



**IMMS**

INSTITUT FÜR MIKROELEKTRONIK- UND  
MECHATRONIK-SYSTEME GEMEINNÜTZIGE GMBH

**GS10-08**

**Investigation of long-term distance measurement repeatability in a large-range nanopositioning machine combined with a laser focus sensor**

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Ilmenau, 26.10.2024

Davi Anders Brasil

**ICPE 2024**

The 20th International Conference on Precision Engineering

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TECHNISCHE UNIVERSITÄT  
**ILMENAU**



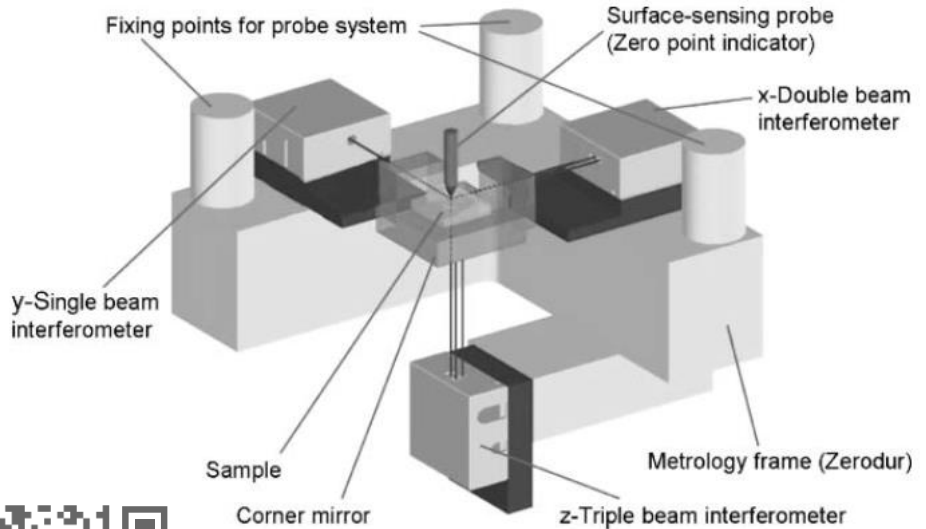
# Background and Motivation

## Nanopositioning machines

- Precise measurements in a 3D space
- Drive technology – Voice coils motors

## Targets

- 6D controlled movements
- Long range measurements and fabrication
  - More than 50 mm x 50 mm (planar)
- Multitool and versatile systems
- Sub-10 nm scale



G Jäger *et. al.* (2009) <https://doi.org/10.1524/teme.2009.0960>

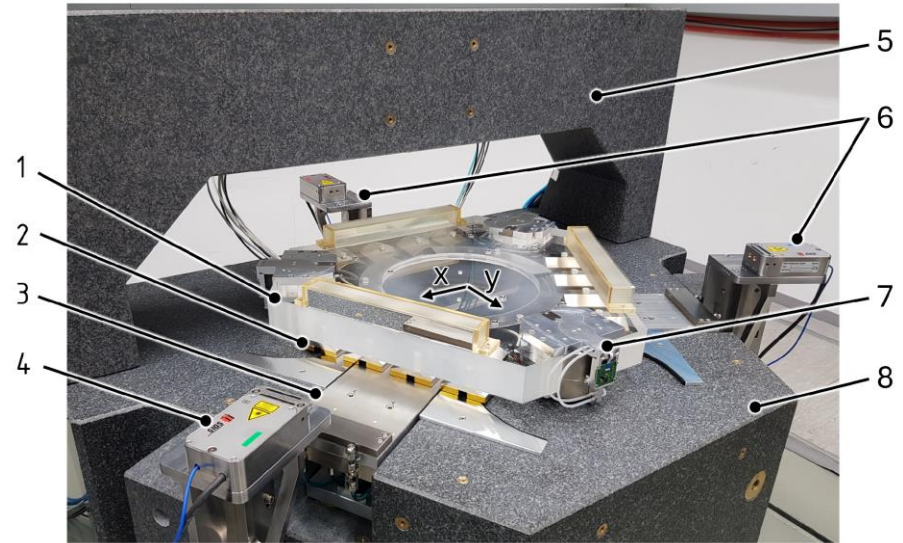
# NPS6D200 – Specifications

Parameter	Value
xy-operating range	Ø200 mm
z-operating range	25 mm
planar velocity <sup>1</sup>	50 mms <sup>-1</sup>
vertical velocity	2 mms <sup>-1</sup>
acceleration	250 mms <sup>-2</sup>
moving mass	36 kg
payload	5 kg
overall dimensions (W x L x H)	1115 mm x 980 mm x 980 mm

