Thermal Design and Dimensional Drift

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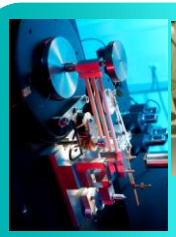
PTB LNE Laboratoire national de métrologie et d'essais Cnam Conservatoire national des arts et métiers NPL National Physical Laboratory VSL Dutch Metrology Institute INSTITUT P' ILMENAU UNIVERSITY OF TECHNOLOGY Fraunhofer IOF




WP1 Development and validation of facilities

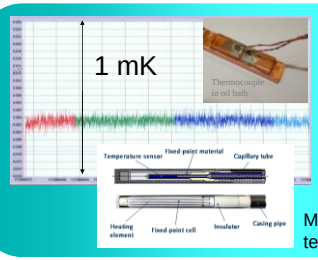
28 PM

Picodrift contactless optical heterodyne interferometer

Instrumented Indentation Tester

Temperature measurement and control tools

Knowledge of stable machine design for improving facilities



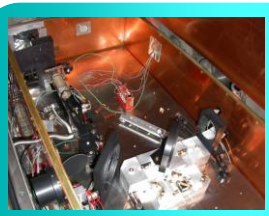
WP3 Development of a temperature measurement and control system

39 PM

Maintenance free temperature measurement

Measurement equipment

New calibration services



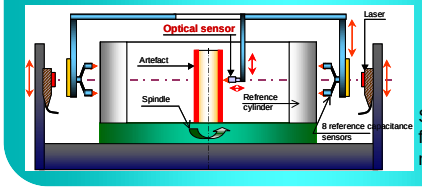
WP2 Behaviour of materials, structures joints and sensors

52 PM

Precision interferometer for long time stability measurement

Parameters for model

WP4 Thermal modelling and optimisation of thermal design



79 PM

Schematics of a form measure-ment machine

Temperature measurement and control tools

Knowledge base for thermal and drift behaviour of material, structures, joints and sensors

Guidelines for machine design and active cooling of subsystems

WP5 Impact

12 PM

Training

staff exchange

Training events

Website and e-learning

Exploitation

Standards for industry

Consultancy services and IP licences

Knowledge transfer

Conference presentations

Guidelines

Reports

Material database

Scientific papers

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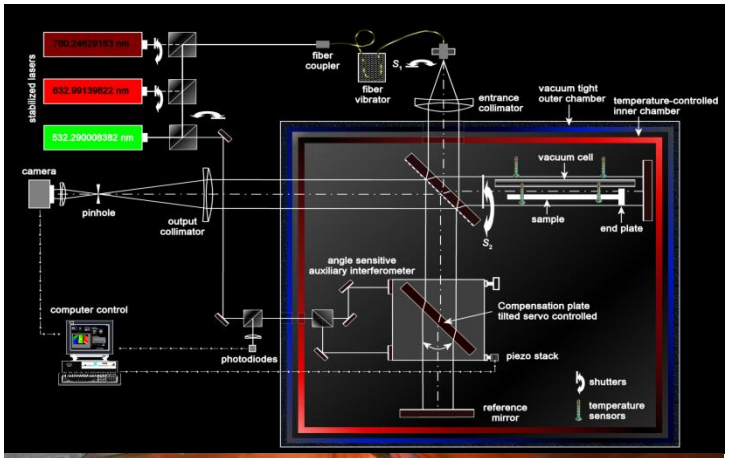
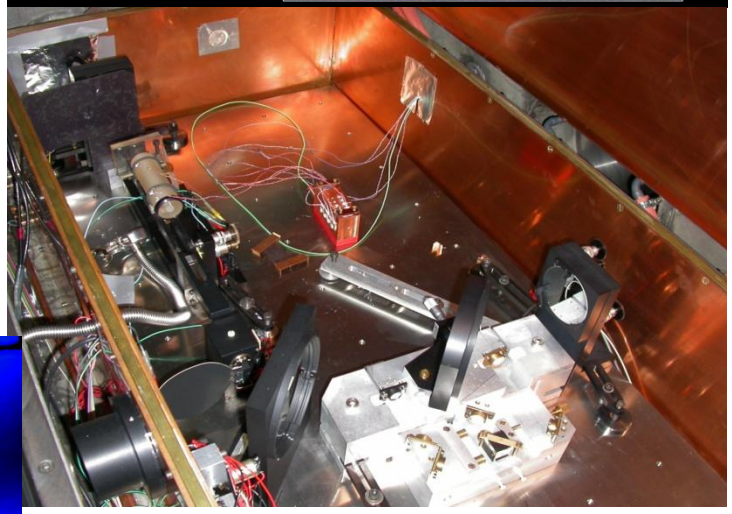
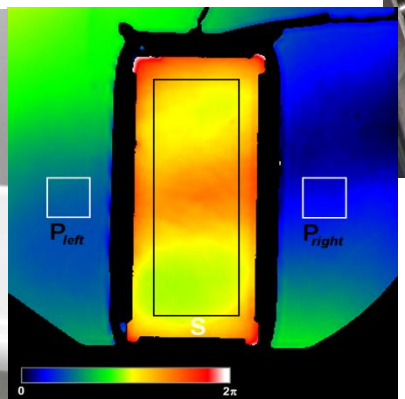
PTB Ultra Precision Interference Comparator

