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# THORLABS

## OTM211 Optical Tweezer System

### User Guide



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## 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.

**SHOCK WARNING**


**Before applying power to the system, make sure that the protective conductor of the three-conductor mains power cord is correctly connected to the protective earth contact of the socket outlet. Improper grounding can cause electrical shock resulting in serious personal injury or death.**

**Ensure that the line voltage switch is set correctly for your local supply and that the appropriate fuses are installed. *Fuses should only be changed by qualified service personnel.***

**The OTM211 contains no user-serviceable parts. Do not operate without cover installed. Refer all maintenance to suitably qualified personnel. Contact Thorlabs for assistance.**

**CAUTION**

**Do not obstruct the unit's air ventilation slots and fan outlets.**

**WARNING**

**This equipment contains a high power infrared laser. Radiations from this laser are not visible to the human eye and can cause serious damage to your eyesight.**

**All laser radiation is enclosed during normal operation.  
Do not attempt to defeat interlocks.**



## Chapter 3 Description

### 3.1. Introduction

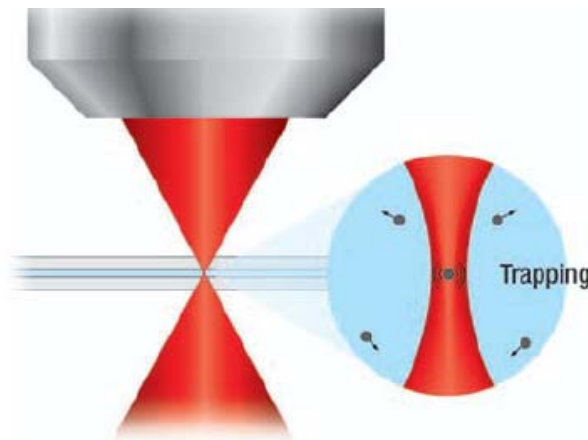
The Thorlabs OTM211 is an optical tweezers system designed for inverted microscopes. It provides two independent trapping beams that allow the manipulation of nano- and micro particles. Each path can be used to create several additional traps. The system is completely computer controlled and offers a graphical user interface which provides the user with a set of tools for the most common trapping experiments. The detector module included in the OTM211 allows users to perform quantitative force measurements and particle tracking. The included Software Development Kit enables users to easily create applications optimized for their specific needs and allows integration into more complex setups.

The OTM211 system integrates with existing imaging modalities, such as fluorescence, Raman, confocal, phase contrast. Further on the system is compatible with all major microscope platforms.

### 3.2. Theory

Optical Tweezers, or traps as they are often called, are created by using a high numerical aperture objective to tightly focus a laser beam thereby creating a spot where a dielectric particle with dimensions of the order of  $0.3\mu\text{m}$  to a few microns will experience a force due to transfer of momentum from the scattering of photons.

Arthur Ashkin in the early 1970s originally demonstrated that optical forces can manipulate micron-sized dielectric particles in water (*Ashkin et al, Optics Letters, Vol 11, No. 5, may 1986*). This technique has become an important tool in a wide range of fields such as bioengineering, material science, and physics due to their ability to hold and manipulate micron-sized particles and to measure forces in the piconewton and femtonewton ranges.



**Figure 1 Theory of Optical Trapping**

The capability of optical tweezers to exert measurable forces on dielectric particles offers a unique and valuable tool for studying cell components such as biological proteins and molecular motors. In many investigations, optical tweezers apply force to functionalized microspheres that have been attached to molecules of interest. Optical tweezers apply a force toward the focus of the trapping laser beam with a magnitude proportional to the distance of the particle from the focus, for small displacements from the center of the trap. This allows the optical tweezers to be modeled by Hooke's law,  $\mathbf{F} = -k\mathbf{d}$ , where  $\mathbf{d}$  is the displacement from the center of the trap and  $k$  is the force constant. As the laser beam passes through a trapped particle, it will be deflected by an amount that depends on the position of the particle. Accurate force measurements depend on precise calibration of the spring constant,  $k$ , and the particle position which varies with laser power and particle properties.

