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## Release the Cat!

### Background:

In earlier labs, we noted that it may sometimes be necessary to replace the expansion lens of a beam expander with a *spatial filter*, which consists of an expansion lens plus a pinhole that can be placed at its focal point, blocking any skewed components of the input beam while allowing passage of the plane wave input component that is parallel to the optic axis. Today, you'll perform a more general kind of spatial filtering: if you place an image in the back focal plane of a lens, and the SLM (in, say, Amplitude Modulation mode) in the front focal plane, you can selectively pass Fourier components *of your choosing*.

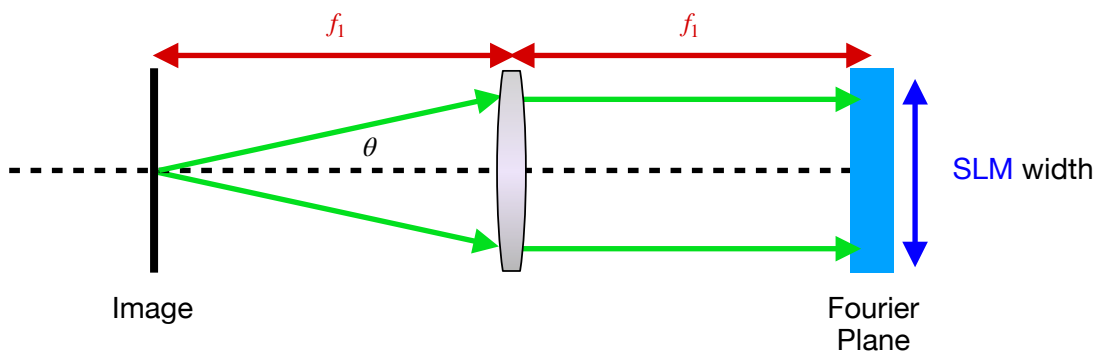
### Equipment needed:

Some people use "presentation software," such as *PowerPoint* or *Google Slides*, to create phase profiles that they can display on what the computer thinks is a second monitor (*i.e.*, the SLM).

In order to ensure that key components are *precisely* located in either the back focal plane or the front focal plane of a lens, you will probably wish to make use of some rails. Moreover, you are encouraged to finalized your alignment of some components via “**back propagation**” of a collimated beam, as in Week 6’s Lab.

### Procedure:

The figure below shows a pair of rays, symmetrically disposed about the optic axis, emanating from an image. If the SLM is *one focal length* from the lens, then rays emanating from different parts of the image, with the *same angle*, will **converge** to a particular point on the SLM.



*After* light is reflected from the SLM, a second lens is used to perform the *time-reversed* operation, where each pair of symmetrically disposed rays, such as those shown, would converge to form a standing wave in a plane where the image is reconstructed.

**“Lab Ticket”** (A *required* pre-lab exercise):

Send me something like [these images](#), that I can print onto a transparency using a 300 dot-per-inch laser printer. The "resolution" of the image corresponds to something like a “fringe spacing” of  $\Lambda = 1/300$  inch. (I think that 600 dots-per-inch resolution is also available, if I use the printer in the Division Office.) In a “time-reversed” version of the preceding figure, we can imagine the two green rays at left converging to form this interference pattern, as in Example 3.1 on p. 35-36 of your text. From this, you can (hopefully by the time of the Final Exam) infer that the highest spatial frequency contained in the image is:

$$u = \frac{k_x}{2\pi} = \frac{k \sin \theta}{2\pi} = \frac{\sin \theta}{\lambda} \quad \therefore \theta = \arcsin \left[ \frac{300}{2} \frac{1}{\text{inch}} \left( \frac{1 \text{ inch}}{25400 \mu\text{m}} \right) \cdot 0.532 \mu\text{m} \right] = 0.18^\circ$$

Rather than having all of the spatial frequencies crowded into a very small zone in the middle of the SLM, it makes sense to **pick a lens** so as to match the range of spatial frequencies to, say, 80% of the SLM width. For the Jasper EDK SLM, the active area is 12.5 mm x 7.1 mm (*i.e.*, rectangular). Since the SLM’s active area is rectangular, let's use the smaller dimension to calculate a reasonable focal length for our lens:

$$f_1 = \frac{0.8w}{2 \tan \theta} = 904 \text{ mm}$$

Of course, standard lenses don’t come with quite this focal length. If we eliminate the factor of 0.8, then we would calculate a focal length of 1130 mm. Any *larger* focal length than that would *cut out* the largest spatial frequencies in the image, and so the cat would start to lose resolution (get blurrier). So, you might simply **select a focal length** that is less than this value. Just to allow concrete *pre-lab* calculations, let's suppose you find a lens with a focal length of 1000 mm.

Your next step would be to measure the spatial period of the cat's bars (perhaps by laying the printed image atop a ruler, and calculating the average spacing for, say, ten bars). From that, you can calculate the *fundamental* spatial frequencies associated with the "standing wave" of bars. (Again, the spatial frequency is the *inverse* of the spatial period. Creating the standing wave involves both positive *and negative* ray angles, and so spatial frequencies will be symmetrically disposed about the optic axis.) By repeating the kinds of calculations performed above, you can **predict** how far apart, in micrometers, these spatial frequencies will be spaced on the SLM.

Then, by thinking about spatial period of the SLM pixels (*i.e.*, the “pitch,” which you found in the second week of term, to be  $\sim 6.4 \mu\text{m}$ ), you can **predict which pixels will contain the fundamental spatial frequency**. Using this, you ought to be able to **construct** an appropriate phase profile to mask that fundamental spatial frequency and, treating the bars as a periodic “square wave,” the appropriate harmonic frequencies. For this phase profile, you’ll need to **use appropriate grayscale levels** determined from your Amplitude Modulation *calibration*, which you found in the third week of term).

Following the SLM, you'll need another lens in order to transform back from the Fourier plane to reconstruct your (optically processed) image of the cat. Note that *magnification* of this image is set by the *ratio* of the focal length of this second lens to that of the lens described above, so if you are projecting this onto a camera, you'll need to consider the size of the detector in your camera.

### Questions:

Exercise #10 from Chapter 10 was the final problem in HW #23, and is related to how you might "Release Schrödinger's Cat!" during your Lab Practical Exam, during the last week of classes. Please review the solution, posted to my OneNote. However, unlike what's encountered in that Pen & Paper problem, in your *experiment* the spatial frequencies will *not* appear, on the SLM, as Dirac Delta functions. **KEY QUESTION:** *What determines their spread of each point?*

### Initiative:

It may be useful to project a magnified version of the *Fourier* plane onto a far wall. This will allow you to see, directly, how your phase profile matches (or fails to match) the set of spatial frequencies that you aim to block. This can be very helpful in making adjustments.

WRITE your conclusions: