Modular Tweezers
OTKB(/M)

User Guide

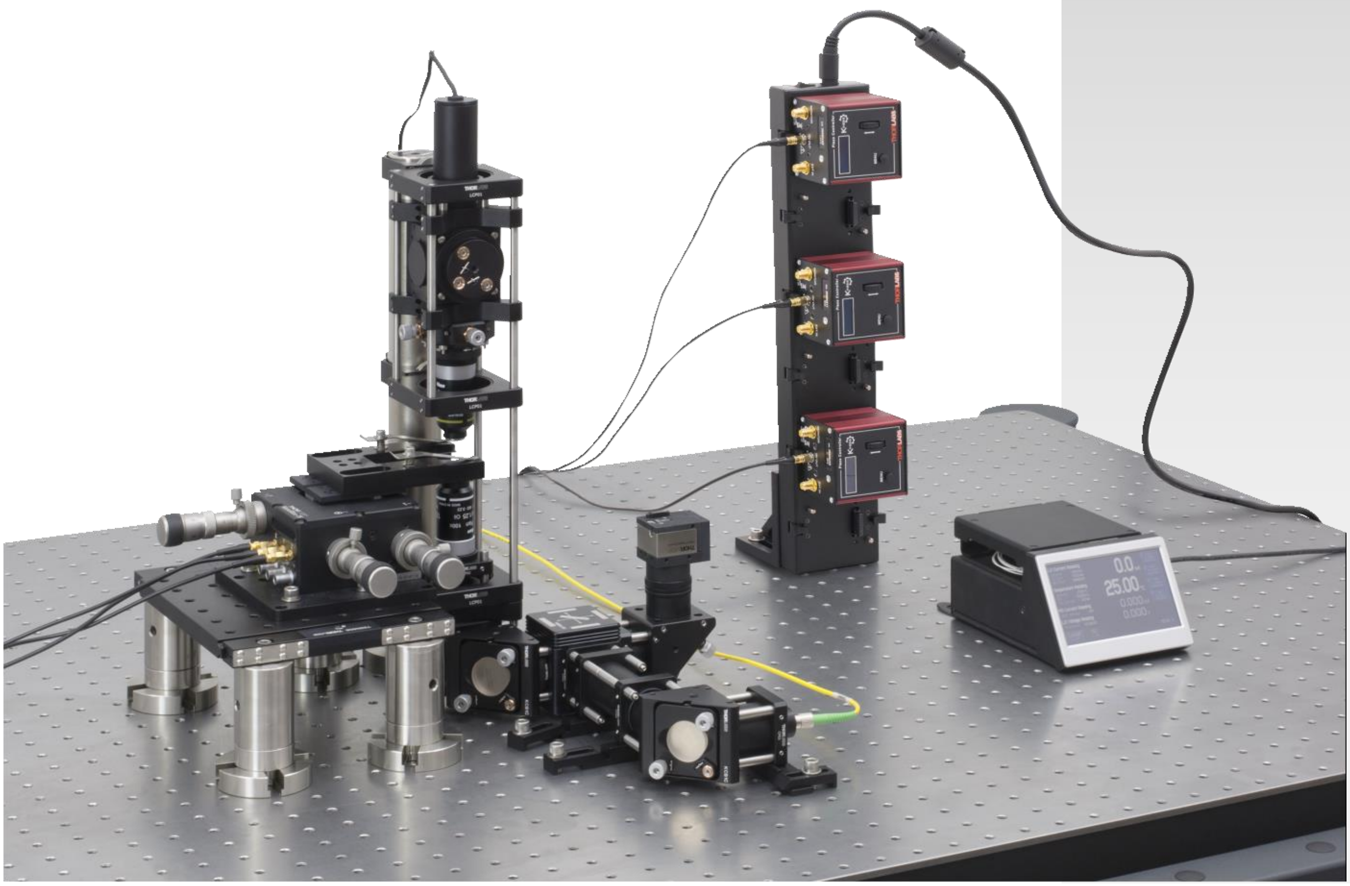
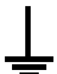
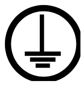
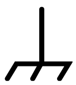


Table of Contents

Chapter 1 Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual or on your device.

Symbol	Description
	Direct Current
	Alternating Current
	Both Direct and Alternating Current
	Earth Ground Terminal
	Protective Conductor Terminal
	Frame or Chassis Terminal
	Equipotentiality
	On (Supply)
	Off (Supply)
	In Position of a Bi-Stable Push Control
	Out Position of a Bi-Stable Push Control
	Caution: Risk of Electric Shock
	Caution: Hot Surface
	Caution: Risk of Danger
	Warning: Laser Radiation
	Caution: Spinning Blades May Cause Harm

Chapter 2 Safety

All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly.

WARNING

Changing the laser diode drive current limit or the TEC drive current on the laser control unit can result in permanent damage to the laser if the limit values of the laser are exceeded.

WARNING

The modular optical tweezers system enables the user to access the laser beam without using tools, e.g. by removing the filter cube from the system. Use proper laser safety precaution at all times and check with your local laser safety officer regarding necessary precautions.

