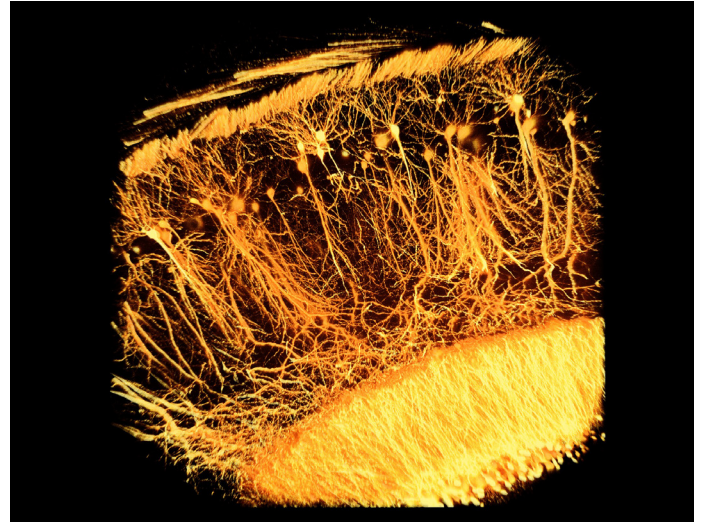
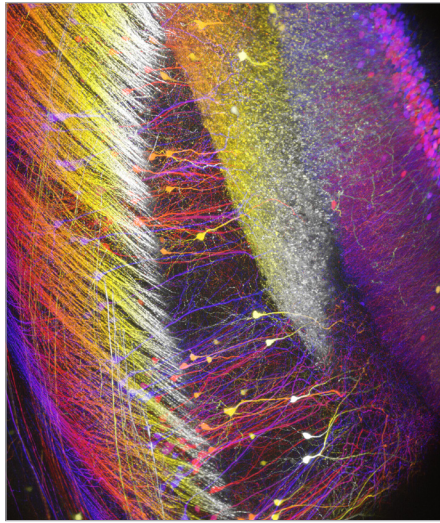
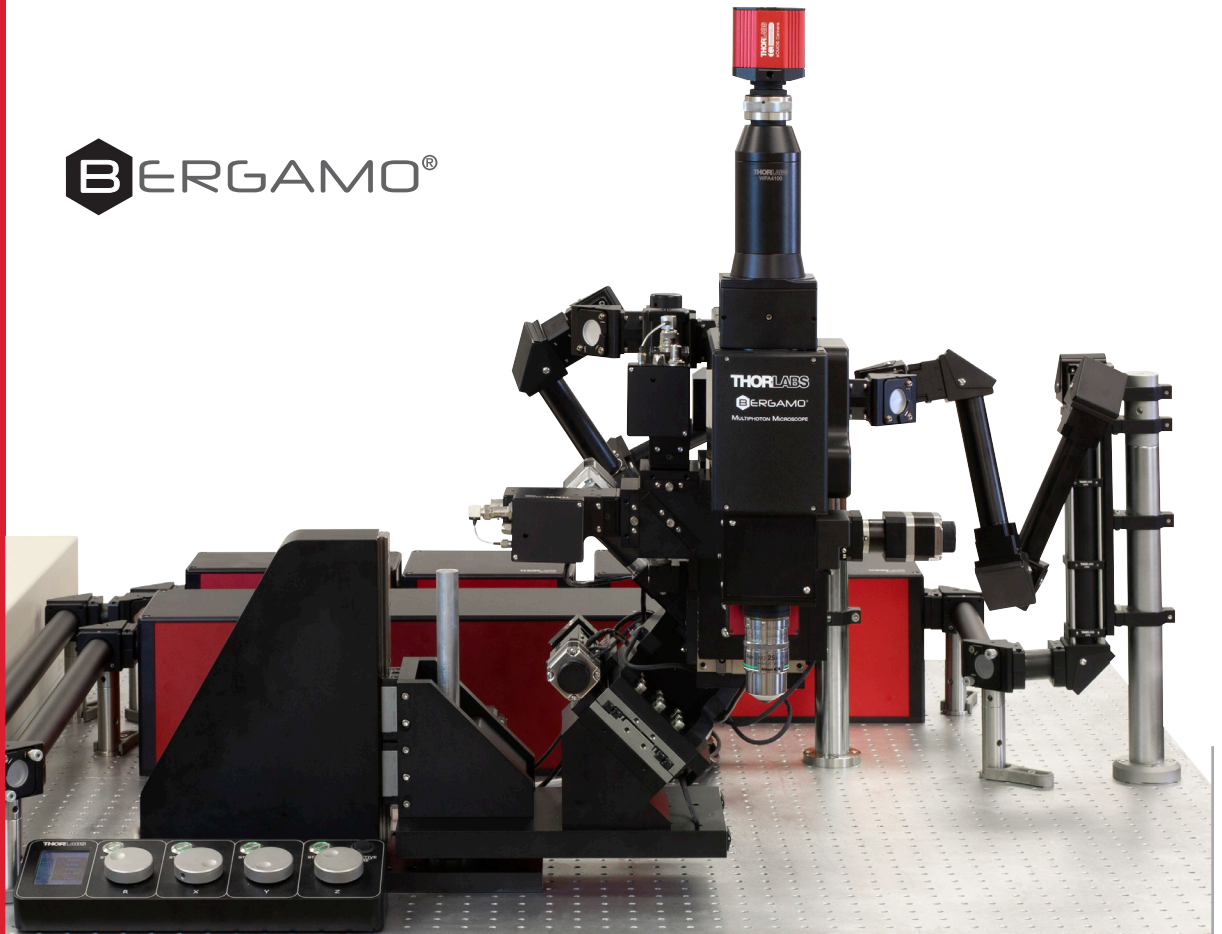


# Multiphoton Imaging



**B**ERGAMO®



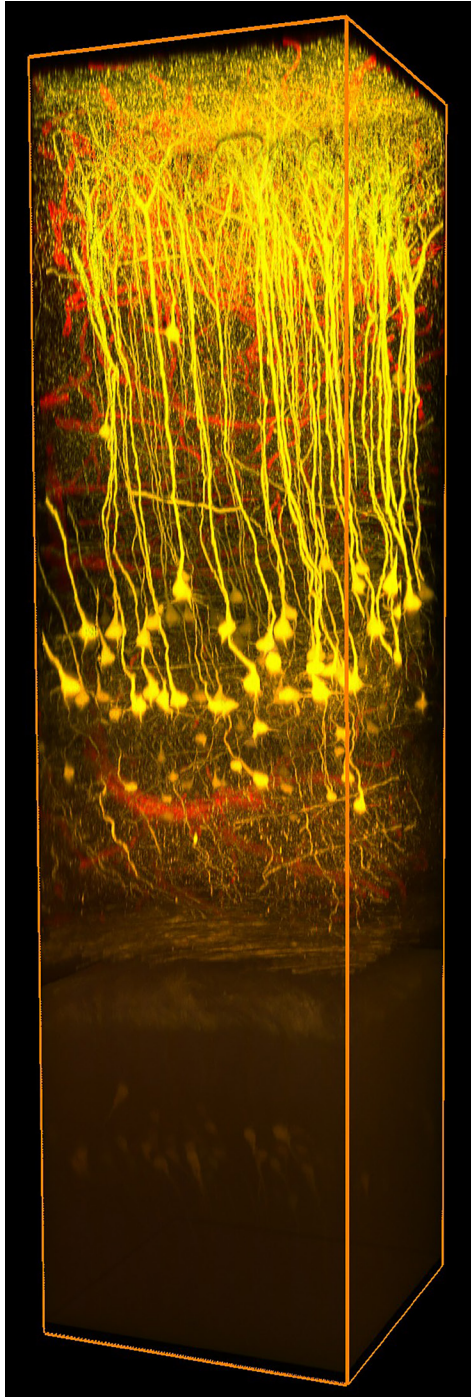
## Bergamo® II: Versatile, High Performance Imaging Platforms

Backed by Thorlabs' skilled in-house team of optical, software, and applications engineers, Bergamo II multiphoton microscopes deliver exceptional performance and a seamless user experience.