Three methods for ascertaining the force constant,  $k$  are: Equipartition, PSD Rolloff and Stokes' drag. Since each method relies on a different physical principle, the combined results provide a convenient way to verify the calibration.

The Equipartition method equates the average potential energy of the particle in the trap to the thermal energy of the solvent molecules. In this method, a sample of particle positions is obtained by recording the position detector output over time and converting the voltages to distances using the detector responsivity. For PSD roll off, the power spectral density of a time series of trapped particle positions is computed and fitted to the response of a harmonic oscillator with known damping due to the viscosity of the solvent. In the Stokes method, the sample is translated in a range of velocities. A force balance between viscous drag on the particle and the trap force is computed.

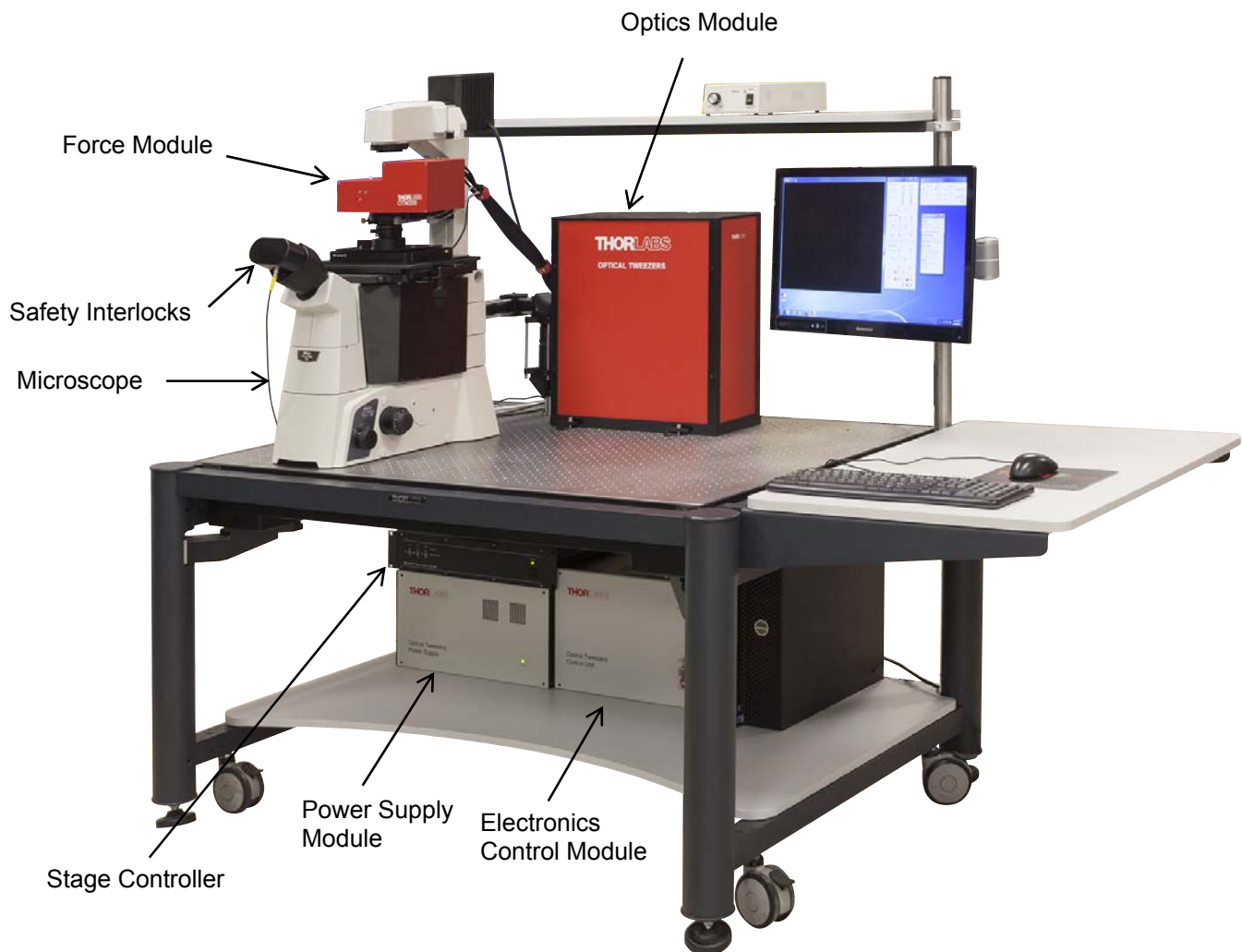
### 3.3. Key System Features

- Multiple traps with computer control
- Force Measurement Capability
- Software user interface with enhanced mouse control of multiple time shared traps
- Multiple trap pattern creation with arbitrary spacing – circles, lines, rectangles
- IR laser with independent power control
- Two independent trap paths with multiple time-shared traps per path
- Active intensity stabilization of each trap beam with integrated noise eaters
- Concurrent standard microscopy techniques like fluorescence
- Compatible with major inverted microscope platforms
- Fully enclosed beam path – Class 1 certified
- Galvo-scanning beam control
- SDK package

### 3.4. System Components

The OTM211 includes the following modules:

- Optics Module
- 1.3NA Trapping Objective and Condenser
- 1600 x 1200 CCD Camera with Imaging Adapter
- Electronics Control Module
- Power Supply Module
- Nikon Eclipse Ti-S Inverted Microscope with high resolution XYZ Piezo Stage
- Force Module
- Computer with Monitor and Accessories



**Figure 2** Modules of Complete OTM211 System

### 3.5. Optics Module

The optics module includes all the optical and opto-electronic components for creating and controlling multiple optical traps. The conditioned output beam is coupled into the microscope. A schematic for this module is shown below.