Objective: Evaluation of thermal expansion and long time stability of materials, joints, sensors and actuators

- Absolute measurement of length between parallel surfaces using phase stepping interferometry
- Beam diameter: 60 mm
- Parallelism for highest precision: 4”







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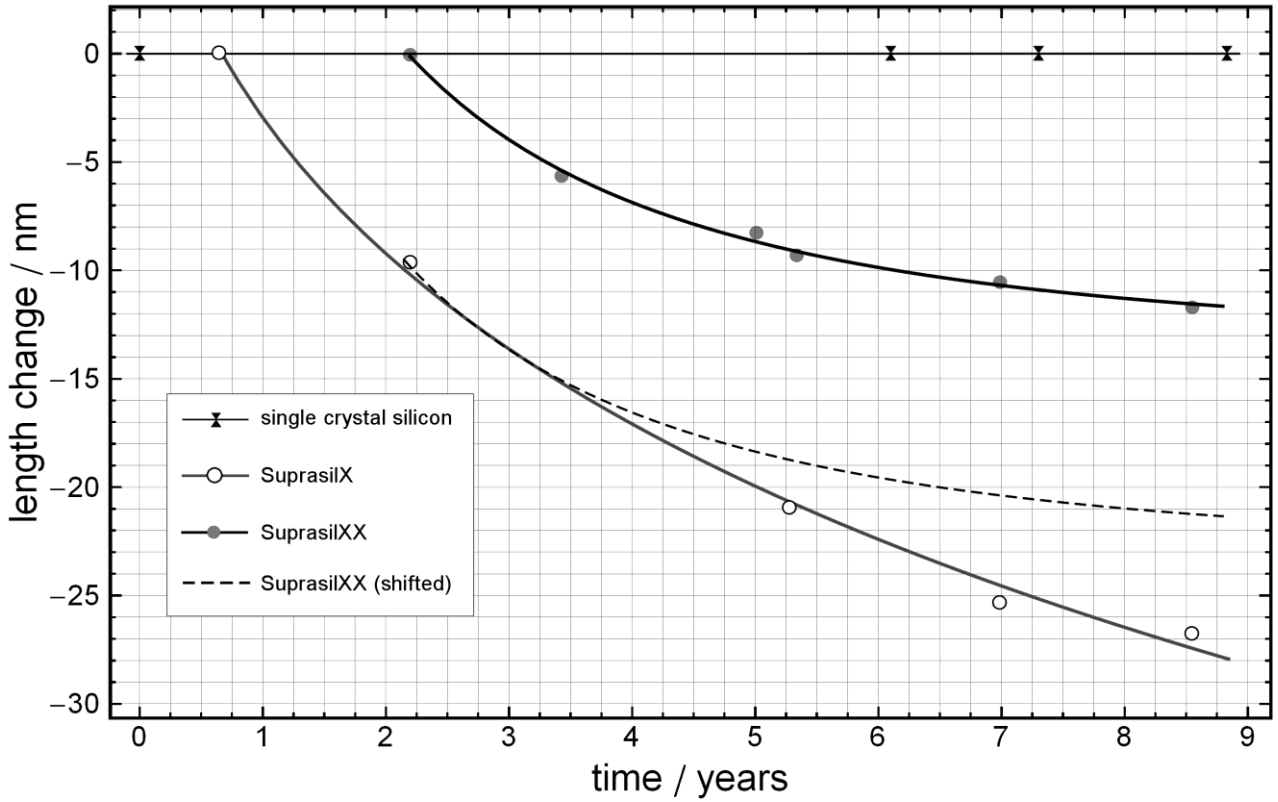
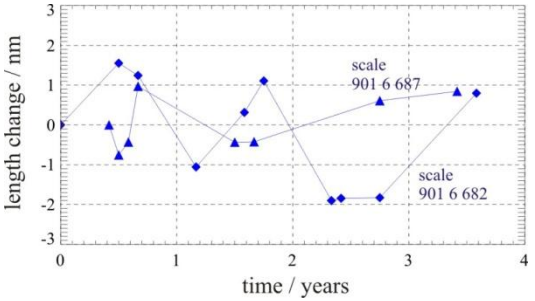
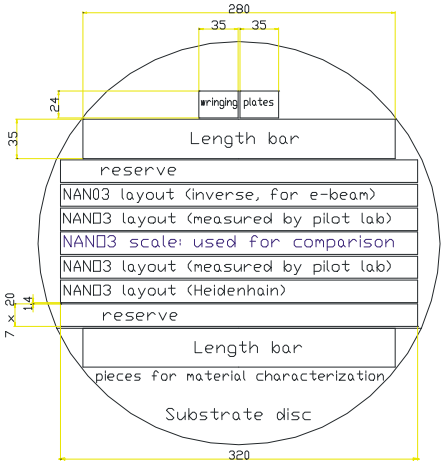
PTB Ultra Precision Interference Comparator

