Instructions for Lab 4: Fourier Optics

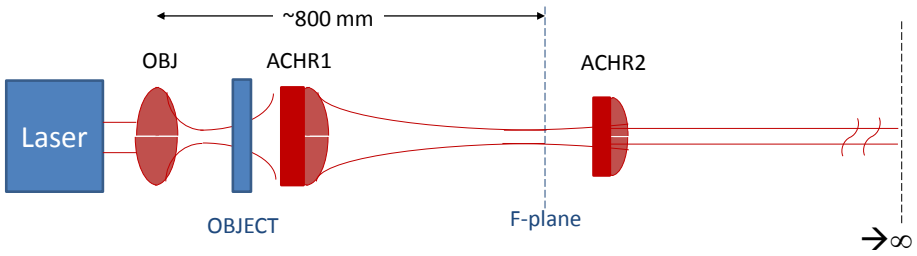
(by Göran Manneberg, Anna Burvall, Katia Gallo)

This lab contains visualizations of the Fourier transform and is rather intuitive, meaning it can be done without heavy calculations. However, if the math background is up to date (in your brain :-) things get a lot easier

Preliminary reading

Chapter 11 in Hecht ”Optics”. Much of the math in this chapter is known (?) from math courses, the new thing being the specialization to two dimensions.

Setting up the experiment



A. The laser is already in its mount. Align it parallel to the rail by using an empty post, an iris or a card with a marker as reference, i.e.: slide the post along the rail and verify that the beam hits it always on the same spot. If not adjust the position of the laser until you get a good alignment of the beam with the rail.
B. Insert the microscope objective (OBJ) in the optical path just after the laser and align it. The blob of light you’ll get after the objective should be aligned along the same axis as in A (i.e. be centred around the same position in your reference iris or card).
C. Insert the f ~ 200 mm achromat (ACHR1, correctly turned) so that a beam waist (a focus) is achieved ~800 mm after the microscope objective (F-plane). There are two ways to do that. One that magnifies the waist and one that does not. Chose the magnifying setup. *Practical trick:* to find the optimum position for the achromat you can put a metallic scatterer in place at the target position for the focus (F-plane) and check what is

happening to the reflected speckle pattern on the wall at some distance as you move the achromat on-axis. The optimum position of the latter is the one where the speckle pattern is most sensitive to slight shifts in the achromat position… (*why should this be true ?*)

D. Place the x-y mount (to be used later) at the position of the ACHR1 focus in C (F-plane).
E. Insert a mount with the OBJECT (nr 6 works fine) between OBJ and ACHR1 and adjust its position so that a sharp image is obtained at infinity (on the wall at the end of the lab).
F. Place the second (small) achromat (ACHR2) after F-plane, adjusting its position so that a sharp image of the diffraction pattern is seen in the far field (= on the wall). Switching between an image of the object and an image of the diffraction pattern is now simply achieved by taking ACHR2 in and out of the post holder.

- Show this to the Teaching Assistant (TA) before proceeding.

Now place an iris in the Fourier plane (F-plane) so that its edges are clearly imaged on the wall when ACHR2 is present. Do not move the lenses, just move the iris. Do this while the TA is still in the room.

Voila! Your setup is now ready !

Analysis of the diffraction patterns from different objects

Object 1) Consists of four geometrical figures (which ones?). Observe and sketch the Fourier pattern for each of them (Be inventive with scissors and business cards).

- Explain what you see to the TA

Object 2) Two circles. The pattern is of course similar to that of one circle, but there is an important difference. Take a closer look at the pattern if you do not see it. Use this "difference" to calculate the quotient between diameter and cc-distance between the circles. Check with a ruler afterwards.

Object 3) Observe and sketch the object and its transform. Why has one got three-fold and the other six-fold symmetry?

Object 6) Check this object and its transform, before and after filtering in the Fourier plane (F-plane). Use the holes and the mounted needle for the latter. Always do the adjustments while keeping the ACHR2 lens in place, so that you can check what's happening to the spectrum (far field image). Start by blocking the zero:th order. How should the image look like? Try to guess before removing ACHR2. *Is Babinet connected to this in some way?*

Then block the three central maxima. Same questions.

Finally, do the reverse and block the higher orders instead.

- Show the TA before proceeding

Object 7) Do the same as for object 6, but also move the filters around in the Fourier plane. After doing that, move the object some centimeters along the rail. What happens?

- Show the TA before proceeding

Object 8) This object is not (only) what it looks like. Try to systematically block and pass different orders and observe the result on the filtered image. Also blocking the upper and lower part of the object is a good idea. Is there a zero:th order max in both? Meaning???

- Show the TA before proceeding

Object 9) This is about pattern recognition. First observe the object unfiltered. Thereafter let a small hole wander along the "arms" in the pattern and observe the filtered image. Explain.

Object 12 (*optional*) Filter so that:

a. one circle

b. two circles

c. the common part between two circles

d. the common part between all three circles light up.