

Name: _____
Partner(s): _____
Date: _____

Virtual Slits: measuring diffraction in the absence of any real diffractive object

The modulo 2π , phase-only optical elements you've begun to create are generally referred to as "[Diffractive Optical Elements](#)" (DOE), and are *marketed* across a wide range of categories:

- Diffractive Lenses (Fresnel Zone Lenses, Lens Arrays, Cylindrical Lenses)
- Line Generators, Crosshair Generators
- Beam Splitters: Fan-out-elements, Pattern Generators
- Beam Shaping Elements
- Wave-Front Generators
- Homogenizers / Diffusers / Random Phase Plates
- Structured Pupil Illumination
- Gratings (Phase, Blazed, Amplitude)

Custom DOE sell for \$ 10000 - \$ 15000. Suddenly the cost of an SLM seems quite reasonable! Are you starting to see how *you* might design DOE of these sorts? — That last entry, "Gratings (Phase, Blazed, Amplitude)" reminds us both of the phase-only blazed diffraction gratings from Fig. 4 of last week's lab, and also that by adjusting the input Polarizer and output Analyzer, we can tune the transmission function of the system to allow for Amplitude Modulation.

Here, we return to **Amplitude-Modulation mode**, to define an adjustable "Aperture Function." Depending on the extent and shape of the aperture the diffraction pattern will vary:

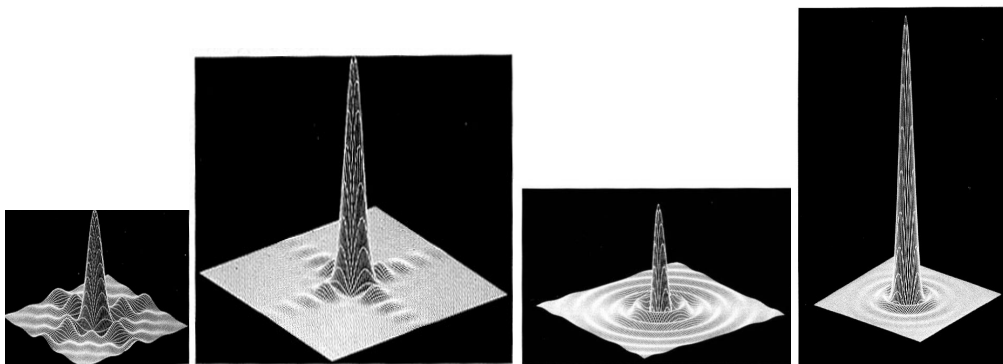


Fig. 1. Left-to-right: far-field (Fraunhofer) limits for diffracted *field*, then *intensity* from a square aperture, followed by *field*, then *intensity* for a circular aperture. [Image credit: R. G. Wilson, Illinois Wesleyan University; seen in [Hecht](#) and in [Wilson](#).]

This is a very general problem with far-reaching applications yet, mostly, *exact* solutions do not exist! Your text considers several different *limiting cases* where we can develop useful forms of diffraction theory, to relate what's going on in the Aperture Plane to what we can expect to find in the Observation plane. We will need to be mindful of the *limits of validity* of each model.

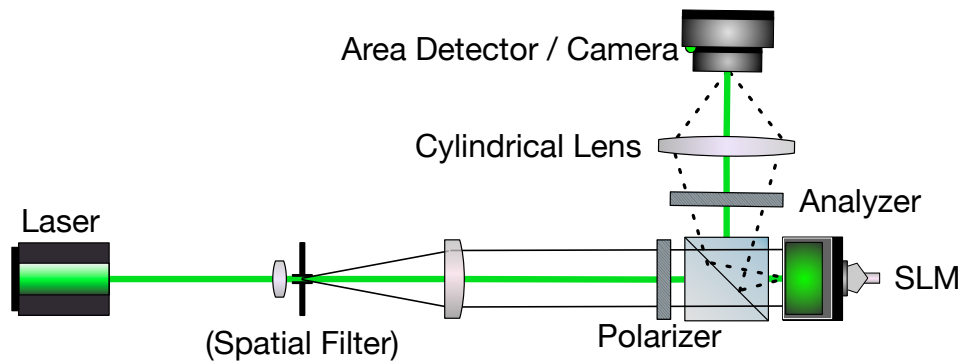


Fig. 1. This is nearly the same as the setup from Week 3, except for the *positioning* of the lens that comes before the screen/detector. **Block** the mirror used last week (which, were it included in this figure, would appear *below* the beamsplitter cube).

