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INSTITUT FÜR MIKROELEKTRONIK- UND MECHATRONIK-SYSTEME GEMEINNÜTZIGE GMBH

GS10-08

Investigation of distance measurements reproducibility for a long-range nanopositioning machine combined with a laser focus sensor

Ilmenau, 26.10.2024

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TECHNISCHE UNIVERSITÄT ILMENAU

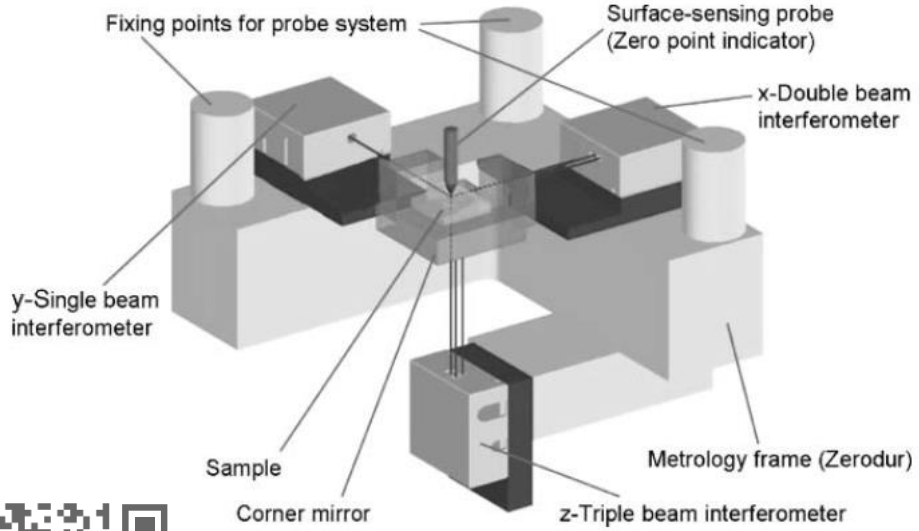
Background and Motivation

Nanopositioning machines

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

Targets

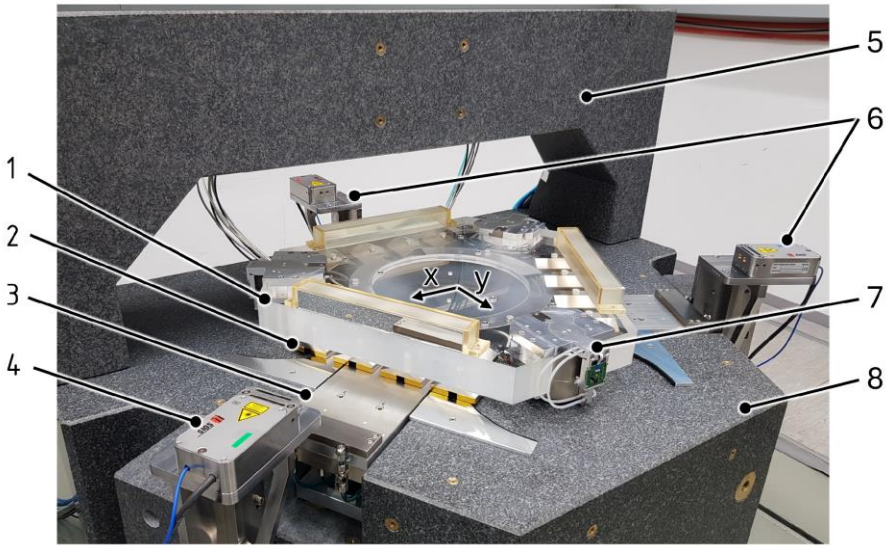
- 6D controlled movements
- Long range measurements and fabrication
  - More than 50 mm x 50 mm (planar)
- Multitool and versatile systems
- Sub-10 nm scale



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 [1]	50 mms^{-1}
vertical velocity	2 mms^{-1}
acceleration	250 mms^{-2}
moving mass	36 kg
payload	5 kg
overall dimensions (W × L × H)	1115 mm × 980 mm × 980 mm



