Object reconstruction by deflectometry

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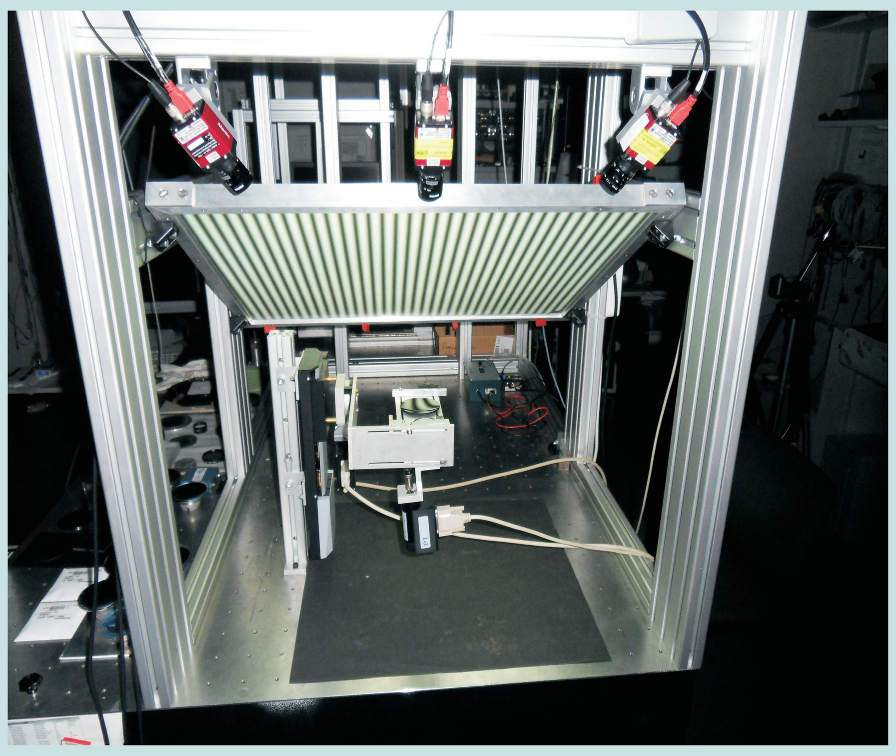

Fig. 1: *A typical deflectometrical setup*

Phase-Measuring Deflectometry is a meanwhile established method to measure specular freeforms [1]. A camera observes a sinusoidal pattern reflected by the specular object under test. While having extremly **high local sensitivity**, it is difficult to achieve a **global accuracy** that can compete with interferometry or CMMs. The reason is that the measured effect depends on two unknowns: **unknown ray deflections** at **unknown positions** in space. The common iterative reconstruction method needs additional knowledge of one single surface point. Apart from the calibration [2], the global accuracy depends strongly on the accuracy of this point.
Now we developed a **new method** which no longer relies on this information.

Common reconstruction method

The reconstruction method is an iteration of two steps. The common approach needs additional information of the 3D- location of **one single point** .

- Step 1: Calculate the normals under a height assumption.
- Step 2: Intergrate the normals to yield a new height assumption. The height result is suspended at the given fixed point.

The reconstructed global shape depends strongly on the accuracy of the suspension point. Even under the assumption of a perfect sensor calibration and perfectly measured data, the reconstructed global shape is inaccurate, if the suspension point is not part of the surface.

