# Stabilising the performance of linear encoders in harsh environment: the biSLIDER

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# Linear encoders

- Linear encoders are widely used in machine tools and CMMs: they are cheap, reliable, yielding standard signals very suitable for closed-loop motion control
- The metrological reference is the scale, regular array of lines
  - ☺In-built, no need of additional equipment
  - ☹Fully sensitive to global or local perturbations of the array due to stresses and thermal expansion, particularly important in harsh environment

# The concept

- Stabilising the scale – particularly long ones – is difficult if not impossible, and certainly not cheap
- Concentrate the metrological core into a single (short) stress-free low-CTE piece of equipment used as a spacer between two read-heads.

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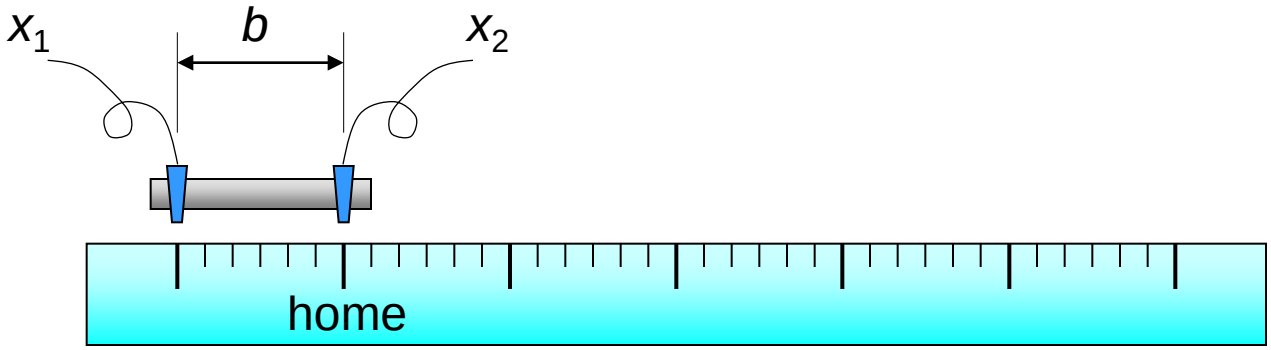
biSLIDER

*biSensor for Linearly Interpolated Differential Error Recovery*

# Te biSLIDER concept




- Two read-heads separated by an invariant spacer, *b*
- The full stroke is scanned in legs of length *b*
- At each leg, the difference $x_2 – x_1$ is recorded