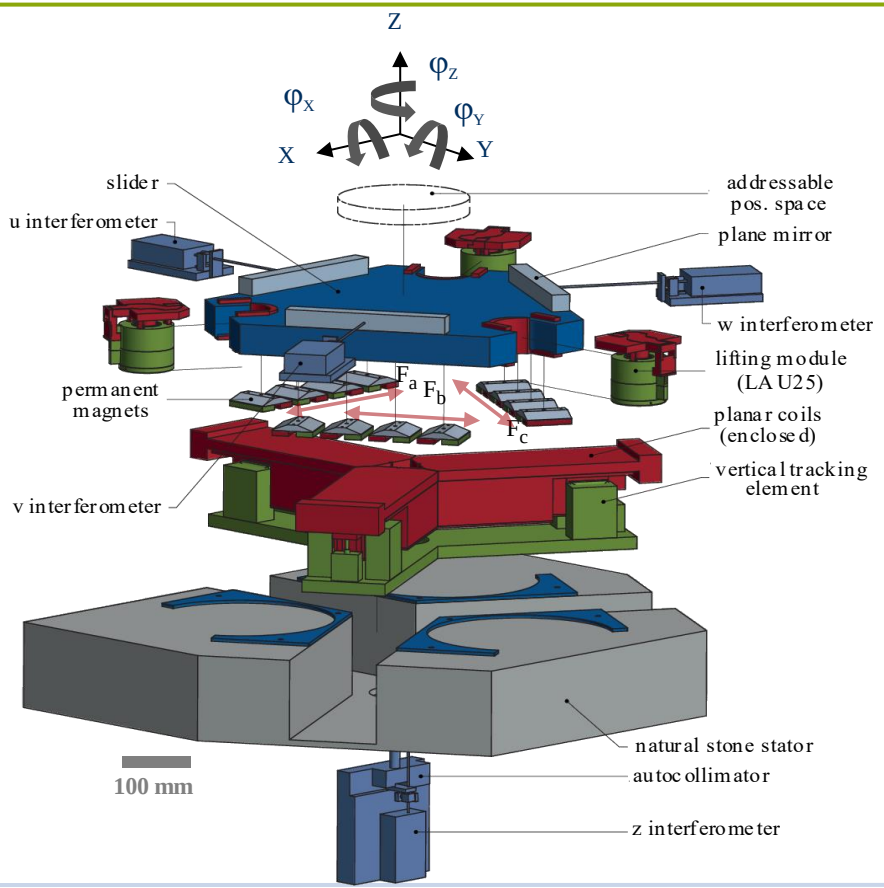
1—slider with reflectors, **2**—magnets of the planar direct drive, **3**—coils of the planar direct drive, **4**—laser interferometer, **5**—granite portal with probe mount interface, **6**—laser interferometer, **7**—lifting module LAU25, **8**—granite base.

- Subnanometric RMS positioning errors

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

NPS6D200 – Specifications

- Nanopositioning platform for Ø200 mm × 25 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.



