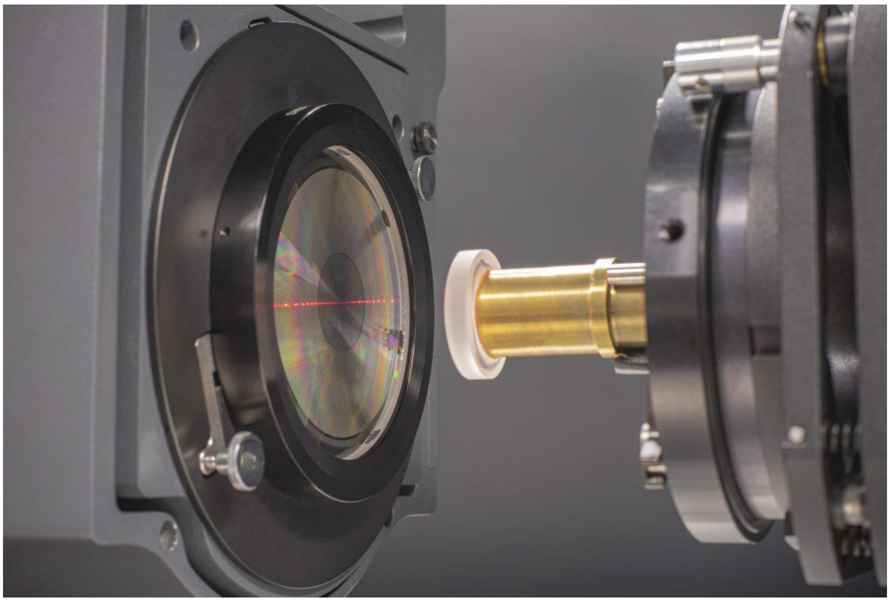
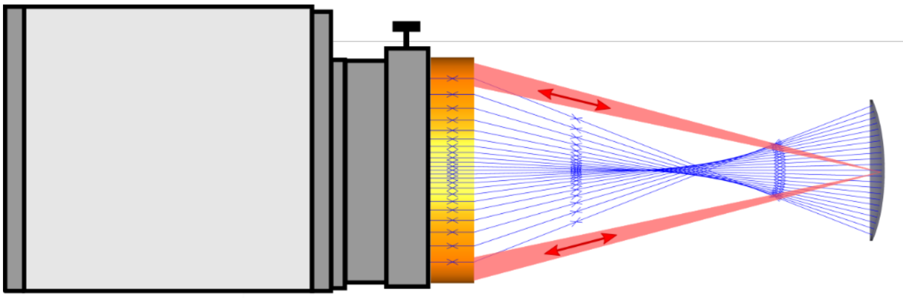
EASY TO USE COMPUTER GENERATED HOLOGRAMS FOR COMPLEX SURFACE METROLOGY

DFNL TYPE CGH WITH INTEGRATED FIZEAU REFERENCE PLANE





There are many metrology methods on the market for testing aspheres. The method with one of the highest known accuracies is based on a Fizeau interferometer, in combination with a CGH. We describe a so called DFNL type CGH, having the CGH diffractive structures integrated into the Fizeau reference surface, which provides a solution for measuring complex shapes that is comparable to the traditional methods used for testing spheres. Compared to a standard CGH, the DFNL simplifies the hardware and alignment steps required to measure a complex optical surface.

DFNL-type CGHs

Diffractive Fizeau Null lenses (DFNL) are computer generated holograms that can be used to test surface shapes with a Fizeau interferometer without having to use an additional reference optic. A DFNL consists of a diffractive structure with binary gratings that creates a unique wavefront such that each ray hits the test surface at a right angle. The reflected wave is then converted to a plane wave in the second pass through the CGH. The reference wave is created by the same surface using the Zero-order in reflection. In this setup only the propagation of the light from the CGH surface to the test surface contributes to the interference signal. Therefore, the only additional wavefront error apart from the test surface is introduced by surface irregularities of the CGH surface. DFNL type CGHs are fully compatible with the ZYGO Bayonet mount and can be used seamlessly with any of the ZYGO Verifire or Dynafiz Laser Interferometers.

