[C4-3]

ON THE APPLICATION OF SYNTHETIC HOLOGRAMS FOR TESTING ASPHERIC SURFACES

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1. INTRODUCTION

Computer generated holograms (CGH) can be used for testing a widespread range of aspheric surfaces with high accuracy.[1-5] Different holographic configuration can be used; for the information storage, photographic material is very often appropriate.
Two beam interferometric arrangement in which both beams pass through the CGH is desirable in order to compensate inhomogenities of the hologram storage material. For symmetrical optical systems to be tested, in-line (Gabor-Type) and off axis CGH are applied. Although we use both configurations we prefer often off-axis arrangements.
The implementation of the technique requires the analysis of errors due to the testing procedure as well as to additional optical components in the beam to be analysed and the manufacturing of the CGH. Automatic fringe analysis is very useful and will be discussed.[6,7] A two wavelength technique can be used to reduce the sensitivity.[8]

2. TESTING PROCEDURE WITH COMPUTER GENERATED

For generating CGH different techniques have been deviced or are in the process of being developed. A computer driven drum scanner ("Optronics") with a PDP 11/34 which is also used to compute the wavefront was found to be appropriate. A one step reduction on high contrast photographic plates or on photoresist for improving the diffraction efficiency was found desirable. A two beam interference arrangement together with an off axis hologram is shown in fig. 1. The incident wave is separated by the beam splitter into the reference wave, reflected back slightly oblique from the mirror M to be used as reference passing undisturbed through the hologram. For the fringe analysis of closed fringes a planeparallel plate is used to shift the phase in the reference beam. The simple lenses L_1, L_2, L_3 are auxiliary lenses to adapt the aperture of the lens under test, TS. They should also image the test surface onto the CGH, a necessary condition for strong aspheric wavefronts, they can also be used to compensate some of the asphericity. L_4 is a high quality lens to be used for testing apherical as well as spherical lenses without a CGH by replacing the auxiliary lenses by L_1'. In addition L_4 and L_1' are used for focussing on the aspherics. A spatial filter in the focus of L_5 avoids unwanted light. L_6 images the fringe pattern, a measure for the discrepancy between the test piece and the perfect aspheric, onto a diode array or a video camera connected with a computer for the fringe analysis. For testing different aspheric surfaces the separation of the lenses L_1, L_2, L_3 may need to be modified or one or more lenses replaced. They are by no means perfect, but need to be tested by replacing the aspherical surface by a known spherical mirror. No fringes should occur for perfect agreement of the data. Sources of errors result from the departure from the lens data and separations used for computing the wavefront as well as centering errors of the components, magnification error and distortion by photo-reduction and errors in generating the hologram. Most of the errors are compensated for the CGH of the lenses to be tested.

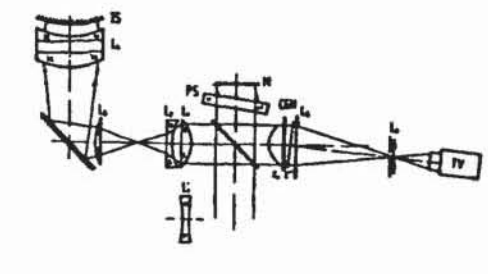

fig. 1

3. AUTOMATIC FRINGE ANALYSIS

For the fringe analysis different methods are applied:

- Photographing the fringe pattern and determining the position of the fringe center to feed into the computer which in turn calculates the phase.
- Measuring the fringe center position directly or applying a phase detection technique[7] by using photoelectric detectors such as diode arrays or television techniques. Simple analysis technique can be used when closed fringes are avoided bv deliberately introducing tilts. Phase shifting techniques are useful for the analysis of closed fringes. The amount and the sign of deformation can be determined at any sample point.
- Heterodyne or AC techniques are used where the phase difference between the two interfering beams is changed at a constant rate in time, producing periodic signals with phase delays according to the optical path difference.

For the phase measurement we use very often a Hammamatsu C-1000 camera, recording the intensities at a selected number of up to 1024 by 1024 data points. For the one dimensional analysis of the wavefront 1024 data points are used. Alternatively 2048 data points of a diode array can be used and analysed in an IBM-PC computer. The phase shifting technique for the analysis of closed fringes is implemented by slightly tilting the plane parallel plate in fig. 1 by means of a computer driven stepping motor to introduce phase shifts of $\pi/2$ and π. The resulting intensities in the two beam interference pattern are:

$$I_1(x,y) = a(x,y) + b(x,y)\cos\phi(x,y)$$
$$I_2(x,y) = a(x,y) + b(x,y)\sin\phi(x,y)$$
$$I_3(x,y) = a(x,y) - b(x,y)\cos\phi(x,y)$$

arriving at the phase $\phi(x,y)$ of the wavefront

$$\phi(x,y) = \text{arc tg}\ \frac{2\,I_2(x,y) - I_1(x,y) - I_3(x,y)}{I_1(x,y) - I_3(x,y)}$$

Furthermore a phase detection techniques based on FFT- or Fourier analysis algorithme by introducing a strong tilt is used on the static interferograms. Sensitivities in the region of $\lambda/100$ were achieved with the described techniques.

4. EVALUATION BY RAY TRACING

To extract information about the shape errors of the aspheric surface under test such as errors of vertex radius or eccentricities, it is desirable to approximate the wavefront by a set of polynomials. Zernike polynomials were used because of their orthogonal properties. They easily interphase with the ray tracing program to calculate the actual deformation of the surface under test by an iterative process.

Small adjustment errors such as decentring and rotation of the hologram as well as decentring and tilt of the aspheric surface can be balanced.

Odd terms of the Zernike approximation are useful to calculate residual adjustment errors. Fig. 2 shows a one and two dimensional analysis of an aspheric Ge-surface.

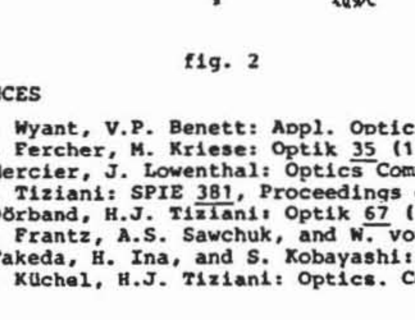

fig. 2

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