

Interferometric measurement of the long-term stability of joining techniques: sample preparation

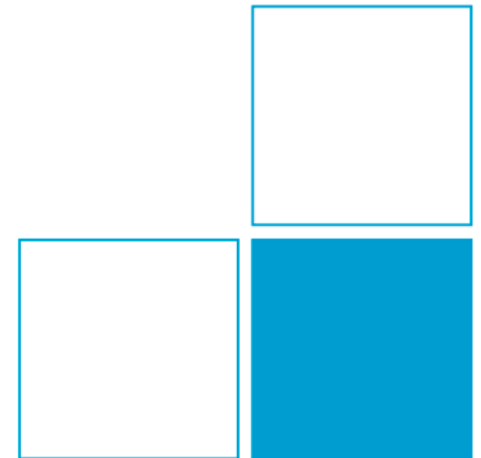
EMRP
European Metrology Research Programme
► Programme of EURAMET

IND13 – T3D workshop: *Thermal Design & Dimensional Drift Issues*

14th euspen conference, Dubrovnik

6th June 2014

Hagen Lorenz, René Schödel



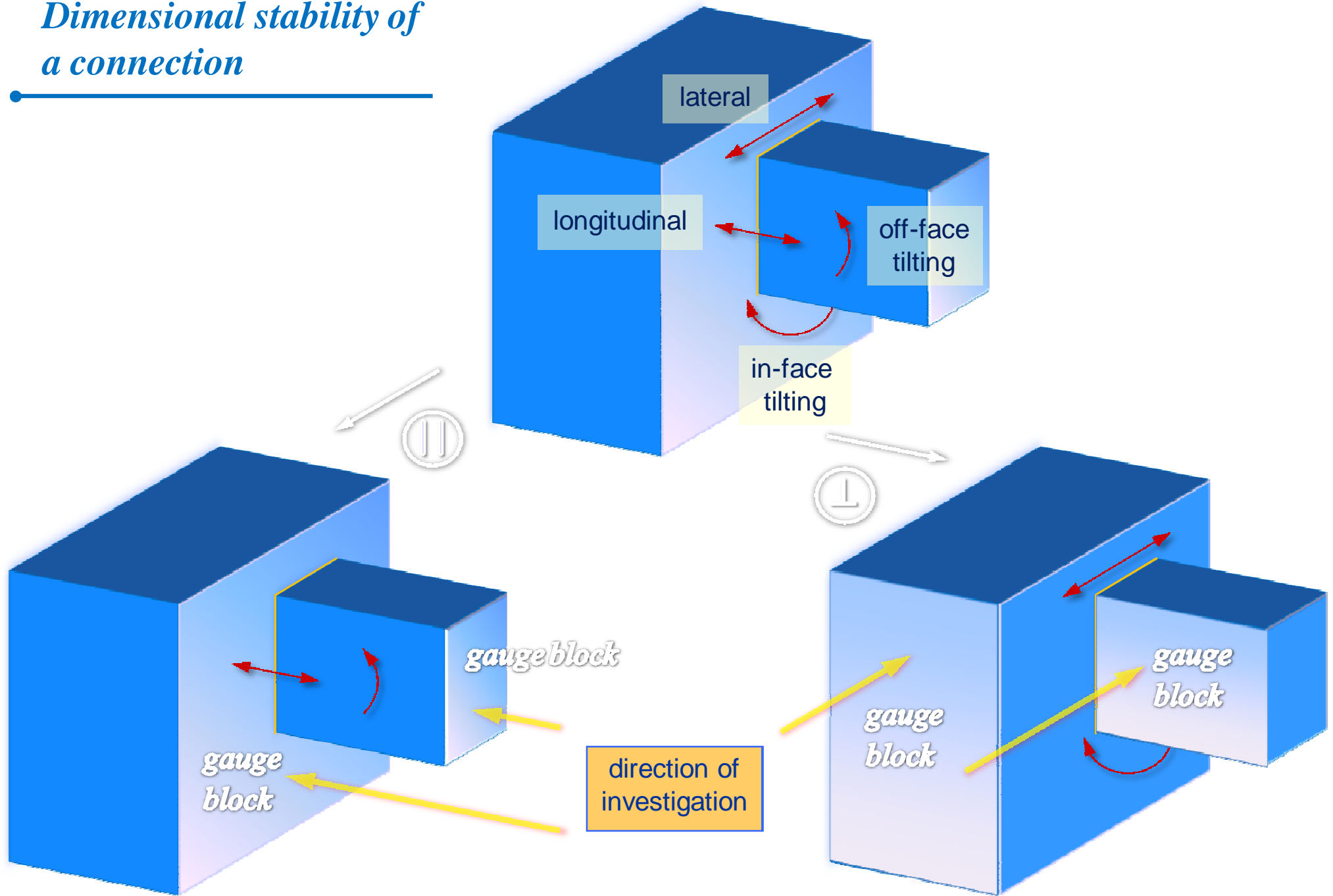
*Thermal **D**esign and time-dependent **D**imensional **D**rift behaviour of sensors, materials and structures*

Time and temperature dependence of materials & joints

Overview

- ❖ Dimensional & thermal stability
 - Wrung gauge blocks
 - Soldered, Bonded connections, *Fraunhofer IOF*
 - Screwed connections
 - Adhesive connections: spacers

Dimensional stability of a connection

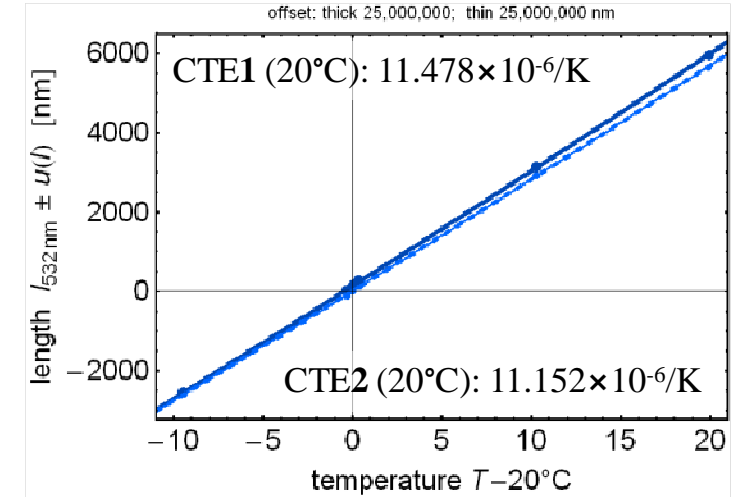


Thermal stability of steel gauge blocks

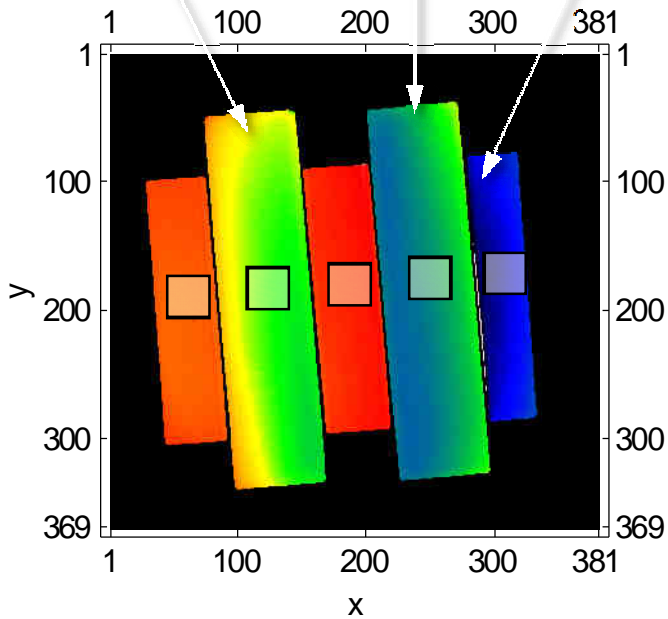
2x2
gauge blocks
à 12.5 mm



2x
thermocouples



wrung GB2, wrung GB1, platen



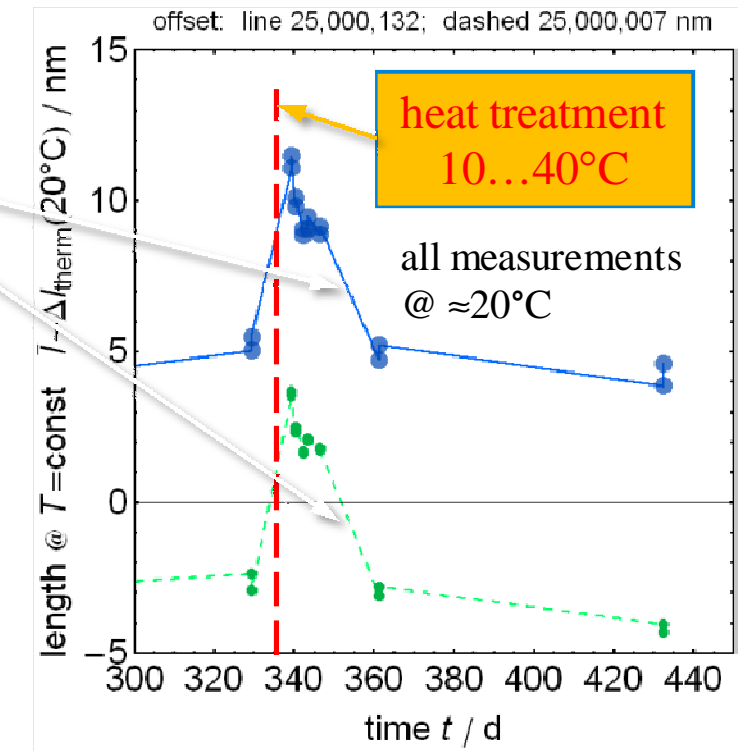
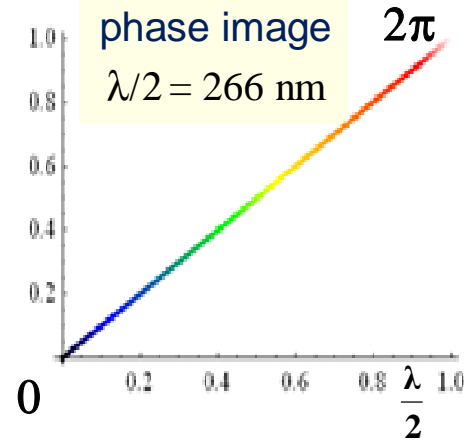
average drift rate

$$\dot{l}/l \approx -10^{-8} / d$$

phase image

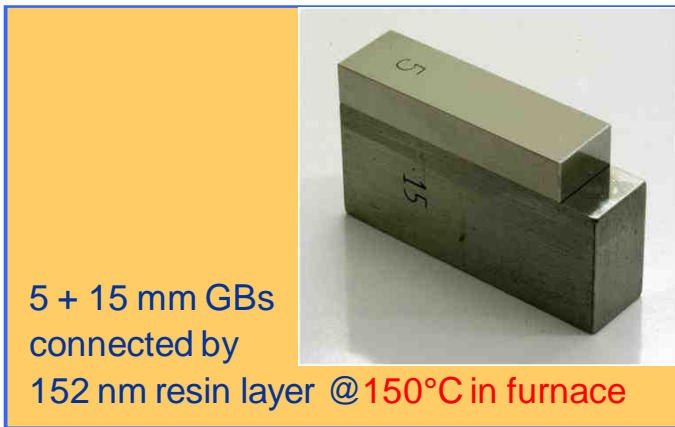
$$\lambda/2 = 266 \text{ nm}$$

2π



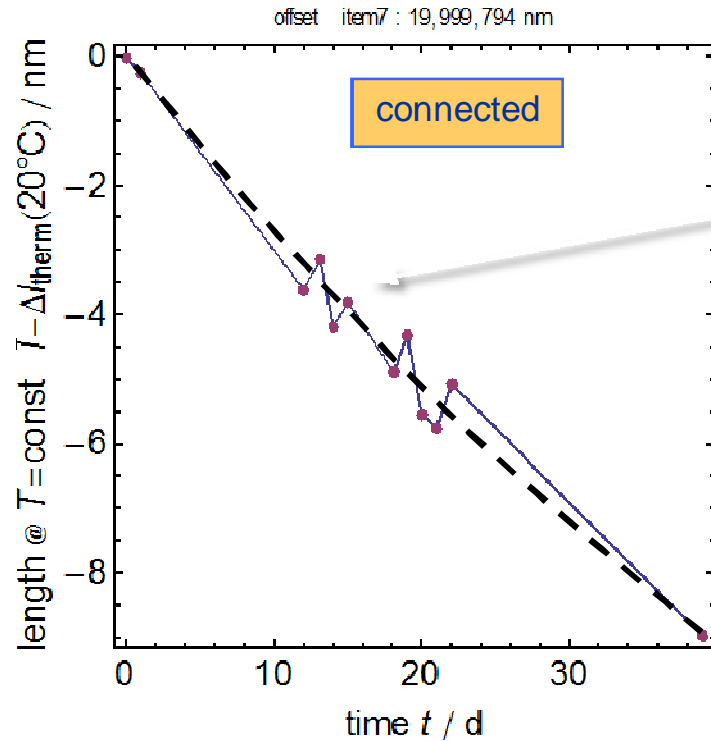
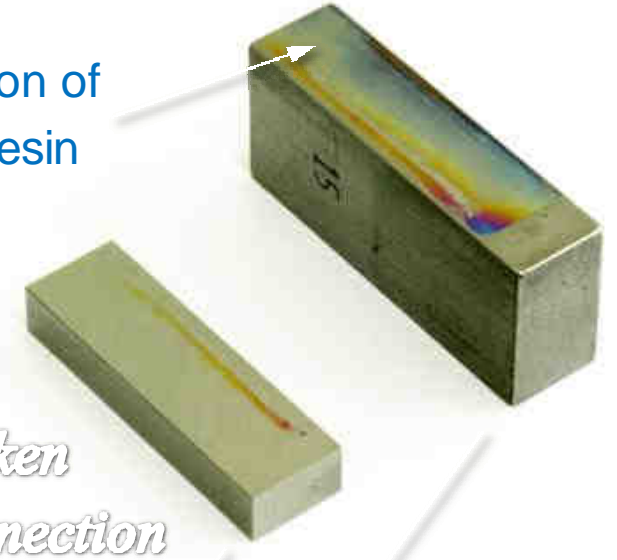
Thermal stability of steel gauge blocks