Major differences to standard CGHs

Standard CGH Nulls are placed between the interferometer's reference optic and the test surface. DFNL type CGHs include an integrated Fizeau reference surface and are directly attached to the 4" or 6" Bayonet mount of the interferometer. This simplifies the alignment procedure and reduces overall measurement time. In addition, alignment errors to the optical axis of the interferometer are eliminated as there is no requirement to align a separate CGH. DFNLs are manufactured on high quality fused silica optical substrates, which provides excellent wavefront qualities. As conventional CGHs are based on e-beam reticles, they are limited in thickness and size. DFNLs however, are available with a diameter up to 220 mm allowing to test larger convex surfaces. Mechanical stability for both vertical and horizontal setups is ensured by choosing substrates with the appropriate thickness - up to 24 mm, which ensures a minimum effect of stress induced wavefront error.

Limitations of DFNL type CGHs

As noted above, a DFNL provides numerous benefits for CGH-based applications but there are a few cases in which DFNL's cannot be applied: (1): DFNLs can only be used in combination with a Fizeau type interferometer. The reference wave for a Twyman Green interferometer, for example, is not at the last surface of the interferometer. Therefore, it is not possible to use the CGH surface to create the reference wave. (2) For very steep surfaces the maximum required diffraction angle cannot be achieved to create a sufficiently precise aspherical wavefront. In this case the use of a standard CGH Null is necessary. At DIOPTIC we recommend the optimum solution based on the lens under test, its surface form, its surface slopes, the required accuracies and the customer's metrology instrumentation.

Which surface types can be tested?

Within the limits of achievable diffraction angles there is a wide range of surface types:

- ✓ Aspherical surfaces
- ✓ Spherical surfaces with a very large radius for which no suitable transmission spheres are available
- ✓ Large convex spherical surfaces, for which no suitable transmission spheres are available
- ✓ Off-Axis aspheres
- ✓ Cylinders and toroidal surfaces
- ✓ Free form surfaces

In addition to the various geometries, it is also possible to test surfaces with diffractive structures. In this case the exact step-height of the zones is taken into account, so for an optimal lens surface the interferogram shows a smooth phase without any discontinuities between two diffractive zones. This way, deviations of the required step height can also be tested.

Various additional alignment holograms or "fiducials" are added to each CGH to allow a quick and easy alignment of the test surface.

What accuracy can be achieved?

The main accuracy limitations of a DFNL are the flatness of the reference surface and the pattern accuracy of the CGH. In contrast to conventional CGHs, DIOPTIC DFNLs are manufactured on precision fused silica substrates with a typical surface flatness of λ/10 (PV). If required, the flatness can be as low as λ/20. Since these substrates provide the reference surface for the interferometer, a highly accurate reference wavefront is generated. The mechanical stability is guaranteed up to a diameter of 230 mm or 9 inches by appropriate substrate thicknesses of up to 24 mm. The patterning error of the CGH is well below 0.1µm resulting in a typical contribution of the wavefront error of λ/100 at 2µm minimum pattern period. An overall qualification of the total error has been performed by testing a reference sphere using a DTS-type CGH (**D**iffractive **T**ransmission **S**phere). The measured phasemap is shown in the figure below, resulting in an error of 35nm PV and 5nm RMS. Principally, the measurement uncertainty can be further reduced by subtracting the surface error of the DFNL substrate.

