Bifocal/Trifocal/Multifocal application notes

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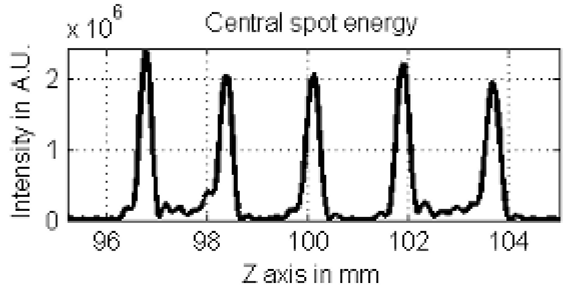


Introduction

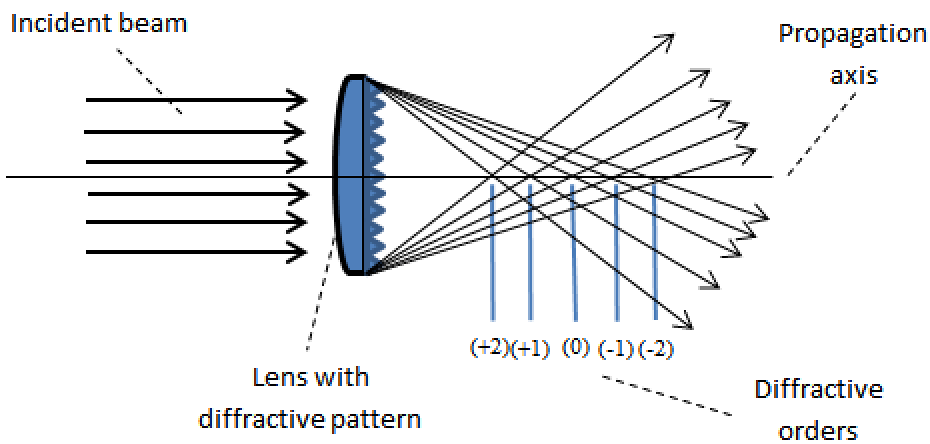
A diffractive Multifocal allows a single incident beam to focus simultaneously at several focal lengths along the propagation axis. The number of foci is determined during the design according to the customer's application requirements. This application note is meant to aid the user's understanding of the functionality and considerations when using a diffractive multifocal element.

Operation Principle:

The operational principle is quite straightforward. From a collimated input beam (single mode or multi-mode), the output beams focus at a fixed number of focal lengths that is predetermined during the design of the DOE based on the customer's system requirements (See figure 1 and 2 below).

The Multifocal DOE comes in two configurations:

- DOE that consists of a Plano convex lens with predetermine focal lengths. Here the diffractive pattern is etched on the Plano side. See figure 1 below.



- The other configuration is a multifocal DOE that consists of a window which specified to the case the customer wishes to get a foci spots at a certain distance. This is easily achieved by the addition of a simple focusing lens after the DOE, whose BFL (back focal length) determines the working distance (WD). See figure 2 below.

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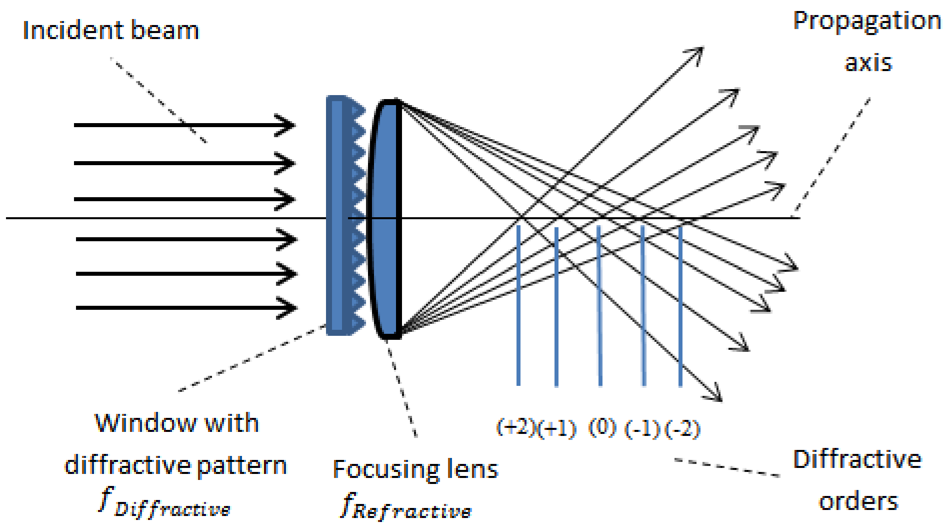

