

GPC Light Shaper User Guide

This guide describes how to install the GPC Light Shaper (GPC LS) in to the setup and align it. Possible clamping, beam expansion options and troubleshooting recommendations for the GPC-LS are also mentioned.

1 The GPC Light Shaper

1.1 Introduction

The GPC Light Shaper is a compact implementation of Generalized Phase Contrast used to efficiently transform a Gaussian laser beam into practical shapes for specific applications. A typical application example is the optimal illumination of rectangular spatial light modulators (SLM's). The conversion from a Gaussian to the desired shape has a high efficiency of up to 84%. At the same time up to 3x power is gained in the shaped region since light that is outside the shaped region is utilized instead of being blocked. This allows a laser to do the same job for 1/3rd the power or to increase the response or addressable areas in experiments. Figure 1 shows a mounted GPC-LS with an attached beam expander.

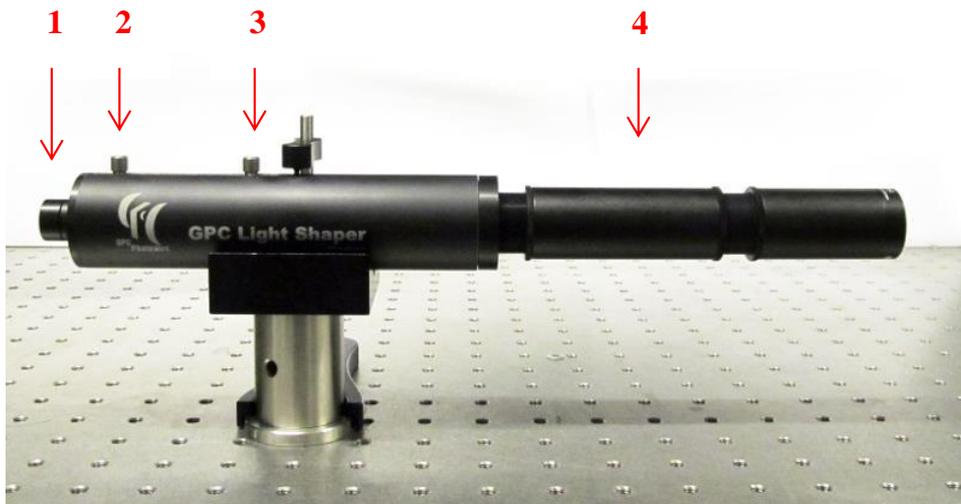


Figure 1. A GPC Light Shaper with an attached beam expander.

1.2 Parts of the GPC Light Shaper

The parts numbered in Figure 1 are the following:

1. Replaceable input phase mask
2. Phase mask translation knobs
3. PCF translation knobs
4. Optional detachable beam expander

The phase mask has a direct imprint of the specific shape that defines the output intensity. Replacing the phase mask, therefore replaces the output beam's shape. A special purpose phase mask called the "darkness" phase mask can also be swapped in for troubleshooting.

Translation knobs for the phase mask and PCF move these parts laterally for alignment purposes.

The beam expander magnifies the output of the GPC-LS so that it matches the required size for the specific application where it is used.

2 Some notes before getting started

2.1 Safety

As with any device, the user should wear the proper attire when using the GPC-LS. This would include protective eyewear and other clothing. Do not look directly at the laser path! During alignment, it is recommended that the laser be set at the minimum power level that is enough to make light visible with the naked eye or a camera. A few milliwatts or less should be enough. The normal operating power level for the specific application can be used after the alignments are done.

2.2 Working with non-visible wavelengths

If possible, it would be convenient to do the initial rough placements of the beam and GPC-LS with a wavelength that is visible, since a camera or other viewing device will not be urgently needed. Fine tuning, however, should be done at the specified wavelength. Light with a different wavelength will refract differently through the device, and the location of the sharp image for a different wavelength can be somewhere else. Different wavelengths from the same laser (such as a visible guide laser) might also have different divergence properties.

