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THORLABS

EDU-OT1 - Aug 3, 2018

Item # EDU-OT1 was discontinued on Aug 3, 2018. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

OVERVIEW

Optical Tweezers Demonstration Kit

- Designed for Educational, Demonstration, and Classroom Use
- Complete Photonics Kit Includes All Hardware and Tools (Computer Not Included)
- Includes Extensive Manual for Easy Assembly and Use
- Choose from Educational Kits Containing Imperial or Metric Components

Sample Microscope Video Captures Taken Using the EDU-OT1(/M) Optical Tweezers Educational Kit to Trap 1 µm and 3 µm Beads

Download Manual and Educational Materials

Educational Kit Details

- Experience the Fundamental Working Principles of an Optical Tweezers Setup
- Examine Brownian Motion and Trapping of Microbeads with a Visible Laser
- Demonstrate 3D Trapping of Microbeads with a Water and Cream Solution
- Portable without Readjustment
- Imperial or Metric Versions Available

Optical tweezers, also known as optical traps, move and manipulate small particles using only a beam of light. A focused laser beam is used to exert forces on electrically uncharged particles with sizes from 1 to 10 µm, allowing the particles to be trapped, moved, and manipulated. This optical tweezers lab kit is optimized for classroom and lab use. It features an easy-to-construct optical path and sample positioning stage, a visible laser source, and a camera system for easy demonstration. The educational kit is assembled on a 30 cm x 60 cm (1' x 2') aluminum optical breadboard (included) and can be easily moved for demonstration purposes without needing realignment.

A sample preparation kit, available separately below, provides additional accessories for preparing samples that can be manipulated with the optical tweezers demonstration kit.

We also offer a highly configurable modular optical tweezers system for research and advanced graduate laboratories. For a comparison of the capabilities of our educational and modular tweezers options, please see the *Comparison* tab.

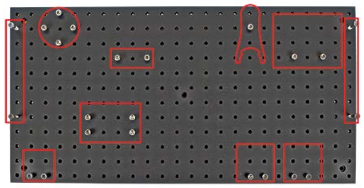
Thorlabs Educational Products

Thorlabs' educational line of products aims to promote physics, optics, and photonics by covering many classic experiments, as well as emerging fields of research. Each kit includes all the necessary components and a manual that contains both detailed setup instructions and extensive teaching materials. These educational lab kits are being offered at the price of the included components, with the educational materials offered for free. Technical support from our educational team is available both before and after purchase.

Purchasing Note: Both English and German language manuals/teaching information are available for this product. The imperial educational kit contains the English manual and US-style power cord. The appropriate manual and power cord will be included in the metric kit based on your shipping location. The power supplies and other electronic devices in both the metric and the imperial kit accept voltages from 100 to 230 VAC. Please contact Tech Support if you need a different language, cord style, or power supply. As with all products on our website, taxes are not included in the price shown below.

KIT DETAILS

Thorlabs demonstration/educational optical tweezers kit is designed for classroom, lab, and other educational uses. It features a visible laser light source and an objective that does not require oil immersion. The CMOS viewing camera can be connected to a PC for demonstration use. The entire system is mounted on a 30 cm x 60 cm (1' x 2') aluminum breadboard and can be easily moved without needing realignment.



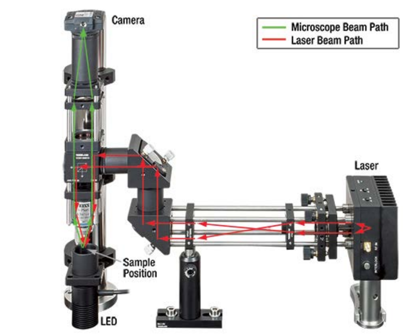
Click for Details
The Optical Tweezers Kit is Mounted on a (1' x 2') 30 cm x 60 cm Aluminum Breadboard and can be Moved Without Needing Realignment. The Screws and Red Outlines Show the Locations of Mounted Components.