thermally induced dimensional drift



CTE: $11.84 \cdot 10^{-6} / \text{K}$

dilute solution of
synthetic resin

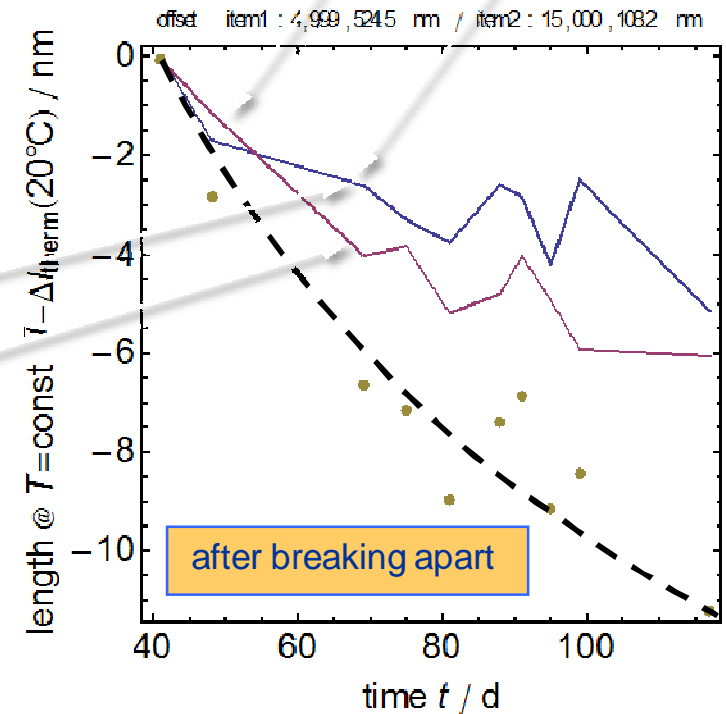


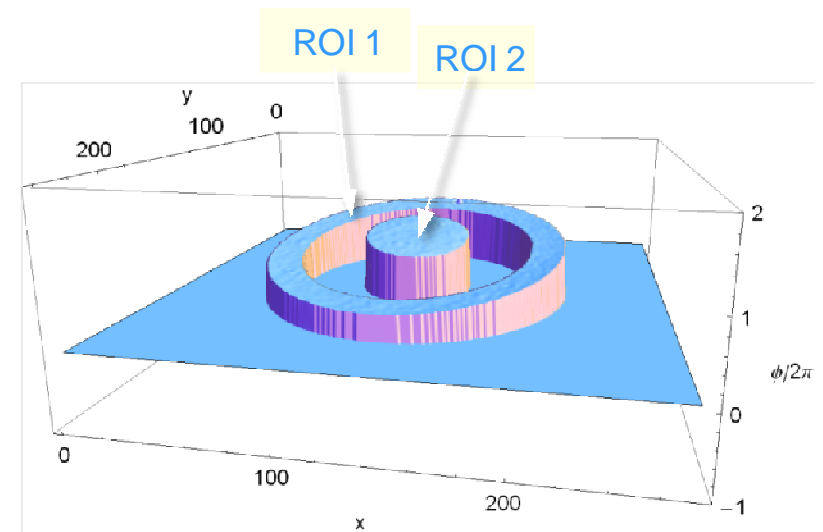
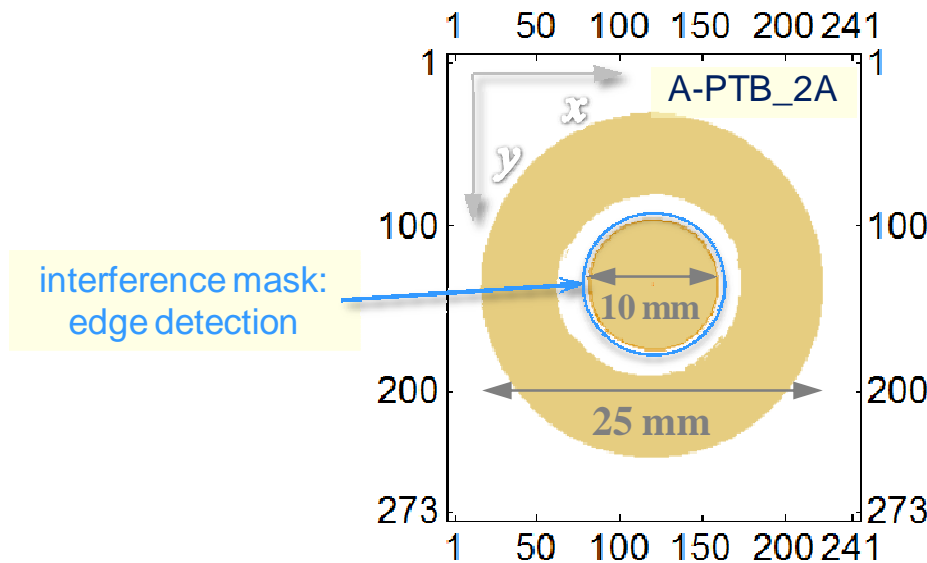
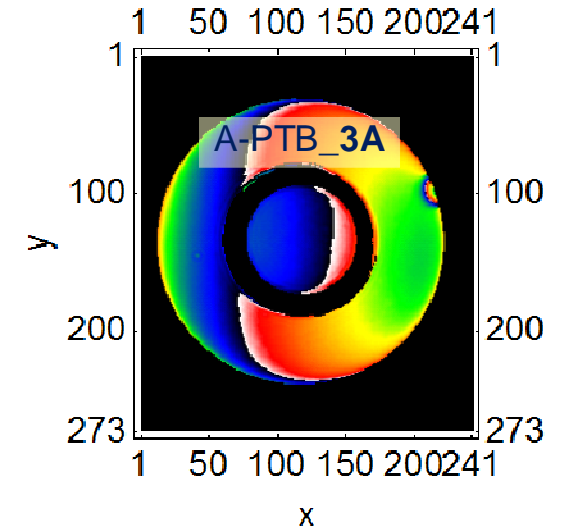
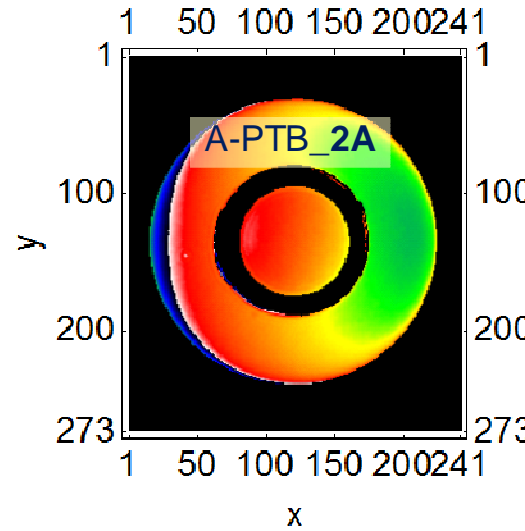
drift rate i/l

$$\approx -1.0 \cdot 10^{-8} / \text{d}$$

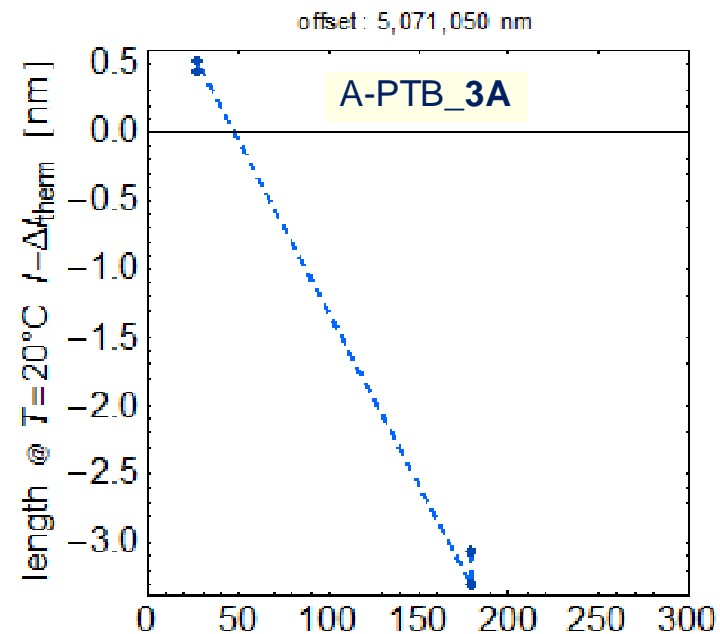
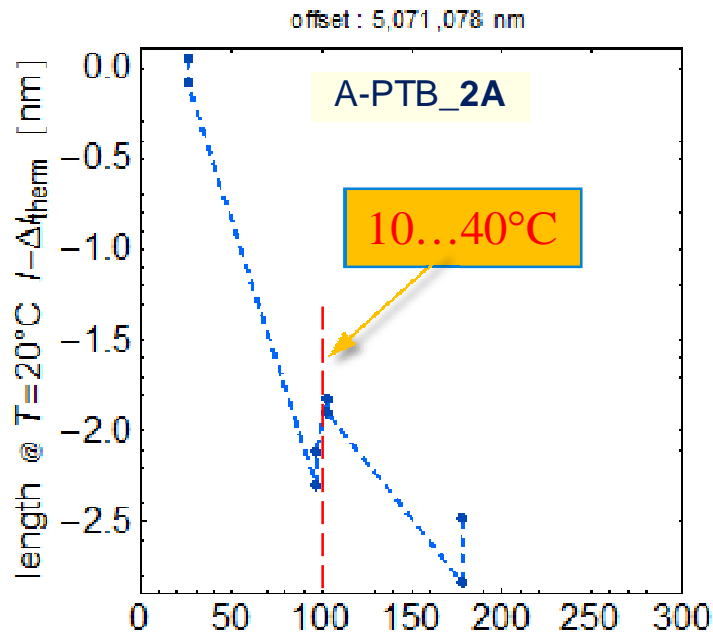
$$\approx -0.5 \cdot 10^{-8} / \text{d}$$

$$\approx -1.5 \cdot 10^{-8} / \text{d}$$





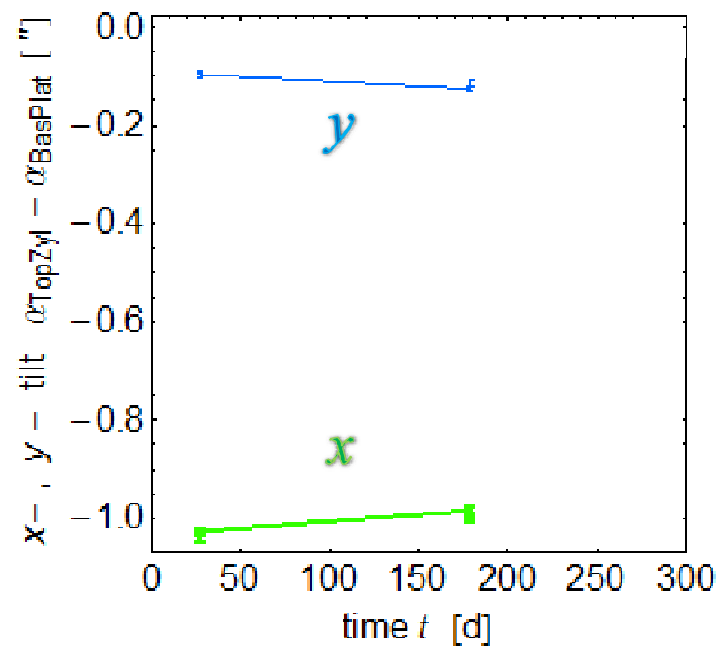
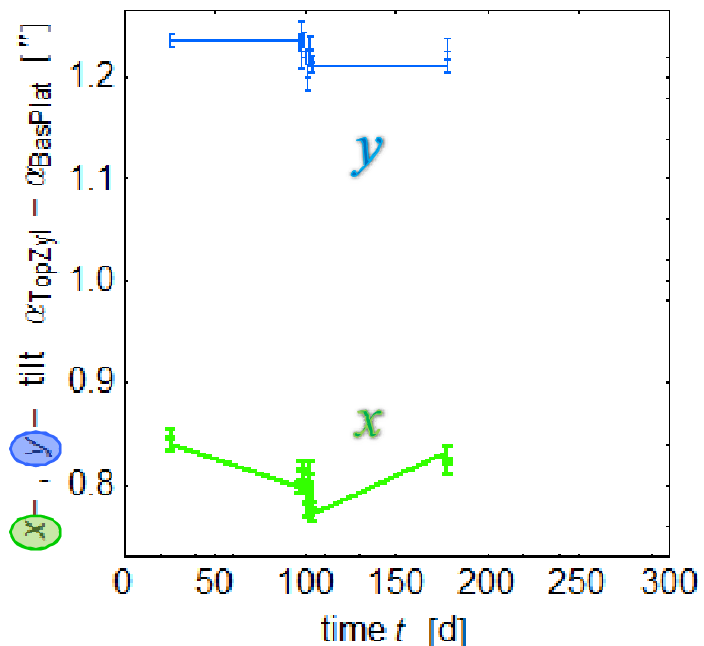
Fraunhofer IOF Silicatic Bonding || fused silica - cylinders



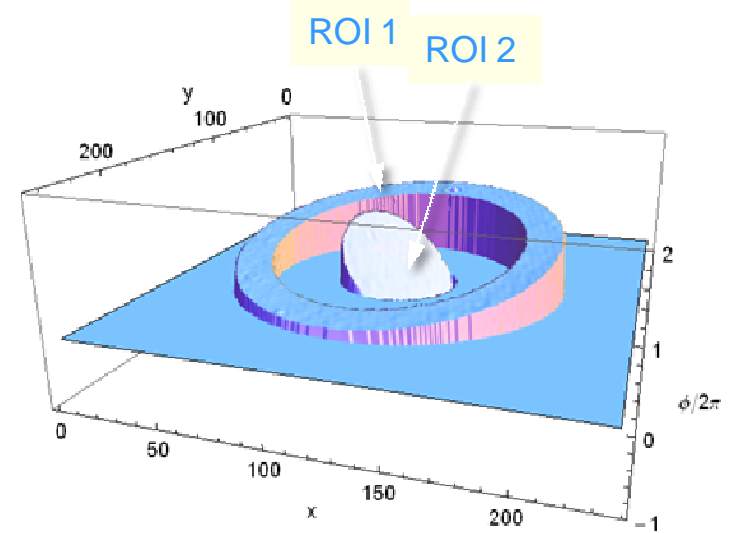
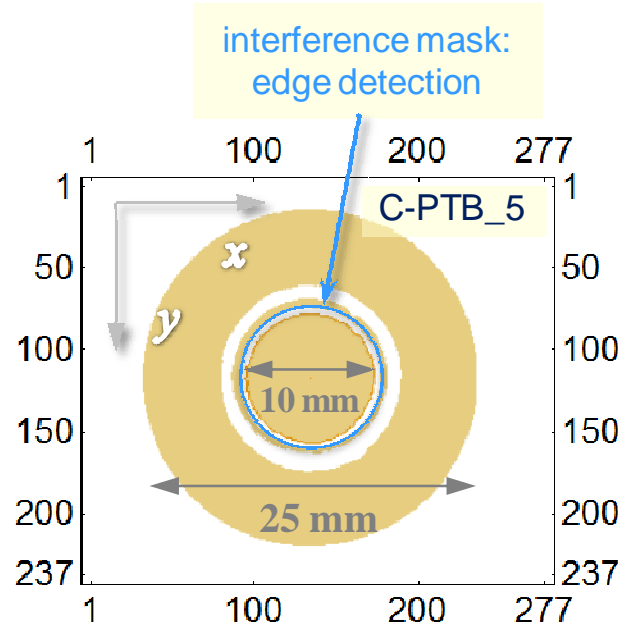
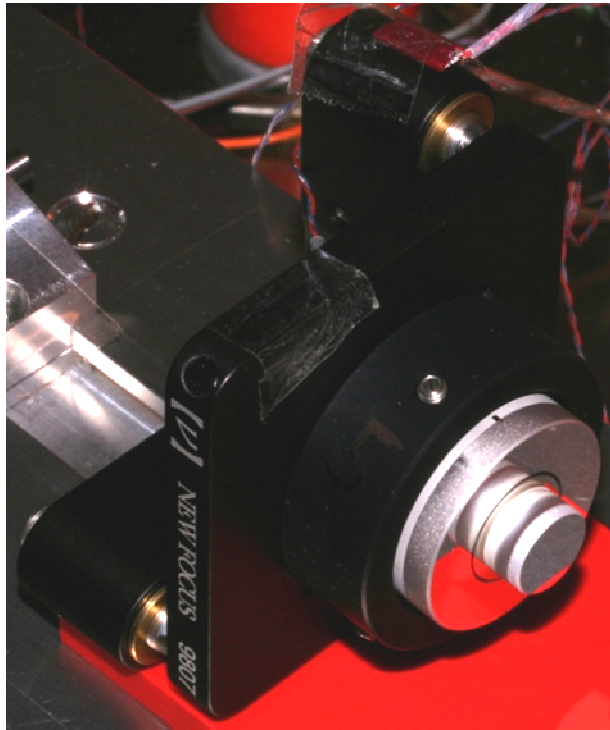
CTE: $4.7 \times 10^{-7} / \text{K}$

