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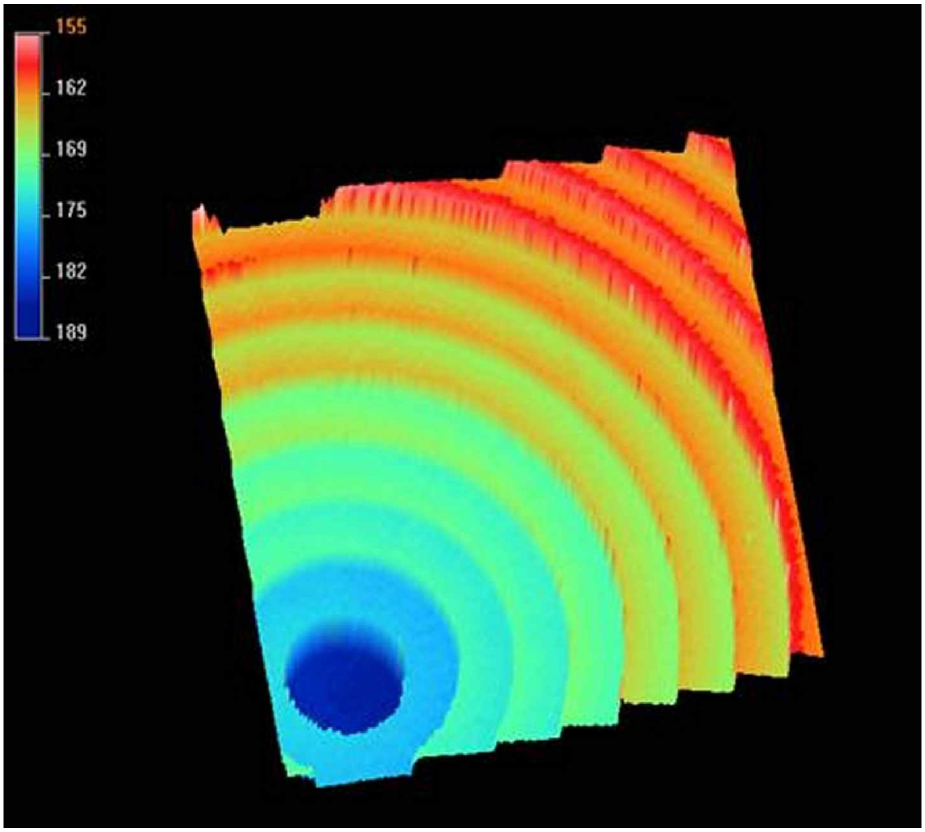
The spectral colours of nanometers



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The spectral colours of nanometers

Contactless metrology becomes increasingly important for in-line or post-process production quality control. Automotive industry, semiconductor industry, and manufacturers) of microsystems and sophisticated components built from glass and plastics need fast and accurate measurements of small structures, surface topography, and layer thickness. Typically, a lateral resolution of a few microns is demanded. The accuracy of the distance measured between the target and a reference plane usually needs to be better than 0,1 µm. Obviously, only optical systems are capable to cope with such demands.

Principle of CHRocodile® optical sensors

For most industrial applications mentioned above the chromatically coded distance detection method turned out to be very well suited. That method takes advantage from a lens error commonly known as chromatic aberration: the axial position of the focal point of an uncorrected lens depends on the color (wavelength) of the light to be focussed. In the visible spectral region, the focal distance for blue light is minimal while it is maximal for red light. The focal points of other colors are located in between according to the row: red, orange, yellow, green, blue, violet. Depending on the distance of the target from the focusing lens, light of just a very small wavelength region λ_1 is focused on the target's surface (Fig. 1). All other spectral components of the light source are illuminating a much wider area of the surface.

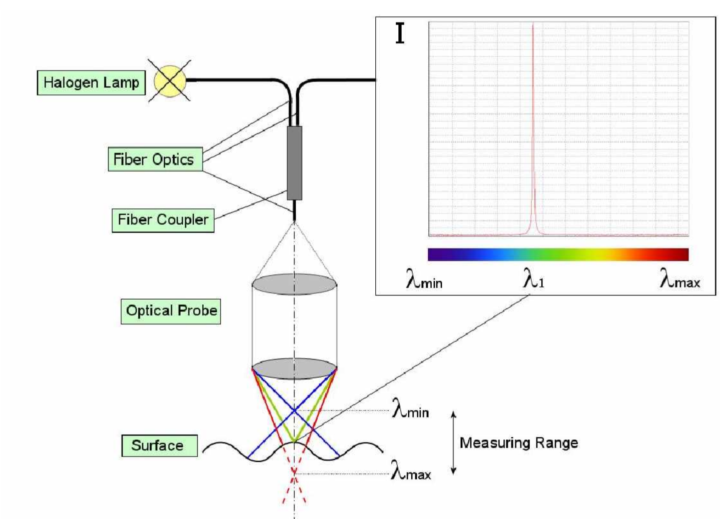

Figure 1. Principle of the chromatically encoded confocal measurement

The focusing lens is also used to receive the backscattered light from the target's surface and to focus it into an optical fiber. Due to that confocal arrangement, light having the wavelength λ_1 is focused to the front of the fiber and enters it without clipping. All other spectral components are spread on a much bigger area. As a consequence, the light fed through the fiber to a spectrometer is almost monochromatic, it´s wavelength λ_1 being a chromatic code about the axial position of the backscattering surface of the target. Therefore, the wavelength scale of the spectrometer can be calibrated vs. the distance to the scattering surface.

