CubEd
Classroom Manual

1

Safe Use Guidance — General

WARNING

CHOKING HAZARD - Small parts not for children under 3 years or any individuals who have a tendency to place inedible objects in their mouths.

Choking Hazard!

This product uses small neodymium magnets! Not for use with children under 3!!!

A Class 3R laser is low powered, which normally does not harm eyes during momentary exposure. This duration is within the aversion response, when a person turns away and/or blinks to avoid bright light.

Do not deliberately look or stare into the laser beam. Laser protective eyewear is normally unnecessary. A Class 3R laser is neither a skin nor materials burn hazard.

However, a Class 3R laser can be a distraction, glare or flash blindness hazard for pilots and drivers. **NEVER aim any laser towards an aircraft or a vehicle in motion.** This is unsafe and is illegal – you could be arrested and jailed.

ONLY ALLOW USE BY RESPONSIBLE PERSONS!!!

This is NOT a toy. Continuous adult supervision is required for children to safely use Class 3R lasers.

2

Lasers

Based on lasers listed for use in associated publication(s).

Laser	Wavelength	Power
Red	638 ± 10 nm	1–5 mW
Blue	405 ± 10 nm	1–5 mW
Green	532 ± 10 nm	1–5 mW

Please refer to the documentation provided by the manufacturer for additional warnings and preventive, protective equipment (PPE) requirements (e.g. laser safety goggles).

Always consult your local Laser Safety Officer or Radiation Safety Officer and refer to your laboratory safety documentation for more information.

You can also consult the Laser Safety Standards ANSI Z136 in North America, SUVA 66049.D in Europe, and BS EN 60825-1 in the UK. Additionally, laser safety standards and regulations are covered by IEC norm 60825-1, and LED eye safety standards and regulations are covered by IEC norm 62471 in Europe.

Safety guideline: Hazardous, visible, or invisible radiation from lasers, lamps, and other light sources used for microscopy can cause permanent damage to the retina, skin burns, and fire. Always follow proper laser safety protocols for your equipment and situation.

Additional Reminders:

- Never touch any lenses or mirrors directly with your hands or fingers.
- Never put any part of your body in the beam path, it is dangerous.

3

Cubes

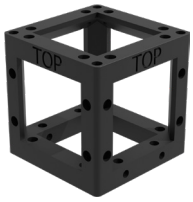
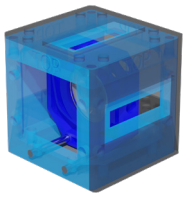
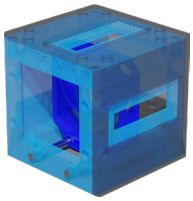
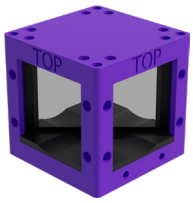
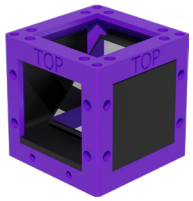
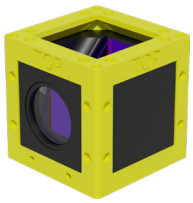
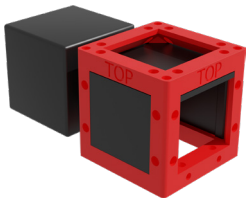
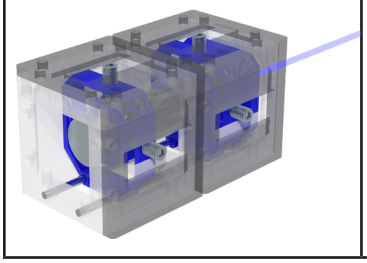
Image	Name	Description
	Support	**Black** cube used for support to place other cubes in the correct position in space.
	Shielded	**Black** horizontal or vertical tunnel that prevents unnecessary noise and signal interruption and provides an easy solution to a safely enclosed light path. Also used to space cubes at the correct distance relative to each other.
	1” Lens	**Light Blue** cube designed to hold a standard 1” optical lens. The lens is fixed in place by an M4 set screw; a press fit cap is included for extra security. The lens is positionally aligned with 2× M6 set screws and a manual rail adjustment.
	0.5” Lens	**Light Blue** cube designed to hold a standard 1/2” optical lens. The lens is fixed in place by an M4 set screw; a press fit cap for extra security. The lens is positionally aligned with 2× M6 set screws and a manual rail adjustment.
	Horizontal Mirror	**Purple** cube designed to fit a rectangular mirror. The mirror’s distance and alignment are determined by 3× heat pressed brass thread inserts, along with an M3 screw contacting magnets on the mirror plate.
	Vertical Mirror	**Purple** cube designed to fit a rectangular mirror. The mirror’s distance and alignment are determined by 3× heat pressed brass thread inserts, along with an M3 screw contacting magnets on the mirror plate.

Image	Name	Description
	Dichroic Mirror	**Yellow** cube that holds a standard 1” dichroic mirror. It is sized for SM1 to hold standard 1” filters via press fit.
	Camera	**Red** cube that fits a standard size SM1 via a press fit and encloses the light path.
	Objective	**Pink** cube that holds a standard microscope objective. It is positioned along the z-axis of the xyz-stage.
	Light Source	White* cube pair that hold the light source and are adjustable similarly to the lenses; the system of 2× mounts facilitates positional alignment as well as tilt. Covers are included to enclose the light once aligned. ***Tip:** These cubes can be printed in the color corresponding with the laser they will hold.