New reconstruction method

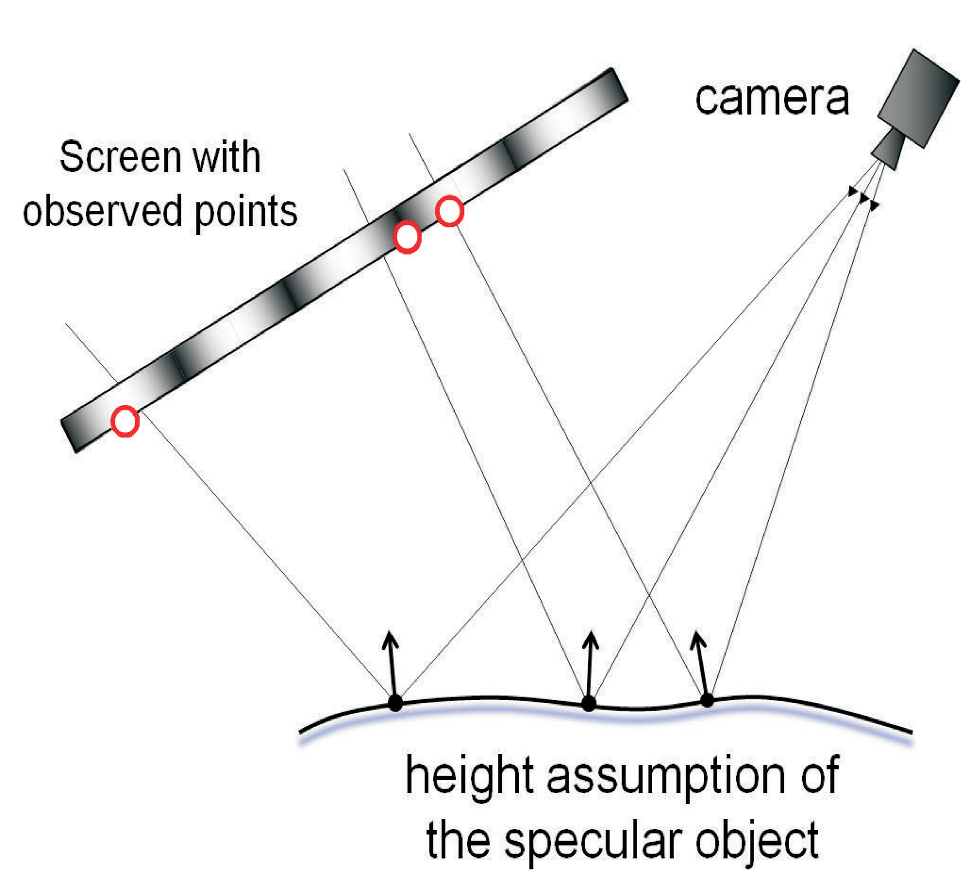

Fig. 2: The calculated height result of iteration step 2 is no longer fixed in one known point. The location of the height is searched by minimizing the distance of the reflected rays to the observed points.

To overcome the dependency of the accuracy on one single point we developed a new reconstruction method by modifying the common iteration. Instead of suspend-ing the intermediate height maps at a given point, the global error of all observed points is minimized (Fig. 2). The location of the calculated height result in step 2 is searched by minimizing the distance of the reflected rays to the observed points on the screen.

Advantages

- No additional / prior knowledge necessary
- The global accuracy no longer depends on the accuracy of one single point
- The new method intrinsically supports the use of multiple cameras and object positions, thereby increasing the measurement field and angular range
- The method is very user friendly