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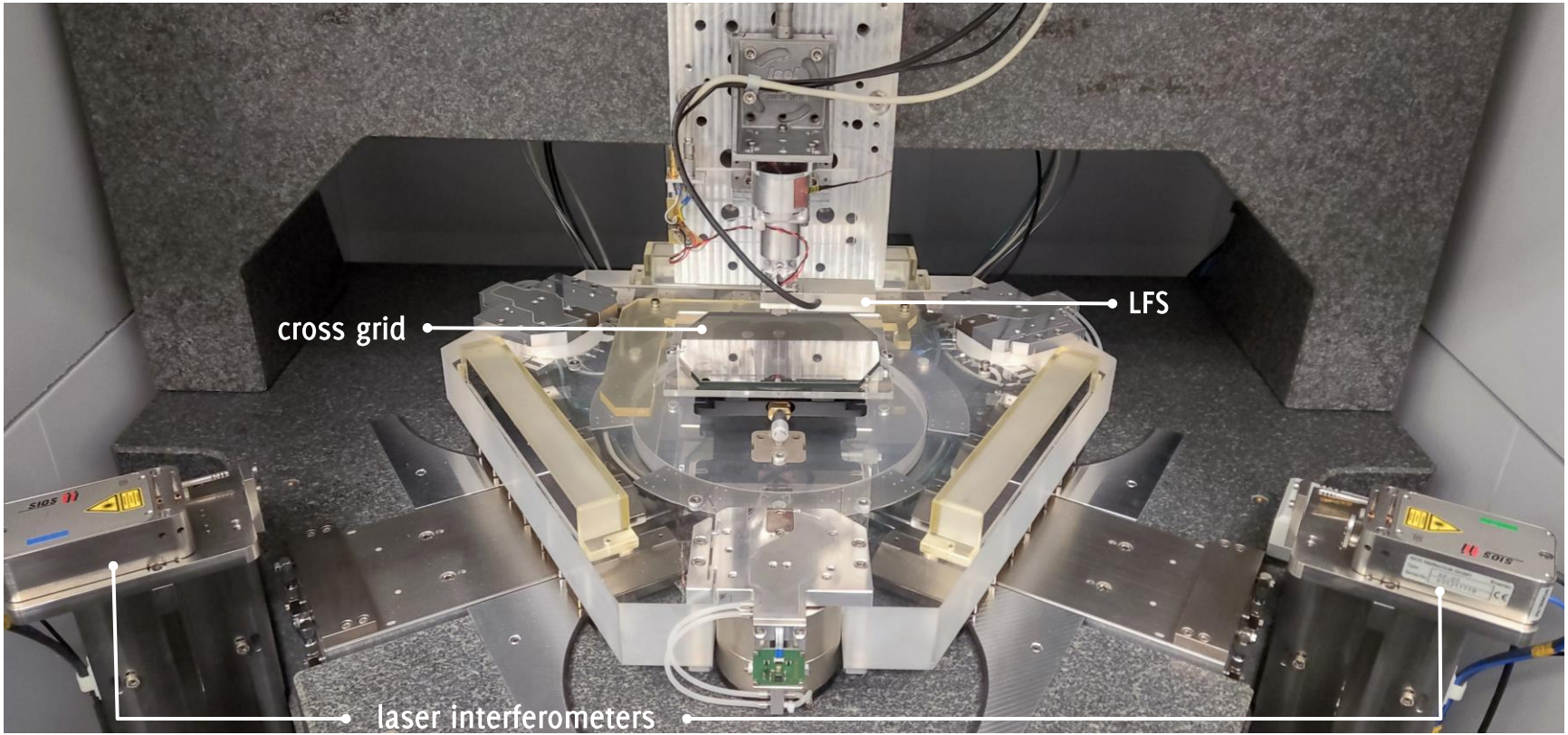
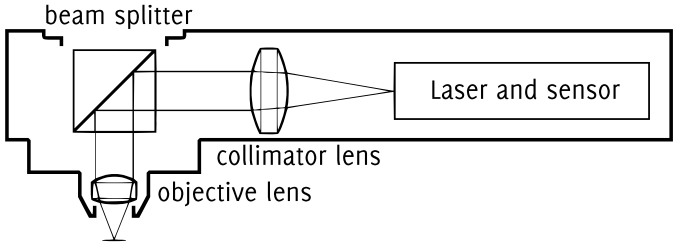
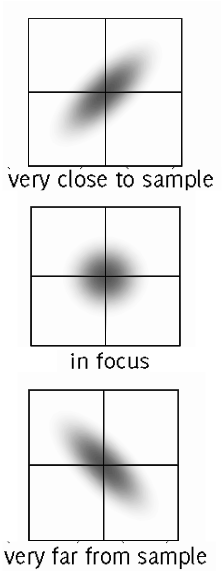
NPS6D200 + Laser Focus Sensor

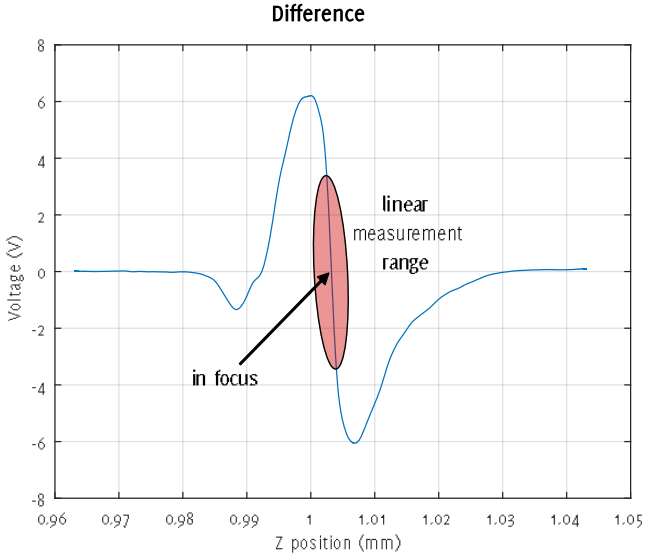


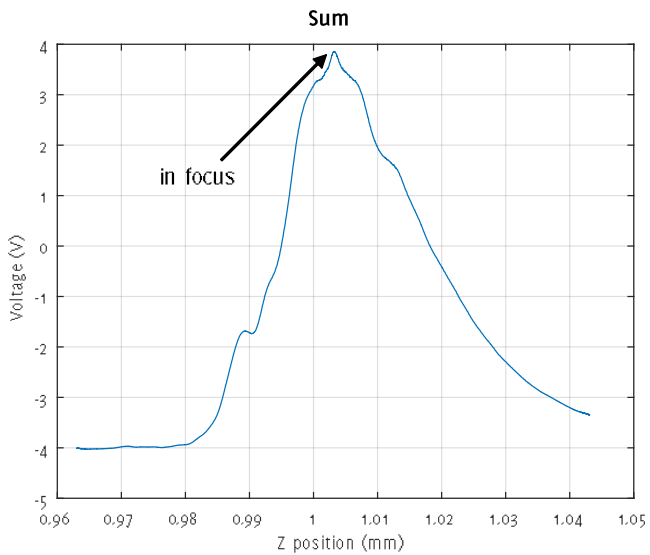
Laser Focus Sensor

- 1 nm resolution
- 3 µm measuring range
- Intensity dependence related to reflectivity