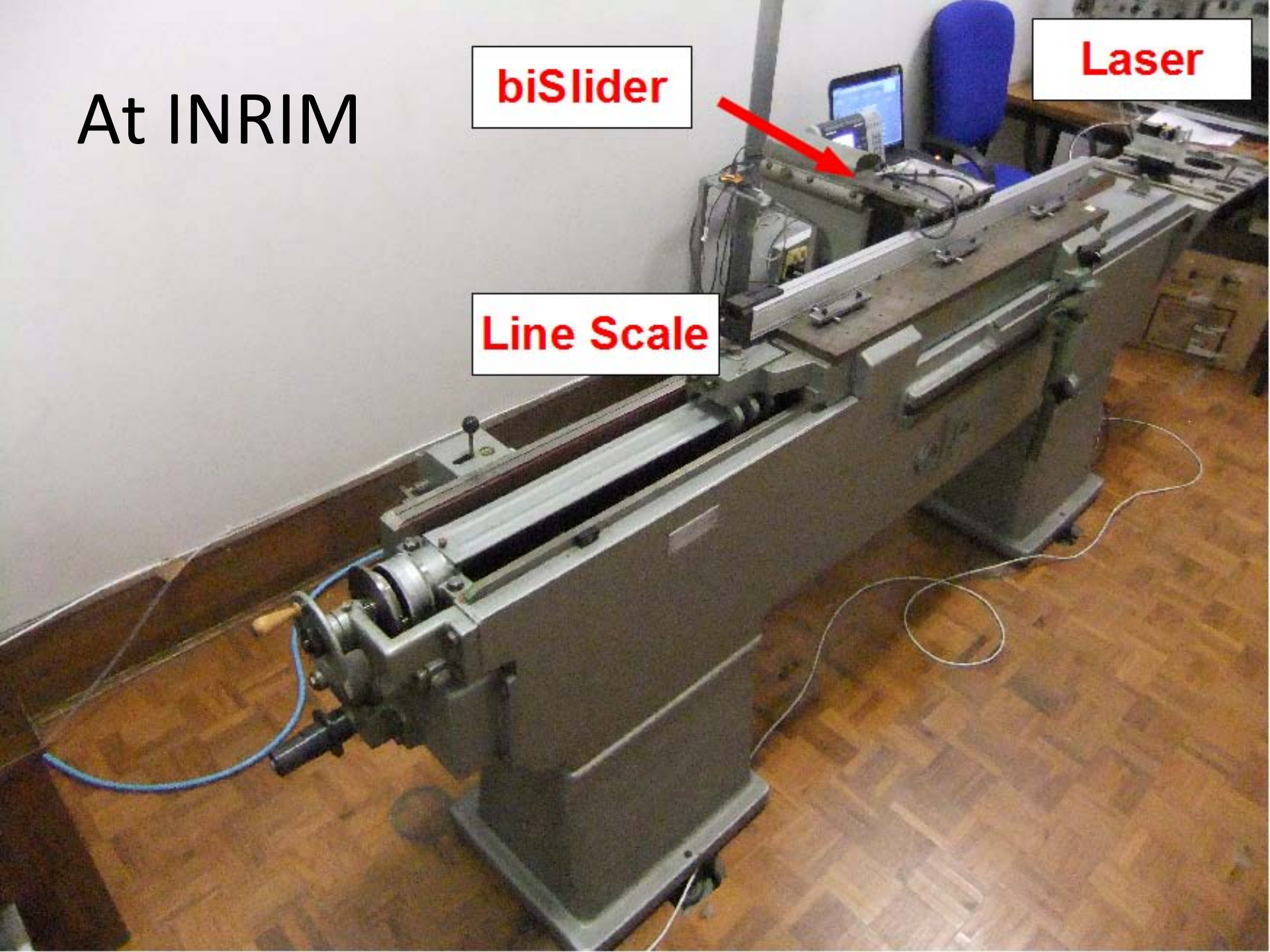
# Procedure

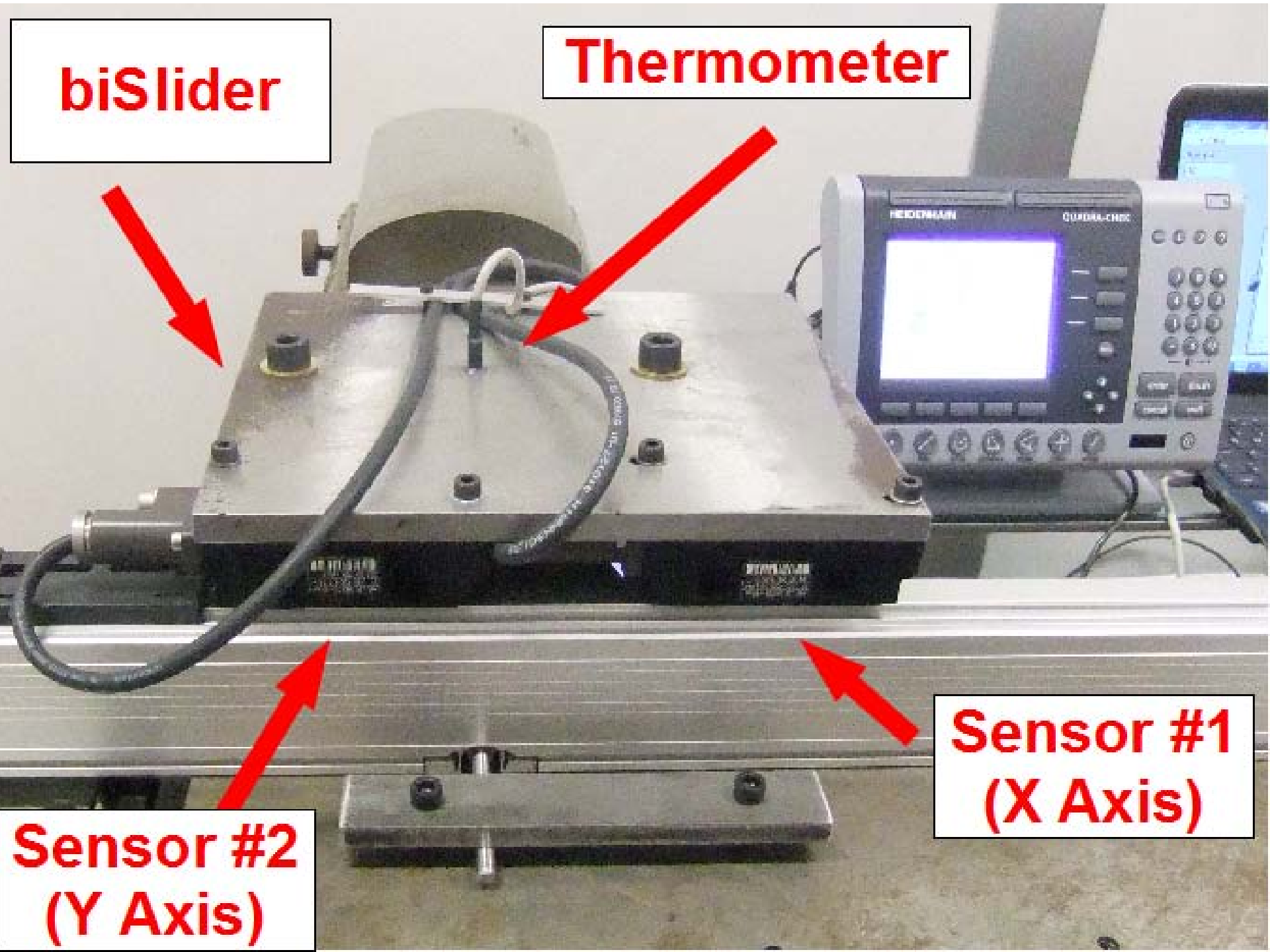
- At reference state $T_0$ (usually immediately after calibration to e.g. an interferometer, *static compensation*)
  - Scan a full stroke and record $(x_2–x_1)_i$ into a *reference table*
- Whenever perturbations are suspected, i.e. at perturbed state $T_k$
  - Scan a full stroke and record $(x_2–x_1)_i$ to form a *recovery table*
  - Being the bislider *b* invariant, any difference to the reference table is attributed to the scale; compute the difference of the *recovery* to the *reference table*
  - Integrate numerically that difference table (accumulation over previous legs) and record the resulting *dynamic table*
- In usual operation, use the *dynamic table* to perform a *dynamic compensation* (in addition to the static compensation, if any)