Laser and Microscope System

The EDU-OT1(/M) kit uses a L658P040 658 nm laser diode as the trap laser source. This 40 mW visible laser allows the spot to be easily observed through the microscope during operation for intuitive classroom demonstrations. The laser is focused through a Zeiss 63X, 0.8 NA objective, which also serves as the objective for the microscope. Sample illumination is accomplished using an MCWHL5 white LED, and the sample is viewed through a Thorlabs DCC1645C color CMOS camera. The laser, microscope, and optical path of the optical tweezers kit are shown below to the left.

Sample Positioning System

Samples are placed on the 3-axis sample positioning stage and moved around the static laser beam during experiments. The stage consists of two motorized MT1-Z8 (MT1/M-Z8) 12 mm travel translation stages for X- and Y-axis travel, plus a manual MT1 (MT1/M) stage for Z-axis translation. The motorized stages are controlled by KDC101 servo motor controllers, each of which features a 1-axis actuator with customizable velocity settings. The sample positioning stage is shown below to the right.



Click to Enlarge
Microscope and Camera Assembly with Beam Paths (Sample Stage not Shown)

Click to Enlarge
Sample Positioning Stage

EDU-OT1(/M) Optical Tweezers Kit Specifications	
Trap Laser Type	Diode
Trap Laser Wavelength (Typical)	658 nm
Trap Laser Power (Typical)	40 mW
Complete Trap Laser Specifications	
Objective NA	0.8
Working Distance	0.3 mm
Camera	DCC1645C CMOS Camera
Camera Resolution	1280 x 1024 Pixels

Optical Tweezers Operation

Optical traps can be characterized by two essential forces: the scattering force and the gradient force. The scattering force can be attributed to the principle of radiation pressure. Since the incoming laser light is partly absorbed and/or reflected by the particles, a momentum transfer occurs, which makes the particles move away from the light source. Thus, the scattering force increases with the laser power.

The second, more important force is the gradient force. If the laser beam acts on particles with a higher refractive index than the aqueous medium in which they are dispersed, they travel in the direction of maximal light intensity, allowing the particles to be trapped in the laser focus. If the laser is tightly focused, the gradient force can exceed the scattering force so that the particles can be trapped and moved in all three spatial directions.

For experimental purposes, microscopic glass or plastic beads (about 1 to 10 µm) or various other objects are dispersed in liquid (water, alcohol) on a glass slide. The particles can then be moved and manipulated by trapping them in the focused laser beam and moving the slide, which is attached to a positioning stage. The objective, CMOS camera, and an additional tube lens compose a microscope, which allows for the observation of the trapping procedure on the PC monitor. Various experiments can be performed with this setup, including trapping of particles with varying laser powers (up to 40 mW), evaluation of the effective viscosity of the dispersion via Brownian motion, determination of the optical trapping forces and their harmonic potential, and statistical analysis of the probability of presence of the particles in the trap.

Laser Safety Information

The class 3B laser diode used in this kit emits up to 42 mW of optical power, which can cause damage to the eyes if viewed directly. The laser driver is equipped with a key switch and safety interlock, which should be used appropriately to avoid injury. Additionally, we recommend wearing appropriate laser safety glasses when using this kit. See the *Laser Safety* tab for details.

EXPERIMENTS

The EDU-OT1(/M) Optical Tweezers Kit Used to Trap and Manipulate Various Particles Including 1 µm and 3 µm Beads and Large Starch and Fat Particles

Several experiments that students can undertake as part of a lab course are outlined below. In addition to these exercises, the manual contains instructions for more activities such as adjusting the setup, finding the correct focus plane for the camera and laser, and arranging trapped particles within a sample.

Sample Preparation

Samples for the optical tweezers kit are simple to prepare. A sample containing 1 µm or 3 µm glass beads is useful, as these are well-suited for getting to know the operation and handling of the optical tweezers. Alternatively, an emulsion of cream in water will also produce particles that can be captured with the optical tweezers kit.

The following materials are necessary to create the sample:

- Microscope Slide with 20 µm Deep Wells
- Cover Glass
- Watch Glass Dish
- Pipette
- Sample Solution:
  - Solution with Glass (Fused Silica) Beads and Distilled Water
  - Cream and Water Emulsion

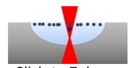
First, place a drop of the solution with the PS beads in the watch glass dish and combine with sufficient distilled water. Place this mixture in a well on the microscope slide using a pipette. Put a cover glass over the sample so that there are no air bubbles between the glass and the sample.