- Subnanometric RMS positioning errors



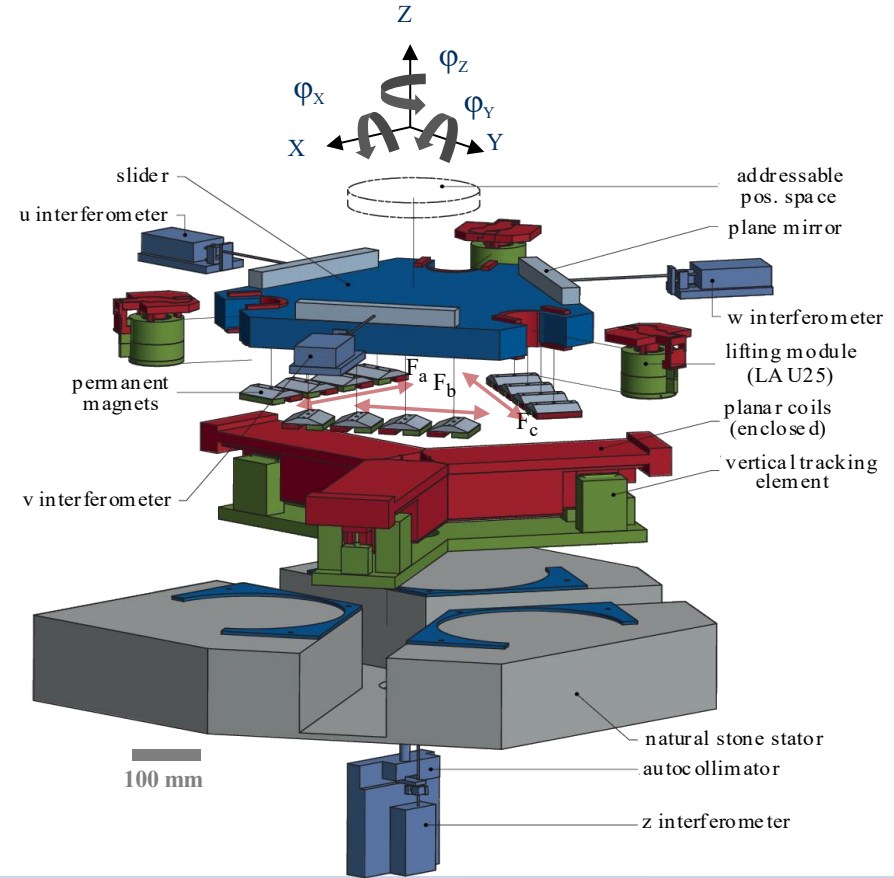
S Hesse *et. al.* (2024) <https://doi.org/10.3390/app14166972>



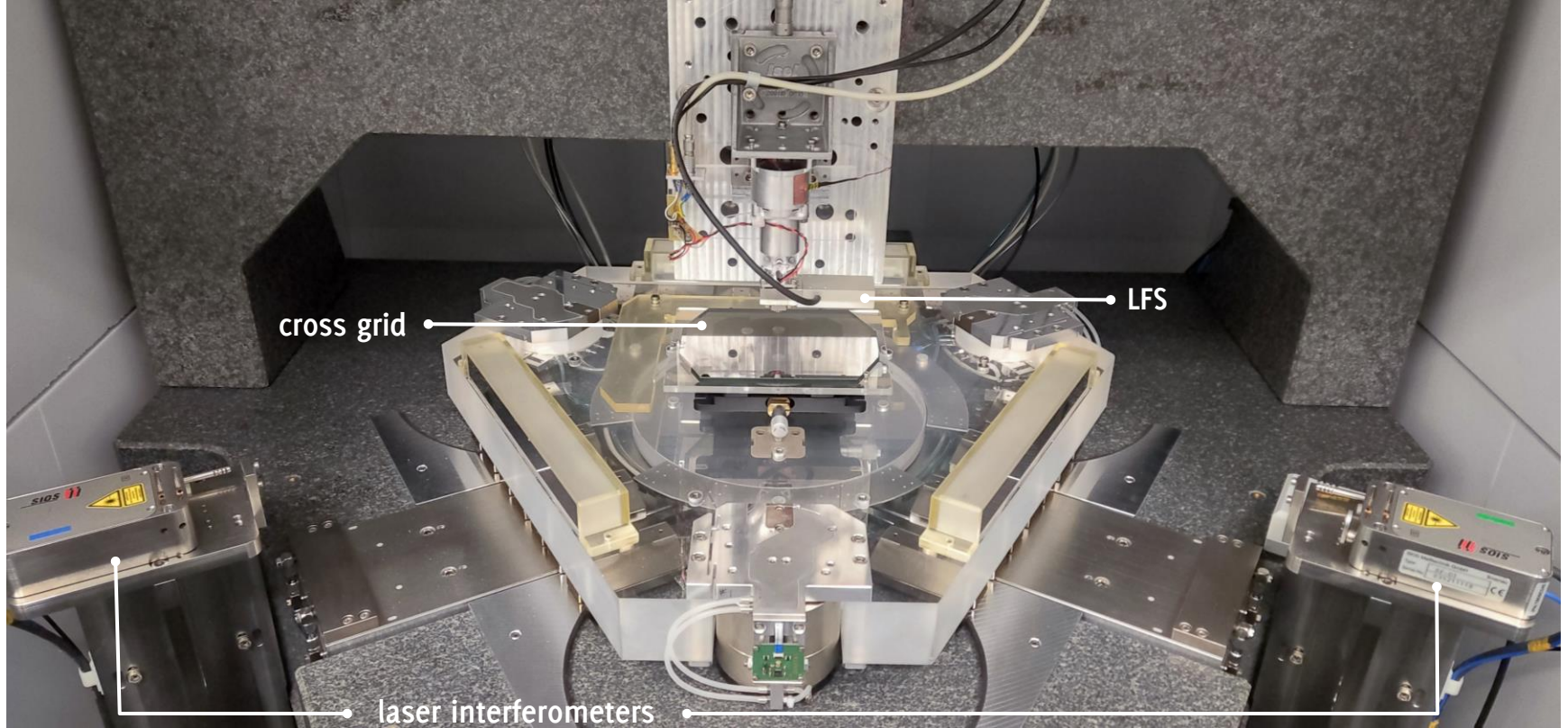
1—slider with reflectors, 2—magnets of the planar direct drive, 3—coils of the planar direct drive, 4—laser interferometer, 5—granite portal with probe mount interface, 6—laser interferometer, 7—lifting module LAU25, 8—granite base.

