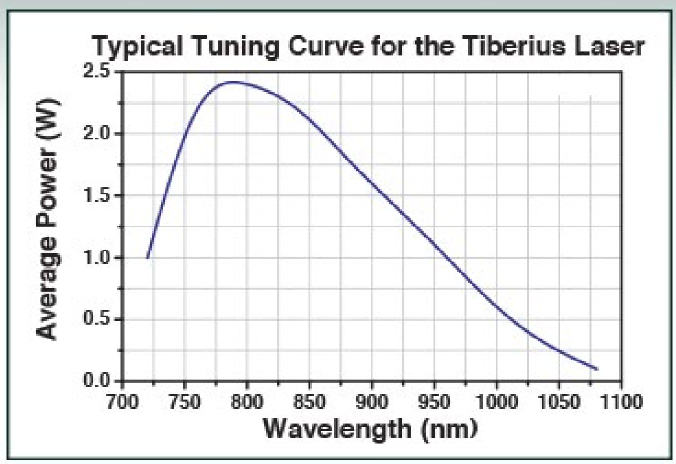
TIBERIUS- August 22, 2024

Item TIBERIUS was discontinued on August 22, 2024. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

TI:SAPPHIRE FEMTOSECOND LASER FOR TWO-PHOTON MICROSCOPY

- **Wide Tuning Range: 720 - 1060 nm**
- **Fast Tuning: Up to 4000 nm/s**
- **Half the Footprint of Competing Models**



TIBERIUS
Ti:Sapphire Femtosecond Laser,
720 - 1060 nm Tuning Range

OVERVIEW

Features

- Wide Tuning Range of 720 nm to 1060 nm
- Industry-Leading Tuning Speed: Up to 4000 nm/s
- High Output Power: >2.3 W at 800 nm
- Ultrafast 140 fs Pulses
- Compact Footprint Uses Half the Table Space of Competing Lasers
- Integrated Spectrometer for Real-Time Diagnostics
- Pure Air Circulator Unit Included to Purge Laser Cavity for Smooth Tuning Through Water Absorption Lines

Typical Applications

- Multi-Channel Fluorescence Images of 3D Volumes
- Photostimulation and Uncaging
- Label-Free Imaging via Multiphoton Autofluorescence and SHG

Matt Kirchner
Site Manager
Laser Divison - Colorado
Feedback?
Questions?
Need a Quote?

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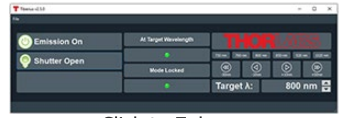
Thorlabs' Tiberius® Ti:Sapphire Laser provides 140 fs pulses over a wide tuning range with industry-leading tuning speeds of up to 4000 nm/s. Collaboratively designed and manufactured in-house with Thorlabs' multiphoton imaging specialists, this femtosecond laser offers hands-free operation that easily meets the stringent demands of the nonlinear optical imaging community. See the *Design and Manufacturing* tab for more information about how the Tiberius Ti:Sapphire Laser leverages Thorlabs' extensive expertise in optical design and precision manufacturing.



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Included GUI for Control of the Tiberius

An ideal choice for two-photon microscopy, the Ti:sapphire laser cavity offers an average power greater than 2.3 W at 800 nm and a wavelength that is tunable from 720 nm to 1060 nm, allowing the user to target specific compounds for two-photon fluorescence imaging and photostimulation / uncaging. Tiberius' industry-leading tuning speed is demonstrated on the *Fast Tuning* tab, and a tuning curve is shown on the *Specs* tab.

This femtosecond laser emits pulses that are 140 fs in duration with a relatively narrow spectral bandwidth. This spectral design reduces the effect of pulse broadening caused by Pockels cells and other dispersive elements while still providing high peak intensity for two-photon excitation.

Since tabletop space is often at a premium, the Tiberius laser has been designed with a vertical cavity construction that minimizes the footprint on the optical table. At 746.3 mm x 190.0 mm (29.38" x 7.48"), the Tiberius' footprint is about half that of competing designs, preserving valuable workspace for the rest of your experimental setup. Each laser also comes with a laser controller, pump laser controller, chiller, and pure air circulator unit.