The samples can either be prepared before each experiment or they can be sealed between the slide and the coverglass with a UV adhesive. We recommend allowing students to prepare new samples as an educational exercise.

The OTKBTK sample preparation kit, available below, contains additional accessories that can be used to prepare samples for this optical tweezers kit.

Manipulation of a Cream Particle within a Cream Water Emulsion

Particles of dairy cream in a cream water emulsion are an appropriate size to be trapped by the optical tweezers in this kit. A sample can be created by mixing a drop of dairy cream with enough water to create a solution that is slightly milky in appearance. If one attempts to trap the cream particles with the laser, they will disappear from the focus and can no longer be clearly seen on the monitor (see the image to the right). The observation can be explained by the composition of the cream/water emulsion. Cream consists primarily of fat, which collects on the surface when mixed with water. The cream particles are therefore located on the surface of the water. However, the laser focus is located at a deeper level: when the cream particles are trapped, they are pulled down into the emulsion. This effect can be observed when the particle at which the laser is directed is tracked by adjusting the height of the stage as the particle moves deeper into the solution.



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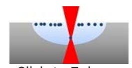
Click to Enlarge
The laser focus pushes down one of the cream particles floating at the surface of the emulsion.



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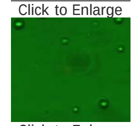
A particle of cream is held at the focus of the laser underneath the surface of the emulsion.

Click to Enlarge

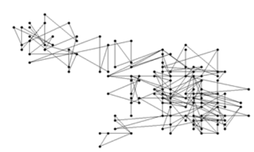


Click to Enlarge
After the laser is turned off, the particle of fat moves back to the surface of the emulsion.

After the cream particle located in the optical trap has been brought into focus and thus can clearly be seen on the monitor, the laser can be switched off and the particle observed. Since the cream particle is not held in place by an optical trap after the laser is switched off, it will move upward once again to the surface of the water. Again, the motion of the particle can be tracked by adjusting the height of the stage.

Brownian Motion

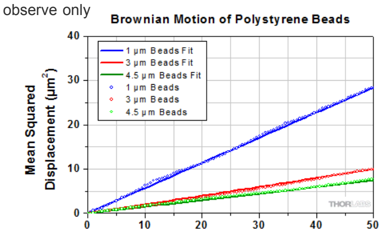
Brownian motion is the random motion (translation and rotation) of microscopic free particles suspended in a fluid resulting from their collisions with the atoms or molecules of the fluid. Under the microscope, the paths of particles are seen as short, straight lines (see the figure to the right). The Brownian motion can be observed in experiments using the optical tweezers. The glass beads are located in a medium that consists of molecules that are constantly moving in all directions. Because of this, the molecules repeatedly bump into the beads, which causes a vibrating motion of the beads that can be observed under the optical tweezers. The higher the temperature, the more the molecules move.



Click to Enlarge
A sketch illustrating Brownian motion.

Use a sample with the 3 µm glass spheres. You must first switch the laser off so that you can observe only Brownian motion. For evaluation, a video sequence with a duration of 2 minutes or more must be recorded. During this period, about 5 particles, which do not touch each other, should be in the image. A similar video should be recorded with the 1 µm spheres. The videos can be evaluated with the aid of image analysis software, which provides the x and y position of a particle over time (see the manual for a recommendation for a free software package).

We recommend evaluating and graphing the data obtained with the aid of a table calculation program. First, the mean squared displacement of the beads must be determined. This can be calculated from the positions of the beads ($x_i(t_i), y_i(t_i)$) at different times, t_i, which can be measured from the video:



Click to Enlarge
The mean squared displacement for different sizes of glass beads is shown in the graph above.

$$r^2(t_i) = (x(t_i) - x(0))^2 + (y(t_i) - y(0))^2$$

The mean position value up to each time t_n can be calculated by averaging all of the measured position values over time. To eliminate statistically possible deviations of individual particles, the mean value should also be averaged over M particles:

$$< r^2 > (t_n) = \frac{1}{M} \sum \frac{1}{n} \sum_{i}^{n} r^2(t_i)$$

We recommend using at least 5 particles for this calculation. The values obtained for the average squared displacement, $<r^2>(t_n)$, with respect to time for three sizes of glass beads are plotted in the graph to the right. Note that the slope of the lines decreases with increasing diameter of the beads, meaning that larger beads move less. This result can easily be explained by Brownian motion: the 1 µm spheres can be more easily set into motion by impact with the water molecules than larger spheres. Therefore, a 1 µm bead travels more in a certain time interval than a larger bead.