3 Placement and alignment of the GPC Light Shaper

The input side of the GPC Light Shaper is the side with the phase mask, and the output side is the one with the beam expander (if included). The input laser beam should be collimated/expanded to the specified diameter (1mm). Keep in mind that lasers slightly diverge as they propagate¹, and ensure that the laser beam the specified beam waist just before the GPC-LS. The shaped GPC output is located after the focal length (f) of the last lens in the device. If an attached beam expander has a last lens with $f = 125\text{mm}$, then the illuminated device such as an SLM should be 125mm away from this last lens.

3.1 Inserting the GPC-LS to the beam path

For more convenience during installation we suggest having two adjustable mirrors in a periscopic configuration to position the beam before it goes through GPC Light Shaper. These mirrors shall be adjusted

¹ http://en.wikipedia.org/wiki/Beam_divergence

until a good profile comes out of the GPC-LS (or attached beam expander) and the receiving device (e.g. SLM) is illuminated at the desired position.

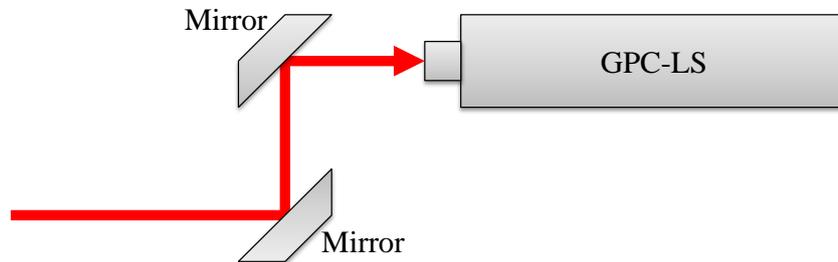


Figure 2. Periscopic mirror configuration allowing the alignment of the beam axis and the GPC-LS axis.

3.2 Adjusting the phase mask

If it is not yet attached, the replaceable phase mask can be screwed-on to the input side of the GPC-LS. If the phase mask is square or rectangular, its orientation can be adjusted by rotating it clockwise. In case of slight shift of the phase mask off the center position, it can be centered by translating the phase mask using the knobs.

The phase mask can be easily dismantled and replaced with another one for a different output shape, which can be ordered separately or together with the GPC Light Shaper.

3.3 Adjusting the PCF

To form a bright shaped output, the beam that is focused inside the GPC-LS should hit the PCF at the phase shifting region. This condition can be verified by observing how the output improves as the PCF is being translated.

If the PCF's phase shifting region is far from the focused light, the output will closely resemble the Gaussian laser profile, except for the visible boundaries of the shape in the phase mask. The brightness outside the desired shape would have a similar level as the brightness within the desired shape.

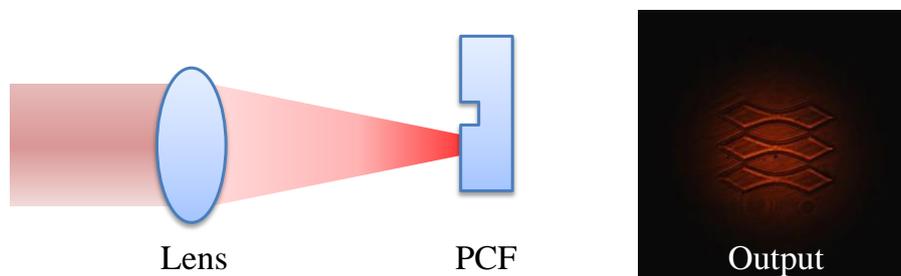


Figure 3. PCF phase shifting region far from the focused light (not drawn to scale) and example output.

When the PCF is translated, there would be observable differences in the beam output. When the PCF's phase shifting region is partially overlapping with the focus, interference effects such as fringes will be observable at the output.

