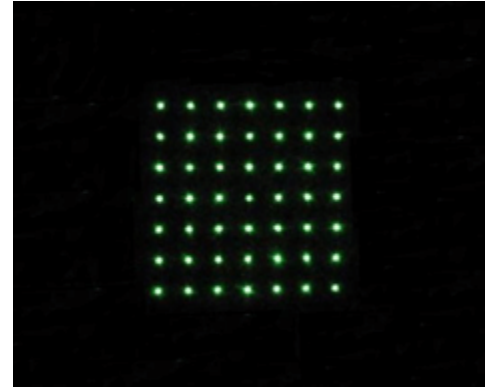


# Beam splitter application notes

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## Introduction

A Beam Splitter is a diffractive optical element (DOE) used to split a single laser beam into several beams, each with the characteristics of the original beam (except for power and angle of propagation).

A beam splitter can generate either a 1-dimensional beam array (1xN) or a 2-dimensional beam matrix (MxN), depending on the diffractive pattern on the element.

A common variation of the laser beam splitter / multispot DOE is a multi-line array, where instead of a 1xN array of spots, the user will get a 1xN array of lines, whose length is determined during the design according to the customer's application requirements.

Our beam splitters are used in a wide variety of research and industrial applications. Some typical areas include:

- Laser scribing such as in solar cells or panels
- Laser dicing
- Laser displays
- Filters for cigarettes
- Medical/aesthetic applications such as skin treatment
- 3-D sensors
- Fiber optics

This application note is meant to aid the user's understanding of the functionality and considerations when using a diffractive beam-splitter element.

## Articles

- [Fractional Laser Skin Treatment Using Diffractive Optics](#)
- [Laser Perforation](#)
- [Laser Beam Splitting by Diffractive Optics](#)
- [Structured Light DOEs](#)

## Operation Principle

The operational principle is quite straightforward. From a collimated input beam, the output beams exit from Beam Splitter DOE with a separation angle that is determined during the design of the DOE based on the customer's system requirements (See figure 1 below). The separation angle is highly accurate (<0.03mR error). The beams' separation is designed for far-field so that as the beams continue to propagate after DOE, they become more well-defined.

For standard beam splitter and odd number of beams, the separation angle is the angle between order +1 and order 0 (The order 0 is a desired beam).  
 For standard beam splitter and even number of beams, the separation angle is the angle between order +1 and order -1 (The order 0 is not a desired beam).  
 However, Holo/Or is also able to design a custom beam splitter and so activate and deactivate any order of the beam splitter. Normally, the customer wishes to get well-focused 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) to the multi-spot focal plane. See figure 2 below.

**Typical Set-Up**

Figure 1: DOE beam Splitter basic set-up

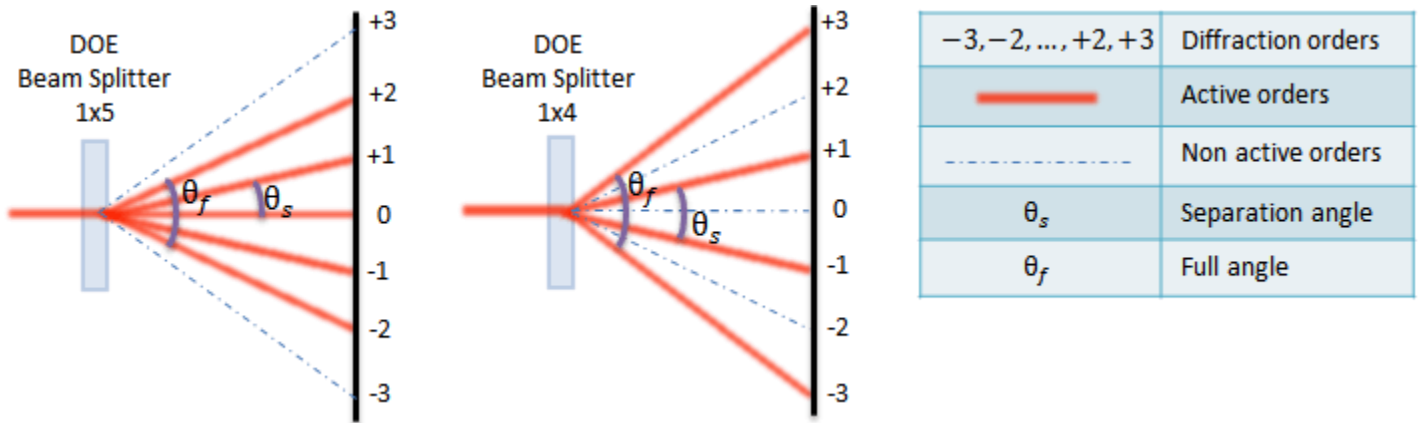
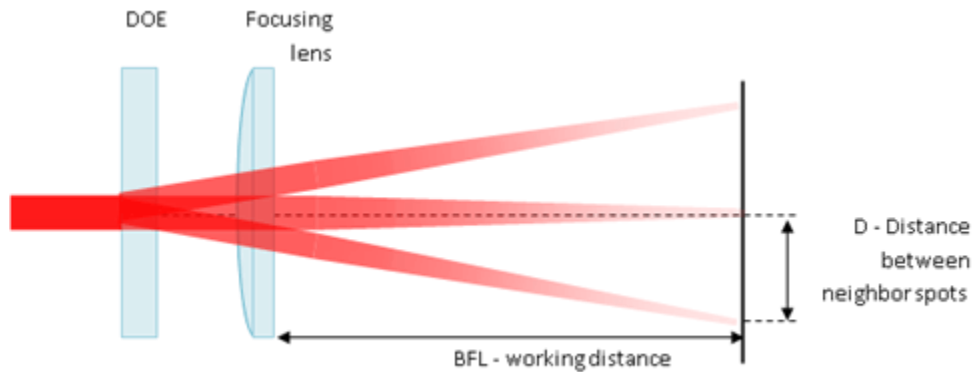


