How to model a Fresnel lens in OpticStudio

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Abstract

This article provides a summary of the ideal and real Fresnel lens models available in OpticStudio Sequential and Non-sequential Modes.

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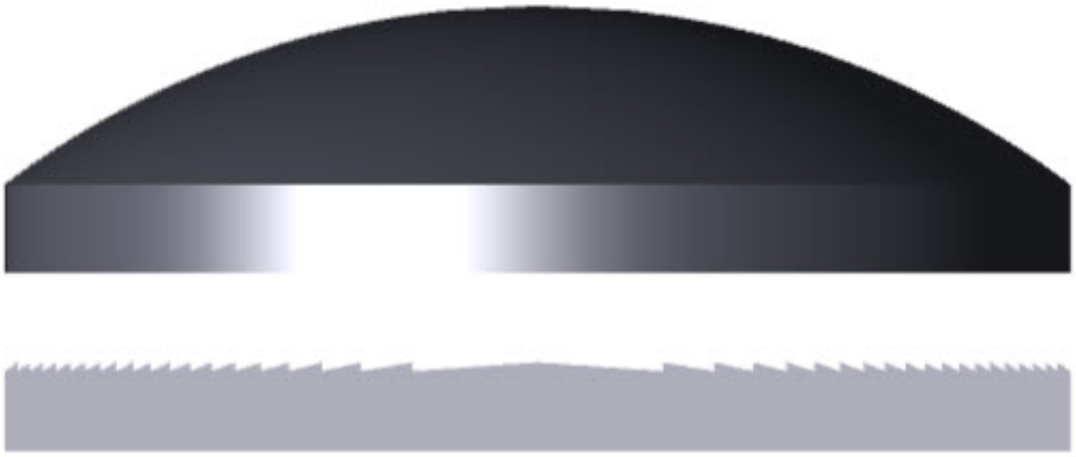
A Fresnel lens employs a discontinuous surface profile that allows for greatly reduced element thickness without compromising optical power. Because the Fresnel lens is thin, there's minimal light loss due to absorption at the expense of image quality. Fresnel lenses are used in lighthouse projectors (http://lighthousegetaway.com/lights/fresnel.html), rear-projection televisions, and as solar concentrators, among several other uses. This article describes the various Fresnel lens object models, and their differences, in both Sequential and Non-Sequential OpticStudio.

Overview of Fresnel models in OpticStudio

A Fresnel lens is a concave or convex lens that has been collapsed in the z-direction. The profile is discontinuous and has grooves that minimize its thickness, but it is otherwise identical to a curved surface.



In OpticStudio, there are several different Fresnel lens models available. The representation of these surfaces either does ("real") or does not ("ideal") include the physical model of the surface profile, depending on the surface type chosen in OpticStudio. Here is a summary of the object types in both Sequential and Non-Sequential Modes:

Mode	Object	Type of Model
Sequential	Fresnel	Ideal
	Generalized Fresnel	Ideal
	Extended Fresnel	Ideal
	Cylinder Fresnel	Ideal
Non-Sequential	Fresnel 1	Real
	Fresnel 2	Ideal
	Tabulated Fresnel Radial	Real
	Tabulated Faceted Radial	Real

To describe the different Fresnel lens models, we use the following definitions:

- Z_S: the sag of the substrate; this is used to calculate the ray intercept with the surface;
- Z_f: the sag of the Fresnel surface; this is used to calculate the ray refraction or reflection.

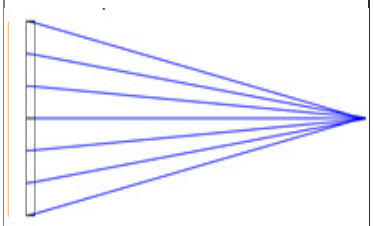
Fresnel models available in Sequential Mode

Note that all models are ideal in Sequential Mode, which means that the software idealizes the grooves to be of infinitesimal height. OpticStudio traces rays to the surface, ignoring the presence of the grooves, and then refracts rays as though the grooves truly exist. The substrate of a Fresnel surface can be flat or curved.

Important: Non-planar substrate Fresnel surfaces do not support calculations that require OPD data—such as OPD fans, MTF, and Zernike coefficients—because there's no reliable way to compute the phase through a Fresnel surface that isn't a plane.