Additional Elements

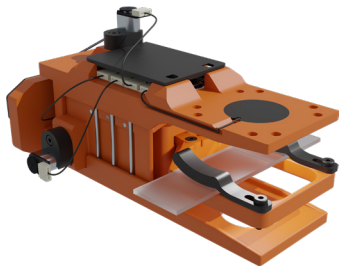
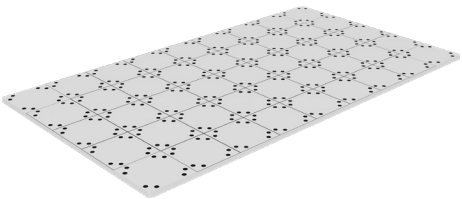
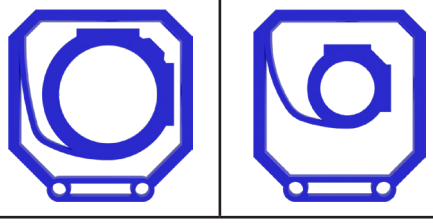
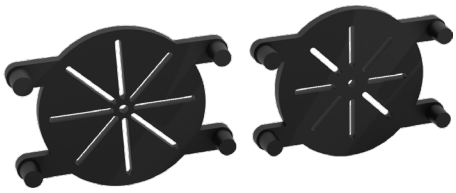
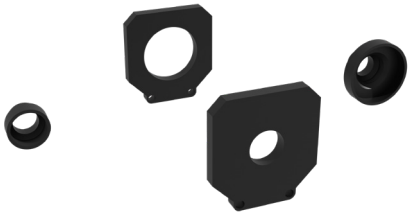
Image	Name	Description
	xyz-Stage	**Orange** housing contains consumer electronics to create a functional, position control stage. Currently the encoders are unused, and other attachments for the stage are available.
	Gamepad	**Orange** gamepad controls the various functions of the xyz-Stage.
	Baseplate	Laser cut acrylic plate holds magnets arranged along a grid to assist in cube alignment and to give some stability to their position.

Image	Name	Description
	Mounts	Provide mounting points inside the cubes that are adjustable within plane.
	Targets	Attach to structural cubes and are used during alignment of the beam path.
	Filter adapters	Adapters that hold either an SM1 or SM05 filter from Thorlabs.

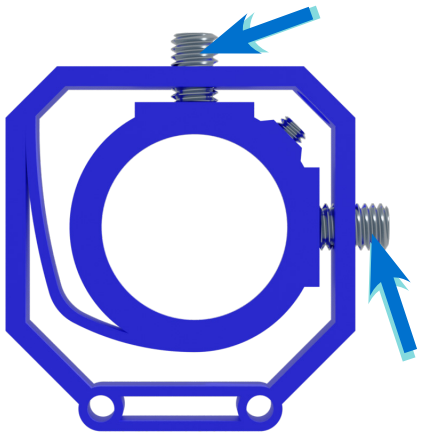
Minimum Requirements

23× Shielded cubes
2× Support cubes
2× Horizontal mirror cube
1× Vertical mirror cube
1× Light source assembly
1× Dichroic cube
1× 0.5” cube containing an f30 lens
3× 1” cube containing an f200+ lens
2× Targets (at least one per type)
1× Objective cube
1× Camera cube
1× xyz-Stage

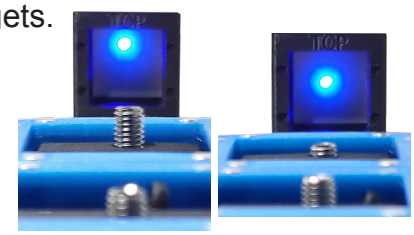
Excitation Beam Path

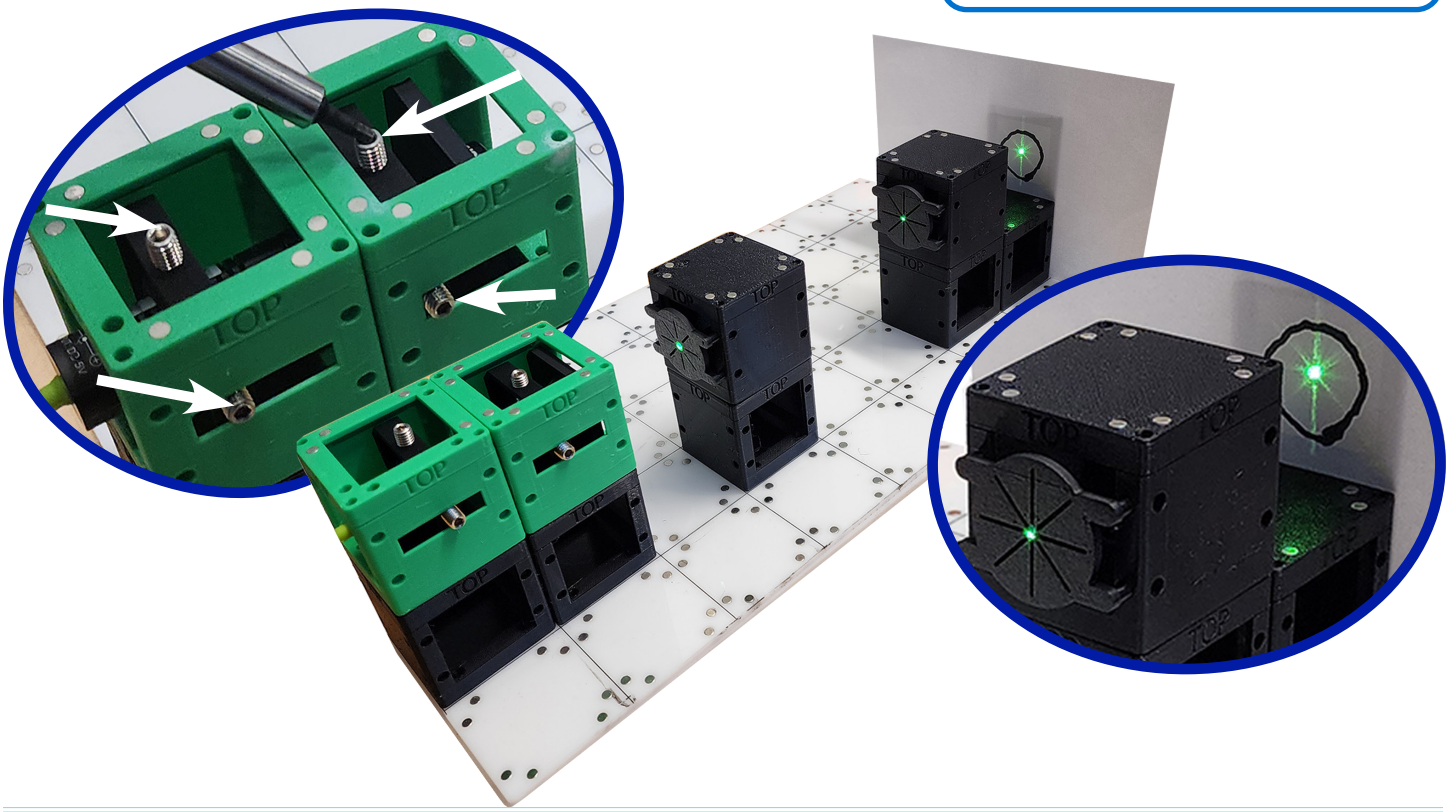
Laser Alignment

1. Place a laser source (pair of colored cubes[1]) on top of two base cubes (black), and position it on the magnetic base plate. Remove the covers from the laser source and unscrew the 4 set screws (2 per mount) so that they are not touching the laser mounts. Be careful not to unscrew them from the mount entirely.
2. Arrange two targets mounted on cubes in front of the laser. The first should be a cube length away from the laser and the second at least three cube lengths away from the first.
   If the targets have different sized holes at their center, position the target with a larger opening closer to the laser.
3. Set up a flat target such as paper beyond the the cube mounted targets, to see how the laser needs to be adjusted.