# Validation plan

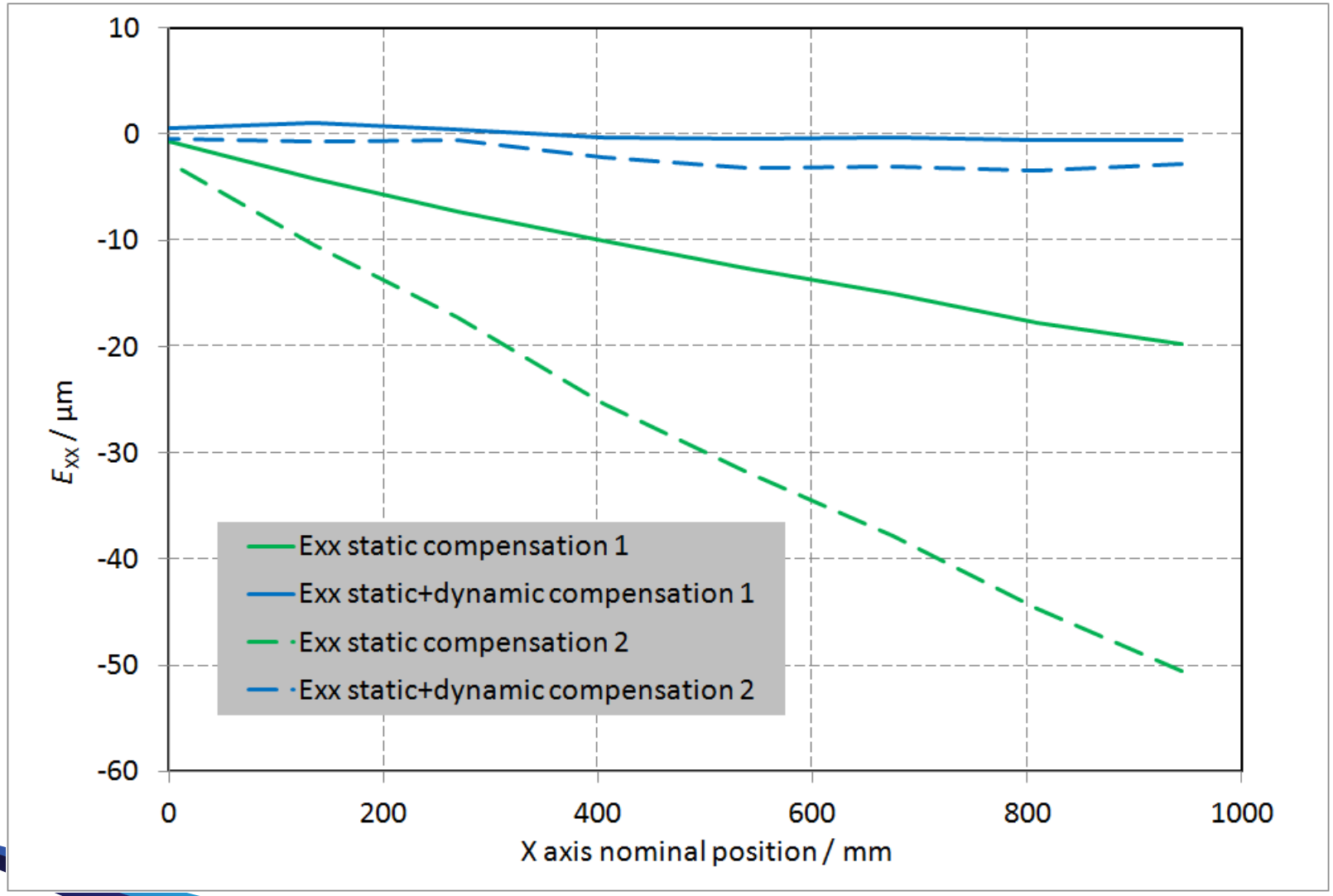
- Reference scan, strain imposed before recovery, compensation according to the biSLIDER concept, comparison to an independent laser interferometer
  - In laboratory at INRIM: stretch the scale by preloading
  - On a real machine tool at Alesamonti:
    - Stretch the scale by preloading
    - Release it to go back close to reference state
    - Load the machine with weight (4 t)
  - In laboratory at INRIM again: non linear strain by stressing the scale in two intermediate points