For laser operation, the Tiberius Ti:Sapphire Laser includes an intuitive GUI. User-programmable buttons provide single-click access to commonly used excitation wavelengths. In addition, the Tiberius is integrated with ThorImage®LS, enabling seamless and synchronized control for photoactivation experiments and live high-speed imaging.


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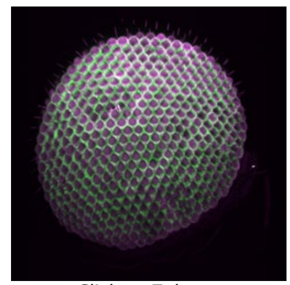
The Tiberius being used with our Bergamo® II Series Microscopes for two-photon imaging. The system shown here features Tiberius as the primary laser in co-registered dual beam paths for simultaneous photostimulation and high-speed imaging.

Two-Photon Imaging

Structural Insight


Click to Enlarge
The Tiberius fs Laser Source Used to Resolve Morphological Features of a Fruit Fly's Eye

Multiphoton microscopy takes advantage of the NIR transparency windows in living tissue and highly localized excitation to generate multi-channel fluorescence images of 3D volumes. Compared to visible light, which is used in conventional widefield microscopy and confocal microscopy, NIR light offers significantly reduced scatter and absorption by biological compounds, resulting in deeper images below the surface.

The image of a fruit fly eye to the right demonstrates the Tiberius' ability to resolve morphological features. This two-channel image contains GFP-labeled photoreceptors and unlabeled regions that exhibit multiphoton autofluorescence. The excitation wavelength was 770 nm and a 25X, NA 1.05 Olympus objective was used.

FAST TUNING

Improved Image Contrast with Fast Tuning

With an industry-leading tuning speed of up to 4000 nm/s, the Tiberius® Ti:Sapphire Laser is ideal for fast sequential imaging. The Tiberius' fast-tuning capability provides high-contrast images when used in multi-color, multiphoton microscopy applications.

Quickly switching between two optimized excitation wavelengths has several benefits over single-wavelength excitation. These include the much higher image contrast provided by fast switching and being able to maximize fluorescence at lower excitation powers, which reduces the risk of photobleaching.

Figures 1 and 2 illustrate the increased contrast enabled by imaging multiple fluorophores in a sample using fast sequential imaging.[†] The sample is a 25 µm thick sagittal section of an adult rat brain. The red channel corresponds to fluorescence from chick anti-neurofilament that is optimally excited at 835 nm, while the green channel corresponds to fluorescence from mouse anti-GFAP that is optimally excited at 750 nm. Figure 1 shows fluorescence from single-wavelength excitation at

788 nm, which sub-optimally excites the two tags simultaneously. Figure 2 is a composite image of the fluorescence from a two-color excitation imaging sequence at 7 fps by fast tuning between 750 nm and 835 nm, which excites both tags optimally.

The video in Figure 3 shows the fast switching between the red and green fluorescence in both real time and at 1/16th the imaging rate, which makes it easier to see the details of each. The two-channel set was collected at an imaging rate of 7 fps with a resolution of 512 x 512 pixels. The Tiberius Ti:Sapphire Laser's fast tuning functionality integrates seamlessly into ThorImage®LS software, enabling synchronized control for photoactivation experiments and live high-speed imaging on millisecond timescales using the same laser.

†This immunofluorescence sample was prepared by Lynne Holtzclaw of the NICHD Microscopy and Imaging Core Facility, a part of the National Institutes of Health (NIH) in Bethesda, MD.

