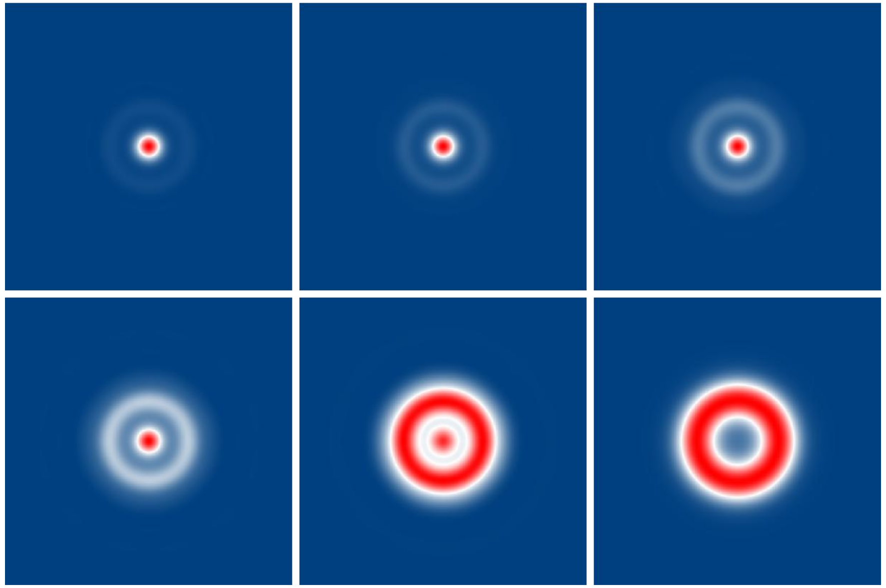
Gauss-Bessel Beam Shaper [Power Control]

From Gaussian to Bessel-like Beams with Power Control



Part of the Beam Shaping Solution Guide

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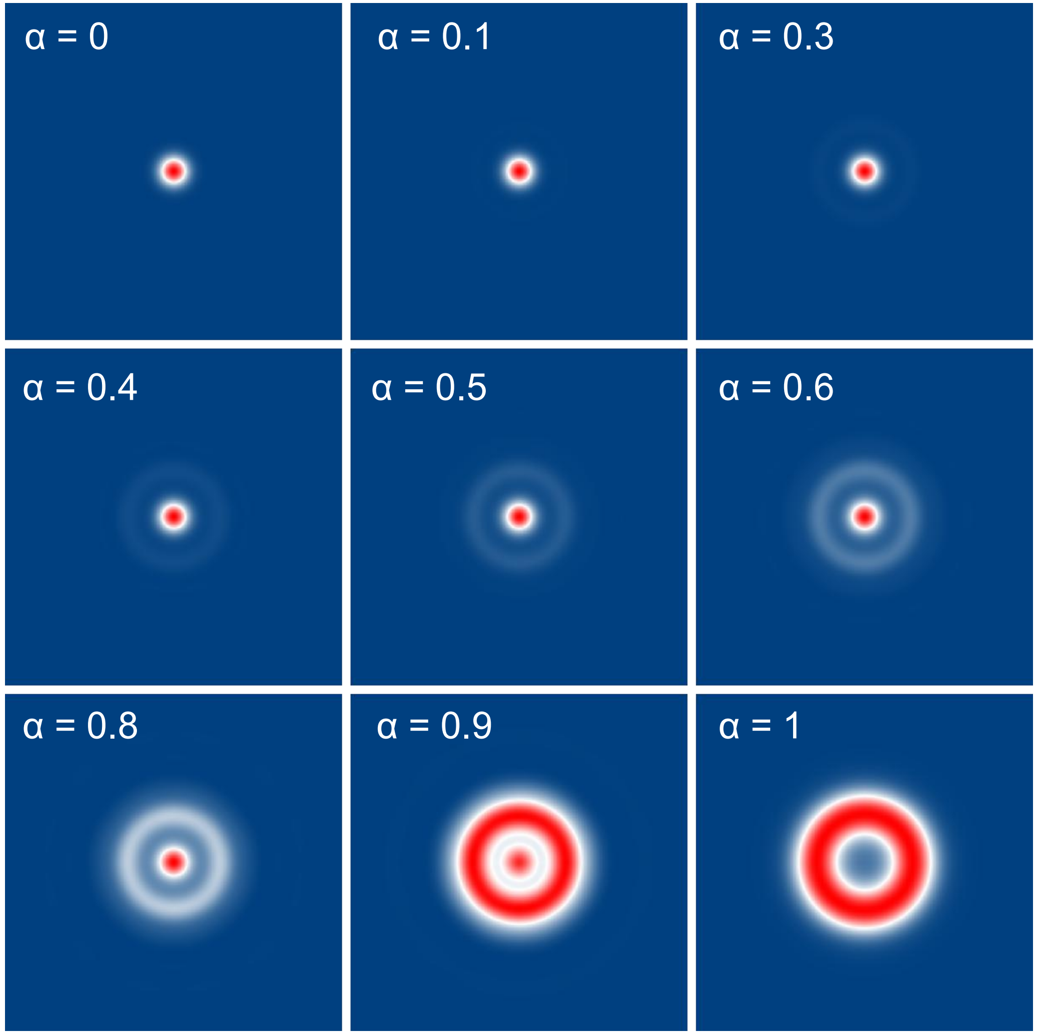
Executive Summary

