Generation of Radial Laguerre-Gaussian modes with a lower threshold using a digital laser

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Electrical field of Laguerre-Gaussian beams with radial-order p

$$u_{p,0} = \sqrt{\frac{2}{\pi}} \times \frac{1}{w} \times L_p^0\left(\frac{2r^2}{w^2}\right) \times e^{\frac{-r^2}{w^2} - \frac{ikr^2}{2R(z)}} \times e^{-i(2p+1)atan\left(\frac{z}{z_R}\right)}$$

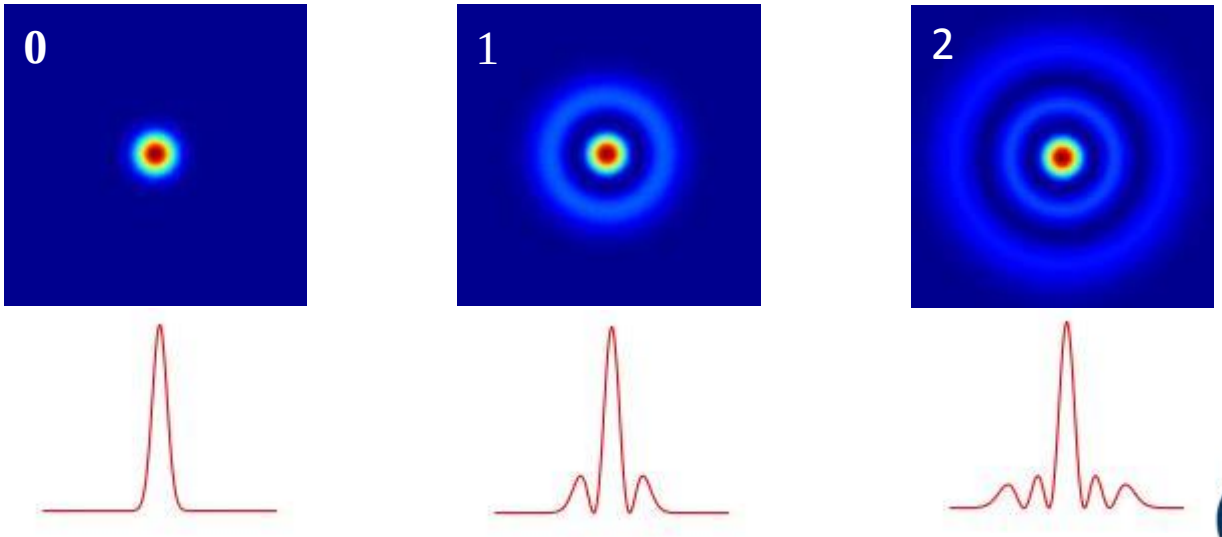
p and r are radial order and coordinates, respectively,

$w_z(z)$ is the beam radius at propagation distance z

L_p^0 is the Laguerre polynomial.

k is the wavenumber, R is the radius of curvature

And z_R is the radius of curvature



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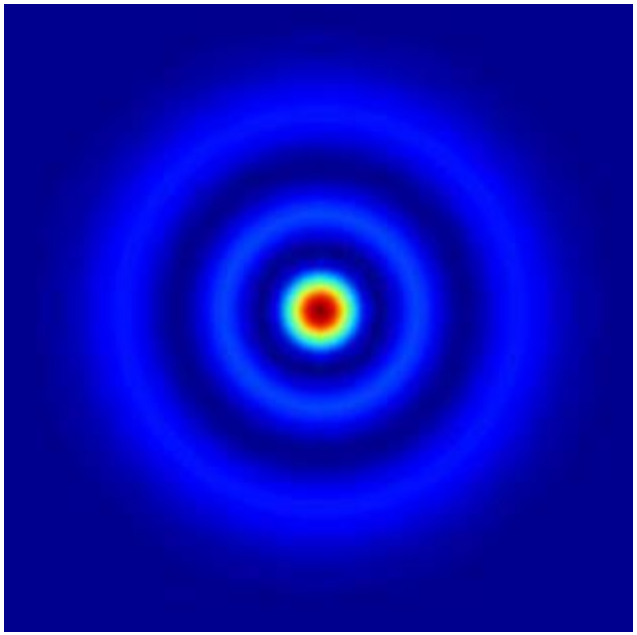
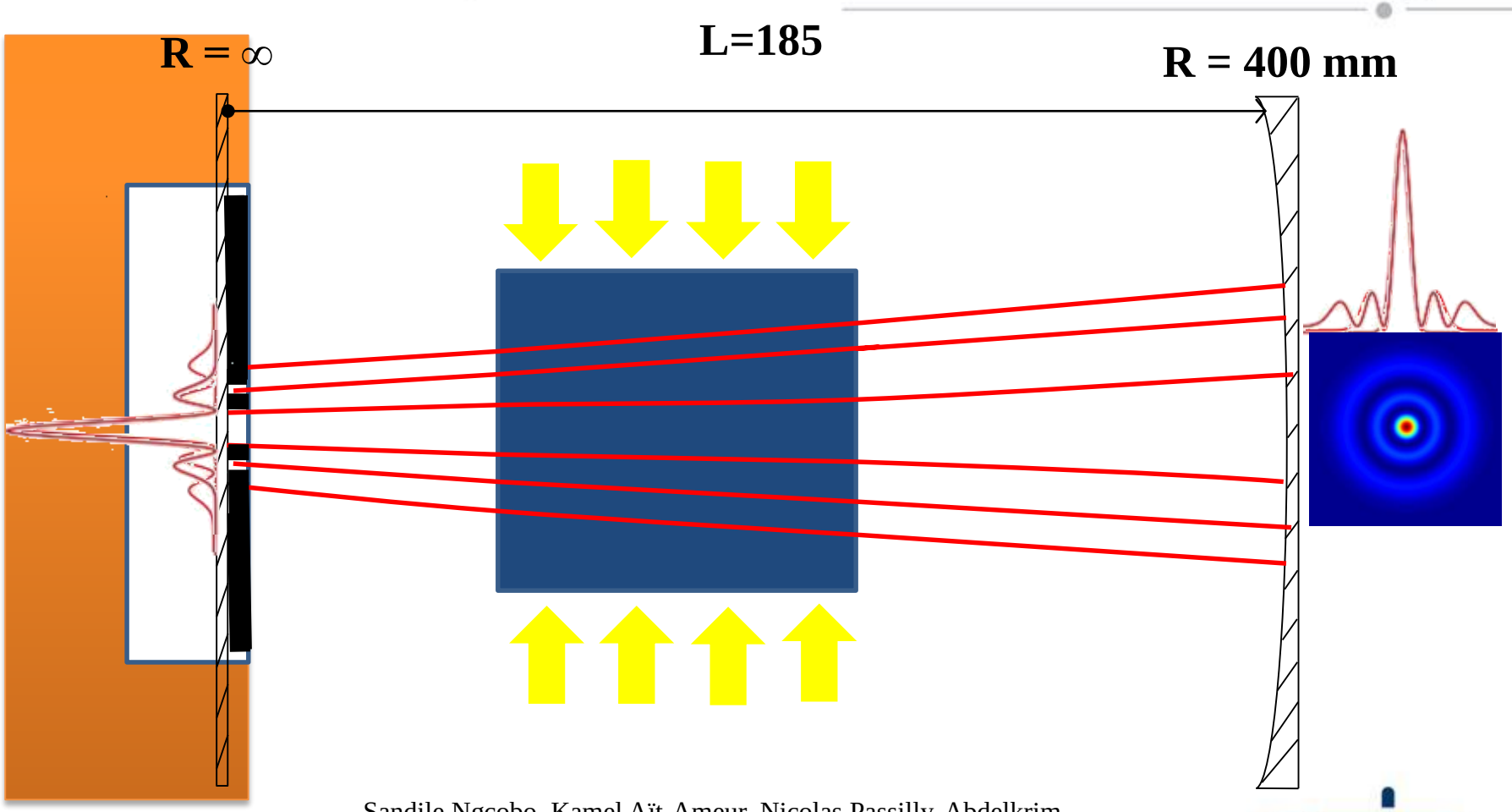
Concept of generating LGp beams using an amplitude mask