# NPS6D200 – Specifications

- Nanopositioning platform for  $\varnothing 200 \text{ mm} \times 25 \text{ mm}$  operating range;
- Multiaxial direct drive system with contactless force application to the moving part;
- Pneumatic weight force compensation;
- Frictionless aerostatic guiding;
- High resolution 6D measurement of the slider position;
- 6D closed loop control;
- Abbe-error reduction;
- Open architecture to implement different applications and sensor tools.

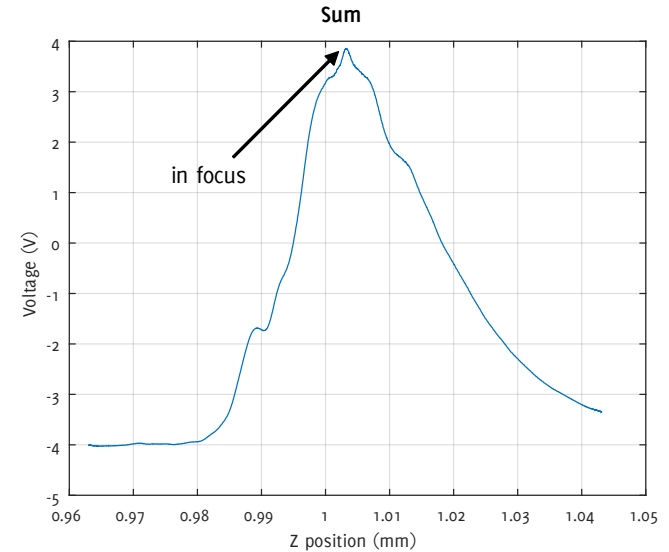
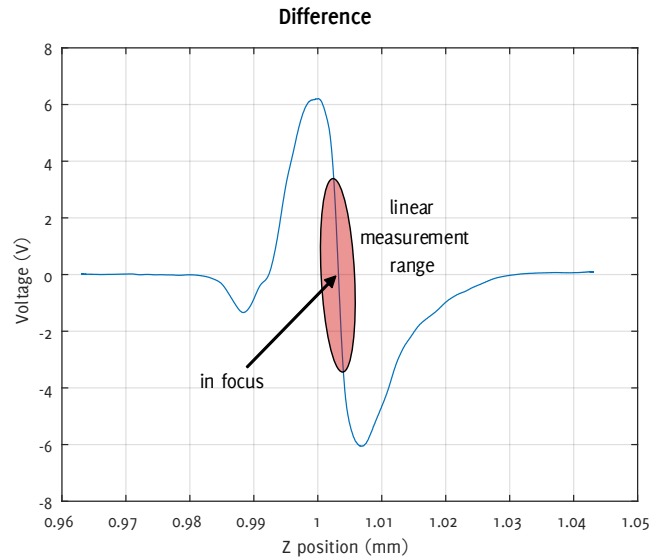
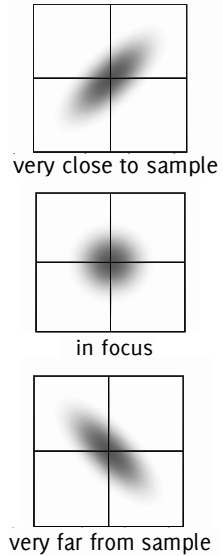
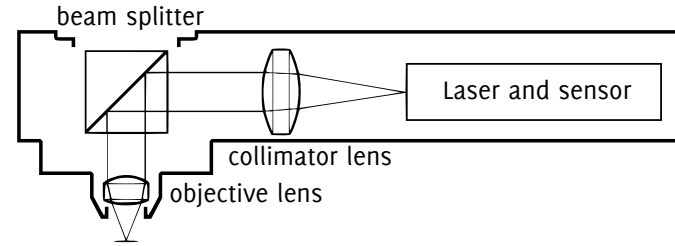