Fresnel

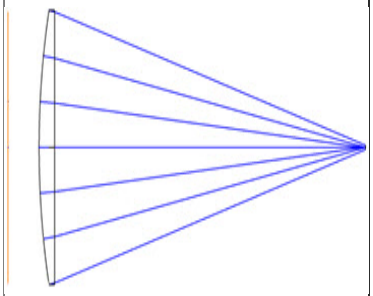
The Fresnel surface is modeled as a flat surface. Once the ray has intercepted the plane surface, the ray reflects or refracts as if the surface had a shape described by an even asphere.

Ray intercept	Ray refraction or reflection
Z_s = Flat surface 	Z_f = Even asphere to the 16th order 

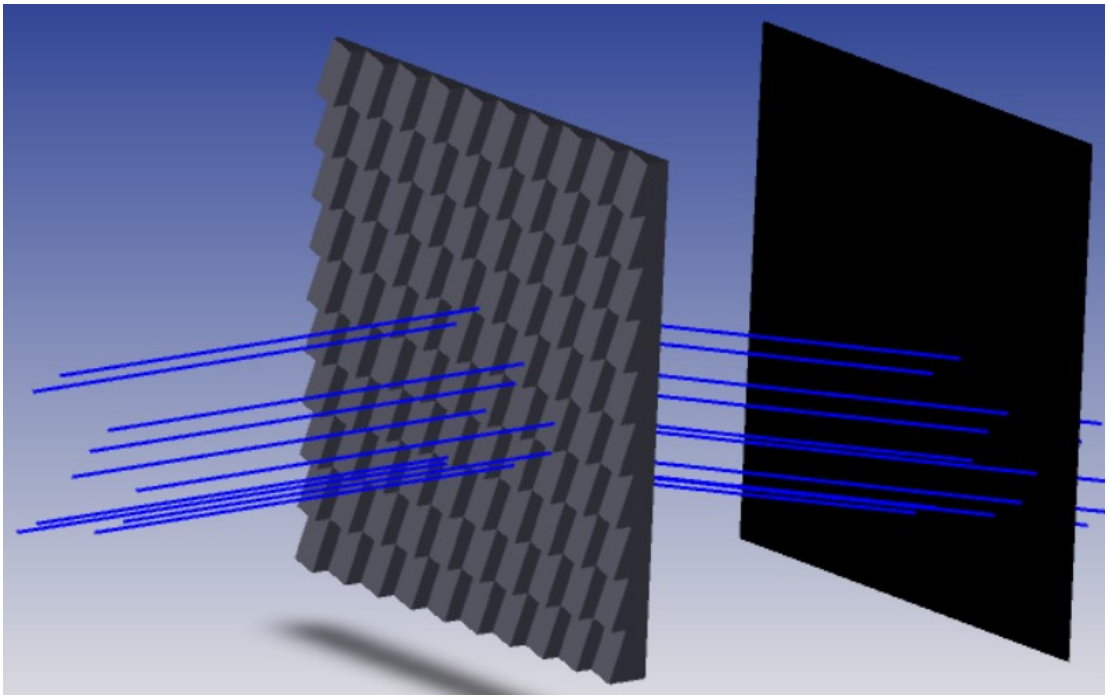
The Fresnel surface can be used for Fresnel lenses with fine grooves (i.e. the groove depth is shallow compared to the aperture). You can find a sample file for such a Fresnel in the Zemax Samples folder at \Zemax\Samples\Short course\Archive\sc_fresnel1.zmx.

Generalized Fresnel

The Generalized Fresnel surface uses a polynomial aspheric substrate model, identical to the Even Aspheric surface. After the ray has intercepted the surface, the ray reflects or refracts as if the surface had a shape described by an extended polynomial.