Can we control the power distribution between the central spot and the surrounding rings of a Gauss-Bessel beam?

Yes. By adjusting the scale factor α, the beam transitions from a pure Gaussian ($\alpha = 0$) to a Bessel-like profile ($\alpha = 1$), redistributing power between the central spot and the rings.



Key Observations

- $\alpha = 0$: pure Gaussian beam (all power in central spot)
- $\alpha = 1$: Bessel-like beam with multiple rings and reduced central peak
- Intermediate α: smooth transition of power between central spot and rings

Introduction

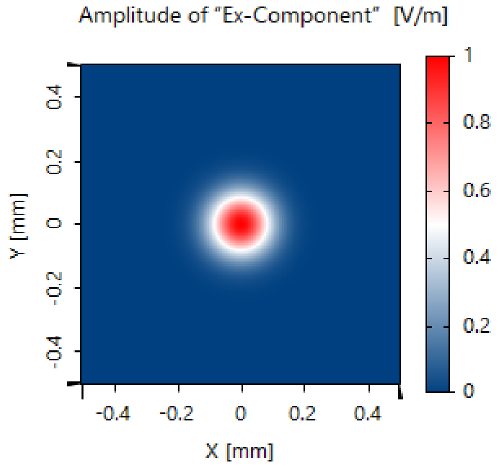
What This Use Case Demonstrates

- Modeling of a Gauss-Bessel beam shaper with power control
- Continuous power control via modulation depth parameter α
- Quantization effects on the beam profile: binary ($Q = 2$), 4-level, 8-level, and continuous phase
- Field propagation through a $2f$ setup

System Overview

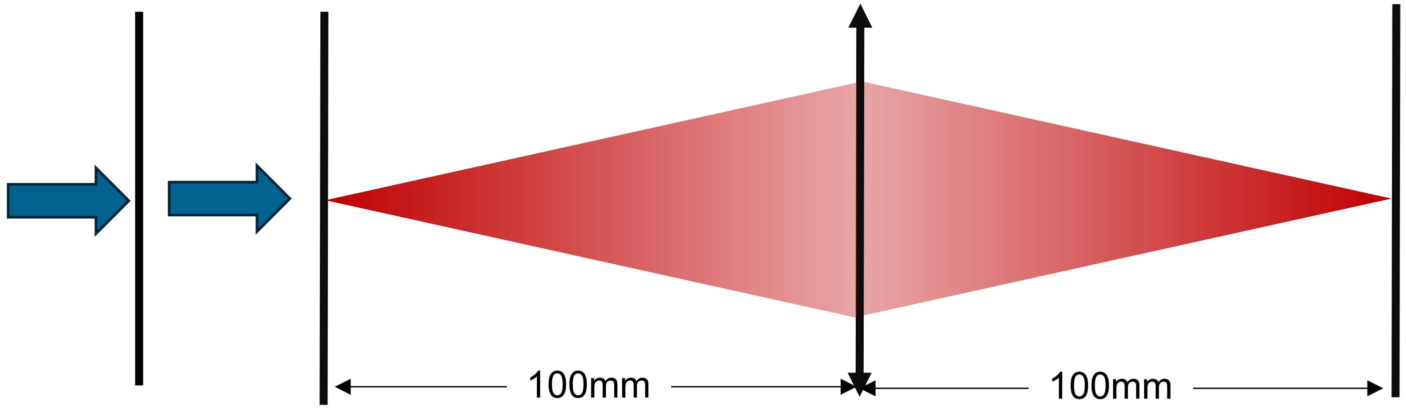
- Collimated Gaussian beam illuminates a quantized radial phase mask (Gauss-Bessel shaper)
- Shaper placed at front focal plane of a lens; intensity observed at back focal plane
- Phase scaling factor α controls energy split between central Gaussian spot and Bessel-like rings
- Quantization level Q determines number and structure of rings