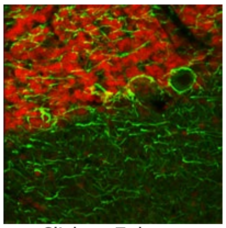


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Figure 2. Fast Switching between the optimal excitation wavelengths of 750 nm and 835 nm provides the high contrast seen in this composite image. The two-channel set was collected at an imaging rate of 7 fps.†

Figure 3. This video shows the real-time flashing between red and green fluorescence excited by the Tiberius Ti:Sapphire Laser's high-speed wavelength switching. Both channels were collected at an imaging rate of 7 fps with a resolution of 512 x 512 pixels. If you experience adverse effects from visual stimuli including flashing lights, please watch this version played at 1/16th the imaging rate as an alternative.†

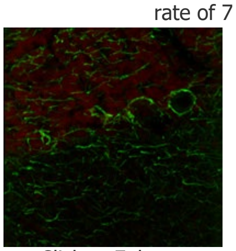

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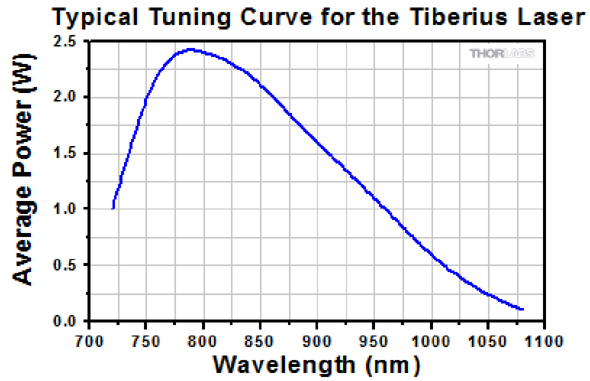
Figure 1. The above image was acquired using single-wavelength excitation at 788 nm, while the optimum excitation wavelengths for the two tags are 750 nm and 850 nm.†

SPECS

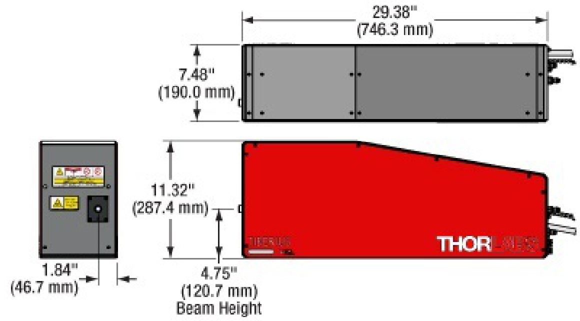
Specifications	
Laser Specifications	
Tuning Range	720 - 1060 nm
Pulse Width	140 fs
Average Power	>1.0 W at 720 nm >2.3 W at 800 nm >1.4 W at 920 nm >0.5 W at 1000 nm >0.3 W at 1040 nm
Noise[a]	<0.15% (RMS)
Repetition Rate	77 MHz (Nominal)
Beam Diameter (1/e^2)	1.5 mm (Nominal)
M^2	<1.2 at 800 nm
Pointing Stability During Tuning	<50 µrad per 100 nm

Electrical Requirements	
Input Voltage	100 - 240 V
Frequency	50 - 60 Hz
Power Consumption	1.2 kW (Max)
Environmental Requirements	
Room Temperature	17 - 25 °C
Room Temperature Stability	<3 °C Over 24 Hours
Housing Dimensions	29.38" x 7.48" x 11.32" (746.3 mm x 190.0 mm x 287.4 mm)

a. Measurement Bandwidth: 10 Hz - 1 MHz



Click to Enlarge
Tiberius Ti:Sapphire Laser Typical Tuning



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Tiberius Ti:Sapphire Laser Dimensions

DESIGN AND MANUFACTURING

In-House Expertise in Design and Manufacturing

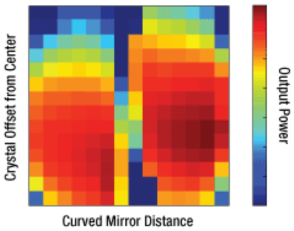
The Tiberius® Ti:Sapphire Femtosecond Laser is designed and manufactured entirely in-house, leveraging our multi-disciplinary team of design engineers and the substantial infrastructure of a vertically integrated company. Thorlabs' Laser Division tightly controls every aspect of the manufacturing, assembly, and testing process of the Tiberius in order to guarantee the laser's stability and reliability.