# NPS6D200 + Laser Focus Sensor

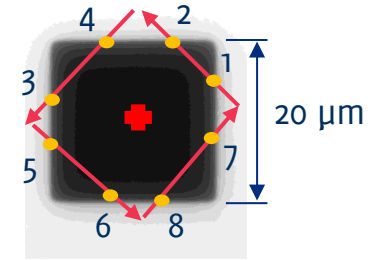
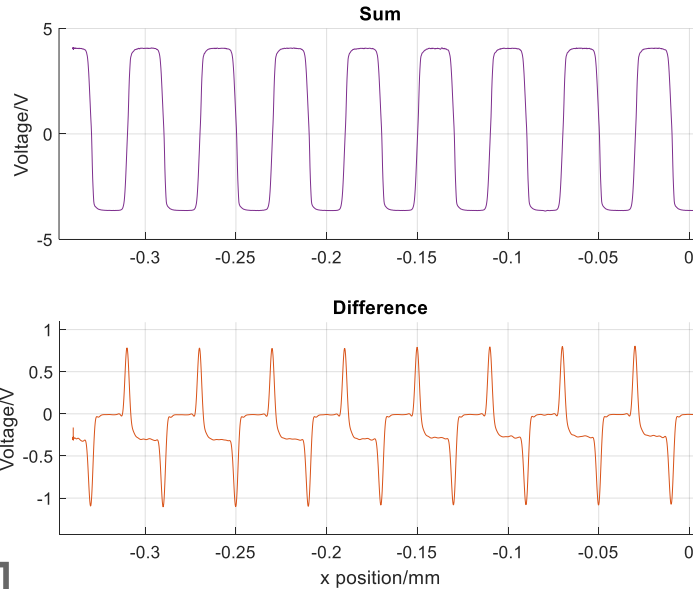
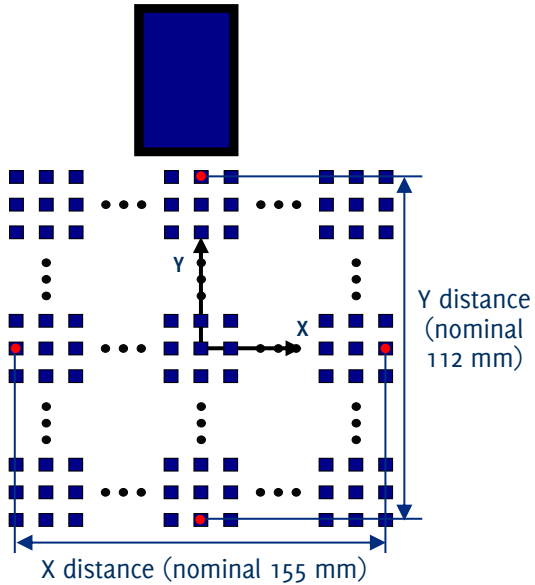


# Laser Focus Sensor

- 1 nm resolution
- 3  $\mu\text{m}$  measuring range
- Intensity dependence related to reflectivity



