

Possible Activities for pre-built AO Demonstrator

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1. Introduction

The planned usage of the AO Demonstrator for MCC purposes, to my current understanding, is the following: (1) To have two advanced students build a similar system to the existing copy in Santa Cruz, CA, under the supervision of Mark Hoffman, John Pye, and myself; (2) to use the unassembled parts in educational activities to supplement the building procedure; and (3) to use the completed system with tour groups or other individuals to teach the basic principles of a working adaptive optics system.

The AO Demonstrator has been used at the AO summer school in August, 2004 with good success. I believe this indicates that the programming content makes this tool usable for educational tours or large groups. Unfortunately, it has not been tested comprehensively for individuals or students with very little grasp of basic principles in adaptive optics. Thus, I make the following recommendations: (1) Give some instruction in optics and AO beforehand, to ready the students for the building process; (2) include several activities or inquiries using the unassembled parts to facilitate the absorption of this background material; (3) make observations during the semester to determine the educational value of constructing the system; and (4) test the completed Demonstrator with both individuals and groups to determine its final value as a demo tool.

The purpose of this document is to highlight several possible activities and inquiries that may be used to augment the construction of the AO Demonstrator. I do not include activities that require the completed system, but only those that use individual unassembled components. I have structured the activities hierarchically, introducing parts to the student one at a time alongside the relevant concepts. In this manner, the student would not be overwhelmed by concepts or parts, although it may prove useful to show the students all parts at the beginning to increase familiarity. It is my hope that these activities will give the students the knowledge they need to vary the design of the Demonstrator, if they so wish, to accomplish certain goals. Note that I have omitted many, many significant concepts that do not specifically apply to the Demonstrator, like interference and polychromatic light; this series of experiments is by no means complete.

2. The Nature of Light

Before beginning this section, it is necessary to impress upon the students the importance of lab safety with lasers. Use laser blocking glasses at all times, if possible, to reduce chance of retinal damage. The students must understand not to point lasers at other people.

2.1. Light travels in straight lines

This may be an explicit inquiry activity. Content goals: (1) Light can be described with ray diagrams; (2) a laser is a collection of parallel rays; (3) white, ambient light is a collection of rays in all directions; (4) Mirrors preserve the angle to the horizontal; (5) beamsplitters do not “replicate” or create light but divide it.

Introduce laser, flat mirrors and beamsplitters. Demonstrate the action of the laser by pointing it around the room. Align the laser with the flat top of a table to show the straight propagation. Draw the ray diagram for a light bulb (point source) to encourage them to draw a ray diagram for the laser. Point the laser at a flat mirror and scan the direction of the reflected beam. To demonstrate the beamsplitter, anchor the laser to the breadboard and place the beamsplitter in the way, observing the intensity of both the transmitted and reflected spot, comparing them to the intensity of the unsplit laser. Encourage the students to draw a ray diagram for both the mirror and the beamsplitter. Also, observe the far-field intensity spot of the laser (possibly using folding mirrors) to show that even a laser cannot get perfectly parallel rays.

2.2. Lenses and optics bend light in different ways

This section can also be an inquiry activity. Content goals: (1) Lenses focus parallel rays down to a point; (2) the focal length of the lens depends on the shape of the lens; and (3) lenses focus ambient light down to an image plane.

Introduce lenses of different focal lengths and lens mounts. Demonstrate proper care of lenses and proper mounting methods beforehand. As starter activities, point the laser directly through the lens. Encourage the students to come up with ray diagrams for the situation. Vary the angle of incidence of the lens while measuring the focal lengths with rulers. Use lenses of different focal lengths to change the location of focus. Encourage the students to deduce what happens when ambient light strikes a lens.

2.3. What is a wavefront?

Content goals: (1) A wavefront is a line that intersects the rays at perpendicular angles; (2) the wavefront of a beam becomes the same shape as an optic when it strikes it; and (3) distorted wavefronts do not produce tight focal spots.

Draw the ray diagram and corresponding wavefront for a point source, then draw ray diagrams for a laser, a laser striking a mirror/beamsplitter, and lenses of different focal lengths. Have the students draw the corresponding wavefronts for each example. Then, draw a slightly aberrated wavefront and instruct the students to draw the corresponding rays. Have them propagate the rays for a large distance. Reproduce this example physically with a laser and an aberrating medium (scratched CD case, etc). Note that the laser spot becomes much larger in the far-field. Have them predict what happens when a lens is used to focus an aberrated beam and verify their predictions with a laser, a lens of long focal length, and a strong aberrator.

