

Design and Prototyping of Optical Systems for Engineering Applications

Experiment 2

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Experiment 2: Meeting Agenda

- Experiment 1 Results, Questions, Comments
- Experiment 2
- Lab Agenda

Lab 1

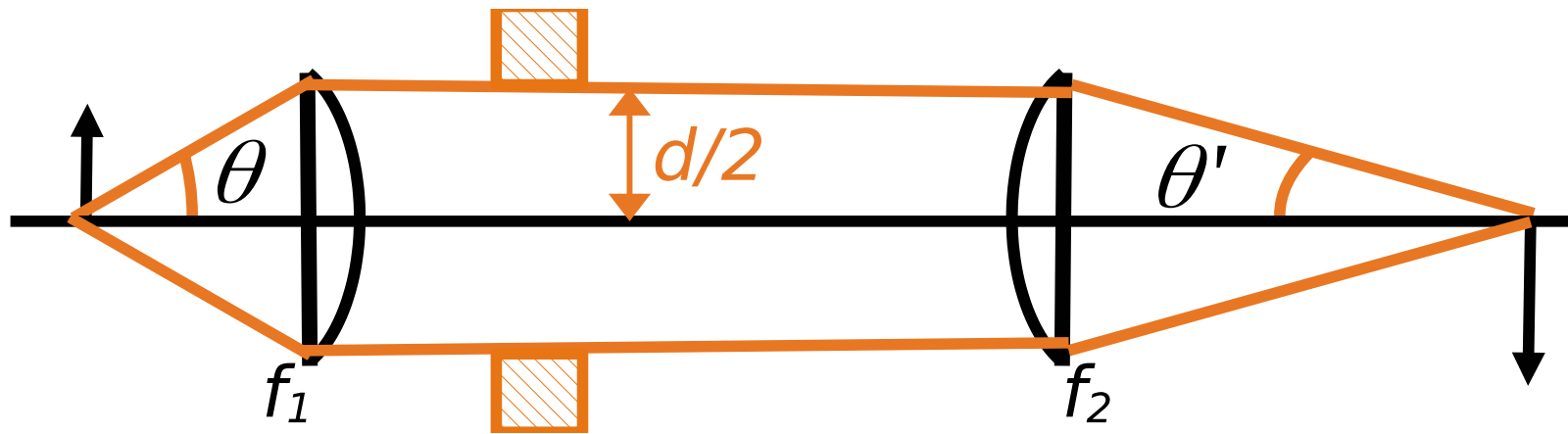
- Your Comments
- Resolution: Diffraction, Aberrations, and Pixels
 - Remember the Sampling Theorem

$$f_x = \frac{u}{\lambda} \quad f_y = \frac{v}{\lambda} \quad |f_{max}| = \frac{NA}{\lambda}$$

- Keep Pixels Smaller than Resolution
- Transmission Measurements

$$T = \frac{\text{Output} - \text{Dark}}{\text{Input} - \text{Dark}}$$

Which NA?