CAUTION

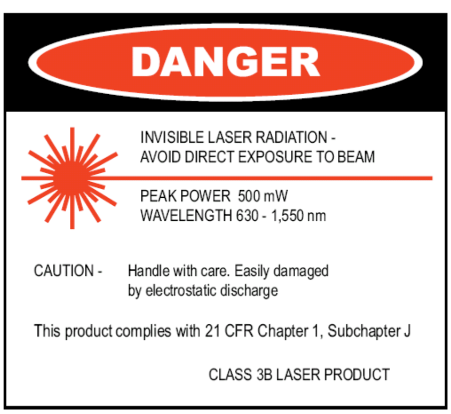
The included laser diode is sold as a component. The purchaser assumes the responsibility to comply with US 21 CFR 1040.10, US 21 CFR 1040.11, and IEC 60825-1, Edition 1.2

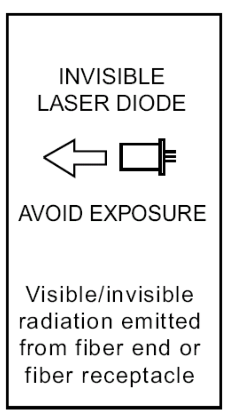
CAUTION

Latex gloves should be worn to prevent oil from fingers from reaching all optical surfaces. Make sure you use appropriate laser safety glasses during operation.

WARNING

Avoid Exposure – ASE and laser radiation emitted from apertures. Never look directly into beam





Chapter 3 Shipping List

The modular tweezers system OTKB(/M) is shipped partially preassembled. The list below describes the parts / segments included. Each segment is bagged separately. Segment 2 and 4 are completely assembled, the other segments include individual pieces as listed below.

3.1. OTKB-1: Laser Segment

Item #	Description	Quantity
BL976-SAG300	Butterfly Laser Diode (Trapping Laser)	1
P3-980A-FC-1	Single Mode Patch Cable, FC/APC, 1 m Long	1
CLD1015	Laser Diode Driver with Mount and Preinstalled ADAFC4	1
TC06APC-980	FC/APC Triplet Collimator, f=6.11 mm, 980 nm, NA=0.28	1
ER6	6" Cage Rods Used During Alignment	2
VRC4CPT	Cage System Alignment Plate with IR Disk	1
VRC5	IR Viewing Card	1
AD12F	Fiber Collimation Adapter	1

3.2. OTKB-2: Beam Expander Segment

Item #	Description	Quantity
-	Optomechanical Assembly with Mounted Optics	1
CL6	Mounting Clamps	6

3.3. OTKB-3: Vertical Segment

Item #	Description	Quantity
-	Optomechanical Assembly with Mounted Optics	1
CL5	Large Mounting Clamps	2
KPS101	K-Cube Power Supply	1

3.4. OTKB-4: Stage Segment

Item #	Description	Quantity
MAX311D (MAX311D/M)	3-Axis Piezo Stage with Feedback and Differential Drives	1
KPZ101	Kinesis Piezo Motor Controller	3
KCH601	6 Port Kinesis Cube Hub	1
MAX3SLH	Sample Slide Holder	1
P2 (P50/M)	Ø1.5" Mounting Post x 2" (50 mm)	4
PB2 (PB2/M)	Mounting Post Base	4
PS3 (PS15/M)	1/2" Mounting Post Shim	4
TBB0606 (TBB1515/M)	Large Area Translation Stage	1
CL5	Large Mounting Clamps	4
AP90	Right Angle Mounting Plate for K-Cube Hub	1
-	M3 screws, 10 mm Long to Mount Sample Holder	4
-	2 mm L-Key	1

3.5. OTKB-5: Camera Segment

Item #	Description	Quantity
-	Optomechanical Assembly with Mounted Optics and Camera	1

3.6. OTKB Accessories, Objective, Condenser

Item #	Description	Quantity
SH25S038 (SH6MS10)	1/4"-20, 3/8" SS Socket Head Cap Screw (M6, 10 mm SS Socket Head Cap Screw)	10
SH6MS12 (SH6MS12)	1/4"-20, 5/8" SS Socket Head Cap Screw (M6, 12 mm SS Socket Head Cap Screw)	10
SH25S125 (SH6MS25)	1/4"-20, 1-1/4" SS Socket Head Cap Screw (M6, 25 mm SS Socket Head Cap Screw)	10
W25S050	M6 Washer	30
OTKCON	Nikon 10X Condenser	1
OTKOBJ	Nikon 100X, 1.25 NA Objective	1

Chapter 4 Introduction

In 2007, three researchers in the Department of Biological Engineering at MIT – Steve Wasserman, David Appleyard, and Matthew Lang – built an optical trapping setup for use in teaching labs. Their results were published in the American Journal of Physics [S. Wasserman, D. Appleyard, and M. Lang, *Optical Trapping for Undergraduates*, Am. J. Phys. **75**, (2007)]. Based on their design, Thorlabs has collaborated with the aforementioned authors to design a modular tweezers system that includes all necessary components and provides the same capabilities. Moreover, since Thorlabs' components are designed to be compatible with each other, the OTKB modular tweezers system is easily modified to provide additional functionalities as your research needs evolve. For example, an excitation light source can be added by incorporating a beam splitting cube into the beam path allowing e.g. fluorescence measurements. The simple and modular nature of the system allows you to adapt it for a wide variety of applications. Additional modules can be added any time, such as the OTKB-FL fluorescence module.

Chapter 5 System Setup

Throughout the setup various hex keys are required to mount components. To remove or clamp cage system components generally a 0.05" or 1.3 mm hex key can be used. During the alignment of the vertical segment the upper dichroic needs to be removed (see step 4). For this a 1/16" or 1.5 mm hex key can be used.