2.4. The action of filters

This activity can be designed as an inquiry. Content goals: (1) Filters either absorb or reflect light to lower the amount of light transmitted and (2) filters may be used to dim the laser intensity to permit viewing on a screen.

Introduce both reflection and absorption filters. Shine the laser through reflection filters of several densities to show that the amount of light transmitted changes. Demonstrate that the reflected light beam increases in intensity when the transmitted is decreased and vice versa. Show that both beams are dimmer

than the single unfiltered beam. Replace the filters with absorption filters and challenge the students to explain the phenomenon. Then, use a lens to focus a strongly aberrated laser beam and show that the structure in the aberrated focal spot is easier to see on a screen with a heavy filter present.

2.5. How is light detected?

This activity may be designed as an inquiry. Content goals: (1) CCDs are grids of light buckets that collect light; (2) saturation occurs when these light buckets fill up and filters may be used to prevent this; (3) ambient light directly incident on a CCD produces no useful information; and (4) a lens at the correct position permits images to be recorded.

Introduce TV, science camera, and camera mounting equipment. Show that a laser incident on the CCD (in a dark room) produces saturation all over the screen. Add successively denser filters until the laser structure is visible. Verify that the laser image seen on the TV matches the laser image on a viewing card (it may be necessary to go to the far field). With the ambient lights on and filters present, show that ambient light produces no useful images on the CCD. Encourage the students to find ways to turn the CCD into an imaging camera. Show that lenses of different focal lengths produce different magnifications on the CCD.

2.6. The telescope

Content goals: (1) Image recording is possible with a single lens and a CCD, but not for visible eye viewing; (2) a telescope system with two lenses produces a magnified image suitable for visible eye viewing; and (3) a telescope changes beam sizes (useful for optical systems).

Begin by using a single lens to attempt to read a high-resolution poster at the far end of the room. The magnification can be changed with a single lens, but the image is not in focus. Add an additional lens and vary the lens positions until the poster is magnified and readable. Then, draw a ray diagram of the telescope to show the lens orientation that magnifies the distant image. Point out a few key features: The distance between the two lenses is equal to the sum of the focal lengths (i.e., the distance between the eyepiece and the focal plane of the objective is equal to the focal length of the eyepiece), parallel rays that enter the telescope also exit parallel, and the beam sizes change. Demonstrate that a telescope is capable of magnifying or demagnifying the parallel laser rays.

3. Electronics background

Before starting, review electronics safety procedures. Ensure that all bare wires in the components are wrapped (i.e., laser) and all metal surfaces are insulated.

3.1. Voltmeters/oscilloscopes

Content goals: (1) Voltmeters are typically used to measure the amplitudes of constant signals and (2) oscilloscopes recognize patterns in time-variant voltages and display the periodic signals.

Use a DC battery with a voltmeter to display the voltage level; demonstrate the oscilloscope with AC

wall voltages. Show that the oscilloscope display may be “stretched” with the horizontal time knob and the vertical amplitude knob. Demonstrate other functions of the oscilloscope if the students have had little experience with such devices.

3.2. Digital/Analog signals and converters

Content goals: (1) Analog signals are constant voltages with a variable amplitude; (2) digital signals oscillate between two values (0 and 5 volts for the parallel port) as a function of time and are used by computers to encode information; (3) Digital-to-analog converters (DAC) are used with computers to produce analog voltages, which are useful for a range of applications.

Introduce converters, computer, and power supplies. Utilize several programs that constantly write digital signals to the parallel port. Use the oscilloscope to display the periodic digital signals and verify that only two values are displayed. Point out that digital signals are sent at constant time intervals set by the “clock” signal, located on one of the parallel port pins. Plug in the DAC and show that it is specially constructed to interpret a given type of signal from the computer. Run a program that instructs the DAC to place given analog voltages on certain pins, and verify the voltages with the voltmeter.

4. Notes on further construction

After these basic experiments that demonstrate the relevant properties of light and several properties of computer control mechanisms, it would be possible to begin constructing the AO system. The construction may be performed component by component, possibly in the following order: (1) Deformable mirror and electronics; (2) science camera with beamsplitters; (3) wavefront sensor with lenslet array; and (4) computer control system connected to the deformable mirror and wavefront sensor. After the functionality of these components are demonstrated individually, these can be placed together with the lens relays to form the completed system.