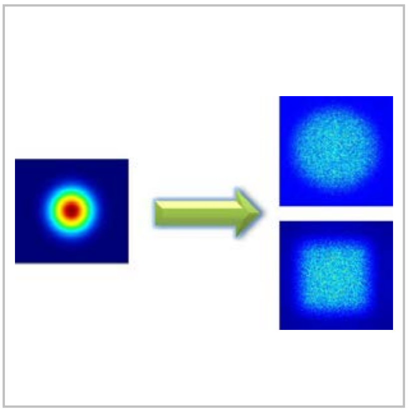
Diffuser / Homogenizer - Diffractive Optics



Introduction

Homogenizer (HM) product line can be useful in many applications requiring a well-defined beam shape with a randomly-diffused intensity profile. For applications requiring a continuously flat-top intensity profile, the **diffuser** will not be a very fitting option. Instead, the TH/ST beam shaper product is most fit for such applications requiring close-to-absolute uniformity.

Principal of Operation

We normally design our diffuser products using a robust hybrid multi-spot/diffusing algorithm, optimized for a given diffusion angle or output beam size. We design any shape requested by customer. The most common shapes requested are square, round, rectangular and elliptical. The edges of the diffusers beam are generally steep and well-defined, as long as the input beam is closely collimated. (See figures 1 & 2 below) The intensity profile of the Homogenizer beam is „grainy" or speckled as can be seen in figure 1 below. The pseudo-random energy diffusion of diffuser creates a randomly speckled pattern in output beam, due to interference from phase overlapping.

Figure 1:
Example of round Diffuser output beam: grainy/speckled intensity features and sharp beam perimeter.

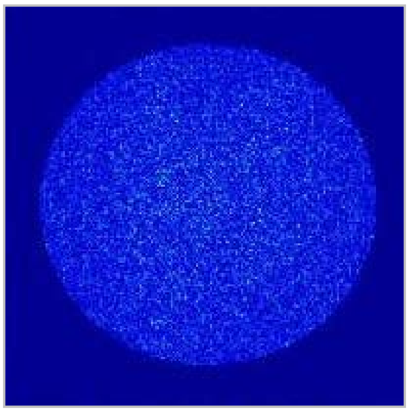
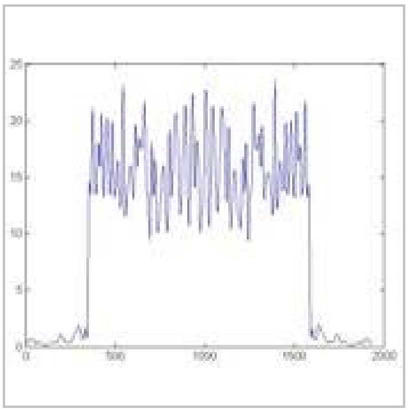


Figure 2:
Typical 1-D intensity profile of Homogenizer output beam. Speckled profile has "noisy" oscillations. Edge transitions are sharp.



01/20 / V07 / IF / holo-or/hm-homogenizer

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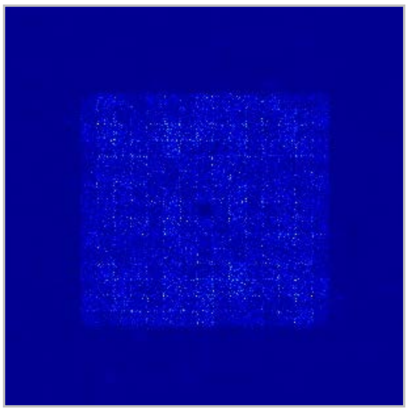
Many applications can suffice with a noisy, speckled intensity distribution and do not require the continuously flat top of our Top-Hat product. Since the noisy speckles are often clustered together in high density, there is a natural smoothing effect in many (but not all) applications which erases any sign of the profile fluctuations.

Another possibility which some use to smooth speckles is the addition of a small vibration device, such as the one found inside cellular phones, whose resulting rapid HM motion has a clear smoothing effect on output beam.