Results: Long time stability of fused silica and single crystal silicon



Long time stability of fused silica line scales from same substrate





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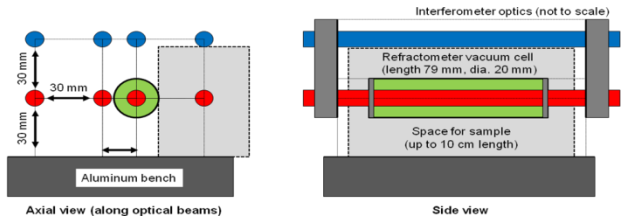
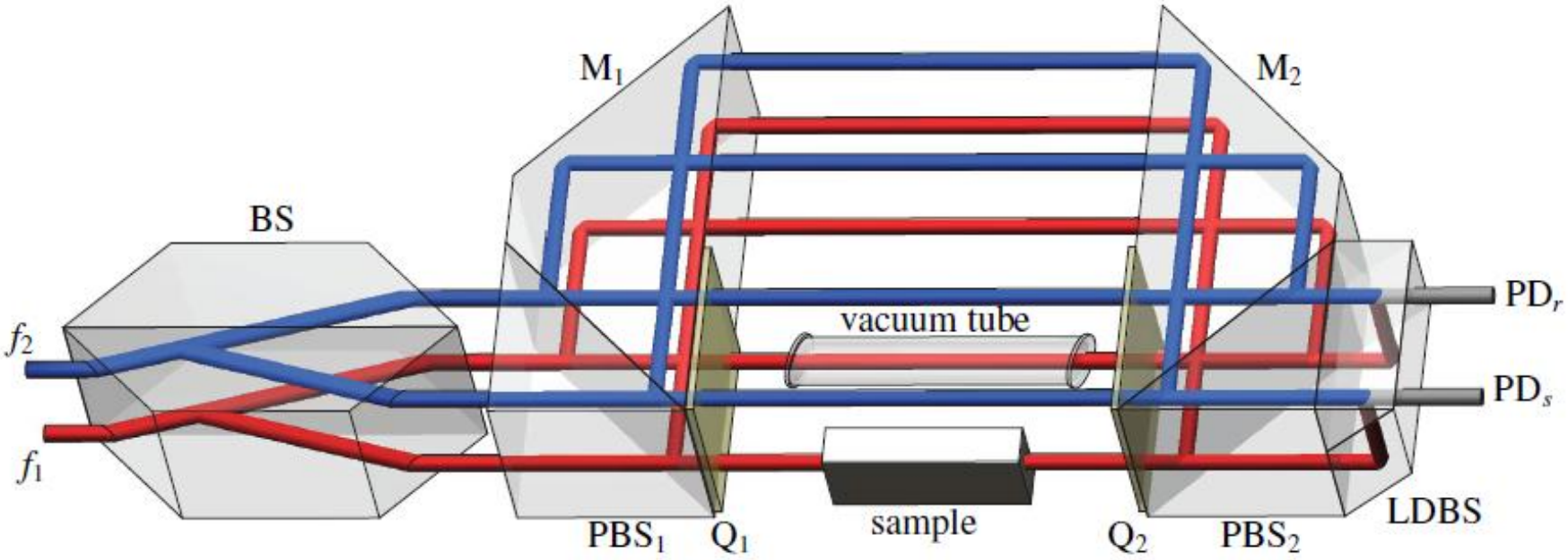
VSL Picodrift Interferometer

