CHALLENGES FOR NANOPOSITIONING

Vibration measurements for the nano analytical microscope „PtyNAMi“ at the Beamline P06 at PETRA III

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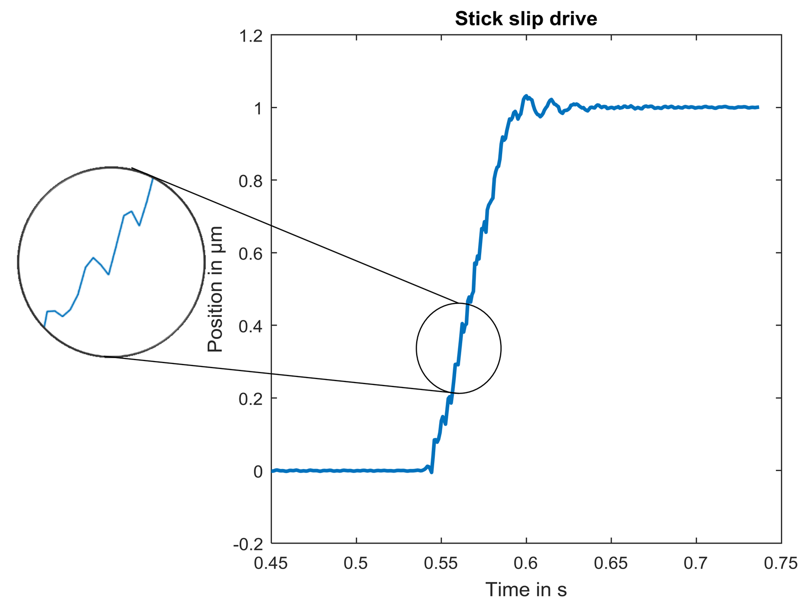
4 DOF SETUP (X, Y, Z + ROTATION)