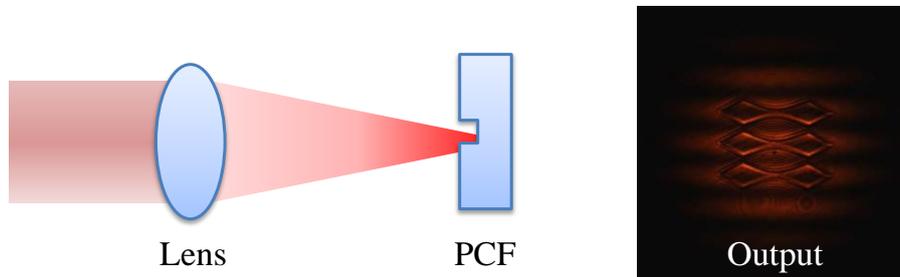


Figure 4. PCF phase shifting region is partially covered by the focused light.

Finally, when the PCF's phase shifting region and beam focus are aligned, light within the desired shape will have a noticeable increase in intensity ($\sim 3x$) and darkness is observed outside the desired shape. Alignment is finished when the output image shows this clear shaped beam.

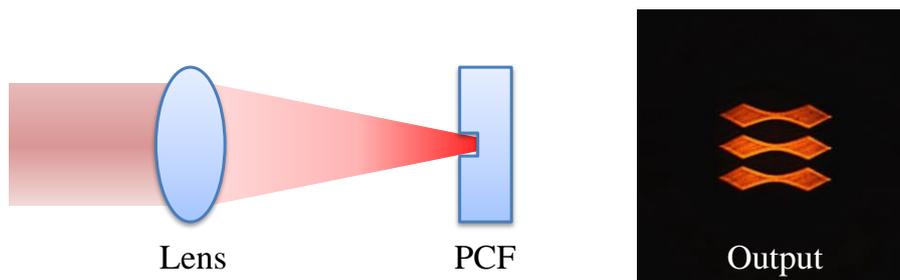


Figure 5. PCF phase shifting region and focused light are aligned.

4 Mounting options

The GPC-LS housing has an outer diameter of 40mm. It can be mounted with V-clamps (Figure 6) typically used for tube shaped optical components such as small lasers or beam expanders. For stability, we would recommend using longer V-clamps, mounted to the optical table using two screws or to use two of short ones.



Figure 6. Example V-Clamps from Thorlabs™ (VC3/M and VC6/M) and Edmund Optics™ (#03-665)

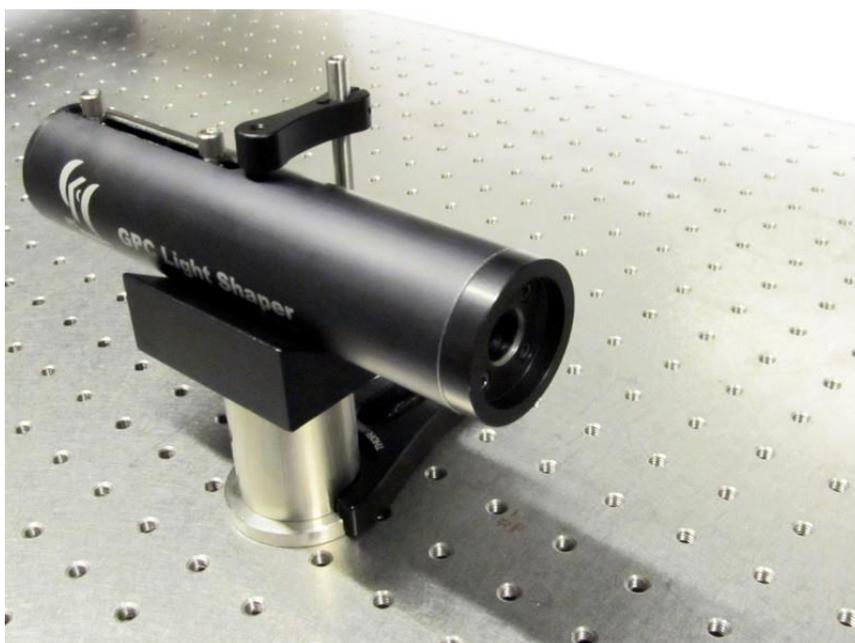


Figure 7. GPC-LS clamped with a short V-clamp (Thorlabs™ VC3/M).

