Mode Purity Analysis of OAM Fiber Modes with a Mobile Phone

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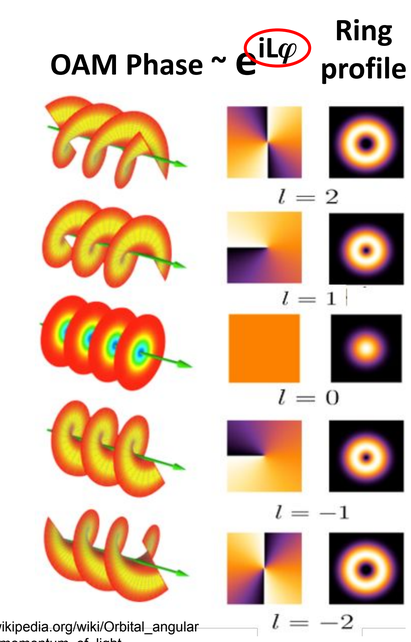
Abstract

Light propagation through optical fibers is the primary means by which the internet transmits data. We have fast been approaching some fundamental limits in how much data can be sent through fiber, and the past decade has revealed that fiber propagation of special beams that travel in a helical path rather than a straight line – called orbital angular momentum (OAM) modes – could play a role in addressing this capacity crunch. Moreover, having many perfect (or pure) OAM beams in a single fiber may also reduce the energy consumed per bit of data – a metric of increasing importance as the global internet consumes ever more power. But OAM beams in fibers are more sensitive to alignments (position, angle) than the regular beams in today's fiber-optic internet. While scientific labs have robust ways to measure and correct for these misalignments, a technician coming to homes to install the internet would have to know a lot more about OAM, photons, etc., than is practically feasible. Here, we have developed a phone app that can both do the measurements that can currently be done only in an advanced lab, and also calculate the metrics by which one can determine how pure an OAM beam out of a fiber is, and whether the fiber is misaligned in position or angle. This simple tool is a step towards making complex technological innovations suitable for transitioning into real world applications.

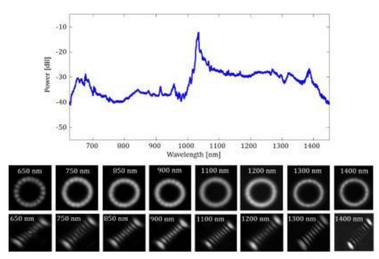
OAM Modes[1]

OAM Phase ~ $e^{i\ell\varphi}$ Ring profile

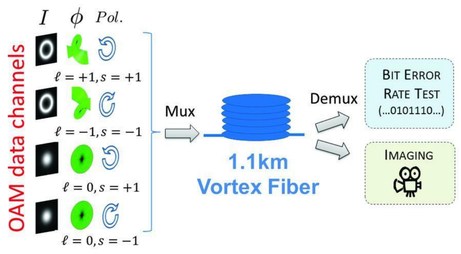


wikipedia.org/wiki/Orbital_angular_momentum_of_light

Applications

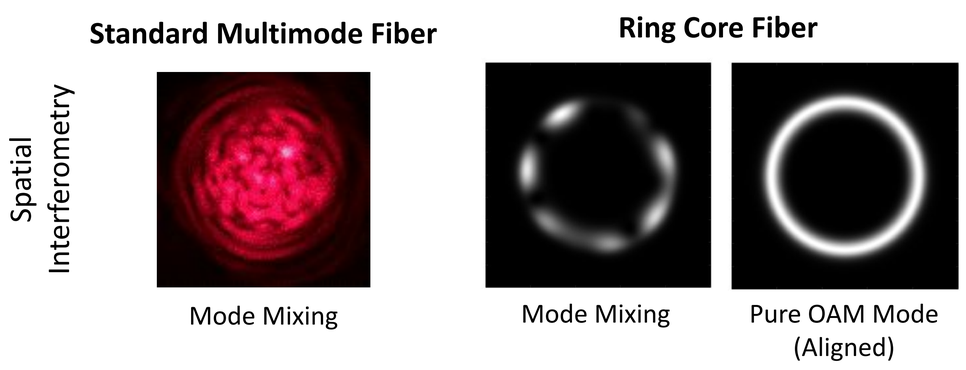


Nonlinear Optics [2]



Telecommunication Data Channels [3]

Ring Technique



OAM Azimuthal Interference:

$$\left|Ae^{iL_1\phi} + Be^{iL_2\phi}\right|^2 \propto AB\sin([L_1 - L_2]\phi) = AB\sin([\Delta L]\phi)$$

For OAM modes of different L interfering:

