Mathematica items needed

Aspheric Surface Testing

AS-1

A scatterplate interferometer is used to perform a null test of a parabolic mirror.

a) Sketch the test setup.

b) How does lateral displacement of the scatterplate change the interference fringes?

c) How does longitudinal displacement of the scatterplate change the interference fringes?

d) How does a scatterplate differ from a simple piece of ground glass?

AS-2

One way of testing an aspheric surface is to use a computer-generated hologram.

a) Sketch the interferometric setup used to test an aspheric mirror using a CGH. Make sure to note which orders are used.

b) How would you test the quality of a particular plotter used to generate a CGH? Include diagram.

c) An important quantity in determining how large of an aberration that can be measured is the space-bandwidth product. Why is it important?

d) Consider an e-beam plotter with a plotting resolution of 0.5 μm over a 1 cm aperture. What is the smallest figure error that can be detected while testing an aspheric mirror with a slope departure of 500 waves/radius from a reference sphere?

AS-3

A computer generated hologram is being made to test a concave aspheric surface having the following parameters:

$r = -2.700105$ inch

$K = -.279229$

$A_4 = 0.011789\ (\text{in})^{-3}$

$A_6 = 0.002166\ (\text{in})^{-5}$

$A_8 = 0.000670\ (\text{in})^{-7}$

$A_{10} = -.001344\ (\text{in})^{-9}$

The semi-diameter of the optic is 1.07 in. The plotter used to make the CGH has 2000 X 2000 distortion free resolution points.

a) To within a factor of 2, what is the minimum peak error in the measurement of the surface shape introduced by the finite number of plotter resolution points if in making the hologram we introduce enough tilt to separate the +1 diffraction order from the other orders?

b) To within a factor of 2, what is the minimum peak error in the measurement of the surface shape introduced by the finite number of plotter resolution points if in making the hologram we do not introduce tilt to separate the first diffraction order?

AS-4

I am testing a wavefront having 40 waves of third-order spherical aberration. I want to make a CGH to test this wavefront.

a) How many waves of defocus should be added to minimize the geometrical spot size?

b) What is the minimum number of waves of tilt across the radius of the pupil required to just separate the zero and first orders produced by the hologram?

c) Minimum number of waves of tilt to separate the first and second orders?

AS-5

A customer wants to use a CGH to test a 3 inch (76.2 mm) diameter, 0.4 inch (10.16 mm)thick, BK7 plano convex lens having a focal length of 10 inches (254 mm). Sketch an interferometer for testing the lens in single pass at infinite conjugates. The plotter used to make the CGH has 1000 X 1000 distortion free resolution points.

a) To within a factor of 2, what is the minimum peak error in the measurement introduced by the finite number of plotter resolution points if in making the hologram we introduce enough tilt to separate the +1 diffraction order from the other orders? (Consider only third-order aberrations.)

b) Devise a good method for using both the +1 and -1 diffraction orders produced by the CGH to test the lens whereby I have to put only 1/2 the aberration into the CGH that would be required if I use the 0 and +1 orders as is normally the case. Compare the error introduced by the finite number of plotter resolution points for cases a) and b).

AS-6

Computer generated holograms are used to test a mirror producing an aspheric wavefront of 20 ρ^4, in units of waves. ρ is normalized to be between 0 and 1.

a) Sketch a reasonable setup being careful to show the planes that are conjugate to one another.

b) How many fringes of defocus should be added to the wavefront the hologram produces so errors due to plotting are minimized?

c) Which diffraction orders should be used for the test and reference beams?

AS-7

A computer-generated hologram is a convenient way of testing an aspheric wavefront of the form $20\lambda\,\rho^4$.

a) How much defocus should be added to reduce the amount of wavefront tilt that must be introduced in the making of the CGH to separate the +1 order from the +2 order? Given this amount of defocus, what wavefront tilt must be introduced to separate the +1 and +2 orders?

b) The CGH is produced using a plotter having a distortion-free resolution of 0.5 micron over a 1 cm aperture. If the largest allowable error due to plotter resolution is 1/10 fringe, what is the largest allowable slope difference between the aspheric wavefront and the tilted plane wave used in the making of the CGH? Give the slope in units of waves/radius.

c) Let the hologram diameter be 1 cm. If a wavefront having a slope of 200 waves/radius is being tested, what is the maximum error introduced by translating the CGH sideways a distance of 10 microns from the optimum position?