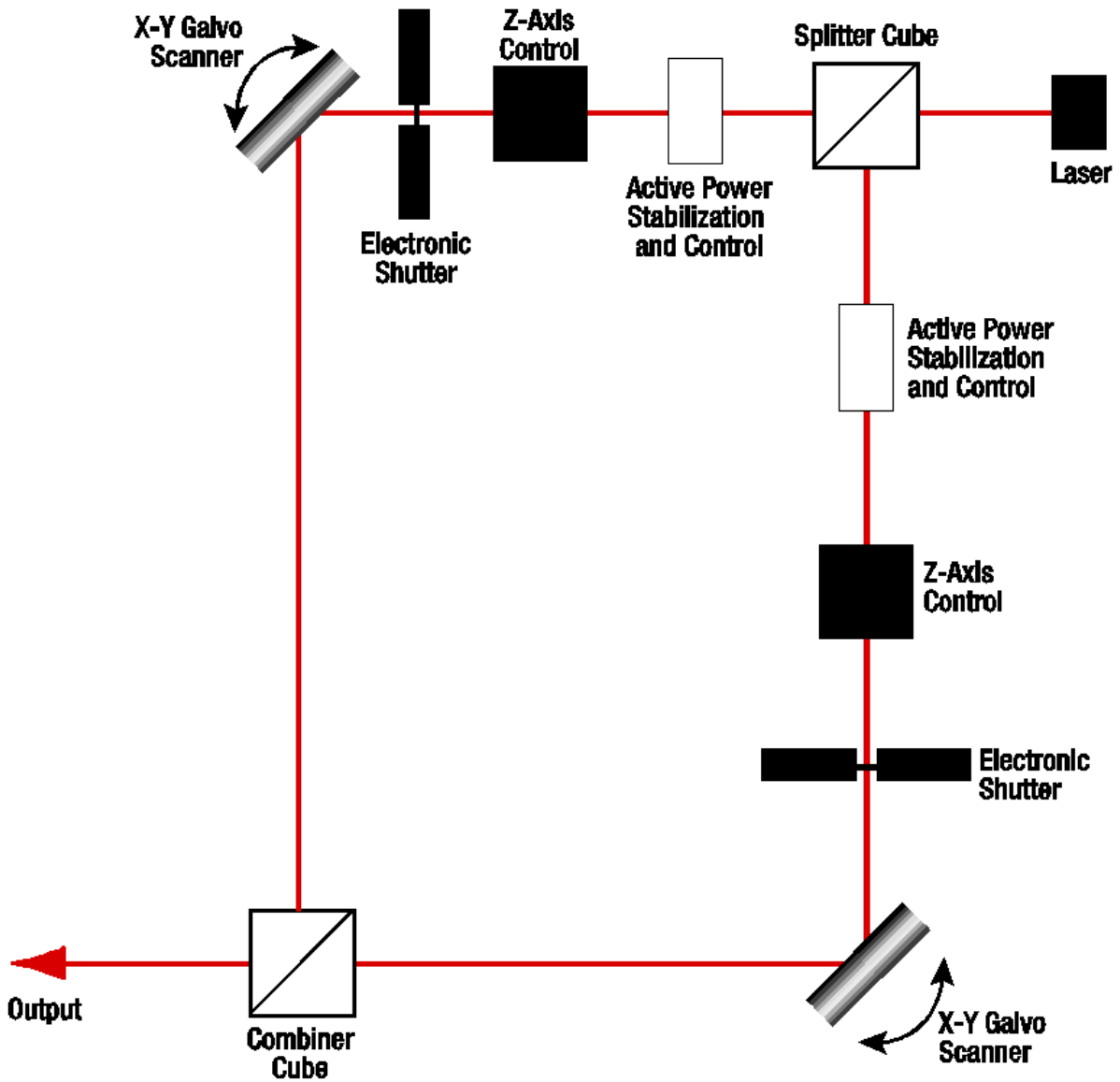
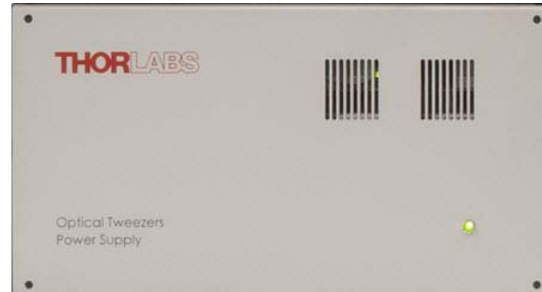


Figure 3 Schematic of Optics Module



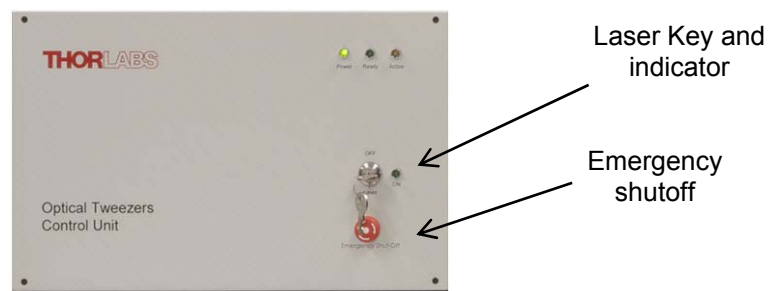
### 3.6. Power Supply and Electronic Module

These two modules provide power and contain the control circuitry for the components in the optics module. The rear panel of the power supply module has connection to the mains power supply and to the electronics module. The front panel has an LED indicator when power is ON.



**Figure 4** Power Supply Module Front Panel

The Electronics module houses the laser source. The rear panel has the interfaces for all cable connections to the optics and power supply modules. The bottom right of the front panel of the electronics control module has a key and an emergency shut-off switch for the laser. Three LEDs at the top are used to indicate main power, PC connection, and USB data transfer.



**Figure 5** Electronic Module Front Panel

### 3.7. Interlock System

For user safety, the system has four interlocks. There is the illumination pillar interlock, the viewport interlock, sample cover interlock. Additionally a remote interlock connection is provided for user integration. All four interlocks must be closed for laser emission.

The system is classified as a Class 1 laser.