Maximum Holding Force of the Optical Trap

Frictional forces from the surrounding liquid will act on the individual glass beads moving through the solution with velocity, v, and inhibit their motion. This force is proportional to the bead size and the viscosity of the fluid:

$$F_R = 6\pi\eta_{eff}Rv$$

Here, R describes the radius of the bead. The viscosity, η_{eff}, describes how "thick" the combination of water and beads is, which means it is different for each sample. It can be calculated from the mean squared displacement of particles in the fluid, which was experimentally determined in the Brownian Motion experiment described above. The slope, *m*, of the line describing the beam squared displacement is related to the viscosity by the following equation:

$$m = \frac{2k_{\mathrm{B}}T}{3\pi\eta_{\mathrm{eff}}R}$$

where η_{eff} denotes the effective viscosity, *R* is the radius of the bead, and *T* is the temperature of the sample in Kelvin, and k_{B} is the Boltzmann constant, which has an approximate value of 1.38×10^{23} J/K. The effective viscosity should be on the order of 10^{-3} N s/m².

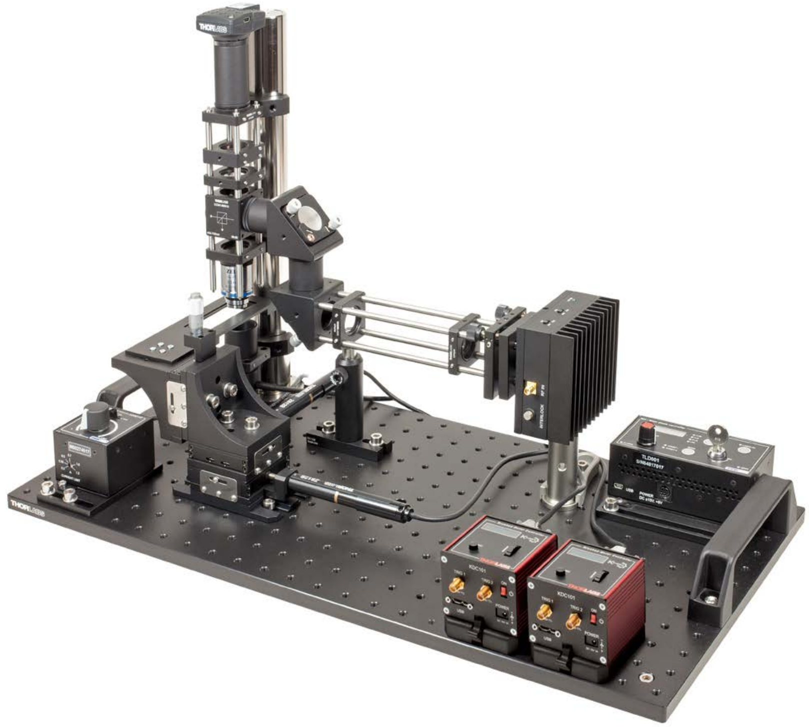
If the bead is in the optical trap, two forces act on it. First, the frictional force, F_{R}, which is caused by the suspension in which the glass bead is located, and the holding force, F_{H}, of the optical trap. The maximum holding force is defined as the force needed to maintain a speed v_{max} at which the bead can just be held by the trap. This is the case where the maximum holding force and frictional force are in balance:

$$F_{\mathrm{H,max}} = F_{\mathrm{R}} = 6\pi\eta_{\mathrm{eff}}Rv_{\mathrm{max}}$$

For the EDU-OT1(/M), the holding force will typically be on the order of several pN, dependent on the contrast in refractive index between the trapped particle and the surrounding liquid.

COMPONENT LIST

Portable Optical Tweezers Kit Components



Thorlabs' Optical Tweezers Demonstration Kits are available in imperial and metric versions. In cases where the metric and imperial kits contain parts with different item numbers, metric part numbers and measurements are indicated by parentheses unless otherwise noted.