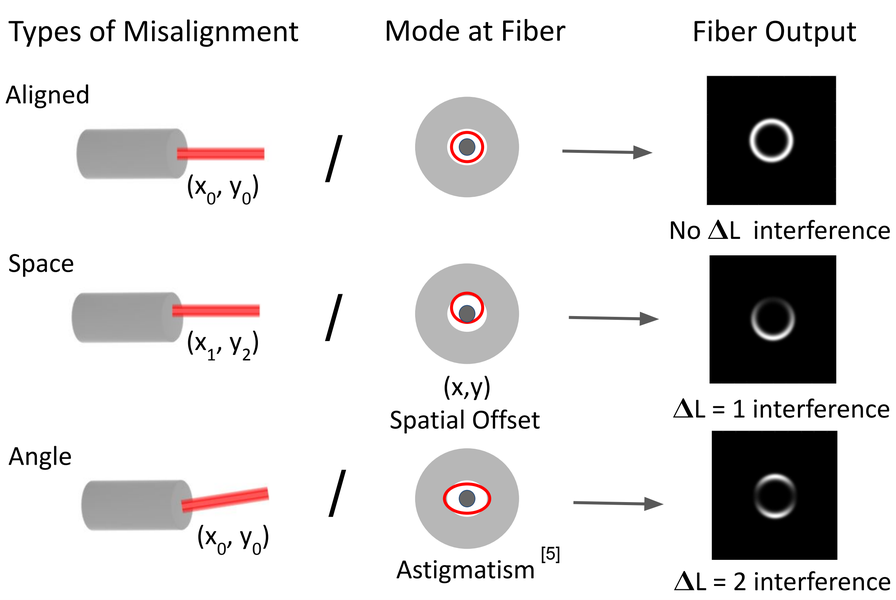
$$I_{linecut} = I_0 + I_1\sin([\Delta L = 1]\phi) + I_2\sin([\Delta L = 2]\phi) + I_3\sin([\Delta L = 3]\phi) + \cdots$$

Intensity linecut can be described by Fourier Series!

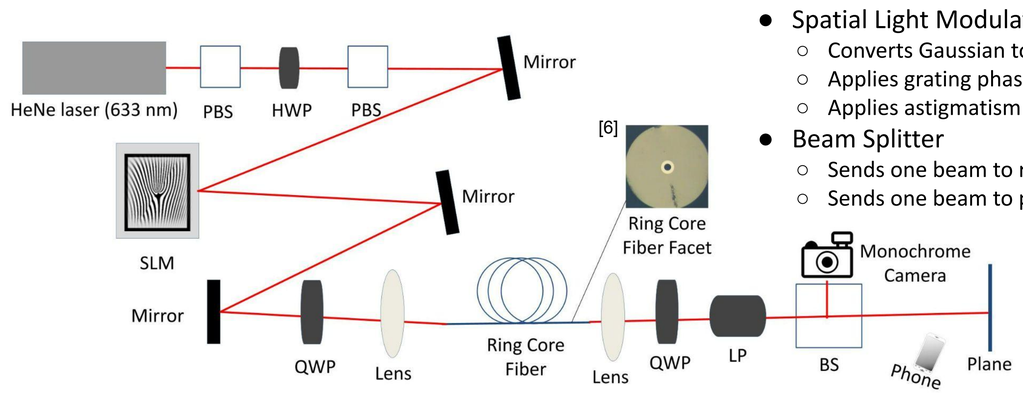
Ring Technique Steps:[4]

1. Center of Mass
2. Azimuthal Linecut
3. Fourier Analysis
4. Modal Purity Calculation

Misaligned Fibers

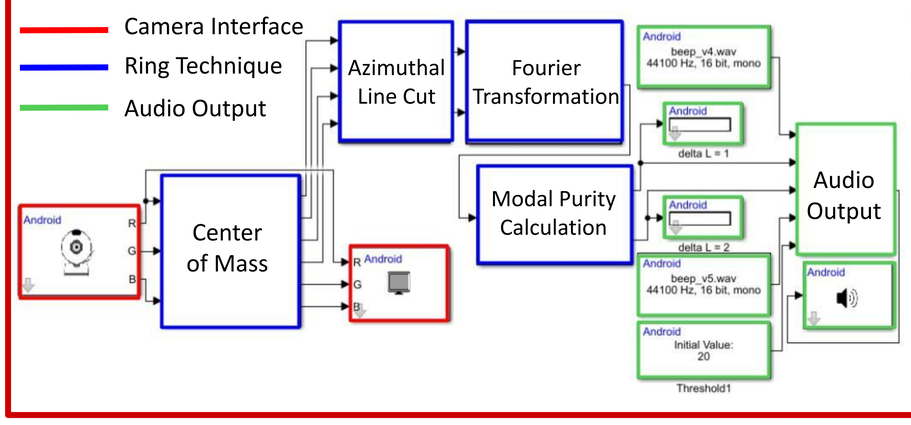


Experiment Setup

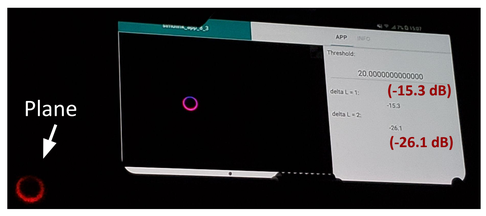


- Spatial Light Modulator (SLM)
  - Converts Gaussian to OAM by applying $e^{iL\varphi}$ phase
  - Applies grating phase (associated with spatial offset)
  - Applies astigmatism (associated with misposition in angle)
- Beam Splitter
  - Sends one beam to reference monochrome camera
  - Sends one beam to plane imaged by phone

