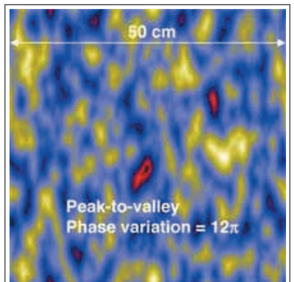
Advanced Optical Components & Technology

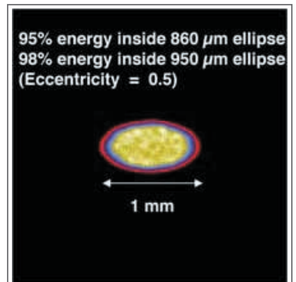
Specialty Diffractive Optics

Kinoform Phase Plates and Multilevel, Diffractive, Beam-Correcting Optics

Kinoform phase plates (KPP) are beam-shaping elements that enable a controlled modification of the focal-plane intensity profile. The focal spot produced by high-power laser beams is often severely aberrated due to optical wavefront errors. KPPs can be designed to produce an arbitrary shaped intensity envelope in the focal plane. The phase plates are designed using a variant of the Iterative Fourier-Transform Algorithm (IFTA). The fine-scale speckle superimposed on the intensity envelope can be smoothed with temporal beam- smoothing methods.



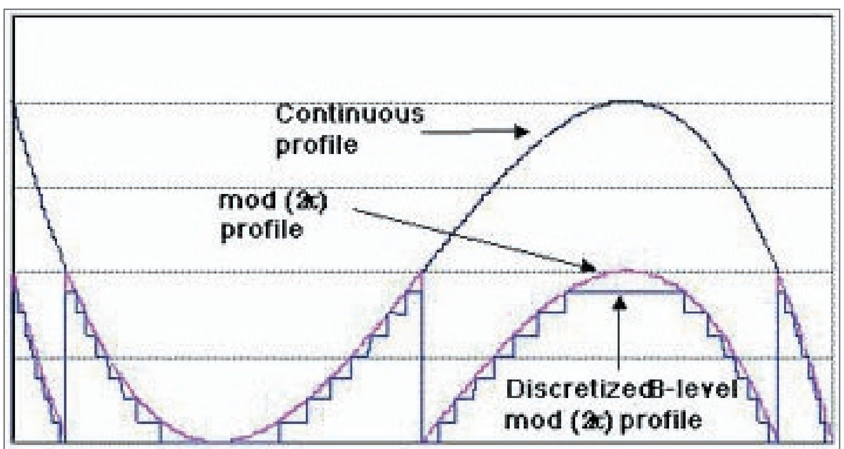
Example of a phase screen that produces an elliptical focal spot.



Focal spot produced by the phase screen shown on the left =351 nm, lens focal length = 770 cm.

Fabrication of Kinoform Phase Plates

Kinoform phase plates can be fabricated as a continuous surface profile – using grayscale patterning techniques – or by photoresist and subsequent dry etching; large-scale implementation of this process is under development at LLNL. Alternatively, the phase profile can be quantized to one wave, then further discretized to eight or 16 levels; the phase profile can then be fabricated using a multiple-mask lithographic process with wet etching. AOCT can fabricate such diffractive optics up to one meter in diameter, with precisions of about one micron.



A continuous profile can be quantized into mod(2) steps one-wave-deep, then further discretized to yield kinoform profiles that can be manufactured with standard lithographic techniques.

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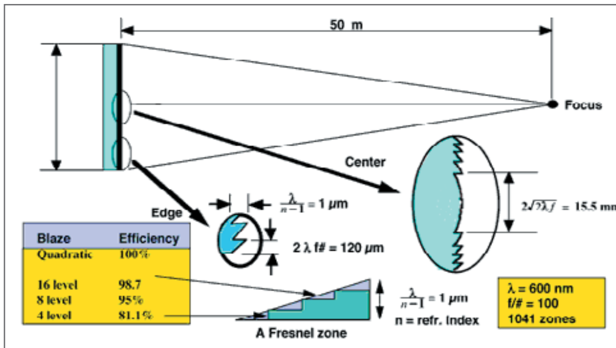
Large-Aperture Segmented Fresnel Lens

A Fresnel lens is the diffractive equivalent of a refractive lens. The quadratic phase profile of a lens is quantized to a one-wave-deep kinoform profile; the focusing efficiency of a Fresnel lens depends on how this phase profile is fabricated.

Fresnel lenses have the advantage of being able to be fabricated on thin, lightweight substrates while maintaining high diffraction-efficiency and excellent optical quality.