The lens following the analyzer (whether you use a cylindrical *or a spherical* lens) should be positioned **one focal length from the SLM**. One way to achieve this is to temporarily insert some mirrors, so that your collimated beam is sent “backwards” through this lens, as shown in Fig. 2 below:

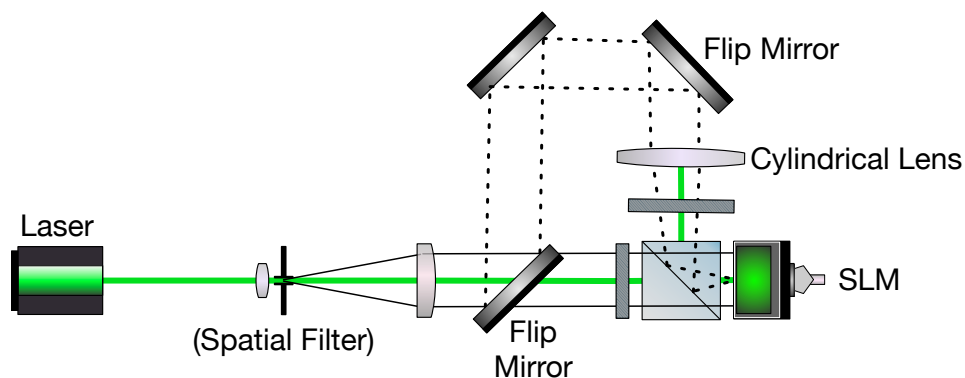


Fig.2. Alignment via “back propagation” with the three added alignment mirror in place, adjust the position of the Cylindrical Lens until the collimated input beam is focused onto the SLM. Then *flip* the alignment mirrors out of the beam path, and place your area detector / camera in the focal plane of the Cylindrical Lens.

Your imaging screen/detector should be placed **one focal length from the Fourier Lens**.

Comment in your notebook about the likely consequences of such an arrangement, where the SLM is in the “back focal plane” of the Lens, and the detector is, as in Fig. 1, in the “front focal plane” of the Lens!!

Adjust the input Polarizer and the output Analyzer so that the system is in **Amplitude-Modulation mode**. For any aperture you create, remember to set the grayscale level to match the **peak** transmittance you experimentally determined in Lab II. Conversely, for any barrier you create, set the grayscale level to match your experimentally determined transmittance **minimum**. Your notebook should include information about the applied phase profiles and **analysis** of the results.

- A) Enter a single-slit image into the SLM.
- B) Adjust the width of the single slit, keeping all else the same, and record the changes in the diffraction pattern.
- C) Replace single-slit image with a double-slit image. (You might wish to then eliminate one of those slits, call it Slit #1, then return Slit #1 and eliminate Slit #2. Compare these particular single-slit patterns to the two-slit pattern.)
- D) Change the spacing between the two slits, keeping all else the same, and record the changes in the diffraction pattern.
- E) Adjust the width of the slits, keeping the widths of the two slits equal, and record the changes in the diffraction pattern.
- F) Come up with a procedure to use, to **analyze** the *systematics* that emerge as you vary the geometry of these (virtual) diffractive objects.

Opportunities for Initiative:

come up with your own ideas!

All of our *published* work on Quantum Entanglement and “Ghost Imaging” has used an SLM to create *virtual slits*:

"[Video recording true single-photon double-slit interference](#)," R.S. Aspden, M.J. Padgett, G. C. Spalding, *American Journal of Physics* **84**, 671 (2016).
Supplemental videos available [online](#).

"[Ghost Imaging](#)," M. Padgett, R. Aspden, G. Gibson, M. Edgar and G. C. Spalding, *Optics & Photonics News* **27** (10) 38-45 (2016).

"[Resolution limits of quantum ghost imaging](#)," P. A. Moreau, E. Toninelli, P. A. Morris, R. S. Aspden, T. Gregory, G. C. Spalding, R. W. Boyd, M. J. Padgett, *Optics Express* **26** (6) 7528-7536 (2018).

"[Experimental Limits of Ghost Diffraction: Popper’s Thought Experiment](#)," P. A. Moreau, P. A. Morris, E. Toninelli, T. Gregory, R. S. Aspden, G. C. Spalding, R. W. Boyd, M. J. Padgett, *Scientific Reports* **8**, 13183 (2018).