# At INRIM



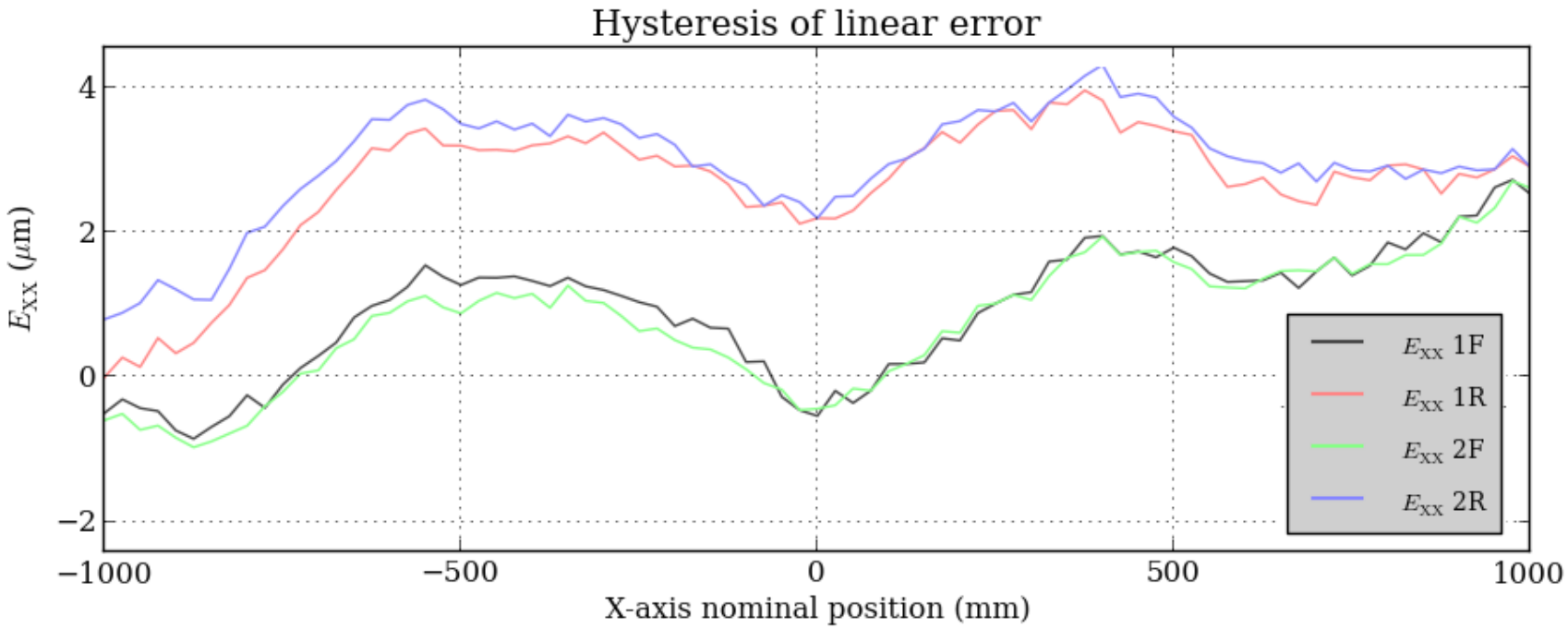

biSlider
Thermometer
Sensor #1
(X Axis)
Sensor #2
(Y Axis)

