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 slide, …or by adding a constant grayscale 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),
- 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.](image)

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

\[ \delta (\rho, \phi) = \ell \phi \]

Here, \( \rho \) is the radial coordinate, \( \phi \) is the azimuthal coordinate, and \( \ell \) 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: \( \delta (\rho, \varphi = \varphi_0) = \delta (\rho, \varphi = \varphi_0 + 2\pi) \), which, in turn, forces \( \ell \) 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 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!