Step 1: Laser Segment (OTKB-1)

Even though the description below will give a quick summary on how to use the laser diode driver (CLD1015), we highly recommend that the user reads the laser control manual.

CAUTION

Laser diode is highly sensitive to electromagnetic discharge. Make sure to wear ESD protection at all times when handling the diode.

Remove the lid from the laser diode controller and mount the laser diode as shown in Figure 1. Make sure the laser diode orientation corresponds to a type 1 pump diode. Use the mounting screws provided with the controller to attach the diode to the controller mount. This will ensure a good thermal contact between laser and mount.

We recommend coiling the fiber so that it can be placed inside the controller. Do not bend the fiber too tightly, this might break the fiber. Make sure to clean the fiber before connecting. Plug the FC/APC fiber connector into the feed through receptacle on the rear side of the controller. Note that the receptacle may be on the opposite side from the picture below. Make sure that you rotate the fiber connector until the key on the connector snaps into the groove on the receptacle. Then use the locking mechanism to screw the connector onto the receptacle.

Connect the patch cable (P3-980A-FC-1) on the outside of the back of the controller. The other end of the patch cable plugs into the collimator on the beam expander segment (see step 2).

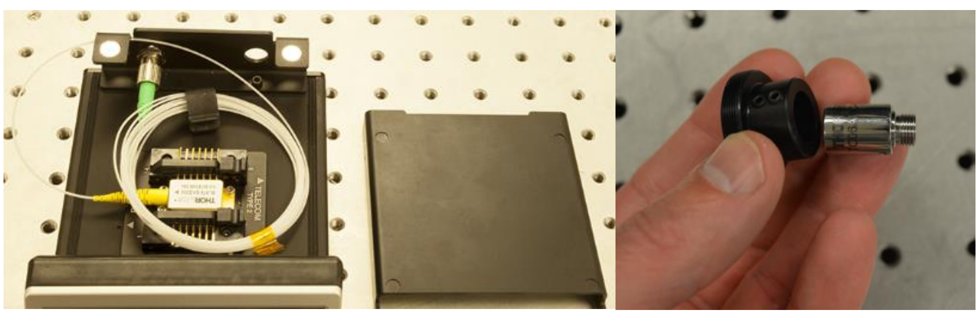


Figure 1 Left Side: Laser controller with diode installed. Right side: Collimator with adapter.

Take the laser collimator (Thorlabs part TC06PAC-980) and connect it to the adapter (Thorlabs part AD12F) as shown in Figure 1 (right side).

The laser controller (Thorlabs part CLD1015) requires settings as shown in Figure 2 and Figure 3.

Figure 2 Laser controller screen at start-up and when entering 'Menu'.

Laser Driver Setup: set 600 mA as Laser Current Limit, enable Noise Reduction Filter

Laser Protection Menu: Use the default settings

Photodiode Input Menu: The Laser is being used in constant current mode. Input Current Range = 20 mA, BIAS voltage level = 0.1 V, Photodiode response = 1000 mA/W

TEC Driver Menu: The TEC Current limit should be set to 1.5 A.

PID Control Loop Menu: Adjust Integral Gain (~0.1 As/K increments) until the Temperature Deviation is minimized, ideally it should show 0.00 °C

Thermistor Calibration Menu: Use default settings for the Thermistor Calibration.

Figure 3 Laser Controller Screens

Step 2: Beam Expander Segment (OTKB-2)

Mount the beam expander segment onto your optical table or breadboard. Six small clamps (Thorlabs item number CL6) will be used to clamp the segment down onto the table. Only tighten the screws at the laser port for now. Remove the caps which were used as protection during shipment. Connect the laser collimator/adapter built in step 1 to the laser port. Connect the patch cord coming from the laser controller.