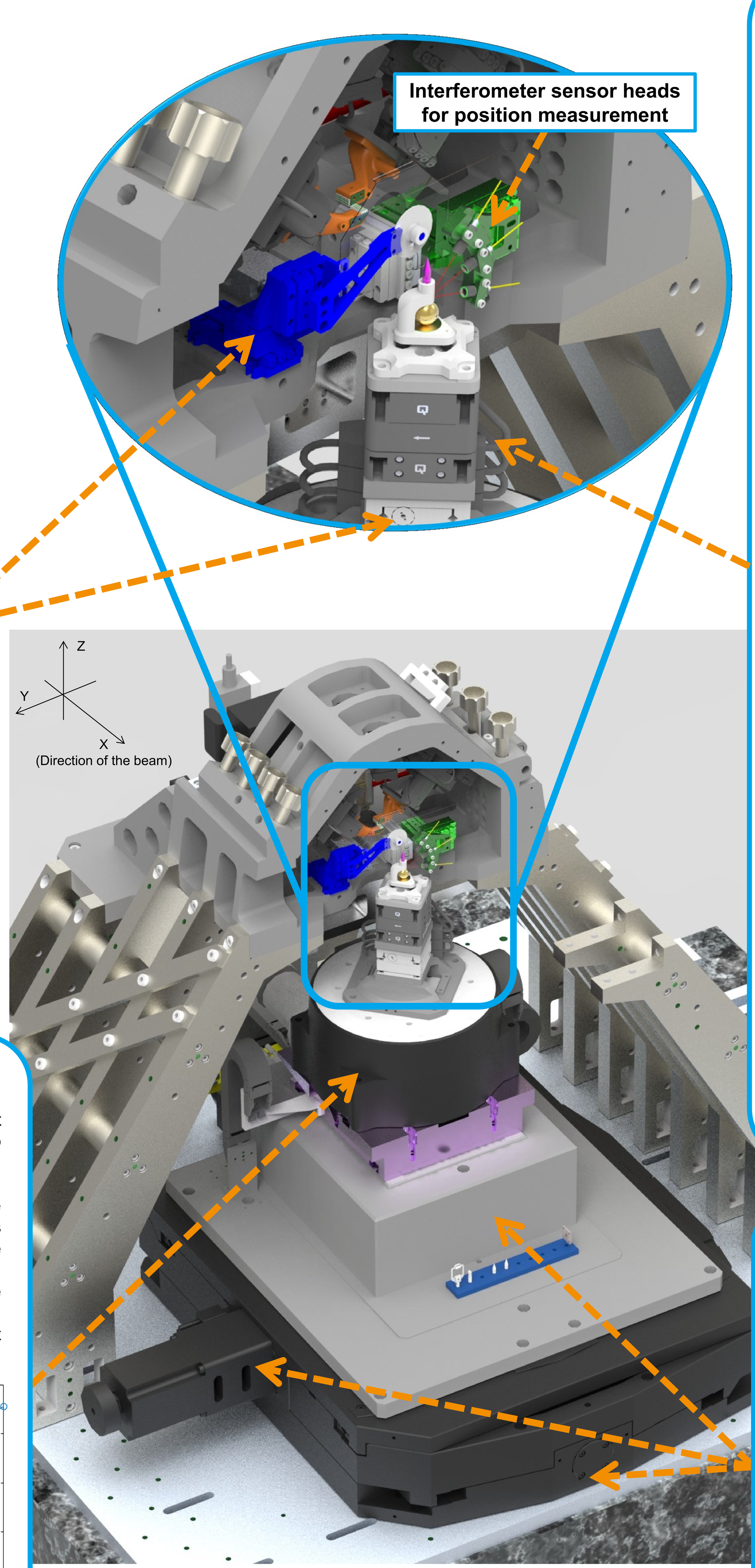
Motivation

For nanometric imaging techniques, the sample, which is moved through the x-ray beam, needs to be stabilized down to a few nanometer and in future even better.To find out, which components produce and which ones transmit vibrations, the setup was analysed by interferometric vibration measurements.

Piezo stepper stages

Due to the stepping mode, these stages provide some millimeters of travel range. The stepping is generated by a stick slip movement of the piezo stack actuator. This is at the same time a disatvantage, if a continious scanning mode is needed, since the stick slip behaviour lets the stage move backwards a few hundred nanometers during one step.

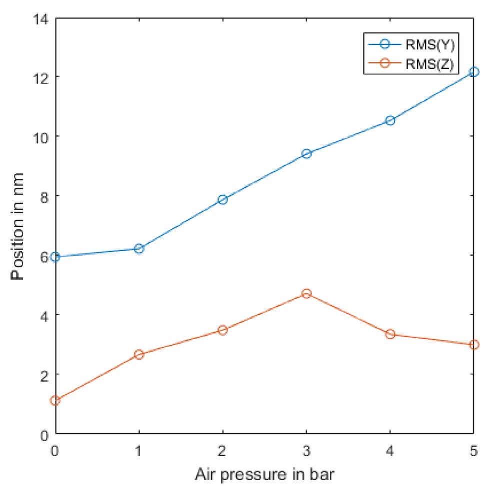


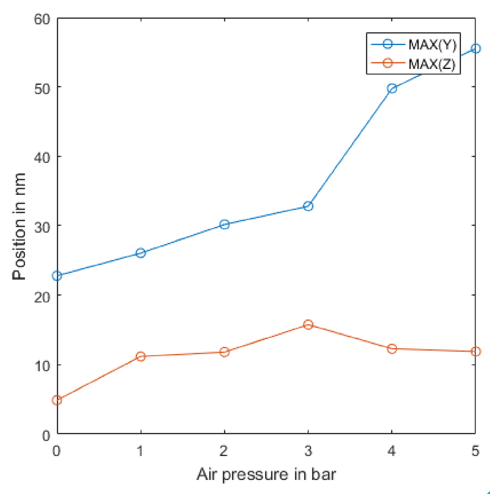


Rotation stage with air bearings

For some measurements with the PtyNAMi setup, the sample need to be rotated at least by 180°. During rotation, the sample has to keep its position inside the x-ray beam. To provide this low eccentricity, a high-precision air-bearing rotation stage is used.

One disatvantage of an air-bearing is, that the air stream generates vibrations. The amplitude of these vibrations depends on the air pressure. The less the air pressure is set, the less are the vibrations. The minimum air pressure, at which the stage can be moved, depends on the mass mounted to the stage. For this setup, the minimum pressure was identified experimentally by reducing the air pressure until the stage couldn't move anymore.
The following plot shows the RMS and maximum vibrations in directions Y and Z at different air pressures.

