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FRESNEL LENS TOPOGRAPHY
WITH 3D METROLOGY

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INTRO:

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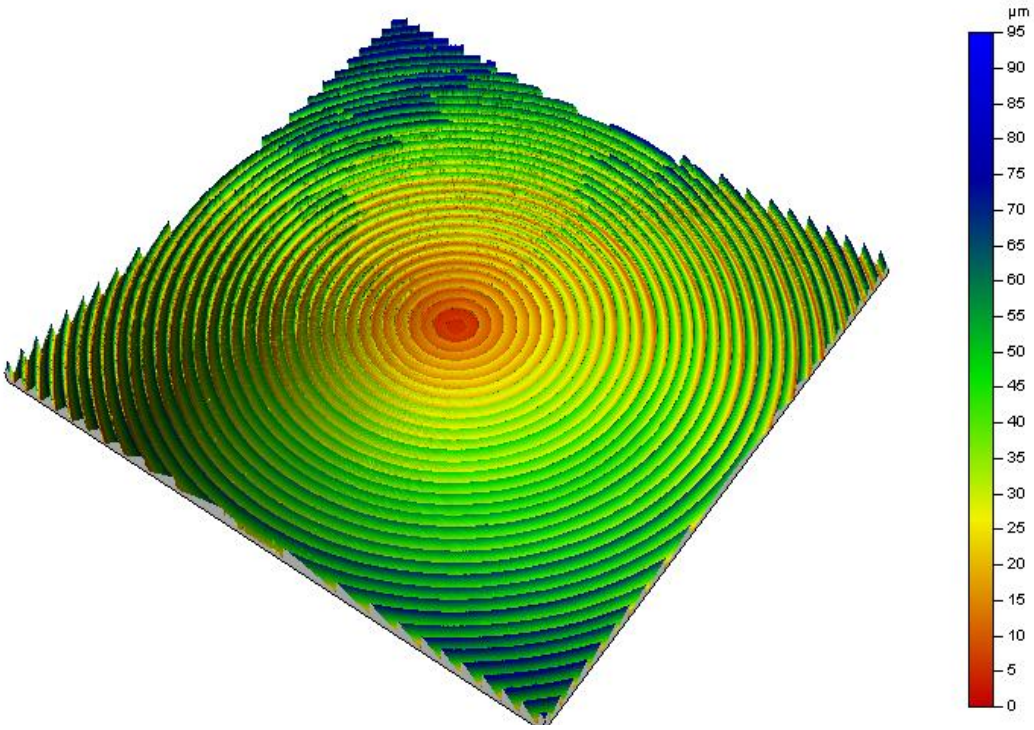
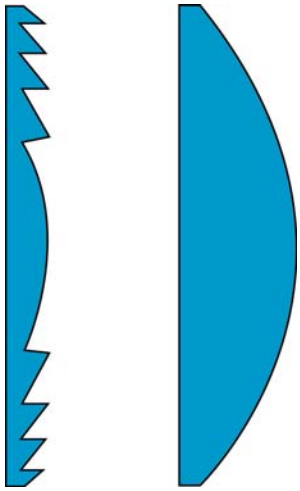
A lens is an optical device with perfect, or approximate, axial symmetry which transmits and refracts light (converging or diverging the light). A simple lens is a lens that consists of a single optical component. A compound lens is an array of simple lenses that share a common axis. Even though spherical surfaces are not ideal shape for making a lens, they are often used and the simplest shape which glass can be ground and polished to.



3D Rendering of Fresnel Lens in Nanovea ST400 Analysis Software

A Fresnel lens consists of a series of concentric rings, which are thin parts of a simple lens, with a width as small as a few thousandths of an inch. Fresnel lenses contain a large aperture and short focal length, with a design that reduces the weight and volume of material required compared to conventional lenses with the same optical properties. A very small amount of light is lost by absorption because the Fresnel lens is thin. However, since Fresnel lenses decrease image quality, they typically are used when quality, or resolution, is not significantly important or when the bulky size of a solid lens is unfeasible.