Optical System Overview



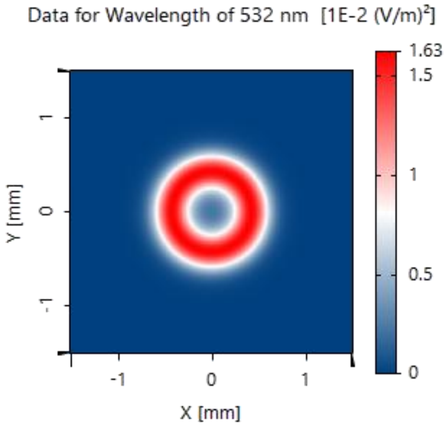
Gaussian wave source

- Radius: 100 um × 100 um
- Wavelength: 532 nm
- Ex polarized

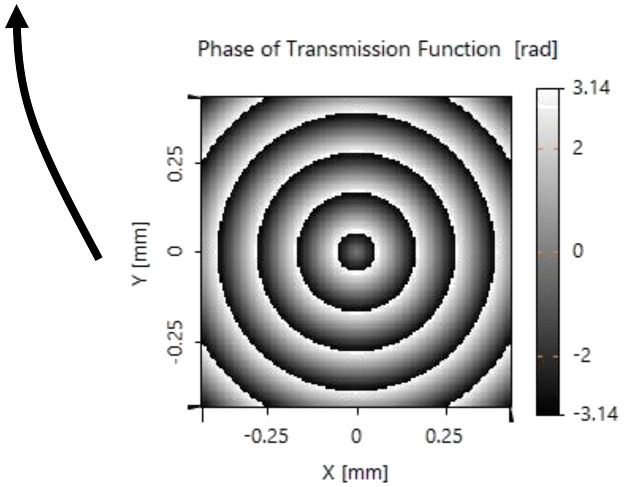


Bessel beam shaper

Thin Lens in 2f setup



Camera Detector

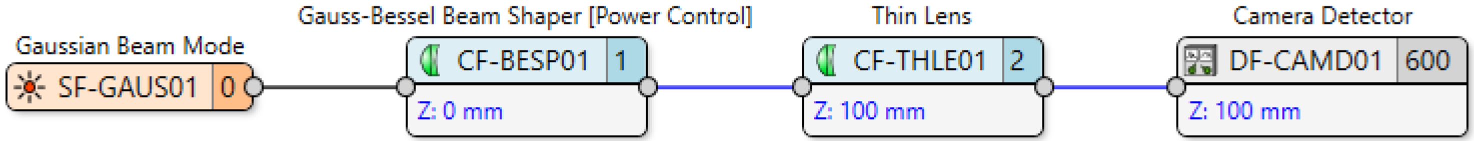


Shaper Config:

- Ring separation (M): 2
- Quantization Levels (N): Continuous
- Scaling of quantized rings (α): 1.0

System Configuration

System Layout



Digital Twin Mapping

Real Asset	Digital Twin	Description
Laser	SF-GAUS01	532 nm, waist 100 μm, collimated
Phase mask	CF-BESP01	$M = 2$, $\alpha = 1.0$, $Q = 0$ (continuous), Sampling Acc.=2
Fourier lens	CS-LENS01	Focal length $f = 100$ mm
Camera	DF-CAMD01	3×3 mm², 1024×1024 pixels, at $z = f$