# Laser Focus Sensor + Cross Grid – Measuring Distances



$$X_{cp} = \frac{\sum_{n=odd} X_n}{4}$$

$$Y_{cp} = \frac{\sum_{n=even} Y_n}{4}$$

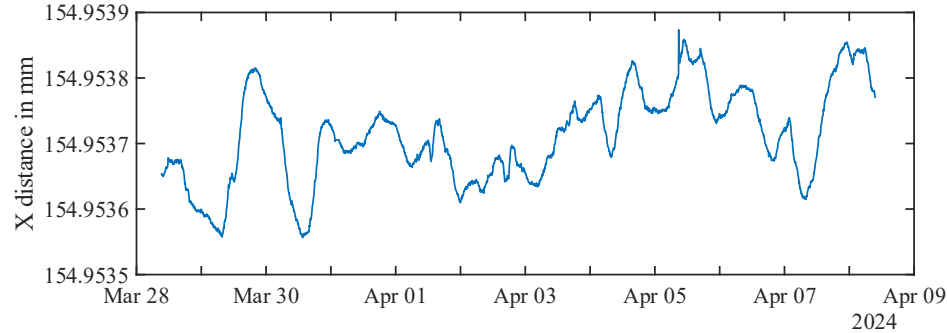
$$X_{distance} = X_{cp1} - X_{cp2}$$

$$Y_{distance} = Y_{cp1} - Y_{cp2}$$

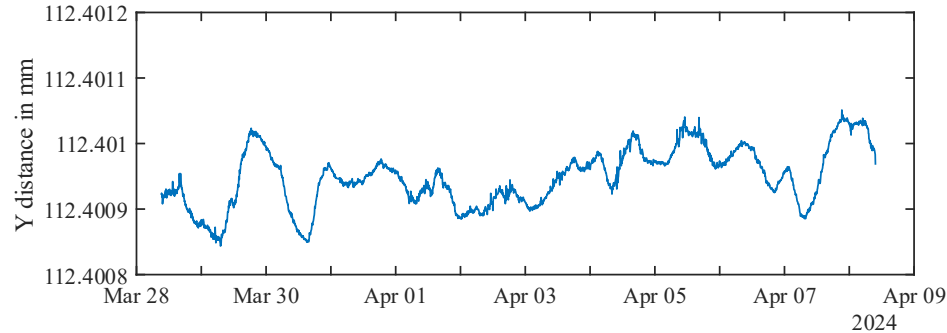
D A Brasil et. al. (2009) <http://dx.doi.org/10.13140/RG.2.2.15730.68808>

# NPS6D200 + Laser Focus Sensor + Cross Grid – Results

- Continuous measurements – 11 days with each targeted square measured every 5 minutes

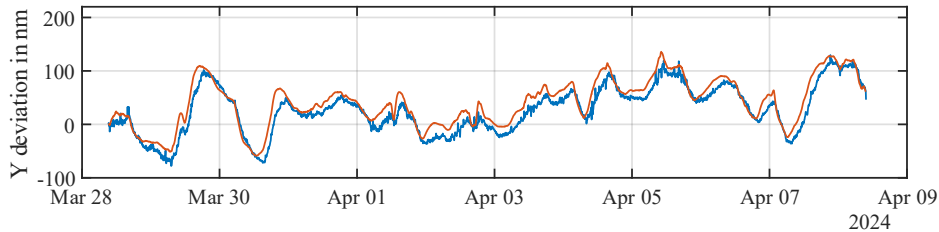
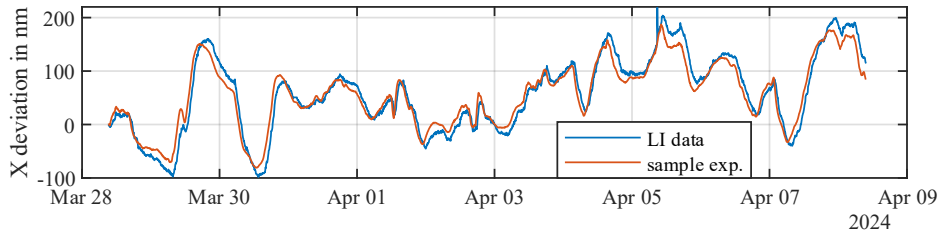
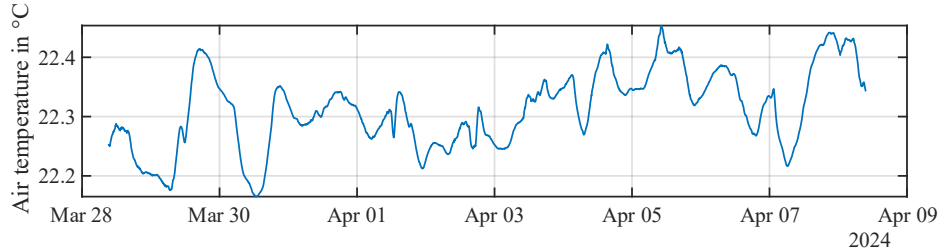