**Figure 6** Interlock System: (left) Viewport (and (right) Sample Cover

## Chapter 4 Operation

### 4.1. Starting the System

To power up the OTM211 system, follow the steps below.

1. Start the Power Supply Module by placing the POWER switch on the back of the unit to the “I” position. Verify that the “POWER ON” indicator turns green on the lower front side of the unit.
2. At this time, the “Power” and “Ready” indicators on the Electronics Control Module will turn on.
3. Turn the key switch on the Electronics Module to the “ON” position.
4. Check the emergency stop button and make sure it is in the “Enable” position.
5. Make sure all interlocks are closed.

### 4.2. Graphical User Interface

The OTM211 system comes with a pre-installed software which contains everything needed for system control and data acquisition. In addition an SDK is provided to allow users to easily create applications optimized for their particular requirements.

The GUI has five main areas:

- The Camera Display
- The Laser Control
- The Stage Control
- The Trap Control
- Tools

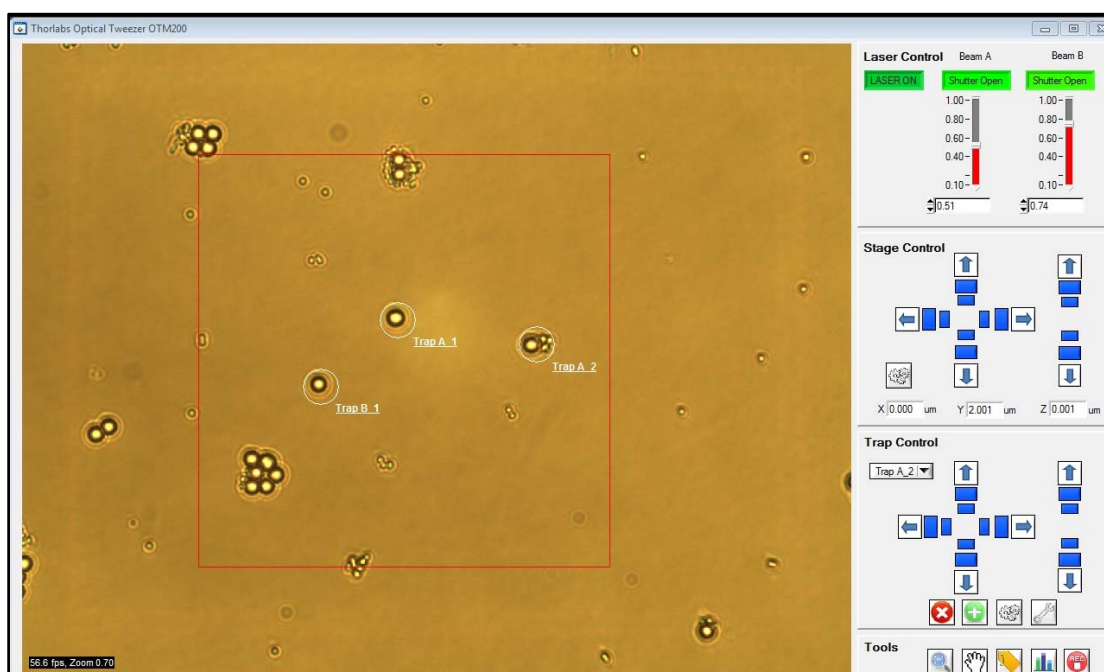


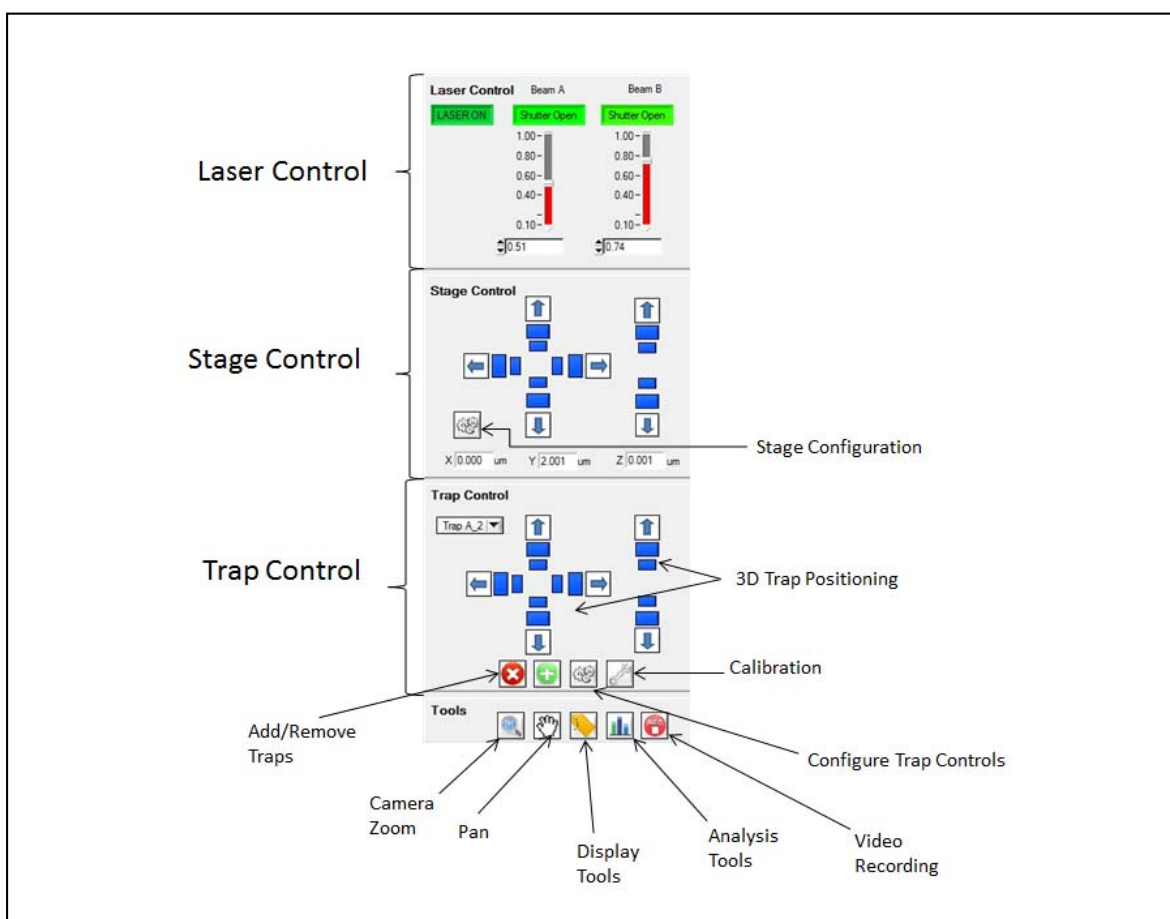
Figure 7 OTM211 Software User Interface

The main screen of the software contains two areas: the video image acquired from the camera on the left side and controls for the system on the right side. The control sections consist of four segments: Laser, Stage, and Trap Control as well as Tools.

In a typical trapping application a user will trap a particle by positioning the trap either by clicking on the camera image or by using the adjuster buttons in the trap control section. Which trap is currently selected is indicated in the drop-down list. If a new trap is added the currently selected beam path (A or B) will be used to add another time-share trap location. The position of the new trap can be set by clicking on the camera image. The tool section allows the user to select information which will be display for the traps on the camera display, such as the trap label and position.

The speed and step size for the trap movement are adjustable and can be optimized, e.g. when switching between different objectives.

The analysis tools depend on the system configuration and provide access to e.g. force spectroscopy measurement or particle tracking.



**Figure 8 OTM211 GUI Showing Controls**

### 4.3. SDK

The OTM211 Tweezers System is supplied with a software development kit (SDK). The SDK gives access to all features of the instrument, thus enabling the creation of custom, application-specific software. The SDK is provided as a 64 Bit Windows dynamic link library (dll). Language bindings for C, National Instruments LabView and C# are available. For details, please refer to the OTM211 Programmer's Reference Manual.