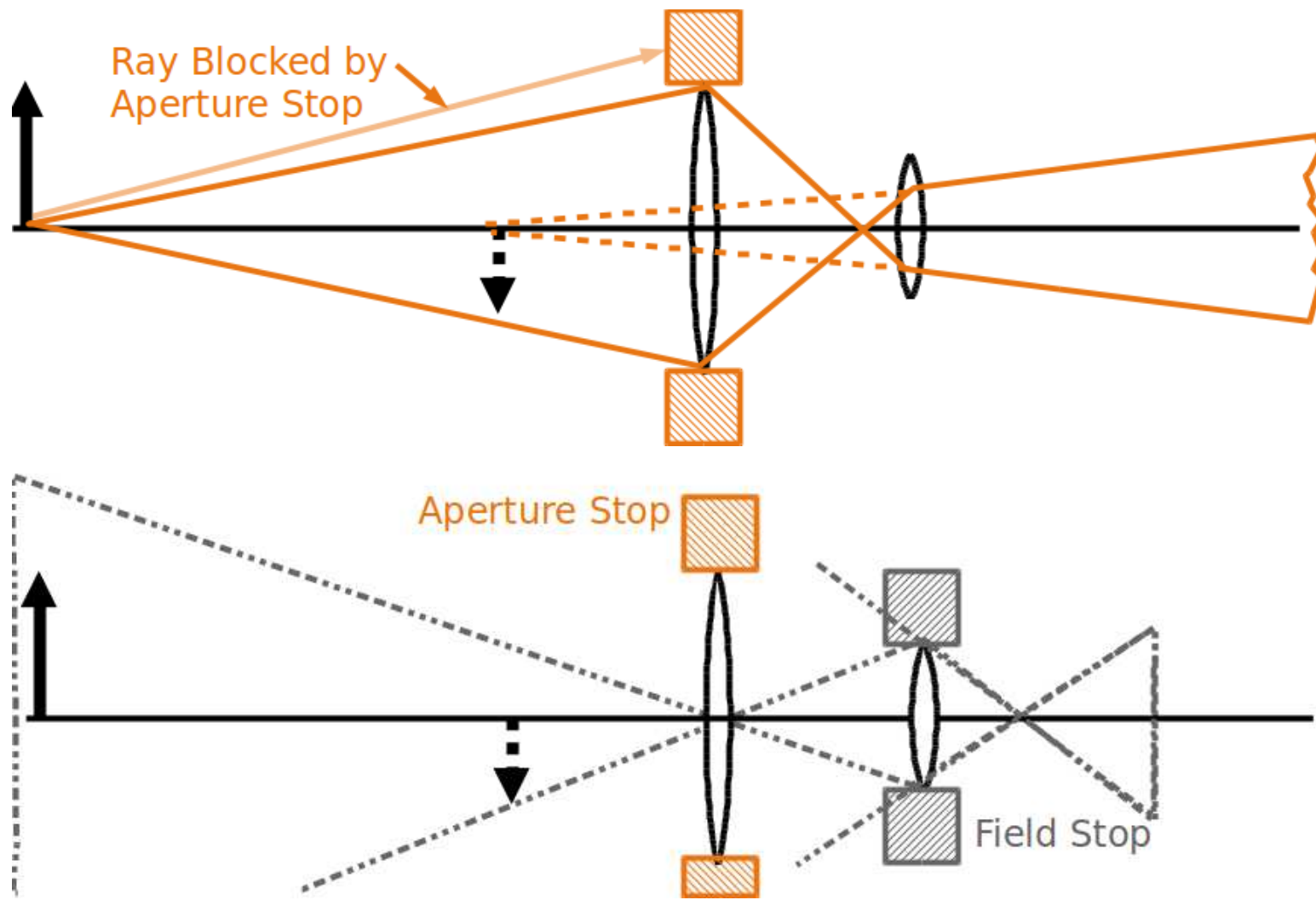


- Object: $NA = \sin \theta$ Using f_1
- Image (Camera Pixels): $NA' = \sin \theta'$ Using f_2
- Useful to Know: $NA' = \frac{NA}{m}$

Learning Objectives 2

- Telescopes: More Telecentric Optics
- Transverse and Axial Magnification
- Aperture Stops and Pupils
- Field Stops and Windows
- Focusing
- Stray Light
- The Tube System

Experiment 2: Telescope



Equations

- Magnification

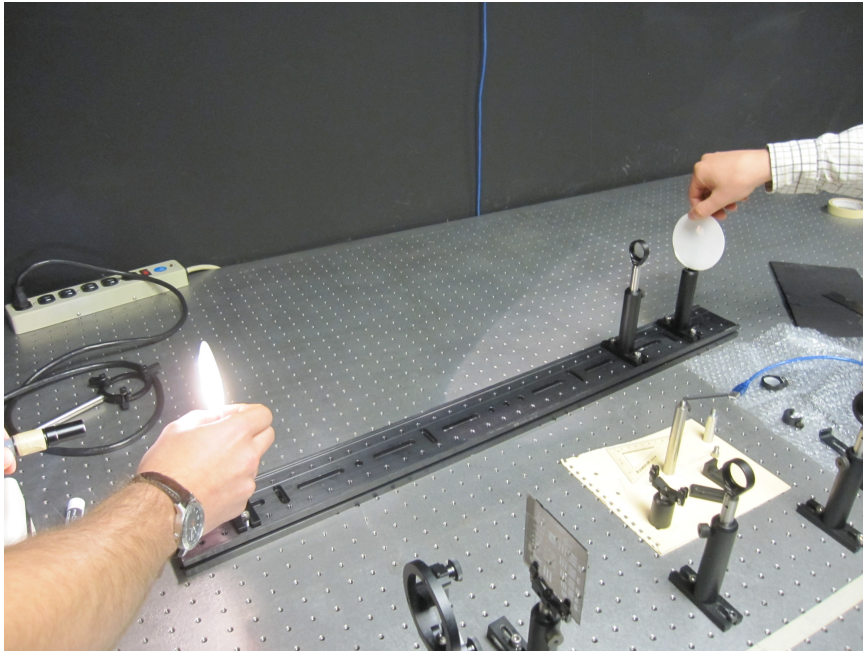
$$m = -\frac{f_2}{f_1}$$

- Angular Magnification (Make this large: Why?)

