High resolution optical displacement measurements of a piezo scanner

Abstract

In this application note, the steps of a piezo scanner are verified. In closed-loop operation using an optical encoder as sensor, a **PICO**SCALE *Interferometer* is employed to reveal single-nanometer steps.

1. INTRODUCTION

Precise positioning of samples is of paramount interest in a variety of applications. While positioning systems with stick-slip piezo technology offers versatile possibilities, the slip-behavior is undesired in some applications. In that case, piezo scanners show their full potential as they can position a sample very accurately over a range of a few micro meters.

2. SETUP

In the experiment a piezo scanner[1] from SmarAct is equipped with an optical encoder and the feedback loop is closed with a motion controller (**MCS**2, SmarAct). The voltage leading to expansion of the piezo ceramics is controlled with a 16-bit digital-to-analog converter. The scanner has a total scan range of 55 µm, which sets the smallest theoretical stepsize achievable with a 16-bit resolution to about $55\,\mu\text{m}/2^{16} = 0.85\,\text{nm}$. In order to verify the positioning resolution, a **PICO**SCALE *Interferometer* (V2) is used. A sensor head is aligned to a mirror mounted on top of the piezo scanner. Consequently, the interferometer will measure the displacement of the scanner via the mirror. A photograph of the setup is shown in Figure 1, the **PICO**SCALE *Interferometer* V2 is shown in Figure 2.

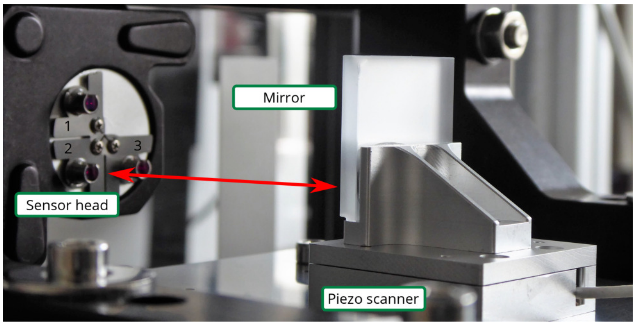

Figure 1. *Experimental setup. Three* **PICO**SCALE *sensor heads (labeled 1-3) are aligned to a mirror, which is mounted on the piezo scanner. The* **PICO**SCALE *measures out-of-loop. The effective working distance of the interferometer (i.e. distance from sensor head to target mirror) is about 56 mm.*

[1] in development

Figure 2. *The* **PICO**SCALE *Interferometer V2. Up to three sensor heads can be connected to the controller, which contains a laser source, detection electronics, FPGA-based fast data processing and several interfaces.*

3. RESULTS

The scanner was commanded to perform a motion sequence of 10 steps back and forth with a stepsize of 1 nm and 2 nm every second. The position of the scanner was controlled with the internal optical encoder and measured with the **PICO**SCALE (see Figure 3).

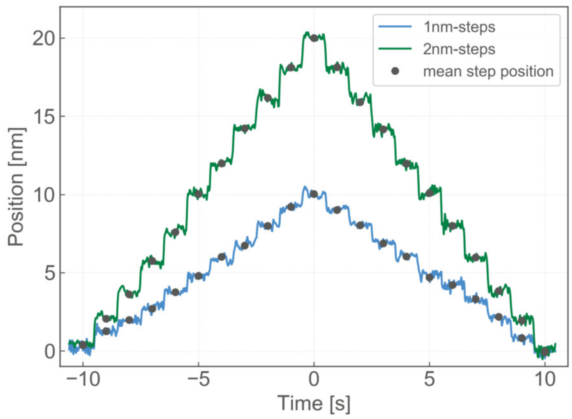

Figure 3. *Measurement of 10 steps back and forth with a stepsize of 1 nm and 2 nm respectively. The measurement is taken 1.5 mm above the top-plate of the scanner and evaluated at the scanner center position by averaging channel 2 and 3 of the* **PICO**SCALE*. The measurement bandwidth is $\approx$ 35 Hz and the mean position data points are determined by averaging 10 individual position data points in the center of each step. The data are corrected by a linear drift between sensor head and mirror ($< 0.1\,\text{nm}\,\text{s}^{-1}$).*

In Figure 4 a close-up to the steps around the turning point are shown. The steps can clearly be identified. The apparent *noise* on the data is mainly caused by the drive voltage resolution of the digital-to-analog converter (0.85 nm per bit as shown above), noise from the optical encoder reading and residual vibrations in the setup. The sensor noise of the interferometer is expected to be less than 0.2 nm_{rms} [1].

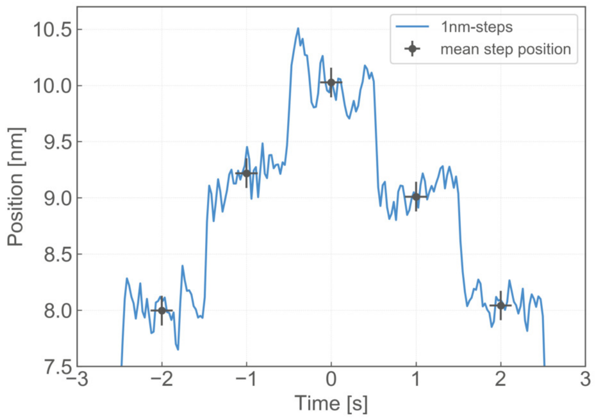

Figure 4. *Zoom into the steps, which can clearly be identified. The errorbars indicate the averaging length in time (350 ms) and the standard deviation of the signal within this time.*

The stepsize of the piezo scanner was analyzed by averaging the data in each plateau as shown in Figure 4 and evaluating the difference between two subsequent steps. The results from both stepsizes are summarized in Table 1 and Table 2 respectively.

Table 1. *Statistics of the 2 nm-steps (10 in each direction).*

	Backward	Forward
Step size	−2.00 nm	1.96 nm
Standard deviation (1 σ)	0.15 nm	0.25 nm

Table 2. *Statistics of the 1 nm-steps (10 in each direction).*

	Backward	Forward
Step size	−1.01 nm	0.97 nm
Standard deviation (1 σ)	0.24 nm	0.21 nm

High performance positioning solutions require high precision metrology during development and quality control. In this application note we show a qualification measurement with the **PICO**SCALE *Interferometer*. The closed-loop motion was verified with sub-nanometer resolution, qualifying both the piezo scanner as well as the metrology equipment for high precision positioning applications.

REFERENCES

[1] SmarAct GmbH. PICOSCALE Interferometer V2. *Specification Sheet*, PS-SS00020, 2021.

FEEDBACK

"The **PICO**SCALE *Interferometer V2 with its very low intrinsic noise allows me to look much deeper into the characteristics of our piezo scanners. This will boost the development and provide high quality specifications which our customers will certainly appreciate."*
Hendrik-Marten Meyer, Development Engineer *Positioning Technology* at SmarAct

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