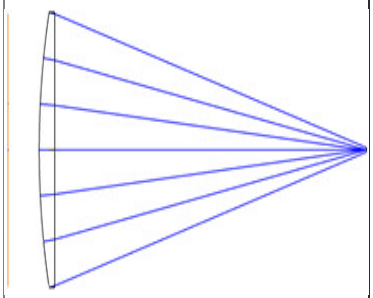
Ray intercept	Ray refraction or reflection
Z_s = Even asphere to the 16th order 	$Z_f = \sum_{i=1}^{N} A_i E_i(x, y)$ 

The Generalized Fresnel surface can be used to model faceted surfaces. For example, a flat substrate may consist of a series of small faceted planes, which would reflect or refract the light as though the surface was tilted. This can be simulated using a flat substrate and a linear x- or y-tilt term in the polynomial coefficients.



Extended Fresnel

In the Extended Fresnel surface, the surface sag is identical to the Even Asphere surface and the sag is used for the ray-surface intercept. The refraction or reflection of the surface is determined by the local slope of the Fresnel facets, which is impacted by the Fresnel facet shape expression for Z_f and the substrate shape expression for Z_s. The refraction at the surface accounts for both the substrate sag and the Fresnel sag, while the ray-surface intercept depends only on the substrate sag.

Ray intercept	**Ray refraction or reflection**
Z_s = Even asphere to the 16^{th} order 	$Z_f + Z_s$ Z_f = Even asphere to the 16th order 

The Extended Fresnel surface can be used to model a Fresnel lens with fine grooves (the groove depth is shallow compared to the aperture) on a curved substrate.

Cylinder Fresnel

In the Cylinder Fresnel surface, the surface sag is identical to the Even cylindrical Asphere surface (in y) and it is used for the ray-surface intercept. The refraction or reflection of the surface is determined by an another even cylindrical asphere sag equation. The refraction at the surface accounts for the Fresnel sag, while the ray-surface intercept depends on the

substrate sag.

Ray intercept	Ray refraction or reflection
Z_S = Even cylindrical asphere to the 16th order in Y	Z_f = Even cylindrical asphere to the 16th order in Y

Note: Z_S and Z_f have independent coefficients.

The Cylinder Fresnel surface can be used to model cylindrical Fresnel lenses with fine grooves (the groove depth is shallow compared to the aperture) on a cylindrical substrate.

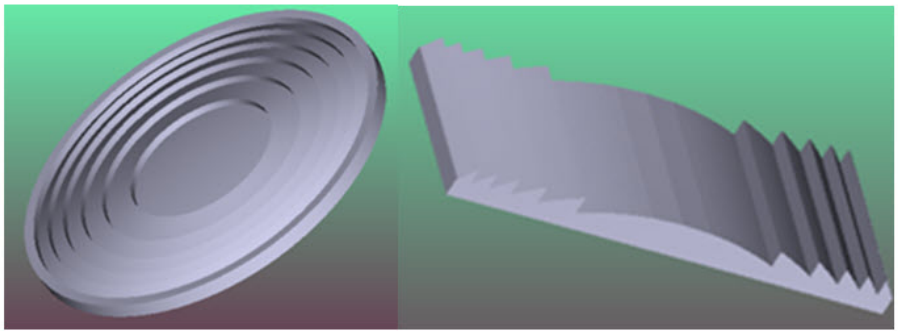
Fresnel models available in Non-Sequential Mode

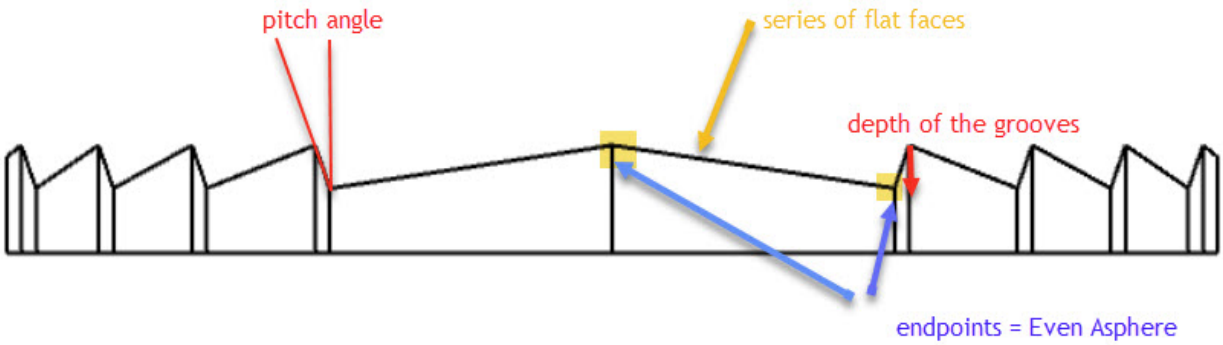
Models in Non-Sequential Mode can be ideal or real. Ideal models are based on the same approximation as the sequential case (the grooves are of infinitesimal height). Real models define the exact profile shape.