The set screws push the inner mount horizontally and vertically, allowing precise control of mount's movement.
As a result, you can make small adjustments to center and tilt the laser so that the beam path passes through the center of both targets.





1 The light source cubes may be another color. Printing them in the color of the laser they contain is recommended when possible, as depicted within this manual. If the color of the laser within the set of cubes is subject to change, it may be beneficial to use white cubes and indicate the laser color another way (e,g. the laser color with electrical tape on the cord).

With only the first target placed, adjustments were made using the 2 set screws on the mount closer target. This aligns the beam along the x,y-axis with the first target.

After adding the second target, the asymmetrical pattern created on the paper indicates the beam is not traveling along the beam path. The beam path would be perpendicular to both targets.
To correct this misalignment, the set screws on the light source mount further from the targets are used to change the *tip* and *tilt* of the light source.

Recommendations

- Remove your screwdriver from the set screws gently to minimize jostling the laser.
- Gently tap the top of the laser source with your screwdriver after adjusting to make sure the internal mount is seated correctly.
- The target positions can be swapped to confirm that the laser is aligned correctly.

If using a laser that exits the tube from a wide end, make sure that end sits outside the cube. This prevents it from interfering adjusting the position of the beam path.

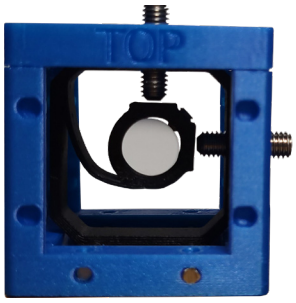
Beam Collimation

Beam Expansion

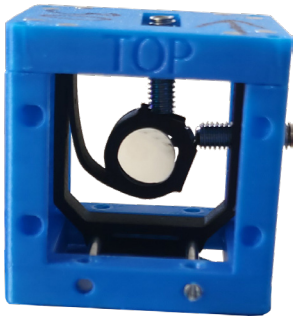
1. Confirm the mounted 0.5” f30 lens is in a neutral position within the cube to start, loosening the 2 set screws as necessary.

In this manual, the arrow points toward the flat side of the lens.

2. Hold the cube and slide the lens mount along the rails from the bottom, positioning the flat side of the lens is as close to opening at one end as possible.
3. Place the cube in front of the light source such that the flat side is pointing toward the laser; the convex side faces away from the laser.
4. Use the set screws to center the lens as close as possible to the beam path.



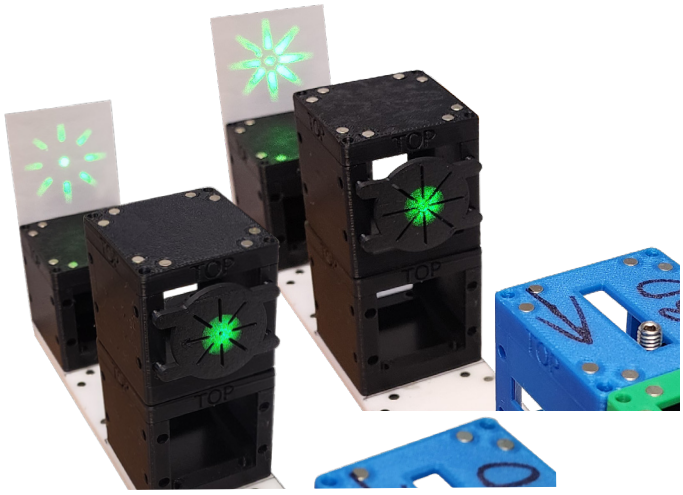
The set screws in a neutral position.



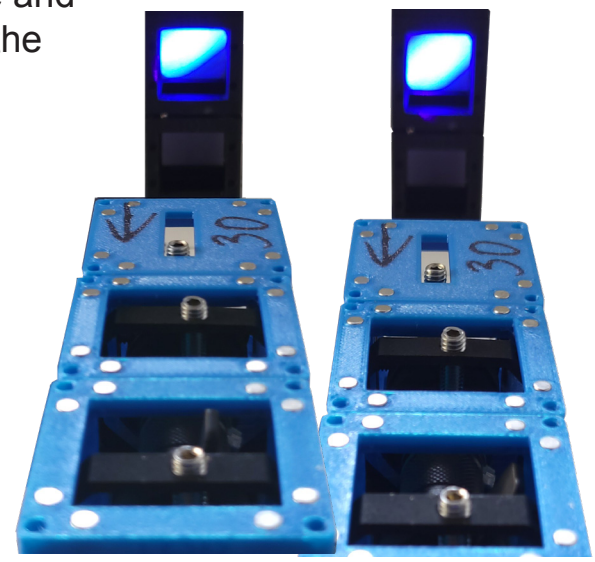
Overtightening one set screw (vertical) impacts the ability to align the lens on the other axis (horizontal).

There are multiple ways to assess beam alignment with the beam path:

- Use the targets as done during *Laser Alignment* (the prefered method).
- Place a cube on the other side of a piece of paper with light behind it (so you can see the outline of the cube) OR with a circle drawn centered on the cube. Either can act as a target for centering the beam path.
- Anchor a white piece of paper behind a cube and align the beam to center of the paper within the boundary of the cube.

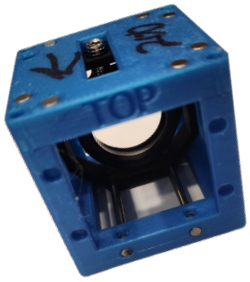


The result of directing an expanded beam through a target with a small versus large pinhole.