$\Delta l \approx -3 \text{ nm}$

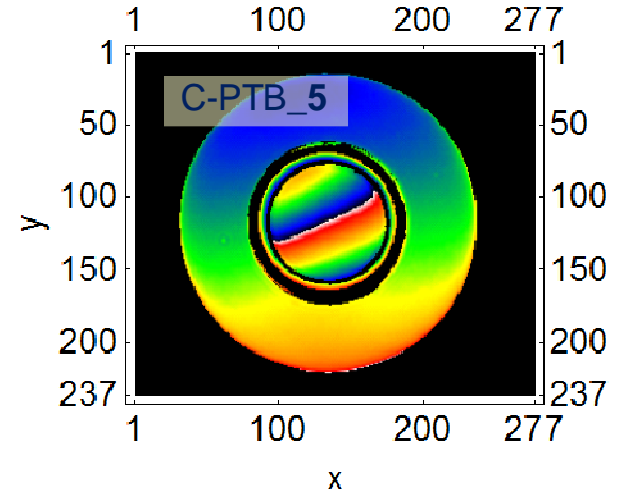
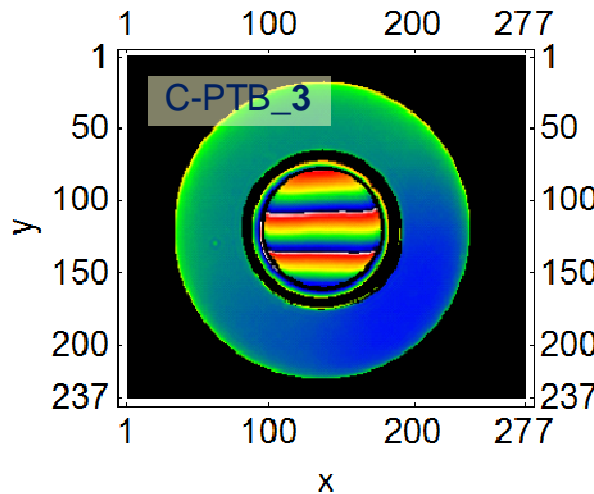
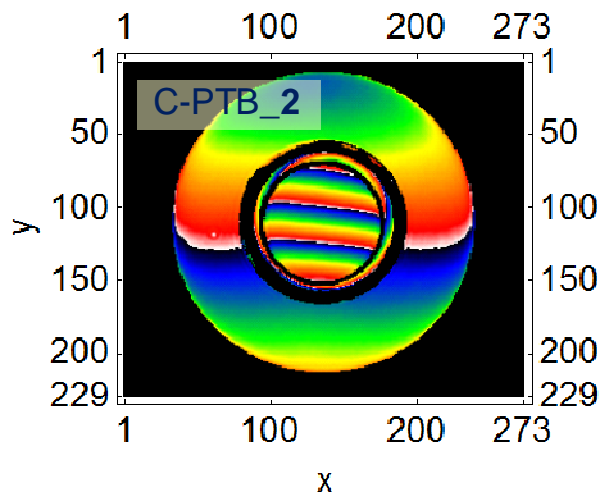
$|\Delta \alpha| < 0.1''$



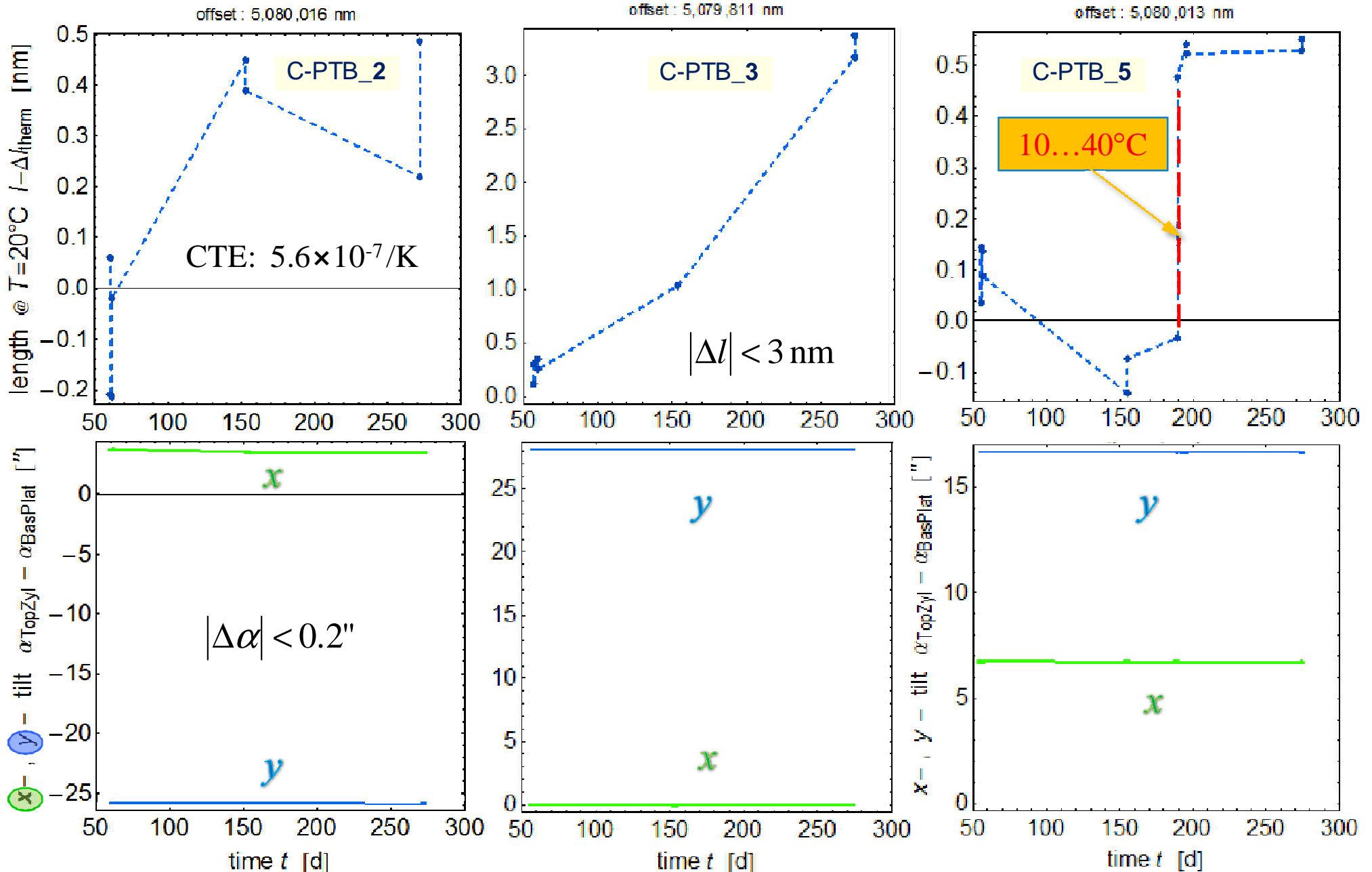
Fraunhofer IOF Au/Sn thin-film soldering || fused silica - cylinders

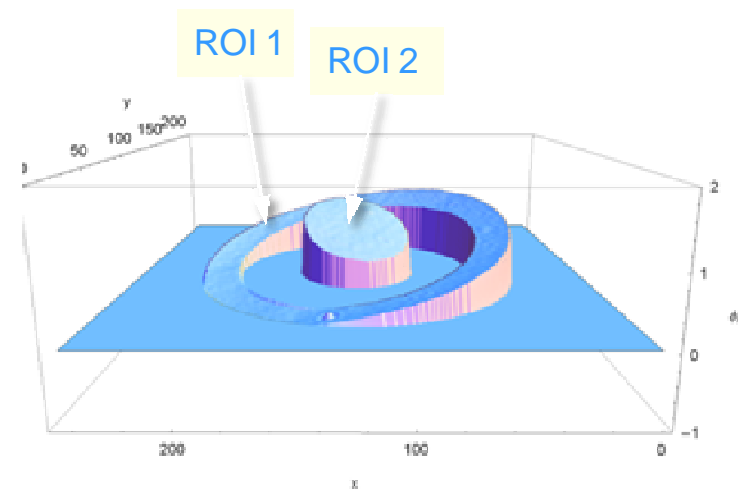
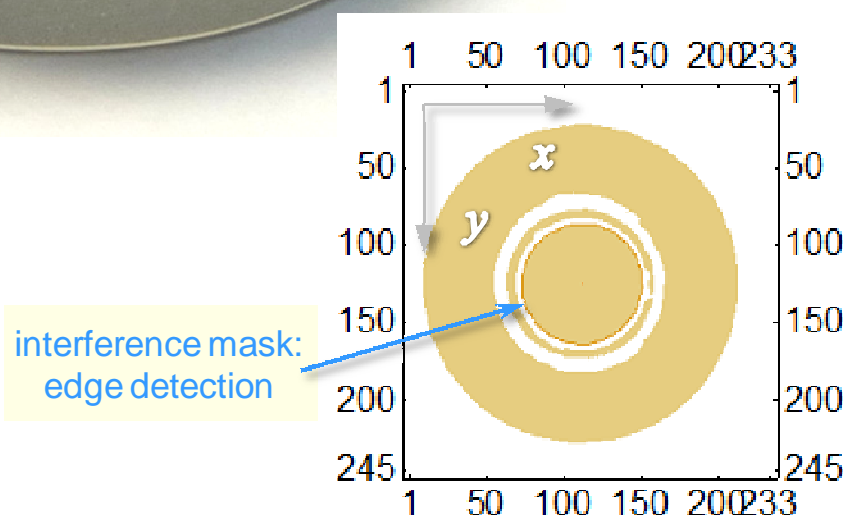
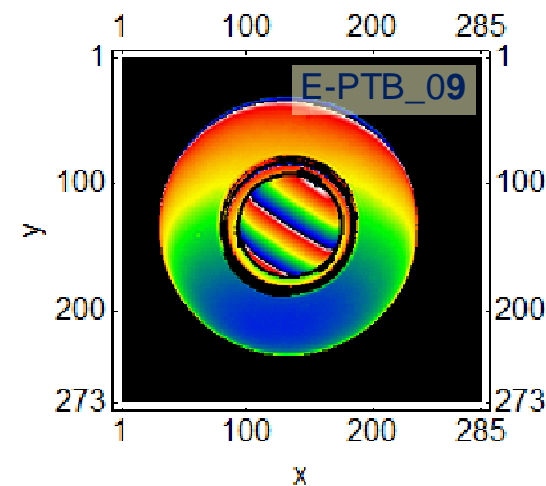
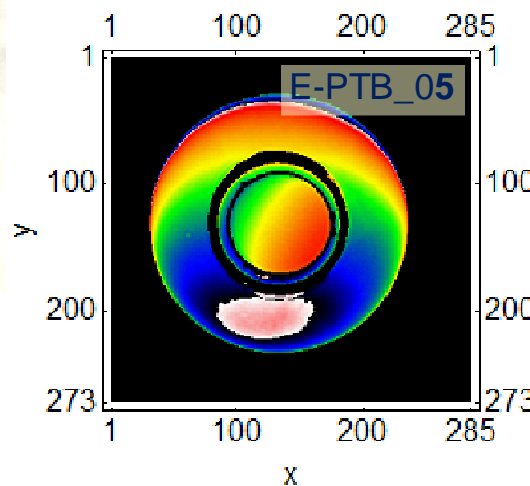
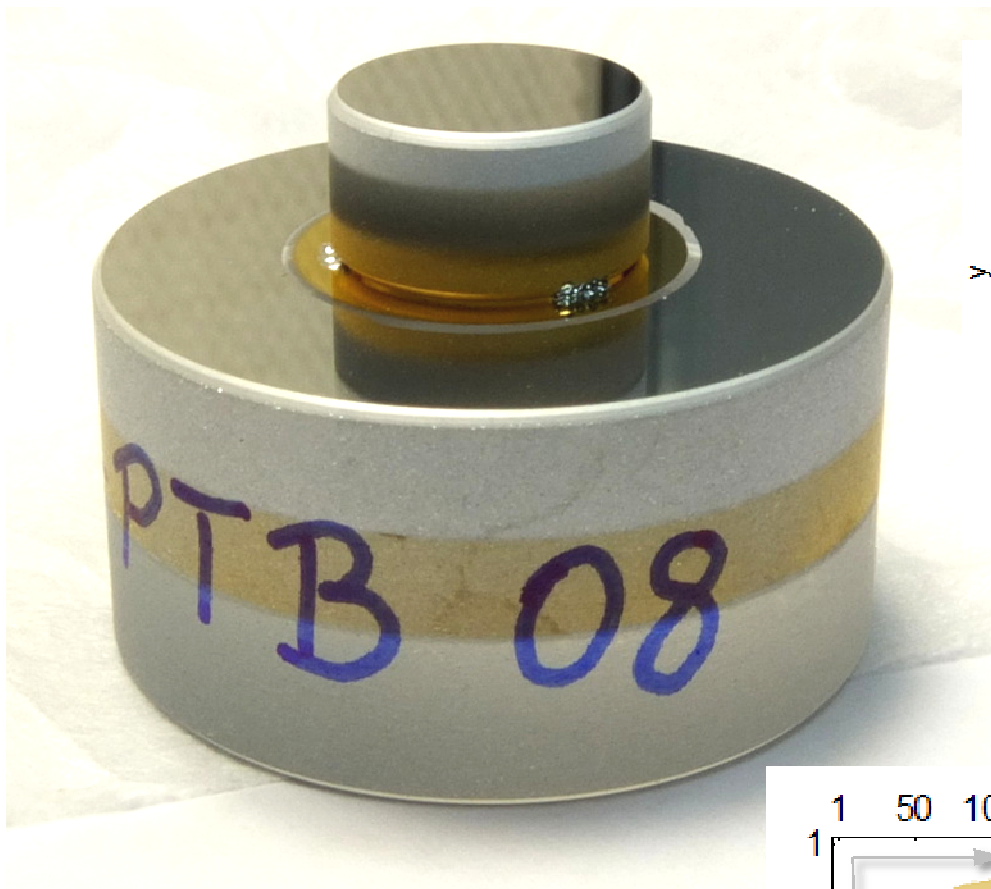