Item #	Description	Qty.
Trapping Laser Source		
TCLDM9[a]	Laser Diode Mount	1
L658P040	658 nm, 40 mW Laser Diode	1
TLD001	Laser Diode Driver	1
TPS002	Laser Diode Driver Power Supply	1
RS3P (RS3P/M)	Ø1" (Ø25 mm) Pedestal Post, 3" (25 mm) Tall	1
CF125	Clamping Fork	1
CAB400	Cable for Laser Diode Driver	1
Laser Collimator		
KC1-T (KC1-T/M)	Tip/Tilt Cage Mount	1
A230TM-B	Mounted Aspheric Lens, f = 4.51 mm	1
E09RMS	Aspheric Lens to RMS Adapter	1

SM1A3	RMS to SM1 Adapter	1
Beam Expander		
ER8	Ø6 mm Cage Rod, 8" Long	4
CP02 (CP02/M)[b]	SM1-Threaded Cage Plate	2
LA1074-A	Ø1/2" Plano-Convex Lens, f = 20 mm	1
LA1509-A	Ø1" Plano-Convex Lens, f = 100 mm	1
SM1A6	SM05 to SM1 Adapter	1
SM05L03	SM05 Lens Tube, 0.3" Long	1
TR3 (TR75/M)	Ø1/2" (Ø12.7 mm) Post, 3" (75 mm) Long	1
PH3 (PH75/M)	Ø1/2" (Ø12.7 mm) Post Holder, 3" (75 mm) Long	1
BA1 (BA1/M)	Mounting Base, 1" x 3" x 3/8" (25 mm x 58 mm x 10 mm)	1
Sample Positioning System		
MT1-Z8 (MT1/M-Z8)	Motorized Translation Stage, 1/2" (12 mm) Travel	2
MT1 (MT1/M)	Manual Translation Stage, 1/2" (13 mm) Travel	1
KDC101	K-Cube Servo Motor Controller	2
KPS101[c]	15 V Power Supply	2
MT402	Right Angle Bracket	1
MT402-SLH-SP	Modified Right Angle Bracket	1
AMA-SLH	Slide Holder	1
MT401	Mounting Base for Translation Stages	1

Item #	Description	Qty.
Right-Angle Mirrors		
KCB1	Right Angle Kinematic Mirror Mount	2
PF10-03-P01	Ø1" Protected Silver Mirror	2
SM1L10[d]	Ø1" Lens Tube, 1" Long	2
SM1T2[e]	SM1 Lens Tube Coupler	2
Microscope		
DCC1645C	Color CMOS Camera	1
SM1T2[e]	SM1 Lens Tube Coupler	2
C1498 (C1498/M)	Ø1.5" Post Clamp	3
SM1L20	SM1 Lens Tube, 2" Long	1
CP02 (CP02/M)[b]	SM1-Threaded Cage Plate	4
CP02T (CP02T/M)	Thick SM1-Threaded Cage Plate	1
FGB37	Ø1" BG40 Colored Glass Bandpass Filter	2
FES0650	Ø1" Shortpass Filter, 650 nm Cut Off	1
LB1676	Ø1" Bi-Convex Lens, f = 100 mm	1
SM1A9	C-Mount to SM1 Adapter	1
CCM1-BS013 (CCM1-BS013/M)	Cube-Mounted 50:50 Beamsplitter Cube	1
SM1CP2	SM1 End Cap	1
DP14A (DP14A/M)	Ø1.5" Damped Mounting Post	1
ER3	Ø6 mm Cage Rod, 3" Long	4
ER2	Ø6 mm Cage Rod, 2" Long	4
MCWHL5	Cold White Mounted LED	1
LEDD1B	T-Cube LED Driver	1
KPS101	15 V Power Supply	1
SM1L10[d]	SM1 Lens Tube, 1" Long	1
-	Zeiss Microscope Objective, 63X, 0.8 NA	1
SM1A17	M27 x 0.75 to SM1 Adapter	1
Additional Components		
MB1224 (MB3060/M)	Aluminum Breadboard, 1' x 2' (30 cm x 60 cm)	1
RDF1	Set of 4 Rubber Damping Breadboard Feet	1
ERSCA	Ø6 mm Cage Rod Adapters	4
BBH1	Set of 2 Breadboard Handles	1
CPA1	Cage Alignment Plate	1