Fresnel 1

In the Fresnel 1 surface, the profile is made of radially flat faces. The endpoints of the faces follow the equation of the Even Asphere surface.

Ray intercept	Ray refraction or reflection
Z_S = Radially flat or rectangular faces whose endpoints are defined by a sag expression identical to the Even Asphere surface. The size of the groove is defined by the +Depth/-Frequency parameter. The Pitch (degrees) is the angle of the “inactive” faces.	$Z_f = Z_S$

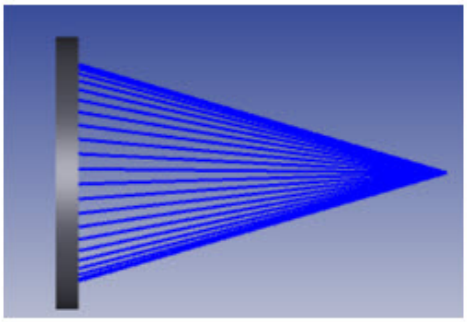




Sample files are available in the Zemax Samples folder at \Zemax\Samples\Non-sequential\Fresnel Lenses\Fresnel lens cylinder structure.zmx and \Zemax\Samples\Non-sequential\Fresnel Lenses\Fresnel lens radial structure.zmx.

Fresnel 2

The Fresnel 2 is an idealized Fresnel lens. This object works as the sequential Fresnel surface.

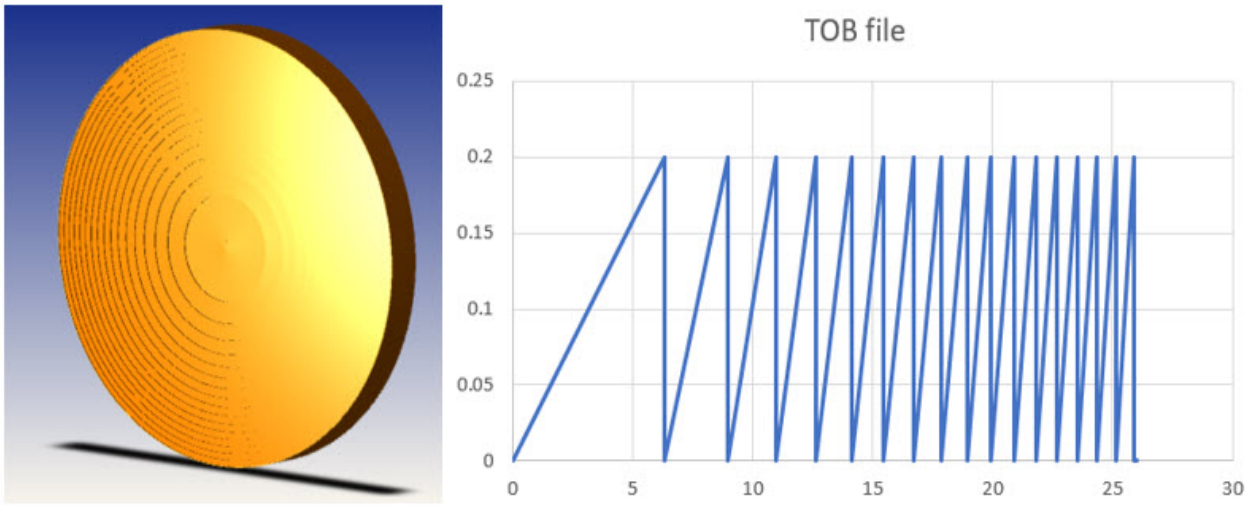
Ray intercept	Ray refraction or reflection
Z_s = Flat surface 	Z_f = Even asphere to the 16th order If the "Is Cylinder?" parameter equals 1, then Z_f = Even cylindrical asphere to the 16th order in Y. 

