NPS6D200 - Realization of high precision long stroke vertical actuation in conjunction with a planar direct drive

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Abstract

Ongoing research in the field of nanotechnology and nanoscience has led to the advancement of the associated technologies down to the sub 10 nm range [1]. Beyond the semiconductor industry, this trend is driven by the growing field of nano applications and research activities at nanometer level, like nanofabrication, nanooptics, biosensing, and quantum devices. Also, in ultra precision production of mechanical components, optical inspection or the qualification of sensor systems, the requirements are shifting from a few tens of nanometers to the single-digit nanometer range. This drives the need for multiaxial position systems that allow for nanometer precise deterministic movements in large operating ranges. However, this combination holds challenges for the realization of the required positioning stages. Critical factors like long structural loops, mechanical resonances, thermal effects or position dependent changes in the system transfer behavior may limit the achievable performance of conventionally structured positioning systems. With this background, IMMS investigates the realization of nanopositioning stages based on planar direct drives [2], [3]. Latest research focused on the integration of vertical actuation into such systems while maintaining the benefits of the direct drive approach. As a result, this led to the development of lifting and actuation units (LAU) that can be combined with a planar direct drive and serve as high sensitivity vertical drives [4]. A newly developed type of these modules is designed for 25 mm vertical operating range and a payload of up to 15 kg. The poster presents the design and the key characteristics of these lifting modules (LAU25) together with the realized nanopositioning system for ∅200 mm x 25 mm operating range (NPS6D200, see Figure 1 (left)). The overall stage concept, that is also shown in Figure 1 (right), and the different functional subsystems (6D drive, 6D feedback, control system) are explained. The key parameters of the NPS6D200 positioning stage are given in table 1. With this setup the stage achieves servo errors in the low nanometer range both in static setpoint operation and in dynamic 3D positioning tasks, [5].

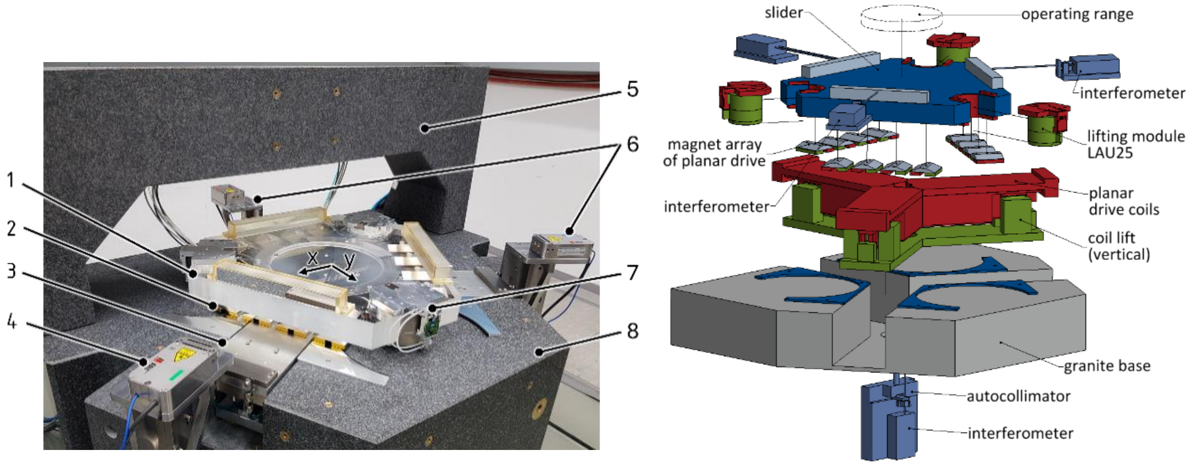

Figure 1: NPS6D200 - Nanopositioning system for ∅200 mm x 25 mm operating range *(left)*; stage concept and main components *(right)*; 1-slider, 2-magnet array, 3-planar drive coils, 4-laserinteferometer, 5-portal bridge, 6-laserinterferometer, 7-lifting module (LAU25), 8-granite base