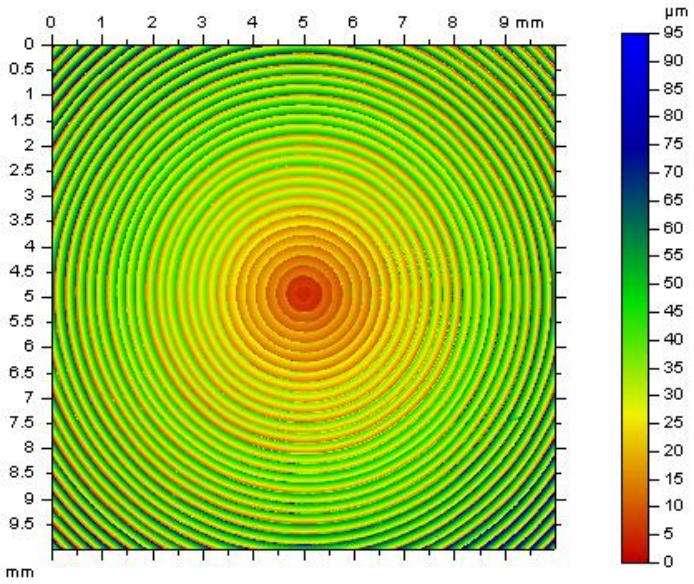
Cross-section of a Fresnel Lens vs. Cross-section of a Conventional Plano-convex Lens of Equivalent Power

PRODUCTION & APPLICATIONS

The inexpensive production of Fresnel lenses can be completed by molding or stamping them out of transparent plastic. Although originally developed for lighthouses, possibly the most extensive employment of Fresnel lenses was in automobile headlights. The Fresnel lens would shape the light beam from the parabolic reflector to meet requirements for beam patterns. Due to weight, impact resistance, and cost, newer cars have discontinued the use of glass Fresnel lenses in the headlights. However, Fresnel lenses remain widely used in automobile marker, tail, and backup lights.

Fresnel lenses are also utilized in the optical landing system for aircraft carriers, where the light assists the pilots in performing proper landings. Another application for a Fresnel lens is enhancing reading lights, for passengers, on Airbus aircrafts so that the focused light beam does not impinge on neighboring passengers. Other applications, where Fresnel lenses are used, include: overhead projectors, railroad and traffic lights, projection televisions, spotlights, floodlights, decorative lights, and cameras.

Recently, Fresnel lenses are becoming prevalent in the field of solar energy, where the lens is applied for the purpose of collecting and concentrating sunlight onto solar cells. As a result, the active solar cell area can be dramatically reduced, compared to conventional solar cells, which, in turn, will provide a significant reduction of budget spending due to lowered material consumption.



2-D False Color Height Representation of a Fresnel lens in Nanovea ST400 Analysis

MEASUREMENT OBJECTIVE

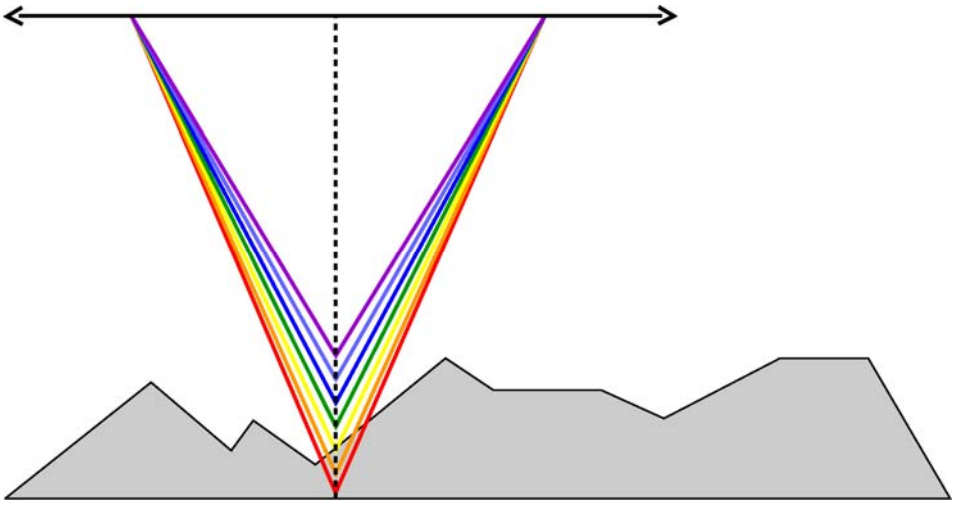
In this application, the ST400 is used to measure the surface topography of a Fresnel lens. The 2.3" x 2.3" Acrylic Fresnel lens measured has a 1.5" focal length, 2.0" effective size diameter, 125 grooves per inch, and an index of refraction of 1.49. The lens was manufactured by Edmund Optics.