Using optical probes with a high numeric aperture allows for measuring polished, rough, highly reflective or opaque surfaces, at a slope of up to e.g. 30° to the probe's optical axis (limited by the numerical aperture $N_a=\sin\alpha$). As the measurement is carried out by using only the perfectly focused part of the reflected light, the effective measuring spot can be kept very small, yielding a lateral resolution of up to 2µm. Different from many other optical measuring principles, the above described measuring principle tolerates shadowing effects, caused by edges or holes with high aspect ratio. Furthermore it reduces the unavoidable measurement errors of triangulating and confocal measuring principles, which are caused by speckle effects and constitute a strong physical limitation to measuring accuracy, to a minimum by usage of a short coherent light source and high numerical observation aperture.

The accuracy of distance measurement also depends on the scattering properties of the target surface. Highly absorbing materials and rough or tilted surfaces may reduce the amount of reflected light entering the optical probe reducing also the signal to noise ratio significantly. That may be compensated to some extent by increasing the exposure time and/or by the use of extremely bright illumination sources. The CHRocodile® X - systems are designed to allow an unsurpassed measuring rate of 14 kHz for almost all technical surfaces without substantial loss of accuracy.

Alternative systems like triangulators (T), conoscopes (C), and cameras operating in autofocus arrangements (A) are suffering from system-inherent disadvantages like comparatively large probe spot size, beam clipping effects and speckle induced failures (T), increased influence of residual stray light effects of the target surface (T, C), comparatively large dimensions of the sensor, and loss of speed due to mechanical closed loop control components (A).

Applications

The quality of printed matter significantly depends on the volume of gravure cells on nip rolls . The CHRocodile® system allows the measurement of the dimensions of the gravure cells with an acceptable uncertainty of a few percent (Fig. 2).

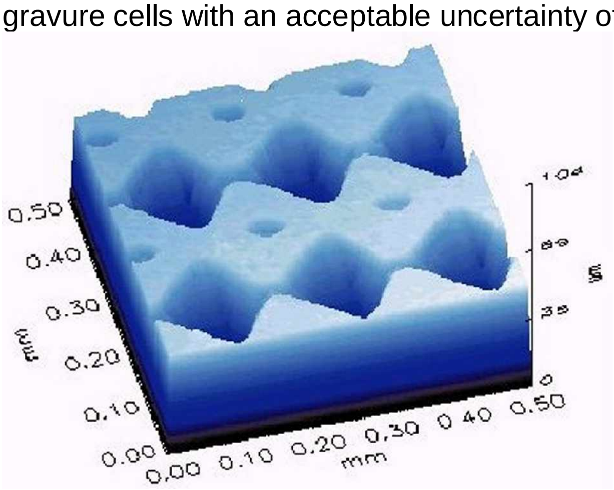

Figure 2. Topography of a nip roll

Lens production systems need accurate information on the central lens thickness. Chromatically coded systems (Fig. 3) are perfectly suited to generate the required accuracy.

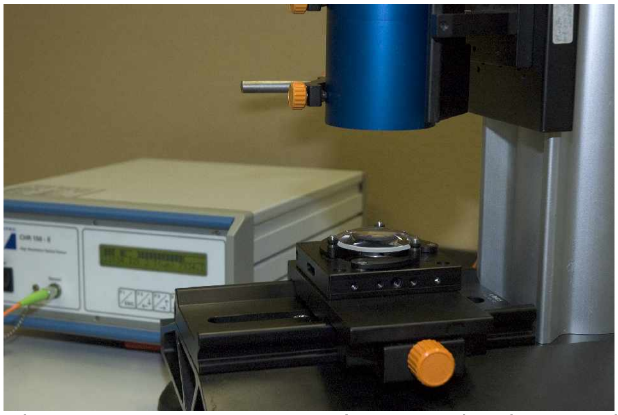

Figure 3. Measurement setup for measuring the central thickness of lenses

The thickness of transparent layers can be measured interferometically with an uncertainty of less than 10 nm. The thickness of multilayers can also be analyzed.

High resolution dimensional control is mandatory for microproduction systems. As an example, Fig. 4 displays the topography of a microlens array. CHR systems are also suited for industrial use such as in-line detection of small cracks in injection valves and for height measurements on saw wafers which are produced by the dicing technique.

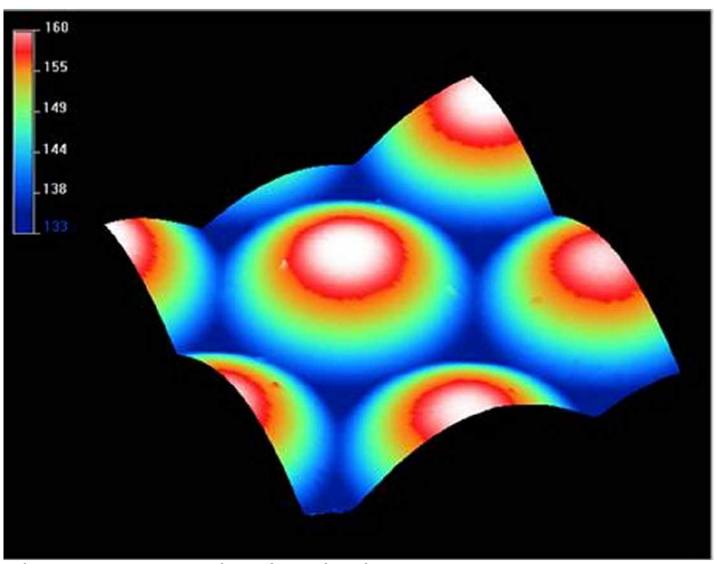

Figure 4. Topography of a microlens array

Chromatically coded high resolution measuring sensors for distance, topography and layer thickness are widely used in the industrial environment. They are utilized as stand-alone sensors or integrated in high precision measuring machines. They are easy to operate and are extraordinary insensitive against surrounding stray light, temperature influence, and speckle phenomena.

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