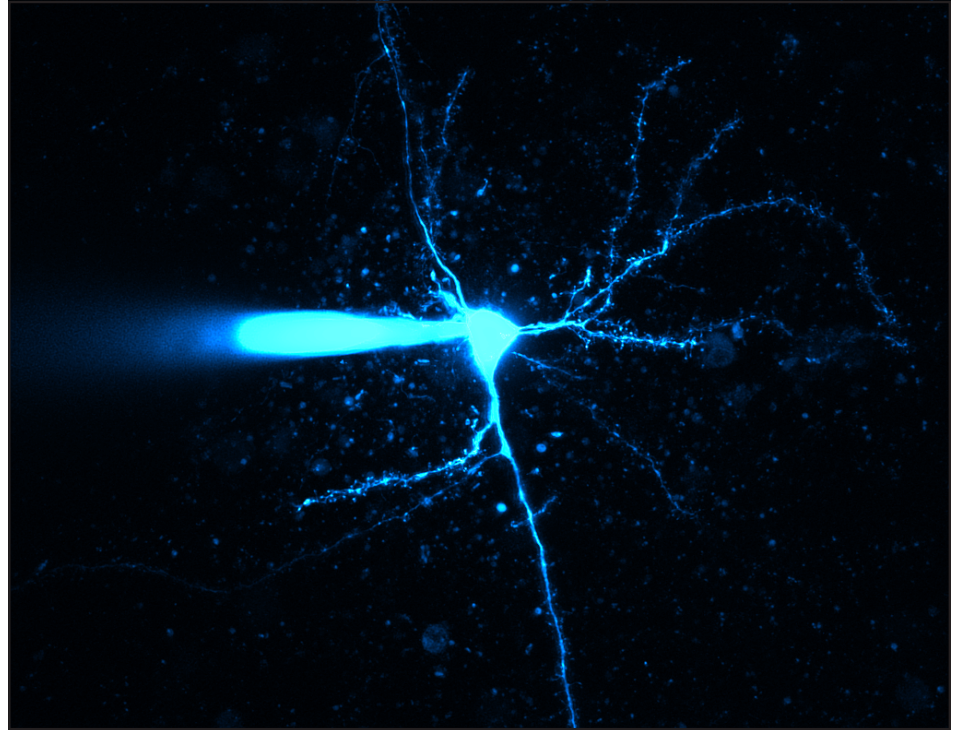
**THORLABS**

# Overview of Bergamo<sup>®</sup> II Microscopes

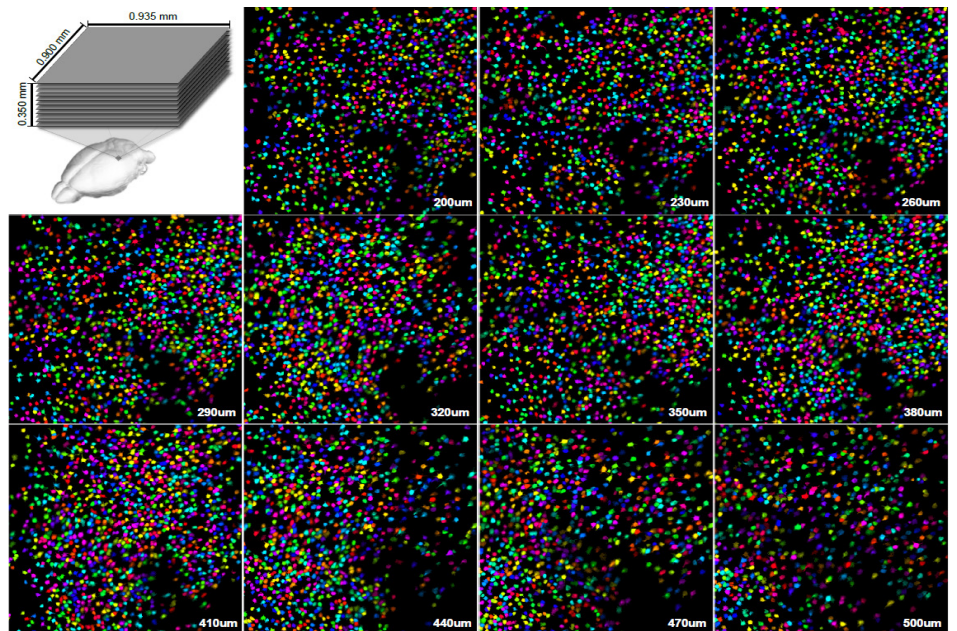
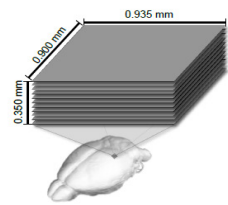
Following the principle that the microscope should conform to the specimen, rather than the other way around, we created the Bergamo II multiphoton imaging platform: a completely modular system that adapts to a wide range of experimental setups.



1.2 mm *In Vivo* Deep Brain Volume<sup>a</sup>



Establishing a Patch in a Neuron<sup>b</sup>



Simultaneous Detection of 10,000+ Neurons in an Awake, Behaving Mouse<sup>c</sup>

## Image Credits

*Cover Page Top Left:* Two-photon image of neurons expressing thy1-YFP in a cleared region of the hippocampus. Courtesy of the 2017 Imaging Structure and Function in the Nervous System Course at Cold Spring Harbor Laboratory, Cold Spring Harbor, NY.

*Cover Page Top Right:* Two-photon image of neurons expressing thy1-YFP in a cleared region of the dentate gyrus. Courtesy of the 2017 Imaging Structure and Function in the Nervous System Course at Cold Spring Harbor Laboratory, Cold Spring Harbor, NY.

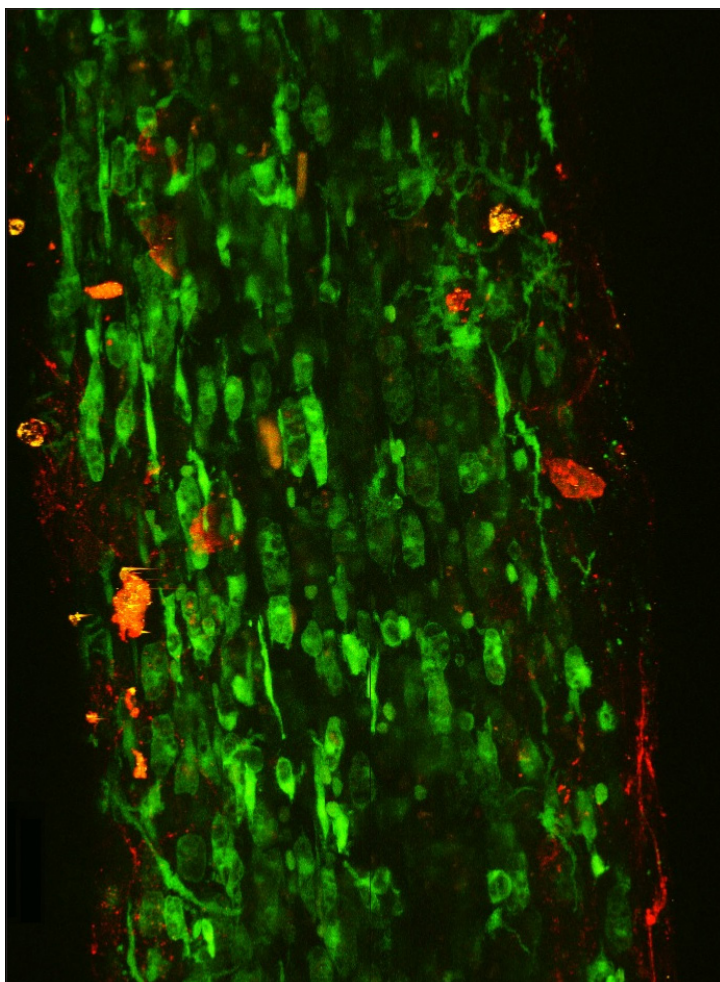
a. Courtesy of Dr. Hajime Hirase and Katsuya Ozawa, RIKEN Brain Institute, Wako, Japan.

b. Courtesy of the 2016 Neurobiology Course at the Marine Biological Laboratory, Woods Hole, MA.

c. Courtesy of Marius Pachitariu, Matteo Carandini, and Kenneth D. Harris, University College London, United Kingdom.

Details at <http://biorxiv.org/content/early/2016/06/30/061507> and <https://github.com/cortex-lab/Suite2P>.

d. Courtesy of Craig Brideau, University of Calgary, Alberta, Canada.



Activated Microglial Cells Expressing Transgenic YFP in an *Ex Vivo* Perfused Mouse Spinal Cord Section<sup>d</sup>

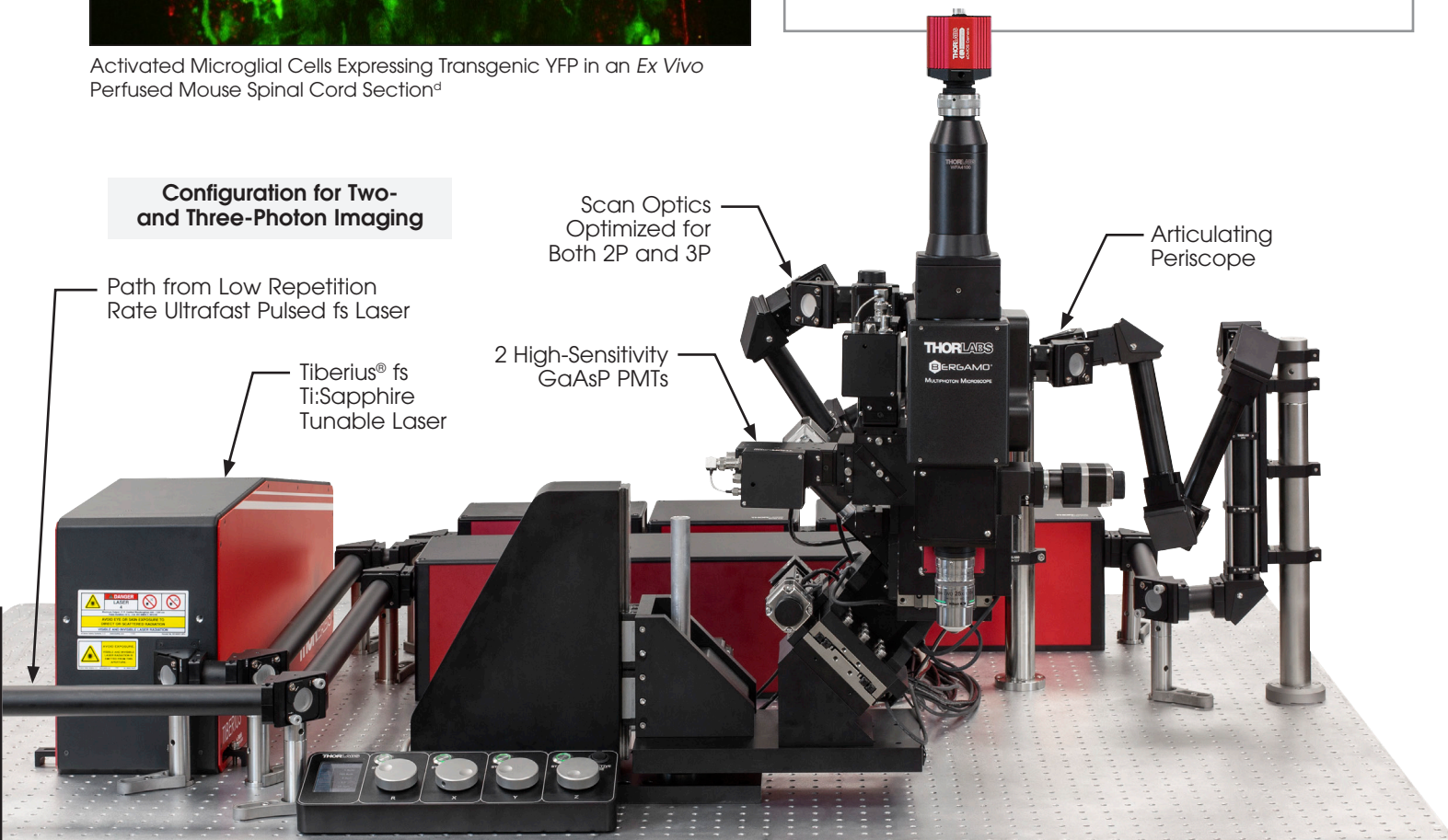
## Techniques

- ◆ Two- and Three-Photon Imaging
- ◆ 2D or 3D Photoactivation/Uncaging
- ◆ Multi-Target Photoactivation with Spatial Light Modulator
- ◆ Confocal Imaging
- ◆ DIC (Widefield and Laser Scanned)
- ◆ Dot Gradient Contrast (Widefield and Laser Scanned)
- ◆ FRAP, FRET, and FLIM
- ◆ Fast Sequential Imaging
- ◆ Fast Functional Imaging
- ◆ Deep Brain Imaging
- ◆ Simultaneous Multi-Channel Detection
- ◆ Rapid Volumetric Imaging Using Bessel Beams