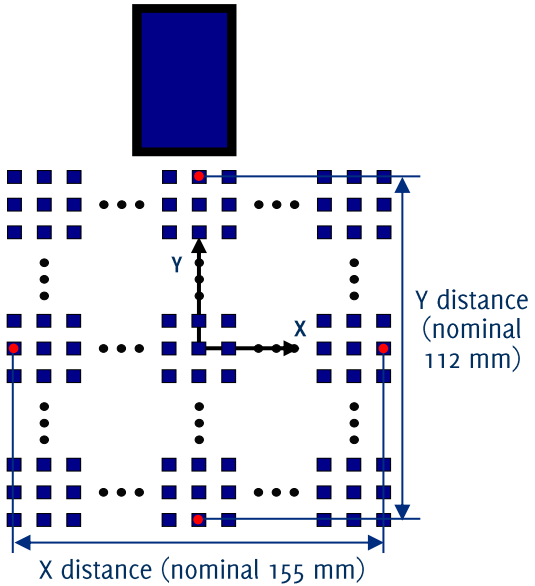


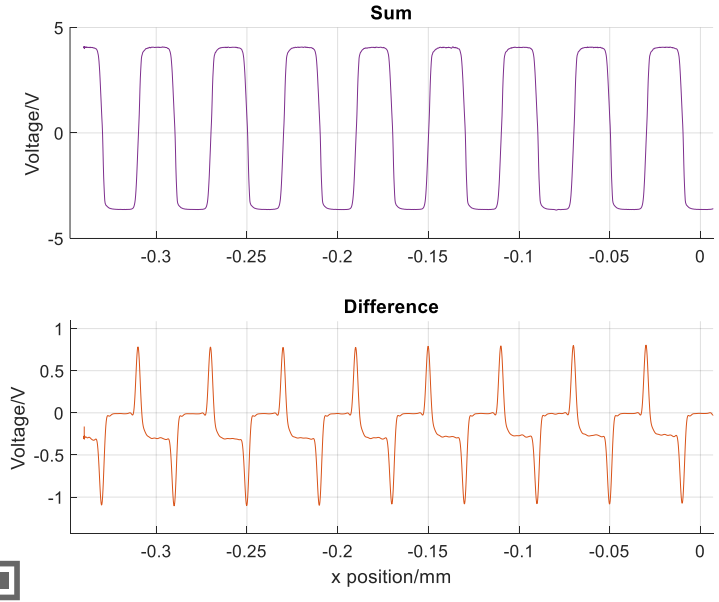


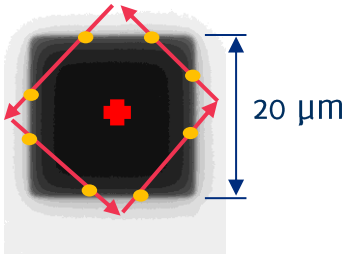




Laser Focus Sensor + Cross Grid – Measuring Distances







$$X_{cp} = \frac{\sum_{i=1}^{8} X_i}{8}$$

$$Y_{cp} = \frac{\sum_{i=1}^{8} Y_i}{8}$$

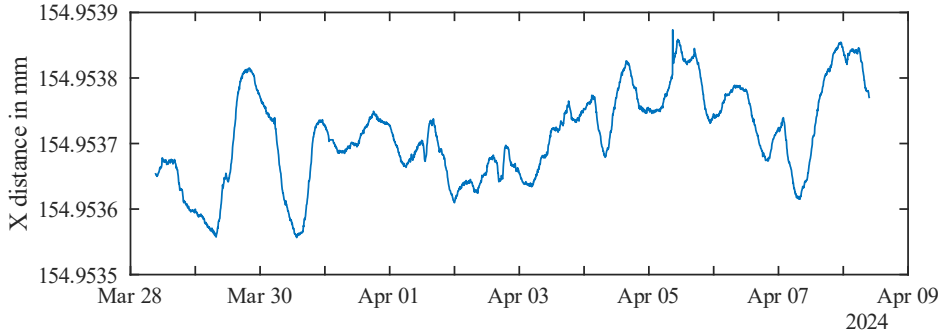
$$X_{distance} = X_{cp1} - X_{cp2}$$

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

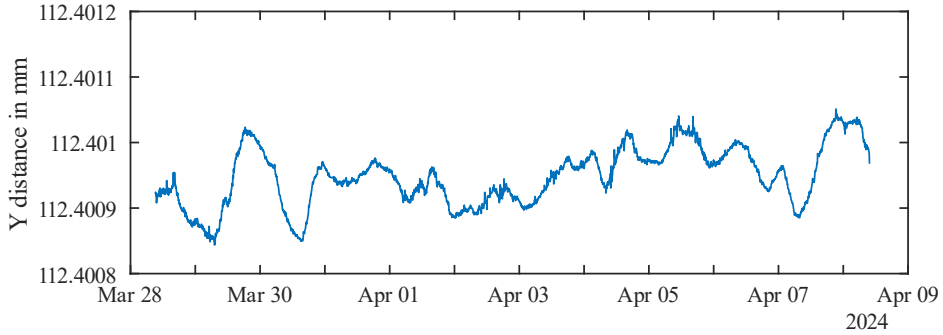
D A Brasil et. al. (2009) http://dx.doi.org/10.13140/RG.2.2.15730.68808

