Quality Control of Precision Motion Systems

Determination of Pitch, Yaw, Roll, and further Performance Acceptance Criteria

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Introduction

Precision linear motion positioners, such as *e.g.* direct magnetic drives, can achieve nanometer accuracy along the axis of translation (1 Degree of Freedom; 1 DoF). However, linear drive technologies inevitably show various motion errors like pitch, yaw, and roll, as well as vertical and horizontal runouts, often in the mrad or µm range, respectively.

These motion errors are critical for on-the-edge applications such as in semiconductor or photonics processing, as they can jeopardize the accuracy within the whole machine. This is especially true for multi-axis motion setups. To reliably fulfil the performance requirements of such industries, suppliers of precision positioners must characterize their products to detect even the smallest positional errors and ensure the highest quality.

attocube's IDS3010 multi-axis laser interferometer is ideally suited to perform such challenging measurements in a variety of quality acceptance tools: certified accuracy, even over long ranges, miniaturized sensor heads, and a broad variety of interfaces allow for flexible integration and full automation.

This Application Note shows exemplary measurement setups, at attocube, where the IDS3010 is used for quality control of nanopositioners. For a better understanding about the achievable results, the characterization of linear nano-positioners with a medium travel range is explained in further detail. The goal is to provide an orientation on how to ensure the highest precision, quality, and reliability for a multitude of positioning systems.

Characterization of Linear Positioners

Figure 1 shows an example for a 6 Degree of Freedom (6 DoF) verification of horizontal linear stages and vertical lifting stages with travel ranges of up to 50 mm. By using two IDS3010 interferometers, with a total of 6 channels, all angular and linear deviations can be measured.

The nanopositioner is placed in the center of the setup, an attached mirror target allows for the continuous measurement of the motion errors over the entire travel range of the nanopositioner.

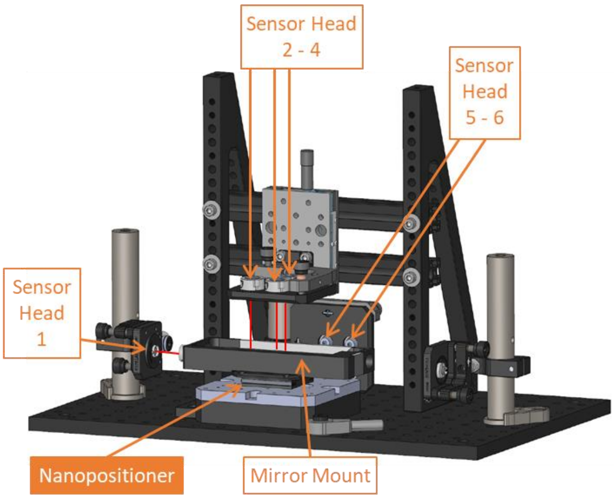

Figure 1: Characterization of linear nanopositioner with travel ranges up to 50 mm based on mirror targets

The measurement results in Figure 2, over a travel range of 30 mm, show the high precision of the measurement system and typical angular and lateral deviations of the analysed ECSx3050 nanopositioner.

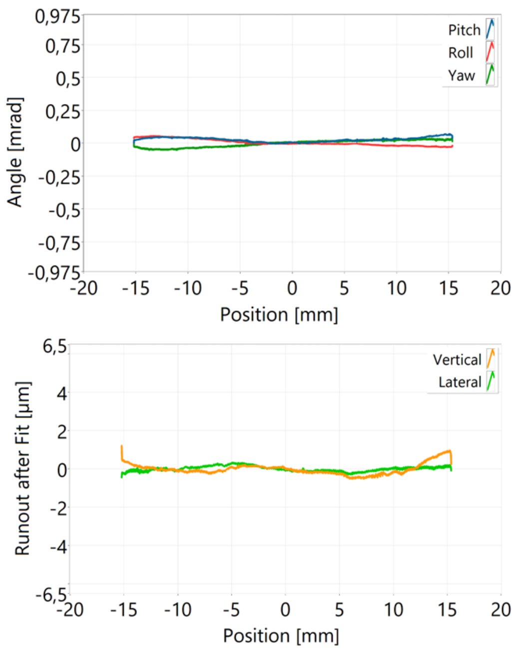

Figure 2: Angular deviations and lateral runout of an ECSx3050 nanopositioner

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While high quality mirrors allow for the most extensive and accurate characterization possibilities, the setup complexity can be reduced by using retroreflectors. Along the axis of translation, retroreflectors allow for even larger measurement ranges of over 1 meter. However, such long-range setups are limited to 3 DoF characterization, as retroreflectors limit the lateral movement to only a few millimetres. Therefore 6 DoF measurements are only possible for positioners with small motion ranges. Figure 3 shows a linear scanner measurement setup, which is designed for scan ranges of only up to 125 µm.