## Applications

- ◆ Structural Neurobiology
- ◆ Neurological Disorders
- ◆ Neural Development and Plasticity
- ◆ Neurogenetics
- ◆ Functional and Molecular Imaging
- ◆ Synapses and Circuits
- ◆ Membrane Protein Localization, Trafficking, and Signaling
- ◆ Cell Biology of Neurons, Muscles, and Glia
- ◆ Drug Discovery

### Configuration for Two- and Three-Photon Imaging



# Other Highlighted Features & Upgrades

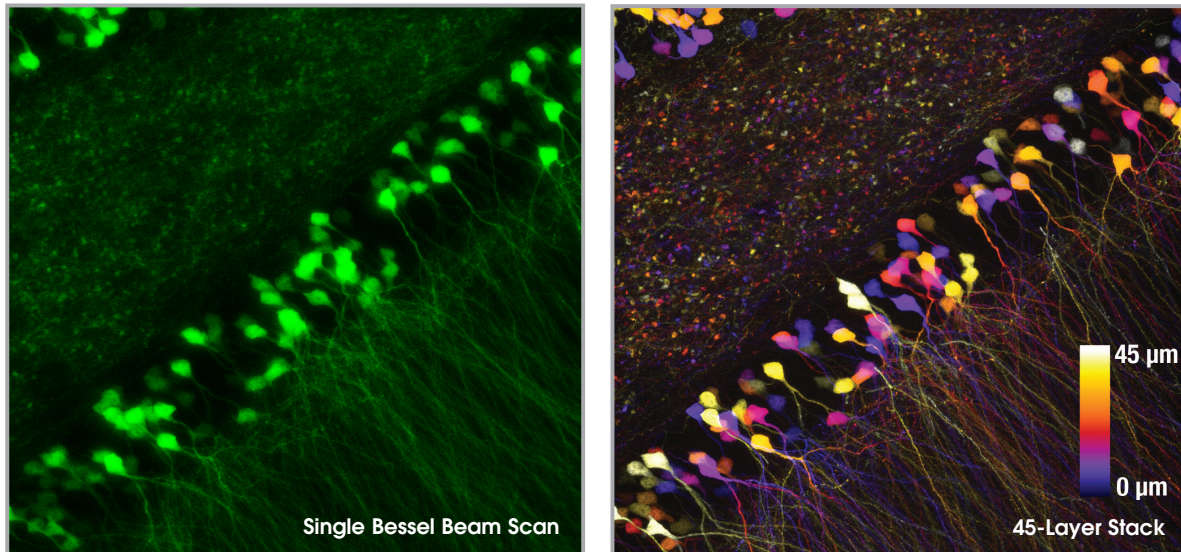
Our Bergamo® II microscopes are modular systems that can be customized in the design process to meet the exact needs of the experiment. The highlighted features below reflect our focus on developing cutting-edge capabilities without compromising usability.

## Rapid Volumetric Imaging Using Bessel Beams

In partnership with the Howard Hughes Medical Institute and Prof. Na Ji (University of California at Berkeley), Thorlabs is offering a Bessel beam module for our Bergamo multiphoton laser scanning microscopes. As demonstrated in Ji's pioneering work, this rapid Bessel beam-based imaging technique has synaptic resolution, capturing  $\text{Ca}^{2+}$  dynamics and tuning properties of dendritic spines in mouse and ferret visual cortices.<sup>1</sup>

*In vivo* volume imaging of neuronal activity requires both submicron spatial resolution and millisecond temporal resolution. While conventional methods create 3D images by serially scanning a diffraction-limited Gaussian beam, Bessel-beam-based multiphoton imaging relies on an axially elongated focus to capture volumetric images. The excitation beam's extended depth of field creates a 2D projection of a 3D volume, effectively converting the 2D frame rate into a 3D volumetric rate.

1. Lu, R., Sun, W., Liang, Y., Kerlin, A., Bierfeld, J., Seelig, J. D., ... & Ji, N. (2017). Video-rate volumetric functional imaging of the brain at synaptic resolution. *Nature Neuroscience*, 20(4), 620-628.

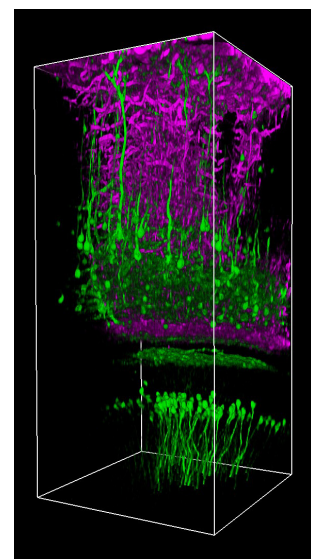


A single Bessel scan (left) captures the same structural information obtained from a Gaussian volume scan created by stacking 45 optical sections (right), reducing the total scan time by a factor of 45. The images show a brain slice scanned over a  $300\ \mu\text{m} \times 300\ \mu\text{m}$  area. Scan depth for the Gaussian stack is indicated by the scale bar.<sup>e</sup>

## Three-Photon Imaging

We have developed scan path optics for the 800 - 1800 nm range in response to requests from our collaborators in the field. Extending deeper into the infrared than the existing choices, these scan optics open the door to three-photon techniques, which provide reduced background scatter for greater sensitivity in deep tissue imaging.

This wavelength range joins 450 - 1100 nm and 680 - 1300 nm as one of the three super broadband options available for newly ordered Bergamo II microscopes.



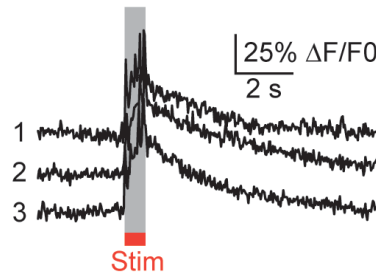
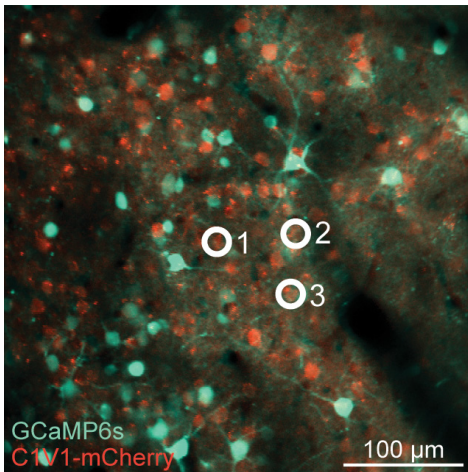
Thy1-YFP male mouse, 21 weeks old, imaged at 1300 nm, 326 kHz repetition rate, pulse width ~60 fs. At the top of the cortex ( $0\ \mu\text{m}$ , 1.1 mW laser power), the window was centered at 2.5 mm lateral and 2 mm posterior from the Bregma point over the somatosensory cortex.<sup>f</sup>

# Spatial Light Modulator for Simultaneous Multi-Site Activation

Thorlabs' Spatial Light Modulator (SLM) uses holography patterns to enable 2D or 3D photoactivation of multiple locations in a specimen simultaneously. Designed for two-photon excitation with femtosecond pulses, the SLM manipulates the phase across the activation profile to generate hundreds of user-determined focal points. Each beam can be shaped to improve the efficacy of photoactivation, a crucial feature for activating neural populations at varying depths within a single FOV.

The SLM phase mask pattern can be rapidly switched, enabling multiple individual focal points to be targeted independently in any sequence. The calibration process, hologram generation, and external hardware synchronization are entirely managed through the ThorImage<sup>®</sup>LS software, enabling seamless control.

Thorlabs' SLM is available for newly ordered Bergamo II microscopes and as an upgrade to existing microscopes by contacting [ImagingSales@thorlabs.com](mailto:ImagingSales@thorlabs.com).



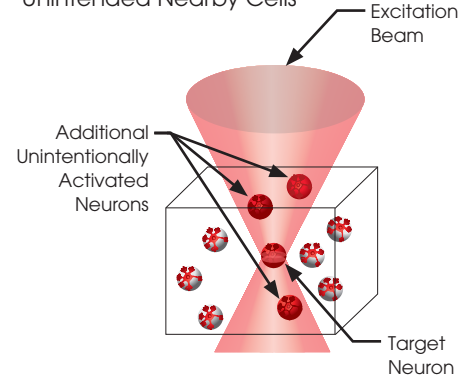
Photoactivation and Ca<sup>2+</sup> Imaging of Three Cells using SLM<sup>®</sup>

## Other Highlighted Features

- ◆ User-Installable Transmitted Light Imaging Tower for Rotating Bodies
- ◆ Piezo Objective Scanner Designed by Thorlabs
- ◆ Mechanical Shutters for 8°, 10°, or 14° Collection Modules
- ◆ Translating Platform with Manual Actuators
- ◆ Conjugated Scanners for Pupil Relay
- ◆ Scientific-Grade Cameras with Color Sensors & USB 3.0 Connectors
- ◆ ThorSync™ Hardware Control Package

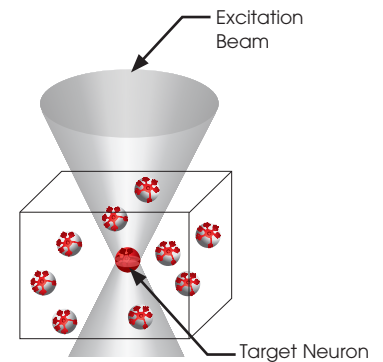
## Single-Photon Activation

- ◆ Lack of Depth Control for 3D Neural Activation
- ◆ Activate Target Cell Along with Unintended Nearby Cells



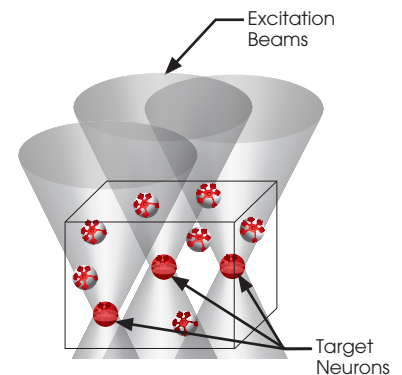
## Two-Photon Activation

- ◆ Single-Cell Resolution Targeting
- ◆ Activate Only Target Cell



## Two-Photon Activation + Spatial Light Modulator (SLM)

- ◆ Generate Multiple Focal Points
- ◆ Simultaneously Activate Multiple Target Cells



Two-photon activation with SLM allows simultaneous excitation of multiple target cells, which is not possible with single-photon (top) or two-photon (middle) activation.

