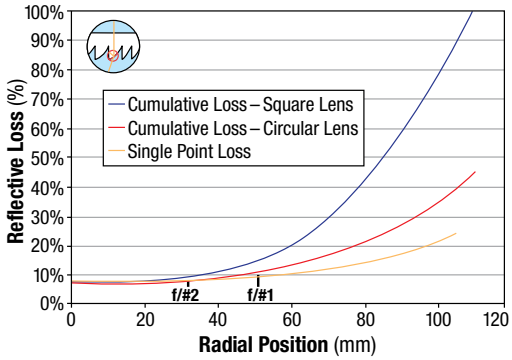
Factors Influencing the Optical Efficiency of Fresnel Lens Concentrators

Introduction

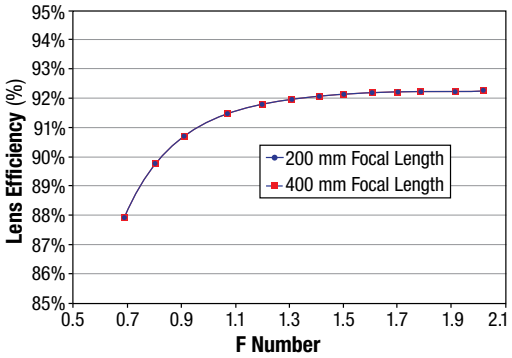
In the production of Fresnel lens solar concentrators, several factors influence the theoretical design efficiency - this technical bulletin describes those factors and 3M's approach to measure the effect of the factors on overall expected lens efficiency.

Fresnel Losses

Fresnel losses are due to fresnel reflections from the air/acrylic interfaces.



The blue line shows reflective losses at discrete radial positions and cumulative lens losses, in red, for a 100 mm focal length lens.

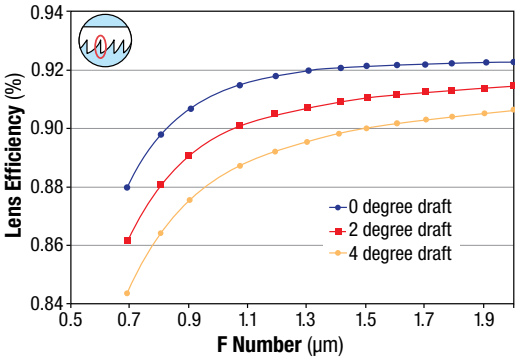


This graph shows lens throughput as a function of f/# (focal length/diameter) for two different lens designs. The relationship between f/# and reflective losses is relatively unaffected through large changes in lens size and focal length.

Data for all charts were generated at a wavelength of 630 nm for an acrylic lens. Calculations are based on square lenses, with the f/# based on the diagonal length of the lens.

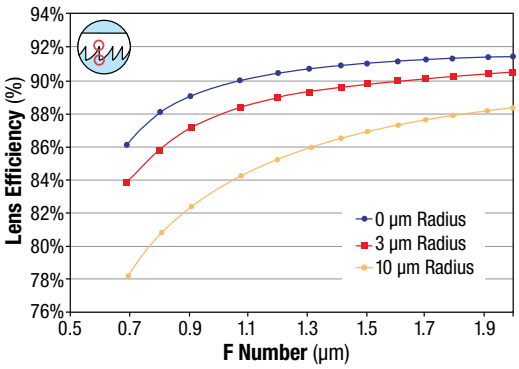
Draft Angle

Losses due to the unused (draft) facet for several draft angles are illustrated in the following graph. The ideal case of 0° draft angle is difficult to meet in lens production.



Facet Corner Rounding

Facet corner rounding is an indication of replication fidelity. It is difficult in most molding processes to get high fidelity replication with the fast cycle times required to produce lenses at low cost.



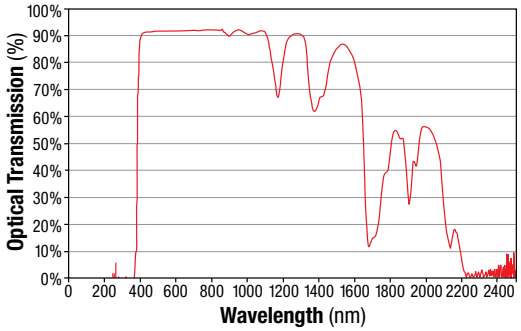
Losses due to the rounding of facet corners, assuming that no light from a rounded corner reaches the target, are illustrated in the above graph.

Absorption

Note: The following technical information and data should be considered representative or typical only and should not be used for specification purposes.

Shown at right are absorption and fresnel losses through the center of an acrylic Fresnel lens panel. The short wavelength cutoff is dependent on the amount of UV protection required. The other absorption peaks are typical of acrylics.

Lens Panel Spectral Absorption



Production Results

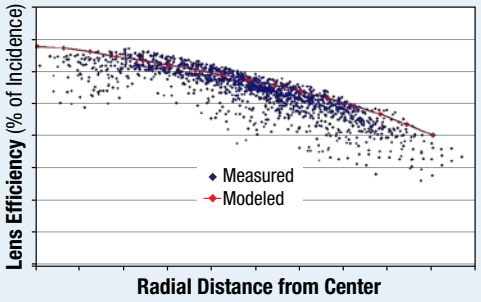
3M has constructed a production scale quality control system for measuring fresnel lens efficiency. This system scans a collimated light source across the lens aperture, measuring transmission at discrete points. Focal position, aperture size, and sampling resolution are adjustable.

Wavelength: 630 nm
Spot Size: 5 mm diameter
Aperture: 25 mm in focal plane

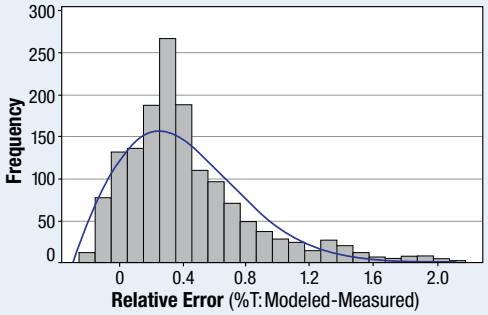
Results in the graph below, from a production lens, show that the best measurements at any radial position are within a few tenths of a percent of the maximum throughput predicted by modeling that takes into account Fresnel losses, draft angle, and vertex rounding.

Modeling based on a target design including a minimum draft angle and anticipated facet corner rounding is sufficient to predict lens efficiency at a single wavelength to better than 1% accuracy.

Measured vs. Modeled Lens Throughput



Error Analysis



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