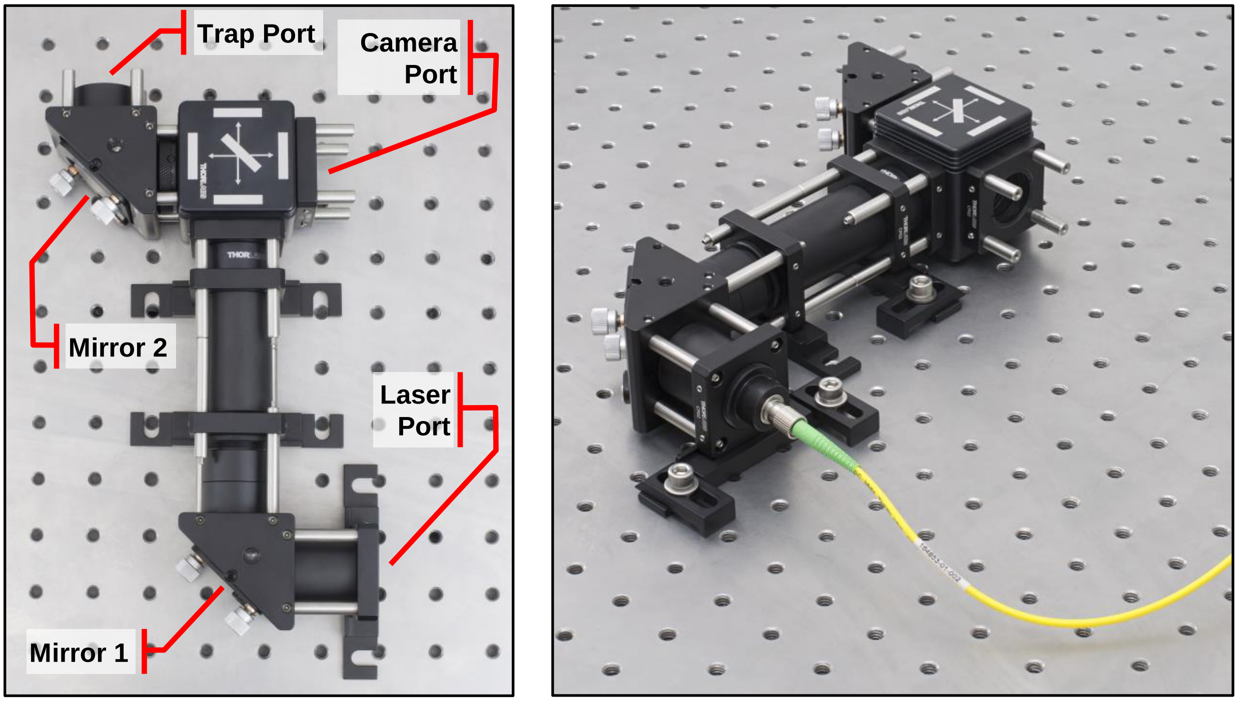


Figure 4 Left: Beam expander segment. Right: Collimator and patch cord connected to beam expander segment.

Open the beam expander segment by loosening the two set screws on the cage plate mirror 1, see Figure 4. Remove the lens tube assembly so that the beam is accessible after Mirror 1. Temporarily move the cage rod connected to the top of the laser safety cylinder, so that you can put the cage alignment plate (Thorlabs item number VRC4CPT) in place which is included in the laser segment as shown in Figure 5. Turn the laser on and use the adjusters on the right angle mirror mount to center the beam. The laser current can be set to around 100 mA for these alignment steps. Follow all laser safety regulations.

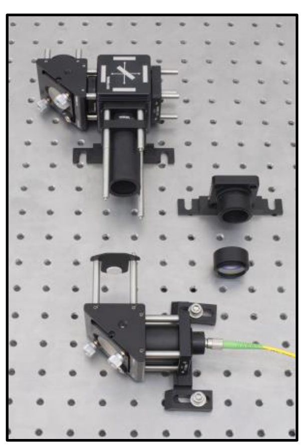


Figure 5 Beam expander segment opened to align first mirror.

Remove the alignment cage plate and put the cage rod back to its original position. Combine the two pieces of the beam expander segment again and use the remaining clamps to fix the beam expander segment in place.

Open the filter cube by pulling off the top piece and remove the cap on the back side of the cube. Be careful not to touch the optics which are premounted in the cube. Use an IR viewing card (VRC5, included with laser segment bag) to check the collimation of the laser beam. The collimation can be optimized by adjusting the distance between the two lenses in the beam expander segment. To allow such adjustment the cage rods between Mirror 1 and the dichroic filter holder do not go all the way through, but are rather connecting the two elements via cage plates where two rods connect to one elements and the other two elements connect to the second element. The first beam expander lens is located in the lens tube assembly after the first right angle mirror mount. Afterwards put the filter cube and the cap back in place to close the filter cube.

Finally connect two 6" long cage rods (included in laser segment bag) to the right angle mirror mount at the trap port, see Figure 6. Two irises are used to align the beam. The irises used in this alignment steps are included in the vertical segment. They are shipped mounted in their final location; iris 1 is located before the objective and iris 2 before the condenser in the vertical segment. Temporarily take those iris out of the vertical segment and use them during this alignment step. Iris 1 should be used with the cage plate to which it is connected in the vertical segment, i.e. simply take the iris with the cage plate out of the vertical segment and slide it onto the 6" rods used in this alignment step. See Figure 7 for the iris positions in the vertical segment.