By measuring the height and pitch of the concentric rings, production variations can be detected by comparing the measured values against the specification values given by the manufacturer of the lens. Quality control by these means could reveal defective production molds or stamps. For instance, the stamp could be wearing over time, causing it to lose its initial shape. Consistent deviation from the lens manufacturer specification could be a positive indication that the mold needs to be replaced.

MEASUREMENT PRINCIPLE:

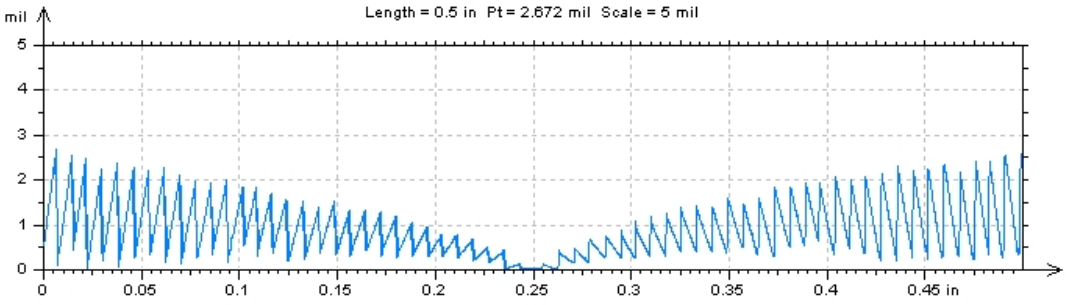
The axial chromatism technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single

monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus.

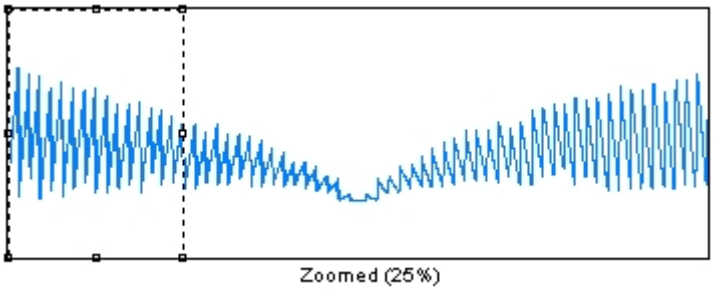


The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.

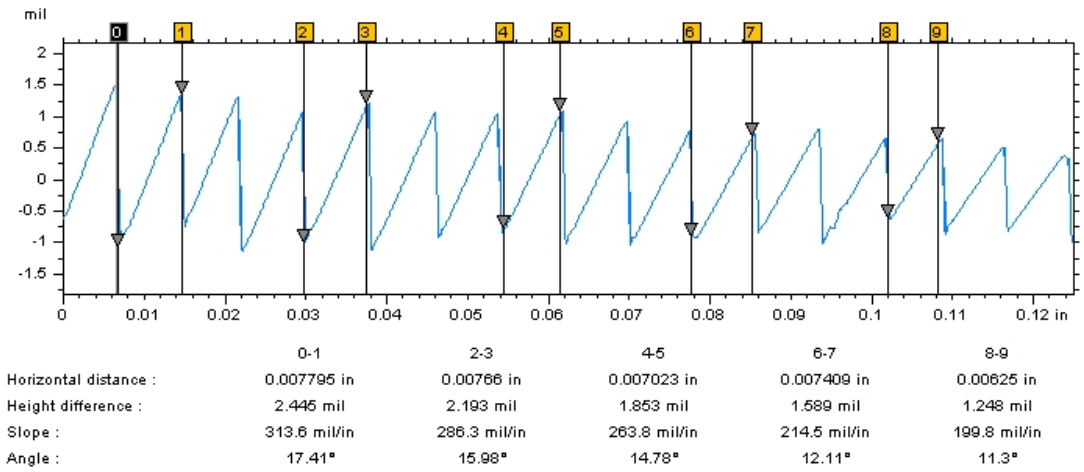
TEST RESULTS:



Fresnel Lens Extracted Profile in Nanovea ST400 Analysis Software



Location of Profile Zoom from Length of 0.5 inch to 0.125 inch

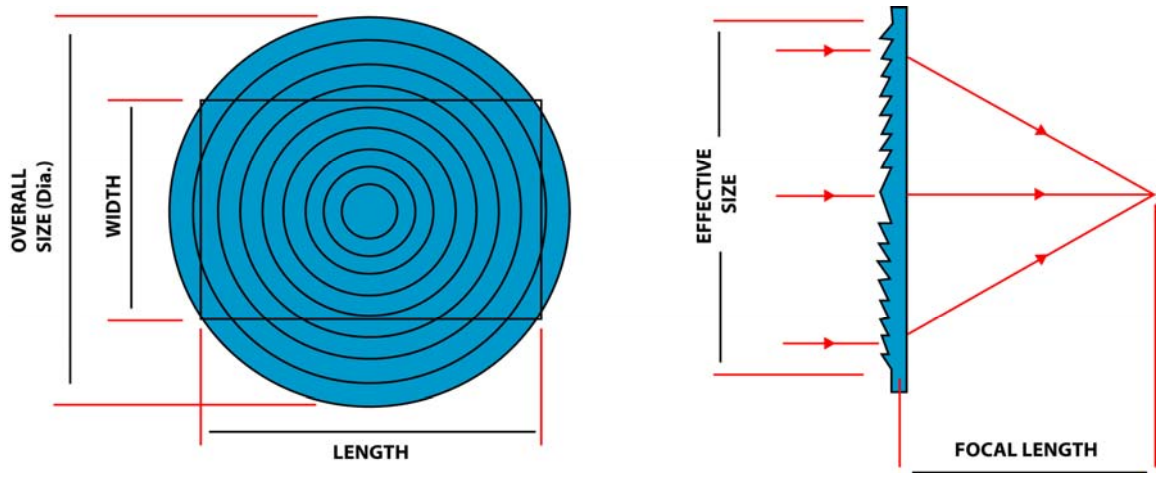


	0-1	2-3	4-5	6-7	8-9
Horizontal distance :	0.007795 in	0.00766 in	0.007023 in	0.007409 in	0.00625 in
Height difference :	2.445 mil	2.193 mil	1.853 mil	1.589 mil	1.248 mil
Slope :	313.6 mil/in	286.3 mil/in	263.8 mil/in	214.5 mil/in	199.8 mil/in
Angle :	17.41°	15.98°	14.78°	12.11°	11.3°

Dimensional Calculations in Nanovea ST400 Analysis Software

TEST DISCUSSION:

There is a noticeable increase in height of the concentric rings, moving outward from the center of this particular Fresnel lens. This is an interesting finding because the schematic from the manufacturer portrays the rings having a constant height throughout. The measured profile could be a good indication that the mold or stamp was not properly machined to fit manufacturer specifications, or expectations. If this is the true surface shape of Fresnel lenses that are being produced by Edmund Optics, the manufacturer diagram should be updated to indicate the gradual increase in height of the concentric rings that emanates from the center of the lens. Someone who purchases this lens and finds that the measured profile of their Fresnel lens does not match the drawing on the manufacturer's website could believe that they have a defective product. However, Edmund Optics may be aware of this ring height increase and have done research to know that it does not have any effect on the overall performance and efficiency of the Fresnel lens.