If the GPC-LS has a beam expander attachment, it could be a good idea to also support the beam expander to improve the stability and to minimize the risk of damage if the beam expander is accidentally bumped. If the beam expander attachment is built from Thorlabs components, it is also possible to use Thorlabs's CP12 cage plate, which fits to Ø1.2" lens tubes, instead of a V-mount.

5 Output beam expansion

Without a beam expander, the direct output from the GPC-LS is quite small for typical applications. This design allows the PCF to be relatively bigger which in turn allows it to be fabricated with a higher relative accuracy and to be more robust to slight misalignments. Hence, the GPC-LS may come with a beam expander that matches the GPC output to the size of the device to be illuminated. However, if a different output size is required, a custom beam expander might be built or purchased from third parties. The magnification of such beam expander should be:

$$\text{Magnification} = \frac{\text{desired output diameter [mm]}}{\text{phase mask pattern diameter [mm]}}$$

For example, to expand a 0.3979mm diameter phase mask pattern to 8mm, the magnification should be about 20x. If desired, a custom beam expander can be built with two lenses whose focal lengths have a ratio that is equal to the desired magnification.

6 Trouble shooting

If a significant amount of background light is observed, or if there is little gain in the output shape region even after PCF alignment attempts, this may be caused by the following:

- The input beam diameter is far from the prescribed one.
- The input beam has a divergence or convergence that is above tolerable levels

6.1 Correcting the input beam diameter

The beam diameter can be corrected by expanding or de-expanding before it goes through the GPC-LS. It is also important to note that even collimated Gaussian beams will naturally diverge. This is more evident with longer wavelengths and longer distances from the laser source. Hence, the GPC-LS shouldn't be placed too far from the source or initial beam expander.

6.2 Input beam divergence

If the input beam is converging or diverging too much, the focus from the GPC-LS will respectively move backwards or forward from the PCF. Thus the GPC system would be sub-optimal. If using an input beam expander, this beam expander should be tuned to minimize the beam convergence or divergence.

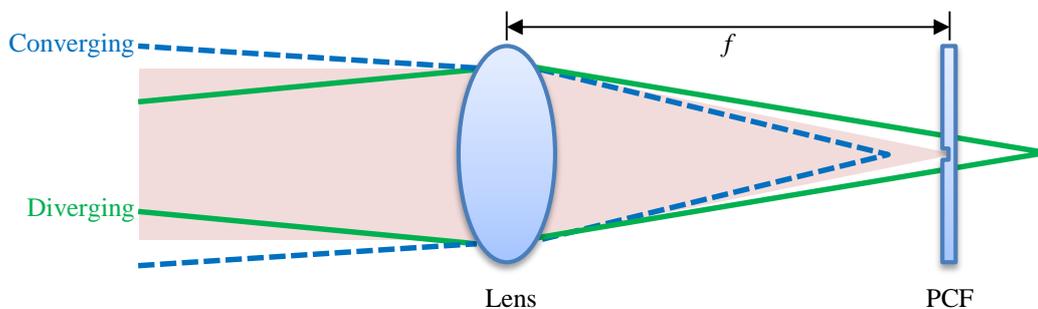


Figure 8. An input beam that is converging or diverging will respectively form a focus before or after the PCF (illustration is exaggerated for clarity).

6.2.1 Using the darkness phase mask

A "darkness" phase mask is provided to fine tune the axial position of the focus. A normal phase mask gives maximum brightness when the GPC components are properly setup. However, it would be necessary to compare a series of measurements to determine when the output is maximally bright. It is far easier to tell if the output is as dark as it gets without referring to another measurement.

It is highly recommended that the axial position of the focus be corrected through the optics before the GPC-LS. The less preferred alternative is to disassemble the GPC-LS and adjust the position of the phase mask with respect to the first lens such that it coincides with the displaced focus.



Figure 9. Output from a GPC-LS with the "darkness" phase mask installed

Since the darkness phase mask is larger than the normally used brightness phase mask, it might be trimmed by beam expanders with high magnifications and the bright boundaries may not be visible. However, it would still be possible to observe the center of the beam output become dark, and compare it with the relatively brighter output when the PCF is laterally displaced.