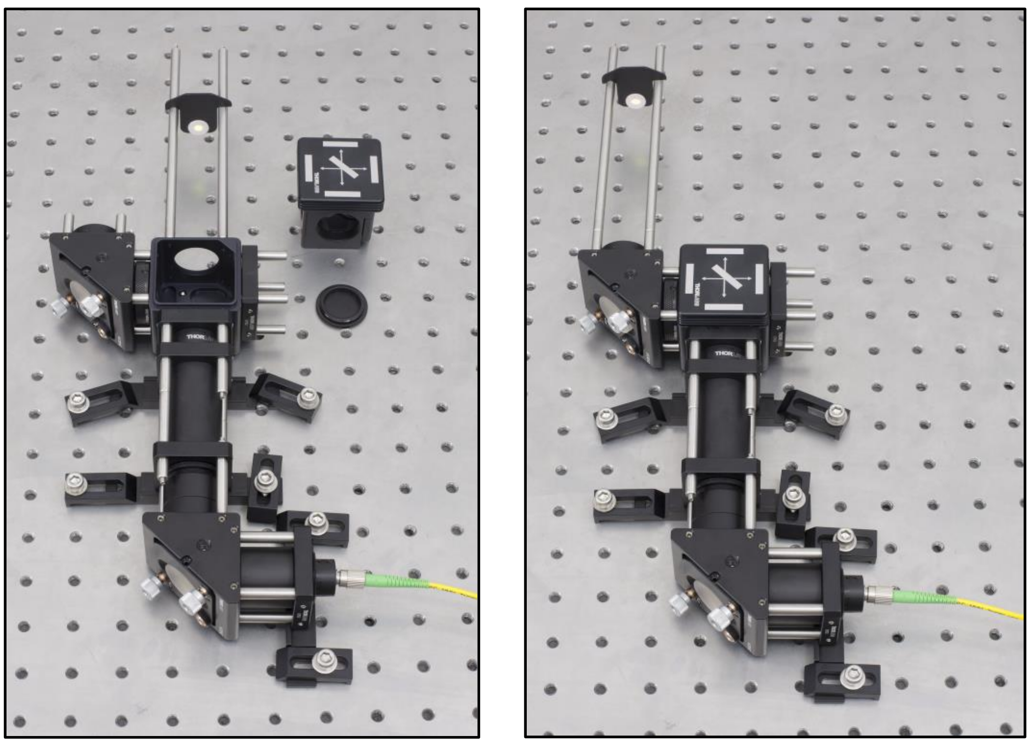


Figure 6 Checking the collimation after the beam expander.

Use a standard two point alignment procedure to center the beam: Close the iris closest to mirror 2 and use adjusters on mirror one to maximize beam throughput. Open that iris and close the second one. Now use adjusters for mirror 2 to maximize the light going through. Toggle back and forth two to three times and then check if you get light through while both irises are almost entirely closed.

Step 4: Vertical Segment (OTKB-3)

Remove any caps at the end of the segment, which are used to protect the optics during shipment.

Carefully connect the vertical segment to the beam expander segment. If the cage rods from the beam expander do not easily fit into the holders on the vertical segment, it might be necessary to loosen the three mounting screws which clamp the vertical segment onto the large vertical post (Thorlabs item number DP14A). Make sure the cage rods connecting the beam expander segment and the vertical segment slide in all the way before using the clamping screws on the cage rod receptacles (Thorlabs item number ERSCA). Based on the position of the cage rod receptacles it might not be possible to reach all clamping screws. Make sure to tighten at least two clamping screws. Use the large clamps included with the vertical segment to fix the assembly in place (Thorlabs item number CL5).

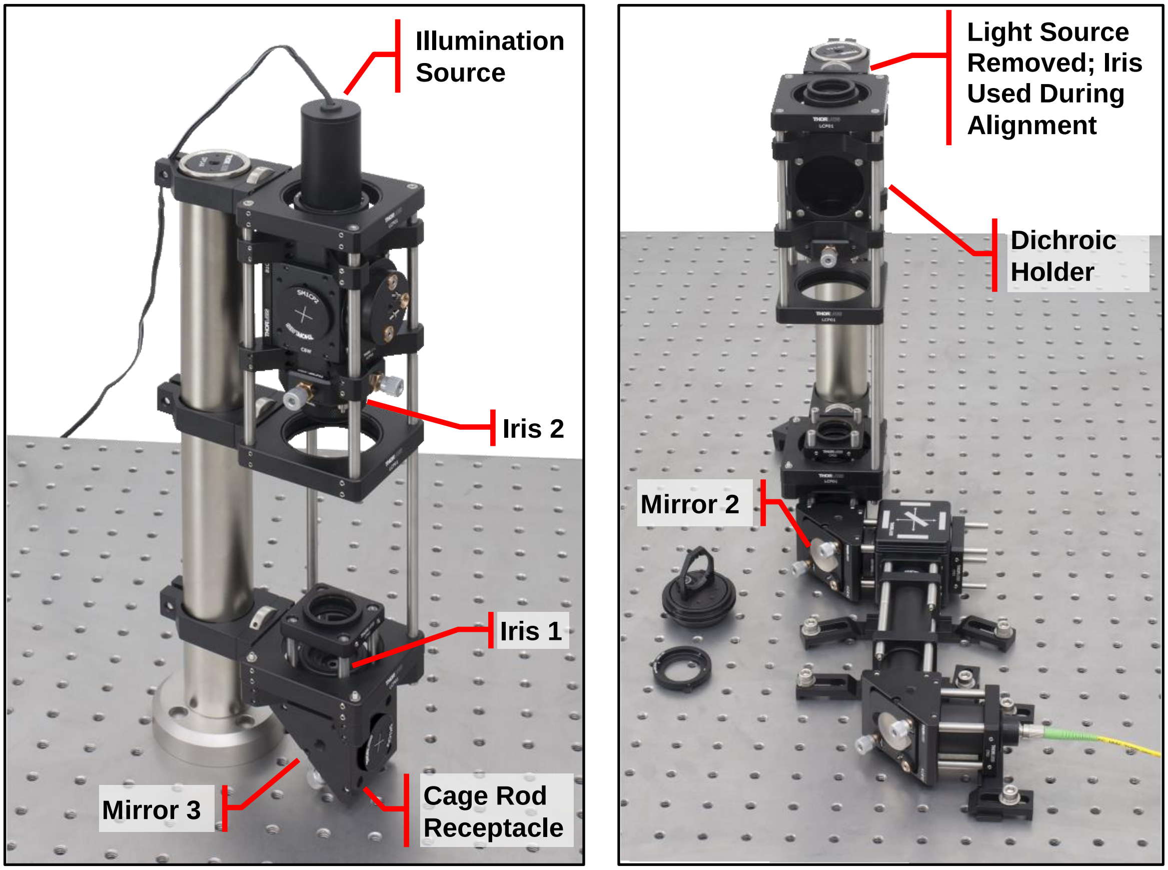


Figure 7 Left Side: Vertical segment with final Iris locations, Right Side: Upper dichroic and visible light source removed, iris temporarily mounted on top.