phase images, $\lambda/2 = 266 \text{ nm}$

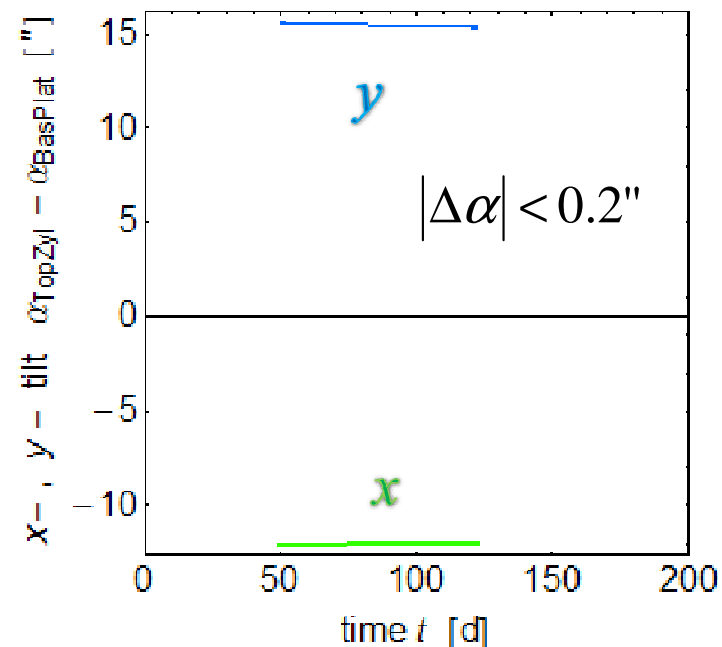
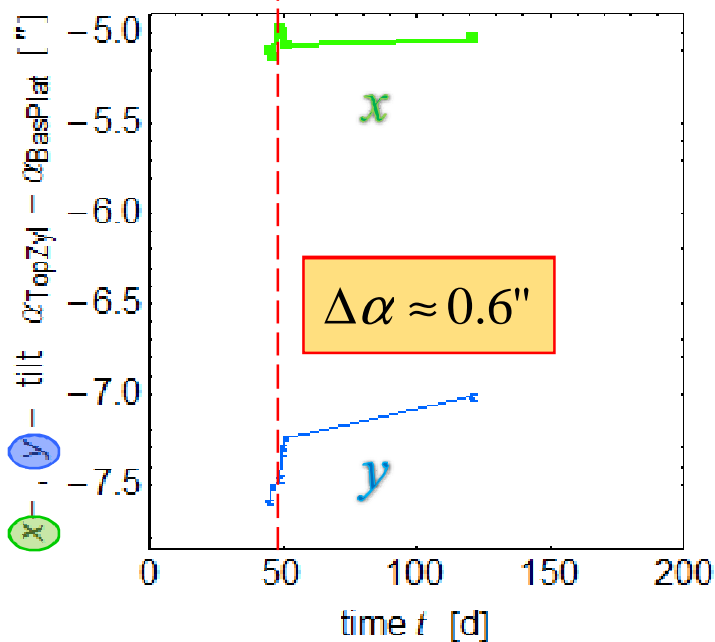
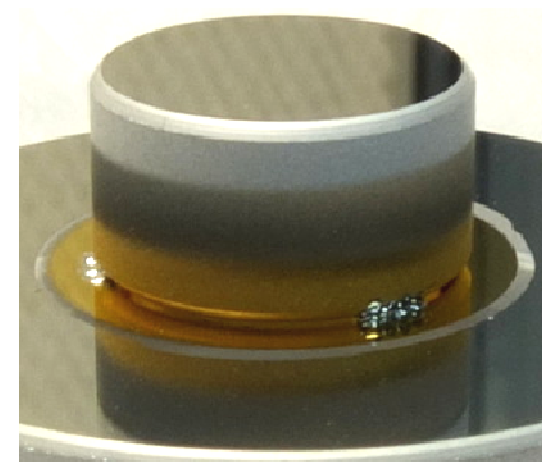
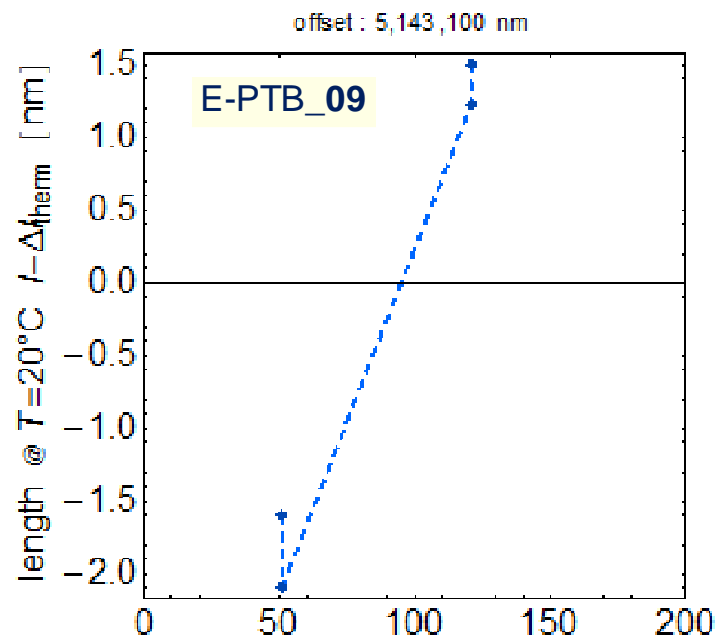
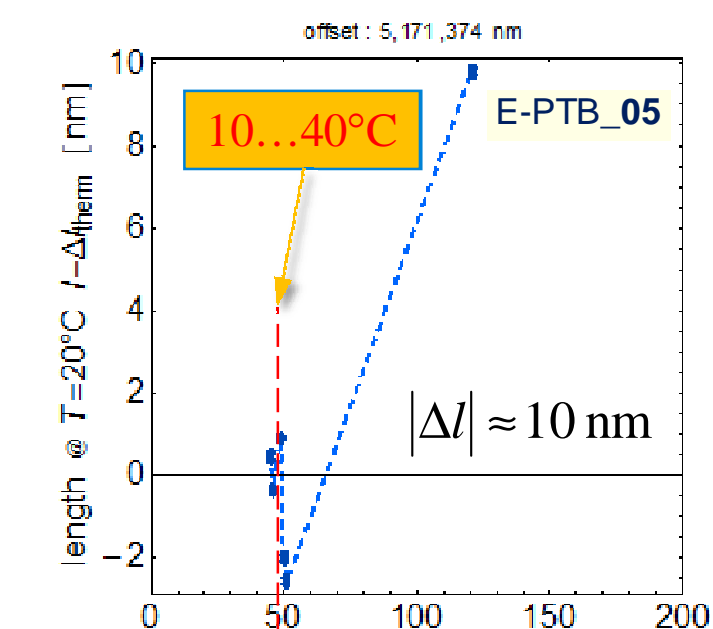


Fraunhofer IOF Au/Sn thin-film soldering || fused silica - cylinders



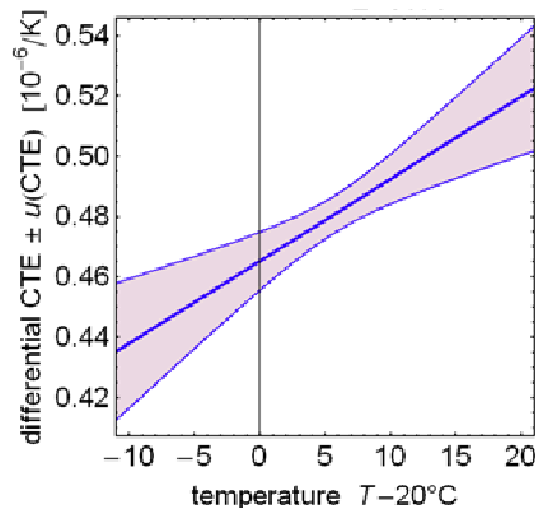
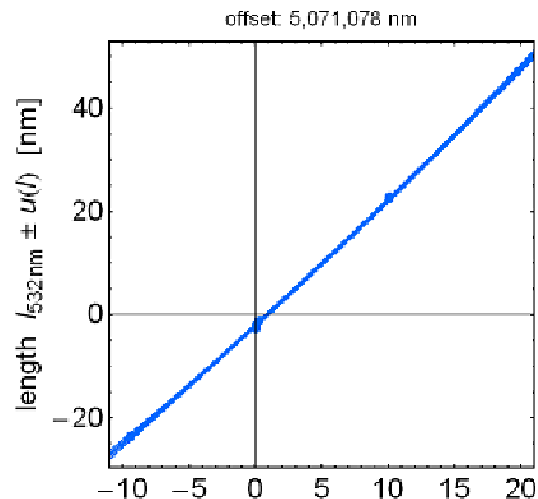


Fraunhofer IOF Sn/Ag/Cu Solderjet Bumping || fused silica - cylinders



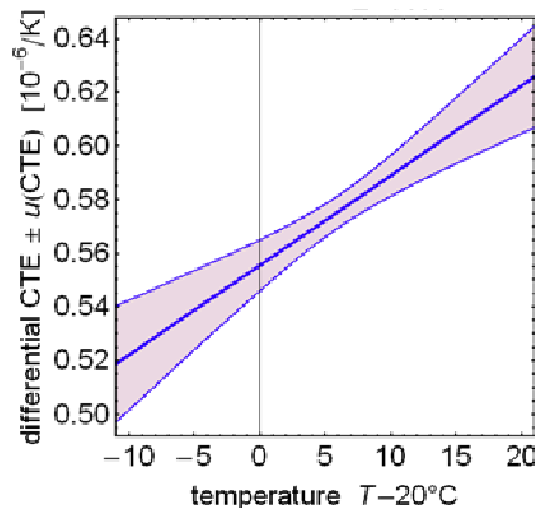
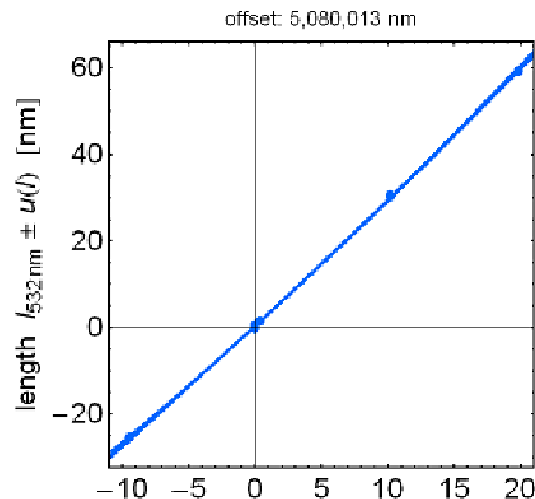
CTE: $1.49 \times 10^{-6}/\text{K}$

Silicatic Bonding



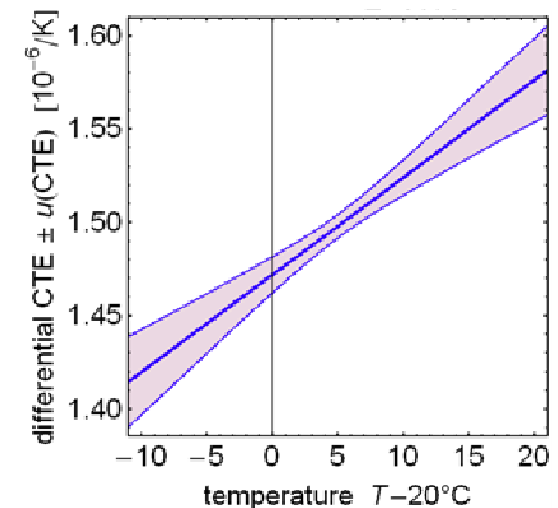
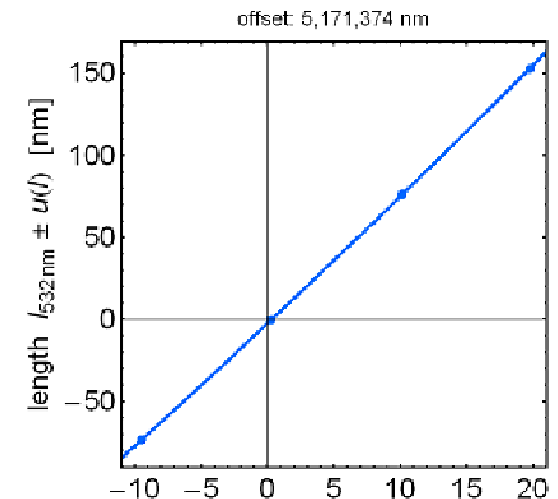
CTE(20°C): $0.47 \times 10^{-6}/K$