Fresnel Lens Schematic by Lens Manufacturer

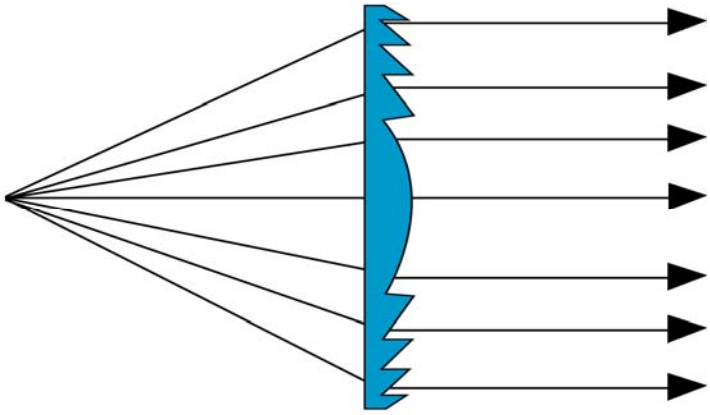
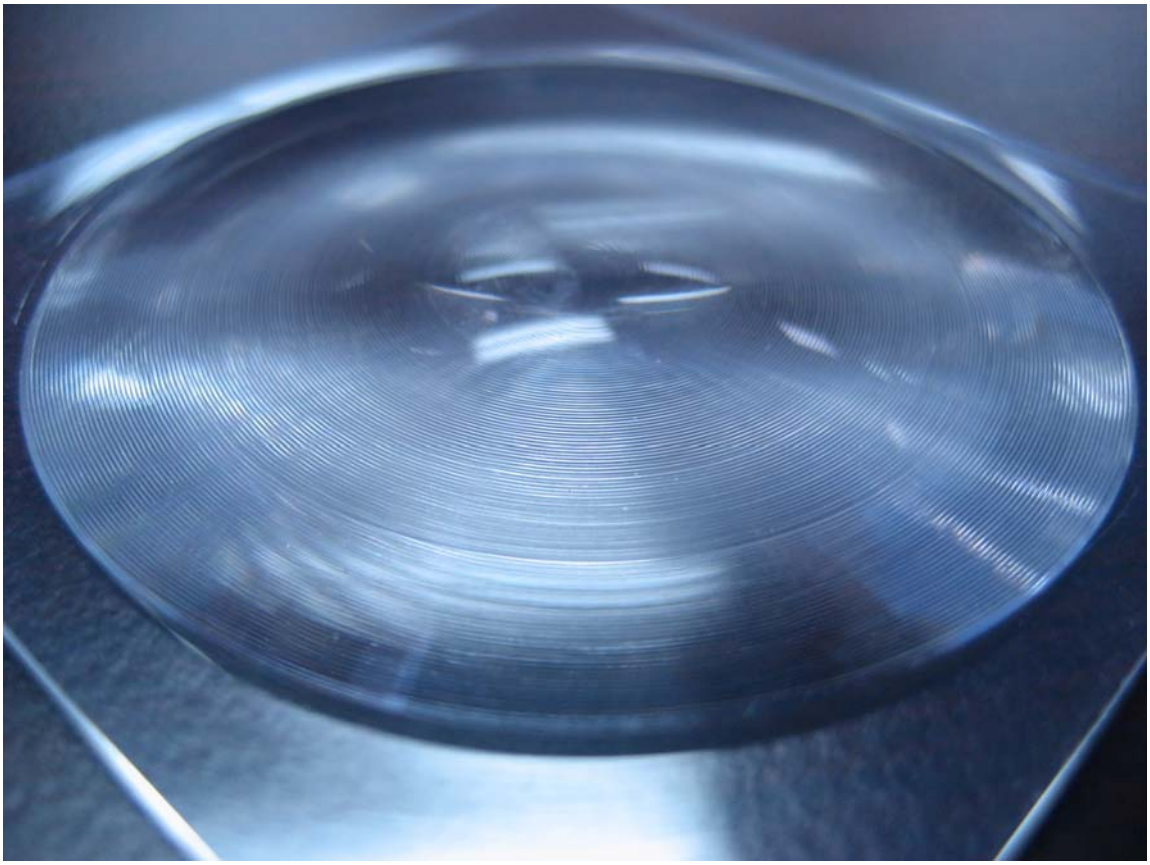


Illustration Depicting Light Rays Traveling Through a Fresnel Lens



CONCLUSION:

The Nanovea ST400 can be used to accurately measure the surface topography of Fresnel lenses, from which height and pitch calculations can be made. The complex, serrated profile of a Fresnel lens can be measured because of the versatile measurement technique used by the ST400. Using the measurement data, the analysis software provided with the ST400 can quickly and precisely perform dimensional analysis. Comparing ring height and pitch values of manufactured lenses against the ideal ring specification is an extremely useful quality control tool to verify that production molds or stamps are maintaining their proper shape.