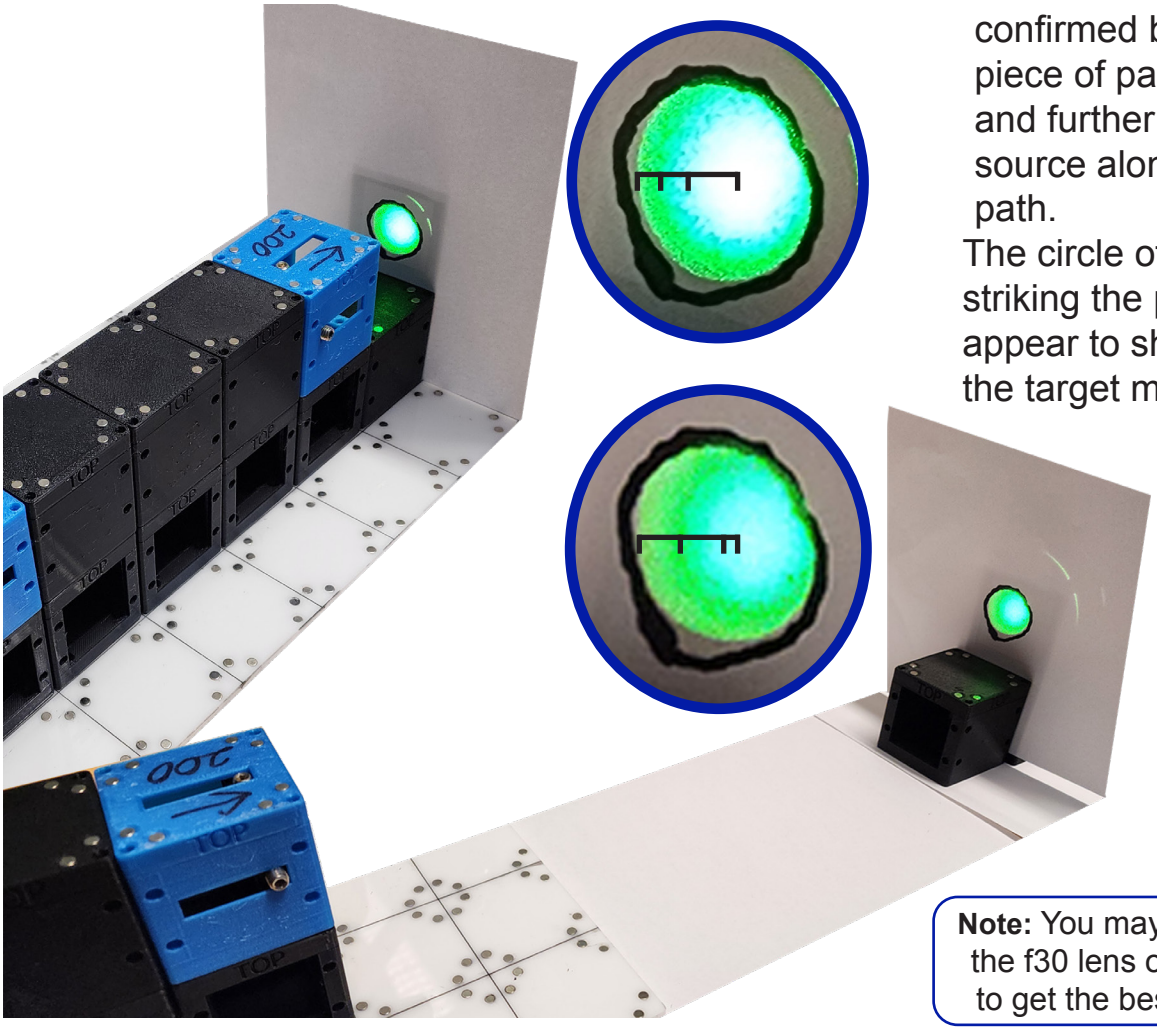
Aligning the beam to the center of a cube. Note the shape of the expanded beam, which is a result of diode used to produce this wavelength (405 nm ± 10 nm).

Beam Collimation



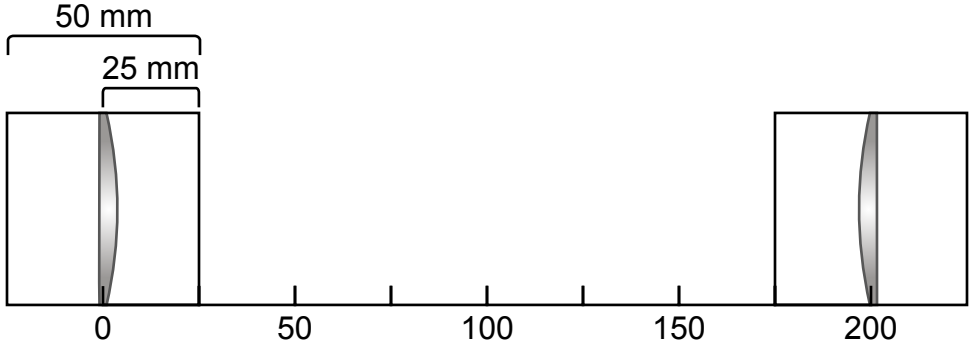
5. Place a 1” f200 lens 200 mm away[1] from the f30 lens with the flat side of the lens pointing away from the laser.
6. Add horizontal tunnel cubes between the two lenses to minimize interference from outside light. This is also a safety measure to reduce exposure to beam scatter.
7. Slide the f200 lens back and forth along the cube rails until it focuses the beam path on the target. The goal is for the emitted light waves to be aligned and parallel—*collimated*.
8. Align the f200 lens using the same method used to align the f30 lens during *Beam Expansion*.
9. Beam collimation can be confirmed by moving a piece of paper closer to and further away from the source along the beam path.

The circle of collimated light striking the paper will not appear to shrink or grow as the target moves.



Note: You may have to adjust the f30 lens on its rails as well to get the best alignment.

