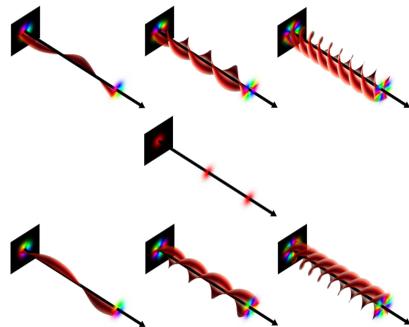


Introduction

Laguerre Gaussian (LG) Beams

- Cylindrically symmetric beams that form a basis set for paraxial light beams
- Properties of beams defined by two indices:
 - Azimuthal number (ℓ) - number of spirals in 2π , related to the orbital angular momentum (OAM) by $L_z = \ell\hbar$
 - Radial index (p) - number of rings from infinity minus one

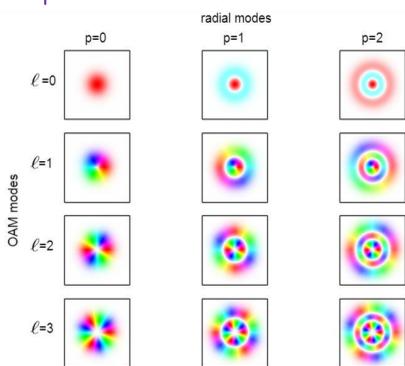


B. Rodenburg, OAM 3D. Unpublished Image.

$$U_{p,\ell}(r, \phi, z) = \frac{C_{p,\ell}^{LG}}{w(z)} \left(\frac{\sqrt{2}r}{w(z)}\right)^{|\ell|} L_p^{|\ell|} \left(\frac{2r^2}{w(z)^2}\right) \exp\left(\frac{-r^2}{w(z)^2}\right) \exp\left(ik\frac{r^2}{2R(z)}\right) \exp[i(2p+|\ell|)\zeta(z)] \exp(i\ell\phi)$$

Goal:

- Separate LG radial modes

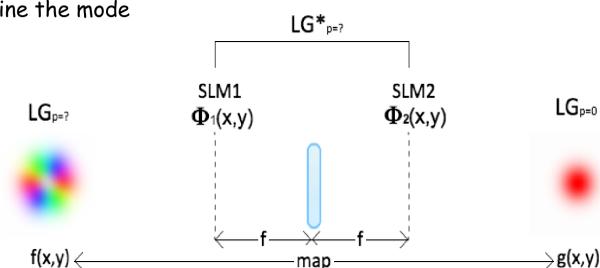


B. Rodenburg, LG OAM Modes. Unpublished Image.

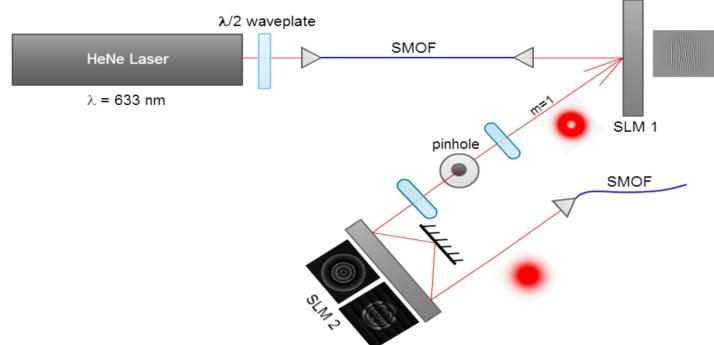
- Extensive work has been done on LG OAM modes recently, but radial modes have been largely overlooked
- OAM modes have applications in:
 - Free space communication (increase channel capacity)
 - QKD (increase tolerance to eavesdropping attacks)
- Applications require method for sorting photons carrying OAM with high precision
- Radial modes with different p values, like OAM modes with different ℓ values, form a large orthonormal set of functions that can be used to encode information
- Could be used for same applications

Projective Measurements

- Mode is imaged onto a conjugate mode and the resulting field is propagated and coupled into a single mode optical fiber
- Method gives yes or no, requires scanning through the radial indices to determine the mode



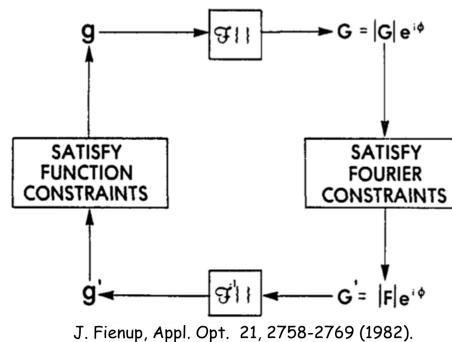
Experiment



- LG radial mode is created by first SLM and converted into a Gaussian by the second SLM.