AuSn Thin-Film Soldering



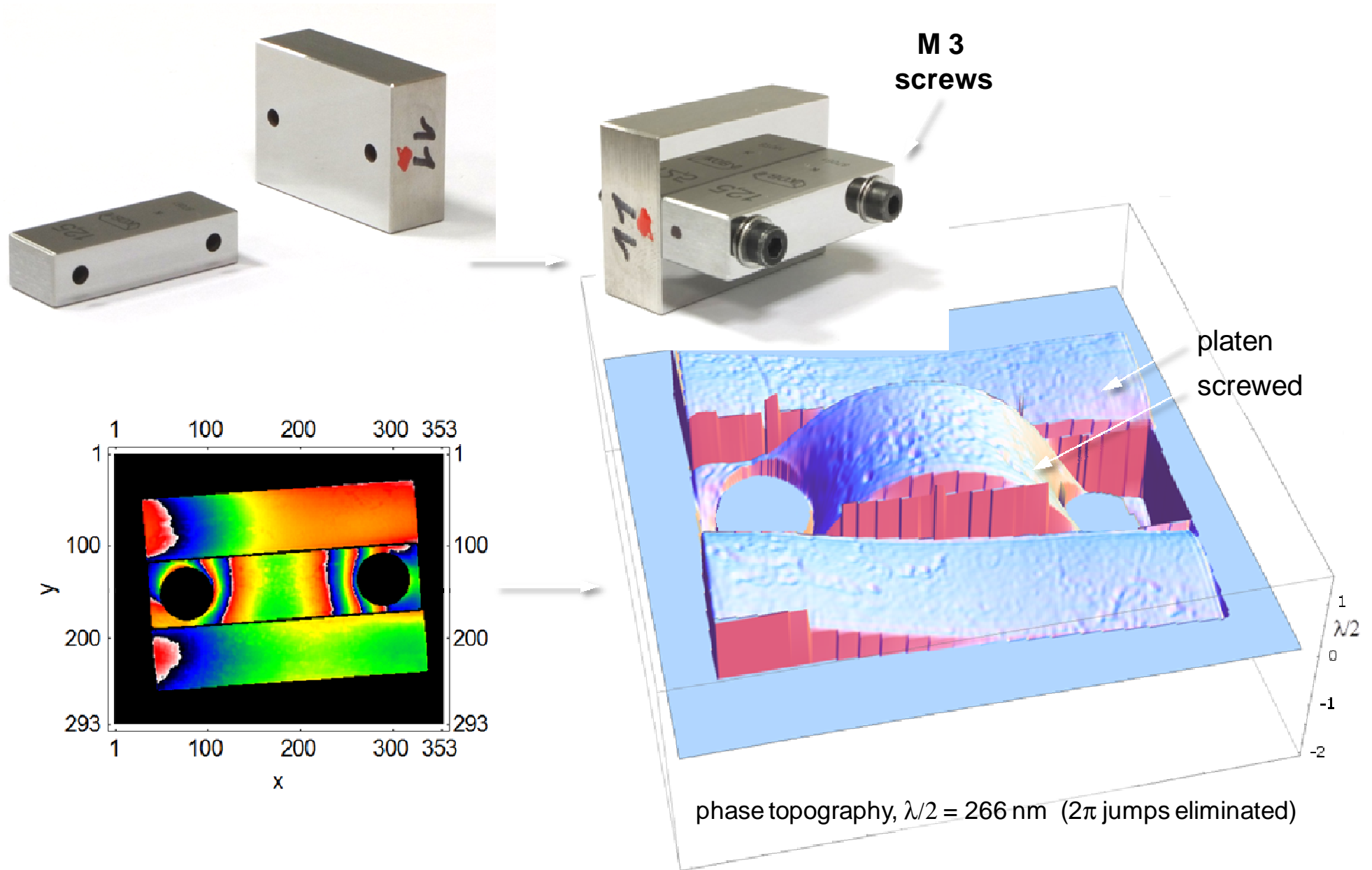
CTE(20°C): $0.56 \times 10^{-6}/K$

SnAgCu Solderjet Bumping



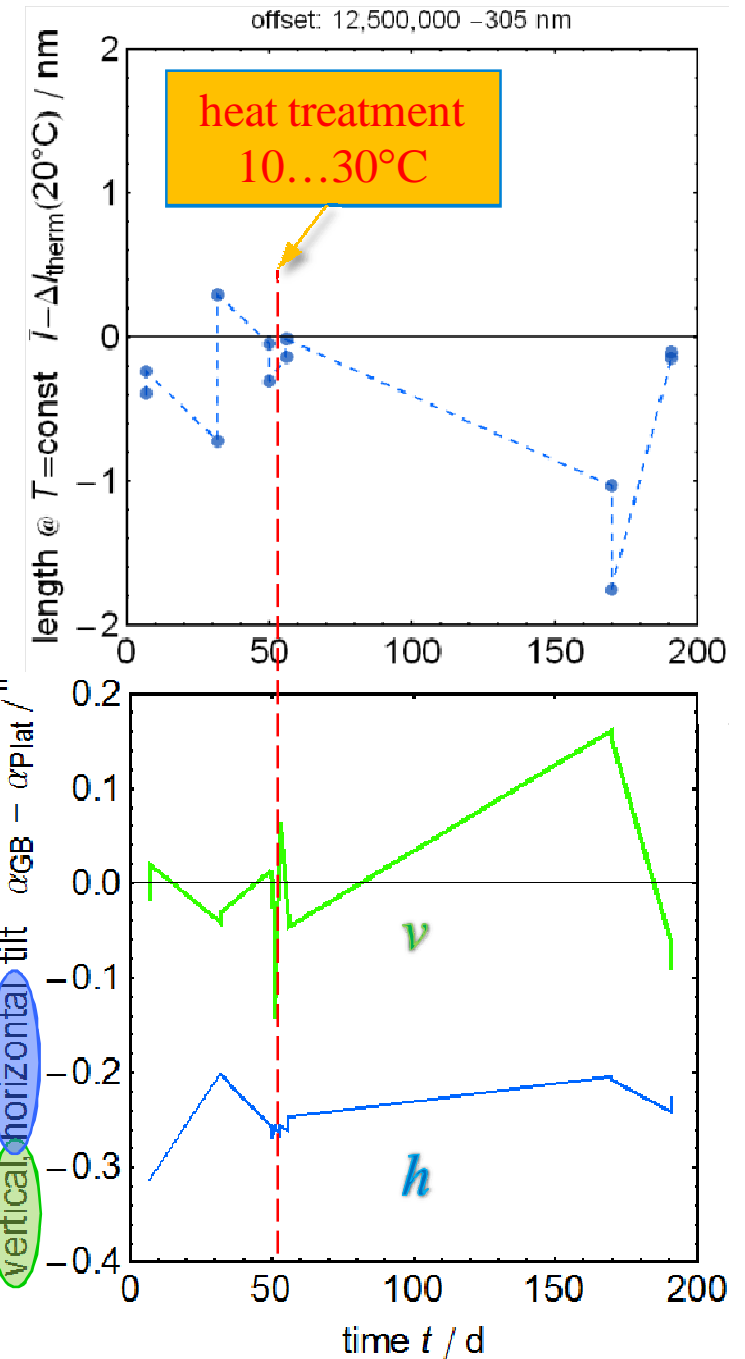
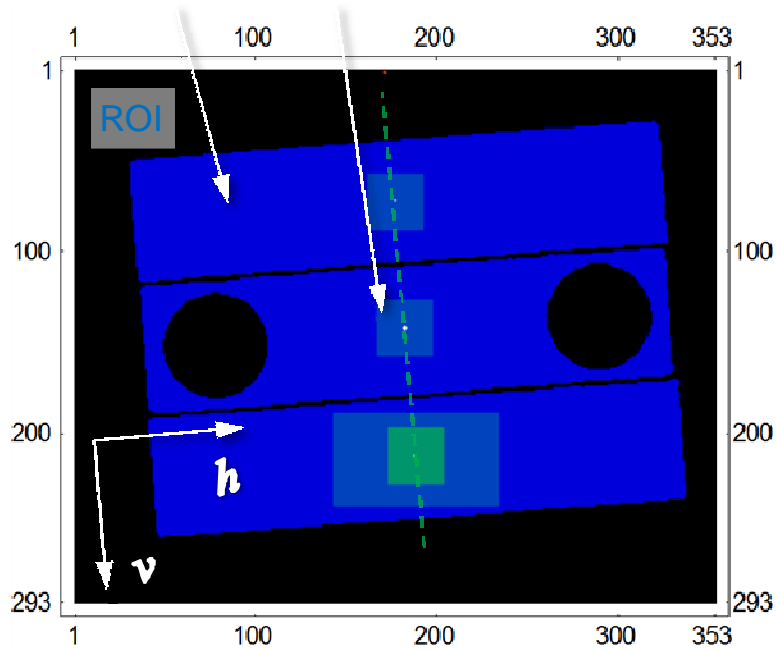
CTE(20°C): $1.47 \times 10^{-6}/K$

Screwed connection (|| to ends)

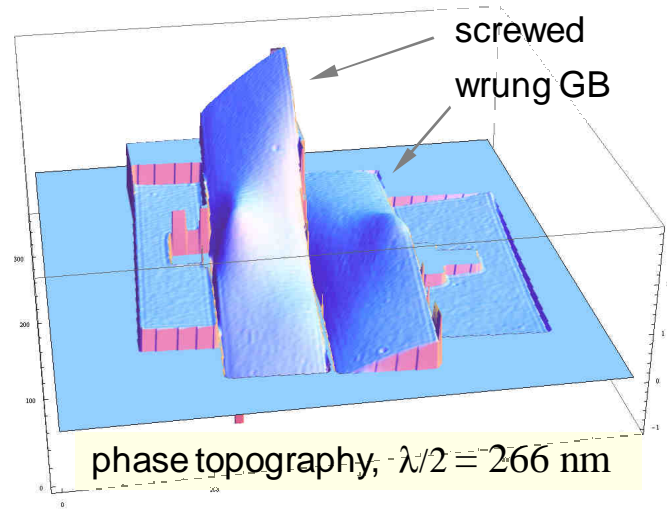
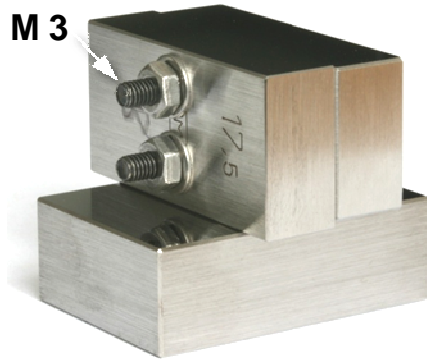


Screwed connection (|| to ends)

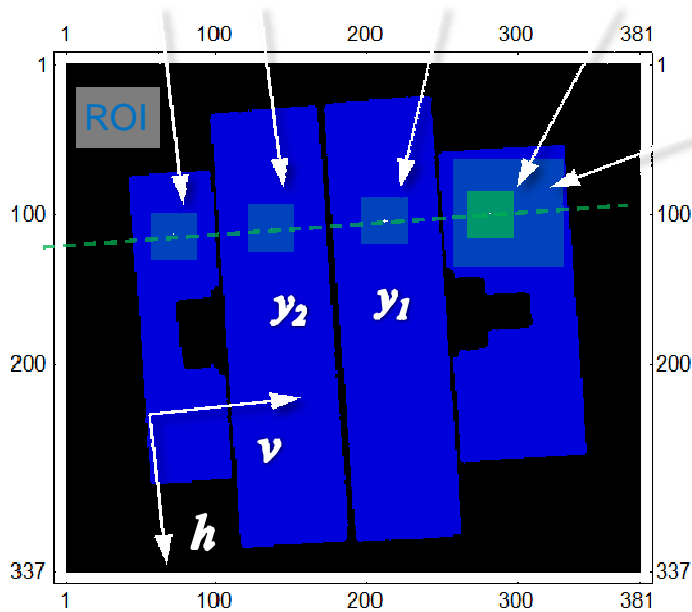
interference mask with ROIs:
 platen, screwed GB, platen



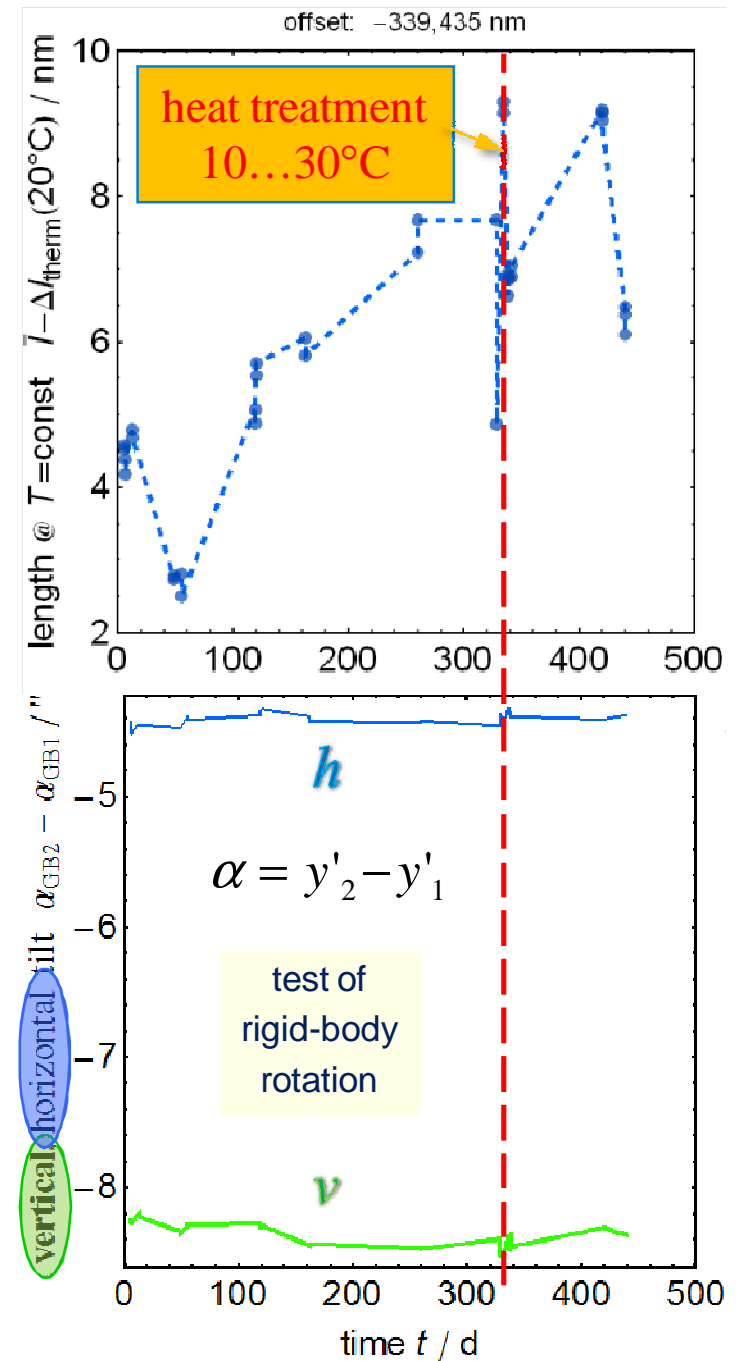
Screwed connection (⊥ to ends)