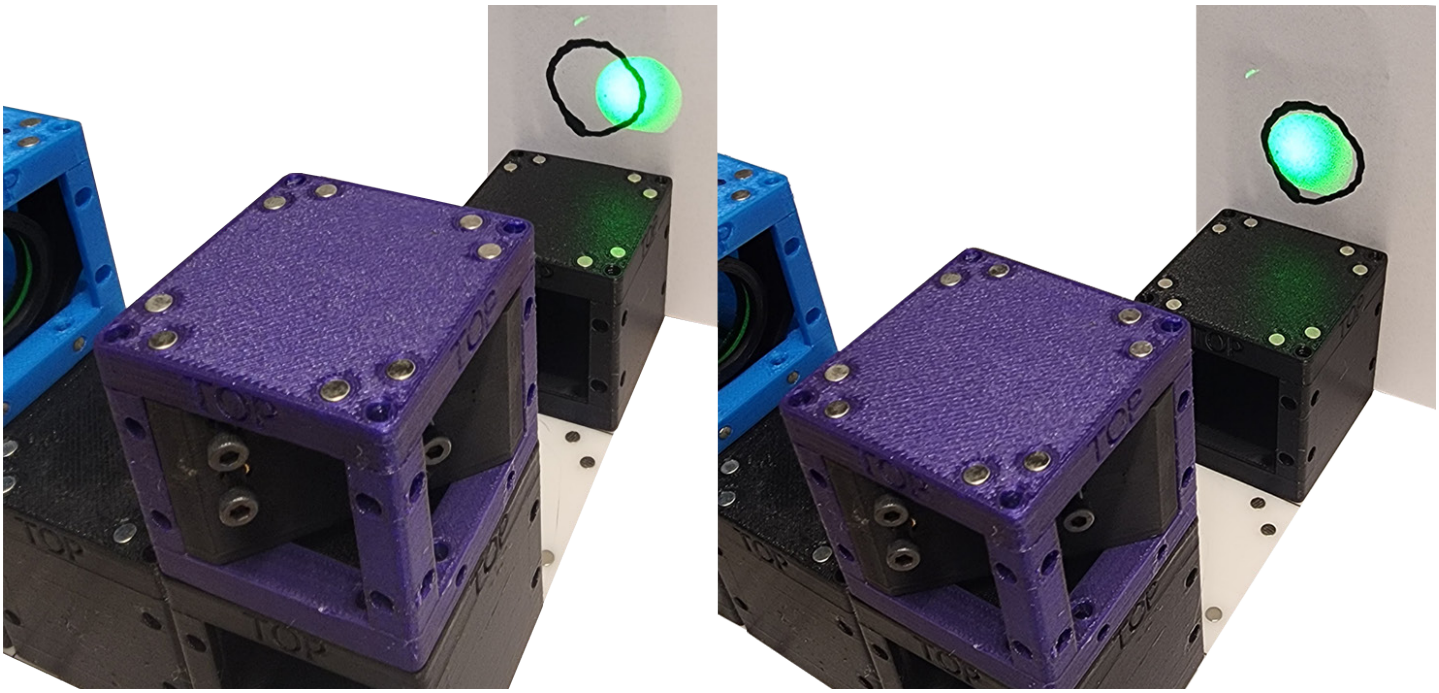
1 The sides of each cube measures 50 mm. Therefore the distance between the center of 2 adjacent cubes is 50 mm. To place a lens 200 mm away, one considers the 50 mm contributed by the 2 lens cubes and adds 150 mm or 3 cube lengths of distance.



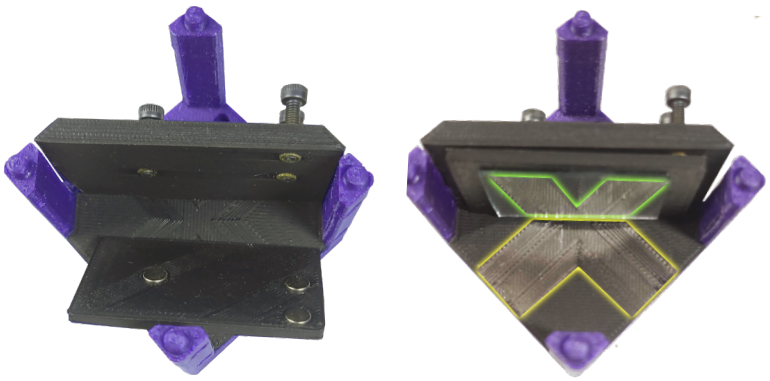
Mirror Alignment

Mirrors can be used to direct the beam. The CubeEd mirrors are orientated within the cube allow a 90° redirection, give or take with adjustments; i.e. the mirrror cubes enable the beam to travel around corners.
Horizontal mirrors can be used to direct the beam path 90° left or right. Vertical mirrors can be used to direct the beam path 90° up or down.

1. Systematically add horizontal mirrors to alter the beam path.
2. After adding each mirror, adjust the mirror angle with the set screws to keep the beam path on the same plane.
3. Before adding the next mirror, confirm the alignment of the beam along the beam path.



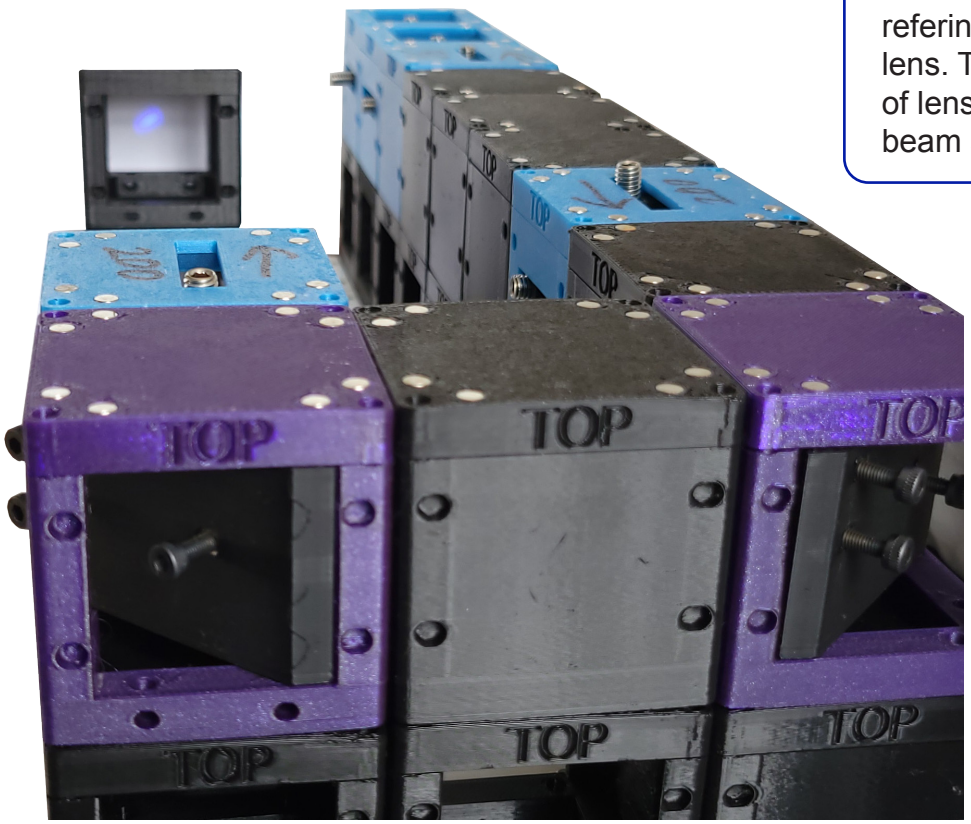
The mirror is attached to the insert with magnets that stick to each screw used for adjustment.
It is important to confirm the mirror is seated on the diagonal within the cube, which can be done by confirming the reflection makes an “X” with the pattern printed on the bottom of the cube. Use the top screw to adjust *tip* and the screws on the horizontal to control *tilt*.