# Results: INRIM, linear strain

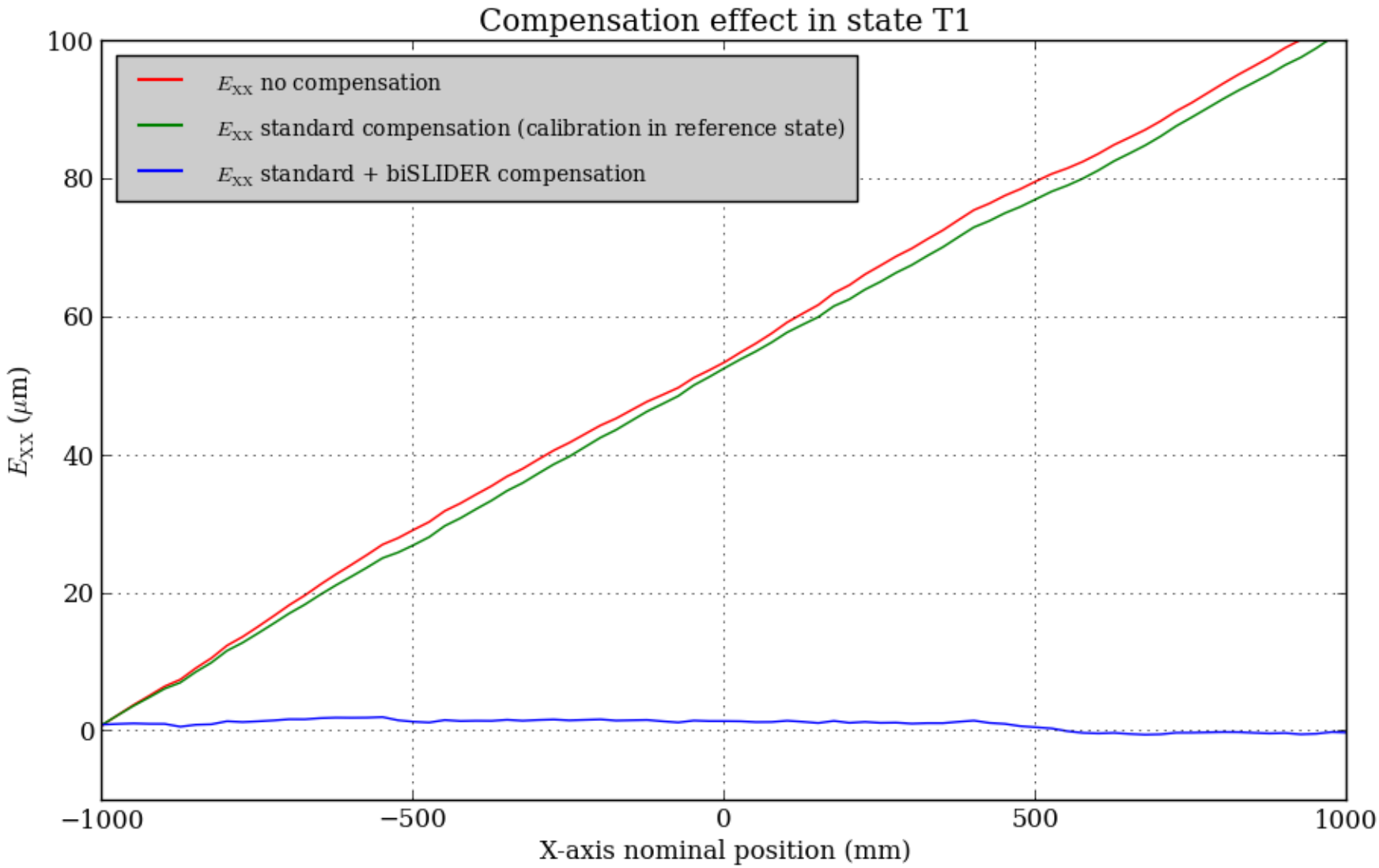


# At Alesamonti

# At Alesamonti: hysteresis

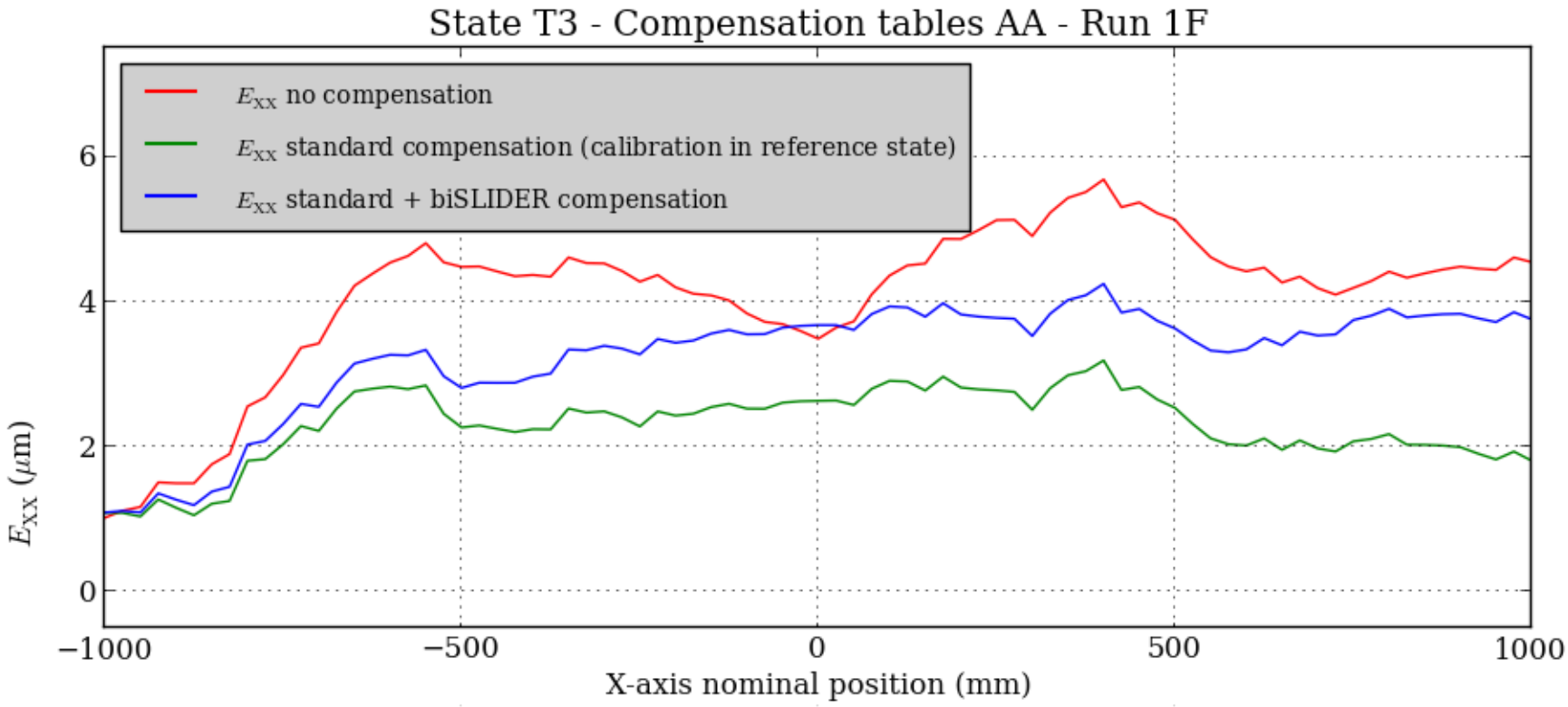


