Implementing a ultra-precision positioning device using interferometric feedback signal and a moving coil actuator

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ABSTRACT
This publication describes a single axis motion control providing position noise in the sub-nanometer regime. The positioning system is driven by an electromagnetic actuator, is guided by air bearings and is controlled with a high-bandwidth motion controller supplied with laser interferometric feedback signals. First measurement results show that a positioning noise of less than 200 pm is achievable.

INTRODUCTION
We aim to improve the position stability of the measurement slide of the one-dimensional length comparator of the PTB, the Nanometer Comparator, by means of a linear moving coil actuator. Former work of our group in the field of laser interferometry has demonstrated, that phase variations [1] as well as interferometer nonlinearities [2] can be detected down to the level of a few picometer. One key to this level of interpolation is a self-developed phase measurement system on the basis of an evaluation board with high-speed analog-to-digital converters. Two ADC’s are connected to a Field Programmable Gate Array (FPGA), in which the digitally converted data stream is demodulated by means of an advanced lock-in method. Thus, the phase meter is capable to detect position data with acquisition rates of about 55 kHz and permits to extrapolate position values for a dedicated motion controller. This approach enables to reduce the latency of the position data, which is transmitted with a resolution of 5 pm via Synchronous Serial Interface (SSI) protocol to the motion controller based on a FPGA equipped card from National Instruments. The motion controller uses the position feedback to compute an actuating variable by means of a simple PD control method. The maximum motion speed of the phase measuring system is about 30 mm/s.

RESULTS
A preliminary experiment setup consists of a Zygo laser head, a simple heterodyne Michelson interferometer and air bearing stage driven by the moving coil. The retro reflector was fixed to the air-bearing stage to control its position with the moving coil. The setup suffered poorly-controlled ambient conditions and a missing vibration isolation. The control loop of the moving stage operated at a rate of 142 kHz, which is restricted by the SSI transmission rate. The resolution of the digital-to-analog converter is limited to 16 bit. Furthermore, the parameters of the PD control algorithm were adjusted only empirically. First measurement results, represented in fig. 1, prove that the moving stage can be controlled in such a manner that 250 pm steps can be resolved. In addition a standard deviation of the position noise of less than 200 pm was obtained in closed-loop mode. The performance was reproducible over the entire moving range of 6 mm.

Further developments will focus on implementing a DAC with 20 bit resolution to improve the control voltage output and on testing advanced control algorithms, such as a feedforward control.

REFERENCES
FIGURE 1. Measurement results of the moving system with 250 pm step width