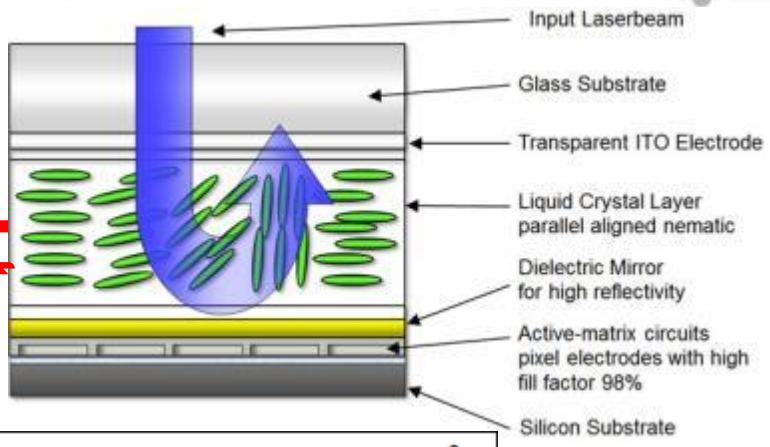
$$L_p^0\left(\frac{2r^2}{w(z)^2}\right)$$

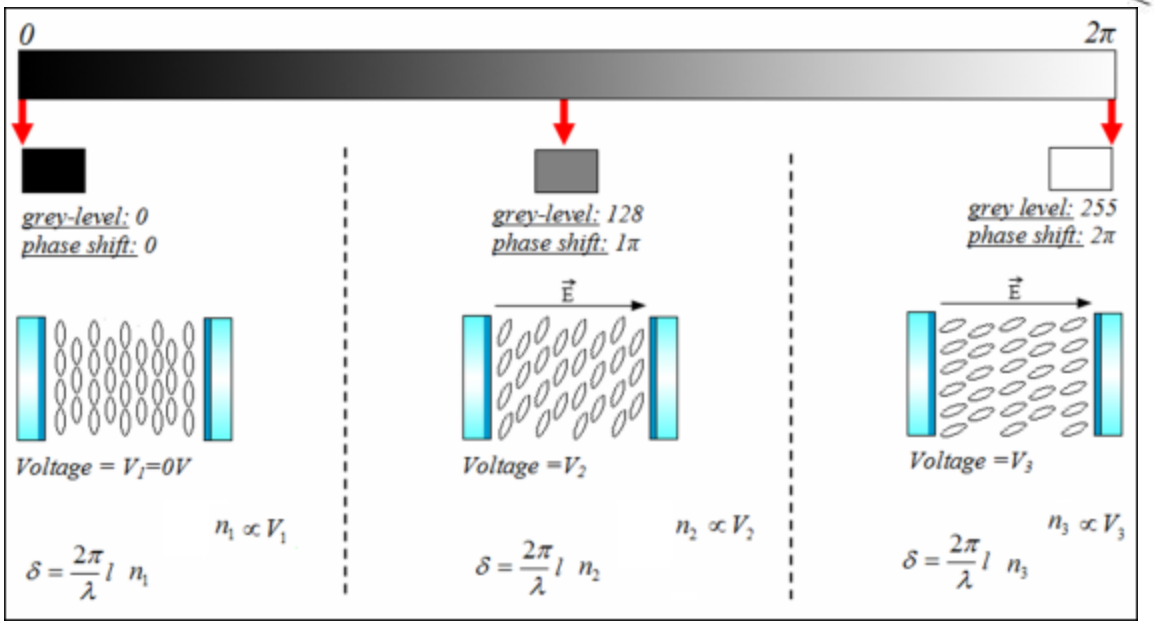
Concept of implementing intracavity amplitude beam shaping to generate LGp beams