HH vs. HM Comparison

In 2011, Holo/Or has developed a new Homogenizer product line with improved homogeneity performance, by utilizing the substrate window's opposite face to add another homogenizing diffractive pattern, optimized in angle and size for best output performance. The HH product's improved homogeneity, is an important functional advantage in many applications. A visual comparison is presented here of typical HH and HM output beams:

Fig. 3:
On left, HM (one-sded) output beam. A keen eye will notice a pattern of squares.
On right, the HH output beam. No fundamental pattern is evident.



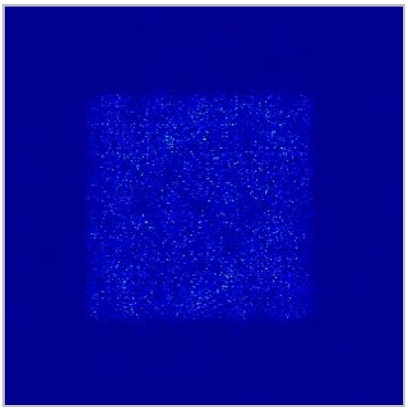
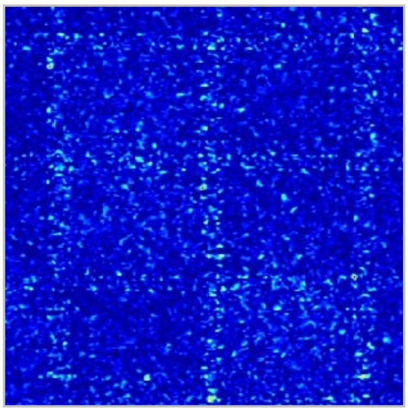
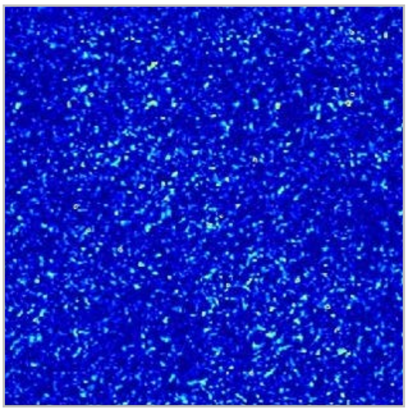


Fig. 4:
Zoom images of figure 3 images. The square pattern is more visible now to unaided eye.
On right, the HH output beam appears clearly more randomized and homogenized.





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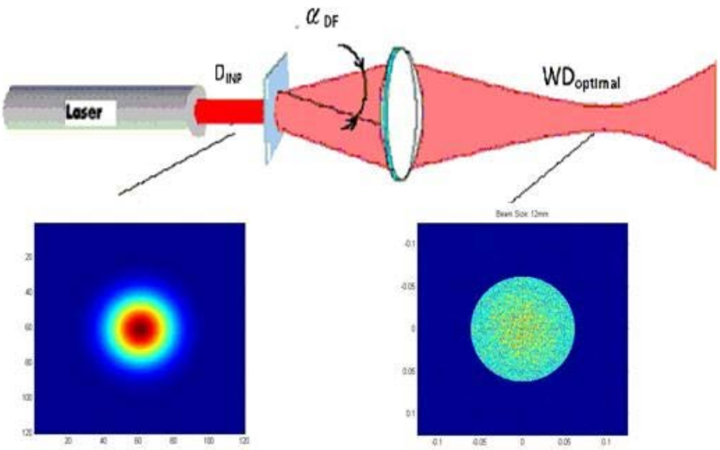
Design Considerations

Fig. 5:Basic set-up using HM



The HM element is designed with a specific diffusion angle αDF. This angle determines the size of the homogenized beam at any given distance. The beam homogeneity becomes pronounced in the far field, or at the focal plane of a focusing lens located after the HM element. Hence, the optimal performance of an HM with diffusion angle αDF and input diameter D_{inp} will normally be obtained at the optimal working distance

$WD_{optimal}$ as in the equation:

$$WD_{optimal} = D_{Outp} / \tan(\alpha_{DF}).$$

We normally manufacture the diffuser element on a window (Pl/Pl), while the customer adds on his own the focusing lens of his choice. This affords maximum flexibility to customer to alter at will his desired beam size by changing lens to a new BFL/WD.

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Input Beam Parameters

The input beam is normally a single-mode Gaussian. However, the diffuser is versatile enough to homogenize well also beams whose Gaussian profiles are corrupted or disfigured, and even super-Gaussian and non-Gaussian profiles as well. Multi-mode beams actually „enjoy" a certain advantage with the diffuser product, as their degraded coherence will produce an output beam that has a more uniform intensity profile and fewer speckles.