NPS6D200 + Laser Focus Sensor + Cross Grid – Results

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



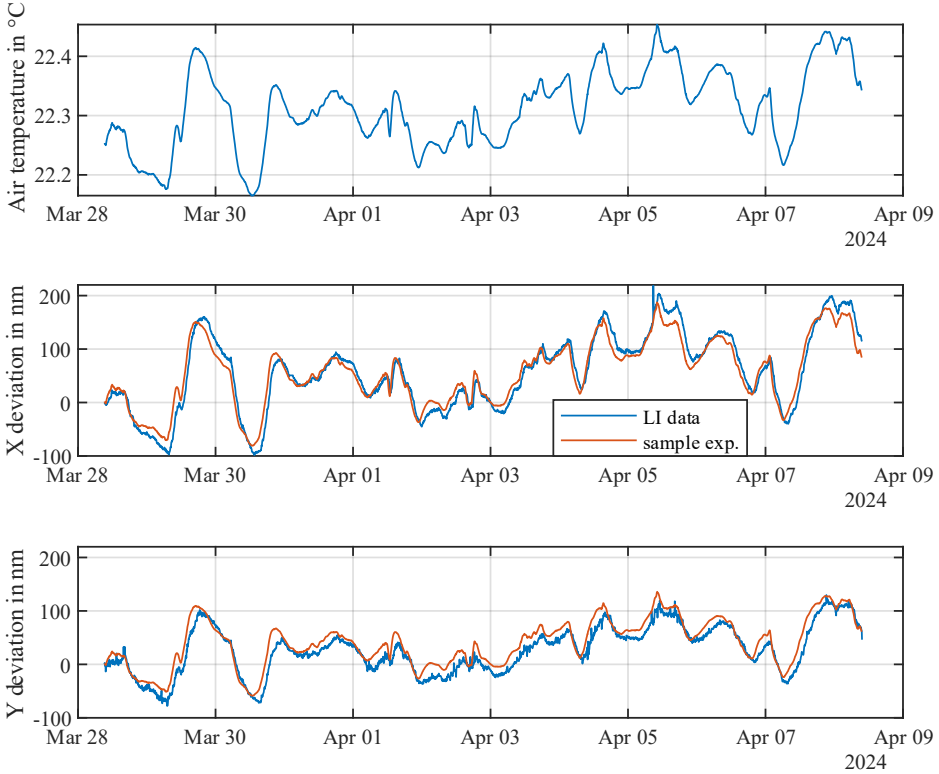
X standard deviation – 70.8nm

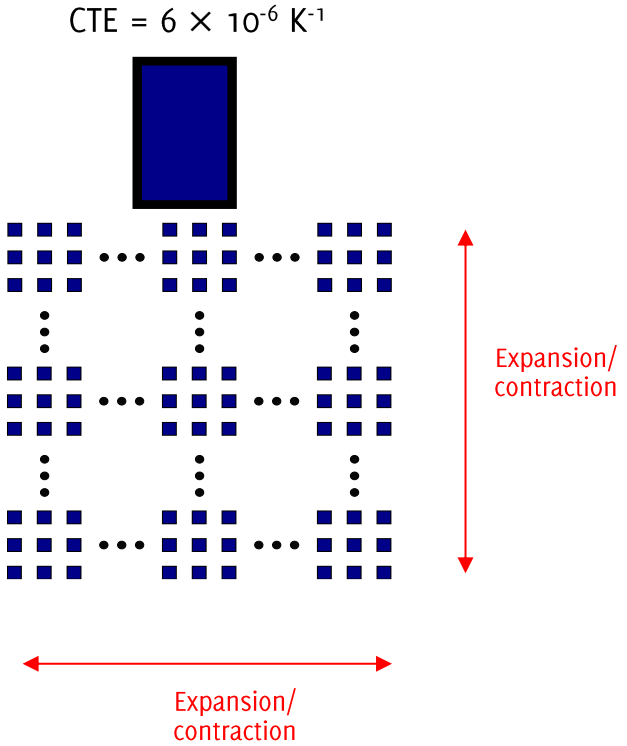


Y standard deviation – 44.3nm

NPS6D200 + Laser Focus Sensor + Cross Grid – Results