Sandile Ngcobo, Kamel Aït-Ameur, Nicolas Passilly, Abdelkrim Hasnaoui, and Andrew Forbes, "Exciting higher-order radial Laguerre–Gaussian modes in a diode-pumped solid-state laser resonator," Appl. Opt. 52, 2093-2101 (2013)

Phase-only Spatial light Modulator (LCD Screen)





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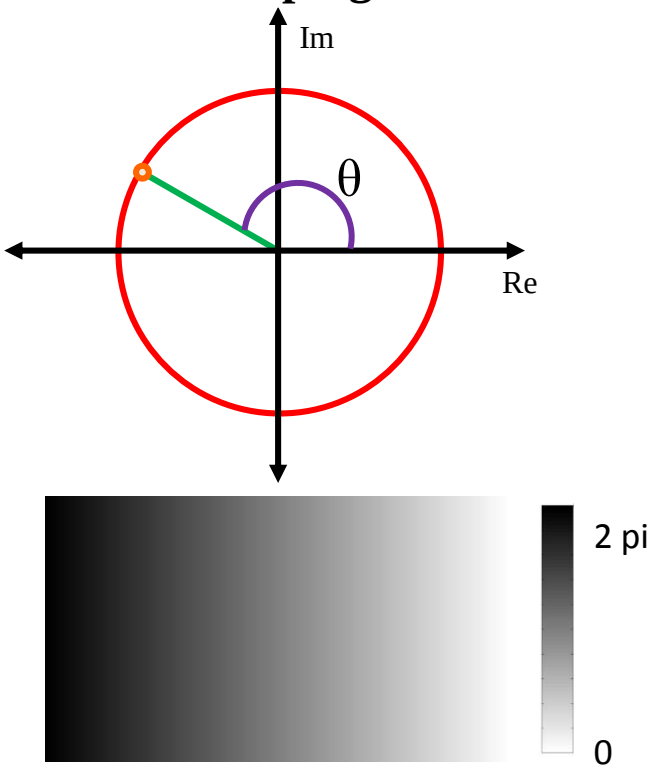
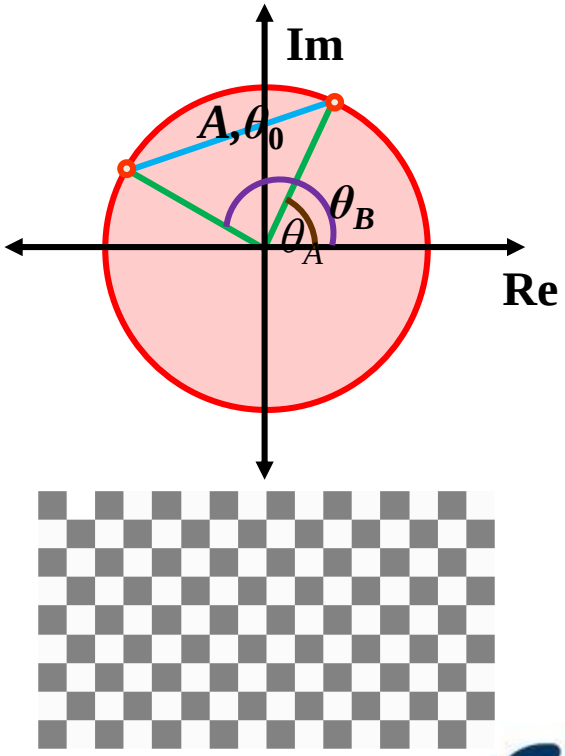
Spatial light Modulator