interference mask with ROIs:
 platen, screwed GB, wrung GB, platen

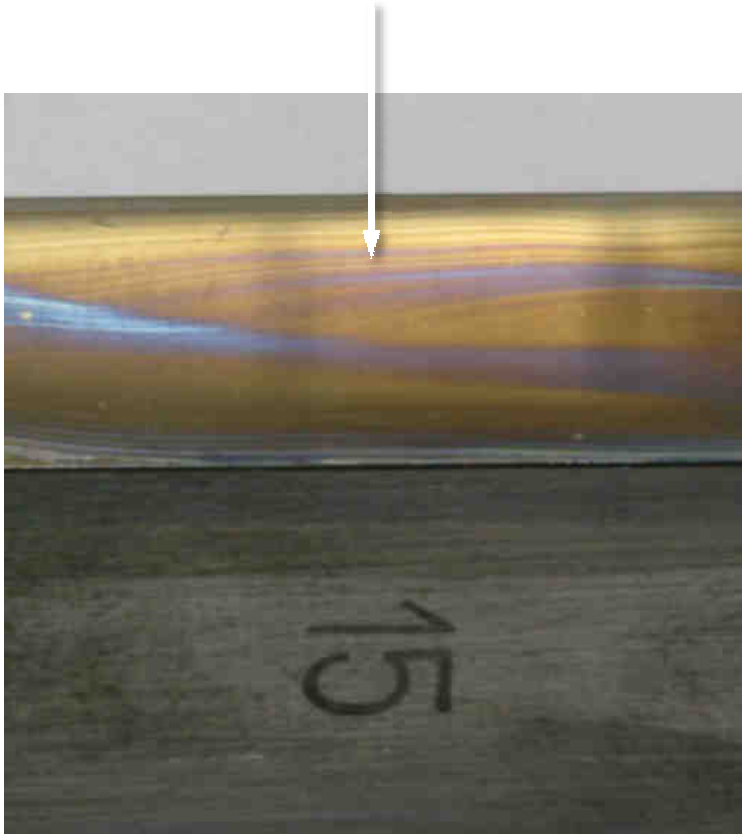


big ROI platen
 $\rightarrow y' = \frac{\partial y}{\partial v}$



Adhesive connection || silicon gauge blocks

2 gauge blocks á 15 mm
+
dilute solution of synthetic resin



resin layer

melting @ 150°C

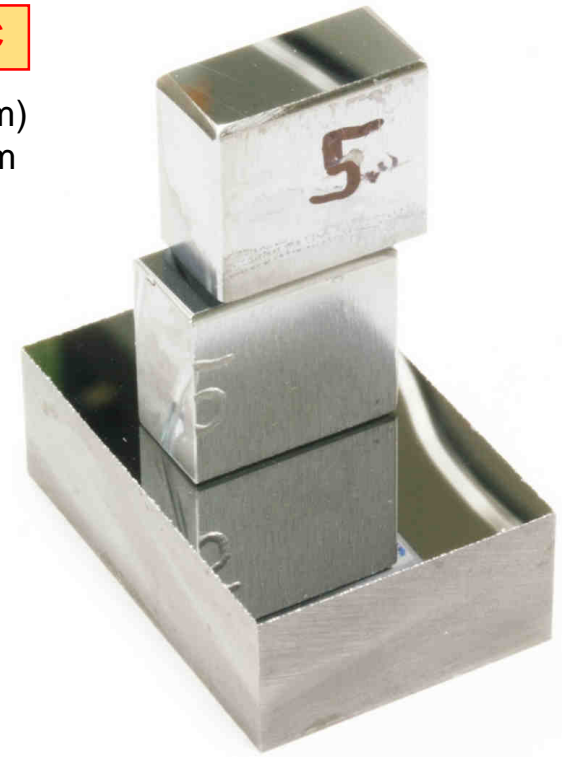
$d < 1 \mu\text{m}$

before furnace 150°C

gauge blocks: 2 x (15 mm + 47.1 μm)
= 30 094 200 \pm 1000 nm

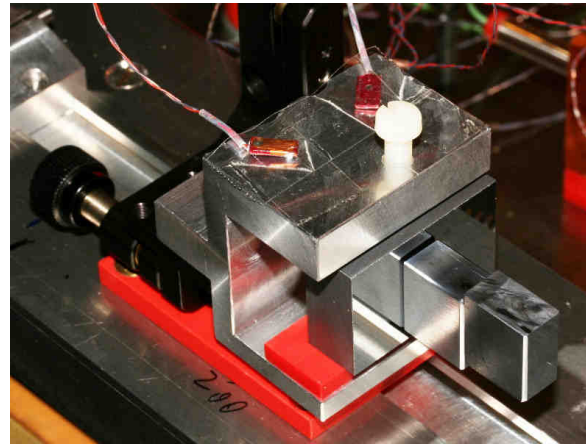
in interferometer

joint length: 30 094 110 nm

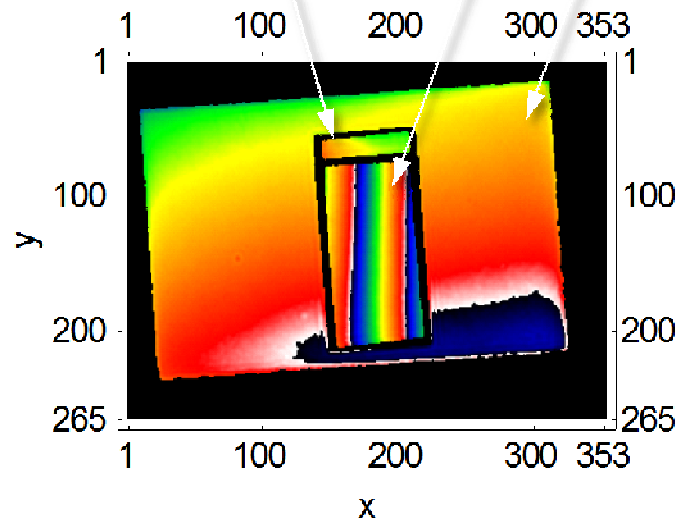


Adhesive connection || silicon gauge blocks

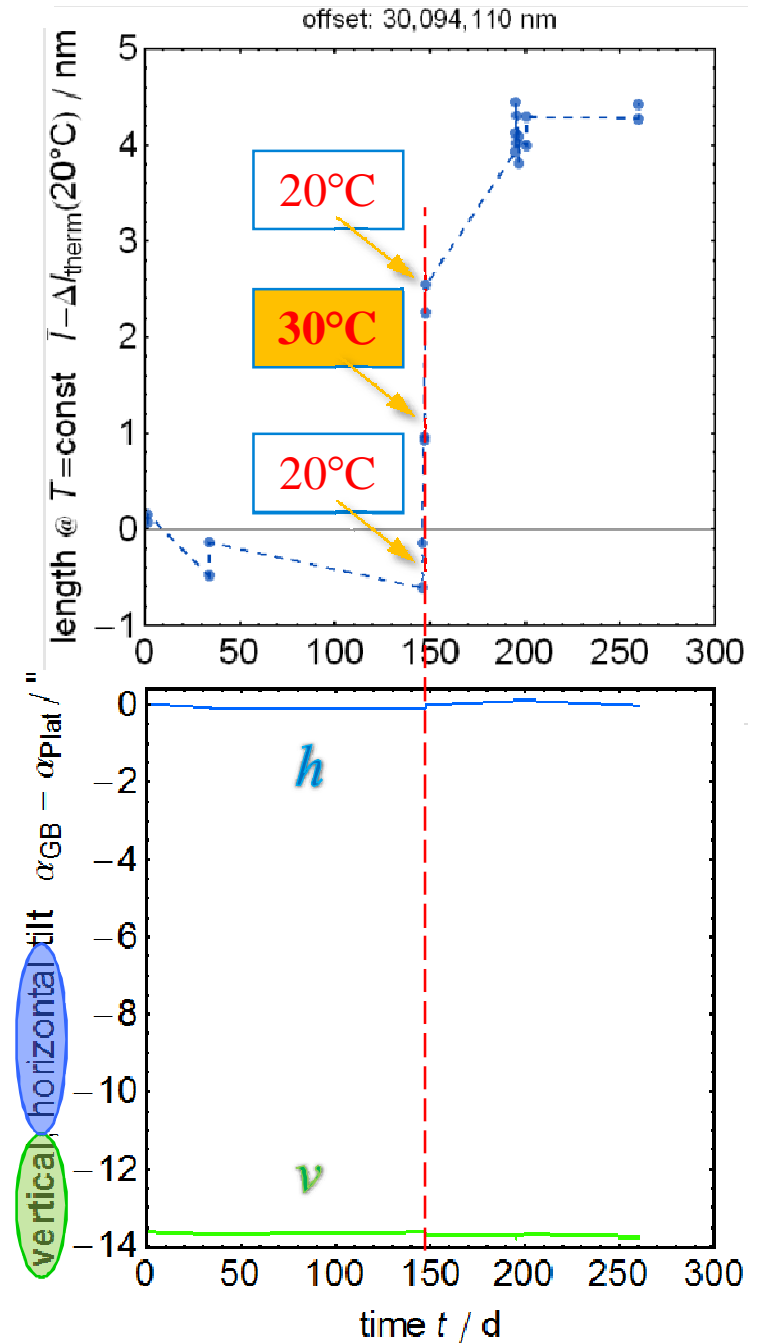
2 gauge blocks á 15 mm
 +
 synthetic resin layer
 $d < 1 \mu\text{m}$



wrung GB, glued GB, platen

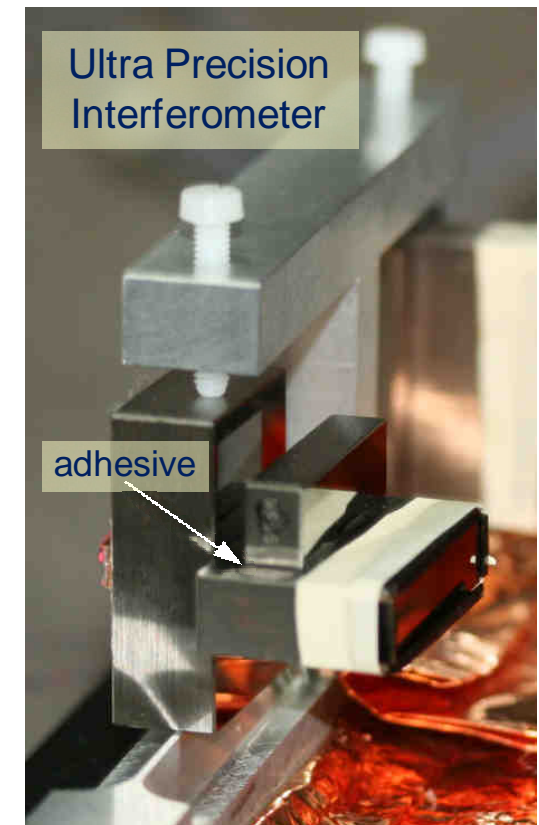
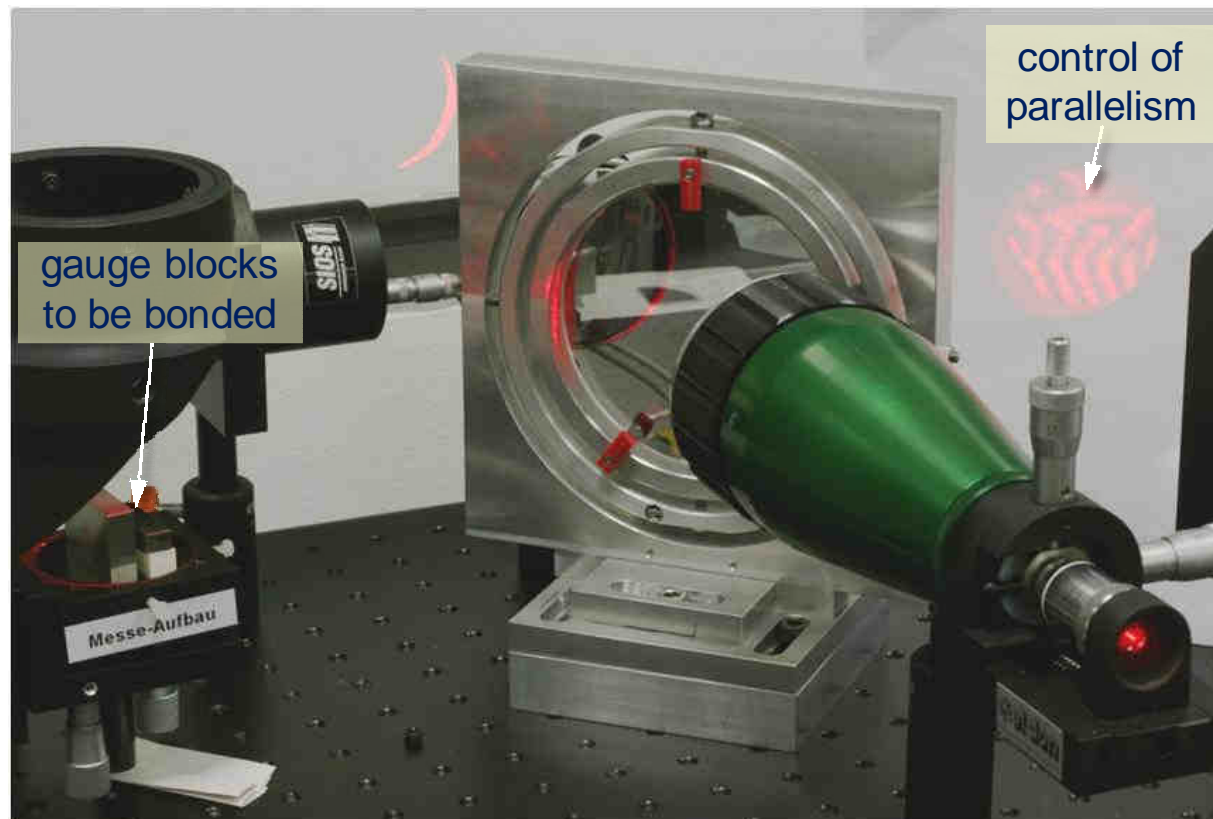


phase image, $\lambda/2 = 266 \text{ nm}$

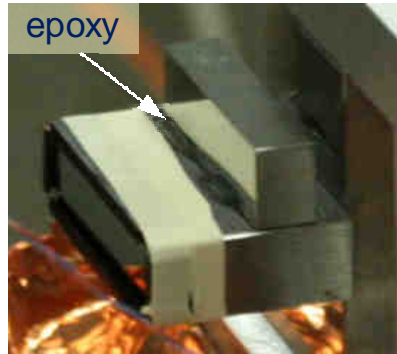
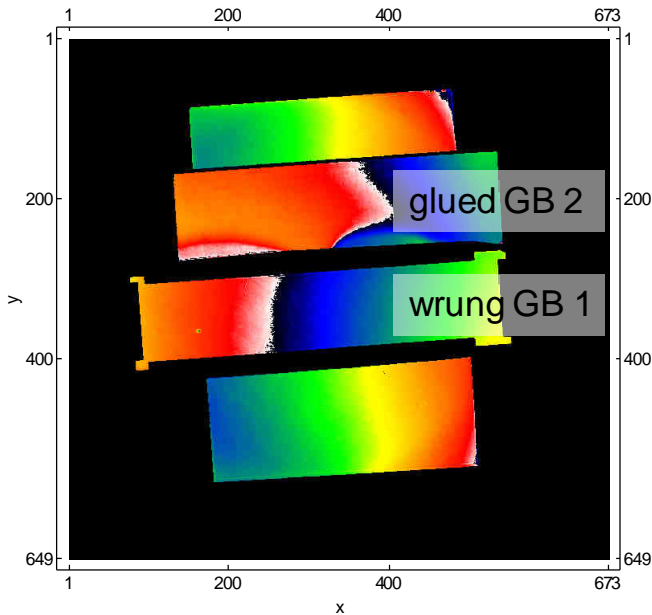


