Measurement noise evaluation, noise bandwidth specification and temperature effects in 3D point autofocusing microscopy

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Introduction

Quantifying the metrological characteristics of a point autofocus instrument is essential to establish its traceability, as such characteristics may influence the results of measurement and have direct contribution to measurement uncertainty (ISO/DIS 25178-600) [1]. In this work we evaluate the measurement noise (N_M), which is the noise added to the output signal occurring during the normal operation of the instrument. To provide proper reference for performance specification comparison, N_M is specified along with the measurement bandwidth; to complete noise evaluation, static noise (N_S) and autofocus repeatability (R_{AF}) are assessed (ISO 25178-605) [2]. This work is a first step towards establishing traceability of a PAI and assessing the influence of environmental disturbance on measurement.

Methodology

N_M: Defined in ISO/DIS 25178-600. Application of average and subtraction method [3]: 15 repeated surface measurements were performed.

$$N_{M,subtraction} = \frac{S_{q,\Delta}}{\sqrt{2}}$$

$$N_{M,average} = \sqrt{\frac{\overline{S_q}^2 - S_{qn}^2}{1 - 1/n}}$$

N_S: standard deviation of the vertical stage fluctuation when lateral scanning is not performed (ISO 25178-605).

R_{AF}: noise (as standard deviation) of autofocus sensor in the absence of environmental disturbance (ISO 25178-605).

N_S and R_{AF} were obtained while focusing on a single point.

Temperature effect: correlation between surface height and temperature was established to account for the influence of environmental disturbance.

Sample and settings

Sample	Calibrated optical flat *Sz* (4±9.8) nm (NPL-BNT 019)
Instrument	MLP-3SP (Mitaka Kohki)
Objective	100×, AN 0.8
Measured area	100 µm × 100 µm
Scanning pitch	0.1 µm
Stepping pitch	1 µm
Temperature probe	Pt-1000 two wire (± 0.15 °C)

Results

- Temperature fluctuation was found to have caused drift in measured surface height.
- Temperature effect can be removed with the drift compensation routine built in the software.

N_M = 2 nm or 0.4 nm/√Hz u_{NM} = 2 nm

N_S = 2 nm R_{AF} = 5 nm

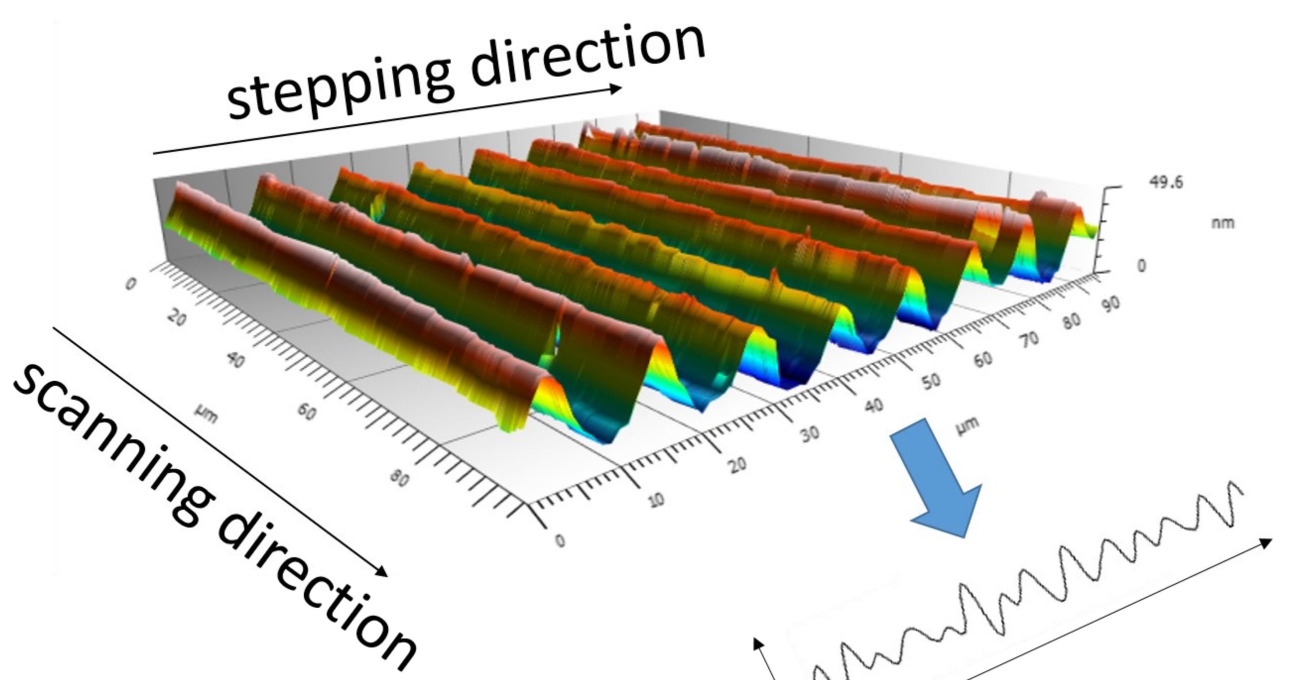

Figure 1: Drift in measured surface topography due to temperature fluctuation.