VSL
Dutch Metrology Institute

Objective: Sub 10 pm accuracy evaluation of short and midterm stability of materials, joints, sensors and actuators





J.D. Ellis, K.-N. Joo, J.W. Spronck, and R.H. Munnig Schmidt, "Balanced interferometric system for stability measurements", Appl. Opt. **48**(9), 1733-1740 (2009).

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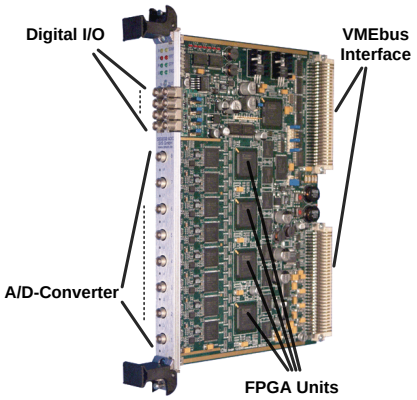
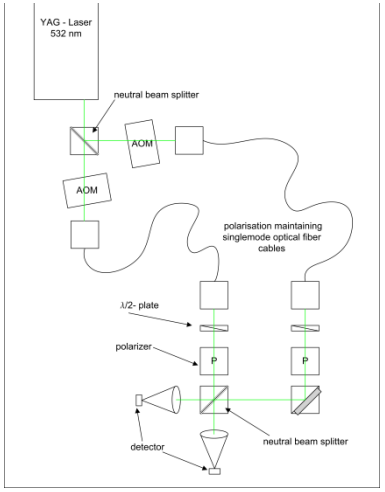
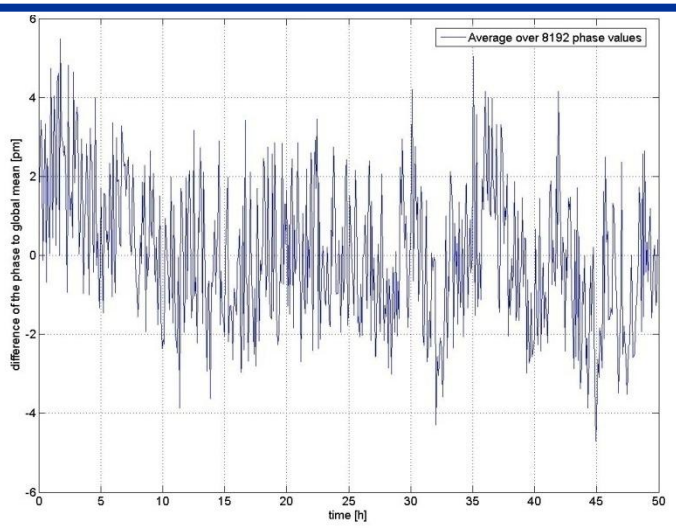
PTB Heterodyne Phasemeter