Next remove the upper dichroic mirror holder using a 1/16" (1.3 mm) hex key to remove the four screws holding the inner ring of the dichroic base plate and temporarily replace the illumination light source with an iris. Place iris 1 with the cage plate used in step 3 back to its final position. Use iris 2 at the light source position. Use a two point alignment to align the beam along the vertical path, i.e. only adjusters on mirror 2 and on mirror 3 should be used. It may help to use cage rods to mount the IR viewer during alignment.

Afterwards mount Iris 1 at its final position and put the illumination light source back. Re-mount the dichroic, making sure it maintains a 45° angle with the respect to the light path.

Step 5: Camera Segment (OTKB-5)

Remove the protective cap and connect the tube lens (Thorlabs Item # AC254-200-A-ML). Connect the assembly to the beam expander segment at the camera port by sliding it onto the cage rods on the camera port side of the beam expander segment. Tighten the clamping screws on the cage rod receptacles.

Figure 8 Camera Segment

Step 6: Stage Assembly (OTKB-4)

Use the four posts, post spacers and post bases to mount the translating bread board and subsequently the nanopositioning stage as shown in Figure 9. To mount the sample holder remove the four M3 screws in the center of the top plate of the nanopositioning stage using the metric key included with the stage assembly. Then add the sample holder and tighten it using the four M3, 10 mm long screws, included in the stage assembly. Position the assembly close to the vertical segment and attach it to the table using the included clamps (Thorlabs item number CL5).

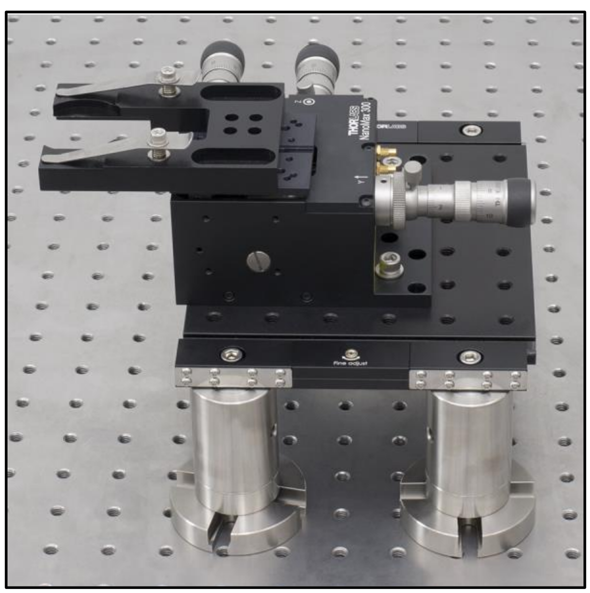


Figure 9 Stage Segment

Mount the piezo controllers (Thorlabs item number KPZ101) on the controller Hub (Thorlabs part KCH601). The included right angle bracket (Thorlabs part AP90) can be used to mount the controller hub vertically as shown in the picture on the front page of the manual. Note that the threads require metric screws. Connect the piezo elements on the stage with the controllers.

Step 7: Software Install

The OTKB system does not include any specific trapping software. The controller units and the camera however come with their respective software programs.

The Piezo K-Cube controllers can be controlled via a PC using Thorlabs' APT software package. This package can be installed using the installation medium included with the controllers. Alternatively the package can be downloaded from the Thorlabs web page (**www.thorlabs.com**), see the Service section, Downloads and select Motion Controllers. After installing the package the APT User Program can be used to control the KPZ101 piezo controllers and adjust the stage position.

The second software element needed is the camera viewer software to display the camera image. Install the corresponding software to display the video image.

Step 8: Testing

After putting the objective and condenser into place, move the sample stage close to the setup and clamp it down on the optical table. The 100X objective is used to create the diffraction limited focal spot and connects to the lower port on the vertical segment. The iris which is located underneath the objective should be fully opened. It can be used to adjust the back aperture size, which affects the trap stiffness. The distance between objective and condenser will need to be around 7 – 8 mm based on the working distances of the two optics.

Connect the illumination light source to its power supply and mount condenser and objective in the vertical segment. Prepare a test sample, according to the instructions in Chapter 7, mount it on the sample holder and use the translating breadboard to slide the sample to a position above the objective. Put immersion oil onto the objective and carefully lift the objective by moving the cage plate to which it is connected upwards. Get the objective close to the slide, ideally so close that you can see the immersion oil making contact with the slide. At that point clamp the cage plate in place and use the manual z-adjuster on the stage to the get the image into focus looking at the camera image.

Enable the laser and set a current value of 500 mA, observe if beads are pulled into the trap. If not, move the stage using the manual stage adjuster (X or Y) to get a bead close to the trap. If still no bead is being trapped, check the camera field of view by closing the iris which is located in the beam expander segment between the dichroic and Mirror 2, see Figure 10, and checking if your camera image is centered. If it is not centered, use the adjusters on the mirror closest to the camera to change the position which is imaged by the camera. If the laser beam alignment is not precise enough your trap might be off-center, in that case adjusting the camera to different image positions might as well allow you to locate the trap.

