Experimental investigation of air bearing noise by means of a 3D nanopositioning system

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Abstract

High-tech semiconductor and optical industries require positioning systems with nanometer precision over large travel ranges. As production advances to sub-10 nm in size, increasing complexity and costs drive the need for flexible, accurate fabrication methods. For this purpose, precise movement is crucial, but passive mechanical guides introduce challenges for position control on nanometre scale such as friction, slick-slip or vibration [1]. Air bearings offer a solution with near-zero friction, hysteresis-free motion, optimizing load, lift, and stiffness by controlling airflow and pressure for stable positioning [2]. Analyzing air bearing performance requires a setup with high sensitivity that minimizes noise and disturbance. In this regard, our research focuses on measuring the z-jitter behavior of different air bearing technologies using a nanopositioning system, NPS3D100 (Figure 1(a)). The setup comprises mainly of a planar direct drive with closed loop control based on high sensitivity interferometer feedback and moving part suspended by three air bearings, which are in scope of the investigations. Detailed explanation of the setup can be found elsewhere [3], [4].

We propose an investigation method to assess the z-jitter performance of various air bearing types, characterized by the standard deviation of z-movement when the slider is stationary (i.e., it is held at constant set point by sub-nanometer servo error). As samples, we use three different air bearings, where two work with porous media technology and one with micro nozzles technology. Measurement of the slider's z-movement is performed by an additional laser-interferometer with 20 pm measurement resolution. The results show promising z-vibration standard deviations of 0.63 nm and 0.64 nm for porous air bearing types, and 0.36 nm for the nozzle type (Figure 1(b)). Additionally, the cumulative amplitude spectrum (CAS) reveals that porous air bearing types concentrate most vibration energy in the 0-200 Hz range, while the nozzle type distributes it over a broader range with much lower overall amplitude (Figure 1(c)).

Air bearing performance is further assessed by investigating the Frequency Response Function (FRF) of the system in the z-direction through vertical excitation with the actuator components of the planar direct drive and interferometer response measurement. Analyzing the first peak in the FRF enables to assess the present air bearings stiffness and gives the possibility to compare the amount of damping.

A lower peak indicates better damping which can be seen in the nozzle air bearing type (Figure 1(d)). In addition, its higher air stiffness results in higher eigenfrequency of the suspended system and thus a better motion performance. While all three air bearings show stable operation without significant permanent oscillations and with sub-nanometer noise, the nozzle air bearing type provides better damping and best noise performance in static operation. However, dynamic mode needs to be investigated in future work.

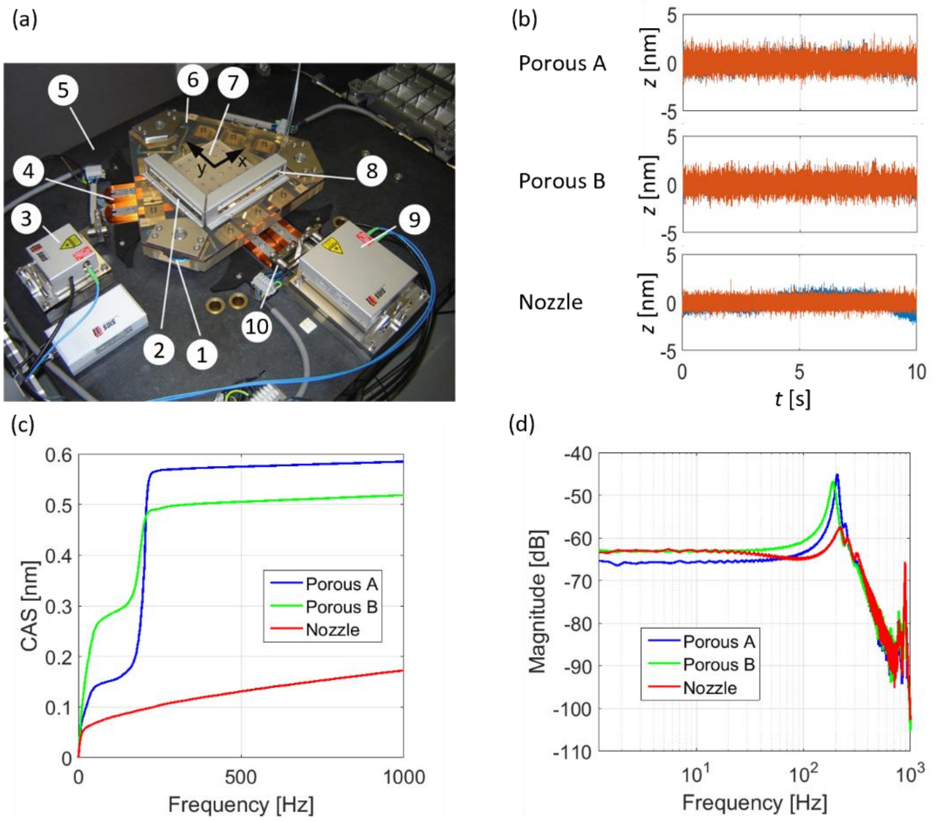

Figure 1: (a) Photograph of NPS3D100 including: 1) air bearing; 2) *x*-reflector; 3) *x*-interferometer; 4) drive coils; 5) granite base; 6) zerodur slider; 7) object table; 8) *y*, ϕ_z-reflector; 9) *y*, ϕ_z-interferometer; 10) capacitive probes. (b) Static performance of different air bearing sliders in (*x,y*)=(0,0) target position. (Blue graph is unfiltered results while the orange graph is filtered results using a highpass filter with passband and stopband frequencies of 5 and 2 Hz, and a zero-phase filter with stopband attenuation of 20 dB.) (c) CAS vs. frequency graph and (d) frequency response of the system with different air bearings.

References:

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