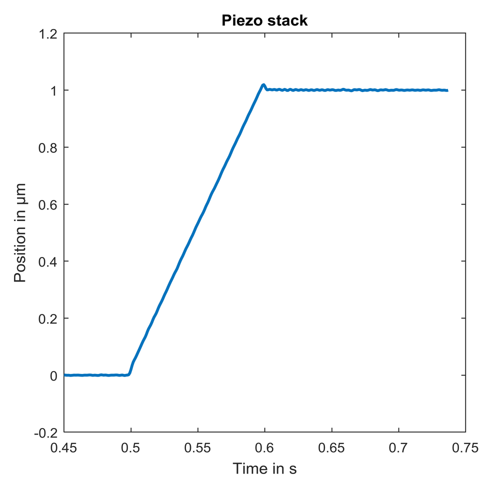


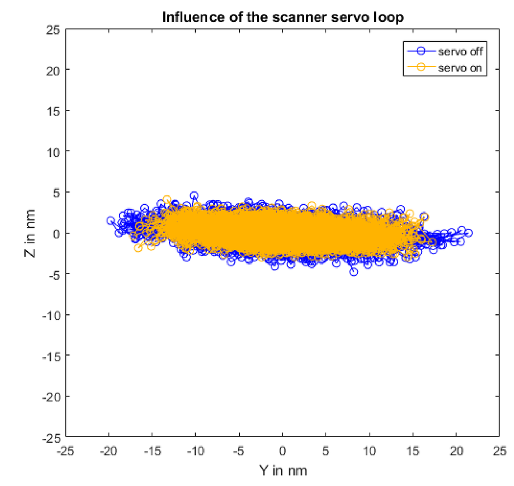


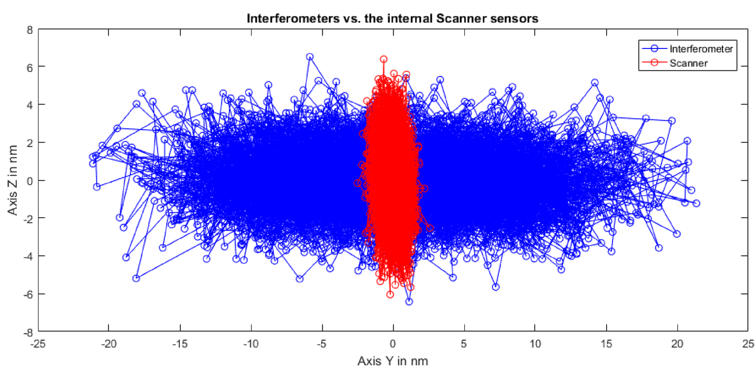
Piezo Scanner with 100 µm travel range in directions X, Y & Z

The scanner provides a smooth positioning behaviour due to an amplified piezo stack actuator without any kind of stepping mode.

With the feedback loop closed, the vibrations decrease only a few nanometers. More important is the fact, that the feedback loop does not cause any new oscillations.