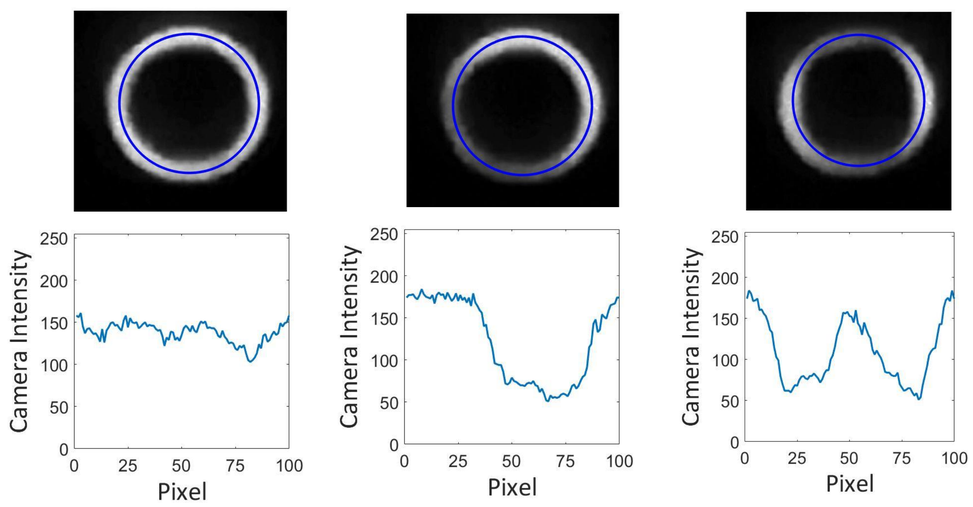
App Development

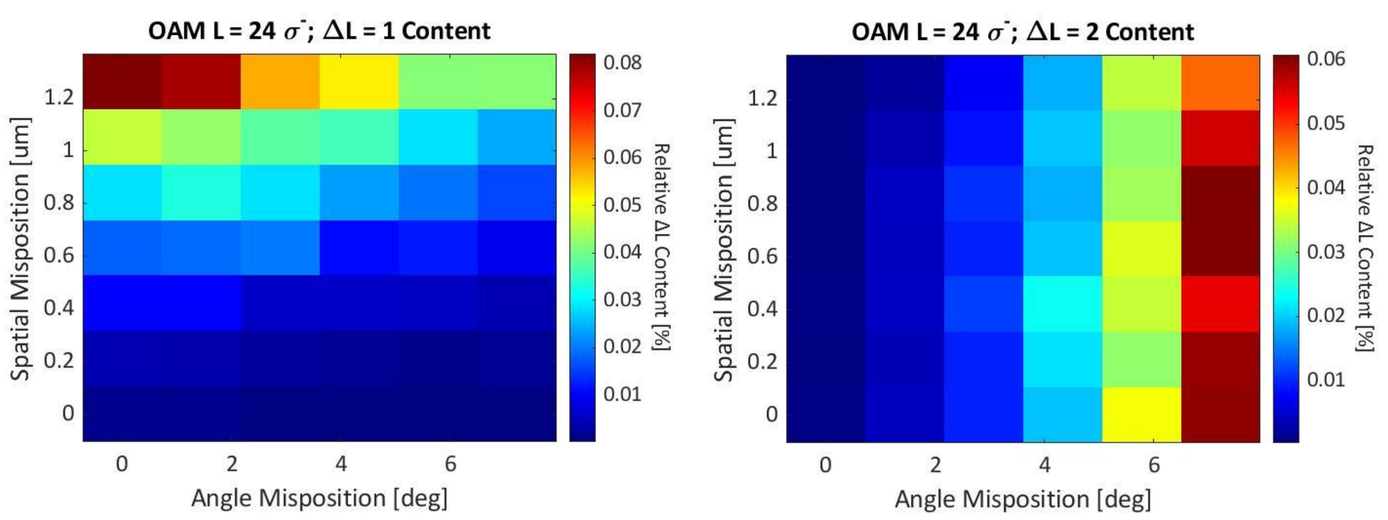


- MATLAB/Simulink
  - live processing and audio response
- Java
  - image capture and device interfacing for data taking
- Built and deployed through Android Studios



Results





- Phone measures ΔL interference (images and azimuthal linecuts).
- $\Delta L = 1$ and $\Delta L = 2$ mode purities were similar to results from a reference monochrome camera.
- Phone can correctly identify misalignments (space and angle) at the setup input based on $\Delta L = 1$ and $\Delta L = 2$ mode purity results.

Conclusions

- Phone app capable of detecting misposition in space, $\Delta L = 1$ interference increases, and misposition in angle, $\Delta L = 2$ interference increases.
- Developed mobile application can determine modal purity
  - can determine misalignments of a fiber in space and angle

References

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Acknowledgements

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