Angular positioning
- ▷ Axial motion
- ▷ Radial motions
- ▷ Tilt motions
- ▷ Squareness

### Solely based on interferometric measurements of the LaserTRACER

- ▷ No additional hardware necessary
- ▷ Very high accuracy
- ▷ Easy use

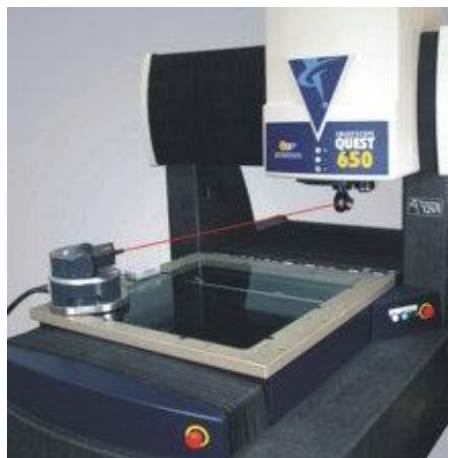
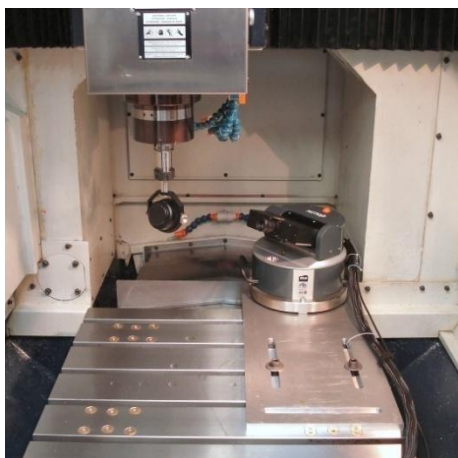
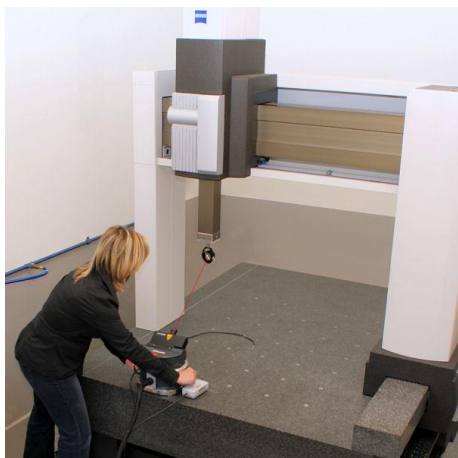
**Open Animation:**



## Summary Error Mapping with TRAC-CAL

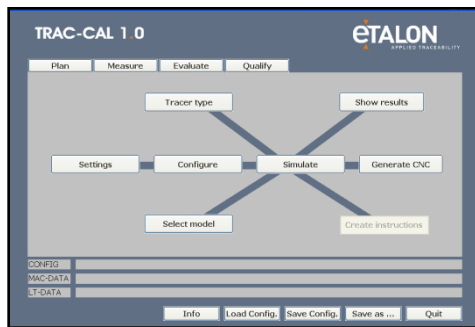
- ▶ Highest accuracy
- ▶ All deviations solely based on the wavelength of a stabilized laser
  - ▶ For linear axes: linear position, straightness, pitch, yaw, roll, squareness
  - ▶ For polar axes: angular positioning, axial motion, radial motions, tilt motions, squareness
- ▶ Suitable for error mapping of CMMs and machine tools
- ▶ Applicable for any size of working volume
- ▶ Fast execution: CMMs 3 - 4 h, machine tools 2 - 3 h
- ▶ Simple setup and data handling
- ▶ Included uncertainty calculation by Monte Carlo methods
- ▶ Interfaces and error mapping format for many CMMs and machine tool controllers available (and library is expanding)