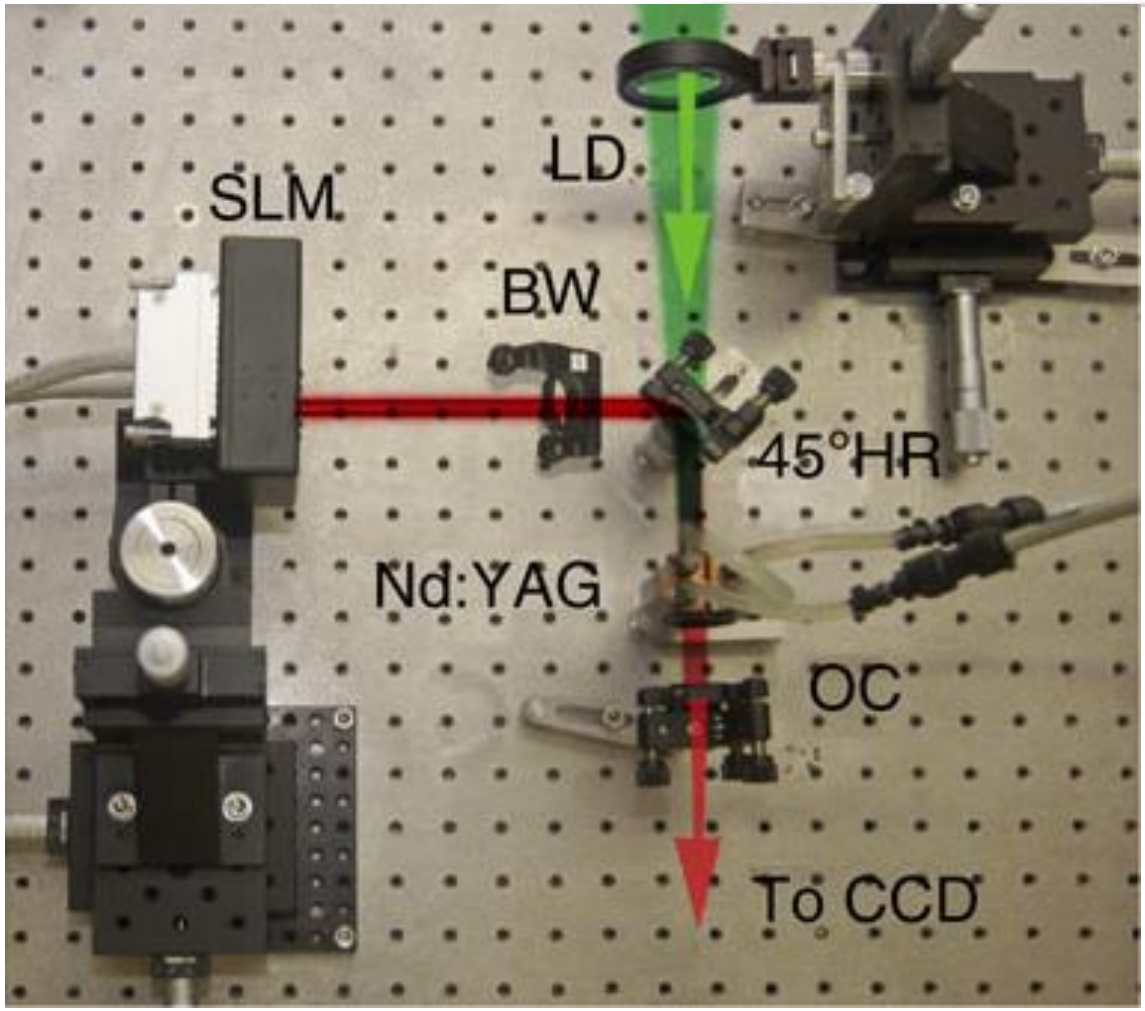
Phase beam shaping:



Amplitude beam shaping:

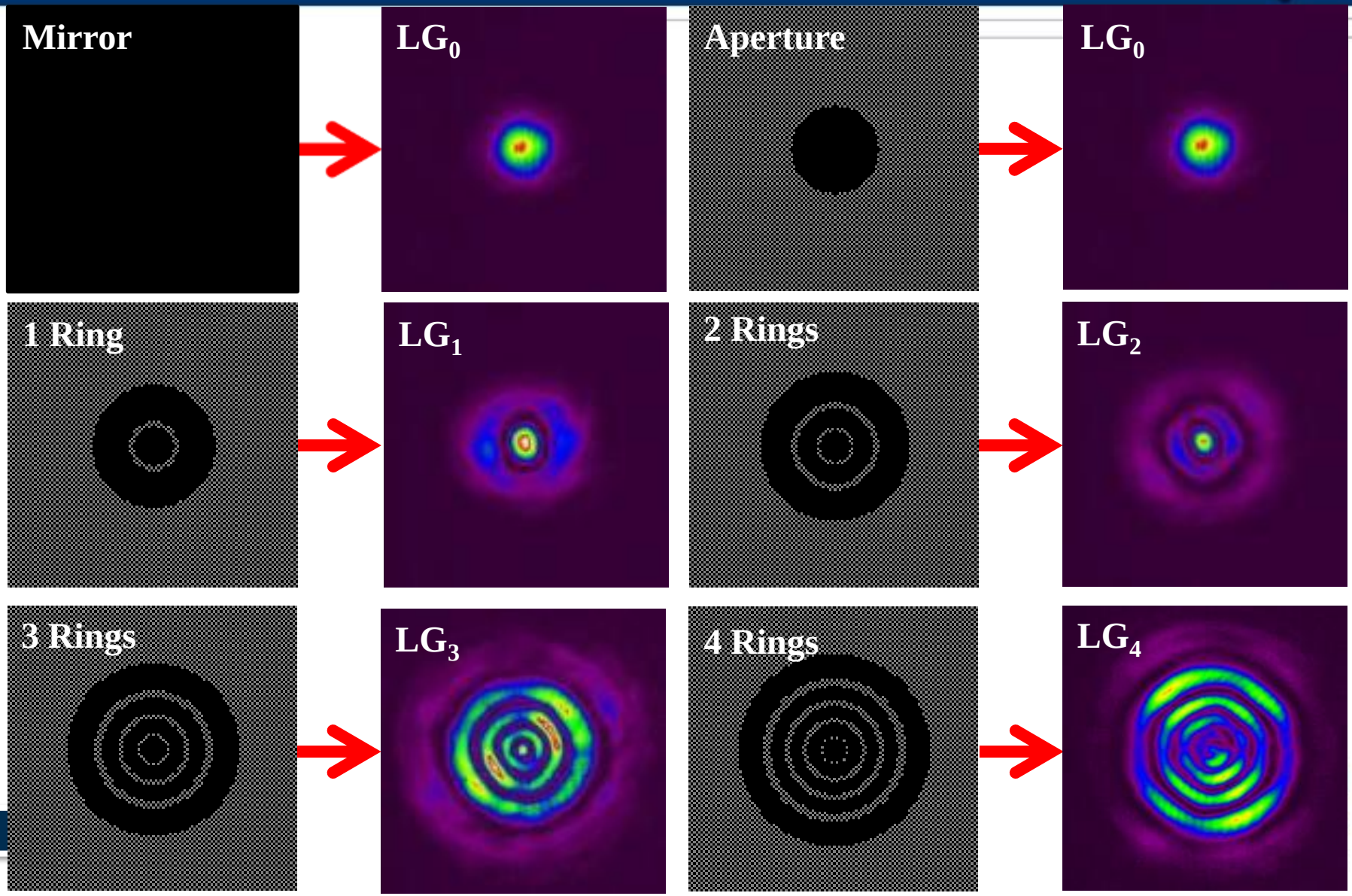


Experimental Setup



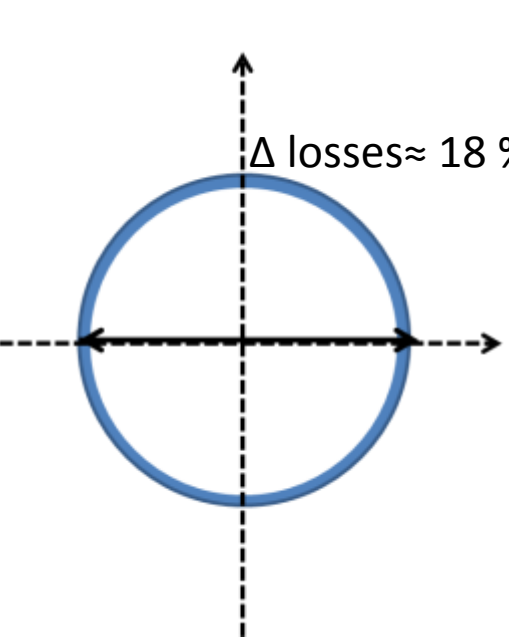
Ngcobo, S., Litvin, I., Burger, L., & Forbes, A. (2013).
A digital laser for on-demand laser modes. *Nature communications*, *4*.

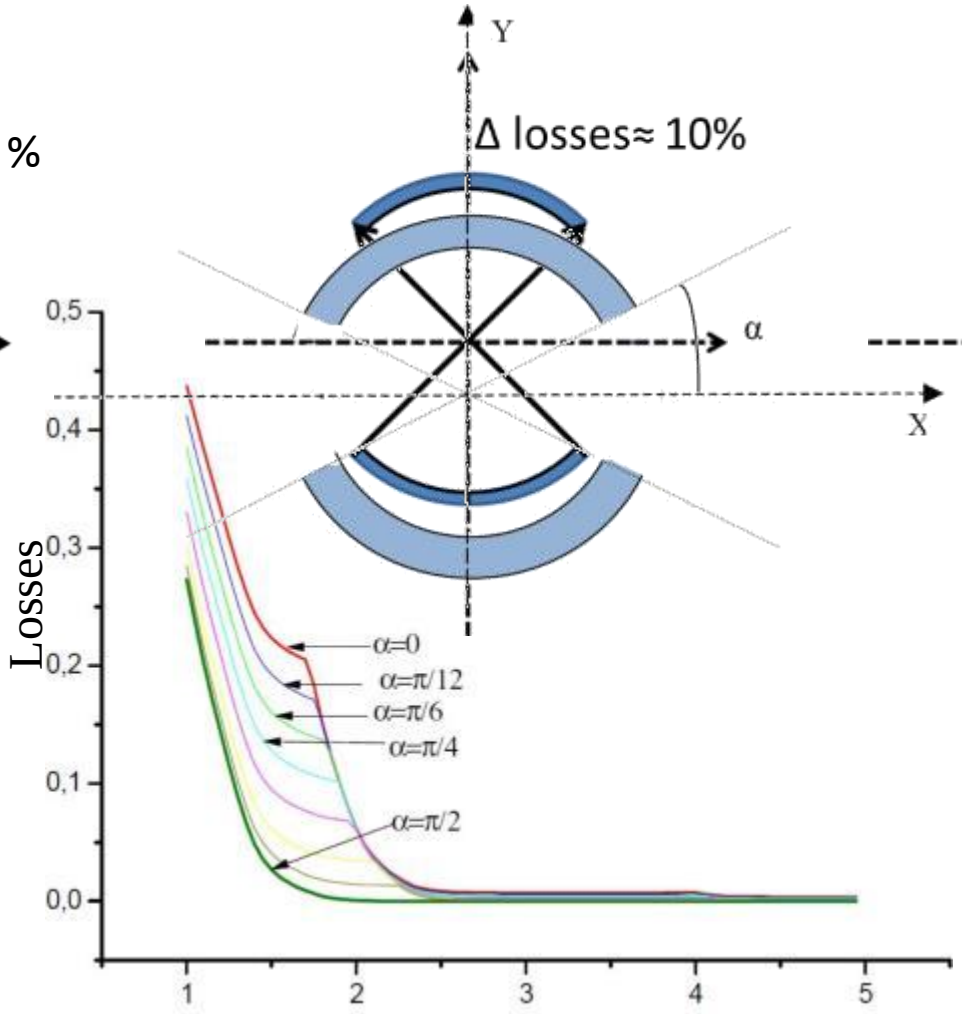
Results- Using Full Ring(s)

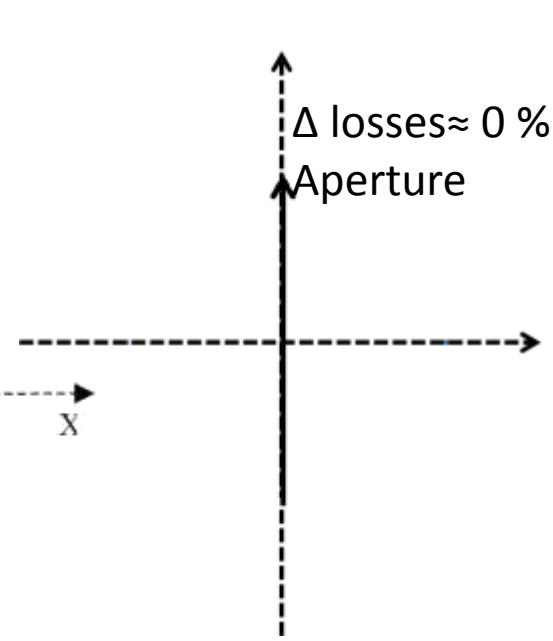


Our concept of how to create LGp beams with a lower loss?