# Two Microscope Body Choices



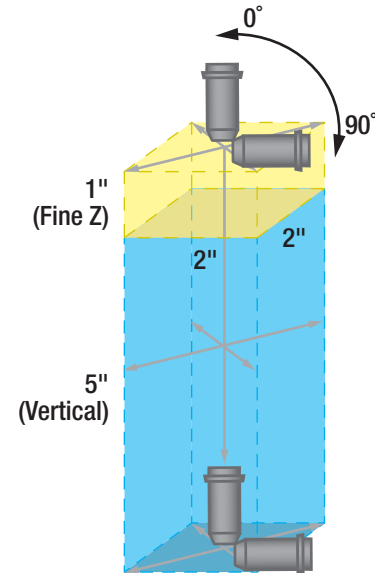
## Rotating Bodies

Rotating Bergamo® II microscope bodies include five axes of motion, providing near-total freedom to study *in vivo* systems. Because the microscope body itself translates, the field of view can move without having to perturb the sample preparation.



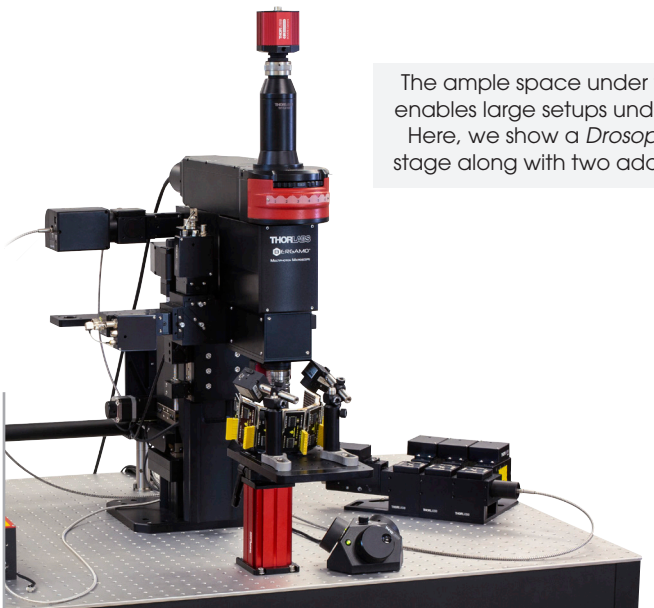
## Range of Motion

- ◆ 5" of Coarse Vertical Motion
- ◆ 0° to 90° or -45° to 45° Rotation Around the Sample
- ◆ 2" of Fine XY Motion
- ◆ 1" of Fine Z Motion
- ◆ X, Y, and Z Rotate with Objective
- ◆ **24+ Cubic Inches** (393+ Cubic Centimeters) of Accessible Objective Volume

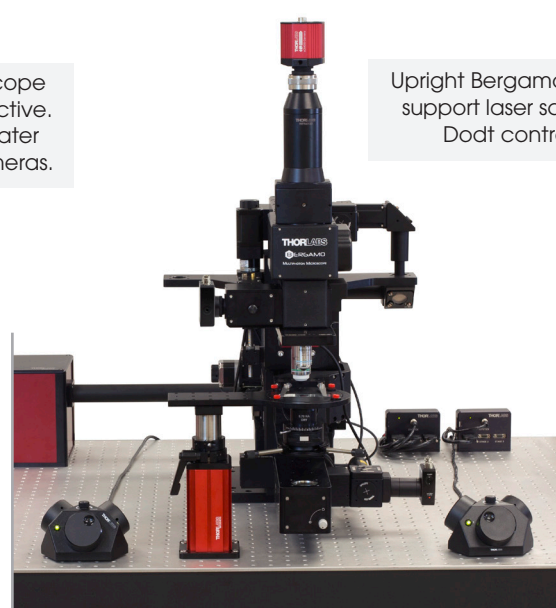


## Upright Bodies

Upright Bergamo II microscope bodies include one or three axes of motion and an industry-leading throat depth, creating a large three-dimensional working volume around the objective and letting the user bring the objective to the experiment.



The ample space under the microscope enables large setups under the objective. Here, we show a *Drosophila* VR theater stage along with two additional cameras.



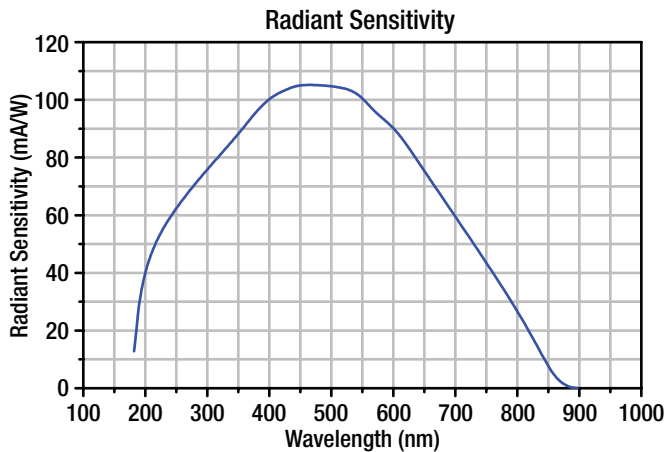
Upright Bergamo bodies support laser scanned Dot contrast.

# Versatile Photodetection Systems

## Simultaneous Multi-Channel Detection

Bergamo II microscopes can collect signals from up to four PMT detection channels simultaneously. The ThorImage<sup>®</sup>LS software integrates with the PMT protection circuit to improve the detector's longevity, and mechanical shutters that shield the photocathode during photoactivation/uncaging are also available.

Magnetically secured filter holders are easily accessed from the front, making it simple to configure the rig for different fluorophores.



Our high-sensitivity GaAsP PMTs reduce the laser exposure necessary to obtain signal from sensitive specimens.

## Detection Options

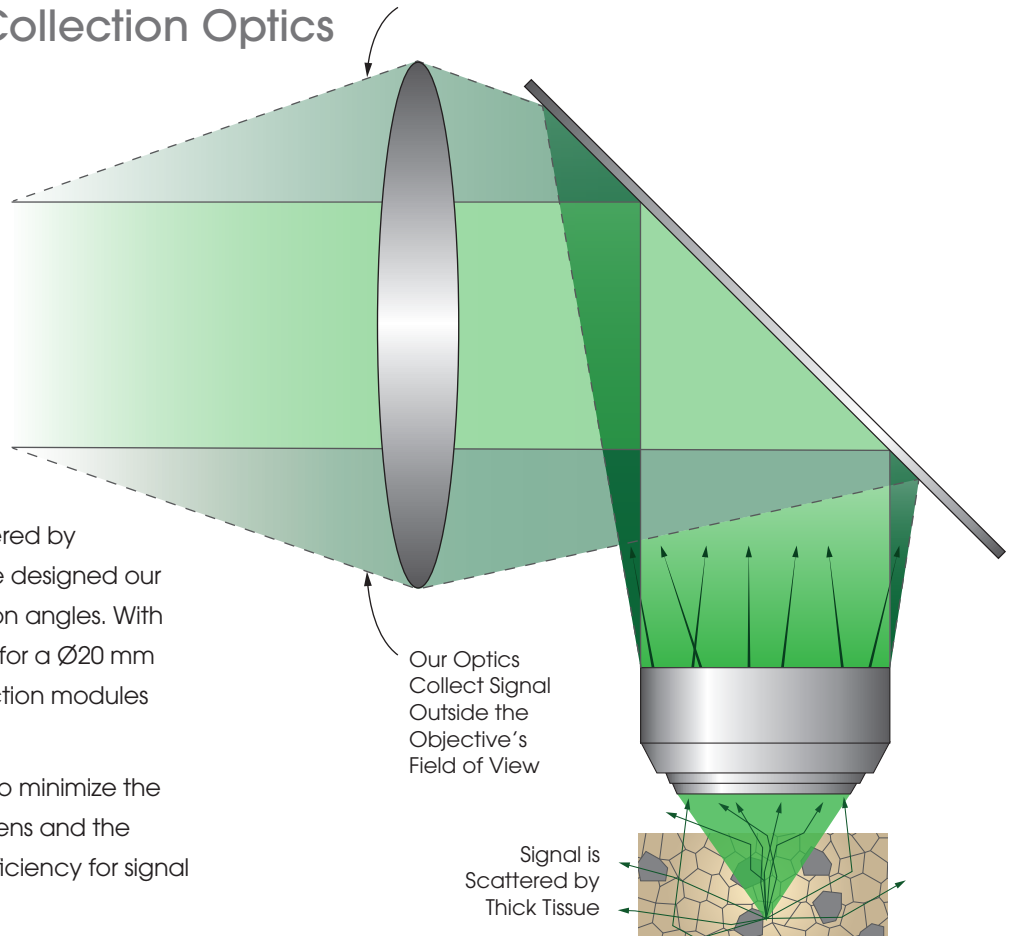
### PMT Modules

- ◆ Up to Four Simultaneous Detection Channels
- ◆ Choice of Thermoelectrically Cooled or Non-Cooled GaAsP PMTs
  - Cooled PMTs Detect Weak Signals
  - Non-Cooled PMTs have Larger Collection Angle
- ◆ Option for Two Highly Sensitive Forward Fluorescence Detection Channels

### Epi-Detection Modules

- ◆ Choice of Collection Angles for Different Imaging Depths
  - 8° (For Two PMTs)
  - 10° (For up to Four PMTs)
  - 14° (For Two PMTs)
- ◆ Available With or Without Mechanical Shutters for Photoactivation Experiments
- ◆ Compatible with All Industry-Standard Fluorescence Filters

## Large-Angle Signal Collection Optics



Because emitted signal can be scattered by thick tissue as it exits the specimen, we designed our detection modules with wide collection angles. With full collection angles of 8°, 10°, or 14° (for a Ø20 mm entrance pupil), our proprietary detection modules enable deep physiological imaging.