Imperial Kit: Included Hardware and Screws

Item #	Description	Qty.	Item #	Description	Qty.
BD-3/16L	3/16" Balldriver	1	-	0.050" Hex Key	1
-	5/64" Hex Key	1	-	3/32" Hex Key	1
-	2.5 mm Hex Key	1	-	1/8" Hex Key	1
SH25S063	1/4-20 Cap Screw, 5/8" Long	30	SH8S050	8-32 Cap Screw, 1/2" Long	3
SH25S075	1/4-20 Cap Screw, 3/4" Long	4	-	8-32 Set Screw, 5/8" Long	3

-	#1/4 Washer	30	-	8-32 Set Screw, 1" Long	1
-	#1/4 Nut	4	SH3M06	M3 x 0.5 Cap Screw, 6 mm Long	4
-	1/8" x 1/4" Steel Dowel Pin	4	SD1	8-32 to 1/4 Counterbore Adapter	3

Metric Kit: Included Hardware and Screws

Item #	Description	Qty.	Item #	Description	Qty.
BD-5ML	6 mm Balldriver	1	-	1.3 mm Hex Key	1
-	2 mm Hex Key	1	-	2.5 mm Hex Key	1
-	3 mm Hex Key	1	-	-	-
SH6MS16	M6 Cap Screw, 16 mm Long	30	SH4MS10	M4 Cap Screw, 10 mm Long	3
SH6MS20	M6 Cap Screw, 20 mm Long	4	-	M4 Setscrew, 16 mm Long	3
-	M6 Washer	30	-	M4 Setscrew, 25 mm Long	1
-	M6 Nut	4	SH3M06	M3 x 0.5 Cap Screw, 6 mm Long	4
-	1/8" x 1/4" Steel Dowel Pin	4	SD1	M6 to M4 Counterbore Adapter	3

- This is our previous-generation Ø9 mm laser diode mount.
- A total of 6 CP02(/M) cage plates are included with this kit, in the beam expander and microscope assemblies.
- A location-specific adapter ships with the power supply based on your location.
- A total of 3 SM1L10 lens tubes are included with this kit, in the right-angle mirrors and microscope assemblies.
- A total of 4 SM1T2 lens tube couplers are included with this kit, in the right-angle mirrors and microscope assemblies.

Note: Spanner wrenches are not included in this kit, as the retaining rings can be easily tightened using other means. However, if you wish to use a spanner wrench to aid in assembly, the SPW602 is compatible with our SM1-threaded retaining rings and the SPW301 can be used to mount the A230TM-B aspheric lens.

S O F T W A R E

Software Downloads

We recommend operating these optical tweezers using the ThorCam™ and Kinesis® software packages. A guide to software installation and settings can be found in the manual.

ThorCam Camera Software

Version 3.0.0

The entire software package can be downloaded here.

The previous generation uc480 Camera Software package is available at this link on the *Archive* tab for interested users.

Software

Kinesis and APT Controller Software

Kinesis: Version 1.14.9
APT: Version 3.21.2

The entire Kinesis software package can be downloaded here.

The legacy APT software package is also available from this link for interested users.

Software

U S E R   C O N T E N T

User-Generated Content

Thorlabs' Educational Kits provide flexibility in the classroom, allowing users to adapt the content to their own teaching needs. With that in mind, we enjoy hearing feedback from our customers with details about how they use the kits in their own classrooms.

Building the Optical Tweezers Kit
The video below was created by of Alessandro Maguzzu, Aykut Argun, and Falko Schmidt (opticaltweezers.org) to provide a different approach for guiding students through the process of constructing the Optical Tweezers Kit.

Please note that the setup shown in the video is built in a different order than described in the manual. In the manual, the beam path is constructed starting from the laser source, since the laser mount is placed on a post with fixed height. In the video, the microscope is assembled first and the laser beam path follows afterwards. In this case, it is crucial that the cage segment holding the two lens systems be level with respect to the breadboard. Therefore, the assembly order in the video requires an additional step that is not shown: the microscope assembly needs to be moved in vertical direction until the cage segment with the lenses is as horizontal as possible. The damped post and sample stage controller are also placed in different positions on the breadboard than directed in the manual, although this will not affect the performance of the kit.