Struck SIS 3302
16 Bit, 100 MHz ADC



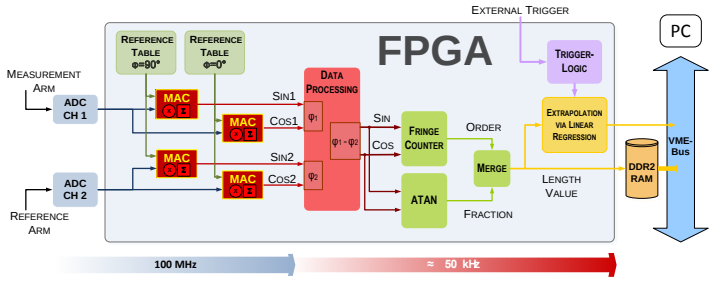
Test setup for stability evaluation

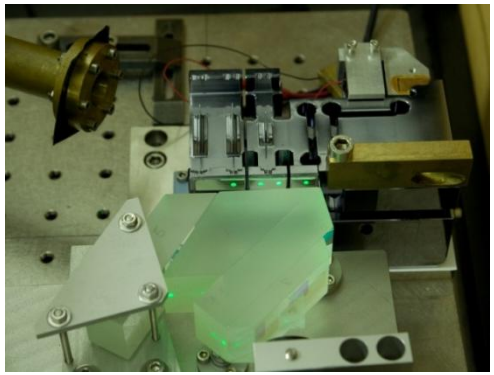


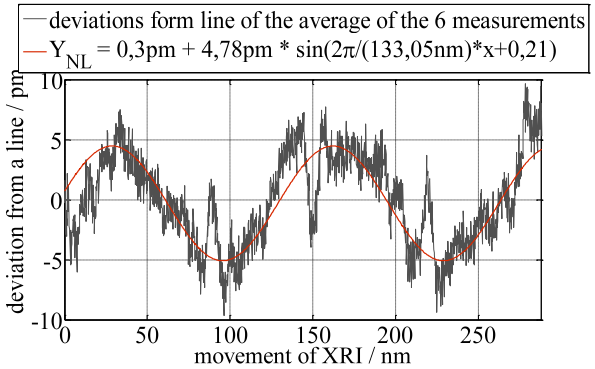


Interpolation nonlinearity below 5 pm shown by comparison with X-ray interferometer

Dual Phase Lock-In Algorithm in FPGA







But due to asymmetry
2 pm / mK sensitivity

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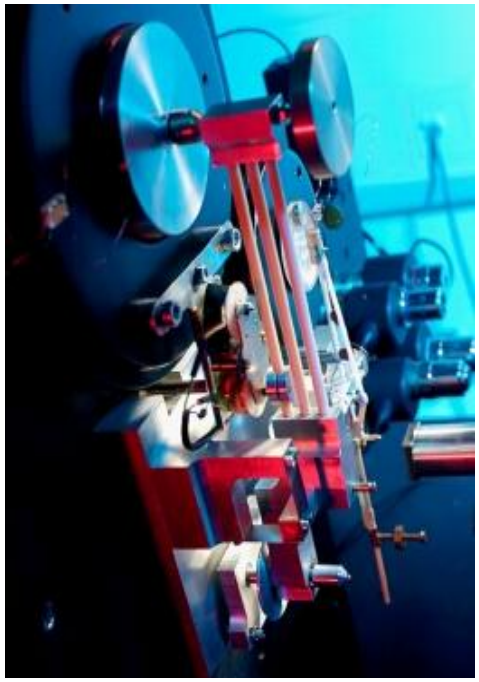
Nanoindentation

Objective: mapping of creep and hardness at temperature by nanoindentation.

- Procedures to be developed to calibrate the nanoindenter instrument at elevated temperatures.
- Dimensional stability to be evaluated and an uncertainty budget produced.
- Procedures developed to map the mechanical properties as a function of temperature.
- Nanoindentation results compared to those obtained from conventional creep measurements.



