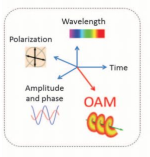
Characterization of Emissions from a HOPS Microlaser

Jacqueline Aquino, Dustin Brown, Zhifeng Zhang, Dr. Liang Feng

UNIVERSITY of PENNSYLVANIA

Introduction

-With adequate integration, Orbital Angular Momentum(OAM) has promising potential to be an additional dimension for information capacity and optical communication next to the limited properties of light like wavelength

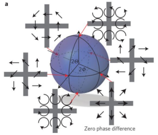


-Points on the Higher Order Poincare(HOP) sphere represent OAM states

$$output = x_1 P_1 + x_2 P_2 * e^{i*q*PHI}$$

(Pole state 1(P1): OAM +2; spin +1
Pole State 2(P2): OAM -2; spin -1)

-Through controlling phase and amplitude differences, the OAM states are mapped onto the HOP surface



Goals

-Detect and characterize OAM states to retrieve phase and amplitude difference

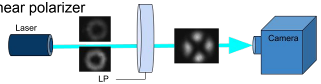
-Optimize original OAM microlaser design

Methods

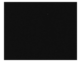
Section 1: Optical Setup and Data Collection

Method 1: **Optical setup oversimplified for explanation purposes*

- Collected intensity patterns after two pole states were filtered through a y-directed linear polarizer

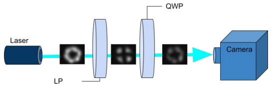


-Background image taken to reduce noise in final output images



Method 2:

- Required additional component: Quarter Wave Plate (QWP)
- Collected intensity patterns at varying linear polarizer and wave plate orientations as well as different heater current conditions



Section 2: Data Analysis/Image Processing

**Utilized Matlab for image processing*

Method 1:

- Tracing interference maxima and minima to retrieve the phase and amplitude information

$$output = x_1 P_1 + x_2 P_2 * e^{i*q*PHI}$$

Important Steps:

1.Normalize the 2 pole state image intensities
2. Determine center of beam given not pure circle
3. Multiplex pattern with OAM phase map

$$E_{+2} = E_1 * e^{(2*i*phi)}$$

$$E_{-2} = E_2 * e^{(-2*i*phi)} * e^{(i*PHI)}$$

Method 2:

-Stokes Polarimetry to determine the phase difference and power ratio at different heater settings

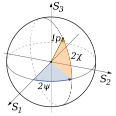
-LP = linear polarization; s = circular polarization

-Psi = Phase difference; Chi = Chiral Ratio

$$S_1(r, \phi) = I_{LP,0}(r, \phi) - I_{LP,90}(r, \phi)$$
$$S_2(r, \phi) = I_{LP,45}(r, \phi) - I_{LP,135}(r, \phi)$$
$$S_3(r, \phi) = I_{S,135}(r, \phi) - I_{S,45}(r, \phi)$$

$$2\psi = \arctan\frac{S_2}{S_1}$$

$$2\chi = \arctan\frac{S_3}{\sqrt{S_1^2 + S_2^2}}$$

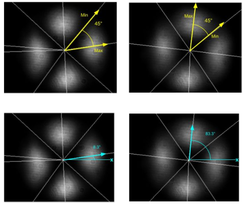


Results

Method 1:

-Angle between min and max is fixed at 45°

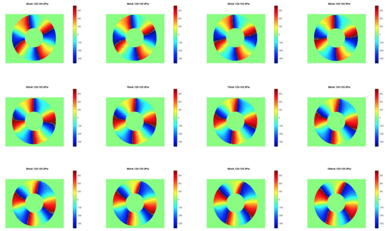
120-130 w/ angle of 8.3°

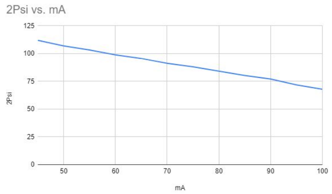


125-135 w/ angle of 83.3°

-Minimum angle is affected by noise from spontaneous emission from beam; naturally cannot get accurate chiral ratio results

Method 2:





Discussion

Method 1:

-Limitation: Interference from noise

-Despite cancelling background noise, there was still prominent noise from spontaneous emission of the beam itself

-Must continue to optimize setup and analyzation method to increase signal to noise ratio

Method 2:

-No noise given both background and spontaneous noise cancel through nature of Stokes Parameter equations (subtraction)

- Data validates use of heater for control/tunability of phase difference

Acknowledgments

-Materials Science and Engineering Department

-Electrical Engineering Department

-CURF Penn Undergraduate Research Mentorship Program (PURM)

References

-Bozinovic, N., Yue, Y., Ren, Y., Tur, M., Kristensen, P., Huang, H., Willner, A. E., & Ramachandran, S. (2013). Terabit-Scale orbital angular momentum mode division multiplexing in fibers. *Science*, *340*(6140), 1545–1548. https://doi.org/10.1126/science.1237861

-Miao, P., Zhang, Z., Sun, J., Walasik, W., Longhi, S., Litchinitser, N. M., & Feng, L. (2016). Orbital Angular Momentum Microlaser. Science, 353(6298), 464–467. https://doi.org/10.1126/science.aaf8533

-Naidoo, D., Roux, F. S., Dudley, A., Litvin, I., Piccirillo, B., Marrucci, L., & Forbes, A. (2016, March 14). Controlled generation of higher-order POINCARÉ Sphere beams from a laser. nature photonics. https://www.nature.com/articles/nphoton.2016.37.

-Wikimedia Foundation. (2021, June 22). Stokes parameters. Wikipedia. https://en.wikipedia.org/wiki/Stokes_parameters.