Tube Lens

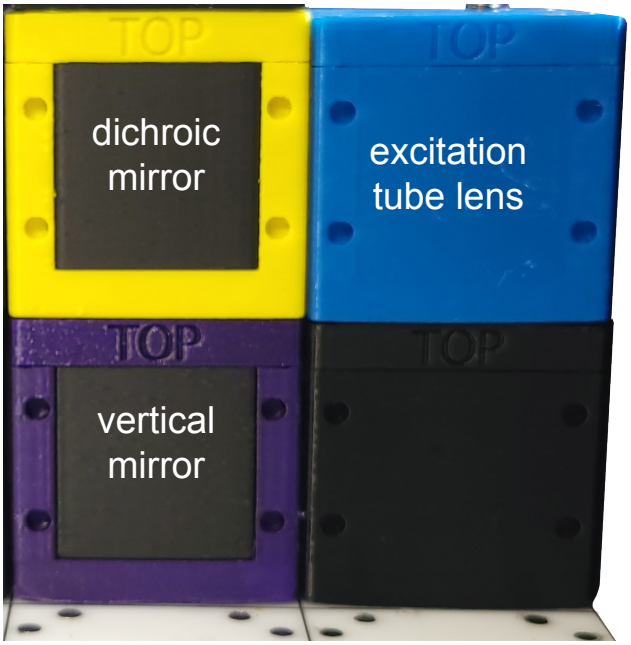
1. Adjust a 1” f200 lens on the rails such the convex side is as close as possible to one end.
2. Add the lens to along the beam path such that the beam will enter the convex side of the lens.
3. Align the beam along the path as before.

Note: The term *tube lens* refers to the job of the lens in terms of microscope function rather than refering to a different type of lens. This lens is the same type of lens used to collimate the beam after expansion.

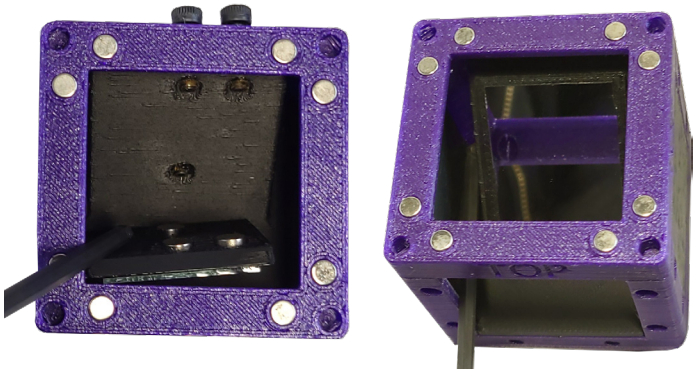


Dichroic Cube

1. Before placing the dichroic cube (yellow), confirm the vertical mirror that it will sit on is correctly seated within its cube and placed.
2. Set the dichroic mirror along the beam path.
3. Align the beam along the beam path as before. If necessary, the set screws of the tube lens and/or horizontal mirror can be adjusted to align the beam.