Nanoindentation instrumentation

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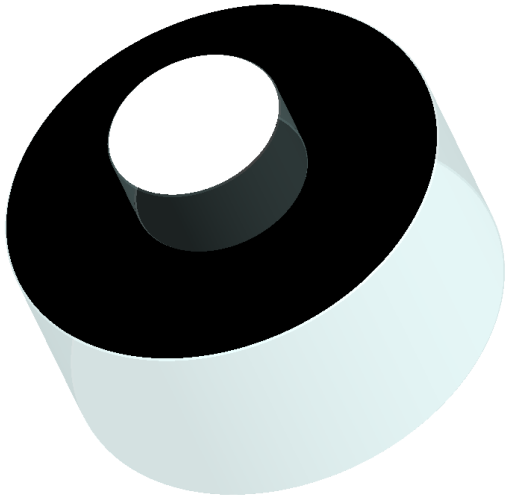
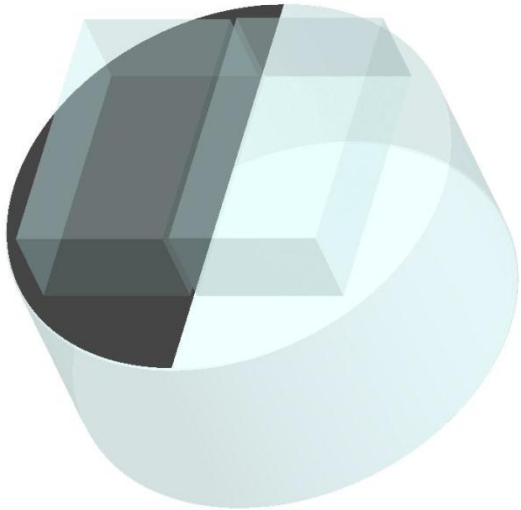
Demonstration Samples

Fraunhofer IOF

Planar Fused Silica Substrates bonded together with 3 different technologies



Demonstrator for one/ two side Interferometry



Demonstrator for Nanoindentation
and one side interferometry
(One probe wrung on base substrate)

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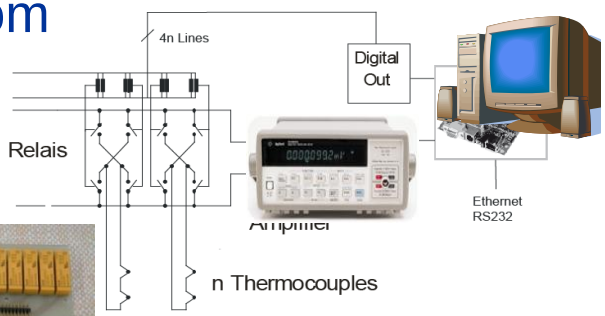
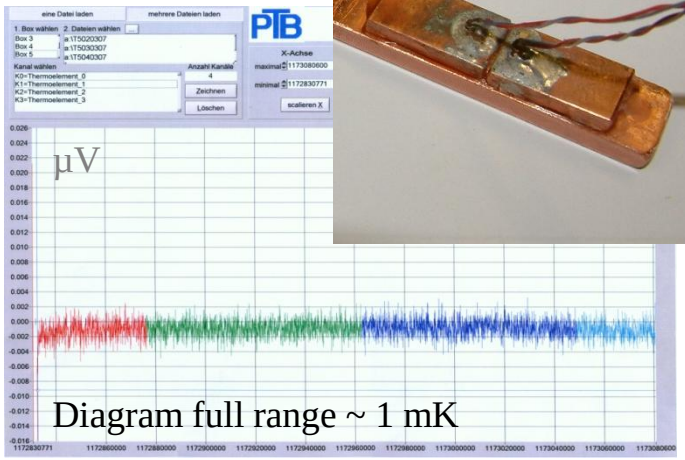
Thermocouple Measurements

Objective: Evaluation of stress sensitivity of zero point and characteristics of thermocouples near room temperature for maintainance free measurements



- Thermocouples are lightweight and with no self heating.
- Direct differential temperature measurement for control of gradients
- Investigation of 32 thermocouples regarding stability of zero point and characteristics dependence on stress and mounting conditions



- Different materials Cu/Konstantan, Ni-Cr/Ni-Al, Pt/Rh, …
- Different wires Manufacturer, length and diameters
- Foil and Thinfilm thermocouples
- Connectors