AS-8

I am using the two-wavelength holography technique to test a 20-cm diameter, 40 cm focal length parabolic mirror at center of curvature. A 2-cm diameter, f/2, diverger lens is used in the interferometer. The hologram is recorded using a wavelength of 514.5 nm, and it is read out using a wavelength of 488 nm. The hologram is recorded on a photographic plate. Between exposure and play back the photographic plate is removed from the interferometer for processing. What is the approximate tolerable error in lateral positioning of the plate (hologram) such that the error in the measurement of the surface of the parabolic mirror is less than 5 microns?

AS-9

I am using two-wavelength holography to test a concave aspheric mirror. The two wavelengths being used are 488 and 514.5 nm. If the diverger lens has no spherical aberration at 488 nm and 1 wave of spherical aberration (single pass) at 514.5 nm, how much error will result in the measurement of the surface of the aspheric mirror?

AS-10

Two-wavelength holography is used to test an aspheric mirror. Phase-shifting interferometry is used and the detector has 256 x 256 detector elements. For this problem you can assume the detectors are point detectors.

a) What is the equivalent wavelength, in units of microns, for the test if one wavelength is 500 nm and the second one is 520nm?

b) How should the defocus in the wavefront being tested be selected such that the steepest asphere can be tested?

c) What is the maximum slope (in units of microns per radius) of the wavefront that can be measured using a single wavelength of 500 nm and phase-shifting interferometry? State any assumptions you make.

d) Repeat part c for the two-wavelength holography test and phase-shifting interferometry.

e) Air turbulence produces 50 nm of error in the making of the hologram. How much error, in units of nm, does this introduce into the measurement of the aspheric wavefront in the two-wavelength holography test?

AS-11

I want to contour an essentially flat object which has some sharp steps in it between 1 mm and 2 mm deep and other sharp steps between 5 and 10 microns deep. I want to measure both of these steps to within an accuracy of 1% of the step height. Someone tells me that I can perform these measurements using a Twyman-Green interferometer and direct-phase measurement interferometry if I use two or three different visible wavelengths. Describe how this would work. Be sure to give reasonable wavelengths and make a realistic estimate as to how well you can and need to measure the phase of the resulting interference pattern.

AS-12

Corning has sent me a piece of glass having dimensions 0.75 X 2 X 2 inches, which is made up of three separate pieces of glass 0.25 X 2 X 2 inches which were fused together. They want to know how good the block is in transmission when viewed through the 0.75 X 2 inch surface. They do not care about surface flatness. My problem is that when I test the block in transmission in a Mach-Zehnder interferometer I see fringe jumps between the fused surfaces and I cannot tell how large the fringe jumps are because of the discontinuity. How would you propose solving this problem?

AS-13

Moiré interferometry is used to contour a surface. The surface is illuminated with two plane waves, and the normalized intensity distribution incident on the film in the camera is

$$\frac{1}{2}\left(1+\mathrm{Cos}\left[2\,\pi\,\frac{(\mathrm{Tan}[\alpha]+\mathrm{Tan}[\beta])\,f[x,y]-y}{d}\right]\right)$$

Assume the photographic recording process is linear in the sense that after development the intensity transmittance of the film is proportional to the exposing intensity. The film is replaced back into the setup in the exact same position it occupied during exposure. The object which had a height distribution $Z = f[x, y]$ is replaced with an object for which $Z = g[x, y]$.

a) What is the resulting moiré pattern? Show that you obtain a so called "beat term" which gives us $f[x, y] - g[x, y]$.

b) It is commonly believed that similar moiré results are obtained if the two intensity patterns are added, i.e., double exposure of the two distributions on one piece of film. Show that superimposing the two intensity distributions does not give the "beat term" if the recording process is linear.

c) Comment upon whether a "beat term" would be obtained if the recording were non-linear.

d) Under proper conditions the naked eye can see the "beat term" by viewing directly two superimposed (added) sinusoidal intensity distributions. What property of the eye makes this possible? Does the eye have to resolve the individual sinusoidal frequencies to see the "beat term" if the patterns are i) added, ii) multiplied?