The ti:sapphire laser's design represents the culmination of complex theoretical cavity simulations combined with "old-fashioned" prototyping. A sound understanding of the intracavity laser dynamics proved fundamental to optimizing the laser for the specific needs of our nonlinear imaging customers.

Precision Optomechanics Manufacturing
The Tiberius benefits from Thorlabs' 25+ years of experience in manufacturing precision photonics components and assemblies. For example, it makes extensive use of the high-performance, ultrastable Polaris® designs that the company has developed for custom OEM needs and industrial-grade applications. These expert designs minimize thermally induced drift and help ensure stable long-term alignment.

Manufacturing at Thorlabs' Headquarters

Click to Enlarge
Machine Shop



2D Numerical Model of Tiberius Ti:Sapphire Laser Cavity

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Ion Beam Sputtering (IBS) Chamber for Ultrafast Optics

Our high degree of vertical integration lowers costs for our customers and ensures that every aspect of the laser performs as intended, delivering superior value and return on investment.

Optimized Ultrafast Laser Optics
To maximize the Tiberius' optical performance, it was critical to optimize the laser cavity geometry and optics together as a single unit. The optical coatings were therefore designed by Thorlabs and are precisely tuned for our cavity's proprietary design, enabling the long-term stability and broad tuning range that multiphoton microscopy requires.

To manufacture these high-performance coatings, we selected ion beam sputtering (IBS), which provides the most precise layer control and the most dense coatings among all coating methods. These characteristics result in coatings with high damage thresholds, minimal dependence on environmental factors, and excellent consistency from run to run. Thorlabs operates a number of IBS machines to produce these critical components for the Tiberius Ti:Sapphire Laser.

Hide Laser Safety

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







- Laser safety eyewear must be worn whenever working with Class 3 or 4 lasers.
- Regardless of laser class, Thorlabs recommends the use of laser safety eyewear whenever working with laser beams with non-negligible powers, 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.
- Laser Safety Curtains and Laser Safety Fabric shield other parts of the lab from high energy lasers.
- 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	Class 3R lasers produce visible and invisible light that is hazardous under direct and specular-reflection viewing conditions. Eye injuries may occur if you directly view the beam, especially when using optical instruments. 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 in this class are limited to 5 mW of output power.	
3B	Class 3B lasers are hazardous to the eye if exposed directly. Diffuse reflections are usually not harmful, but may be when using higher-power Class 3B lasers. Safe handling of devices in this class includes wearing protective eyewear where direct viewing of the laser beam may occur. Lasers of this class must be equipped with a key switch and a safety interlock; moreover, laser safety signs should be used, such that the laser cannot be used without the safety light turning on. Laser products with power output near the upper range of Class 3B may also cause skin burns.	
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.		

Hide Pulse Calculations

PULSE CALCULATIONS

Pulsed Laser Emission: Power and Energy Calculations

Determining whether emission from a pulsed laser is compatible with a device or application can require referencing parameters that are not supplied by the laser's manufacturer. When this is the case, the necessary parameters can typically be calculated from the available information. Calculating peak pulse power, average power, pulse energy, and related parameters can be necessary to achieve desired outcomes including:

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- Protecting biological samples from harm.

- Measuring the pulsed laser emission without damaging photodetectors and other sensors.
- Exciting fluorescence and non-linear effects in materials.

Pulsed laser radiation parameters are illustrated in Figure 1 and described in the table. For quick reference, a list of equations are provided below. The document available for download provides this information, as well as an introduction to pulsed laser emission, an overview of relationships among the different parameters, and guidance for applying the calculations.