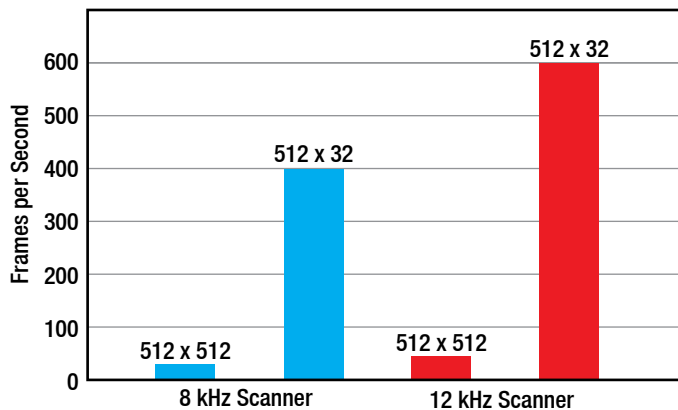
We have engineered these modules to minimize the distance between the first collecting lens and the objective, improving the collection efficiency for signal photons.

# Highly Flexible Scanning & Photoexcitation Systems

New and existing Bergamo® II microscopes can be configured with a resonant-galvo-galvo scan path, a galvo-galvo scan path, a galvo-resonant scan path, and/or a spatial light modulator (SLM). These choices allow the user to optimize each experiment as needed for high frame rates, high sensitivity, and/or targeted exposure of the region of interest.

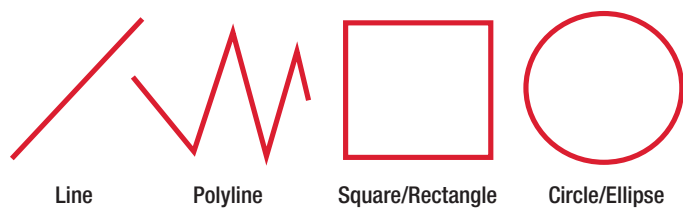
## Galvo-Resonant Scanners for High-Speed Imaging

Thorlabs offers 8 kHz and 12 kHz galvo-resonant scanners. Our 8 kHz scanners utilize the entire field of view and offer a maximum frame rate of 400 fps, while our 12 kHz scanners provide an increased maximum frame rate of 600 fps.



## Galvo-Galvo Scanners for Custom Scan Geometries

Galvo-galvo scanners support user-defined ROI shapes (lines, polylines, squares, and rectangles) and photo-stimulation patterns (circles, ellipses, polygons, and points).

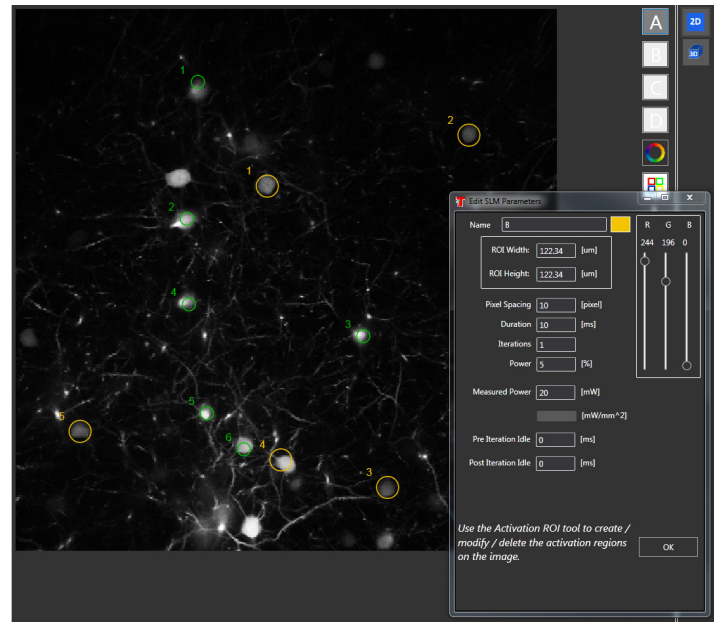


## Resonant-Galvo-Galvo Scanners for Multimodal Scanning

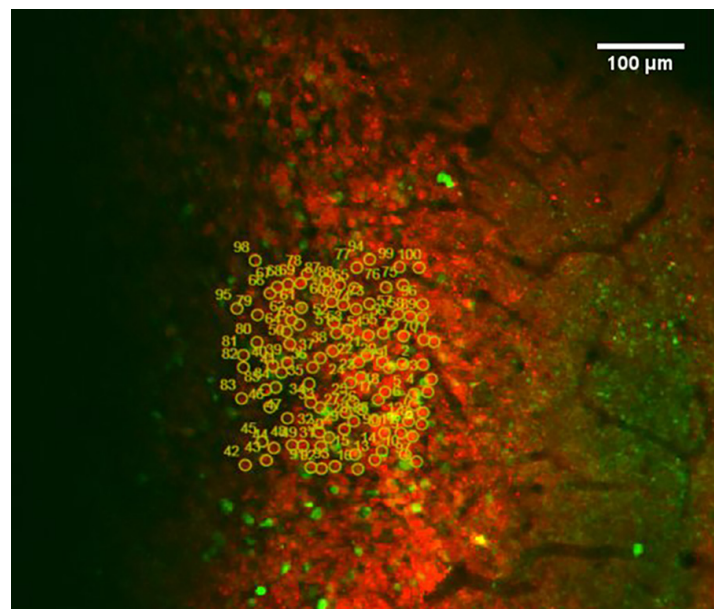
Thorlabs offers 8 kHz and 12 kHz resonant-galvo-galvo (RGG) scanners. This multimodal scanner provides features of both the galvo-resonant and galvo-galvo scanners in a single scan head. Our 8 kHz scanners version utilize the entire field of view and offer a maximum frame rate of 400 fps, while our 12 kHz scanners provide an increased frame rate of 600 fps. The galvo modality supports user-drawn scan geometries (lines, polylines, squares, and rectangles) and also supports custom photoactivation patterns (circles, ellipses, polygons, and points).

## Spatial Light Modulator for Simultaneous Targeting

Unlike scanners, which physically move from point to point, our SLM uses holography to direct the beam. This allows multiple sites in a sample to be photoexcited simultaneously.



The ThorImage®LS software suite provides intuitive graphical control over photostimulation within the FOV.



Simultaneous photostimulation of 100 cells co-expressing GCaMP6f (green) and C1V1 (red), obtained using SLM. (Courtesy of Lloyd Russell, Dr. Adam Packer, and Professor Michael Häusser, University College London, United Kingdom.)

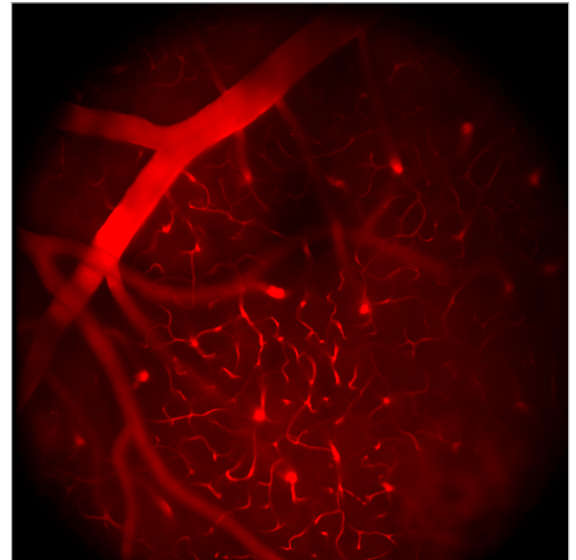
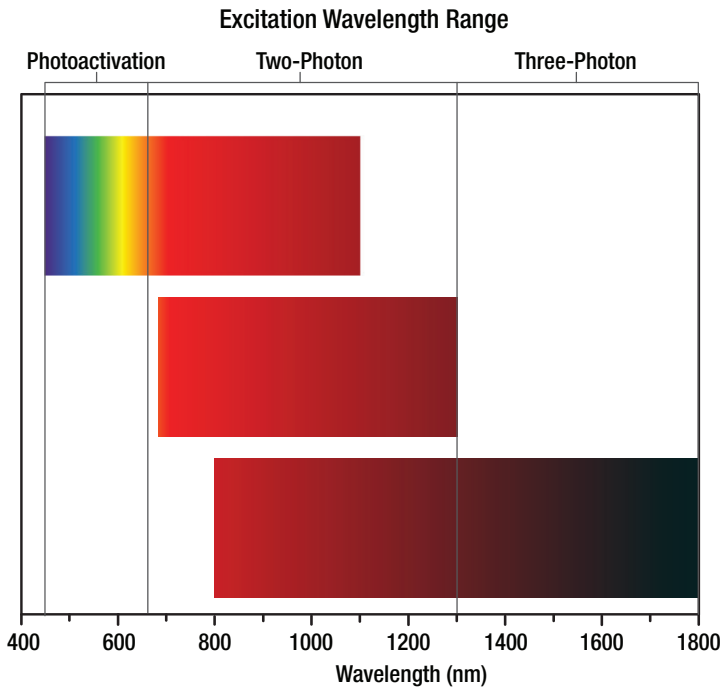


# Super Broadband Scan Optics

The excitation wavelength ranges supported by Bergamo II microscopes accommodate the most recent lasers, fluorophores, and techniques. Three choices are available: 450 - 1100 nm, 680 - 1300 nm, and 800 - 1800 nm.

These super broadband ranges allow imaging of a wide range of fluorophores, and are optimized for photoactivation, two-photon excitation, or three-photon excitation. Our proprietary scan optics are fully compatible with popular tunable Ti:sapphire lasers and optical parametric oscillators, and also support dual-output lasers such as the Chameleon Discovery.

With a maximum field number (FN) of 20, they are well matched to the low-magnification, high-NA objectives that are the workhorses of multiphoton microscopy, helping to capture large sample areas, as shown below.

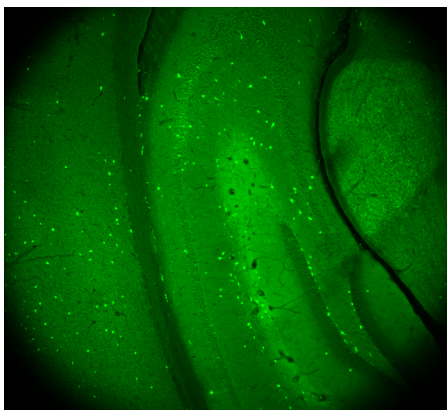


A large field number of 20 allows the 20X objective to obtain this deep tissue image over a 1 mm x 1 mm area.<sup>h</sup>

## Adapts to a Wide Range of Multiphoton Objectives

Bergamo II microscopes accept infinity-corrected objectives with M34 x 1.0, M32 x 0.75, M25 x 0.75, or RMS threads. Together, these options encompass the vast majority of low-magnification, high-NA objectives. With a large field number of 20, our scan optics ensure that Bergamo II microscopes are able to collect more photons than competing microscopes using the same objectives.