– Sample temperature – biggest influence





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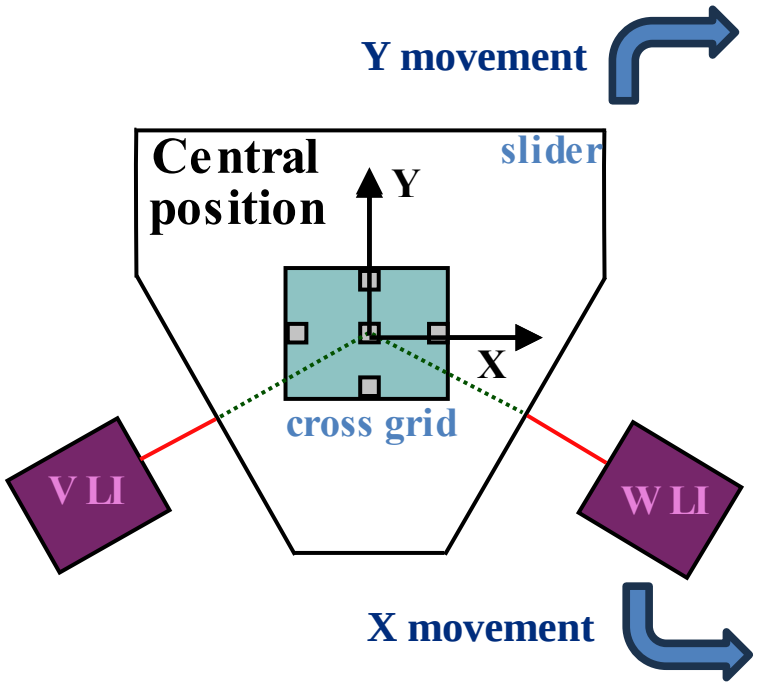
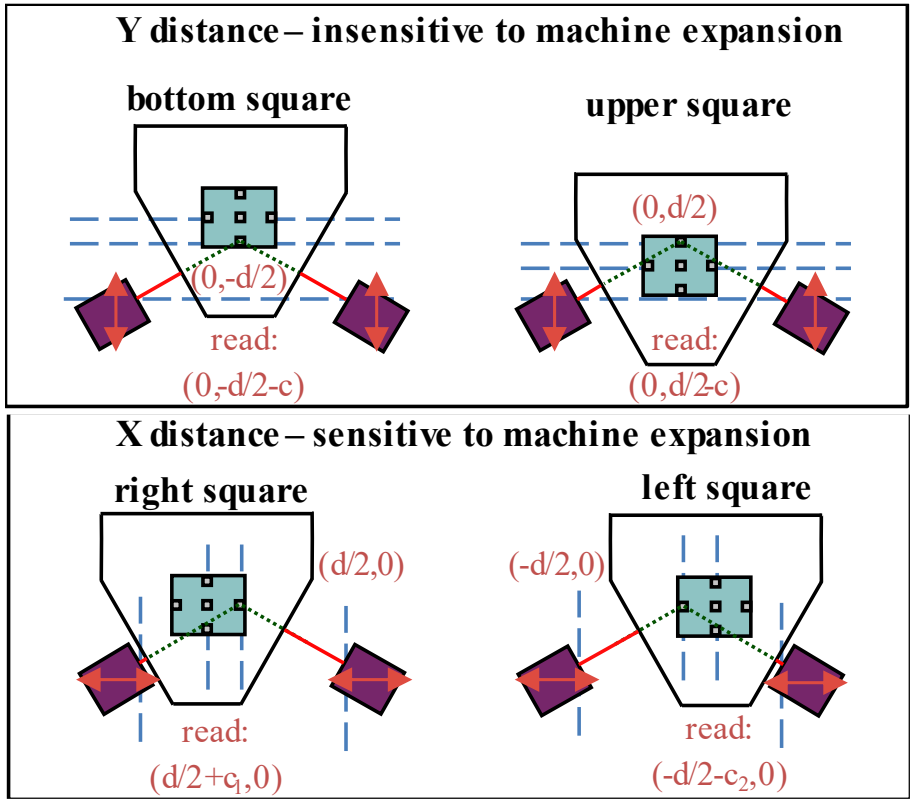
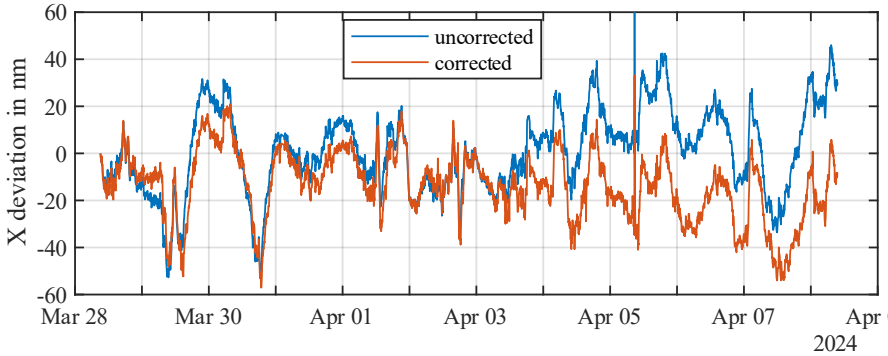
– Machine expansion (granite stator)