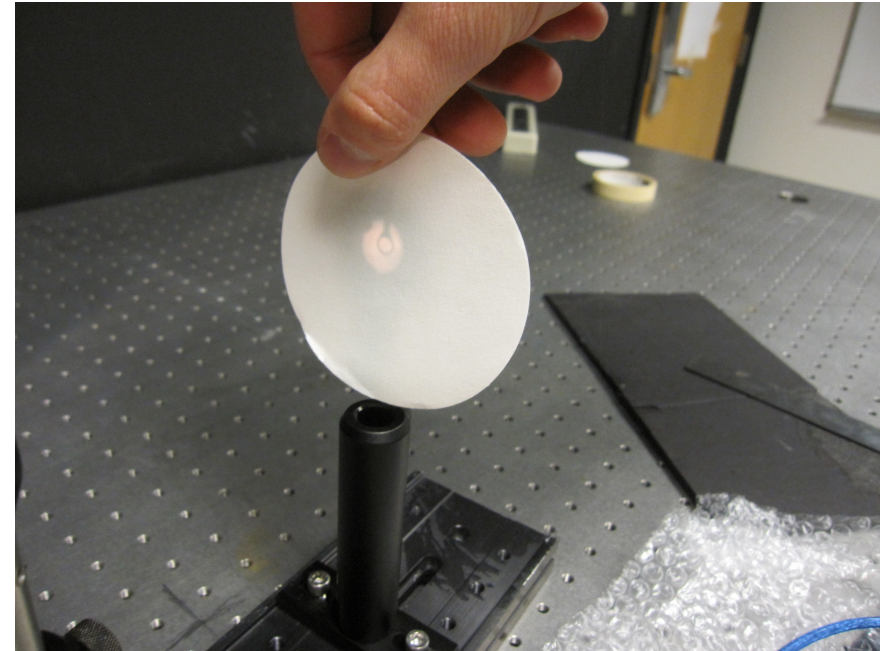
$$m_\alpha = \frac{1}{m}$$

- Eye Relief: Use Primary as Object for Secondary
- Field of View: Use Secondary as Object for Primary
- Angular Resolution $2.44 \frac{\lambda}{D_{primary}}$

Finding the Exit Pupil

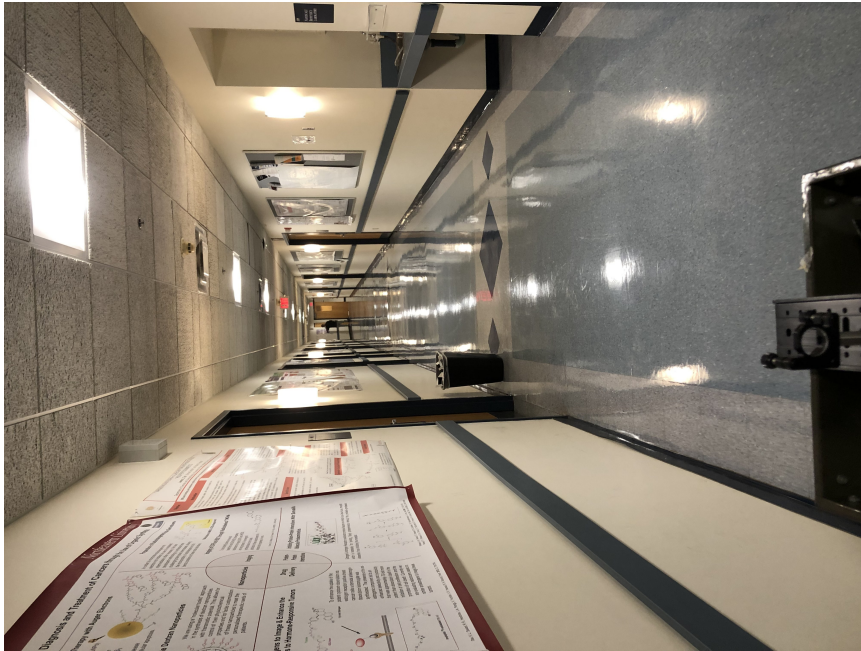


A. Illuminating the Pupil



B. Viewing the Pupil

Working Telescope



C. Testing the Telescope



D. Image

Prelab 2

Design a $5X$ telescope with at least 2 cm of eye relief. Specify the lenses (focal length and diameter).

Use plano-convex lenses and decide which way to mount them (curved surface toward the object or away from it?). Explain your decision in view of what you learned in the first lab.

Determine the size of the pupil (mm) and field of view (radians).

Note that the magnification as we usually define it is actually $1/5$. Why does it appear to magnify the object?

What is the diffraction limited resolution (radians) assuming visible light.

Experiment 2

Implement your telescope design in the laboratory as closely as possible with available components. Measure the exit pupil and the field of view. Hint: If you illuminate the telescope from the object side with a flashlight, you should see the real image of the aperture stop in the appropriate place.

Use the telescope as a beam expander to expand the beam from a low-power red laser pointer. Couple a laser to the small end of the telescope with a rotatable mirror at the “exit” pupil. Here we use the telescope as a beam expander. Rotate the mirror. What is the angular magnification? What happens if the point of rotation is not in the pupil plane? Notice that if we use a scanning mirror it is important to place the mirror close to a pupil plane.

Implement your telescope using the “tubes.” Try taking a photo with a camera (mobile phone camera for example). Make sure you can adjust the focus. Look at different targets to see what you can and cannot resolve. Try moving the telescope toward and away from your eye to see the effect of the exit pupil.

Take the telescope outdoors. Pick a distant object that you can just barely resolve (eg. a brick in a wall). Estimate the angular extent of the object.

Reflection 2

How well did your telescope match your design? Did you get the expected magnification? Is the image as good as you would have expected?

How easy was the tube system to use? What advantages does it provide?

Explain why it is important to position your eye correctly to match the eye relief.

How well does the resolution compare with your expectation?

Lab Agenda

- Finish Experiment 1. Return all components to the right locations.
- PR Photos
- Begin Experiment 2