# Results: Alesamonti, linear strain



# Results: Alesamonti, released

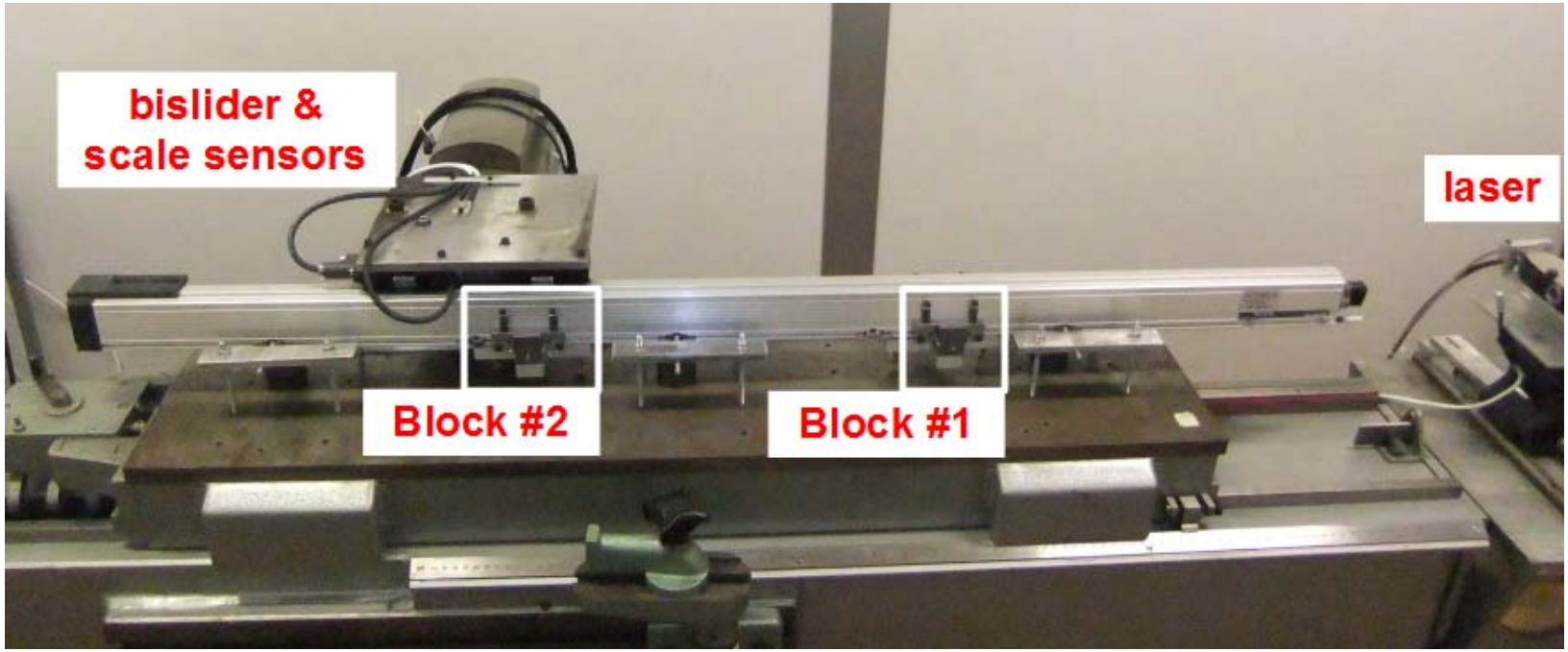
# Results: Alesamonti, loaded (4 t)



