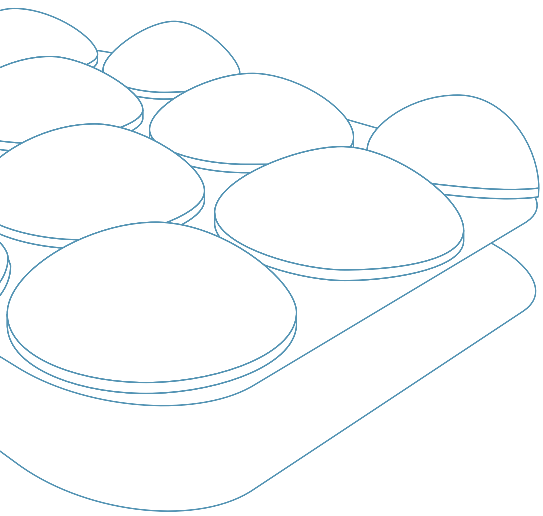


Characterization of micro optics with Digital Holographic Microscopy

DHM™ instruments and Koala Software system make measurements easy in micro optics. Its real-time interferometric accuracy allows:

- **3D optical topography**
- **Shape and aberration coefficients determination**
- **Any lens measurement without setup modification**
- **Roughness measurement**
- **Fast and full wafer control**

This efficient technology is perfectly suited for sample optimization in process engineering.

The constraints imposed in micro optics and in particular with microlens wafers are extremely demanding. Precise control of the shape, surface quality, and optical performance of the micro optics are required, as well as uniformity of these parameters across the wafer. Many different metrology approaches exist, and non-contact techniques are preferred. The Twyman–Green interferometer is probably the most precise tool for shape characterization, and direct analysis of optical performance is often performed with Mach–Zehnder interferometers. White-light interferometers with fully automated measurement capabilities are commercially available. However, these instruments are often not suited for characterization of the entire lens profile, yielding accurate information for the vertex of refractive microlenses only.

Such interferometric techniques have several drawbacks. Indeed, to achieve high precision, they require

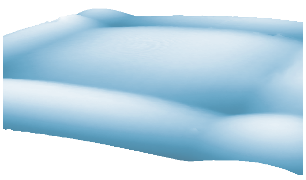
- Calibration and optimization procedures that are often difficult to implement as an automated process of quality control, especially for entire wafers
- Autofocusing or/and scanning procedures resulting in a low measurement rate (2-6 sec per lens)
- Vibration-insulating devices which increase the costs
- Accurate control of the specimen position and orientation
- Setup modification depending on micro optic shape (spherical, cylindrical, Fresnel lenses, gratings,...)

To overcome those drawbacks, Lyncée Tec provides a unique tool for Micro optics Investigation: the DHM™ technology

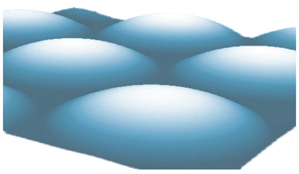
- No calibration process
- Digital focusing
- Real-time measurements
- Insensitive to external vibrations
- Digital compensation of movement or orientation of the specimen
- No dependance on micro optics

Furthermore, ease of use digital processing tools implemented in the Koala Software allow fast, efficient and quantitative evaluation of:

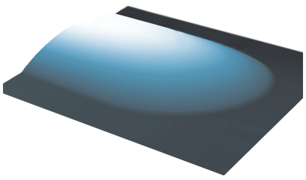
- Micro optic shape
- Radius of curvature (ROC)
- Surface quality (roughness, defects)
- Aberration coefficients



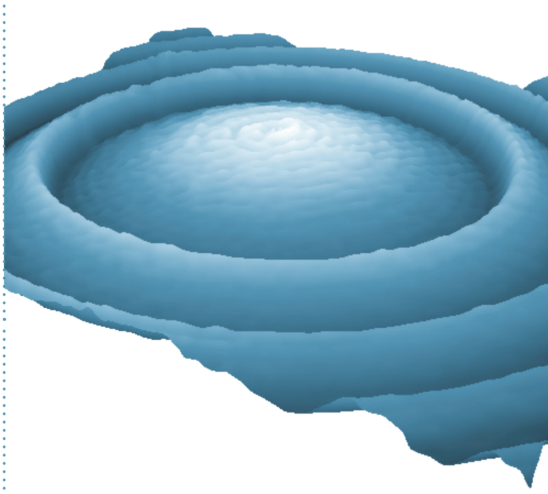
Squared lenses
pitch: 500µm, height: 5.5µm



Spherical lenses
diameter: 125µm, height: 10µm



Cylindric lens
diameter: 160µm, height: 8µm



3D optical topography of a Fresnel lens obtained with DHM™ R1000.

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Shape and ROC

To illustrate shape and ROC measurement, two different types of microlenses are investigated: a quartz refractive transmission lens and a silicon refractive lens. Figure 1 presents the measurements of a 240µm diameter quartz spherical lens, observed in transmission (DHM™ T1000). Figure 1a presents the modulo-2π phase image and Fig. 1b, the unwrapped phase image. The profile extracted form the centre of the lens is presented in Fig. 1c. Results obtained in Fig. 1 enables direct estimation of the lens shape, in particular ROC and the height. The ROC for example as measured with the DHM™ T1000 and a Twyman Green interferometer gives differences in the measured values much lower than 1% (quartz lens ROC: 349µm with Twyman Green interferometer, 351µm with DHM™ T1000).