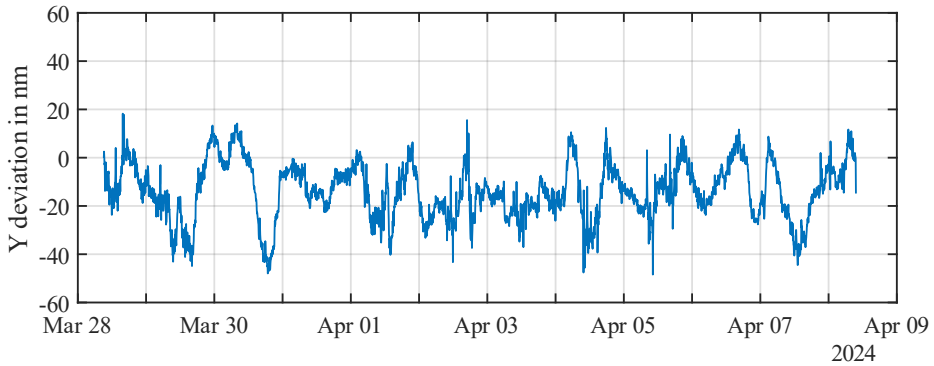


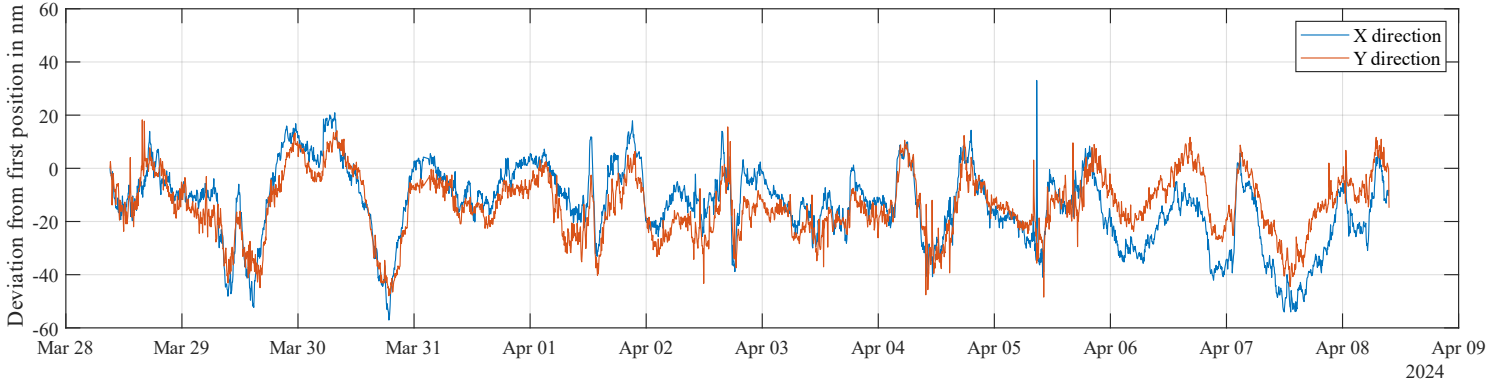


NPS6D200 + Laser Focus Sensor + Cross Grid – Results

– Machine expansion

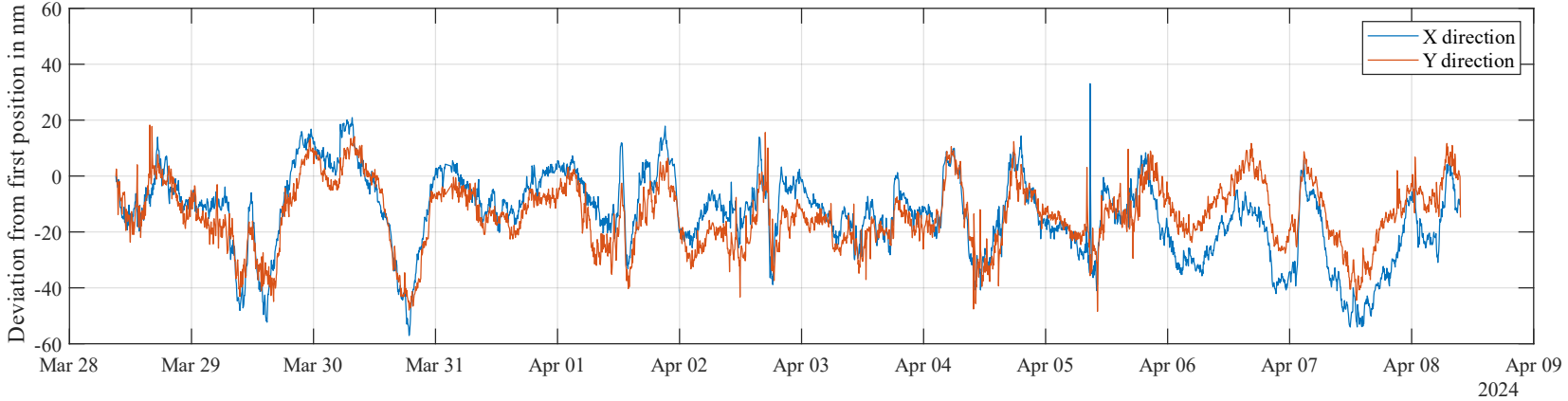






NPS6D200 + Laser Focus Sensor + Cross Grid – Results

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



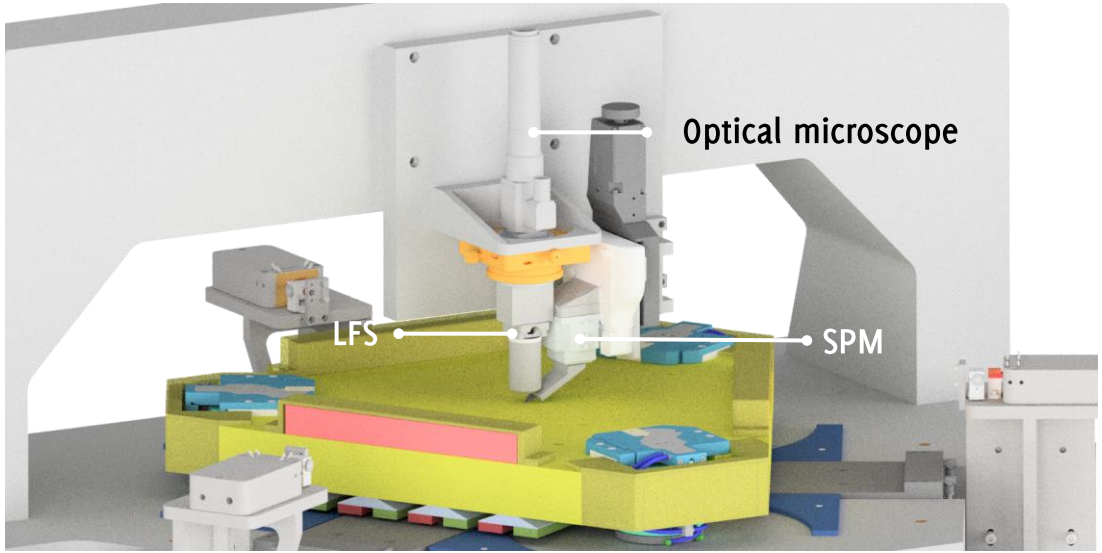
Conclusion

- NPS6D200 + LFS + Cross Grid
  - Potential capability to measurements and fabrication with nanometers precision
  - Good reproducibility for 11 days
    - Standard deviation of 14.4 and 12 nm for X and Y 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

Future Work

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

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

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