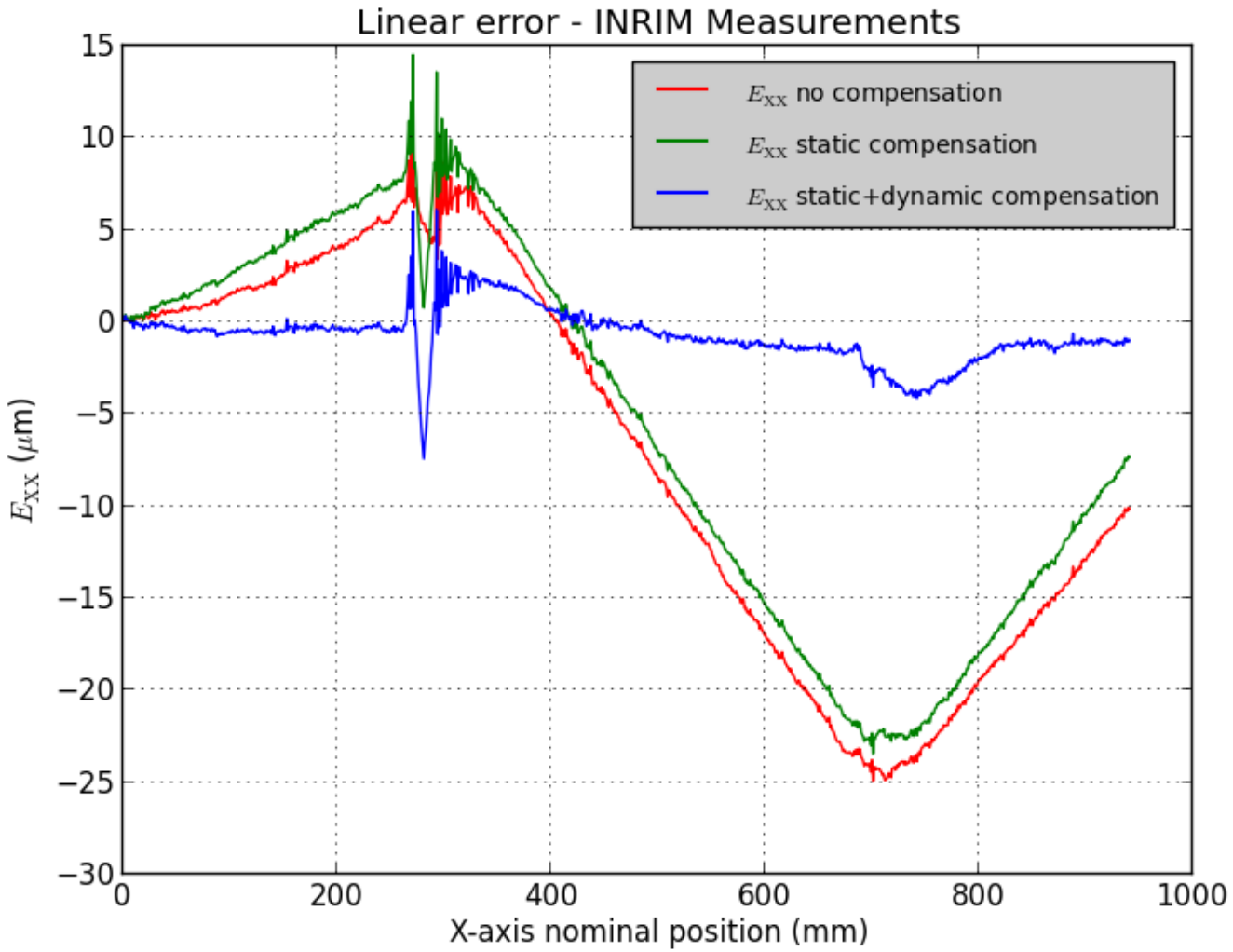
# At INRIM: how to generate non uniform strain

- Linear expansion (uniform strain) was tested already in previous experiments
- Non uniform strain to be tested
- To do so, two opposite forces were applied at intermediate points of the scale
  - Two aluminium blocks glued to the scale, slightly moved by sliding device preventing torques
  - Unfortunately one of the two glueing perturbed the scale locally unexpectedly

# At INRIM: experimental set up




# Results: INRIM, non uniform perturbation



# Conclusions

- The biSLIDER concept has been demonstrated both in laboratory and on a real machine tool
- The compensation is effective, both globally and locally (within the limit of the bislider length, *b*)
- The recovery procedure is easy and fast
- Only standard and commercially available equipment is used $\Rightarrow$ cheap implementation
- Most NC's provides redundant encoder channels: adding an extra read-head allows for retrofitting

# Acknowledgments

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° CP-FP 229112-2.


Patent pending