# Application examples



# The ETALON solution

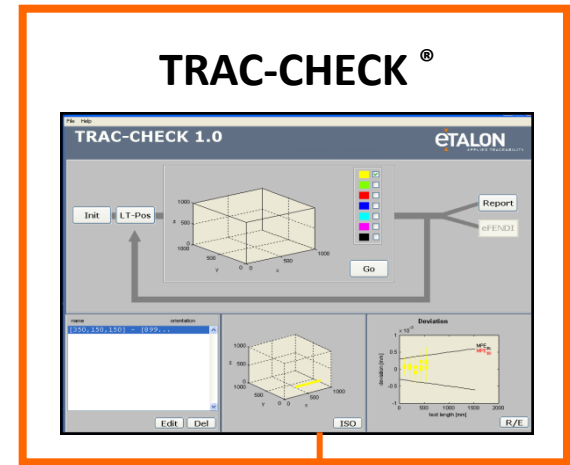
## TRAC-CAL<sup>®</sup>



## LaserTRACER



## TRAC-CHECK<sup>®</sup>



**Error mapping and  
compensation**

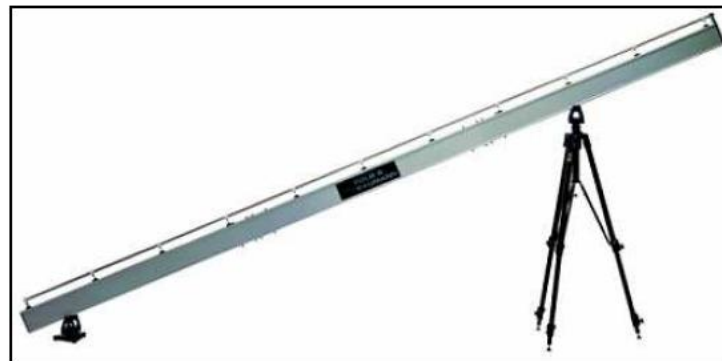
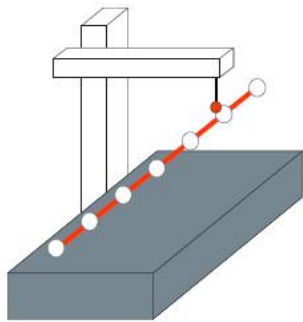
**Testing and qualification**

## Conventional methods (examples)

E.g. ball bars, conventional laser interferometers, ball plates

Bulky standards, which must be calibrated frequently.

For each tested line a new, manual alignment is necessary.



# Machine Testing with TRAC-CHECK

## Principle:

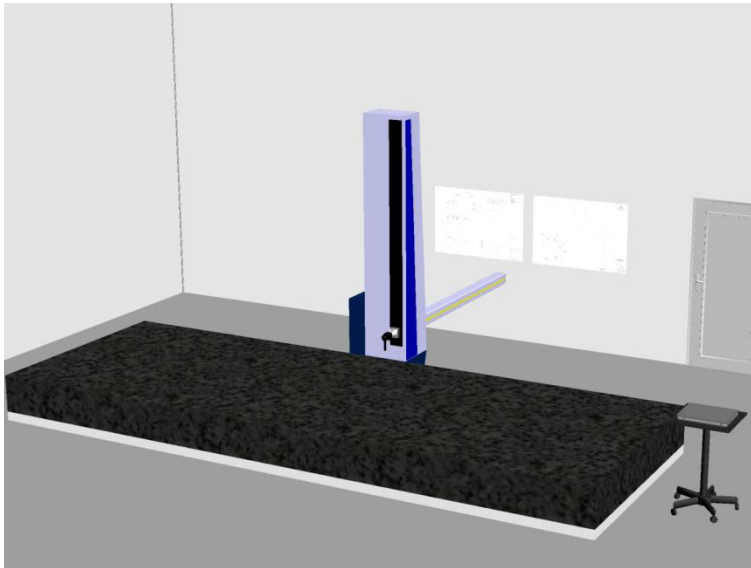
The LaserTRACER operates in “Static Interferometer Mode” but the measurement direction is automatically aligned by machine motion

- ▶ Laser displacement measurement in any direction without manual alignment
- ▶ No cosine error
- ▶ Direct control of the machine
- ▶ Data evaluation according to **ISO 10360** (CMM) or **ISO 230** (machine tools)

The test according to ISO 230 **part 6** is especially informative compared to the more well known part 2.

Both cases can be performed with TRAC-CHECK easily in shortest time.