### 10X Super Apochromatic Objective



- ◆ Ideal for Two-Photon Microscopy
- ◆ Infinity-Corrected Dry Objective with Super Apochromatic Axial Color Correction
- ◆ Correction Collar Enables Use with Samples in a Variety of Media
- ◆ 0.50 NA, 7.77 mm Working Distance, 400 to 1300 nm Transmission
- ◆ M32 x 0.75 Threading

Native fluorescence from a 1 mm GFP-GAD65 transgenic mouse brain section. Image size: 2 mm x 2 mm.<sup>l</sup>

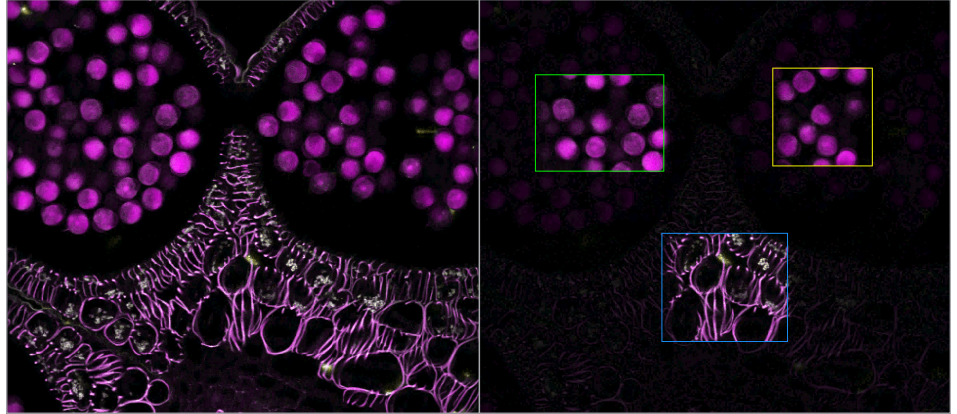


TL10X-2P

# Pockels Cells for Image Uniformity

Pockels cells provide edge blanking and high-speed masking. These techniques provide improved laser excitation uniformity across the region of interest, while also preventing unnecessary exposure.

Masking is particularly useful for specimens that are sensitive to physical movement, since it can be used to select regions of interest without moving the sample or the microscope.

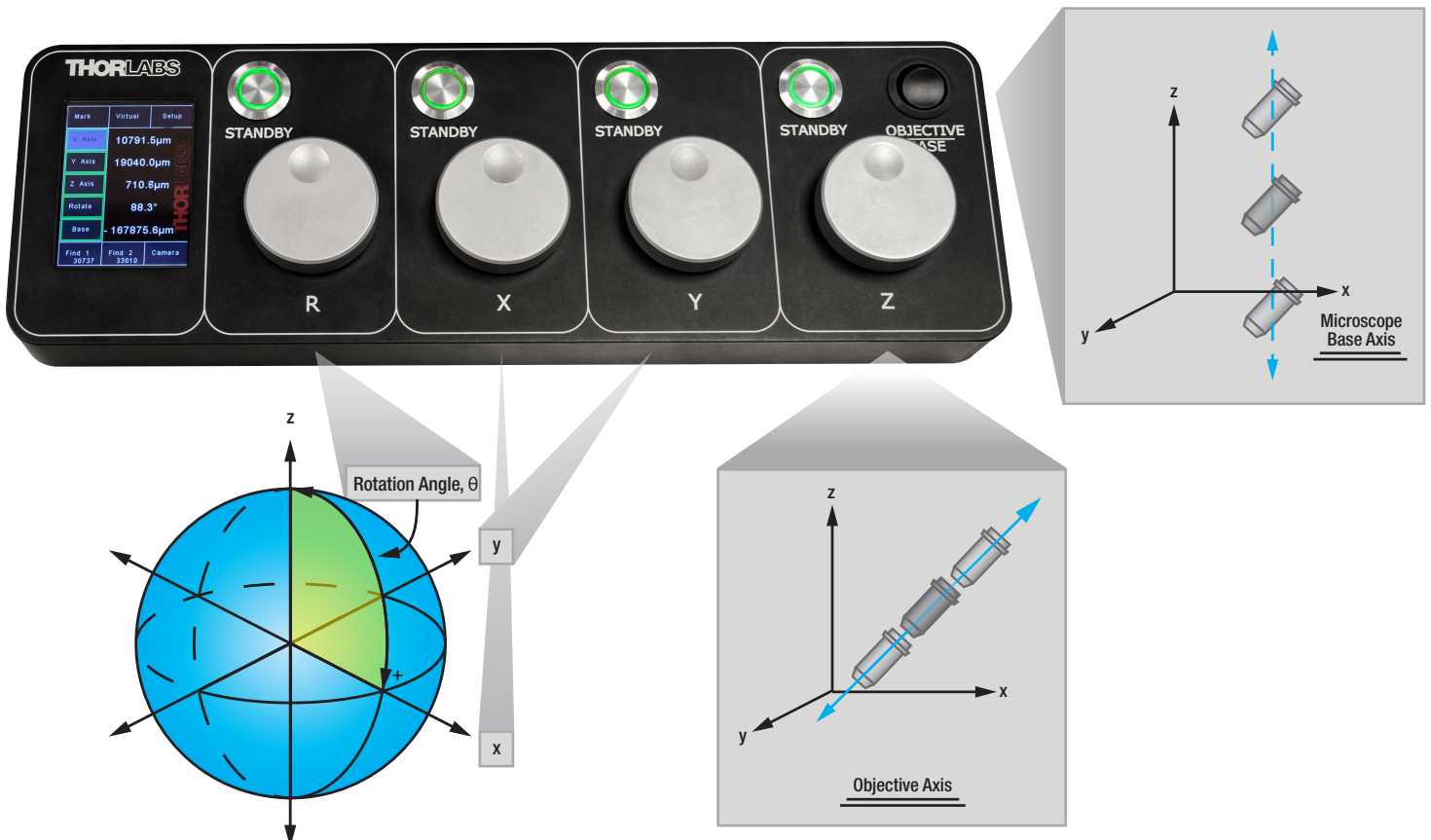


ThorImage®LS allows regions to be masked by a simple drag and drop across the live image.

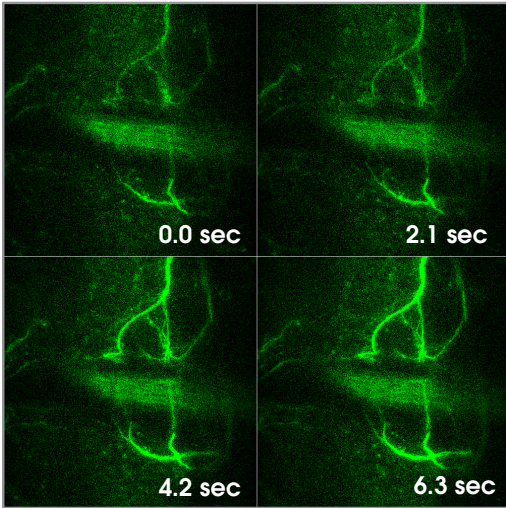
# Multi-Axis Touchscreen Controller for Rotating Body

Designed for the rotating Bergamo® II microscope, this controller displays, sets, and recalls the positions of all five axes of movement. It rotates the objective and controls the X, Y, and Z axes (which rotate along with the objective). In addition, it moves the microscope base over a 5" vertical range.

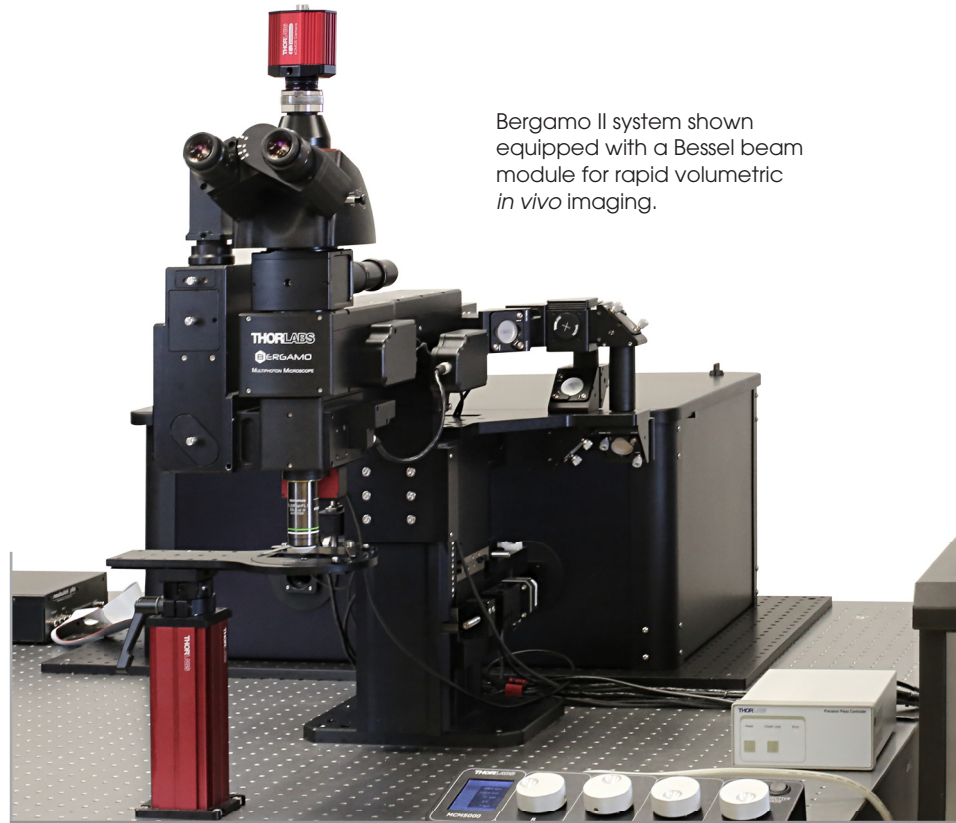
The integrated touchscreen offers quick, convenient retrieval of two spatial locations, while ThorImage®LS can save up to eight positions, easing experimental repeatability.