Figure 2: DOE with focusing lens (example of Triple spot in the picture)



### Choosing the right lens

Choosing the right lens for the application is quite easy using the following mathematical relationship between the working distance WD, angle between diffracted spot and optical axis propagation  $\alpha$  and distance between diffracted spot to optical axis D:

$$D = WD * \tan(\alpha)$$

**D:** Distance between diffracted spot and optical axis (zero order)

**WD:** Working distance

**$\alpha$ :** angle between diffracted spot and optical axis propagation

The spot size at the focal plane is given by the formula:

$$\frac{4 * L * \lambda}{\pi * D} * M^2 = D.L. \text{ spot size}$$

L: Working Distance

$\lambda$ : Wavelength

D: Input Beam Size

M2:  $M^2$  value of input laser beam

### Design considerations and limitations

In double-spot configuration, power efficiency can reach nearly 80% due to physical constraints, while the multi-spot (>2) configurations can reach nearly 85% in binary etching process, and nearly 95% in multi-level etching. The remaining power is distributed among the other (parasitic) orders.

Multi-level etching is worthwhile only in cases where the minimum feature of the diffractive pattern is not so small. If too small, then manufacturing tolerances will likely reduce efficiency level to near binary level. The minimum feature size is a function of the total angular divergence of the beam splitter and the wavelength.

Energy distribution can be designed for either spot uniformity or for any non-uniform distribution meeting the application's requirements.

Often, for initial testing purposes, a user may want to use a standard product whose design wavelength is not exactly the wavelength in the user's application. Holo/Or can provide in such cases the expected performance (power distribution among orders) with the user's alternative wavelength.

The **minimum input beam size** is determined by various design parameters specific to the application at hand, and is given as at least 3 times the size of the Period in the DOE. The Period in turn is given by the equation:

$$\frac{m * \lambda}{\sin \alpha} = \Lambda$$

$\Lambda$  = Period of DOE

$m$  = diffraction order

$\lambda$  = wavelength

$\alpha$  = angle between diffracted beam of order  $m$  and optical axis

In cases where the period is very large, and the laser beam is very small, the user can widen the input beam using a beam expander that matches his/her wavelength and required magnification.

### Tolerances

In configurations involving an even number multi-spot, the zero-order spot is undesired. Tolerances in the manufacturing process may result in a zero-order intensity differing slightly from the theoretical simulations; likewise, for uniformity and efficiency. For any particular design, the expected values can be supplied to the customer upon his/her inquiry.

Normally, due to standard tolerances in etching, the zero-order intensity can vary by about 0.2% of input beam in IR applications, and is typically more in the UV.

Click [here](#) for more explanations on zero order.

>> Click [here](#) for beam splitter standard products.