Results

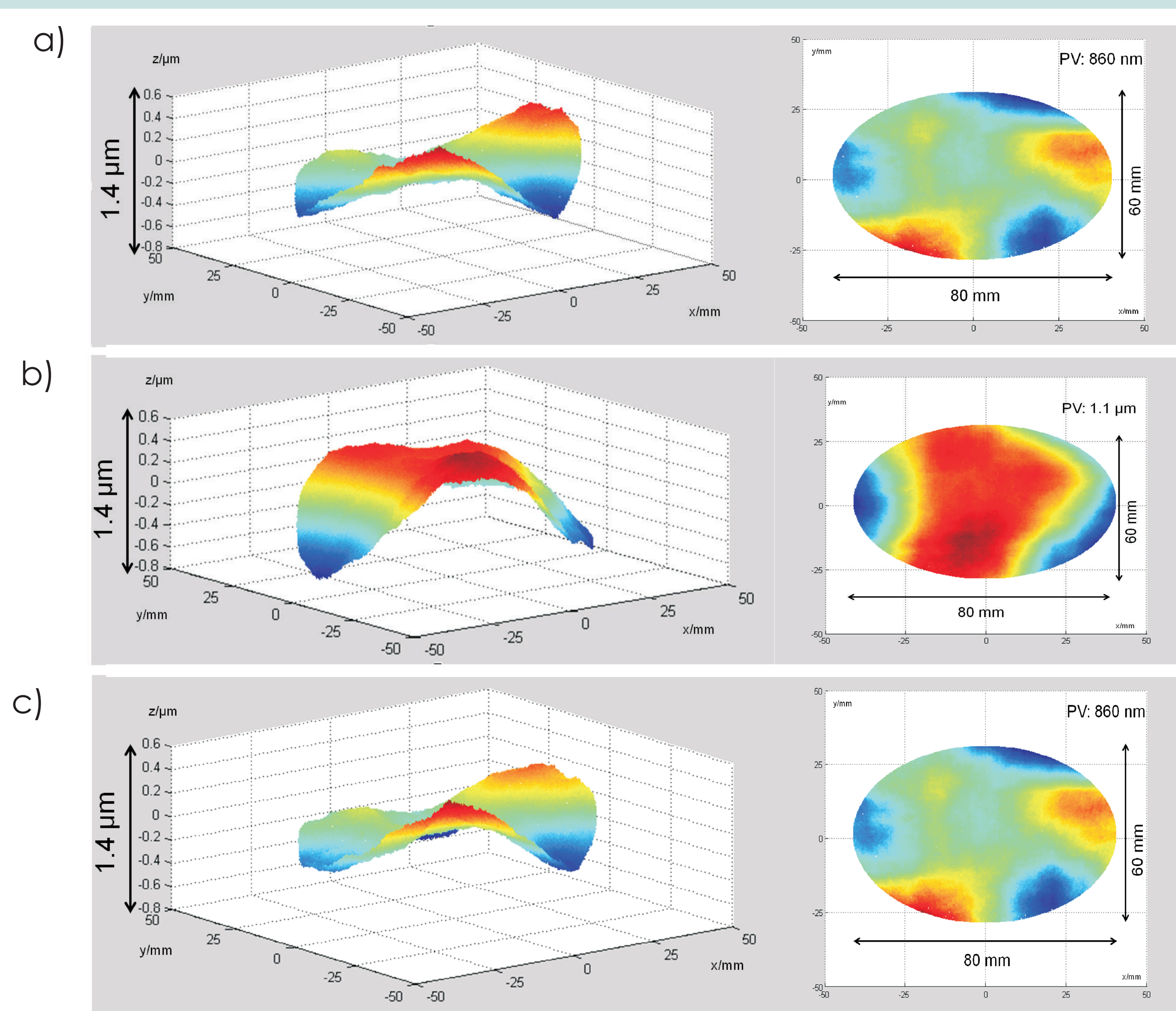

Fig. 4: *Height deviation reconstructed (a) with a perfect fixed point; (b) with a wrong fixed point shifted by 20 µm ; (c) with the new reconstruction method*

A perfect sphere with a radius of 146.29 mm was measured. We reconstructed the height first with the common fixed point iteration. The additional point was cal-culated by stereo deflectometry [3]. Fig. 4 (a) shows the result. After changing the height location of the fixed point by only 20 µm, the height result is strongly affected (Fig 4(b)). Fig 4(c) shows the result with the new method. The accuracy is similar to the fixed point iteration under perfect conditions, but **does not require knowledge of a suspension point**.

[1] M. Knauer, J. Kaminski, G. Häusler, "Phase Measuring Deflectometry: a new approach to measure specular free-form surfaces", Proc. SPIE 5457, pp. 36-376 (2004)
[2] E. Olesch, Ch. Faber, G. Häusler, "Deflektometrische Selbstkalibrierung für spiegelnde Objekte, DGaO-Proceedings, 112, A3 (2011)
[3] M. Knauer, J. Kaminski, G. Häusler, "Absolute Phasenmessende Deflektometrie", DGaO-Proceedings, 105, A15 (2004)

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