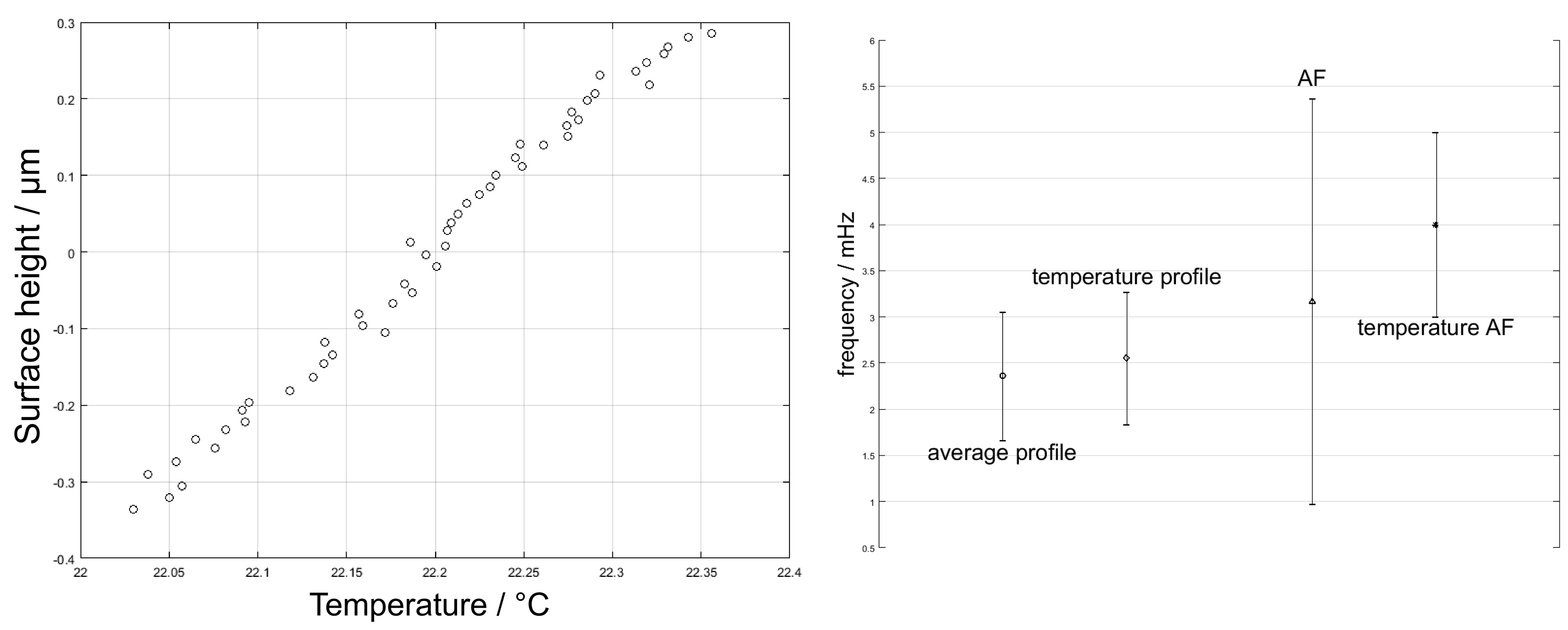

Figure 3: Correlation between surface height and chamber temperature.