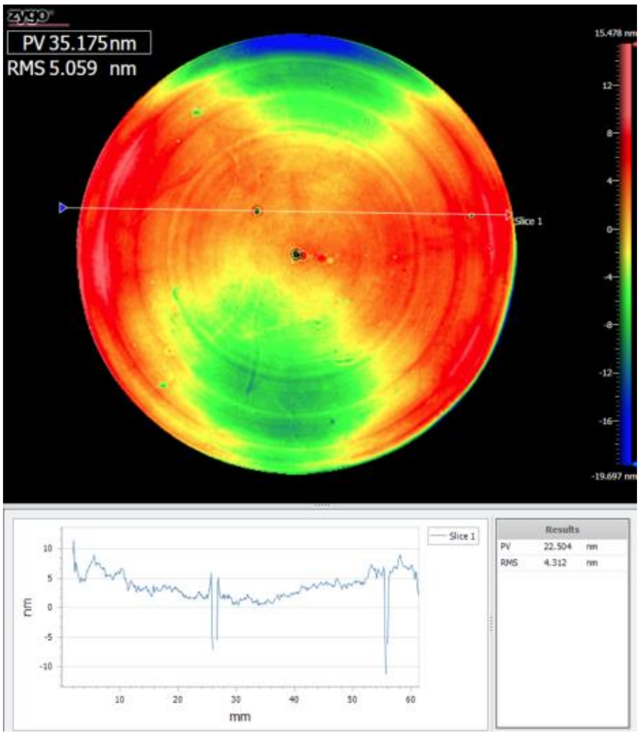


Figure 1: Characterization of a diffractive transmission sphere. The PV wavefront error is λ/20

How to certify the accuracy of aspherical wavefronts

Trust is good, control is better! Even though the manufacturing process of our CGHs is very well controlled there are several test measurements that can be performed to verify the patterning accuracy. The main error source of the patterning process is due to thermal drifts during lithography writing, which can take several hours. Therefore, the use of specific fiducial squares for quality assurance has been developed per the following two-step process:

(1) Before writing the CGH we create several small fiducial markers placed on a regular grid covering the complete substrate. These markers are written within a few seconds so no drifts due to temperature changes or humidity can occur.

(2) During the writing of the CGH which can take several hours the central column of lines in the fiducial squares are written. Any patterning error due to drift will result in a shift between the central column to the adjacent ones and can be detected with uncertainties below 50 nm. DIOPTIC guarantees patterning accuracies of less than 0.1µm over the whole substrate.

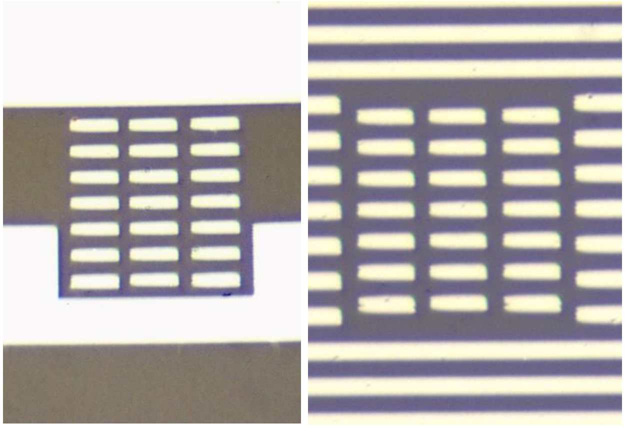


Figure 2: Fiducial marks to verify the writing process of the CGH structure

All CGH delivered by DIOPTIC comes with a test report that includes a full set of documentation, including

- ✓ Optical layout
- ✓ Recalculated sag table
- ✓ CGH phase function and diffractive periods
- ✓ CGH induced scale deformation
- ✓ Alignment sensitivities
- ✓ Ghost analysis
- ✓ Substrate qualification tests
- ✓ Error budget, especially showing the patterning accuracy using the fiducial squares and the results of their image analysis
- ✓ Diffraction efficiencies across the CGH

If you interested in additional information about CGHs, interferometry for aspheres, optomechanical accessories for metrology of aspheres and other complex surfaces please get in touch with our expert:

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