## Chapter 5 Operating Conditions and Environmental Requirements

The system will be installed by a member of the Thorlabs team. In preparation for install, the following considerations should be taken into account.

### 5.1. Selecting a Suitable Operation Environment

In order to deliver optimal performance we recommend installing the OTM211 Optical Tweezers System on an actively vibration-damped surface. Thorlabs offers a variety of vibration-damped optical tables and microscopy workstations. Please contact Thorlabs Technical Support for detailed information.

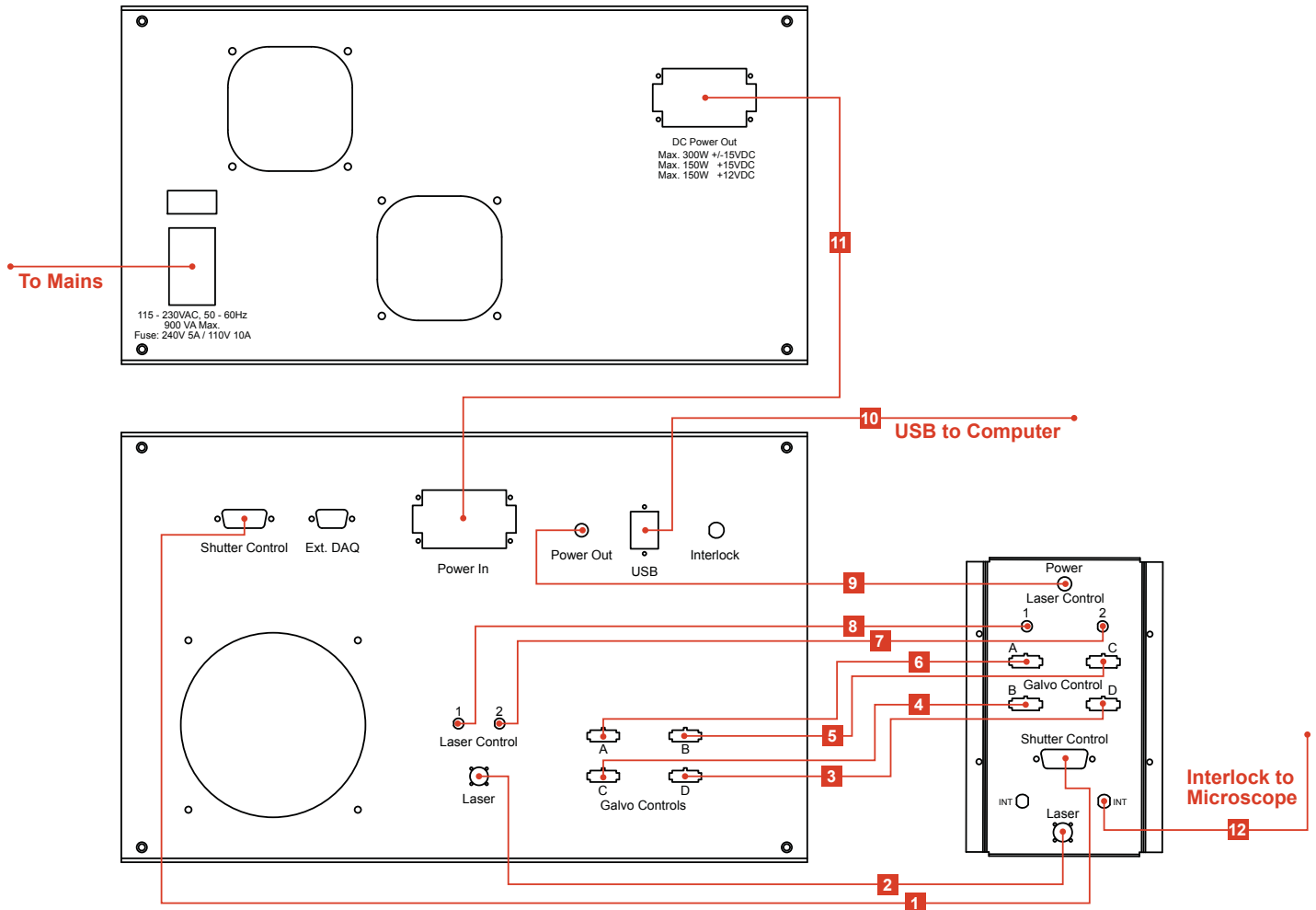
The following guidelines should be considered when installing the system:

- Do not store or operate in damp, condensing environments
- Do not expose to direct sunlight
- Do not use solvent on or near the equipment
- Keep away from dust, dirt, and air-borne pollutants
- The system is not designed for outdoor use. Protect from rain, snow, and humidity
- Do not expose the system to mechanical or thermal extremes. Protect the equipment from rapid variation in temperature
- Handle all connectors and wiring with care. Do not use unnecessary force as this may damage the connectors.
- Handle the optical fiber with care. Mechanical stress can decrease performance and potentially destroy the fiber. Continual bending of the optical fiber can cause damage. We suggest keeping the optical fiber as straight as possible and maximizing bend radii.
- The OTM211 optical tweezers system is a precision instrument and must be handled accordingly. If the system needs to be moved to a new location, please contact the Thorlabs team prior to doing so.

## Chapter 6 System Connections and Care

### 6.1. Module Connections

The figure below shows the schematic for the rear panel connections for the optics, electronics, and power supply modules.



**Figure 9 Schematic of Rear Panel Connections**

#### 6.1.1. Cable Descriptions

- 1: Shutter
- 2: Fiber
- 3-6: Galvos
- 7-8: Laser Power Control
- 9: Power Cable for active Laser stabilization
- 10: USB to computer
- 11: Electronics Module Power Supply
- 12: Interlock Cable to Microscope

The **Shutter Control** cable, **NE Power Out**, **USB**, **Laser Control 1** and **2**, **Galvo Controls** cables (**A**, **B**, **C** and **D**) for all four scanners) are labeled on the Optics Module Connecting Cable Bundle. The Ext. DAQ Connection is reserved for custom applications.

## **6.2. Service**

Only trained Thorlabs personnel are allowed to open any of the modules to service the system. Please contact Thorlabs Technical Support for more information.

## **6.3. Accessories and Customization**

The Thorlabs OTM211 Microscope Tweezers System can be offered in several configurations, e.g. different wavelength, optical power levels, integrated with additional imaging modalities.

To achieve the listed specifications the system should only be used with the accessories that Thorlabs provides. Any modification or maintenance by unqualified personnel will render the warranty null and void, leaving Thorlabs free of liability. Please contact Thorlabs Technical Support for questions on customization.

## Chapter 7 Specifications

### 7.1. Laser Specifications

Laser Specifications	
Center Wavelength	1064 nm
Emission Bandwidth (FWHM)	<0.25 nm
Output Power (before split)	5 W
Fiber	Panda 980
Polarization State	Linear
Output Power instabilities (rms)	<0.2%
Output Beam Shape	Gaussian, with $M^2 < 1.1$

### 7.2. Power Requirements

Power Specifications	
Voltage	120 – 240 V
Maximum Power Consumption	1000 VA

### 7.3. Dimensions and Weights

Dimensions and Weights		
	Dimensions	Weight
Optics Module	17" x 8" x 19" (432 mm x 204 mm x 483 mm)	40 lbs (18 kg)
Electronics Module	17" x 15" x 10" (432 mm x 381 mm x 254 mm)	20 lbs (9 kg)
Power Supply Module	17" x 13" x 9" (432 mm x 331 mm x 229 mm)	40 lbs (18 kg)
Piezo Stage Controller	17.7" x 3.5" x 13.5" (450 mm x 88 mm x 343 mm)	17.5 lbs (7.9 kg)

## Chapter 8 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.

### 8.1. 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.

### 8.2. 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 9 Thorlabs Worldwide Contacts

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



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