X standard deviation – 70.8nm

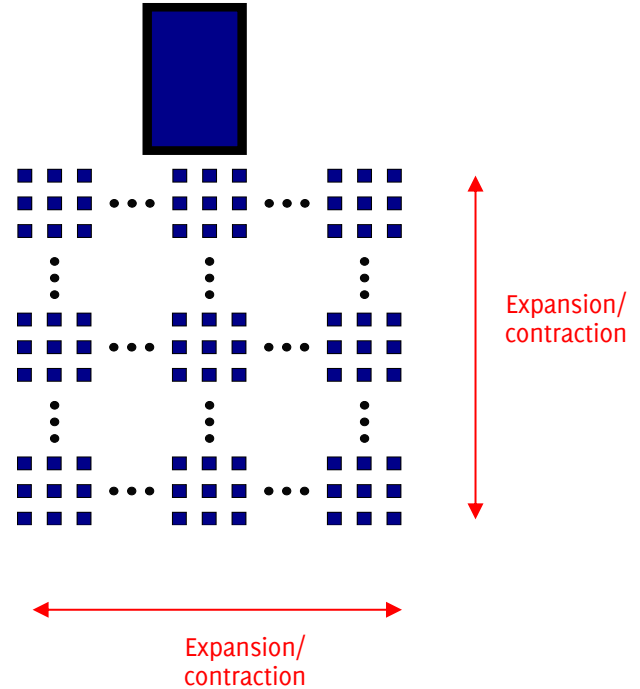


Y standard deviation – 44.3nm

## – Sample temperature – biggest influence

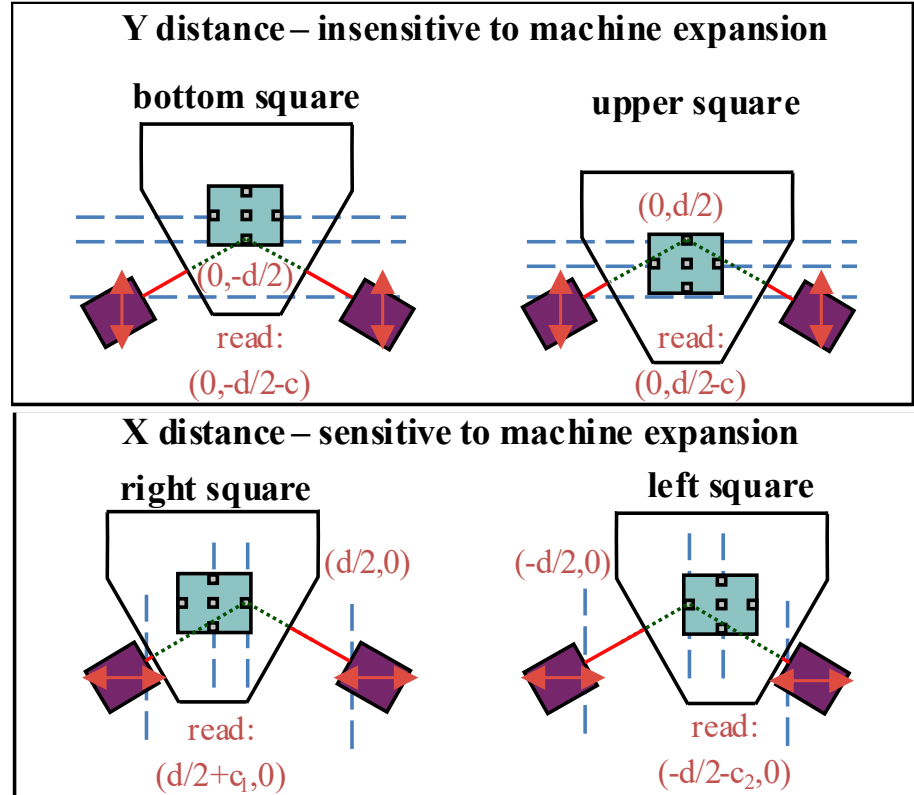
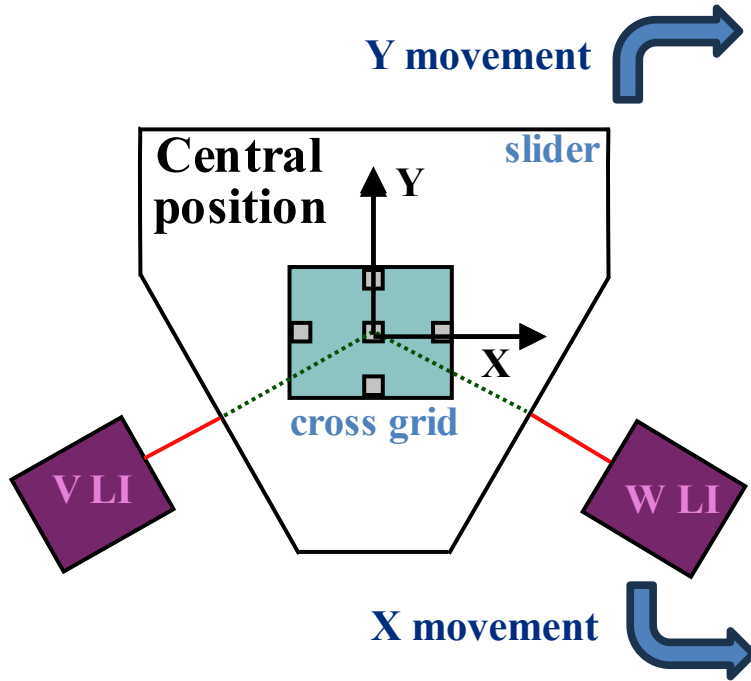