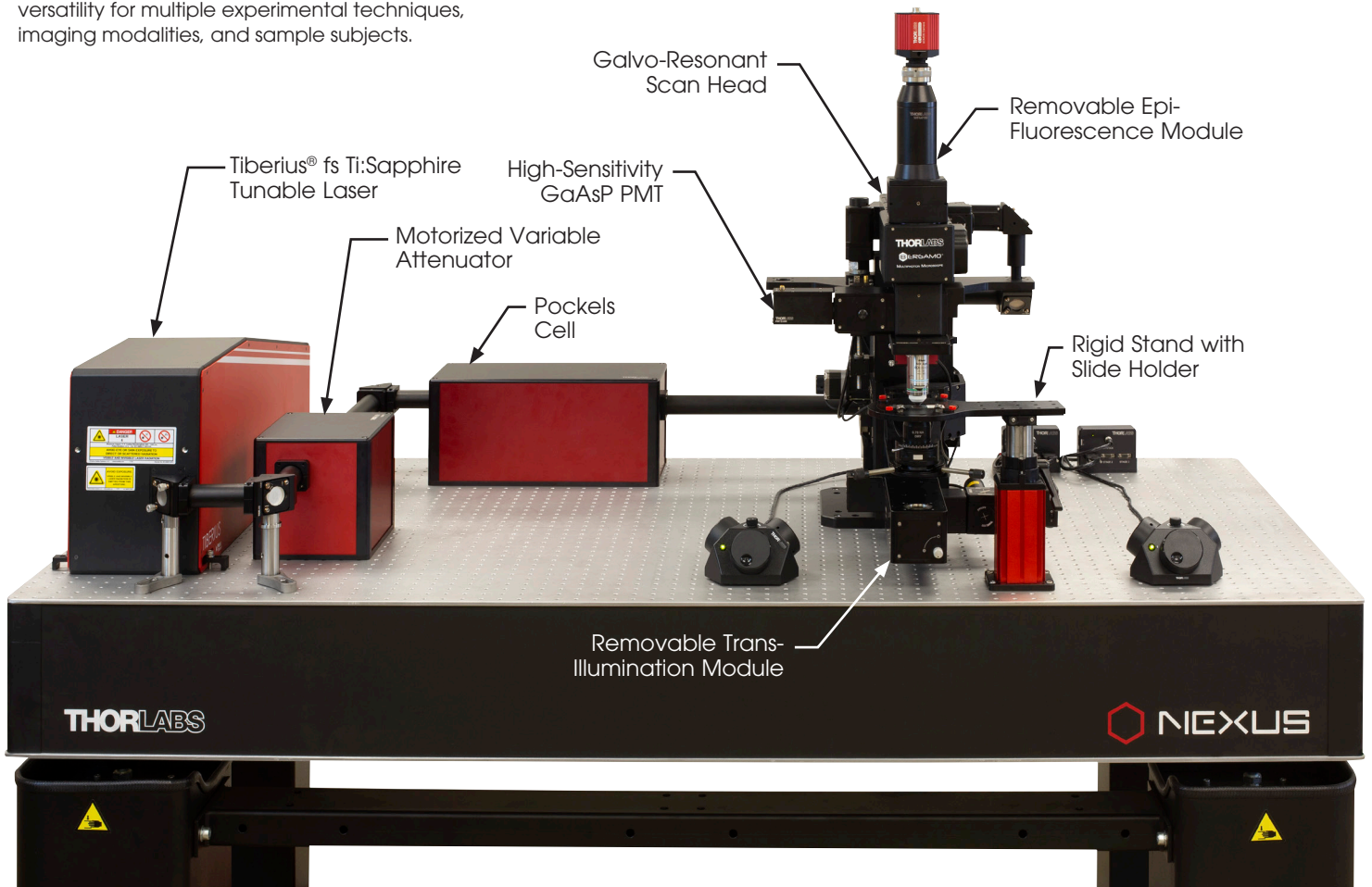
# Example Configurations



GCaMP6s expression in two neuron pairs arborized within the subesophageal zone of a fly brain.  $\text{Ca}^{2+}$  transients are captured by XY-scanning a  $30\ \mu\text{m}$  Bessel focus at a rate of 30 frames per second. A single Bessel scan corresponds to an XY scan with no translation in the Z-direction.<sup>1</sup>



This configuration is well-balanced for both *in vitro* and fixed stage *in vivo* microscopy research. The modular system with a removable trans-illumination module provides high versatility for multiple experimental techniques, imaging modalities, and sample subjects.



# Specifications

## Laser Scanning

<b>Multiphoton Excitation</b>	Wavelength Range	◆ 450 - 1100 nm, 680 - 1300 nm, or 800 - 1800 nm
	Scan Paths	◆ Resonant-Galvo-Galvo Scanners, Galvo-Resonant Scanners, Galvo-Galvo Scanners, or Spatial Light Modulator ◆ Single or Dual Scan Paths
	Resonant-Galvo-Galvo and Galvo-Resonant Scan Speeds	◆ 8 kHz: 2 fps (4096 x 4096 Pixels); 30 fps (512 x 512 Pixels); 400 fps (512 x 32 Pixels) ◆ 12 kHz: 4.4 fps (2048 x 2048 Pixels); 45 fps (512 x 512 Pixels); 600 fps (512 x 32 Pixels)
	Galvo-Galvo Scan Speeds	◆ 3 fps at 512 x 512 Pixels; 48 fps at 512 x 32 Pixels; 70 fps at 32 x 32 Pixels ◆ Pixel Dwell Time: 0.4 - 20 $\mu$ s
	Galvo-Galvo Scan Geometries	◆ Imaging: Line, Polyline, Square, or Rectangle ◆ Non-Imaging: Circle, Ellipse, Polygon, or Point
	Field of View	◆ 20 mm Diagonal Square (Max) at the Intermediate Image Plane (12 mm Diagonal Square (Max) for 12 kHz Scanner)
	Scan Zoom	◆ 1X - 16X (Continuously Variable)
	Scan Resolution	◆ Bi-Directional: 2048 x 2048 Pixels (Max) (1168 x 1168 Pixels (Max) for 12 kHz Scanner) ◆ Unidirectional: 4096 x 4096 Pixels (Max) (2336 x 2336 Pixels (Max) for 12 kHz Scanner)
<b>Confocal Imaging</b>	<ul style="list-style-type: none"> <li>◆ Motorized Pinhole Wheel with 16 Round Pinholes from <math>\varnothing</math>25 <math>\mu</math>m to <math>\varnothing</math>2 mm</li> <li>◆ Two to Four Laser Lines (Options Range from 405 nm to 660 nm)</li> <li>◆ Standard Multialkali or High-Sensitivity GaAsP PMTs</li> <li>◆ Easy-to-Exchange Emission Filters and Dichroic Mirrors</li> </ul>	
<b>Three-Photon Imaging</b>	<ul style="list-style-type: none"> <li>◆ Scan Optics for 800 - 1800 nm Range</li> <li>◆ Achieve Reduced Background Scatter for Greater Sensitivity in Deep Tissue Imaging</li> </ul>	
<b>Volume Imaging Using Bessel Beams</b>	<ul style="list-style-type: none"> <li>◆ 3D Volumetric Functional Imaging at Video Frame Rates</li> <li>◆ Enhanced Temporal Resolution for Studying Internal Systems at Cellular Lateral Resolution <i>In Vivo</i></li> </ul>	

## Multiphoton Signal Detection

<b>Photomultiplier Tubes (PMTs)</b>	<ul style="list-style-type: none"> <li>◆ Thermoelectrically Cooled or Non-Cooled GaAsP PMTs with Preamplifiers Included</li> <li>◆ Simultaneous Detection up to Four Channels</li> </ul>
<b>Epi-Detection</b>	<ul style="list-style-type: none"> <li>◆ Up to Four Ultrasensitive GaAsP PMTs, Cooled or Non-Cooled</li> <li>◆ Easy-to-Exchange Magnetic Filter Holders</li> </ul>
<b>Forward-Direction Detection</b>	<ul style="list-style-type: none"> <li>◆ 13° Signal Collection Angle* (Two Ultrasensitive GaAsP PMTs, With or Without Shutters)</li> <li>◆ Easy-to-Exchange Emission Filters and Dichroic Mirrors</li> </ul>
<b>Collection Optics</b>	<ul style="list-style-type: none"> <li>◆ 8°, 10°, or 14° Collection Angle*</li> <li>◆ Easy-to-Exchange Emission Filters and Dichroic Mirrors</li> </ul>

\*Angles are quoted when using an objective with a  $\varnothing$ 20 mm entrance pupil.

## Translation

<b>X and Y</b>	<ul style="list-style-type: none"> <li>◆ 2" (50.8 mm) Total Fine Travel; 0.5 <math>\mu</math>m Encoder Resolution</li> </ul>
<b>Z</b>	<ul style="list-style-type: none"> <li>◆ 1" (25.4 mm) Total Fine Travel; 0.1 <math>\mu</math>m Encoder Resolution</li> <li>◆ Piezo Objective Scanner               <ul style="list-style-type: none"> <li>- Open Loop: 600 <math>\mu</math>m <math>\pm</math> 10% Travel Range; 1 nm Resolution</li> <li>- Closed Loop: 450 <math>\mu</math>m Travel Range; 3 nm Resolution</li> </ul> </li> </ul>
<b>Microscope Base (Rotating Bodies Only)</b>	<ul style="list-style-type: none"> <li>◆ 5" (127 mm) Total Coarse Z Travel; 1 <math>\mu</math>m Encoder Resolution</li> </ul>
<b>Rotation (Rotating Bodies Only)</b>	<ul style="list-style-type: none"> <li>◆ 0° to 90° or -45° to 45° Around the Sample</li> <li>◆ 0.1° Encoder Resolution</li> </ul>

