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# Efficient shaping of light

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Energy efficiency is always desirable. This is particularly true with lasers that find many applications in research and industry. Besides efficiency, many applications favor having light with continuous phase and intensity distributions, sharply defined against a dark background. Conventional amplitude masking easily achieves such requirements but truncating a Gaussian beam wastes a lot of power[1]. Non-absorbing, phase-only light shaping methods are efficient, but common diffractive or refractive approaches suffer from speckle noise or edge roll-off. Noise is a problem in display applications and, more so, when enhanced by nonlinear processes such as in two-photon optogenetics[2], direct laser writing or materials processing. Adopting a phase imaging approach, Generalized Phase Contrast (GPC) inherits the efficiency advantages of phase-only light shaping while maintaining the speckle-free, high-contrast output qualities of amplitude masking. Hence, a GPC light shaper (LS) can be an efficient alternative to a simple amplitude masking.

To illustrate the benefit of using a GPC-LS, consider illuminating a rectangular area to a specified power (Fig. 1(a))[3]. To fill a rectangle with e.g. 84W, an amplitude mask must block 216W from a 300W Gaussian laser source. On the other hand, a GPC-LS can utilize 84W from a less powerful 100W source. Although losing 16W, a GPC-LS uses 200W less power to achieve the same result. This saves amazingly 93% of typical amplitude masking losses. We have experimentally verified this with a compact GPC-LS designed for $\lambda$=750nm, and $1/e^2$ beam waist, $2w_0$=1mm.[4] Static illumination shapes are formed with ~80% efficiency, ~3x intensity gain, and ~90% energy savings (Fig. 1(b-c)). Using a phase-only spatial light modulator (SLM), we have also shown dynamic shaping at $\lambda$=532nm and $2w_0$=4mm. Patterns applicable for materials processing and biological research[2] are shown in Fig. 1(e-h). To demonstrate its practical application, we replaced a rectangular aperture with a GPC-LS to optimally illuminate an SLM[5]. For the same input power, hologram reconstructions are ~3x brighter or alternatively ~3x more focal spots can be addressed maintaining the original brightness. This allows better response in experiments or increased parallel addressing for e.g. optical sorting, manipulation or opto-electronic switching and for direct laser writing. Simple yet effective, a GPC-LS could save substantial power in applications that truncate lasers to a specific shape.

**References**

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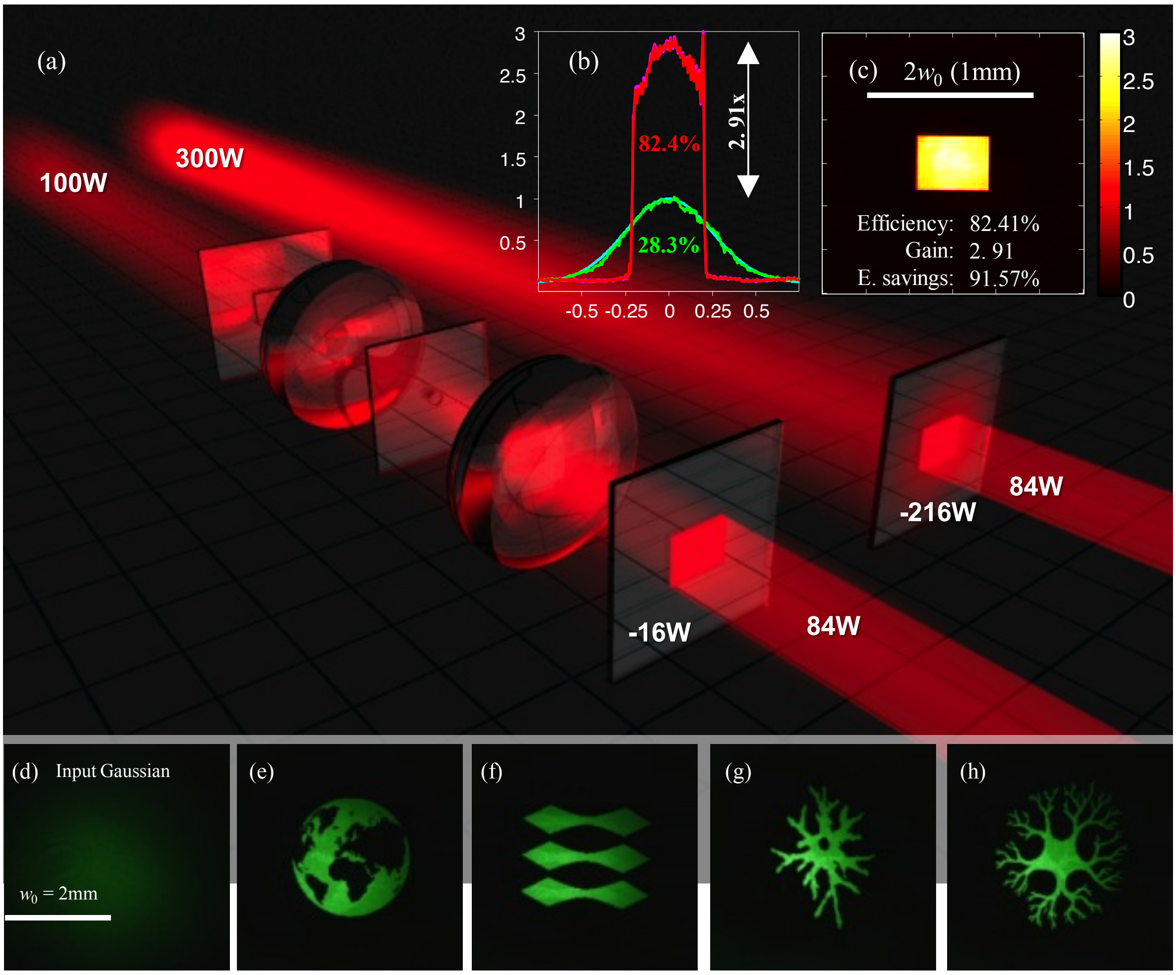


**Fig. 1.** A GPC Light Shaper and an amplitude mask transmitting the same power through identical rectangular apertures (a). Amplitude masking utilizes only 28% of the incident light. The GPC LS utilizing up to 84% of the incident light, requiring 1/3 less incident power and saving up to 93% of typical losses. Insets (b-c) show experimental verifications using a 750nm Gaussian laser beam. Arbitrary patterns in (e-h) are generated with a dynamic phase-only spatial light modulator.