PICOSCALE Interferometer Noise and Resolution

Abstract
The **PICO**SCALE is a measurement device based on a Michelson interferometer. The signal noise of an interferometer is an important performance benchmark. This document demonstrates that the **PICO**SCALE interferometer achieves a noise level in the sub-picometer region.

1. EXPERIMENTAL PROCEDURE

In order to determine the noise floor of the **PICO**SCALE, a sensor head is adjusted to a plane target mirror at 2 cm distance. The setup is mounted inside an enclosure in order to suppress perturbations by thermal expansion and air fluctuations. The setup is mechanically isolated by a foam pad and placed in a thermally stabilized environment (about 21.5 °C). The data shown in section 2 is obtained with the **PICO**SCALE GUI. Except shifting each data set by its mean value, no further post processing was done.

2. RESULTS AND DISCUSSION

The **PICO**SCALE GUI provides a range of filter rates and streaming rates. This parameter has a deciding influence on the investigated measureands. To this end, each experiment is performed at three different frame rates and corresponding filter rates (1.22 kHz, 39.06 kHz and 10 MHz). Figure 1 shows the **PICO**SCALE distribution of 10000 data points of the position of the target for three different frame and filter rates. (Please note, that when sampling with 1.22 kHz the total recording time was as high as 10 s and thermal and air fluctuations influence the noise. The values for the standard deviations in Table 1 would get even smaller with an ideal setup, especially for low streaming rates.)

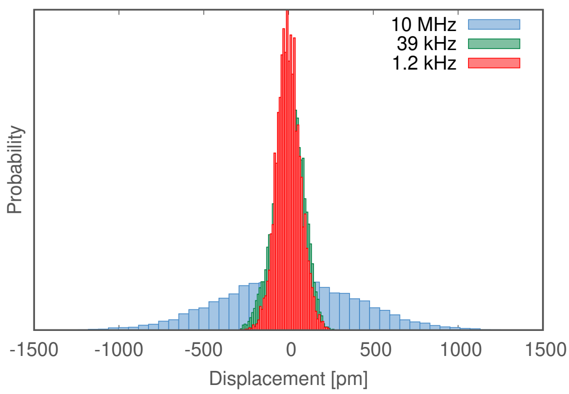

Figure 1. *Normal distributions of the position signal at different filter rates. The small deviations between the Gaussian curves and the raw data is caused by the change of target mirror position as it can be seen in section 4.*

It can be seen that the signal becomes less noisy with decreasing filter and streaming rate. This results from the decreasing cut-off frequency for lower filter rates. The standard deviations for the distributions from Figure 1 are shown in Table 1.

Filter rate	Standard deviation
1.22 kHz	70 pm
39.06 kHz	86 pm
10 MHz	399 pm

Table 1. *Standard deviations of the distributions of Figure 1.*

The time traces as well as its corresponding FFT's for the different frequencies are shown in section 4. Each FFT graph was generated by the **PICO**SCALE GUI using a Hanning Window. The curves were averaged over 20 seconds while the number of averages was set to 10. The ordinate assigns the amplitude spectral density (ASD). It can be seen that the noise floor is always below 10 pm/$\sqrt{\text{Hz}}$ for frequencies higher than 100 Hz.

3. CONCLUSION

It has been demonstrates that the **PICO**SCALE interferometer achieves a noise level in the sub-nanometer range. Regardless of the streaming frequency, the σ width of the normal distributed noise is well below 1 nm. It has also been shown, that the noise floor does never exceed 10 pm/$\sqrt{\text{Hz}}$ for relevant filter rates above 100 Hz.