# How TRAC-CHECK works in practice



Open Animation:



# TRAC-CHECK 1.6

ISO 10360-2

# eTALON

APPLIED TRACEABILITY

Init → LT-Pos → Report  
traceSYS

Start

Name: [798, -1255, -233] - [798, -11... Y  
[703, -1279, -233] - [10, -11, ... XY  
[798, -1264, -294] - [798, -11... YZ  
[798, -1255, -233] - [798, -11... Y  
[706, -1286, -287] - [10, -11, ... XYZ

Orientierung

Abweichung [µm]

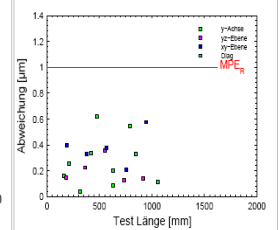
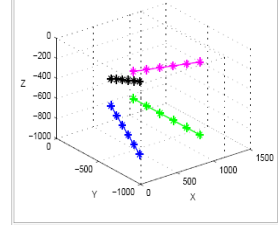
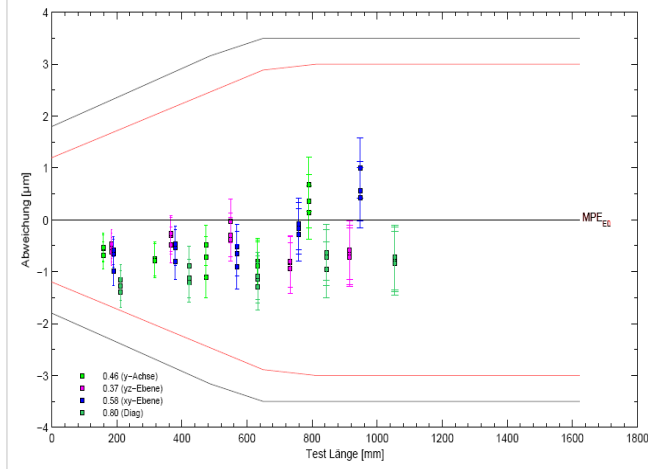
Y-Achse -2000 0 X-Achse 1000

Detail Entf ISO

Konfig C:\Dokumente und Einstellungen\uhltechnik\Desktop\test leica.t

Daten C:\Dokumente und Einstellungen\uhltechnik\Desktop\test leica.t

Ermittelte Abweichungen: (alle Messungen) / Messgerät: / Seriennummer: / Beginn: 11-Feb-2008 13:59:46 / Ende: 11-Feb-2008 15:37:06

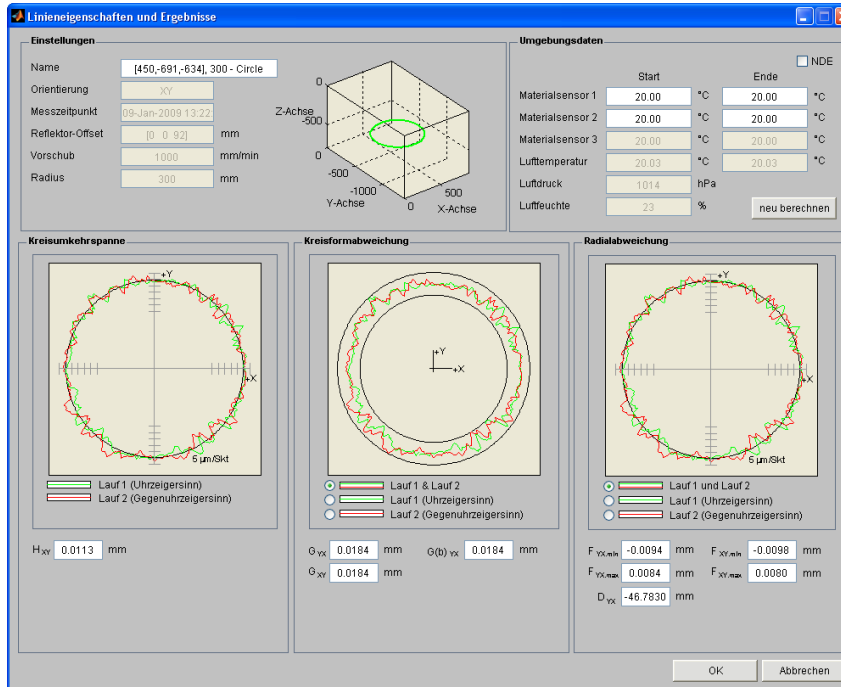


### Alle Messlinien

	E0	EL	R	
Anzahl der gemessenen Linien:	4	---	4	Spezifikation E0: 1.2 µm + 2.6 µm/m, <= 3.0 µm
Anzahl der gemessenen Längen:	20	---	20	
Messungen je Länge:	3	---	3	
Ü-Faktor:	0.29	---	0.28	Spezifikation EL: 1.8 µm + 2.8 µm/m, <= 3.5 µm
Bedingung ISO 10360-2 erfüllt:	nein	---	nein	
Außerhalb der Spezifikation:	0 (0%)	---	0 (0%)	
Innerhalb der Spezifikation:	60 (100%)	---	20 (100%)	Spezifikation R: 1.0 µm
Nicht eindeutig:	0 (0%)	---	0 (0%)	



# New: Circular test



## Following the ISO 230-4:

- ▷ Bi-directional deviation
- ▷ Circular deviation
- ▷ Radial deviation
- ▷ ...