Phase Retrieval

- Method for recovering phase when only intensity information is known
- Used to calculate the phase masks needed to convert radial modes to Gaussians and vice versa
- Used Gerchberg-Saxton method of phase retrieval

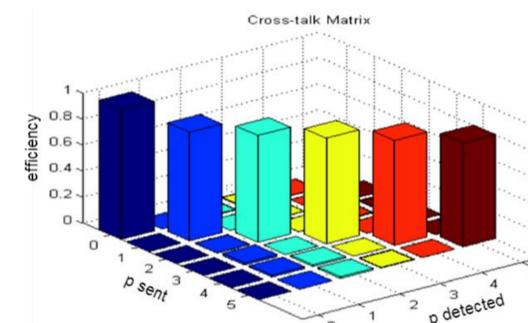
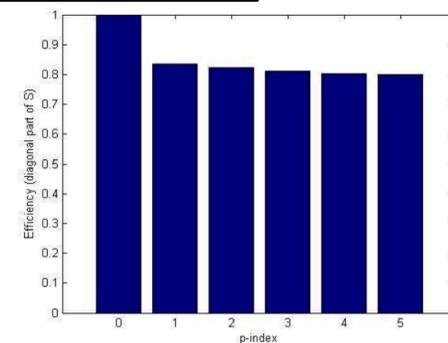


J. Fienup, Appl. Opt. 21, 2758-2769 (1982).

- Used Hankel transform to force phase masks to be radially symmetric

$$g_R(r) = 2\pi \int_0^\infty \rho G_0(\rho) J_0(2\rho) d\rho$$

$$G_0(R) = 2\pi \int_0^\infty r g_R(r) J_0(2r) dr$$



- Theoretical coupling efficiencies of around 80% for $p = 1-5$ with low cross-talk between modes

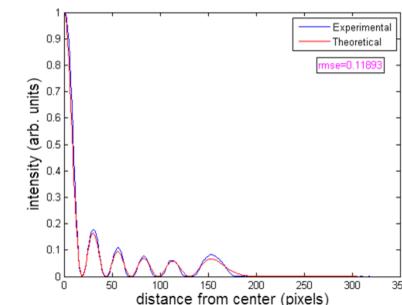
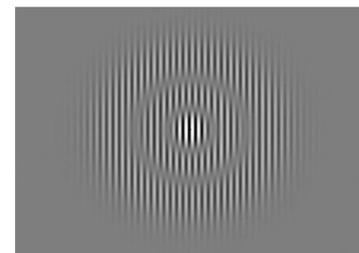
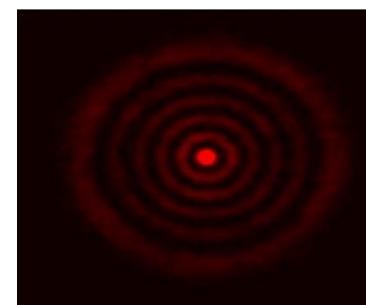
Creating Radial Modes

LG radial modes were created by placing a computer generated hologram (CGH) on a spatial light modulator (SLM).

- Hologram was essentially a phase mask with blazed diffraction grating on top
- Can be implemented using spatial light modulator (SLM) with reduced phase domain

Goal:

- Produce LG radial modes $p=1-6$ with a RMS error below 0.2



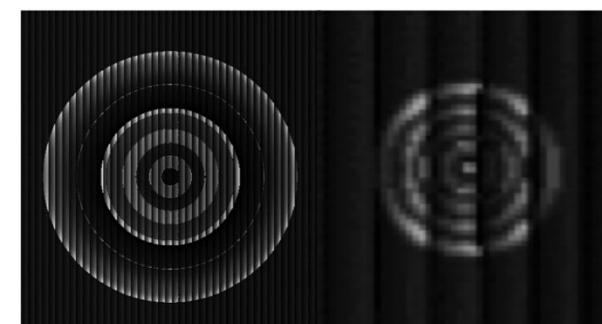
Transforming Radial Modes

LG radial modes were transformed into Gaussians in the same manner as radial modes were created, by placing a CGH on a SLM.

- No amplitude modulation, only phase modulation
 - Allows for usage of a binary diffraction grating
- Each half of SLM controlled separately
 - Variable tip, tilt, lens, and centering can be added in real-time

Goal:

- Transform LG radial modes $p=1-6$ into Gaussians



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Future Work

- Finish implementing experimental set up
- Sort LG radial modes

Acknowledgements

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