4. FIGURES

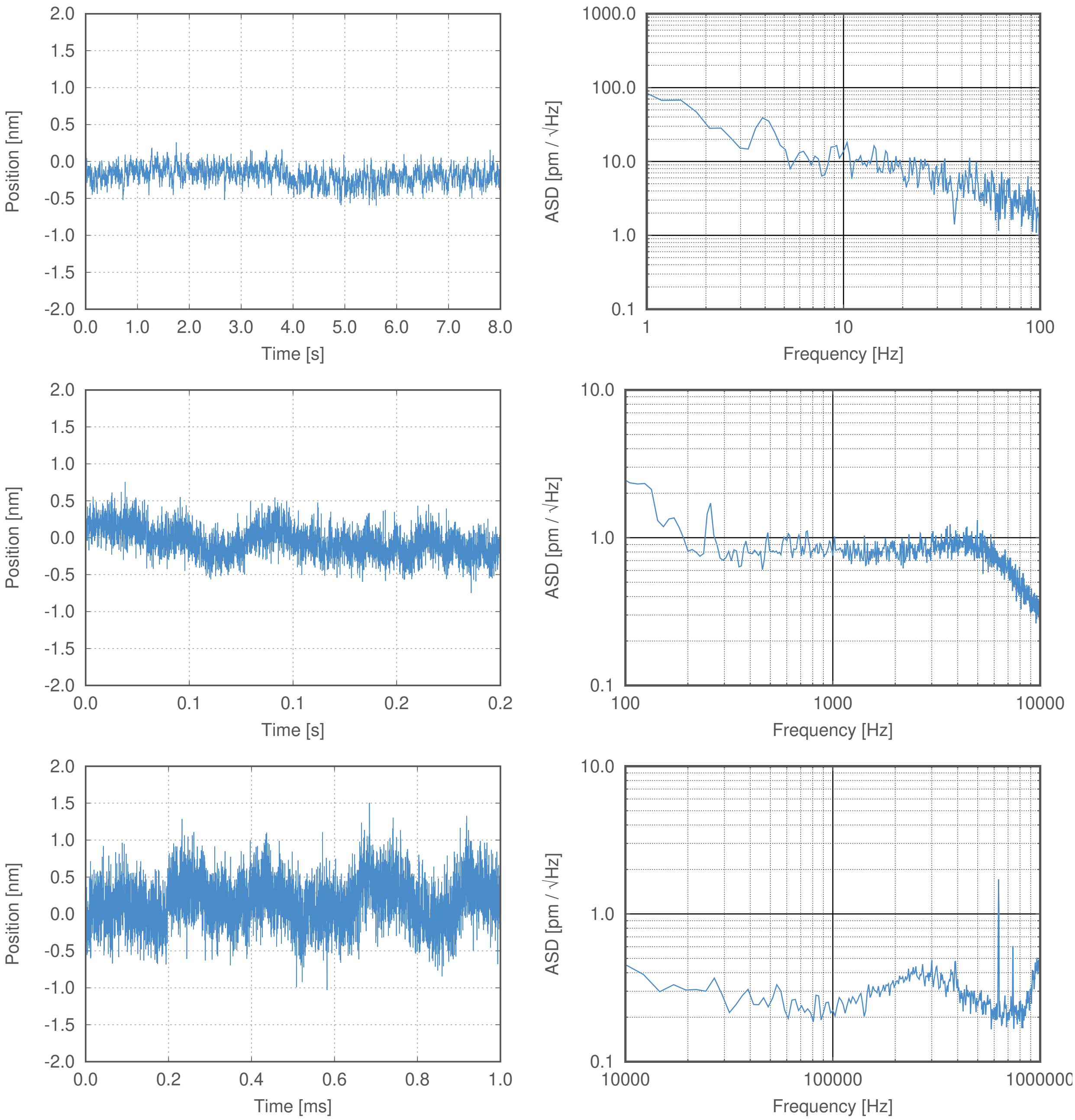

***Figure 2. Position** data (**left** column) and **FFT** (**right** column) for different filter rates. **Top** row: **1.22 kHz**. **Middle** row: **39.06 kHz**. **Bottom** row: **10 MHz**.*