Results – Phase Scaling Parameter Run

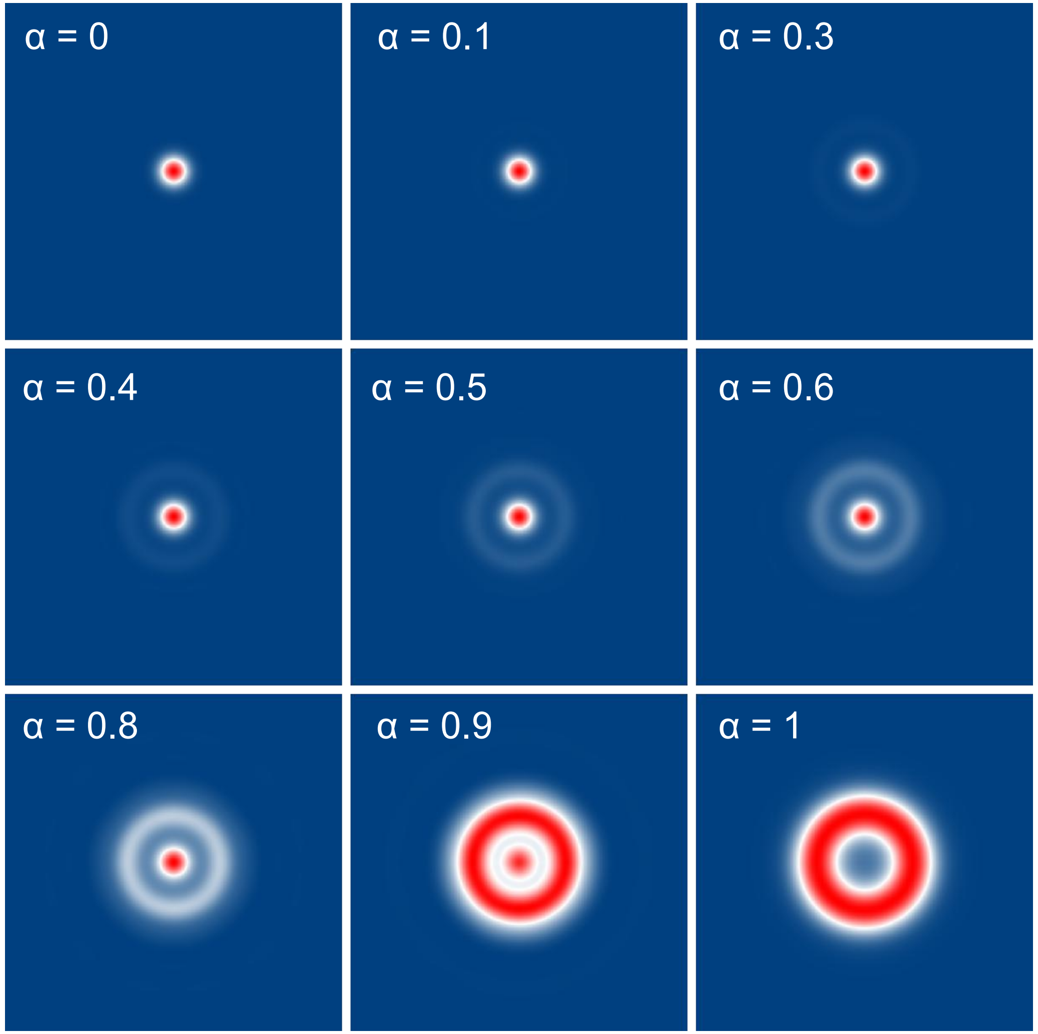
Power Control via α

α	**Observation**
0.0	Pure Gaussian spot, no rings
0.7	Central spot brightens, rings weaken
0.85	Central spot appears, rings remain strong
1.0	Bessel-like ring, central intensity nearly zero

The full parameter run from $\alpha = 0$ to 1 in 9 steps shows a smooth transition.

Physics Insight

- α scales the phase modulation depth; the shaper transmission is $\exp(i\alpha\phi_{\text{ideal}})$.
- For $\alpha < 1$, the field contains both an unmodulated Gaussian component and a modulated Bessel-like component.



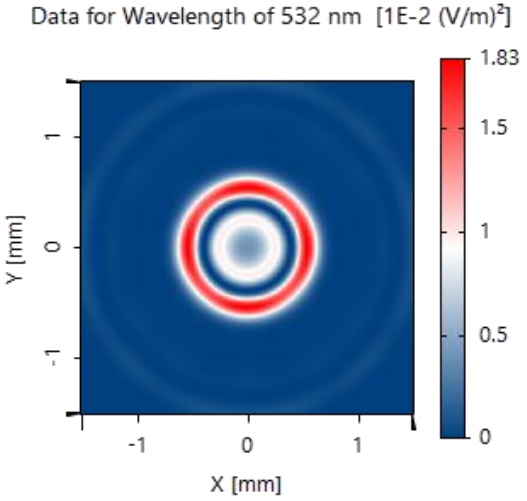
Results – Different Quantization Levels

Quantization Effects ($\alpha = 1$)