Techniques to produce connections with very parallel end faces

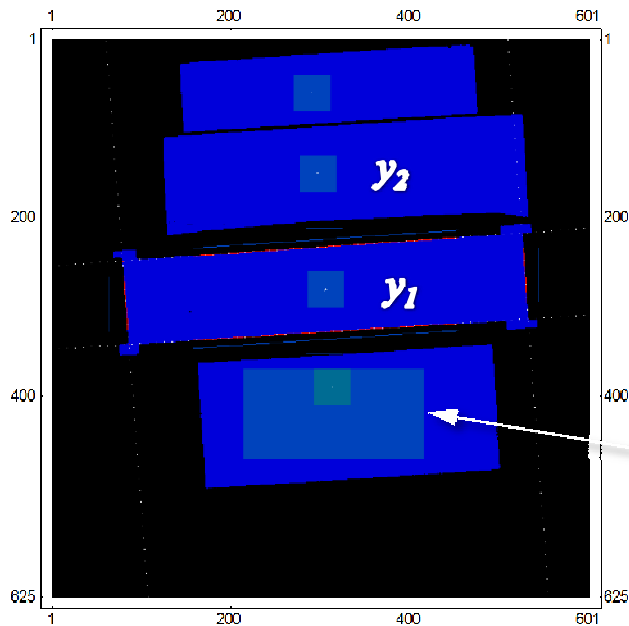
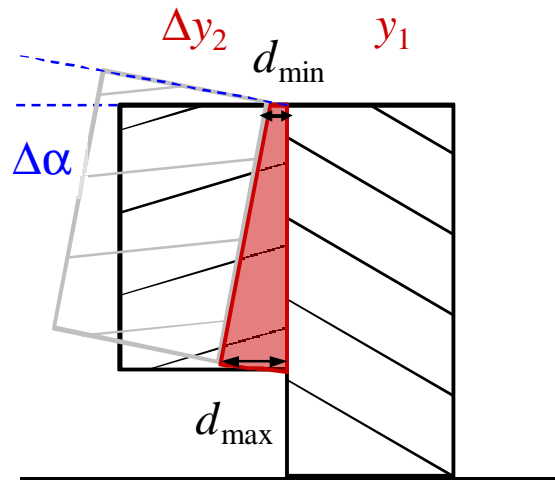
- ① very thin bonding layer
- ② bonding in interferometer



Adhesive connection (⊥ to ends)

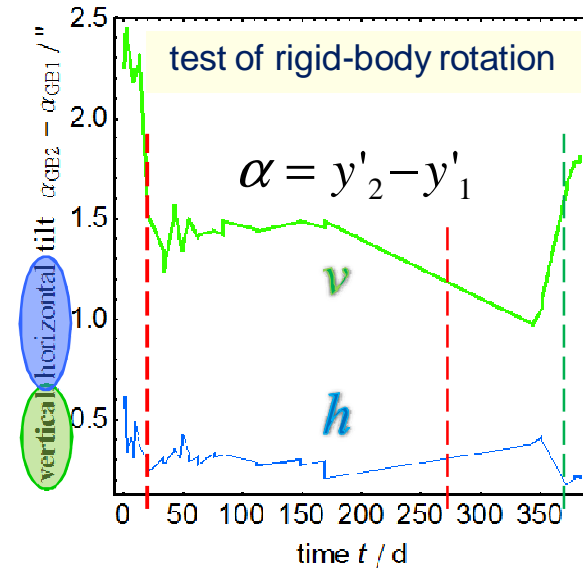
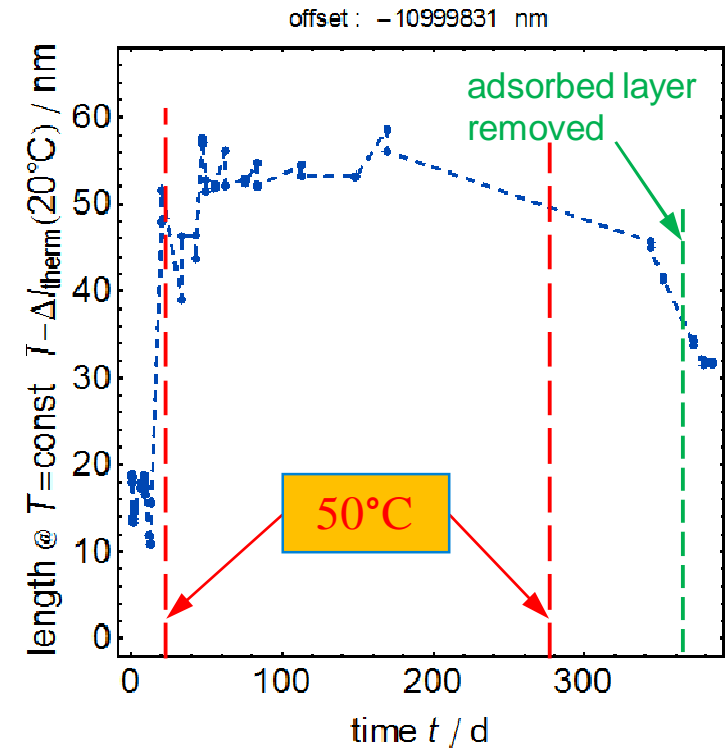


epoxy layer $d = 58 \dots 91 \mu\text{m}$

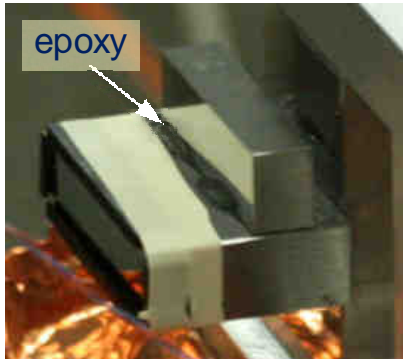


big ROI platen

$$\rightarrow y' = \frac{\partial y}{\partial v}$$



Adhesive connection (\perp to ends)

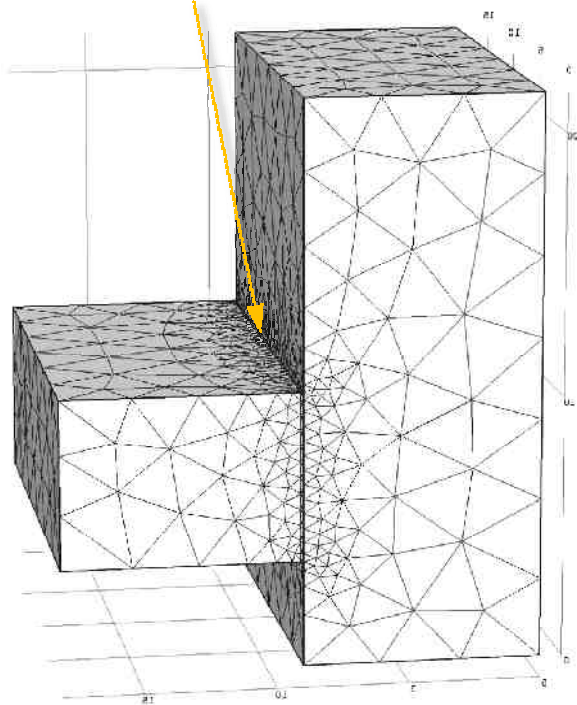


3D FEM mesh
2nd-order elements

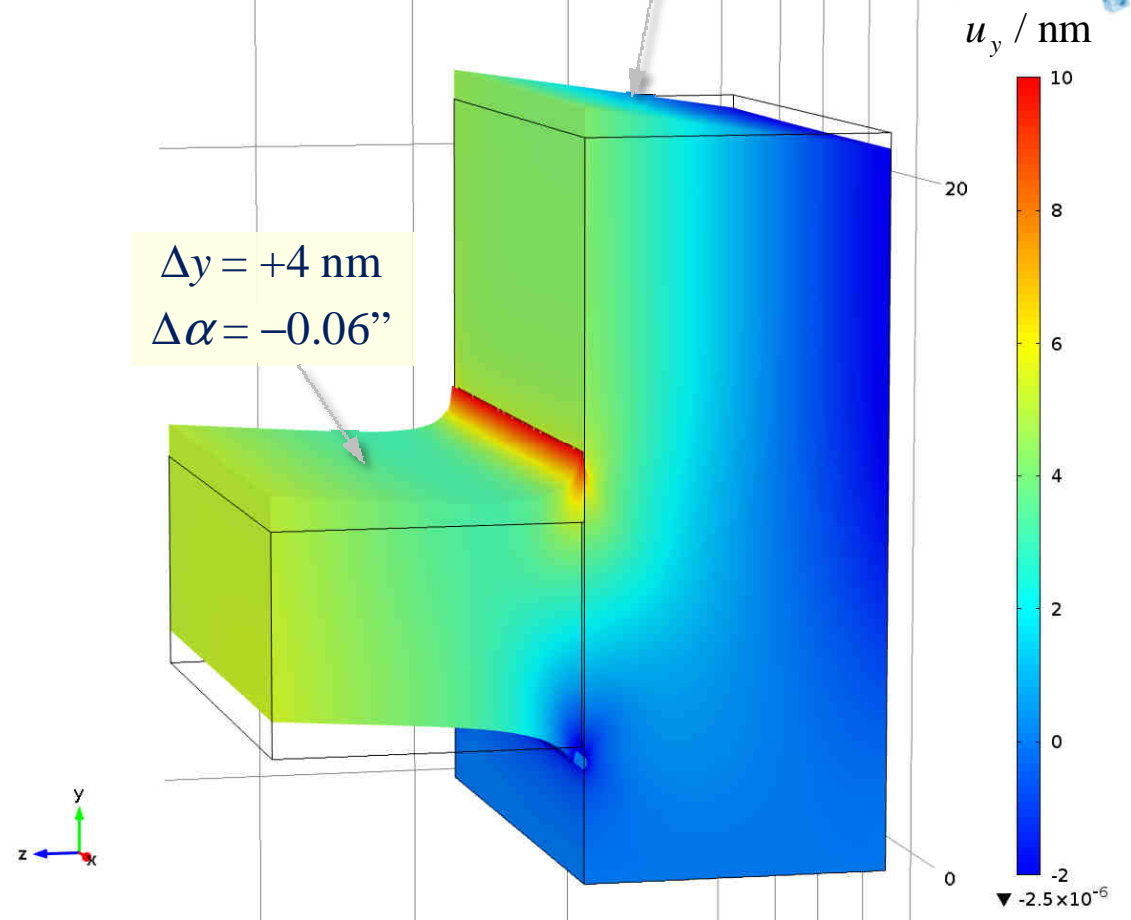
input:

epoxy layer $\Delta T = 30 \text{ K}$

$d = 74 \mu\text{m}$ $\Delta l : 0.24 \%$



Surface: Displacement field, Y component (mm) Scale Factor 200,000

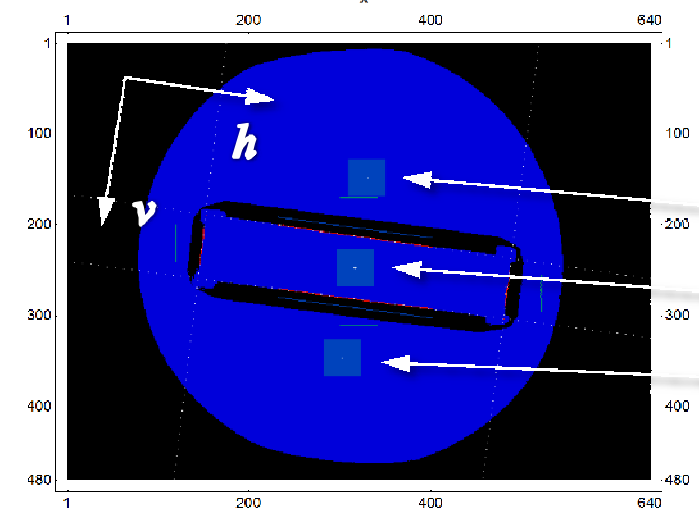
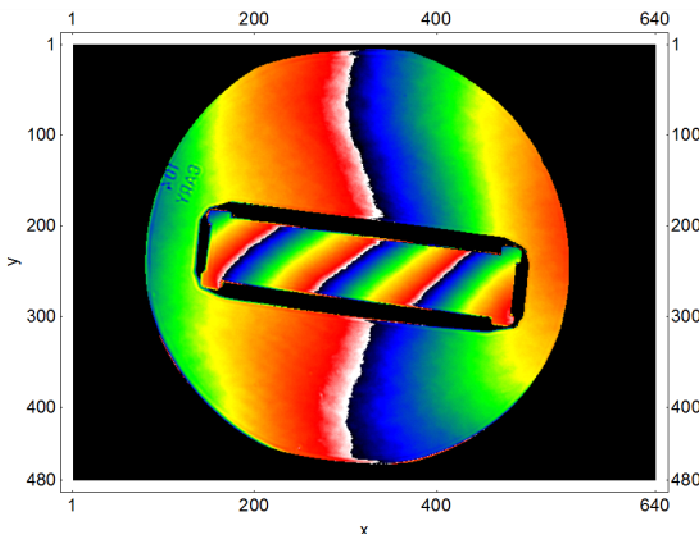


calculated deformation too small
→ measured tilting must result from:
non-parallel glue gap

Adhesive connection with epoxy || steel gauge blocks

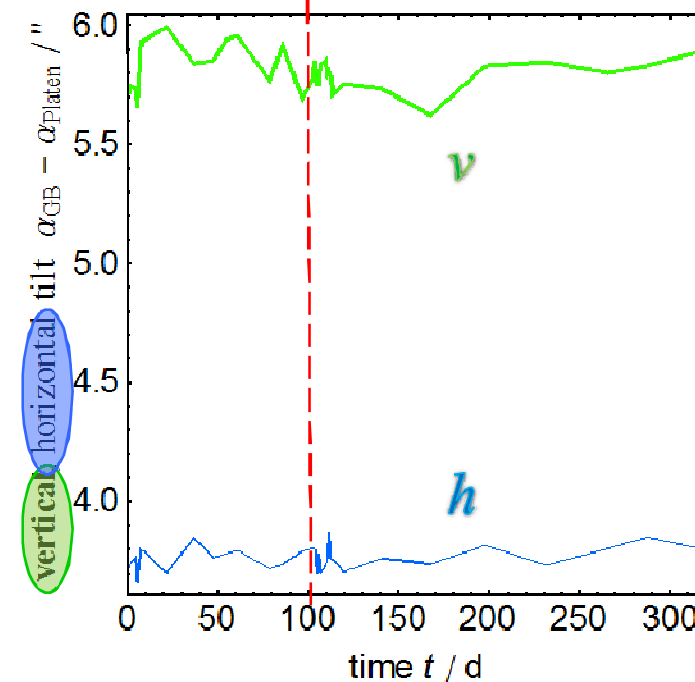
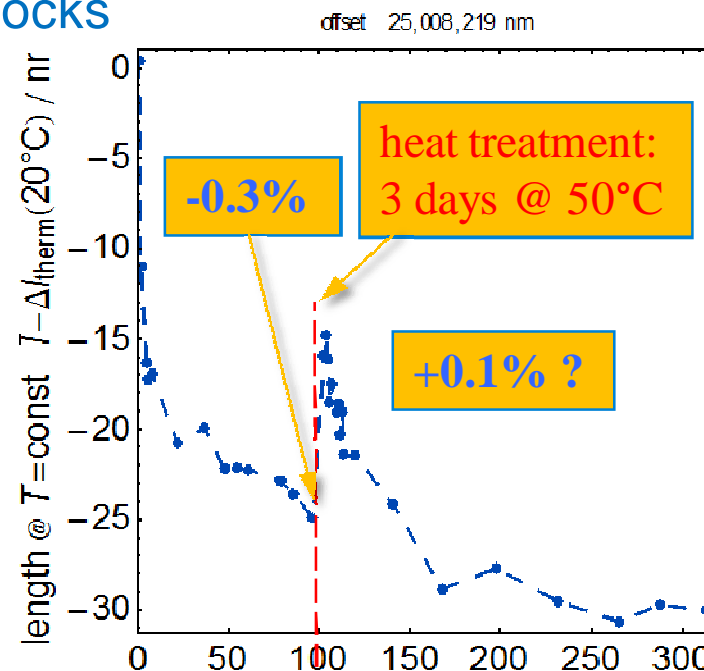
epoxy layer **curing @ 20°C**