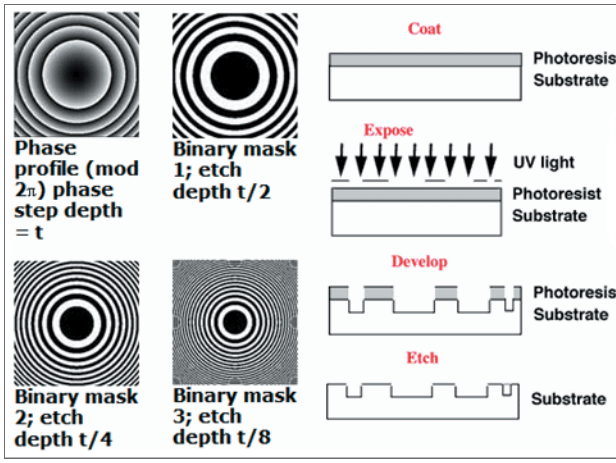
Example characteristics of a diffractive Fresnel lens are illustrated left.

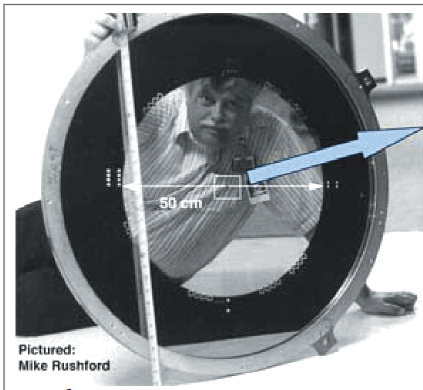


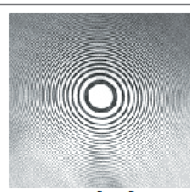
Example of a phase screen that produces an elliptical focal spot.

The Lithographic Process for Fresnel Lens Fabrication

For long f-numbers, Fresnel lenses can be patterned using lithographic methods. The required binary masks, and the process itself, are schematically illustrated left and below.







Expanded view of the center of the mask.

Mask parameters:
Aperture diameter = 50 cm
Focal length = 50 m
Design wavelength = 0.6 µm
Central zone diameter = 11 mm
Last zone width = 60 µm
Number of zones = 1041

A 20-cm diameter, 16-level Fresnel lens fabricated on a fused silica substrate.

20-cm diameter replicated Fresnel lens in a 40-µm thick polymer membrane.

A binary mask for a 50-cm Fresnel lens.

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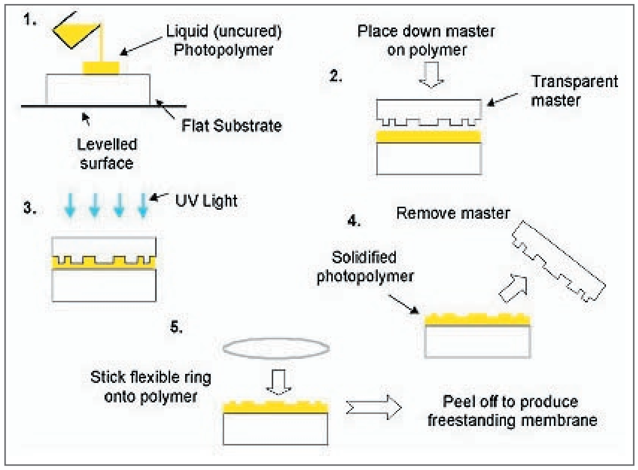
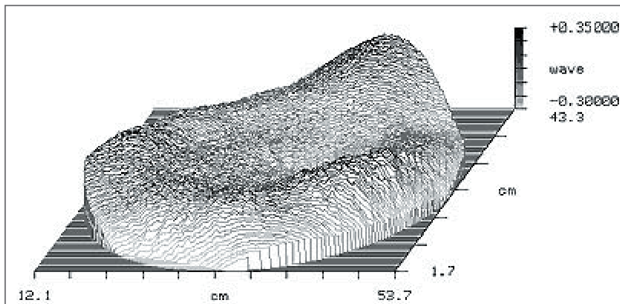
Large-Aperture Replicated Optics

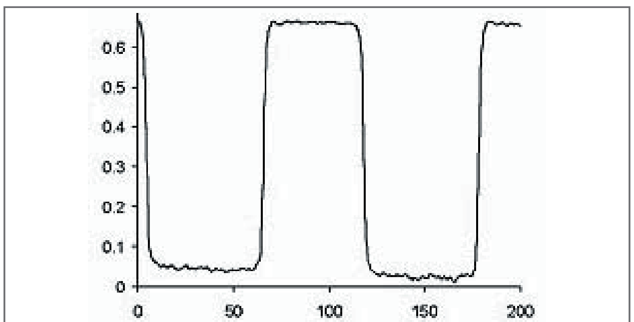
Large-diameter surfaces can be precision-replicated using a UV-embossing process. A liquid photopolymer is held between two surfaces with the desired properties (one an optical flat, the other containing a diffractive structure). After curing solidifies the photopolymer, it can be released from both surfaces to produce a freestanding membrane or left attached to one of the surfaces to give an embossed film.