Chapter 6 Setup Details

The following section describes the various optical components used in the modular tweezers setup as well as the optical path in the system in general. The corresponding Thorlabs item numbers are listed, so that additional information for those parts can be accessed via the Thorlabs Homepage at **www.thorlabs.com**:

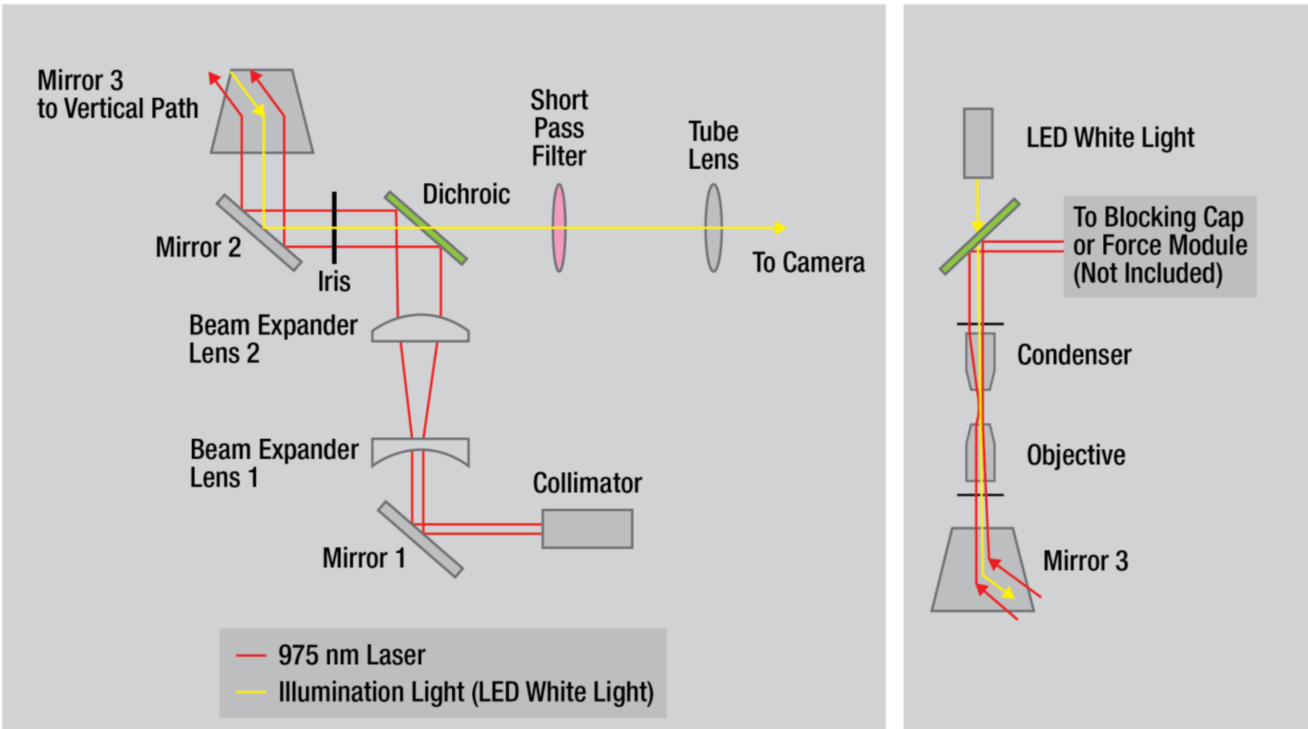


Figure 10 Left Side: Beam Expander Segment. Right Side: Vertical Segment

The laser light is being delivered to the system via a SM980-5.8-125 single mode fiber. The corresponding Thorlabs Part Number of the patch cord included in the system is P3-980A-FC-1. This fiber has a numerical aperture of 0.14. The laser light is then collimated using a high-end triplet collimator, Thorlabs item number TC06APC-980, focal length of 6.11 mm, NA=0.28 which results in a beam diameter of about 1.7 mm.

After mirror 1 the beam is expanded by a Galilean beam expander using achromatic doublets with -50 mm and +150 mm focal length (Thorlabs item numbers ACN254-050-B and AC254-150-B). The expansion factor is approximately 3.

A dichroic reflects the 976 nm trapping laser towards the objective and transmits the visible illumination light towards the camera (Thorlabs item number DMSP805R). To prevent any laser light from reaching the camera a premium hard-coated shortpass filter is placed in front of the camera. It has a cut-off wavelength of 750 nm (Thorlabs item number FESH0750). A mounted achromatic lens with 200 mm focal length in front of the camera is used as tube lens (Thorlabs item number AC254-200-A).

The 976 nm trapping laser source is a pigtailed Fiber Bragg Grating (FBG) stabilized single mode laser diode in a hermetically sealed 14-pin butterfly package. The maximum drive current of the laser diode is 730 mA. The maximum TEC current for this laser is 0.9 A. The laser is used in constant current mode.

The trapping objective is a 100X oil immersion Nikon objective lens with 0.23 mm working distance, the condenser is a 10X Nikon objective lens with 7 mm working distance. The calculated diffraction limited trap diameter is 1.1 µm. The 10X Nikon objective used as the condenser collimates the beam after forming the optical trap in the sample plane.