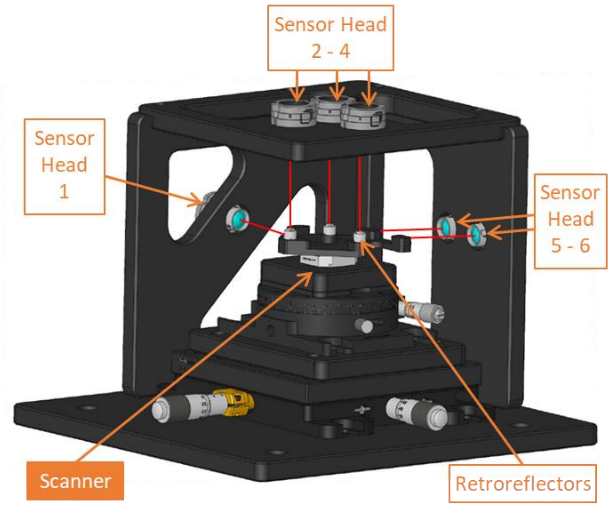

Figure 3: Characterization of linear scanners with travel ranges up to 125 µm based on retroreflector targets

The measurement results of the scanner test setup are very similar to the displayed data in Figure 2, aside from the much shorter travel range. In both setups, the nm repeatability of the positioner or scanner can be verified, as the interferometer offers much higher resolution and accuracy than any positioner integrated encoder.

Versatile Acceptance Testing

In addition to 6 DoF characterization of linear stages, the IDS3010 can also be used for acceptance testing of multiple other motion systems, such as angular tilting positioners or rotators. Figure 4 shows a setup which verifies the angular accuracy of goniometers and characterizes the wobble of rotation positioner, which is essential for demanding sample positioning applications in, for example, x-ray tomography tools.

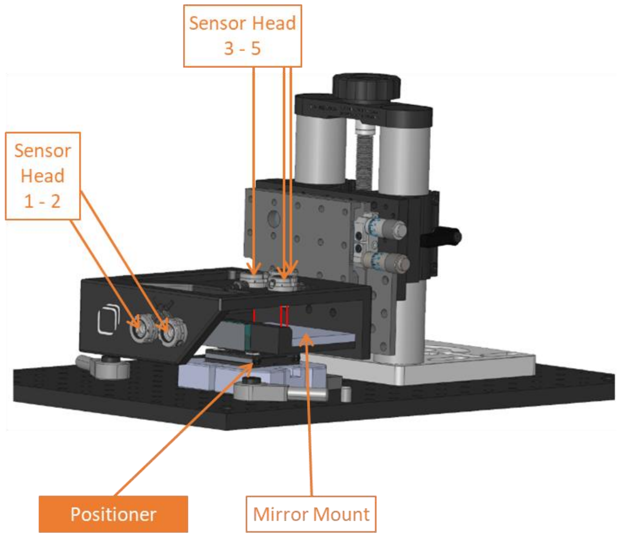

Figure 4: Characterization of goniometers and rotation positioners based on mirror targets

Furthermore, sub-nm resolution and the high measurement bandwidth of the IDS3010 allow for sophisticated vibration analysis of multi-axis setups, leading to valuable information about the control behavior, the in-position jitter, and the mechanical properties of the system. This can ensure the highest position stability and reliability as *e.g.* required for ultra-precise beam alignment applications. The IDS3010 is even able to characterize single positioners or multi-axes positioners in ultra-high vacuum (UHV) conditions to ensure the needed performance in challenging operating environments.

Conclusion

The modularity and flexibility of attocube's IDS3010 interferometer enable ultra-precise quality control for a broad range of positioning solutions from direct magnetic drives to piezo scanners and positioners. The IDS3010 interferometer offers highly accurate characterization, co-located to the point of interest. In combination with the sensor heads compatibility in extreme environments, this offers true application focused control of acceptance criteria and therefore drives advances in all industries which rely on high performance and quality in precision positioning.