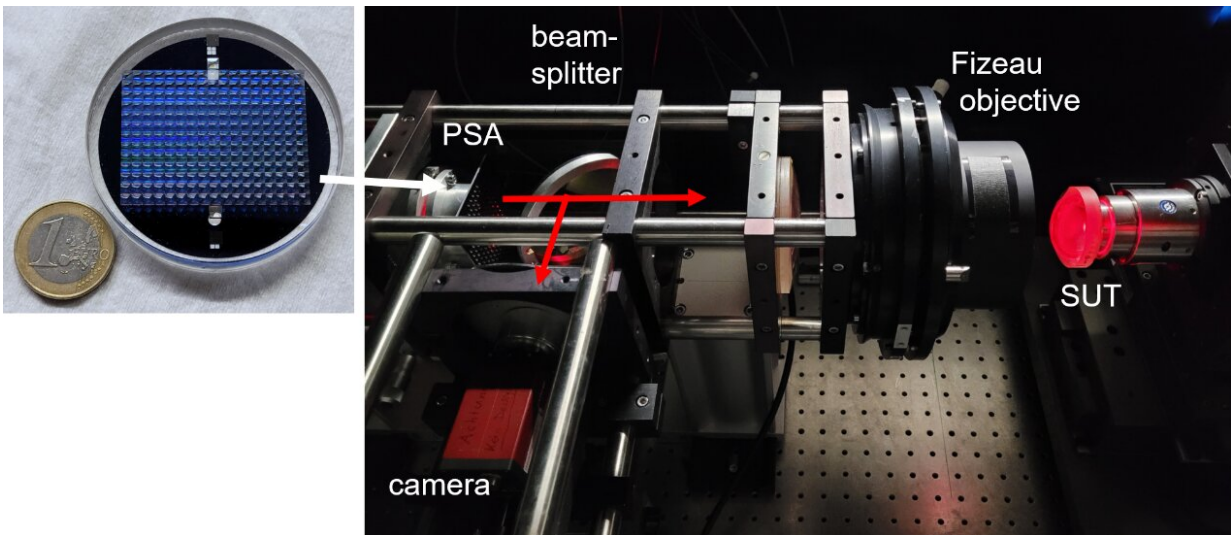


Common path principle improves shape metrology of complex precision optics

November 4 2022



Experimental realization of the Tilted Wave Fizeau Interferometer measuring an aspheric SUT. The light paths are highlighted in red. The monolithic point source array used for illumination is shown in detail. Credit: Christian Schober et al.

In order to push the performance of optical systems, aspheric- and freeform surfaces are used in state-of-the-art optic design for correcting aberrations. The production of these complex-shaped surfaces requires measuring the surface deviation from the nominal design. There are a lot of optical measurement methods, such as pointwise and stitching methods.

Other solutions, such as shearing-based measurement systems, do not measure topography but determine the surface gradient. Direct, fast topography measurements with high precision are possible with full-field interferometric methods. They contain a reference and a measurement wavefront which interfere with a camera chip.

The surface deviation can be calculated from the phase difference between the two wavefronts. Due to different beam paths, vibrations and temporal environmental effects like temperature or air fluctuations strongly influence the measurements' uncertainty. These effects are inherently reduced in common path interferometers, such as the widely used Fizeau-type interferometer.