Chapter 7 Sample Preparation and Measurement

For initial testing we recommend 1 µm or 2 µm silica beads. The sample solution loaded into the channel using a microscopy slide with built-in channel (offered via our optical trapping accessories kit, Thorlabs item number OTKBTK, sold separately), or you can build a simple channel by placing double sided tape on a standard slide, and adding a cover glass on top. Liquid can be pipetted in-between. The two open sides can be sealed off with nail polish, to prevent the sample from drying out. Place the slide onto the sample holder and carefully place the slide between objective and condenser. Make sure to either use immersion oil on the bottom of the slide or to apply it to the objective before trying to image the sample.

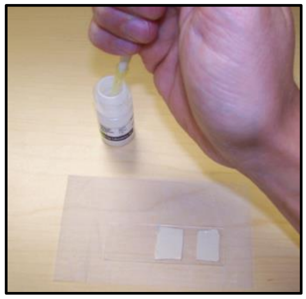


Figure 11 Beads are diluted using a pipette and placed between strips of double sided tape.

Chapter 8 Accessories and Add-on Modules

The open design concept of the modular tweezers setup allows the user to add modules to the system as required. The integration of our force measurement module enables the user to do quantitative force measurements and a fluorescence module enhances the imaging capabilities of the setup. Figure 12 shows an example including the force module as well as the fluorescence module. Please contact us for additional information regarding those modules.

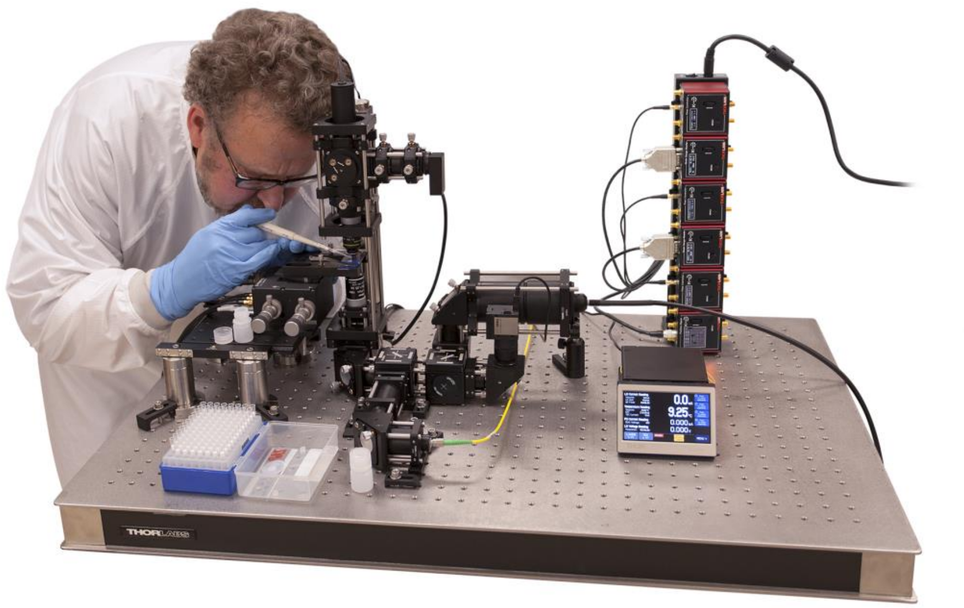


Figure 12 Modular tweezers system with force and fluorescence modules.

The following list of parts will be helpful to setup and operate the trap. They are not part of the Modular Tweezers System:

- Sample Preparation kit including immersion oil and silica beads, Thorlabs Part Number OTKBTK
- Power meter, e.g. Thorlabs Part Number PM100D with S121C measurement head.
- Appropriate laser goggles, like the Thorlabs Part Number LG1 – (Laser Safety Glasses, Light Green Lenses, 59% Visible Light Transmission).

Chapter 9 Key Features and Specifications

9.1. Features

- Pre-assembled segments
- Trap Laser Source
  - SM Fiber Coupled DFB Laser, 14-Pin Butterfly Package
  - 976 nm, 300 mW (Max)
  - Integrated TEC Element for Temperature Stabilized Output
  - LD Controller and Mount Included
- Nikon 100X Oil Immersion Objective
- Nikon 10X Condenser
- Inverted Light Microscope Design
- 3-Axis Sample Positioning Stage with piezo adjustment and closed loop capability
- Camera with USB Interface for Video Imaging

9.2. Specifications

General Specifications	
Trap Force	~10 pN*
Spot Size	1.1 µm
Depth of Focus, estimated	1 µm
Trap Laser Output Power (Max)	300 mW (at Fiber End)

* At a trap wavelength of 976 nm, laser power at the trap focus of 140 mW, and a beam diameter of 5.1 mm at the back aperture of the objective.

Nikon 100X Oil Immersion Objective	
NA	1.25
Back Aperture	∅5 mm
Working Distance	0.23 mm
Transmission	380 – 1100 nm
Recommended Cover Glass Thickness	0.17 mm

Nikon 10X Air Condenser	
NA	0.25
Working Distance	7 mm
Transmission	380 – 1100 nm

Chapter 10 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

- This offer is valid for Thorlabs electrical and electronic equipment:
- Sold after August 13, 2005
- Marked correspondingly with the crossed out "wheelie bin" logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated

Wheelie Bin Logo

As the WEEE directive applies to self-contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:

- Pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

Waste Treatment is Your Own Responsibility

If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

Chapter 11 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at www.thorlabs.com/contact for our most up-to-date contact information.

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UNLEASHED
Ezra