A sample file is available in the Zemax Samples folder at \Zemax\Samples\Non-sequential\Fresnel Lenses\Fresnel lens ideal.zmx.

Tabulated Fresnel Radial

The Tabulated Fresnel Radial is a tabulated object based on YZ sag coordinates defined in a TOB file. A TOB file contains two columns of data: the first column represents the local Y coordinate, and the second column represents the local Z coordinate. A figure of revolution around the local Z axis is generated by replicating the YZ curve over a specific angular range. The radially symmetric faces that result are smooth.

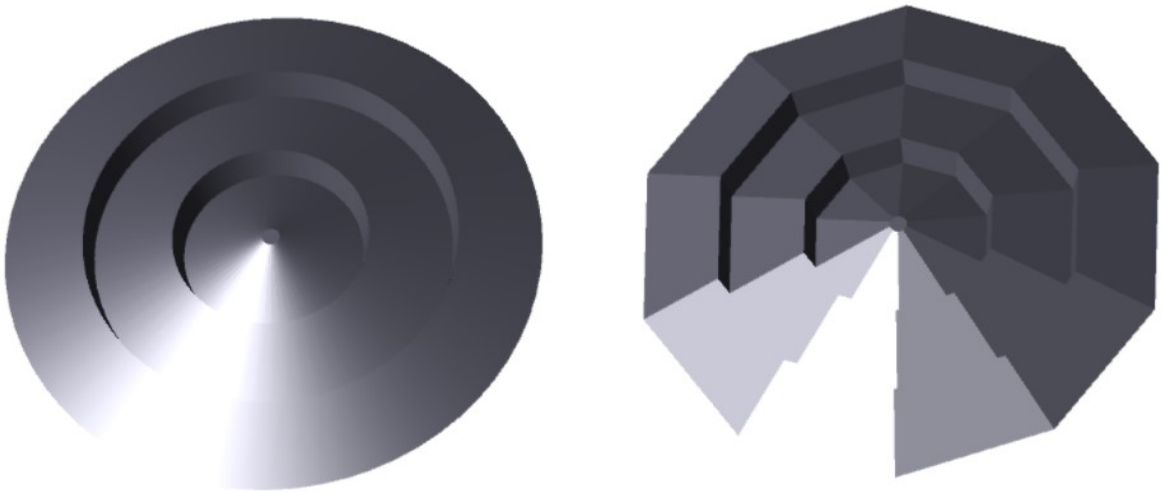
Ray intercept	Ray refraction or reflection
Z_s = Tabulated Fresnel Radial	$Z_f = Z_s$



Tabulated Faceted Radial

The Tabulated Faceted Radial object is nearly identical to the Tabulated Fresnel Radial object. The key difference is that the radially symmetric faces are not smooth in this object, as opposed to the Tabulated Fresnel Radial described above.

Ray intercept	Ray refraction or reflection
Z_s = Tabulated Faceted Radial	$Z_f = Z_s$



Other Fresnel lenses

When working in non-sequential mode, there are several solutions to resolve instances when any of the built-in objects are not appropriate to describe a Fresnel lens. For example, a Fresnel lens can be built from a series of annular aspheric lenses (~/Knowledge-Base/kb-article/?ka=KA-01373). If none of the models listed above are sufficient to model the Fresnel lens in your system, you can construct your own DLL model. For more information, see the corresponding OpticStudio Help File:

- For Sequential Mode, navigate to "**Setup tab...Editors Group (Setup Tab)...Lens Data Editor...Sequential Surfaces (lens data editor)...User Defined**;"
- For Non-Sequential Mode, navigate to "**Setup Tab...Editors Group (Setup Tab)...Non-Sequential Component Editor...Non-Sequential Geometry Objects...User Defined Object**."

This article has described the various different Fresnel lens models available in OpticStudio, in both Sequential and Non-Sequential Modes, and how their sag profiles are determined and used in ray tracing.

Keywords: Fresnel lens, Sag, Fresnel, Generalized Fresnel, Extended Fresnel, Cylinder Fresnel, Fresnel 1, Fresnel 2, Tabulated Fresnel Radial, Tabulated Faceted Radial