Equations:

***Period* and *repetition rate* are reciprocal:** $\Delta t = \frac{1}{f_{rep}}$ and $f_{rep} = \frac{1}{\Delta t}$

***Pulse energy* calculated from *average power*:** $E = \frac{P_{avg}}{f_{rep}} = P_{avg} \cdot \Delta t$

***Average power* calculated from *pulse energy*:** $P_{avg} = \frac{E}{\Delta t} = E \cdot f_{rep}$

***Peak pulse power* estimated from *pulse energy*:** $P_{peak} \approx \frac{E}{\tau}$

***Peak power* and *average power* calculated from each other:**

$$P_{peak} = \frac{P_{avg}}{f_{rep} \cdot \tau} = \frac{P_{avg} \cdot \Delta t}{\tau}$$ and $$P_{avg} = P_{peak} \cdot f_{rep} \cdot \tau = \frac{P_{peak} \cdot \tau}{\Delta t}$$

Peak power* calculated from *average power* and *duty cycle*:**

$$P_{peak} = \frac{P_{avg}}{\tau / \Delta t} = \frac{P_{avg}}{duty\ cycle}$$

*Duty cycle ($\tau / \Delta t$) is the fraction of time during which there is laser pulse emission.

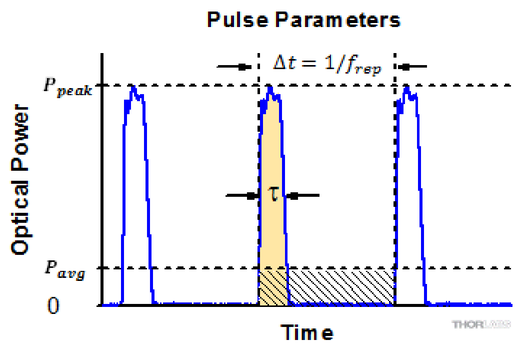

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Figure 1: Parameters used to describe pulsed laser emission are indicated in the plot (above) and described in the table (below). **Pulse energy** (**E**) is the shaded area under the pulse curve. Pulse energy is, equivalently, the area of the diagonally hashed region.

Parameter	Symbol	Units	Description
Pulse Energy	**E**	Joules [J]	A measure of one pulse's total emission, which is the only light emitted by the laser over the entire period. The pulse energy equals the shaded area, which is equivalent to the area covered by diagonal hash marks.
Period	**Δt**	Seconds [s]	The amount of time between the start of one pulse and the start of the next.
Average Power	P_{avg}	Watts [W]	The height on the optical power axis, if the energy emitted by the pulse were uniformly spread over the entire period.
Instantaneous Power	**P**	Watts [W]	The optical power at a single, specific point in time.
Peak Power	P_{peak}	Watts [W]	The maximum instantaneous optical power output by the laser.
Pulse Width	τ	Seconds [s]	A measure of the time between the beginning and end of the pulse, typically based on the full width half maximum (FWHM) of the pulse shape. Also called **pulse duration**.
Repetition Rate	f_{rep}	Hertz [Hz]	The frequency with which pulses are emitted. Equal to the reciprocal of the period.

Example Calculation:

Is it safe to use a detector with a specified maximum peak optical input power of **75 mW** to measure the following pulsed laser emission?

- Average Power: 1 mW
- Repetition Rate: 85 MHz
- Pulse Width: 10 fs

The energy per pulse:

$$E = \frac{P_{avg}}{f_{rep}} = \frac{1\ mW}{85\ MHz} = \frac{1\ x\ 10^{-3} W}{85\ x\ 10^{6} Hz} = 1.18\ x\ 10^{-11} J = 11.8\ pJ$$

seems low, but the peak pulse power is:

$$P_{peak} = \frac{P_{avg}}{f_{rep} \cdot \tau} = \frac{1\ mW}{85\ MHz\ \cdot 10\ fs} = 1.18\ x\ 10^{3}\ W = \mathbf{1.18\ kW}$$

It is ***not safe*** to use the detector to measure this pulsed laser emission, since the peak power of the pulses is >5 orders of magnitude higher than the detector's maximum peak optical input power.

Part Number	Description	Price	Availability
TIBERIUS	**Tunable Femtosecond Ti:Sapphire Laser for Multiphoton Microscopy**	**$0.00**	**Lead Time**