Name: ______________________
Partner(s): ______________________
Date: ______________________

Interference between a ***Shaped*** Wavefront and a Reference Beam

Come up with a procedure to use, using Michelson Interferometry, to observe the interference between a reference beam coming from a mirror, and shaped wavefronts coming from the SLM.

What is the smallest interval of *time* that you have personally ever measured? As you explore each type of wave, note any effect of introducing a variable constant offset ("piston" or "bias") phase shift into one arm of the interferometer, either by physically moving the mirror position along a slide or, say, by inserting a *tiltable* glass coverslip, …or by adding a constant grayscale ("piston") level to the SLM. — At the end of this lab, record in your lab notebook, the smallest interval of *time* that you have measured, explaining your method.

Come up with a procedure to use to analyze the *interference patterns* from the images captured.

Utilize your methods to examine:

- *tilted* plane waves (a *linear* phase profile applied to the SLM),
- Conical wavefronts (a phase delay linear in radial coordinate approximates a "Bessel" beam)
- cylindrical wavefronts (1D quadratic phase profile), and
- spherical waves (2D quadratic phase profile)
- Optical Vortex Beams (azimuthal gradient, described below)

There are many kinds of vortex beams (including sonic screwdrivers). They all share a helicity that has been added to the wavefront, which you can encode as a ***spiral phase profile***

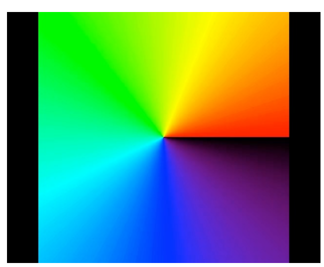


Fig. 1. A spiral phase profile, where color is now used to represent the magnitude of the *time lags* we're introducing. For a cyclic wave, the horizontal line is ***not*** a discontinuity. The only "singular point" lies at the origin.

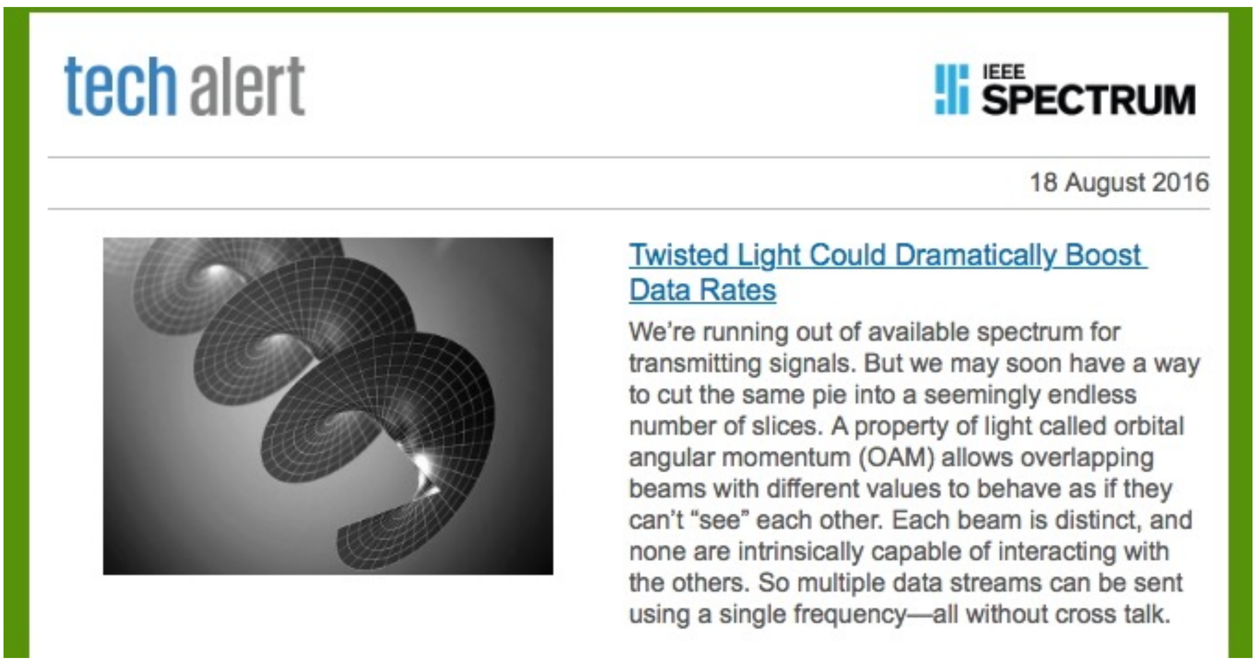
In cylindrical coordinates, we can express a spiral phase profile, of the sort shown in Fig. 1, as:

$$\delta(\rho, \varphi) = \ell\varphi$$

Here, ρ is the radial coordinate, φ is the azimuthal coordinate, and ℓ is a multiplicative factor. As this lab demonstrates, physical waves and wave functions are measurable, via interference. As such, their measurable value at a given point must be *single valued*. This constraint forces the imposition of periodic boundary conditions: $\delta\left(\rho, \varphi = \varphi_0\right) = \delta\left(\rho, \varphi = \varphi_0 + 2\pi\right)$, which, in turn, forces ℓ to be an **integer**, if we are to create a stable interference pattern.

Use the SLM to impose spiral phase profiles (for $\ell = 1$, 2, and some other integers).
[Note: to make sure that the laser beam is centered at the origin of the spiral phase pattern on the SLM, you may need to move the pattern around on the SLM.]

If you insert a microscope slide into the arm of the interferometer containing your reference beam, tilting the slide along the direction of propagation means that the reference beam must pass through a greater thickness of glass, and so the arrival of crests at your measurement point can be controllably delayed relative to those associated with your helical beam. ***Predict*** what


tech alert

IEEE SPECTRUM

18 August 2016

Twisted Light Could Dramatically Boost Data Rates

We're running out of available spectrum for transmitting signals. But we may soon have a way to cut the same pie into a seemingly endless number of slices. A property of light called orbital angular momentum (OAM) allows overlapping beams with different values to behave as if they can't "see" each other. Each beam is distinct, and none are intrinsically capable of interacting with the others. So multiple data streams can be sent using a single frequency—all without cross talk.

you expect to see, and then give it a try! (Remember: protocol dictates *celebration* each time you complete a test of one of your predictions.)

Encoding information into superpositions of vortex beams has been demonstrated, in the lab, to be capable of transmitting information at 100 Tbit/sec. (That's ~ 120 Blu-Ray discs/sec!!!)
As a student member of IEEE, you could, as an *initiative*, take notes on the IEEE Photonics Society's webinar, from 2018: "Transporting Data on the Orbital Angular Momentum of Light."
(Alternatively, see Chapter 2 of Andy Ding's IWU Senior Undergraduate Honors Thesis.)

Other Possible Initiatives would include examination of the following types of waves:

- 2D radial gradient (“Bessel” Beams),
- 1D radial gradient ("Crossed Saber” Beams),
- Cubic phase profile (“Airy” Beams)

Whoever makes a compelling case for having measured,
in this lab,
the *smallest* time interval wins a prize!