Table 1: Key parameters of the NPS6D200 positioning system

Travel range:	200 mm x 25 mm	Measurement resolution x, y, z:	20 pm
Velocity planar:	50 mm/s	Measurement resolution φ_z:	1.4 nrad
Velocity vertical:	2 mm/s	Measurement resolution φ_x, φ_y:	40 nrad
Acceleration:	250 mm/s^2	Moving mass:	36 kg
Footprint:	1115 x 980 x 980 mm^3	Payload:	5 kg

With the system in full 6D closed loop operation it offers the possibility for a focused test of the functionality and performance of the vertical drive system. The lifting modules combine a pneumatic actuator for static weight force compensation and a voice-coil actuator to apply dynamic forces. One major challenge in the vertical motion control is to handle this overactuation to achieve synchronized multiaxial motion with servo errors in the low nanometer range. For a performance analysis in this regard, experimental tests with stepwise pure vertical motion as well as multiaxial synchronized movement in x, y and z were carried out. Figure 2 shows the position data and the control signals for such a positioning exercise with a tilted circle of ∅160 mm and a z-difference of Δz=8 mm as commanded trajectory. The results show that servo errors below 2 nm (RMS) are achieved in such a motion scenario while the power loss in the actuator coils of the LAU25 remains below 0.2 mW.

The results of the different motion exercises are presented and discussed in the poster. They illustrate the coordinated operation of the two actuators in each of the three LAUs as well as the overall positioning capabilities of the NPS6D200 system. Further research work at the NPS6D200 will focus on the system's metrological characterization and the implementation of different probing systems.

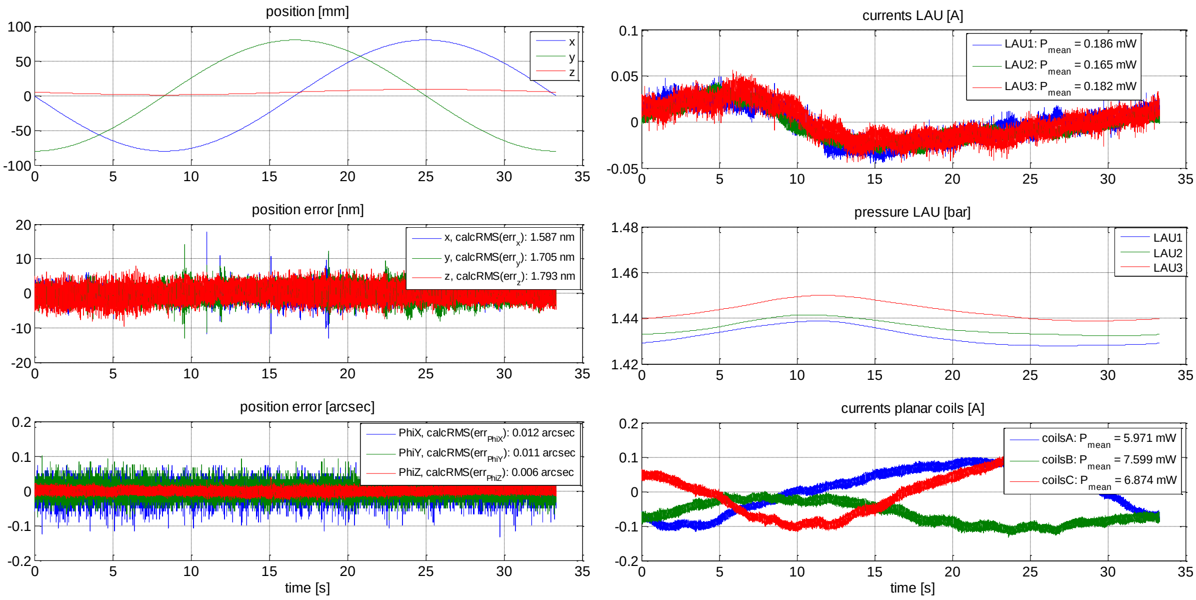

Figure 2: Positioning data and actuator control signals at a 3D synchronized movement; tilted circle (∅160 mm and Δz=8 mm); setpoints and servo errors *(left)*; actuator currents and pressures *(right)*

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