Video Provided Courtesy of Alessandro Maguzzu, Aykut Argun, and Falko Schmidt

If you would like to submit your own user-generated content, please e-mail us at techsupport@thorlabs.com.

COMPARISON

Thorlabs offers three different optical tweezers options: our Microscope System for users who desire an out-of the box research solution, our open-architecture Modular System designed for research and advanced teaching labs, and the Demonstration Kit featured on this page designed for introducing the basics of optical trapping. While our modular system and the demonstration kit look similar there are many key distinguishing features that are summarized in the table below.

	Educational Demonstration Kit	Modular System
Item #	EDU-OT1(/M)	OTKB(/M)
Laser Wavelength	658 nm (Visible)	975 nm (IR)
Laser Power	40 mW	340 mW
Objective Type	Air	Immersion
Positioning System	Servo Motor in XY; Manual in Z	Piezo Actuators and Strain Gauge in XYZ
Force Measurement	Camera Image Analyzed with Open Source Software	Back Focal Plane Detection via Position Sensing Detector (Optional)
Configuration	Upright	Inverted
Target Groups	• Undergraduate University Lab Courses • Labs for Advanced High School Students	• Research Labs in Need of an Optical Micromanipulation Setup with Full Access to All Components • Ability to Customize / Extend System • Ability to Combine with Imaging Modalities such as Fluorescence or Raman Microscopy • Advanced University Lab Courses
Educational Aspects	• Fundamental Working Principles of an Optical Tweezers Setup • Preparation of Samples • Finding the Right Focal Plane • Demonstrate 3D Trapping with Water and Cream Solution • Examine Brownian Motion • Estimate Trapping Forces • Estimate the Effective Viscosity of a Sample Solution	• Probing Individual Cells and Their Internal Components • Measuring Forces Generated by Molecular Motors • Analysis of Biological Macromolecules • Drag Forces in Microfluidics • Trapping of Nanoparticles

LASER SAFETY

Laser Safety and Classification

Safe practices and proper usage of safety equipment should be taken into consideration when operating lasers. The eye is susceptible to injury, even from very low levels of laser light. Thorlabs offers a range of laser safety accessories that can be used to reduce the risk of accidents or injuries. Laser emission in the visible and near infrared spectral ranges has the greatest potential for retinal injury, as the cornea and lens are transparent to those wavelengths, and the lens can focus the laser energy onto the retina.

Safe Practices and Light Safety Accessories

- Thorlabs recommends the use of safety eyewear whenever working with laser beams with non-negligible powers (i.e., > Class 1) since metallic tools such as screwdrivers can accidentally redirect a beam.
- Laser goggles designed for specific wavelengths should be clearly available near laser setups to protect the wearer from unintentional laser reflections.
- Goggles are marked with the wavelength range over which protection is afforded and the minimum optical density within that range.
- Blackout Materials can prevent direct or reflected light from leaving the experimental setup area.
- Thorlabs' Enclosure Systems can be used to contain optical setups to isolate or minimize laser hazards.






- A fiber-pigtailed laser should always be turned off before connecting it to or disconnecting it from another fiber, especially when the laser is at power levels above 10 mW.
- All beams should be terminated at the edge of the table, and laboratory doors should be closed whenever a laser is in use.
- Do not place laser beams at eye level.
- Carry out experiments on an optical table such that all laser beams travel horizontally.
- Remove unnecessary reflective items such as reflective jewelry (e.g., rings, watches, etc.) while working near the beam path.
- Be aware that lenses and other optical devices may reflect a portion of the incident beam from the front or rear surface.
- Operate a laser at the minimum power necessary for any operation.
- If possible, reduce the output power of a laser during alignment procedures.
- Use beam shutters and filters to reduce the beam power.
- Post appropriate warning signs or labels near laser setups or rooms.
- Use a laser sign with a lightbox if operating Class 3R or 4 lasers (i.e., lasers requiring the use of a safety interlock).
- Do not use Laser Viewing Cards in place of a proper Beam Trap.