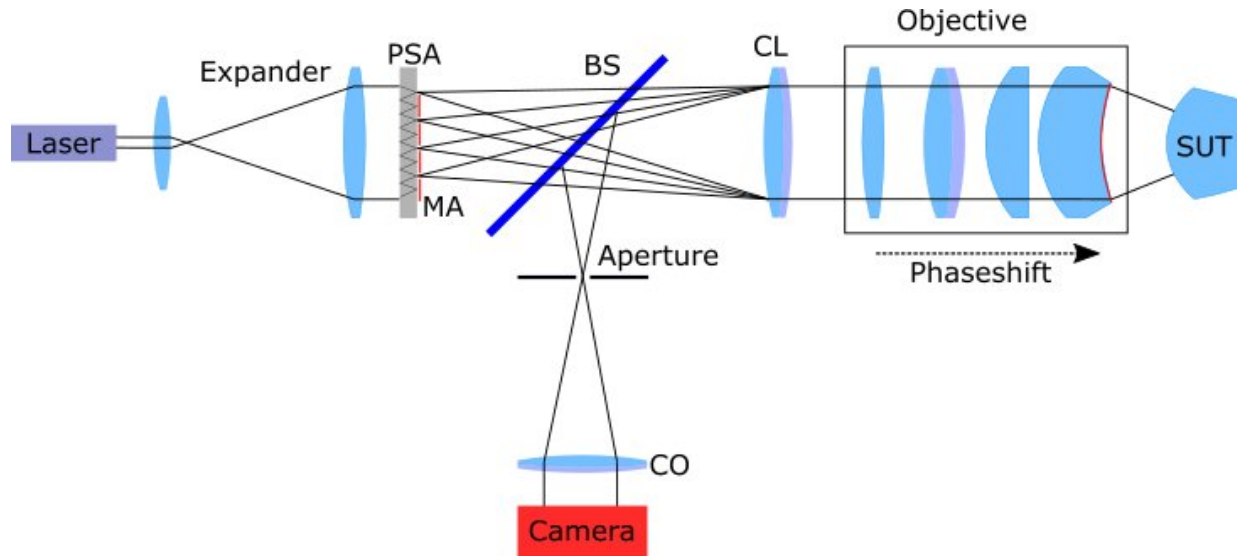
In a new paper published in *Light: Advanced Manufacturing*, a team of scientists from the University of Stuttgart have presented a new approach to Tilted Wave Interferometry. Their paper, titled "Tilted Wave Fizeau Interferometer for flexible and robust asphere and freeform testing," showed an improvement of one order of magnitude compared to classical approaches.

Compensation optics such as computer-generated holograms (CGH) are state-of-the-art for measuring non-spherical optics. However, they require a new compensation element for each new type of surface under test (SUT). When measuring surfaces with significant deviations from the reference shape, [interference fringes](#) with high fringe densities and retrace errors occur.

If the deviation becomes too high, vignetting of the measurement light produces unmeasurable areas of the surface under test. All these effects limit the classical Fizeau interferometer when complex-shaped surfaces are measured.

The Tilted Wave Interferometer (TWI) was invented at the University of

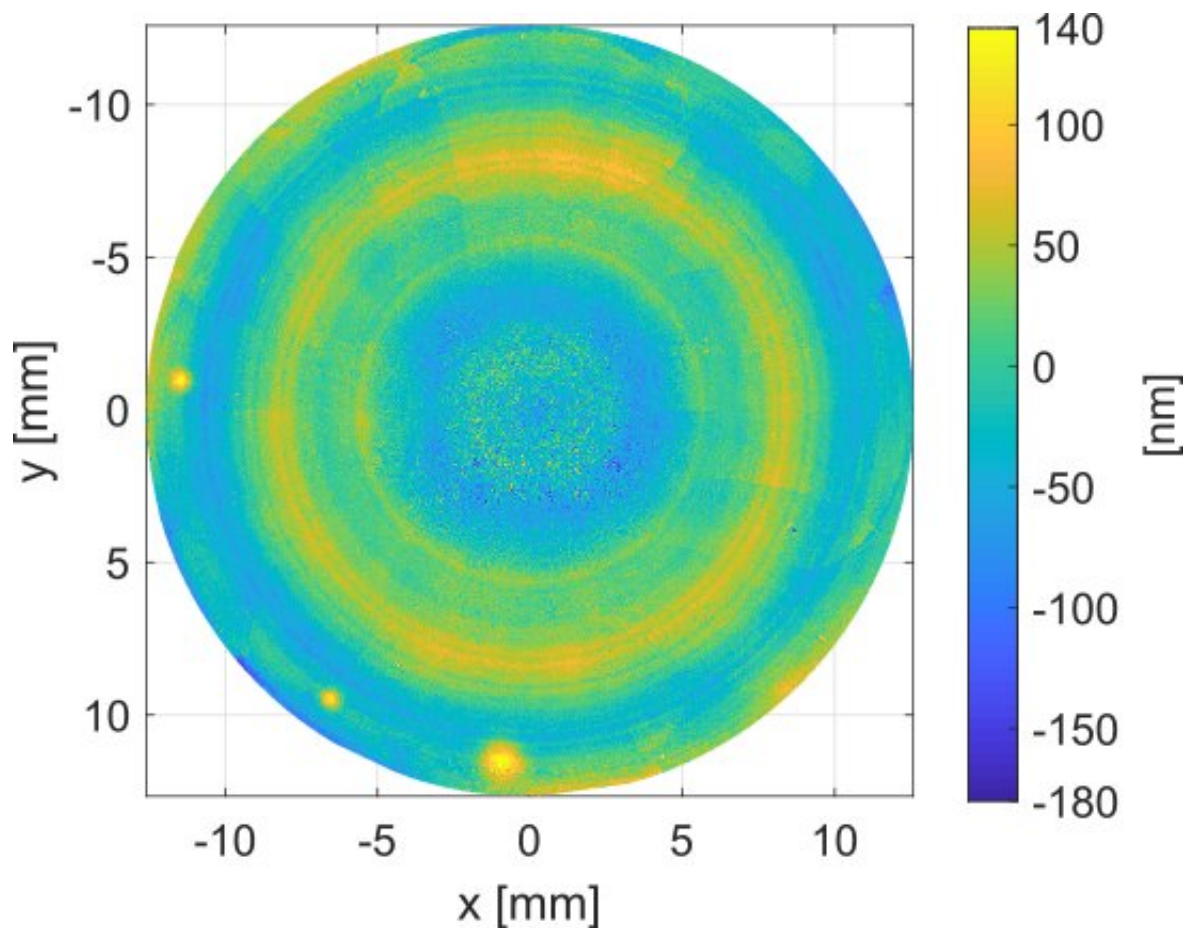
Stuttgart to overcome these issues. It uses a grid array of light sources for off-axis illumination of the SUT. The different sources and the reference wavefront generate multiple sub-interferograms on the camera chip. The tilted wavefronts' tilt angles locally compensate for the effect of the gradient of the SUT.