The replication process reproduces the contacted surfaces very well, with a uniform shrinkage of about 1% over the part. Micron-scale gratings and smooth, refractive surfaces have also been replicated successfully over smaller sizes. Up to 50-cm-diameter surfaces can be replicated with film thicknesses of 40 to several hundred microns.

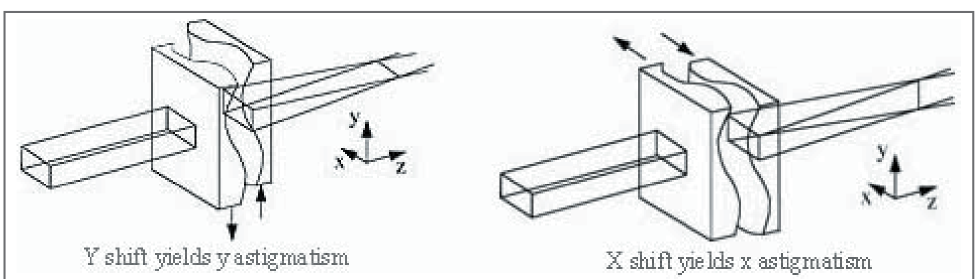




The transmission wavefront (for 633-nm light) is less than 1 wave P-V over the whole aperture, with the central 25-cm region being 0.2 waves.

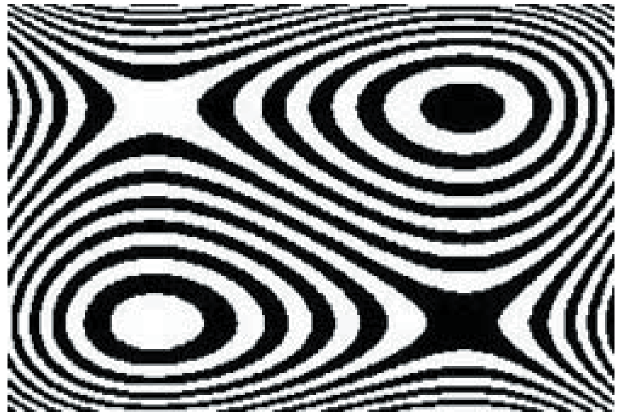


Surface profile of a radial section of a binary Fresnel lens. Period and groove depth was reproduced from the master with 99 percent accuracy.

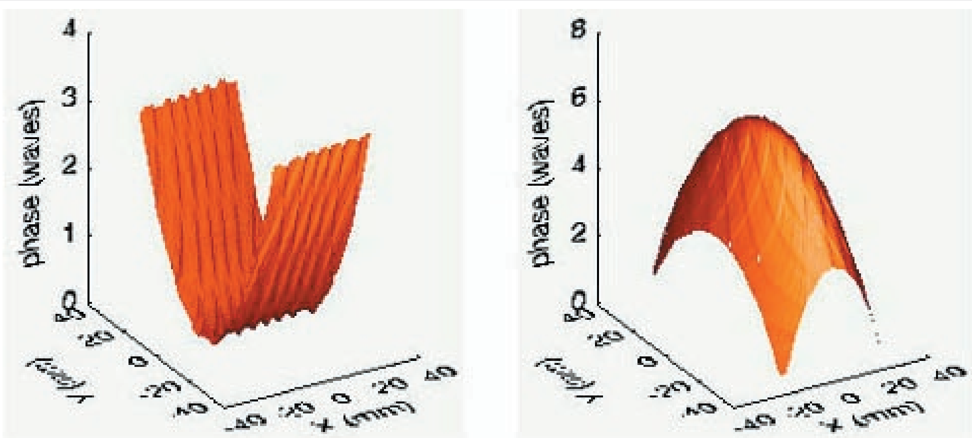


Alvarez Lenses for Aberration Correction and Control

An Alvarez lens pair* comprises two bicubic phase-profile optics, one the inverse of the other. When in perfect registration, the optics produce a null wavefront. The translation of one optic relative to the other along an axis results in cylindrical focus (or defocus) along this axis. Translation along both axes produces variable spherical or astigmatic power, for wavefront correction, or a controlled aberration source. AOCT has made mod(2p) diffractive kinoform Alvarez lenses at 10-cm aperture, and has replicated continuous contour Alvarez lenses in UV-curable polymer.



A 100x75 mm phase mask for a discretized mod(2p) diffractive Alvarez lens. This is one of four masks used to create a 16-level kinoform lens.



Measured transmitted wavefront of diffractive Alvarez lens pair when translated along one axis and both axes. The approximately 10th wave ripple seen in these figures is due to discretization of the phase profile.

*L.W. Alvarez, U.S. Patent 3,305,294