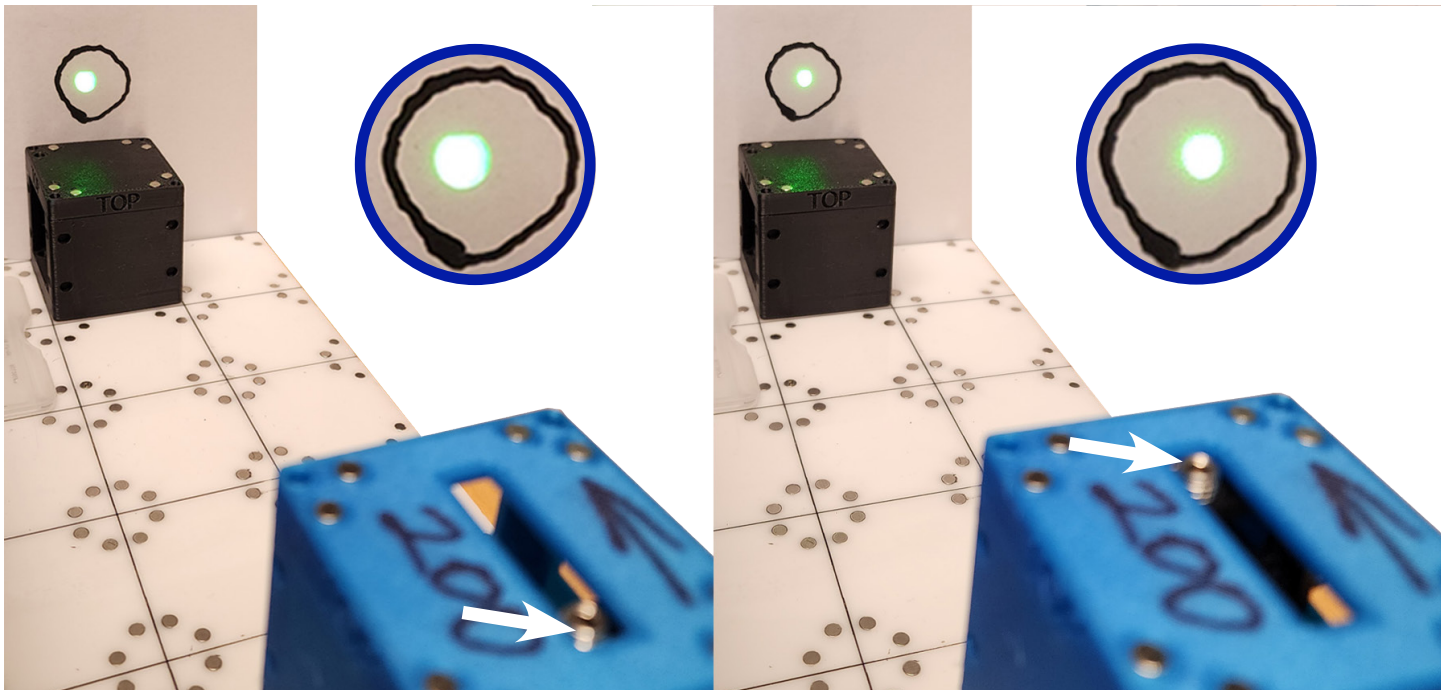


The mirror is attached to the insert with magnets that stick to each screw used for adjustment.
It is important to confirm the mirror is seated on the magnets. Nudge the mirror gently to confirm it is properly seated before placing it in your build. Once the dichroic is placed, the inside of the cube will not be directly accessible.



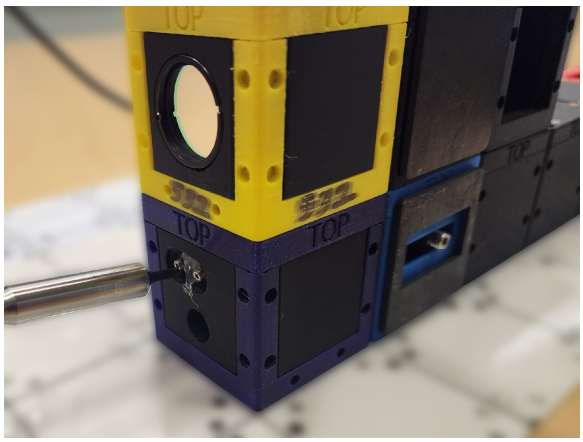
4. Confirm the beam is aligned.

Note: The structural cube shown here was added to hold the paper target for beam visualization. It is not part of the final microscope build.



Think about it:
Why does adjusting the excitation tube lens changes the diameter of the beam path?

Emission Beam Path

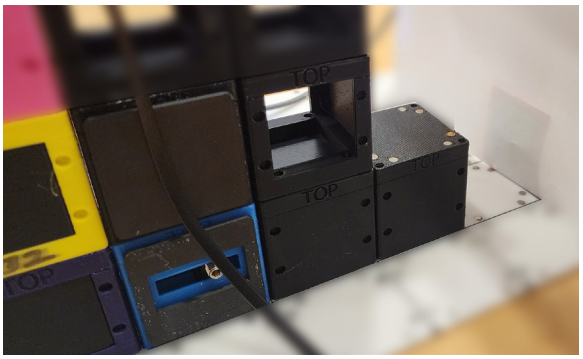


Note: The photos in this section were taken of a fully constructed CubEd.
Add each optical component sequentially, checking the beam path as each element is added.

1. Let the beam pass through the filter cube and onto a vertical mirror. Adjust the vertical mirror angle to follow a parallel beam path, directing the path forward.

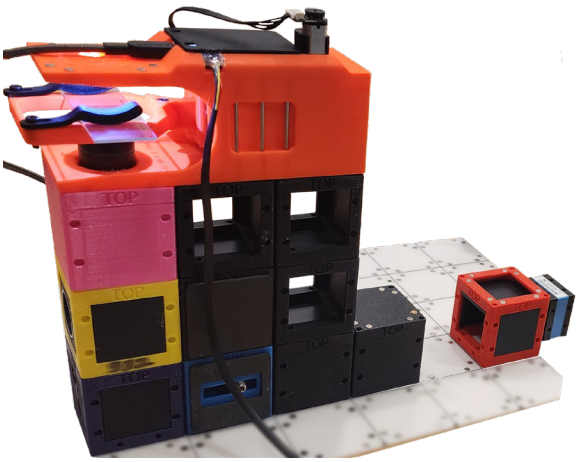
Excitation Tube Lens

1. Place a 1” f200 lens in the beam path following the vertical mirror. Center the lens using the set screws.



2. Confirm the alignment of the beam path as before.

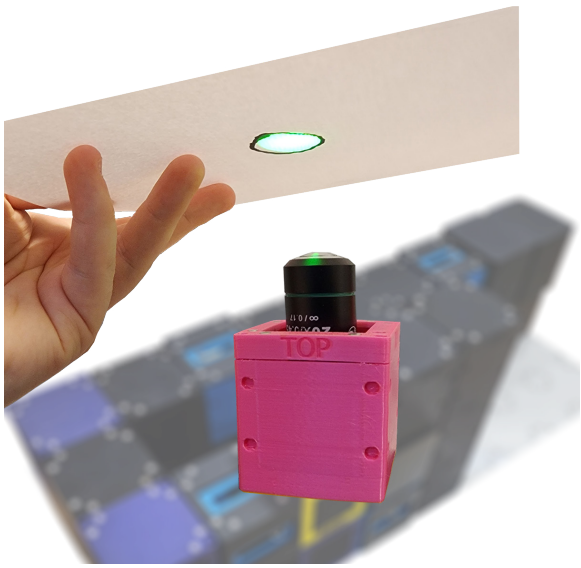
Tip: Use the same paper method as that used in the *beam collimation* step 3 to ensure that the beam path stays straight.

