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Operation and performance evaluation of vertical nanopositioners for 10 mm stroke in a 3D lift and tilt test setup

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Abstract

A positioning system that allows for precisely controlled motions on nanometer level is a key prerequisite for many high tech applications not only in semiconductor fabrication. In this context the authors investigate the design of long stroke nanopositioning systems based on a planar drive approach and realized systems for Ø100 mm xy-travel range [1]-[4]. Ongoing research focuses on the integration of vertical actuation into such systems which enables more functionality and higher accuracy due to the ability to compensate for flatness deviations and to consistently touch the probe with minimum Abbe-error. However this adds complexity to the mechanical system and the control system as well as additional disturbances and might also lead to significant heat introduction into the operation space. With this background integrated lifting and actuation modules (LAU) for 10 mm vertical stroke were developed, combining a voice-coil actuator with a pneumatic weight force compensation and an aerostaic guiding in one compact design [5]. The threefold implementation of such LAU into a planar nanopositioning system will enable vertical displacement of the slider requiring full 6D closed loop control. In a first realization step the LAU were set up and operated individually in a single device test setup. Based on experimental investigations a controller was developed and tuned to achieve subnanometer RMS servo error in closed loop operation [6], [7]. In a subsequent step a three device test setup was realized which allows for 3D closed loop operation adressing z, φx and φy, see Figure 1 *(left)*. The three LAU are placed on the corners of a triangular slider just as with the later connection with a planar drive. Based on interferometer feedback for the displacement in z and AKF-sensor feedback for φx, φy closed loop control is realized with dSpace realtime control hardware. In this configuration for the z-position of the slider a RMS servo error below 0.4 nm was achieved within the whole 10 mm travel range with an actuator current below 1 mA which confirms the choosen approach for vertical actuation and marks an important intermediate step towards the full 6D implementation, see Figure 1 *(right)*.

The paper presents the design and the function of the LAU and their implementation in the three device test setup. The experimental investigation of the characterisics of the 3D LAU arrangement is

described such as the analysis of the transfer behaviour and the closed loop positioning performance regarding the three actuated DOF. The characteristics of the pneumatic subsystem and the influence of different operation modes with constant or variable pressure setpoint are explained. In conclusion an outlook is given to the 6D-system which will arise from the connection with a Ø100 mm planar nanopositioning system.

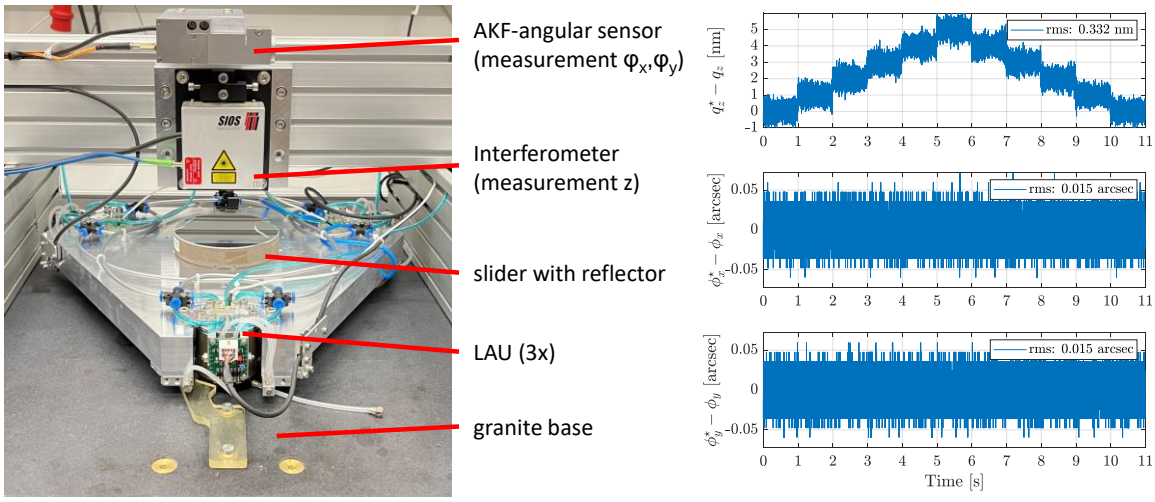

Figure 1: Photograph of the 3D test setup *(left)*;
Raw data of z, φx, φy time series for 1 nm vertical steps in 3D closed loop control *(right)*

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