The beam of a laser is expanded by a telescope (expander) to illuminate a point source array (PSA). The PSA contains diffractive microlenses on its front side that focus the incoming light onto a pinhole array on the backside. Thus it converts the incoming plane wave into a grid of spherical wavefronts. These are collimated at the collimation lens (CL). The subsequent Fizeau objective, often referred to as transmission sphere, has a spherical last surface (Fizeau surface), which reflects a part of the incoming wavefront. This reflected wavefront serves as reference beam. The other part of the propagating light is reflected back from the sample (SUT) thus carrying the desired shape information of the SUT. The reflected light from the SUT and the reference beam propagate via the beamsplitter (BS) and the camera objective (CO) to the chip of the camera where their interference pattern is recorded. Credit: Christian Schober et al.

A sophisticated volume calibration and evaluation method are used to subtract systematic errors to treat retrace errors numerically. Combining the TWI principle with the Fizeau common path interferometer is not straightforward. Every off-axis illumination source generates a reference wave reflected from the Fizeau [surface](#). It leads to overlapping wavefronts on the detector, which makes it impossible to evaluate the interferograms.

There is a fiber switch-based Fizeau-type interferometer with switchable off-axis illumination. However, no analysis of the influence of the multiple interference effects between sub-interferograms has been reported yet.



Measurement result of an aspheric shaped specimen measured with the novel

Tilted Wave Fizeau Interferometer. The deviation from the nominal design surface shape is shown. The specimen shows three markers at the lower rim of the surface. These are three Gaussian shaped dips that nicely illustrate the high lateral and height resolution of the method. Credit: Christian Schober et al.

This paper's main contribution is the realization of the new common path Tilted Wave Fizeau Interferometer that overcomes the reference wave problem. It combines the robust, well-established Fizeau [interferometer](#) technique with greatly enhanced flexibility and short tilted wave interferometry measurement time.

The researchers found a new tool that addresses an urgent metrology need for advanced optics fabrication. It included a detailed description of the multiple beam interference problem, followed by the mathematical description of the new calibration algorithm. The results section presented benchmarks and comparisons to the classical Twyman-Green TWI.

More information: Christian Schober et al, Tilted Wave Fizeau Interferometer for flexible and robust asphere and freeform testing, *Light: Advanced Manufacturing* (2022). [DOI: 10.37188/lam.2022.048](https://doi.org/10.37188/lam.2022.048)

Provided by Chinese Academy of Sciences

Citation: Common path principle improves shape metrology of complex precision optics (2022, November 4) retrieved 4 July 2024 from <https://phys.org/news/2022-11-common-path-principle-metrology-complex.html>

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