New improvement in calibration strategy for **S**trucutured-**I**llumination **MA**croscopy

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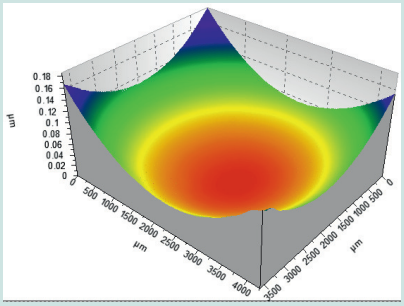
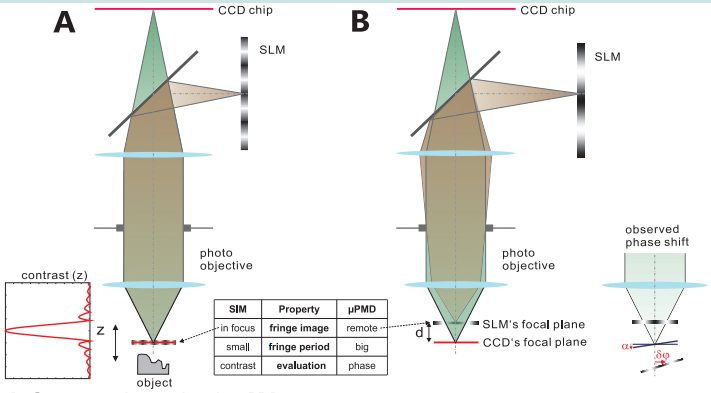


Fig. 1 *Concave mirror with radius of 24mm.*

With **S**tructured-**I**llumination **MI**croscopy (SIMI), the 3D-topography of technical surfaces can be acquired with **high angular dynamics** of up to ±70° in **nanometer** regime [1], if implemented with a **high NA** objective and **diffraction limited** PSF. We want to scale up this principle for macroscopic objects. However, for a macroscopic field, such a lens is **not available** for reasonable cost. As consequence, in up-scaled SIM, the unavoidable aberrations will cause **lower local precision** and a **reduced global accuracy** (retrace error). To solve these problems, we combine SIM with slope-measuring microdeflectometry [2] to achieve both an **improved global accuracy** and a **significantly improved local precision**.

SIMA & Microdeflectometry



A: **S**tructured-**I**llumination **MA**croscopy
→ height measurement
B: Microdeflectometry
→ slope measurement

Features:
- incoherent illumination
- extended depth of field
- high angular dynamics

	SIMA	µDefl.
rough surface	$\delta z = \frac{\lambda}{2\pi \sin^2 u} \approx 200\text{nm}$	
smooth surface	$\delta z = \frac{\lambda}{Q \cdot f_{best} \cdot \sin^2 u} \approx 100\text{nm}$	$\delta z = \delta x \cdot \delta a = \frac{\lambda}{Q} \approx 1\text{nm}$

Retrace error & Calibration

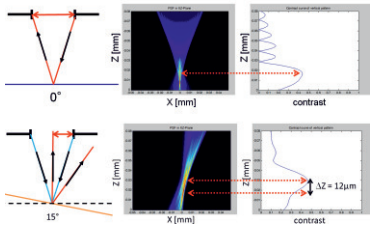


Fig. 2 *Simulation of retrace error with presence of spherical aberration.*

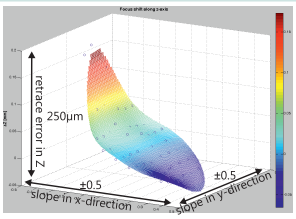


Fig. 3 *Measured retrace error in Z with vertical stripe at one camara pixel.*

To measure the height, SIMA compares the object shape with an **etalon** which is the **focal surface** of the objective. Unfortunately, due to the unavoidable aberrations, the shape of focal surface is **slope dependent** (Fig. 2, Fig. 3). We choose a **model-free** calibration strategy for the error correction [3].

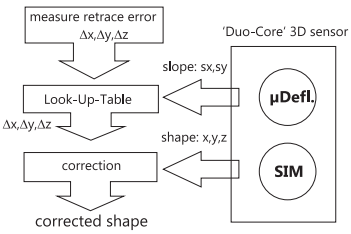


Fig. 4 *Scheme of the calibration strategy for correcting retrace error.*

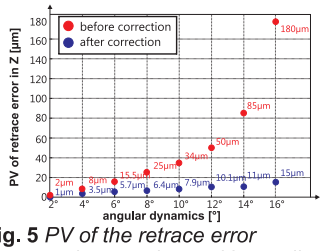


Fig. 5 *PV of the retrace error measured on a sphere with a radius of 5mm before and after correction.*

We rely on the **precision of photogrammetry**. By comparing the measured shape with the calculated shape from photogrammetry, we are able to generate a **field- and slope-dependent LUT** of the retrace error. After correction using this LUT, we reduced the systematic error to **less than 15µm** for an angular dynamic range of ±16°.

Improvement of local precision

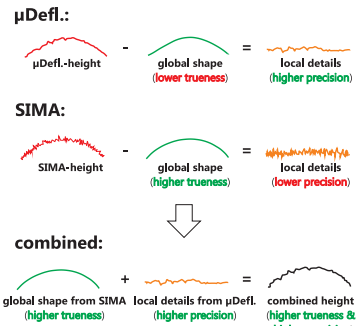


Fig. 6 *Combination of SIMA- and µDefl.-height for optimizing the local precision.*

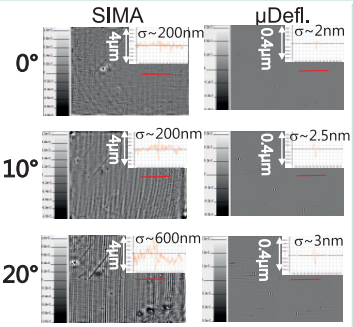


Fig. 7 High frequency content of height data measured by SIMA and µDefl. on a planar mirror, at tilting angle of 0°,10° and 20°.

In contrast to SIM, the **local precision** of microdeflectometry is **not dependent** on NA. Thanks to this feature, we can significantly optimize the local precision down to **a few nanometers**, by combining the **high frequency content** of µDefl.-data with the **low frequeny content** of the **calibrated** SIMA-data.

[1] Z. Yang, Ph. Dienstbier, A. Bielke and M. Vogel, Ch. Faber, G. Häusler:"Full-field macroscopic measurement of specular, curved surfaces with SIM" in DGaO-Proceeding: A6 (2011).
[2] G. Häusler, C. Richter, K.-H. Leitz, M.C. Knauer: "Microdeflectometry - a novel tool to acquire 3D microtopology with nanometer height resolution", Opt. Lett. (2008).
[3] Z. Yang, A. Bielke, E. Olesch, Ph. Dienstbier, G. Häusler: "Measurement of optical surfaces by Structured Illumination MACROSCOPY- with correction of the retrace error" in DGaO-Proceeding: A10 (2012).

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