The most important parameters of input beam for the design are the beam divergence value, the beam diameter (1/e2) and the operating wavelength. The input beam's divergence angle determines the sharpness of the output beam's edge features (a.k.a transition region). The ratio of the divergence angle to the HM's diffusion angle, determines the ratio of the transition region to the well-homogenized region of the output beam.

As a rule of thumb, to maintain good power efficiency results, we recommend to keep input beam size (1/e2) under 67% of clear aperture. This will ensure 99% energy throughput.

To enlarge the input beam size, the user can easily integrate into his system a beam expander module. These are considerations that need be taken into account during the design stage. Once we have designed the diffuser, using a given input beam size, the optimal performance will be achieved using this design beam size.

The diffusion angle minimum is approximately equivalent to 10 times the diffraction-limit. Also here, a larger angle will increase the performance quality. The formula for the diffraction-limited spot diameter at 1/e2 follows:

$$\frac{4 \times L \times \lambda}{\pi \times D} \times M^2 = D.L.spotsize$$

L: Working Distance
λ: Wavelength
D: Input Beam Size
M2: M2 value of input laser beam

Each diffuser element is manufactured to be wavelength-specific. The diffractive etching pattern is unique for a given diffusion angle at a given wavelength. So, using a diffuser element at a wavelength other than the design will result in a new diffusion angle as well as beam size, dictated by the ratio of ***new λ : design λ***.

In addition, since the etching depth is optimized for a certain design wavelength, use at another wavelength will cause energy migration in beam, with some portion of the diffused power moving to the non-homogenized zero order, appearing as a central peak in output beam.

Nonetheless, our mask inventory can be used flexibly to produce a wide variety of diffusion angles over a wide wavelength spectrum, and only our etching process need be optimized per customer.

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Homogenizer's High Tolerances: Big Advantage

- High power threshold
- Available with standard (75%) or high efficiency (>90%)
- Low sensitivity to X-Y displacement:
- 10% of the input beam will have small effect on performance.
- Low sensitivity to working distance
- Low sensitivity to input beam size:
- Rotation insensitive: for round shape.

Optical Set-Up with MM Fiber

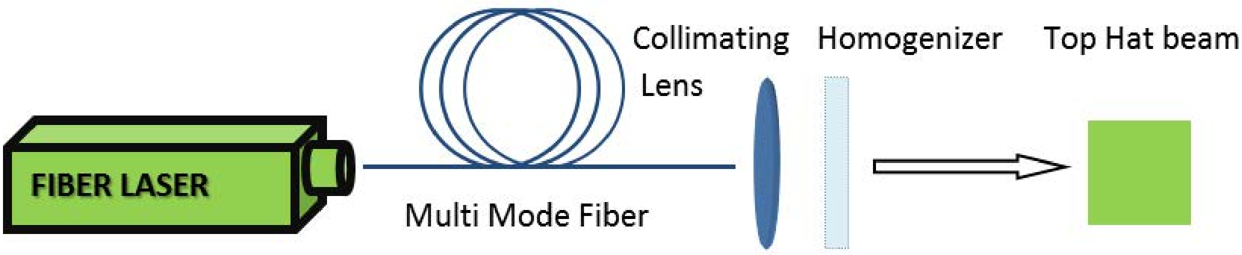
Below optical setup shows a laser coupled to a MM fiber to achieve uniform intensity distribution in the far field or alternatively in the focal plane if used with a focusing lens.

In many cases this configuration shows a good price performance ratio reaching highly uniform intensity profiles at a very reasonable cost.

The key part in this optical setup is the MM fiber, its purpose is to produce as many as possible modes at the exit of the fiber.

The number of modes in the output is proportional to the fiber length. Fiber of some meters will be good enough in most applications.

Each mode of the fiber's output field that propagates through a diffractive Homogenizer will create an interference pattern in the focal plane. However, in contrast to a single mode beam, the multi mode contains many of these modes. Each mode creating a different pattern, that overlap with each other. In the focal plane, this creates a well averaged uniform output. The setup does not require any specific property of the laser beam parameters.



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