$$\text{CTE} = 6 \times 10^{-6} \text{ K}^{-1}$$



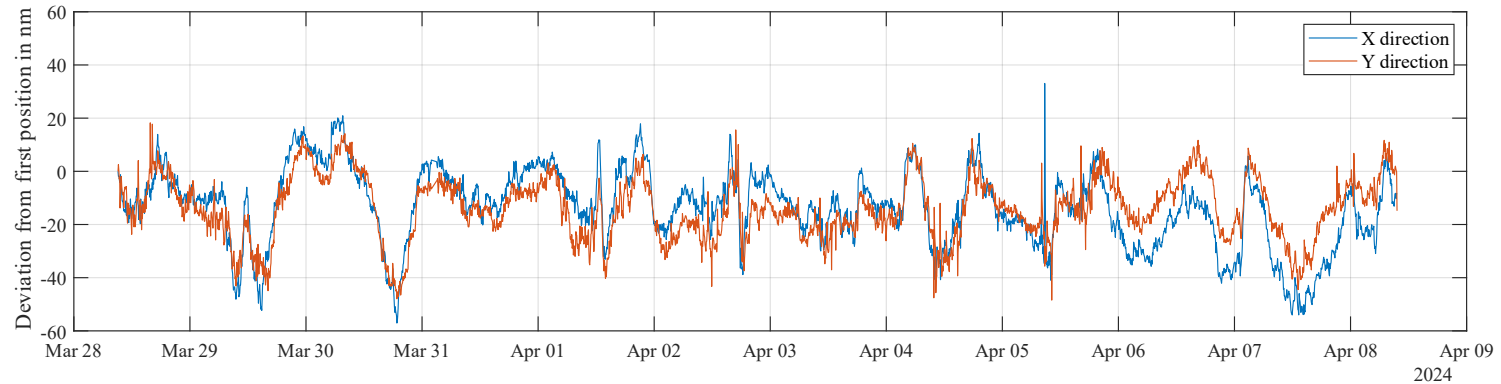
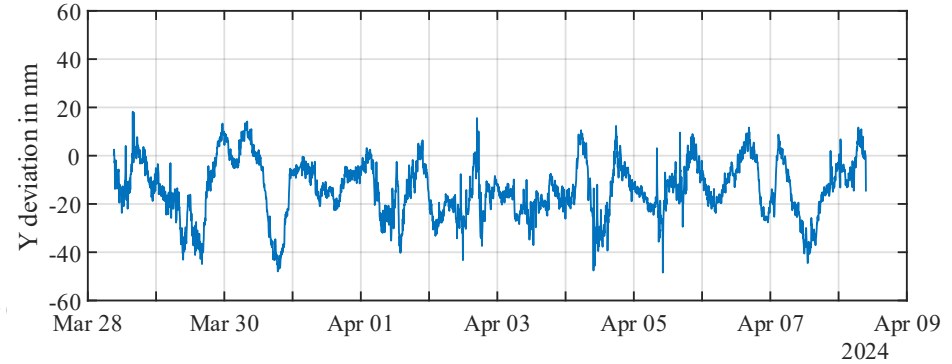
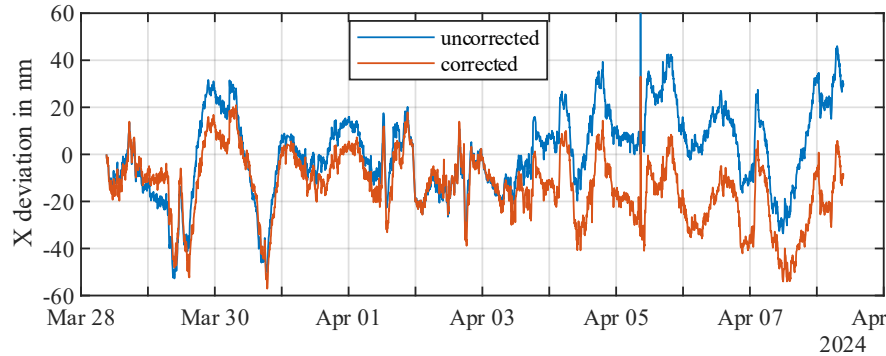
# NPS6D200 + Laser Focus Sensor + Cross Grid – Results

- Machine expansion (granite stator)