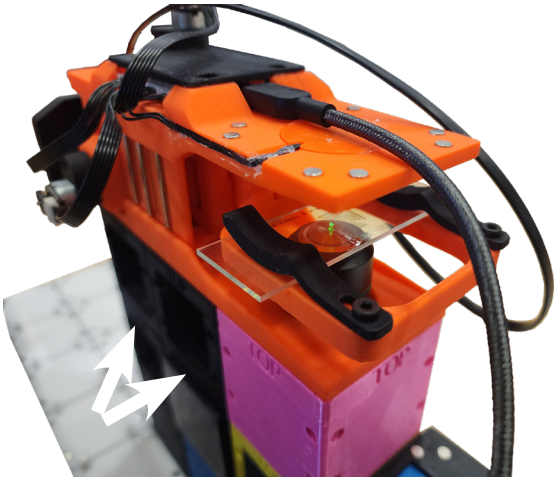


3. Place the camera so the camera sensor is about 200 mm from the f200 lens.

Objective Focusing

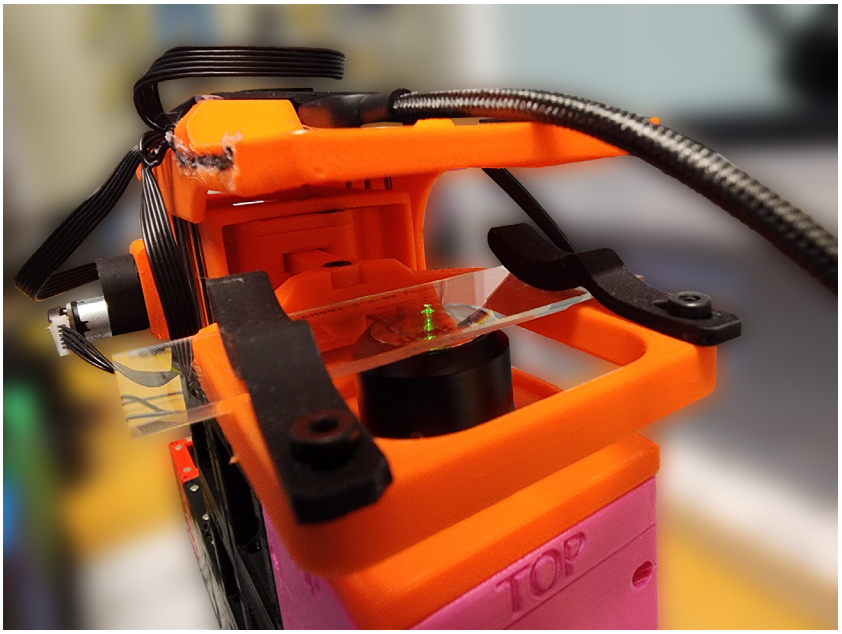
1. Focus the beam through the objective (pink) using the f200 lens: slide the lens along the rails to adjust the distance between the lens and objective until the beam path passes through the infinity corrected objective.





2. Place the *xyz*-stage (orange) on top of the objective. If necessary, use support cubes to reinforce the structure.

3. Direct the beam through the appropriate set of filters and dichroic mirror, mounted in the filter cube (yellow), and up through the objective.

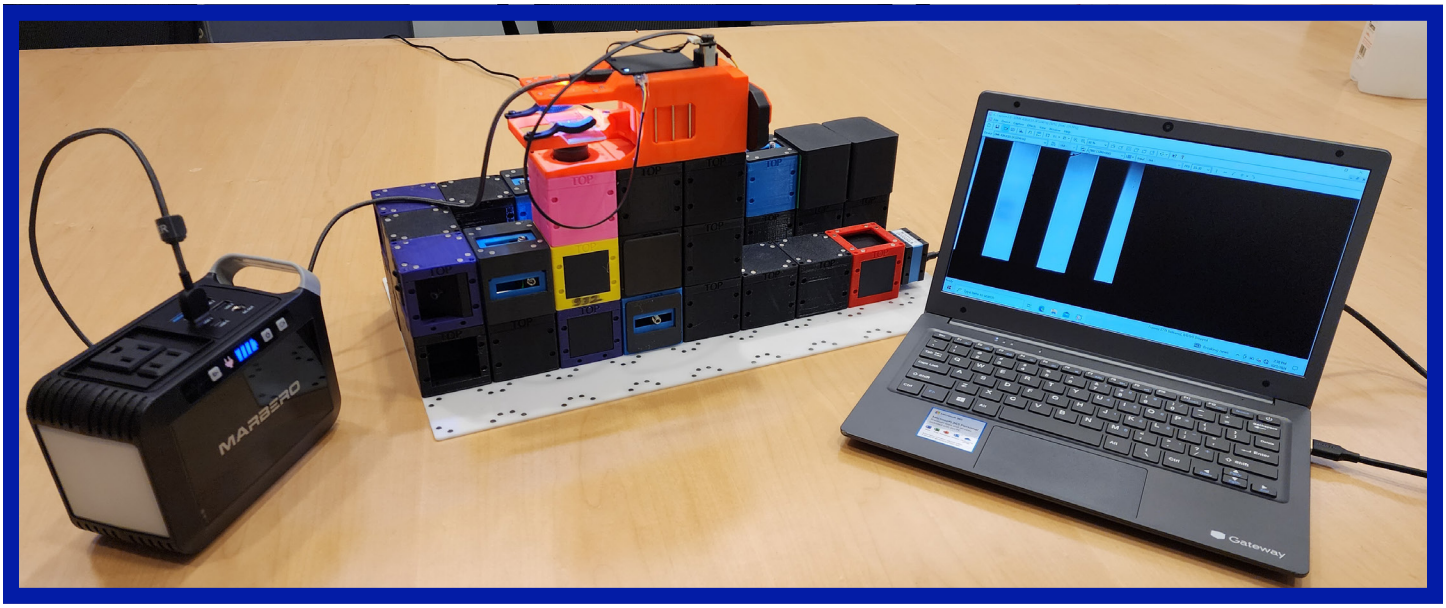


Controlling the Stage

Joystick	Controls the movement of the stage. Does not contribute to speed control. Push the joystick all the way in one direction at a time to move the stage. Movement of the x- and y-axes are controlled in one mode, the z-axis is controlled in a second mode.
Start	Switches between the two joystick modes: x/y and z (z-mode only uses the vertical axis of the joystick). Hold for one second to switch.
Select	Resets the stage to the “home” position: hold for one second to switch.

Y	Motor Speed 27.5%
X	Motor Speed 62.5%
A	Motor Speed 100%
B	Toggle LED On/Off

Note: When the xyz-stage is first powered, it will run a “homing” routine to establish the stage boundaries.


MARBERO
Gateway