$d = 8.2 \mu\text{m}$
 $\pm 0.4 \mu\text{m}$

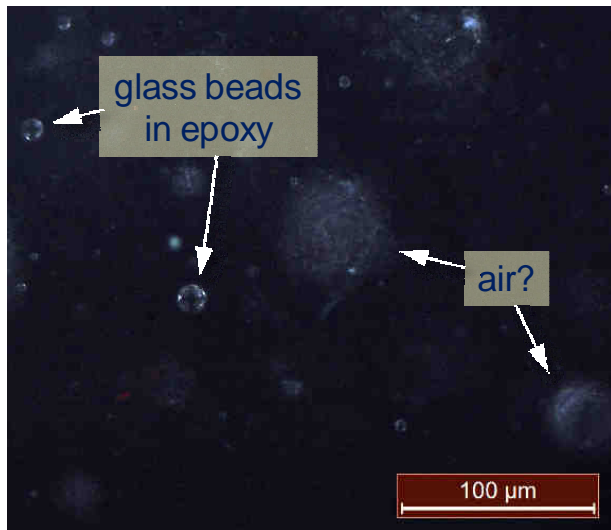
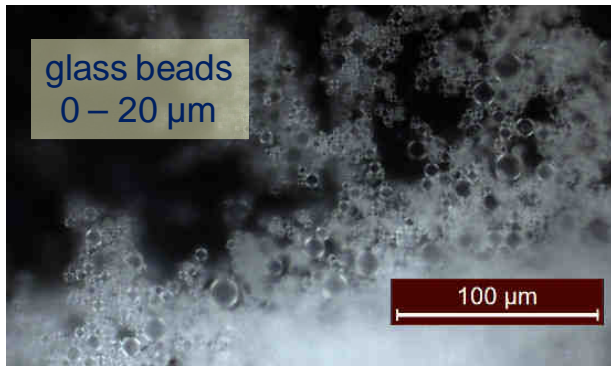


ROIs:

- platen
- glued GB
- platen



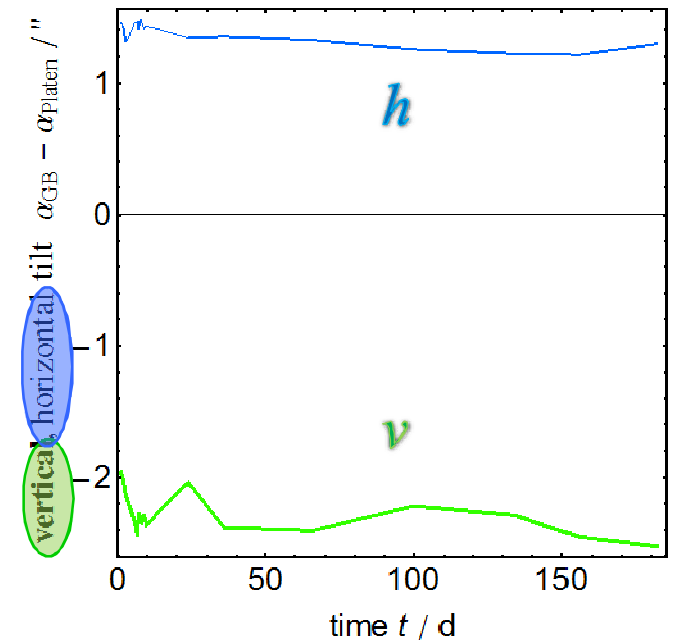
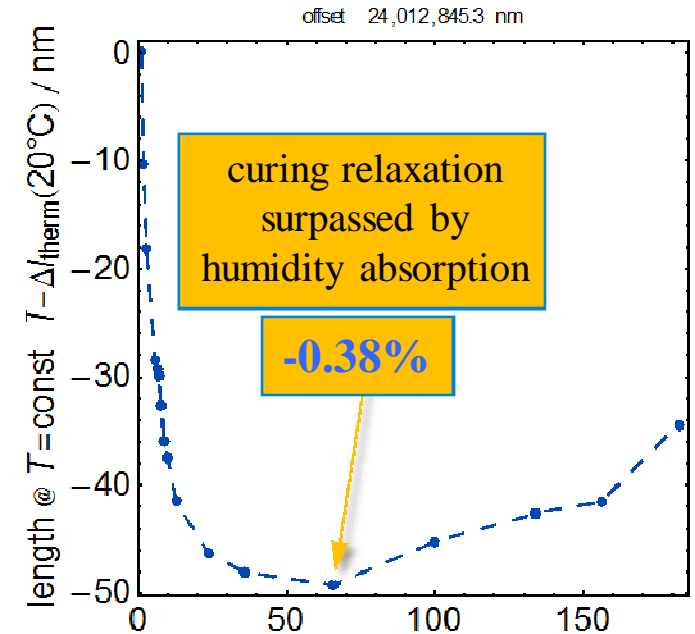
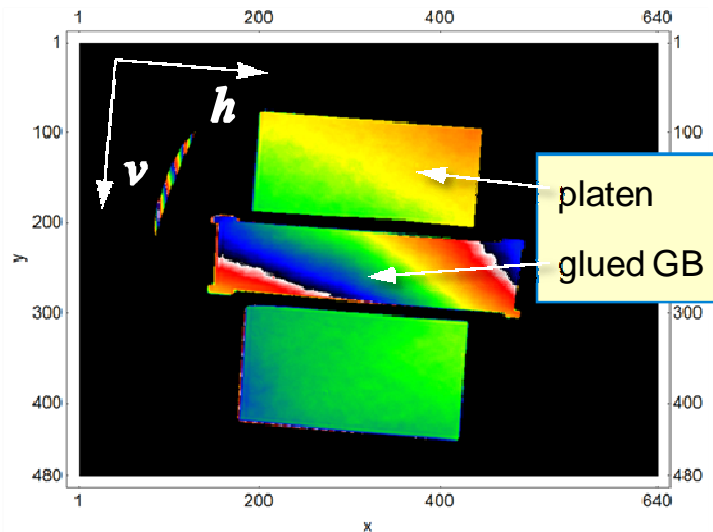
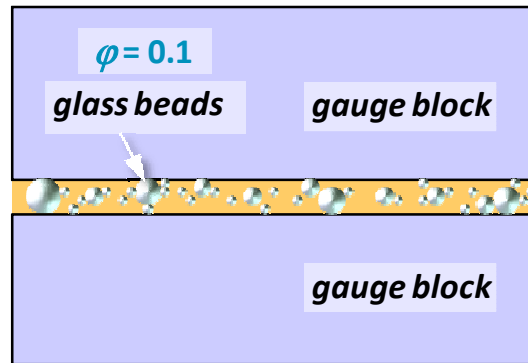
Adhesive connection with 0...20 μm spacers || steel gauge blocks



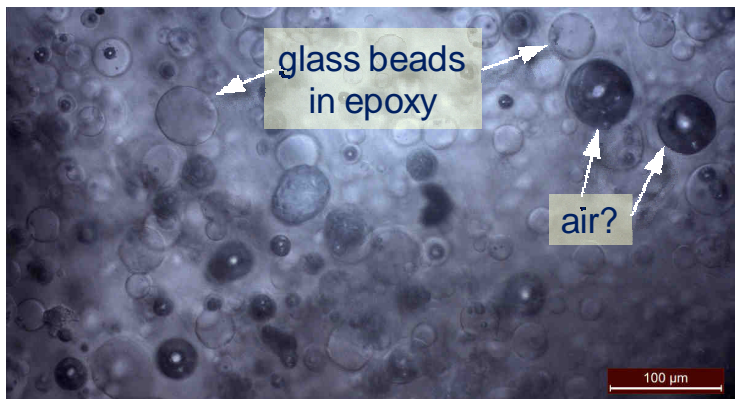
epoxy layer with
10% glass beads

curing
@ 20°C

$d = 12.7 \mu\text{m}$
 $\pm 0.2 \mu\text{m}$



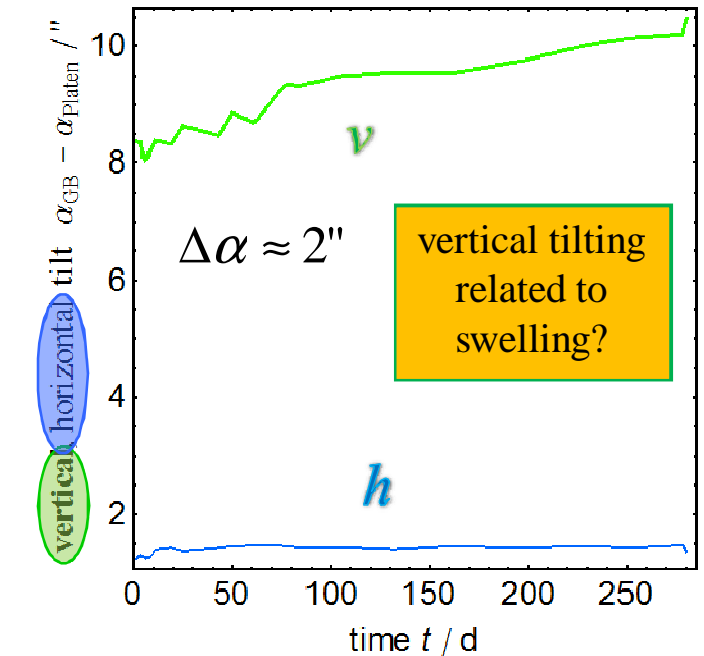
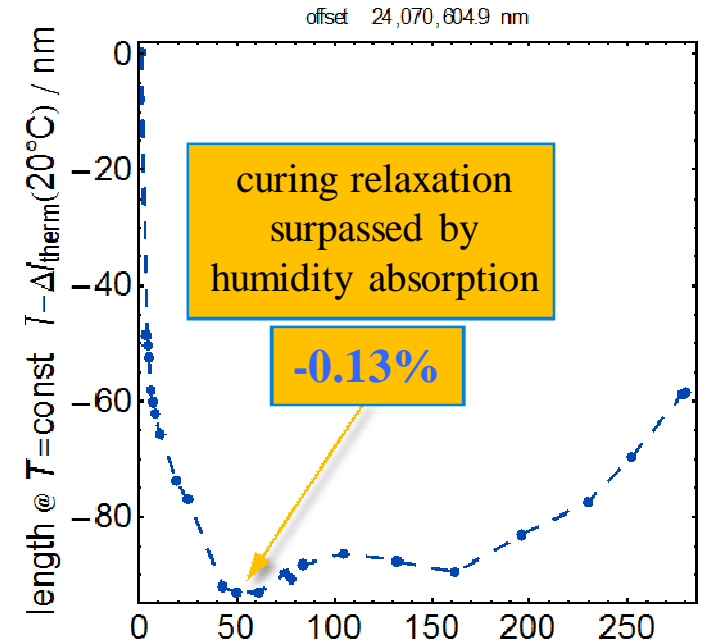
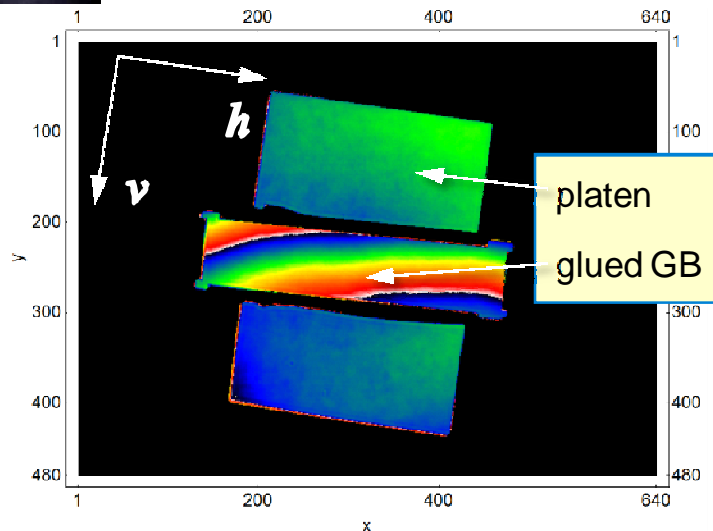
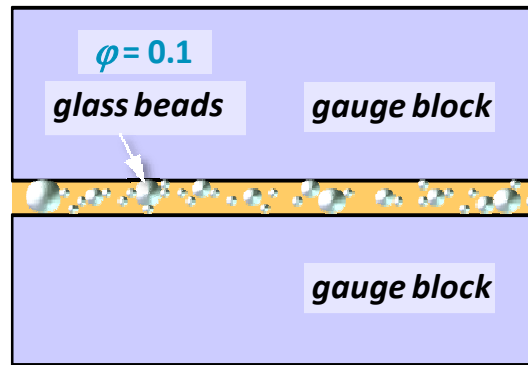
Adhesive connection with 0...70 μm spacers || steel gauge blocks



epoxy layer with
10% glass beads

curing
@ 20°C

$$d = 70.59 \mu\text{m} \pm 0.25 \mu\text{m}$$



Summary

Demonstrated: **connections of gauge blocks** applicable for **interferometry**

Wrung steel gauge blocks

- are slightly sensitive to thermal treatment

Bonded & soldered connections, IOF

- **AuSn thin-film soldering, silicatic bonding:** almost no change during 200 days
- **SnAgCu Solderjet** bumps are slightly sensitive to thermal treatment (40°C)

Screwed connection

- no drift detected during 1 year & stable with respect to thermal treatment

Adhesive connection

- Si single crystal with **synthetic resin:** slightly sensitive to thermal treatment
- **epoxy** adhesive not stable & sensitive to thermal treatment + humidity
- non-parallel glue gap → tilting & length change
- **spacers** can increase glue gap → swelling ?

Thank you:

*...and for your
attention!*

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