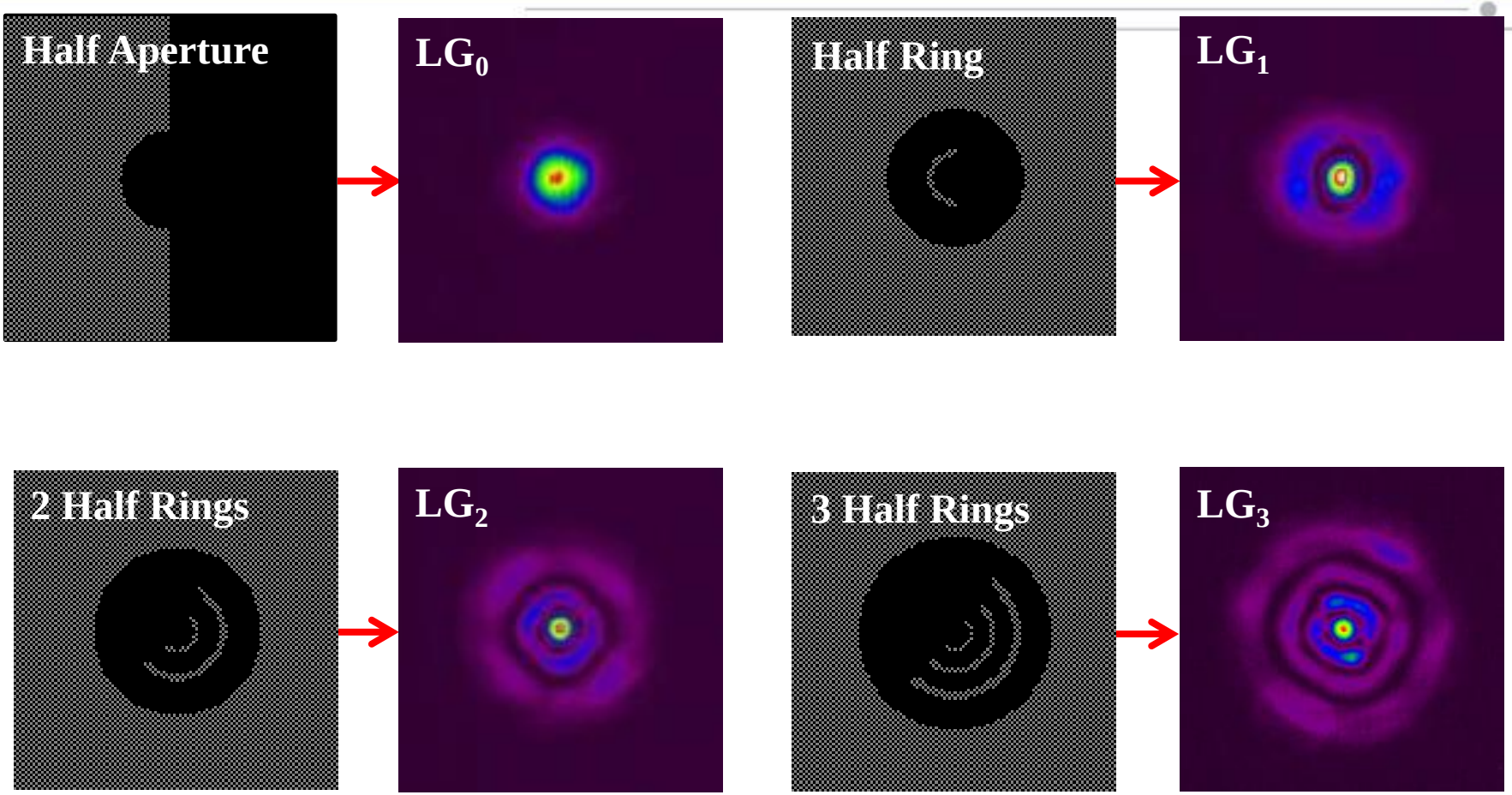
For examples: Fundamental Mode(LG_{10}) Losses