## Additional Features

<b>Widefield Viewing</b>	<ul style="list-style-type: none"> <li>◆ Manual or Motorized Switching Between Scanning and Widefield Modes</li> <li>◆ Illumination Provided via LED or Liquid Light Guide</li> <li>◆ C-Mount Threads for Scientific Cameras</li> </ul>
<b>Transmitted Light Imaging</b>	<ul style="list-style-type: none"> <li>◆ Differential Interference Contrast (DIC) or Dodt Gradient Contrast (DGC)</li> <li>◆ Illumination Provided by Visible and/or NIR LEDs</li> <li>◆ Compatible with Air and Oil Immersion Condensers</li> </ul>
<b>Objective Focus Control</b>	<ul style="list-style-type: none"> <li>◆ Stepper Motor: 1" (25.4 mm) Travel Range; 0.1 <math>\mu</math>m Encoder Resolution</li> <li>◆ Piezo Objective Scanner with Nanometer-Level Axial Resolution for Objective Positioning and Z-Stack Acquisition</li> </ul>
<b>Sample Holder</b>	<ul style="list-style-type: none"> <li>◆ Choice of Sample Holders               <ul style="list-style-type: none"> <li>- Rigid Stand with Platform, Slide Holder, or Recording Chamber</li> <li>- Translating Platform Ideal for Micromanipulators</li> </ul> </li> </ul>
<b>Microscope Controller</b>	<ul style="list-style-type: none"> <li>◆ Advanced 5-Axis Controller with Touchscreen               <ul style="list-style-type: none"> <li>- Rotating Body: Control X, Y, Z, Microscope Base, and Rotation Angle</li> <li>- Upright Body: Control X, Y, and Z Axes</li> <li>- Speed Adjustment, Saved Positions, and an Interactive User Interface</li> </ul> </li> <li>◆ 3-Axis Controller               <ul style="list-style-type: none"> <li>- Motorized Condenser Focus Control</li> </ul> </li> </ul>
<b>Beam Conditioning Modules</b>	<ul style="list-style-type: none"> <li>◆ Pockels Cell               <ul style="list-style-type: none"> <li>- Edge and Fly-Back Blanking to Minimize Sample Photobleaching</li> <li>- High-Speed Masking for ROIs</li> <li>- Customize Laser Power at Each Slice Using Software Control</li> </ul> </li> <li>◆ Variable Attenuator with One-Click Shutter               <ul style="list-style-type: none"> <li>- Manual and Computer Control of Laser Power in Systems without a Pockels Cell</li> <li>- Improves Pockels Cell Performance</li> </ul> </li> <li>◆ Beam Stabilizer               <ul style="list-style-type: none"> <li>- Maintain Stable Beam Pointing While Changing Excitation Laser Wavelength</li> </ul> </li> </ul>

## Image Credits

- e. Sample Courtesy of Qinrong Zhang, PhD and Matthew Jacobs; the Ji Lab, Department of Physics, University of California, Berkeley, CA.
- f. Courtesy of the Chris Xu Group; Cornell University, Ithaca, NY.
- g. Courtesy of Lloyd Russell, Dr. Adam Packer, and Prof. Michael Häusser; University College London, United Kingdom.
- h. Image Courtesy of the Neurobiology Course at the Marine Biological Laboratory; Woods Hole, MA.
- i. Sample Courtesy of Lynne Holtzclaw; NIH/NICHD/MIC, Bethesda, MD.
- j. Sample Courtesy of Zepeng Yao; the Scott Lab, Department of Molecular & Cell Biology, University of California, Berkeley, CA.

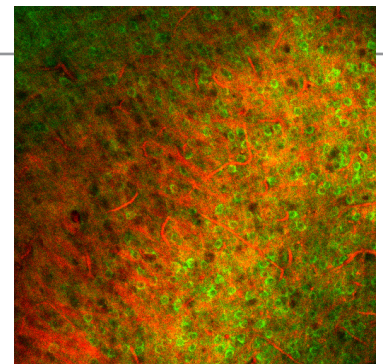
# Recent Publications Using Thorlabs' Imaging Systems

1. Tsuji, M., Nishizuka, Y., & Emoto, K. (2023). Threat gates visual aversion via theta activity in Tachykinergic neurons. *Nature Communications*, 14(1), 3987.
2. Villanueva, C. B., Stephensen, H. J., Mokso, R., Benraiss, A., Sparring, J., & Goldman, S. A. (2023). Astrocytic engagement of the corticostriatal synaptic cleft is disrupted in a mouse model of Huntington's disease. *Proceedings of the National Academy of Sciences*, 120(24), e2210719120.
3. Holstein-Rønsbo, S., Gan, Y., Giannetto, M.J. et al. (2023). Glymphatic influx and clearance are accelerated by neurovascular coupling. *Nature Neuroscience*, 26, 1042–1053.
4. Serradj, N., Marino, F., Moreno-López, Y., Bernstein, A., Agger, S., Soliman, M., ... & Hollis, E. (2023). Task-specific modulation of corticospinal neuron activity during motor learning in mice. *Nature Communications*, 14(1), 2708.
5. Inayat, S., McAllister, B. B., Whishaw, I. Q., & Mohajeri, M. H. (2023). Hippocampal conjunctive and complementary CA1 populations relate sensory events to movement. *iScience*, 26(4), 106481.
6. Untiet, V., Beinlich, F. R., Kusk, P., Kang, N., Ladrón-de-Guevara, A., Song, W., ... & Nedergaard, M. (2023). Astrocytic chloride is brain state dependent and modulates inhibitory neurotransmission in mice. *Nature Communications*, 14(1), 1871.
7. Anthoney, N., Tainton-Heap, L. A., Luong, H., Notaras, E., Kewin, A. B., Zhao, Q., ... & van Swinderen, B. (2023). Experimentally induced active and quiet sleep engage non-overlapping transcriptional programs in Drosophila. *bioRxiv*, 535331.
8. Boster, K. A., Cai, S., Ladrón-de-Guevara, A., Sun, J., Zheng, X., Du, T., ... & Kelley, D. H. (2023). Artificial intelligence velocimetry reveals in vivo flow rates, pressure gradients, and shear stresses in murine perivascular flows. *Proceedings of the National Academy of Sciences*, 120(14), e2217744120.
9. Scarpetta, V., Bodaleo, F., Salio, C., Agarwal, A., Sassoè-Pognetto, M., & Patrizi, A. (2023). Morphological and mitochondrial changes in murine choroid plexus epithelial cells during healthy aging. *Fluids and Barriers of the CNS*, 20(1), 1-16.
10. McDermott, K. D., Frechou, M. A., Jordan, J. T., Martin, S. S., & Gonçalves, J. T. (2023). Delayed formation of neural representations of space in aged mice. *bioRxiv*, 531021.
11. Matthews, M. D., Cook, E., Naguib, N., Wiesner, U. B., & Lewis, K. J. (2023). Intravital imaging of osteocyte integrin dynamics with locally injectable fluorescent nanoparticles. *Bone*, 174, 116830.
12. Tort-Colet, N., Resta, F., Montagni, E., Pavone, F., Allegra Mascaro, A. L., & Destexhe, A. (2023). Assessing brain state and anesthesia level with two-photon calcium signals. *Scientific Reports*, 13(1), 3183.
13. Esteves, I. M., Chang, H., Neumann, A. R., & McNaughton, B. L. (2023). Consolidation of cellular memory representations in superficial neocortex. *iScience*, 26(2), 105970.
14. Quezada, A., Ward, C., Bader, E. R., Zolotavin, P., Altun, E., Hong, S., ... & Hébert, J. M. (2023). An in vivo platform for rebuilding functional neocortical tissue. *Bioengineering*, 10(2), 263.
15. Yang, J. Y., O'Connell, T. F., Hsu, W. M. M., Bauer, M. S., Dylla, K. V., Sharpee, T. O., & Hong, E. J. (2023). Restructuring of olfactory representations in the fly brain around odor relationships in natural sources. *bioRxiv*, 528627.

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Primary Visual Cortex of Transgenic Mouse Expressing  
GCaMP6f (Green) and Third Harmonic Autofluorescence (Red)  
(Courtesy of Jacob Reimer and Andreas Tolias, Baylor College of Medicine, Houston, TX, and  
Tianyu Wang, Dimitri Ouzounov, and Chris Xu, Cornell University, Ithaca, NY)



## Sales Contact

Whether you are seeking more information about Bergamo II microscopes or are ready to make a purchase, our dedicated sales team is here to provide assistance.

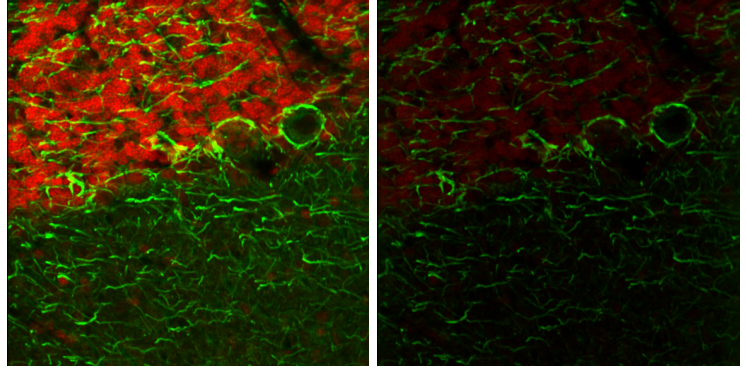
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**TIBERIUS**  
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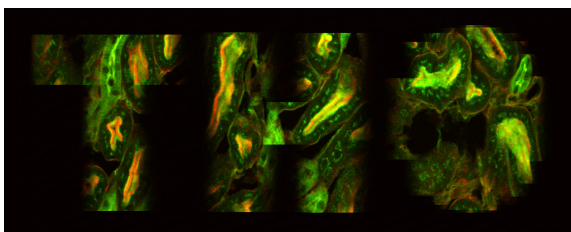
Fast switching between the fluorophores' optimal excitation wavelengths of 750 nm and 835 nm provides high contrast, seen in the composite image (left) when compared to the image acquired utilizing only a non-optimal 788 nm wavelength (right). (Sample Prepared by Lynne Holtzclaw of the NICHD Microscopy and Imaging Core Facility, a part of the National Institutes of Health (NIH) in Bethesda, MD.)

## Fast Laser Power Modulators for Two-Photon Microscopy



**OM6NH**  
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Dimensions: 291 mm x 173 mm x 71 mm (L x W x H)

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- ◆ 700 - 1100 nm or 700 - 1350 nm Operating Ranges
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- ◆ Near-Zero (<math><100 \text{ fs}^2</math>) Dispersion
- ◆ <math><1 \mu\text{s}</math> On/Off Time



Two-channel 2P image of mouse kidney cells acquired with Thorlabs' Bergamo® II microscope and Tiberius fast-tuning Ti:Sapphire laser, using the OM6N fast laser power modulator to define a region of interest.

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