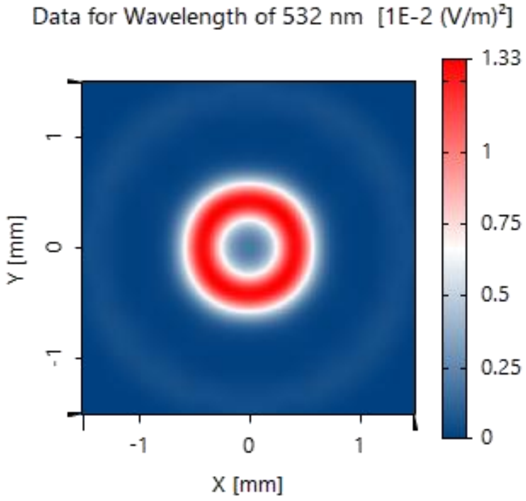
Q	Observation
2 (binary)	Multiple rings; double-peaks visible
4	Fewer higher orders, first ring dominant
8	Nearly ideal Bessel-like ring
0 (continuous)	Ideal Bessel-like ring, single ring

Physics Insight

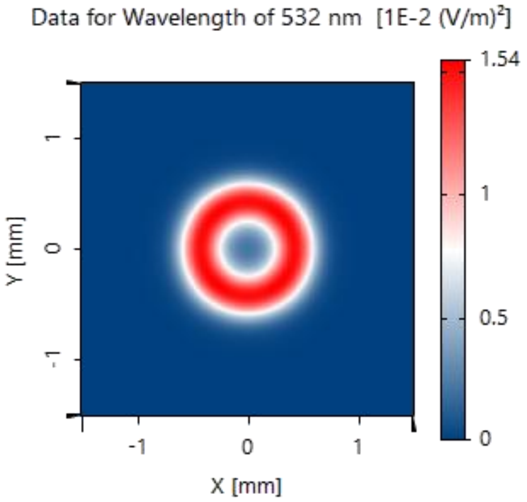
- Lower Q introduces quantization noise, generating additional diffraction orders.
- Binary phase ($Q = 2$) acts as a radial square wave, producing odd orders with double-peak radial structure.
- Higher Q approximates the ideal continuous phase, concentrating energy into the first Bessel-like ring.



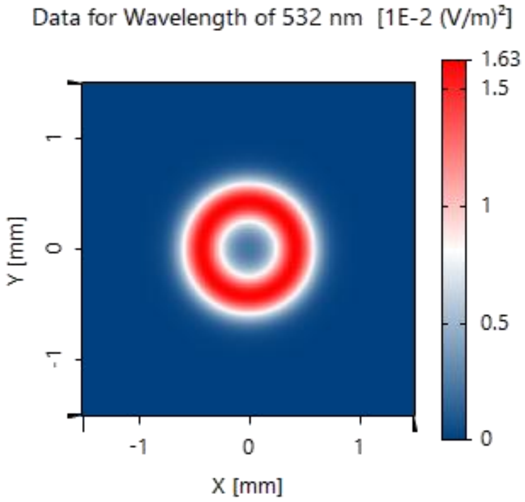
2 Level Quantization



4 Level Quantization



8 Level Quantization



Continuous Phase

Demonstration Workflow

Step-by-Step Workflow

1. **Setup:** Add Gaussian source (`SF-GAUS01`).
2. **Shaper:** Place `CF-BESP01` at the front focal plane of the lens.
3. **Lens:** Add lens (`CS-LENS01`) with $f = 100$ mm at distance f from shaper.
4. **Detector:** Place detector (`DF-CAMD01`) at the lens's back focal plane.
5. **Configure:** Set $M = 2$, Divergent = false, Sampling Accuracy = 2.
6. **Simulate:**
    - Run a parameter run for α from 0 to 1 in 9 steps with $Q = 0$.
    - Separately configure the beam shaper with $Q = 2, 4, 8, 0$ with $\alpha = 1$. Run field tracing for each case.
7. **Analyze:**
    - Create overview images from the Parameter Sweep to visualize the power control.
    - Observe the intensity profiles from the Camera Detector for different quantization levels.

References

Specification Sheets

- `SF-GAUS01` — Gaussian Beam Source
- `CF-BESP01` — Gauss-Bessel Beam Shaper [Power Control]
- `CS-LENS01` — Thin Lens
- `DF-CAMD01` — Camera Detector