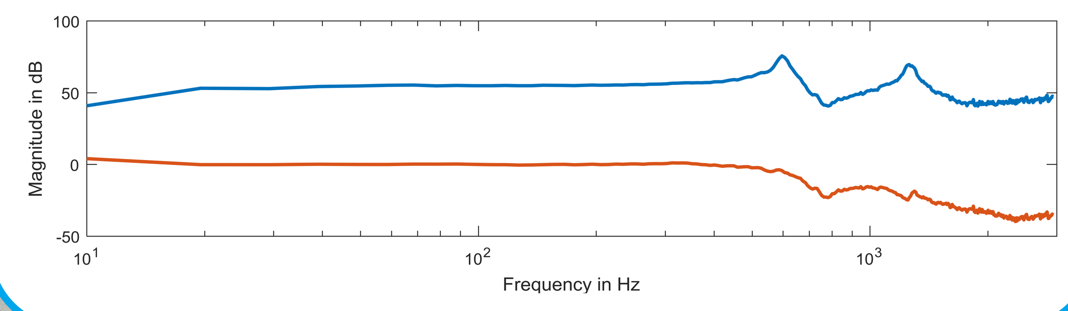






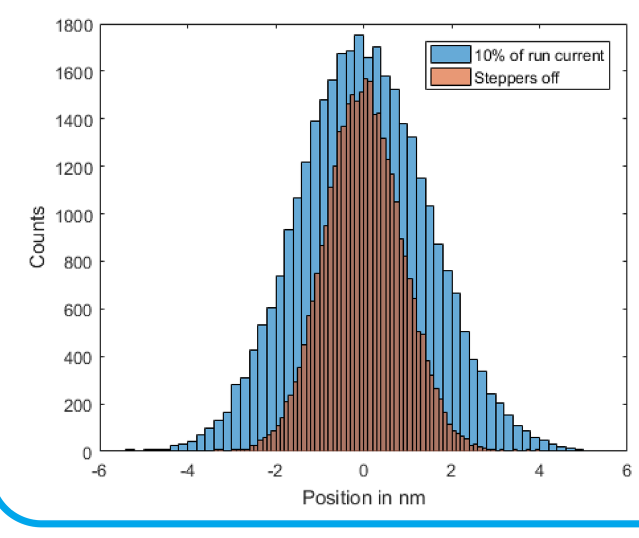
This plot shows the vibrations measured by the interferometers (blue) and the internal scanner-sensors (red). There is around 17 nm amplitude in Y-direction which is not caused by the scanner's flexure joints but somewhere else along the sample tower.

The frequency response of one scanner axis' positioning behaviour is shown below. The blue line represents the plant with two resonance peaks due to the built-in flexure joints. The red line is achieved after compensating the resonances with notch-filters and closing the feedback loop. A closed loop bandwidth of 600 Hz is reached.



Stepper motor driven stages for long travel ranges in X, Y and Z direction

Stepper motors are typically driven by a pulse width modulated voltage (PWM amplifier). This rectangular signal induces vibrations in each mechanical system, that is not absolutely rigid.



At a test setup, that has similar characterisitics than the experimental setup, the vibration of the steppers were measured once with a stop current of 10% of the run current and once with the steppers turned off completely. The motors were not moving during the measurement. As the histogram shows, the steppers produce some nanometers of aditional vibration amplitude.

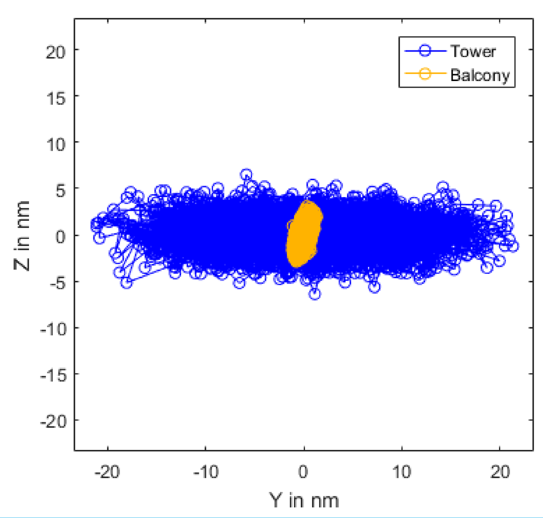
3 DOF SETUP (X, Y, Z - 100 µm TRAVEL RANGE)