Calculation of the multifocal spots location can be deduced by using Holo/Or's optical calculator (section Multifocal)

Theory:

The multifocal spots location is a function of refractive focal length $f_{Refractive}$ and predetermined diffractive focal length $f_{Diffractive}$
The foci spot at the "zero" order refers to the refractive focal length of the lens being used.
The other diffractive foci spots, orders +/-1,2,3…, appear symmetrically around the refractive "zero" order. An approximation of the distance between the foci spots can be described by the equation below:

$$\frac{1}{f_{"m"\text{Diffractive}}} = \frac{1}{f_{\text{Refractive}}} + \frac{1 \cdot m}{f_{\text{Diffractive}}} \quad m = \pm 1, \pm 2, \pm 3 \ldots$$

$f_{"m"}$: Focal Length for "m" diffractive order
$f_{Refractive}$: Focal Length (FL) of the refractive lens
$f_{Diffractive}$: FL of the diffractive lens
m: order of multi-focal spot
In the case of optical set-up with several lenses or thick lenses, please contact Holo/Or for detailed design. At multifocal DOE with an even number of foci spots, the disappearance of the zero order spot is achieved by special design and processing.

Design considerations and limitations:

For binary designs (2 levels etching), power efficiency can vary between 75% (for Bifocal and multifocal) to 85% (Trifocal) due to physical constraints.
Multi-level etching isn't always recommended because of manufacturing limitations.
Often, for initial testing purposes, a user may want to use a standard product whose design wavelength (nominal wavelength) is not exactly the wavelength in the user's application. In such case the defective order FL will change according the equation:

$$\frac{\lambda_{nominal}}{\lambda_i} = \frac{f_{D\ nominal}}{f_{D\ i}}$$

$\lambda_{nominal}$: The nominal wavelength
λ_i: Wavelength used by the user
$f_{D\ nominal}$: Diffractive Focal Length (FL) for a nominal wavelength
$f_{D\ i}$: Diffractive FL for the wavelength used by the user.

Holo/Or can provide in such cases the expected performance (power distribution among orders) with the user's alternative wavelength. Each focal spot contains a fraction of the input beam power.
For example a trifocal DOE (with around 85% efficiency), the first focal spot will have around 28% of the input beam power at precise diffractive FL, "+1" order. Moving forward on the propagation axis, a focus will appear at the nominal FL of the lens. Here again the focus spot will have around 28% of the input beam power. The last focus appears at the "-1" order (diffractive order) which will have the same power. At each order the rest of the power (~72%) will be spread around the focus in the form of an halow.

The minimum input beam size is determined by various design parameters specific to the application at hand, and is given as at least the first 3 Fresnel rings in the DOE.

Change of distance between foci:

Some times because of manufacturing limitations or application requirements changes, is needed to change separation between foci. The simplest way to do this is to change Effective Focal Length EFL of the optical system. Separation between two neighbor foci can be calculated according to:

$$\frac{1}{\Delta} = \left[\frac{(\Delta_0 + f_{r0}) \cdot f_{r0}}{f_r^2 \cdot \Delta_0} - \frac{1}{f_r}\right] \cdot \frac{\lambda_0}{\lambda}$$

Where:

- Δ: separation between foci
- Δ_0: initial separation between foci
- λ: operating wavelength
- λ_0: initial wavelength
- f_r: EFL of the system after adding additional lens
- f_{r0} initial EFL of the system

Same mathematical relation can be used for manufacturing semi standard Multifocal lenses for specific wavelength. In this case $\lambda \neq \lambda_0$

>> Click here for multifocal standard products

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