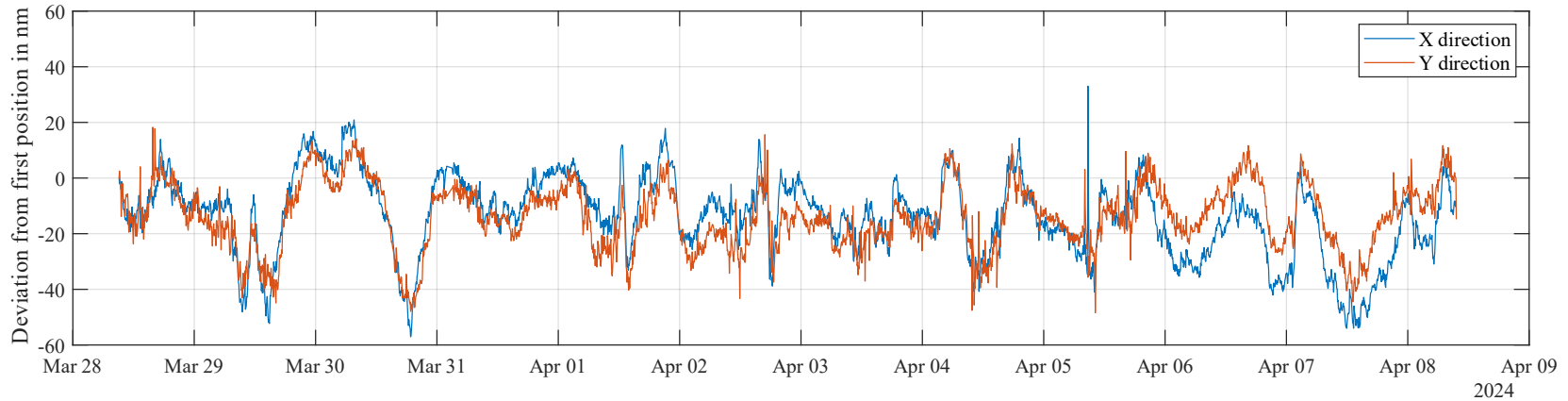
# NPS6D200 + Laser Focus Sensor + Cross Grid – Results

## — Machine expansion



## NPS6D200 + Laser Focus Sensor + Cross Grid – Results

- Standard deviation **14.4 nm** and **12 nm** for X and Y scale distances respectively
- 1 day oscillation: from **20 nm** to **70 nm**



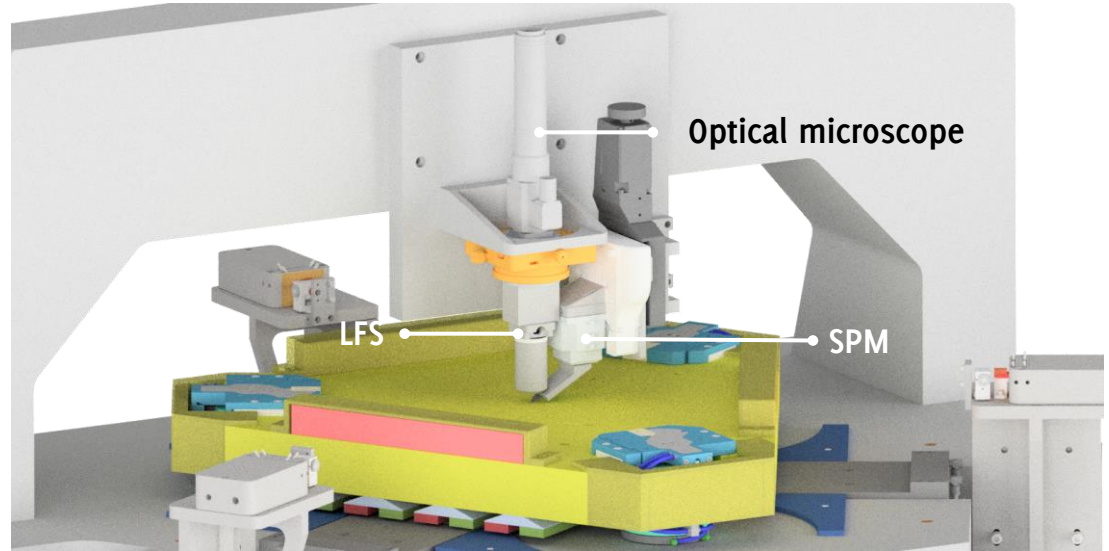
## Conclusion

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- NPS6D200 + LFS + Cross Grid
  - Potential capability to measurements and fabrication with nanometers precision
  - Good repeatability for 11 days
    - Standard deviation of 14.4 and 12 nm for X and Y scale movements
  - Big oscillation in 1 day from 20 to 70 nm (deeper investigation needed)
  - Fast measurements performance
  - Alternative to avoid structural changes influence: Virtual Metrology Frame

## Integrated multitool probing system

- Optical microscope
  - Large-area inspection
  - Visualization of ROI
- Laser focus sensor
  - Contactless probing
  - High-speed measurements
- Scanning probe microscope (SPM)
  - Long-range for SPM scan
  - High performance in measurements and fabrication



# Acknowledgments



Deutsche Forschungsgemeinschaft (DFG) in the framework of the Research Training Group “Tip- and Laser-Based 3D-Nanofabrication in Extended Macroscopic Working Areas” (GRK 2182) – DFG

Project No. 274711337



We would like to work with you on the next ideas for the future!



**IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH (IMMS GmbH)**

Ehrenbergstr. 27, 98693 Ilmenau, Germany, Tel: +49 3677-8 7493 00, Fax: +49 3677-8 7493 15, [www.imms.de](http://www.imms.de)

**Davi Anders Brasil**, [davi-anders.brasil@imms.de](mailto:davi-anders.brasil@imms.de), Tel. +49 3677 - 8 74 93 64