4 Measurements / Min.

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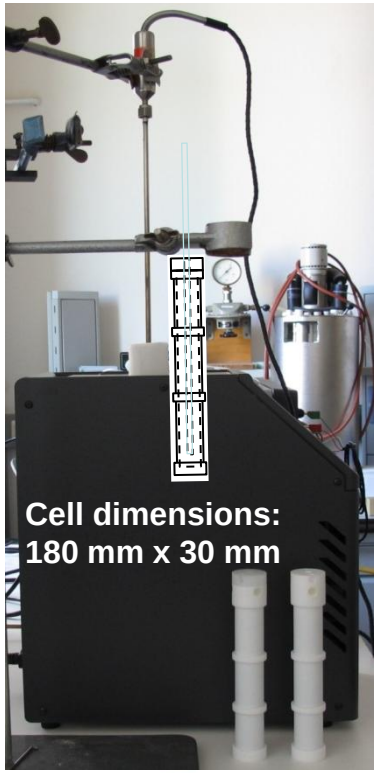
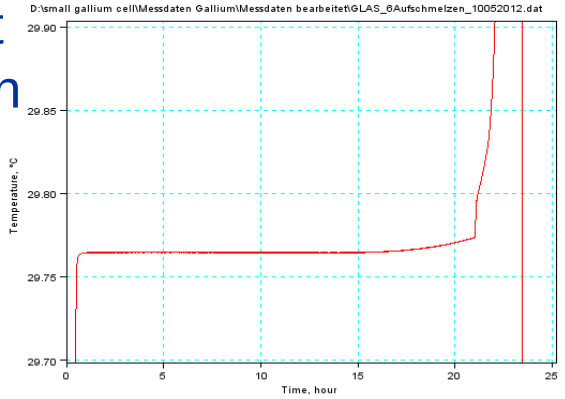
Development of a fixed-point cell (binary Ga-Sn alloy)

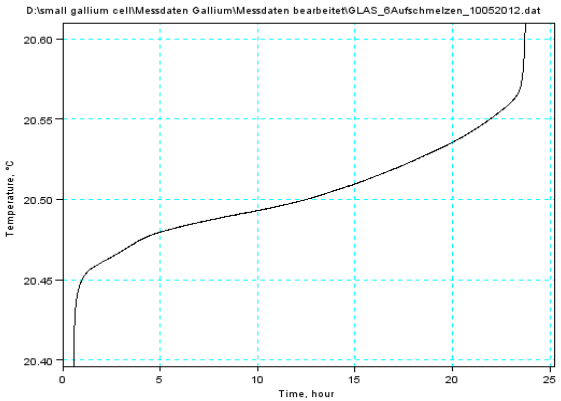
Objective: Development of a miniaturized fixed point cell near room temperature for in machine calibration of Pt-reference thermometers.



- Investigation of the influence of fixed point cell materials on the melting and supercooling behaviour of pure gallium
- Fixed point cell doped with tin to produce an eutectic binary alloy with gallium to get a fixed point temperature at about 20.4°C.
- Find optimum boundary conditions and algorithms for a stable and reproducible detection of melting plateau.



Melting plateau of pure gallium



Melting plateau of an eutectic Ga – Sn alloy at about 20.5 °C

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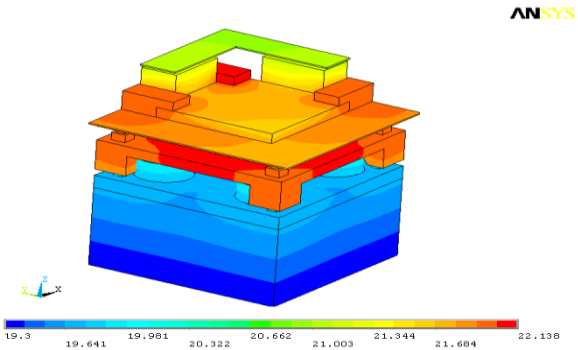
Thermal Modelling and Optimisation

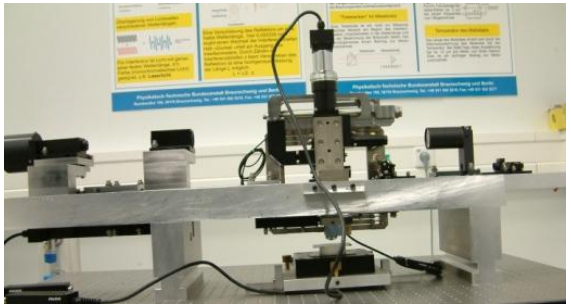
ILMENAU UNIVERSITY OF TECHNOLOGY

Objective: Thermal modelling and active temperature control for the optimisation of Precision Engineering tools.

