Determination of the contribution of topography fidelity on the measurement of a tilted optical flat using a virtual instrument

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The metrological characteristics framework introduced in ISO 25178-600 combines the different influence factors that contribute to the uncertainty of a measurement into a list of seven explicitly stated metrological characteristics which when propagated through an appropriate measurement model allow for an evaluation of measurement uncertainty [1]. The determination of the metrological characteristics is carried out with the use of calibrated material measures as found in ISO 25178-70 [2]. Topography fidelity is specified as the *'closeness of agreement between a measured surface profile or measured topography and one whose uncertainties are insignificant by comparison'*. Currently there is no single material measure that incorporates the features that topography fidelity aims to capture. An alternative approach to material measures is to employ the use of a virtual instrument, effectively a digital twin of a physical instrument, based on a combination of physical models. The virtual instrument considers the different influence quantities and simulates the measurement using an accurate model that mimics the real measurement process.

The virtual instrument developed by Su et al. [3] is used to examine the effect of topography fidelity by evaluating the measurement noise of a tilted optical flat using a coherence scanning interferometer (CSI). The default procedure for determining measurement noise is to measure a material measure at the same location at a short interval and then calculate the *Sq*, the root mean square value of the surface height variation, of the height difference of the two maps as defined in ISO 25178-2 [4]. The subtraction method should make the result independent of the underlying topography, removing the form and all systematic effects present in the measurement. However, the measurement noise of a tilted optical flat using a CSI is considerably higher compared to measuring the material measure with null fringes. This indicates that vibration has a random component that influences the topographic noise map. It is these effects that are investigated using the virtual instrument as a comparison to the physical one. In this work, we investigate the random effect vibration has in the measurement of a tilted optical flat and compare the output of a physical CSI to the simulations of the virtual instrument for a number of tilt angles ranging from 1° to 10° [6], based on the method outlined in Figure 1.

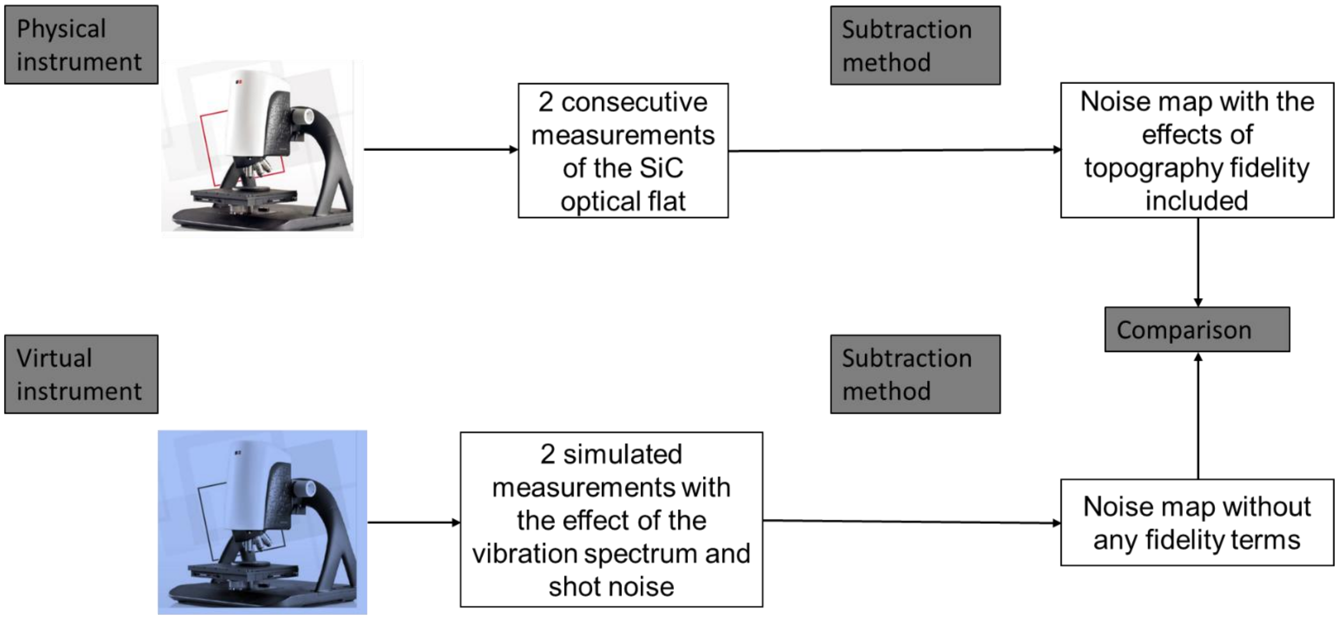

Figure 1 Topography fidelity comparison method

[1] ISO 25178-600:2019, Geometrical product specifications (GPS) — Surface texture: Areal — Part 600: Metrological characteristics for areal topography measuring methods. International Organization for Standardization

[2] ISO 25178 part 2 2012 Geometrical product specifications (GPS) —Surface texture: Areal— Part 2: Terms, definitions and surface texture parameters (International Organization for Standardization)

[3] Su R, Leach R K 2021 Physics-based virtual coherence scanning interferometer for surface measurement *Light: Advanced Manufacturing* **2**:9

[4] Giusca C L, Leach R K, Helary F, Gutauskas T, Nimishakavi L 2012 Calibration of the scales of areal surface topography-measuring isntruments: part 1. Measurement noise and residual flatness *Meas. Sci. Technol.* **23** 035008

[5] ISO 25178 part 2 2012 Geometrical product specifications (GPS) —Surface texture: Areal— Part 2: Terms, definitions and surface texture parameters (International Organization for Standardization)

[6] Hovis C, Shahinian H, Evans C 2019 Observations on the effect of retrace error in scanning white light interferometry of smooth optical surfaces *Proc. Opt. Fab. And Tes. Jan.*

[7] Shahinian H, Hovis C, Evans C 2021 The effect of retrace error on stitching coherent scanning interferometry measurements of freeform optics *Opt. Express* **29** 28562