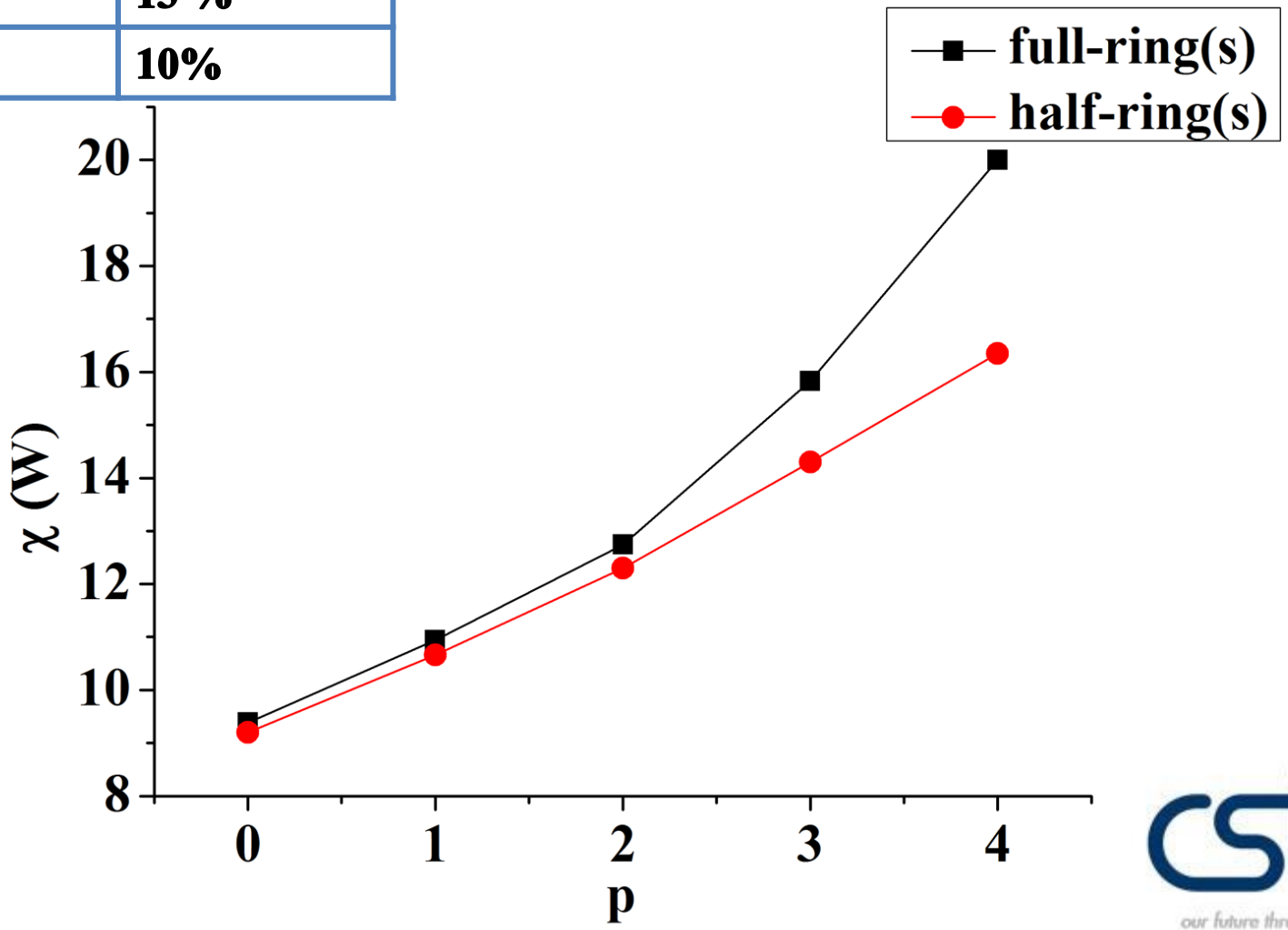


Results-Using Half Ring(s), $\alpha=\pi/4$

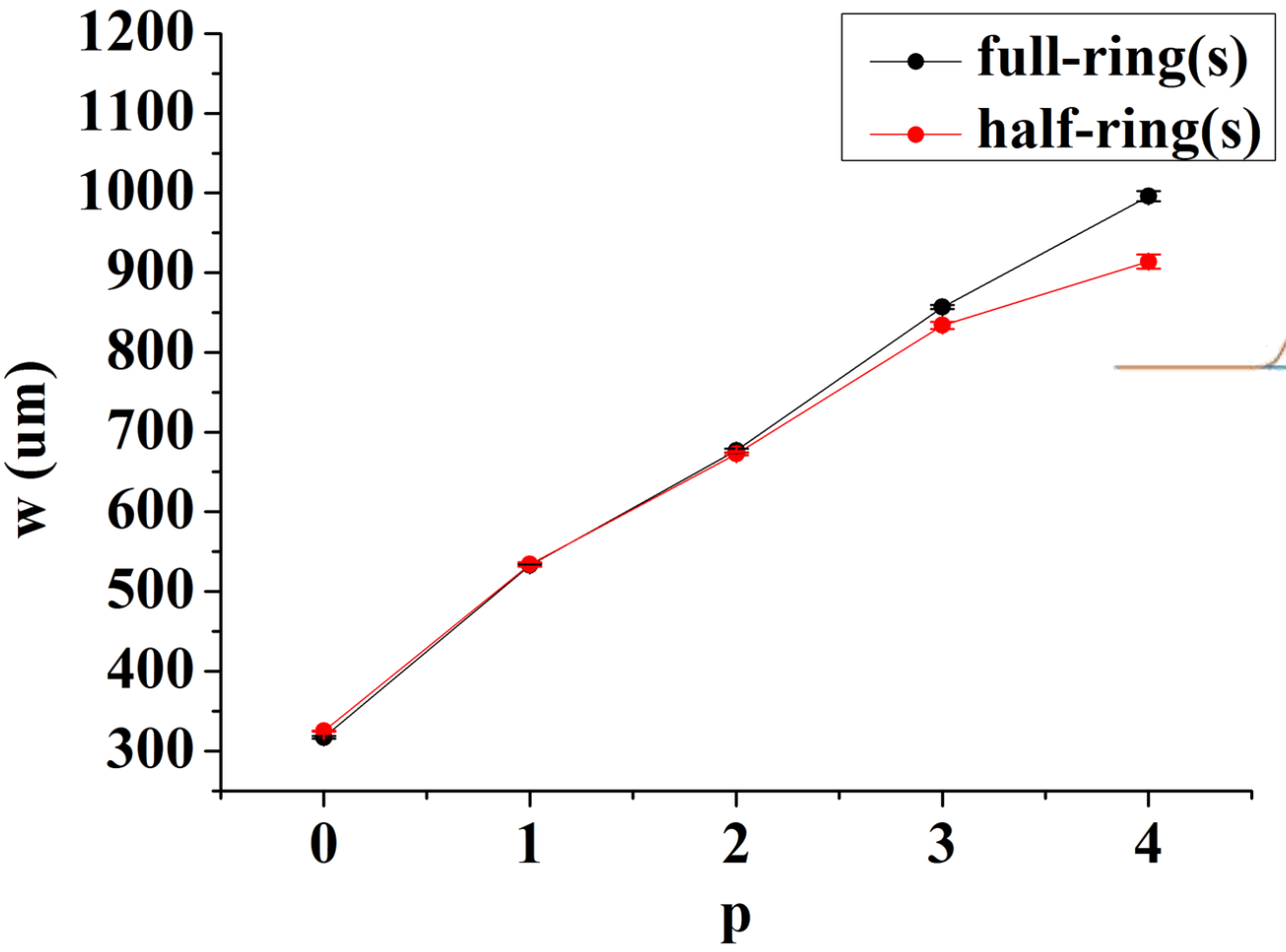


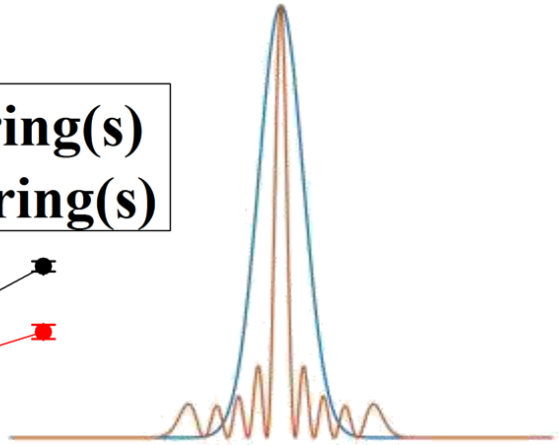
Results: Pump threshold χ

loss	Simulated	Experiment
LG_0	18 %	13 %
LG_1	10%	10%



Results: Output beam radius (w) as a function of the radial order p





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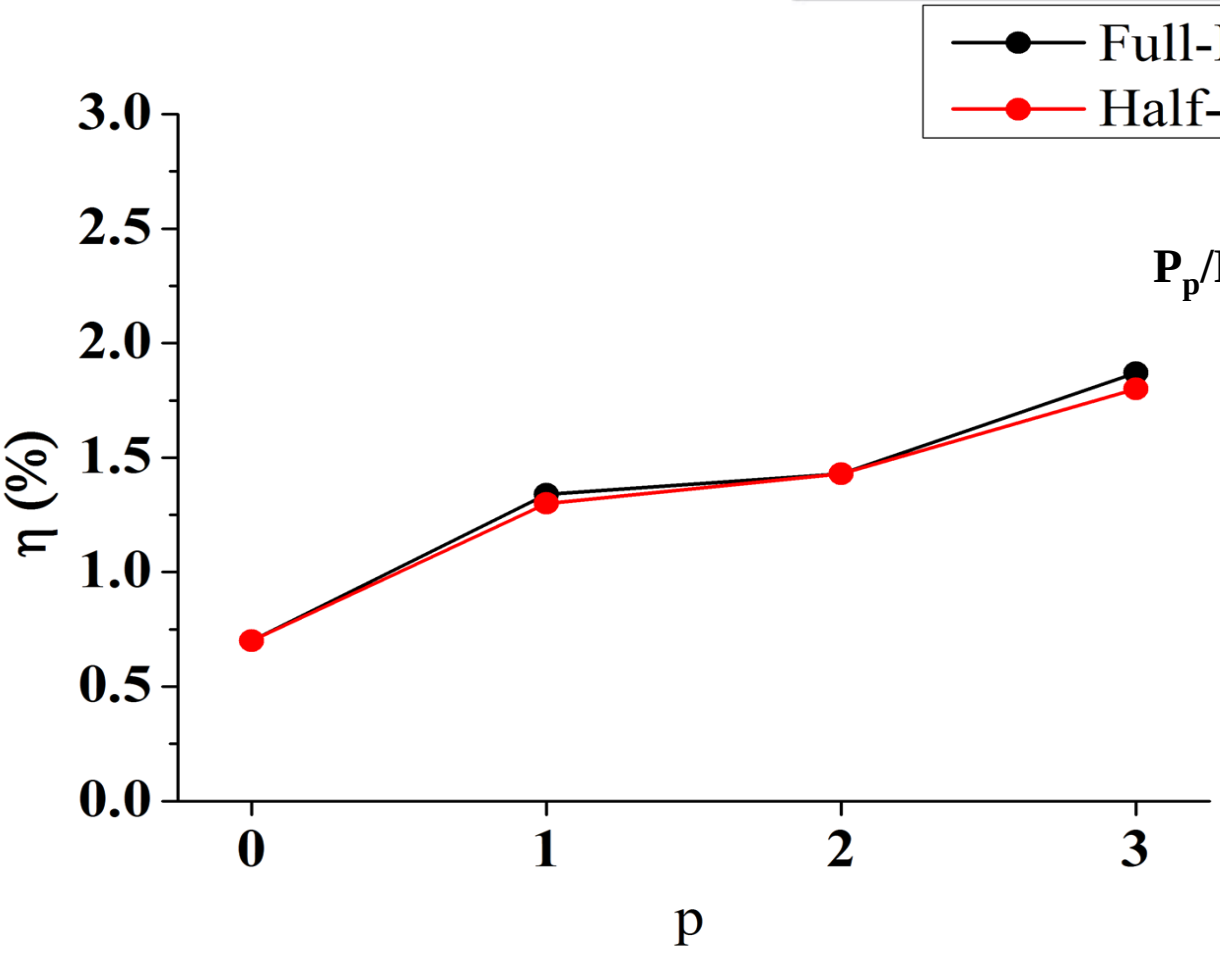
Results: Slope Efficiency η



$P_p/P_0=(2p+1)x\delta_0/\delta_p$

Conclusion

- ✓ Same LGp beams with same propagation properties were generated using both full and half-ring.
- ✓ One can generate high-order LGp modes with lower losses using half-rings.
- ✓ Nevertheless, the ratio of losses remain the same, which results in same output power.
- ✓ This work may lead to the ease of generating higher order LGp modes without pump power limitations.

ACKNOWLEDGEMENT

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Thank you!

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