Metrology of Freeform Optics

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Freeform shapes are becoming more popular in optical components. Their use allows e.g. simplified design with less components. Modern production methods allow producing freeform shapes with quality and cost that is competitive to traditional spherical optics. As their use increases there is increasing need for characterization of freeform optical components. Freeform shapes are typically measured using tactile instruments like μCMMs, whereas purpose built optical interferometers are used for large spherically symmetric optics. Tactile instruments are slow for measurement of large number of data points typically needed for characterization of freeform shapes and risks damaging the sample whereas traditional interferometers cannot handle shapes with large deviation from sphere. To tackle these challenges, instruments such as tilted wave interferometers, confocal sensors, focus variation, deflectometers and white light interferometers are used. Tactile instruments are often used to validate the measurements by optical instruments.

VTT has improved its freeform measurement capabilities by developing a multi sensor optical profilometer for large surfaces. This allows measurements with higher sample spacing and vertical precision for cm sized samples than CMM and tactile profilometers and much higher sample slopes than Fizeau interferometer that is used for flat samples.

The profilometer uses commercial scanning white light interferometer and chromatic confocal sensors for height measurements. White light interferometer has nm level vertical precision and ability to measure freeform shapes but used magnification limits it to either low slopes and horizontal resolution or small measurement area. This trade-off is solved by stitching several images into large high-resolution dataset. 2D laser interferometer for tracking horizontal sample movements which allows simple stitching with known horizontal offsets of sub-images, which simplifies stitching computations. The confocal sensor allows rapid measurement of large areas with coarser data sampling. Total measurable area is 100 × 100 × 3 mm3.

The multi sensor profilometer was tested by measuring machined and 3D printed freeform shapes. In internal tests stitching accuracy of <10 nm was reached and total measurement uncertainty was < 50 nm for typical samples and ~100 nm for highest and widest possible samples. The instrument also performed well in interlaboratory comparison.