Laser Classification

Lasers are categorized into different classes according to their ability to cause eye and other damage. The International Electrotechnical Commission (IEC) is a global organization that prepares and publishes international standards for all electrical, electronic, and related technologies. The IEC document 60825-1 outlines the safety of laser products. A description of each class of laser is given below:

Class	Description	Warning Label
1	This class of laser is safe under all conditions of normal use, including use with optical instruments for intrabeam viewing. Lasers in this class do not emit radiation at levels that may cause injury during normal operation, and therefore the maximum permissible exposure (MPE) cannot be exceeded. Class 1 lasers can also include enclosed, high-power lasers where exposure to the radiation is not possible without opening or shutting down the laser.	
1M	Class 1M lasers are safe except when used in conjunction with optical components such as telescopes and microscopes. Lasers belonging to this class emit large-diameter or divergent beams, and the MPE cannot normally be exceeded unless focusing or imaging optics are used to narrow the beam. However, if the beam is refocused, the hazard may be increased and the class may be changed accordingly.	
2	Class 2 lasers, which are limited to 1 mW of visible continuous-wave radiation, are safe because the blink reflex will limit the exposure in the eye to 0.25 seconds. This category only applies to visible radiation (400 - 700 nm).	
2M	Because of the blink reflex, this class of laser is classified as safe as long as the beam is not viewed through optical instruments. This laser class also applies to larger-diameter or diverging laser beams.	
3R	Lasers in this class are considered safe as long as they are handled with restricted beam viewing. The MPE can be exceeded with this class of laser, however, this presents a low risk level to injury. Visible, continuous-wave lasers are limited to 5 mW of output power in this class.	
3B	Class 3B lasers are hazardous to the eye if exposed directly. However, diffuse reflections are not harmful. Safe handling of devices in this class includes wearing protective eyewear where direct viewing of the laser beam may occur. In addition, laser safety signs lightboxes should be used with lasers that require a safety interlock so that the laser cannot be used without the safety light turning on. Class-3B lasers must be equipped with a key switch and a safety interlock.	
4	This class of laser may cause damage to the skin, and also to the eye, even from the viewing of diffuse reflections. These hazards may also apply to indirect or non-specular reflections of the beam, even from apparently matte surfaces. Great care must be taken when handling these lasers. They also represent a fire risk, because they may ignite combustible material. Class 4 lasers must be equipped with a key switch and a safety interlock.	
All class 2 lasers (and higher) must display, in addition to the corresponding sign above, this triangular warning sign		

A C K N O W L E D G E M E N T S

The Portable Optical Tweezers Demonstration Kit was developed in cooperation with Antje Bergmann and Daniela Rappa from the Karlsruhe Institute of Technology.

Do you have ideas for an experiment that you would like to see implemented in an educational kit? Contact us at techsupport@thorlabs.com; we'd love to hear from you.

Optical Tweezers Demonstration Kit

Part Number	Description	Price	Availability
EDU-OT1/M	**Portable Optical Tweezers Demonstration Kit, Metric**	**$8,557.80**	**Lead Time**
EDU-OT1	**Portable Optical Tweezers Demonstration Kit, Imperial**	**$8,557.80**	**Today**

Sample Preparation Kit


Click to Enlarge

The OTKBTK is designed for use with our OTKB Modular Optical Tweezers, our OTM200 Optical Tweezers Microscope System, and our EDU-OT1 Educational Discovery Kits. It allows users to quickly prepare a sample and test for optical trapping once they have completed construction. Included with the kit are the following:

- Non-Drying Immersion Oil for Microscopy, Cargille Type B
- Non-Functionalized Fused Silica Beads in Deionized Water, Ø2.06 µm, 2 g/ml
- Mini Pipette with a 50 µL Volume
- Two Plastic Slides with Built-In Channel, 400 µm Height, 100 µL Volume
- 5 Microscope Glass Slides with Reaction Wells, Ø10 mm, 20 µm Deep
- 100 Pieces of 18 mm x 18 mm Cover Glass, No. 1.5 Thickness
- Dropper for Immersion Oil

Part Number	Description	Price	Availability
OTKBTK	**Optical Tweezer Kit - Sample Preperation Kit**	**$148.00**	**Lead Time**