## Solely based on interferometric measurements of the LaserTRACER

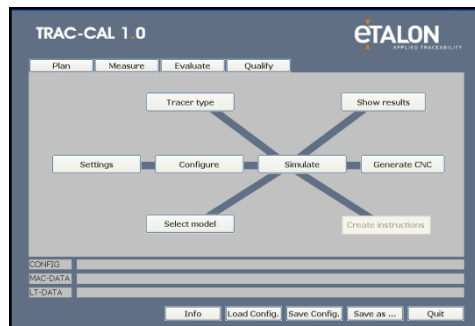
- ▷ No additional hardware necessary
- ▷ Very high accuracy
- ▷ Easy use
- ▷ Up to a radius of 12 m

## Summary Machine Testing with TRAC-CHECK

- ▷ Highest accuracy
- ▷ Semi-automated execution
- ▷ No alignment of interferometer required
- ▷ Application for machines of almost any size
- ▷ Fast execution: Full geometry test in 30 minutes
- ▷ Complete report function satisfying highest traceability demands
- ▷ For CMMs: In accordance with latest revision of ISO 10360-2
- ▷ For Machine Tools: Testing according to ISO 230-2, -4 and 6

# The ETALON solution

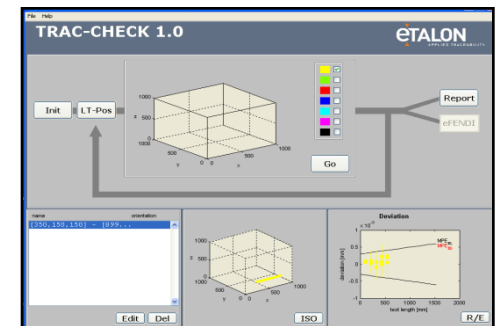
## TRAC-CAL<sup>®</sup>



## LaserTRACER



## TRAC-CHECK<sup>®</sup>



Error mapping and  
compensation

Testing and qualification

# ETALON's customers

(over 40 systems sold in Europe, Asia, North America and South America)

## ▶ Customers in the branch of Coordinate Measuring:

- Carl Zeiss IMT GmbH / Germany
- OGP (Optical Gaging Products INC.) / USA
- Volkswagen AG / Germany
- PTB (Physikalisch-Technische Bundesanstalt) / Germany
- NPL (National Physical Laboratory) / Great Britain
- INRIM (Istituto Nazionale di Ricerca Metrologica) / Italy
- INTI (Instituto Nacional de Tecnologia Industrial) / Argentina
- Fundação CERTI (Centros de Referência em Tecnologias Inovadoras) / Brazil
- SLAC National Accelerator Laboratory / USA
- Eumetron GmbH / Germany

## ▶ Customers in the branch of machine tool :

- Gebr. Heller Maschinenfabrik GmbH / Germany
- Deckel Maho Pfronten GmbH / Germany
- Dr. Johanners Heidenhain GmbH / Germany
- Röders TEC GmbH / Germany
- Bornemann Maschinenbau GmbH / Germany
- SMS Meer GmbH / Germany
- Fraunhofer Institute IPT, IPK, IWU / Germany
- Universität Darmstadt (PTW) / Germany
- University of Huddersfield / Great Britain
- Cracow University of Technology / Poland
- Busan Techno-Park / South Korea
- AfM Technology GmbH / Germany
- Sigma 3D GmbH / Germany
- HIT Automotive / South Korea
- YKT / Japan

## ETALONs distribution and service partner



## Further partners of ETALON

- ▶ Official partner companies for machine compensation



Solution Partner

Automation

SIEMENS

- ▶ Companies with cooperation for machine compensation



- ▶ System-partner for the testing of large machines



- ▶ Partner for measuring service



Visit us at



[www.etalon-ag.com](http://www.etalon-ag.com)