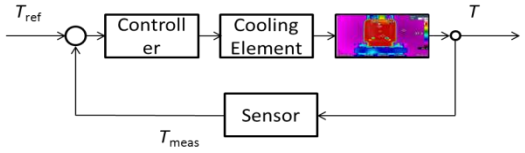
- Thermal modelling of complex engineering equipment and comparison of Modelling approaches (FEM for complex models, *Modal identification method* for reduced models).
- Development of a demonstrator for validation of models and investigation of joint structures
- Development of thermal control algorithms and cooling elements for an exemplarily temperature control of a measuring microscope at the PTB line scale comparator.



Thermal model of the SIOS NMM



Test setup for the CCD Microscope



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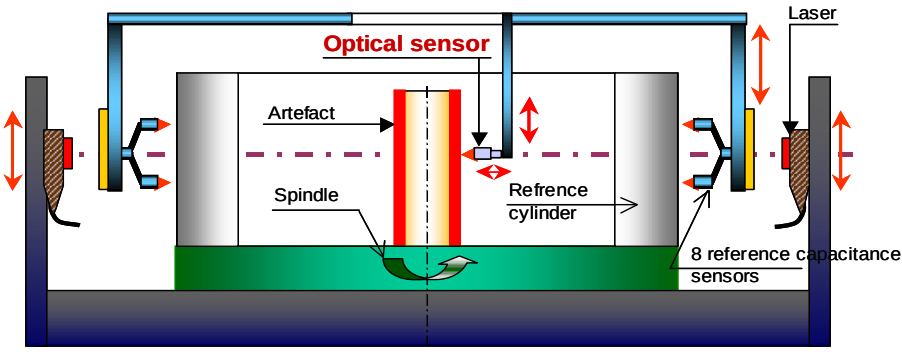
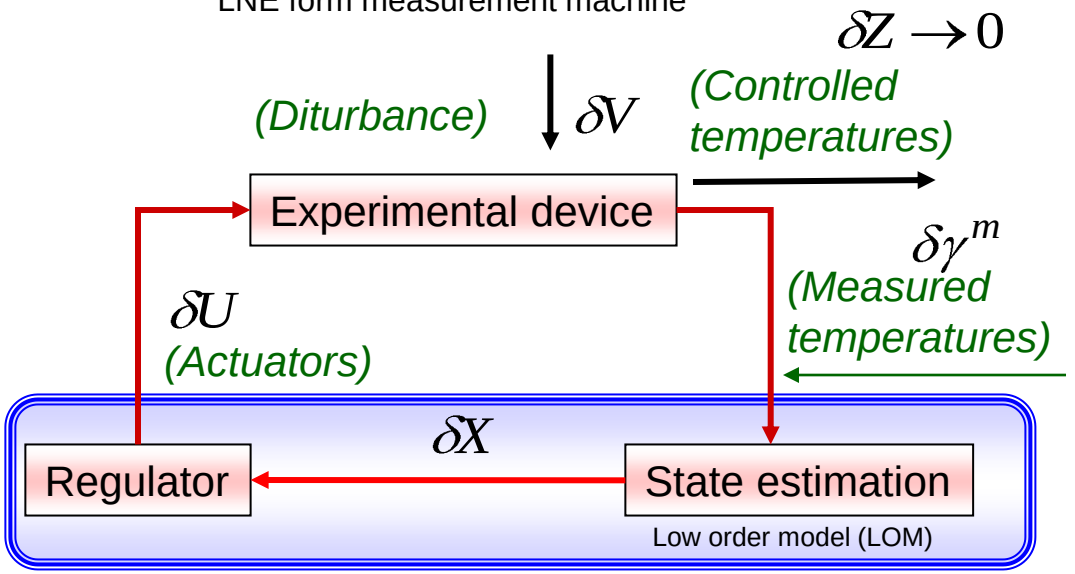
Thermal Modelling and Optimisation

Objective: Exemplarily thermal modelling and optimisation of the LNE form measurement machine.



LNE form measurement machine

- Local measurement of the temperature
- Equations and modelling issues
  - *Local governing equations*
  - *Modelling issues*
- Low order model approach
  - *Low order model*
  - *Modal identification method (MIM)*
- State feedback thermal control
  - *Linear quadratic regulator (LQR)*
  - *Linear quadratic Estimator (LQE)*
  - *Linear quadratic Gaussien compensator*
- Control test case and results



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