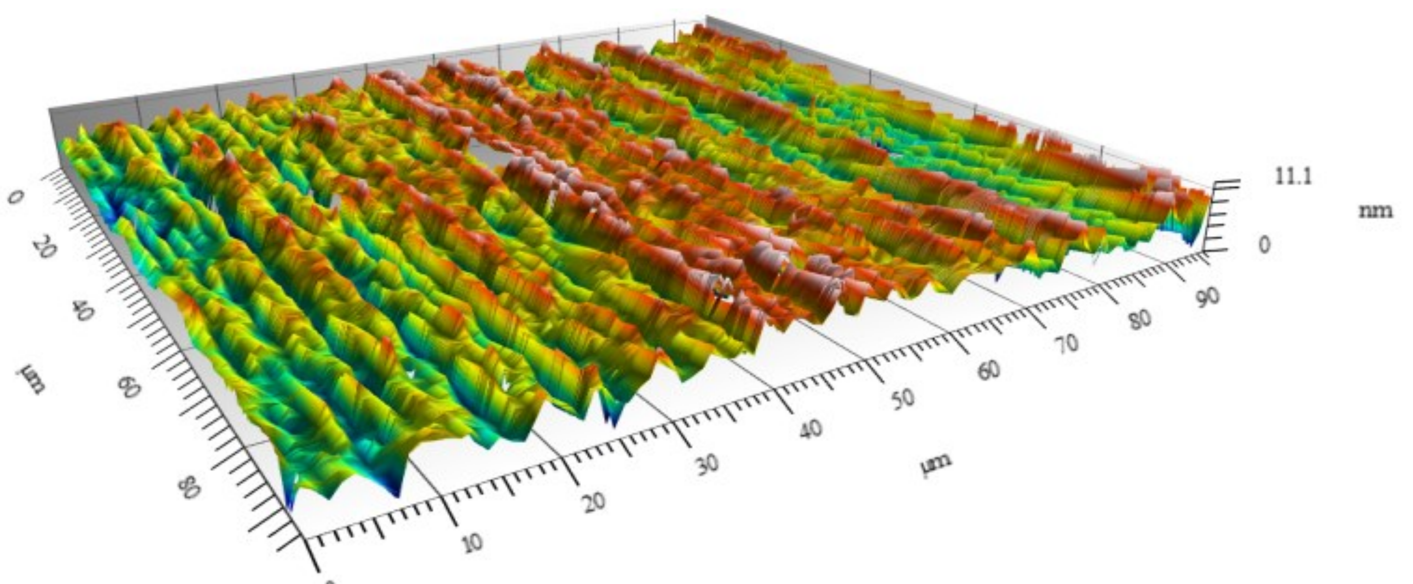

Figure 2: Surface topography after drift compensation.

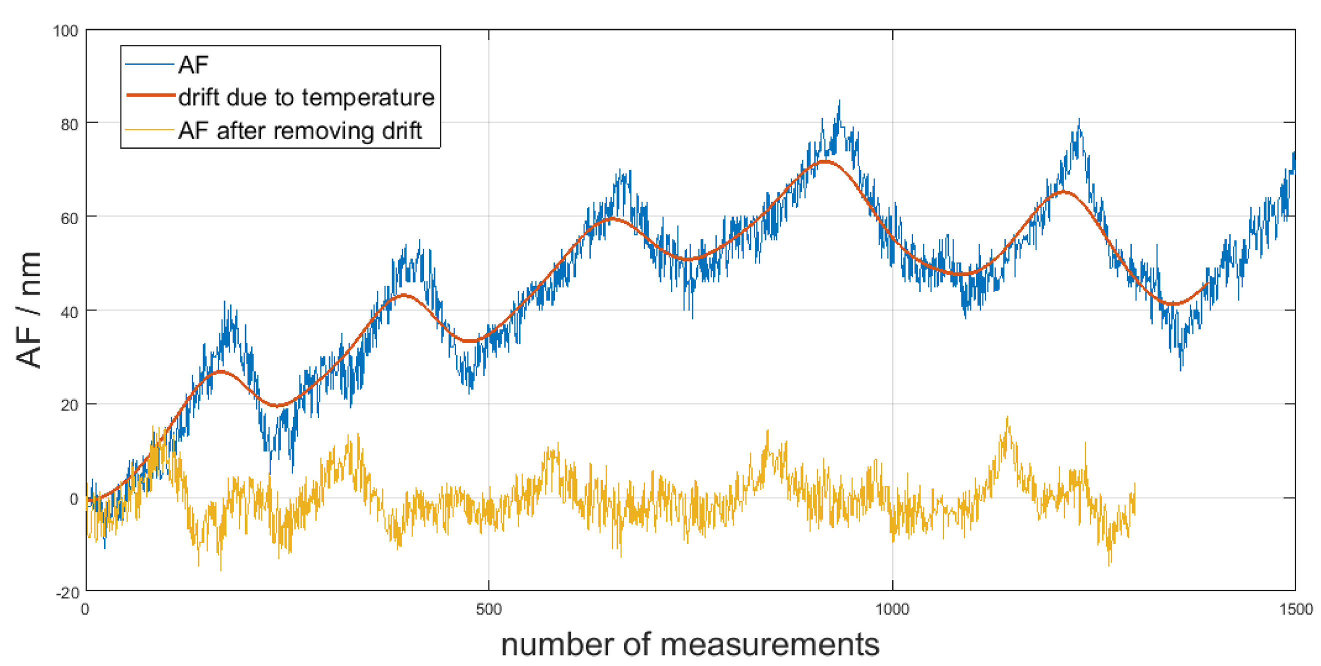

Figure 4: Repeatability of the autofocus sensor R_{AF}.

Future work

To complete the characterisation of PAI, the remaining metrological characteristics (flatness deviation, amplification coefficient and linearity deviation of the three axes, *x*-*y* perpendicularity, topographic spatial resolution and maximum measurable local slope) shall be evaluated also exploiting methodologies proposed in good practice guides and draft ISO specification standards.

References

[1] ISO/DIS 25178-600 2016 Geometrical product specification (GPS) - Surface texture: Areal– Part 600: Metrological characteristics for areal-topography measuring methods

[2] ISO 25178-605 2014 Geometrical product specification (GPS) - Surface texture: Areal– Part 605: Nominal characteristics of non-contact (point autofocus probe) instruments

[3] Giusca C L, Leach R K, Helary F, Gutauskas T, Nimishakavi L 2012 *Meas. Sci. Technol.* **23** 035008

Acknowledgements

The authors would like to acknowledge funding from EPSRC grant EP/M008983/1.