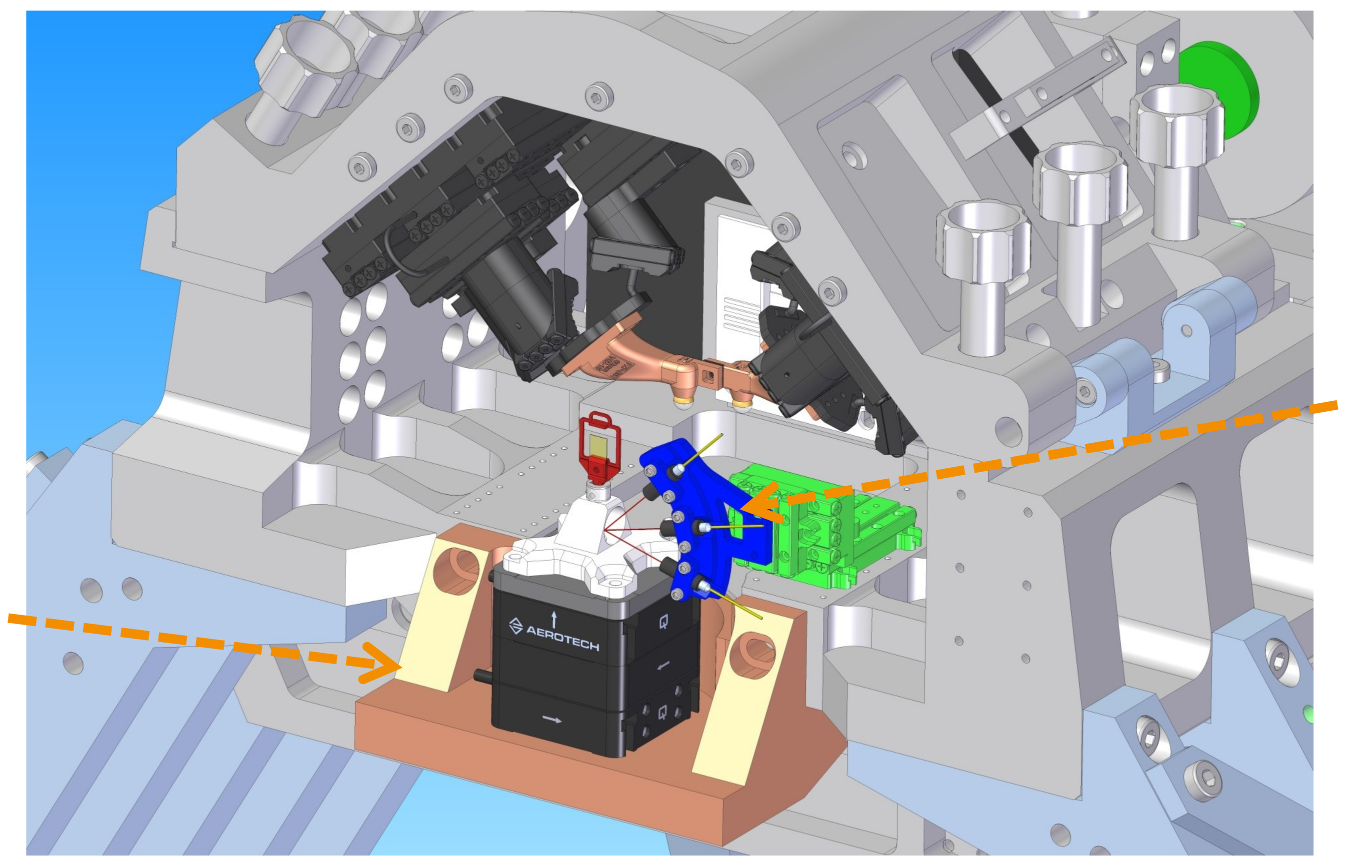
Motivation

With the so called „balcony-setup“, the scanner is mounted directly to the optic's environment to minimize the relative movement between the sample and the x-ray lenses. In this configuration, it can only be moved in directions X, Y and Z with a travel range of 100 µm each, but not be rotated anyhow.

Improvement of stability

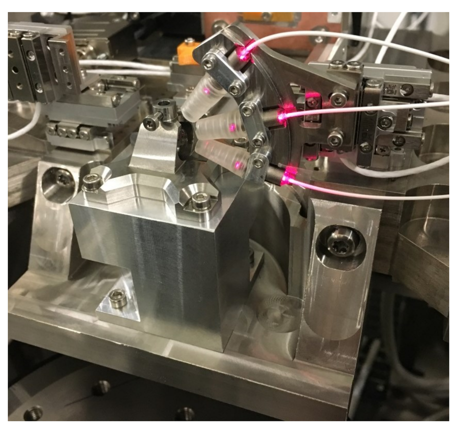
The plot below shows the vibration amplitudes of the balcony setup compared with the sample tower with 4 DOF and larger travel ranges. The amplitude of 20 nm in Y-direction is decreased down to around 3 nm.





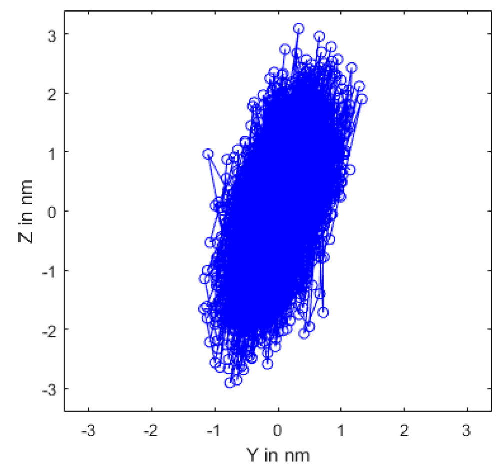
Interferometric position measurement

Three Interferometer sensor heads measuring on a ball shaped retro-reflector. The sensors are adjustable in X, Y and Z by piezo stick slip drives.



An aluminum dummy replaces the scanner to measure the stability of the holder without the influence of the scanner's flexure joints.

The vibration ampltitudes are the same than with the real scanner axes. For further reduction of vibrations within the position measurement system, the stability of the holder and the piezo stages need to be investigated closer.



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