Figure 2 presents the comparison of the profiles measurements on the silicon refractive lens between DHM™ R1000 and a mechanic stylus probe. The instrument is an Alpha-step 200 from Tencor Instruments and yields measurements of profiles with an accuracy of 5nm (vertical resolution) with a 12µm tip diameter. Figure 2a illustrates the very good global agreement between both techniques. Figure 2b enlarges the profiles comparison at the base of the lens to focus on the discrepancy between the two measurements: this is simply due to the width of the tip used in the Alpha-step 200, which makes the lens appear larger than expected on the graphs. This artifact is not present when measuring the top of the lens, as shown on Fig. 2c.

Surface Roughness

A numerical representation of the lens shape allows digital treatment to measure the deviation from the mathematical model. Figure 3 illustrates this feature of DHM™ R1000 with a silicon refractive lens. Figure 3a shows the phase image obtained after the automatic subtraction of a mathematical description of the lens, in this case a parabolic function, from the measured data. A first advantage of this representation of the lens is that small defects, scratches or material inhomogeneities, become more apparent. The surface quality, roughness can then be evaluated. For example, Fig. 3b presents a profile extracted from Fig. 3a, showing an average roughness R_a = 4.2nm and a peak-to-valley roughness R_t = 26.7nm.

Aberrations

By using for instance a Zernike polynomial model as mathematical description of the lens, quantitative aberration coefficients of the lens are automatically extracted from the same image. Figure 4a presents the automatic subtraction of measured data with the Zernike polynomials model, and Fig. 4b presents the values of the Zernike coefficients.

Conclusion

The DHM™ 1000 Family, used in conjunction with the Koala Software Tools, enables a fast, versatile and efficient investigation of micro optics. In a single shoot and without scanning or calibration, DHM™ system provides topography, shape coefficient, ROC, roughness and quantitative aberration coefficients, allowing efficient R&D and production process engineering optimization, and production line quality control.

References

F. Charrière, "Characterization of microlenses by digital holographic microscopy", Appl. Opt. 45, 829-835 (2006)

http://www.lynceetec.com/downloads/

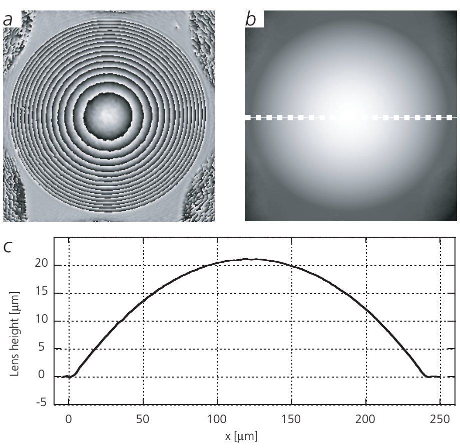

Figure 1: *Phase images of a quartz refractive transmission lens (diameter 240µm, maximal height 21.15µm, measured ROC 351µm) obtained with DHM™ T1000: (a) wrapped, (b) unwrapped and (c) height profile taken along the dashed line in (b).*

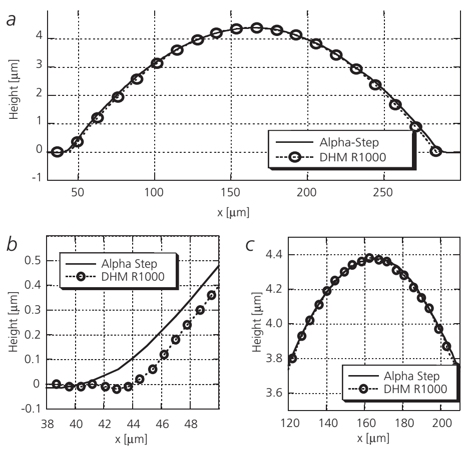

Figure 2: *A comparison profile of the same SI refractive lens measured with DHM™ R1000 and Alpha Step 200 from Tencor Instrument: (a) complete profile, (b) discrepancies between the two methods at the base of the lens and (c) perfect match between the two methods at the top of the lens.*

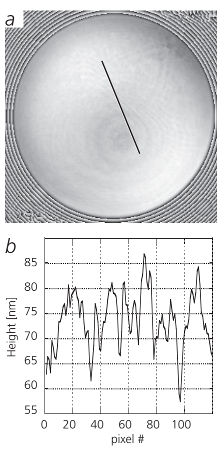

Figure 3: *Roughness measurement on the surface of a silicon refractive lens after shape factor removal. (a) Phase image and (b) phase profile along black line defined on (a).*

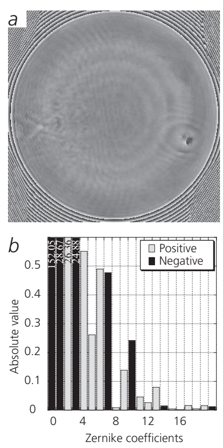

Figure 4: *Measurement of aberrations. (a) Subtraction of phase data with Zerrnike polynomials models, (b) determined Zernike coefficients.*