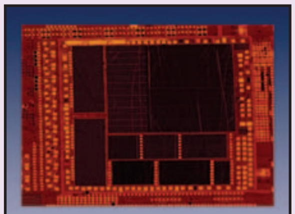
ASOM
Spectral Radar OCT
Swept Source OCT
Video-Rate Laser Scanning Microscope
Swept Source Lasers
OCT Components
Laser Microscopy Optics
Microscopy Tools

Adaptive Scanning Optical Microscope...Page 1 of 8



Microprocessor

Mosaic Imaging Provides 40mm Diameter Composite FOV Image with a 1.5µm Resolution

Breaking the barrier between large field of view (FOV) and high resolution without moving the sample or microscope. The ASM9600 captures 50,000 x 50,000 pixel mosaic images in just 20 seconds.

ASM9600

ASOM Specifications

- **Composite Field of View:** 40mm (Diameter)
- **Total Observable Field Area:** 1250mm^2 (3215 Tiles at 0.39mm^2/Tile)
- **Resolution:** 1.5µm
- **Static Optical Magnification:** 6.5X (Object to CCD Image Plane)
- **Numerical Aperture:** 0.20
- **Working Distance:** 19mm
- **Operating Wavelength:** 490-530nm
- **Camera Pixel Count:** 1024 x 768
- **Camera Pixel Size:** 4.7µm x 4.7µm
- **Camera Dynamic Range:** 50dB
- **Camera Shutter:** 1/15s to 1/6000s
- **Manual Sample Stage Trasnlation Ranges:** X=1.75", Y=2.25", Z=1.35"

Thorlabs is pleased to offer the world's first optical imaging microscope based upon a new adaptive optic technology that circumvents the trade-off between field of view (FOV) and image resolution. By combining a high-speed steering mirror, a large aperture scan lens, and a deformable mirror, the Thorlabs Adaptive Scanning Optical Microscope (ASOM) is capable of delivering a large field of view (40mm in diameter) while simultaneously providing a uniform image resolution of 1.5µm throughout the entire composite image. Current microscope designs can only generate this type of functionality via moving stages, large microscope arrays, or very expensive lithography-based imaging systems.

ASOM Image Scanning Features

- Moving Object Tracking
- Rare Event Detection
- Spatially Separated Individual Tiles
- Full Contiguous Area Coverage

ASOM System Includes

- Complete Microscope With Transmissive & Reflective Illumination Sources
- All Drive Electronics
- Pentium-Class PC With Windows XP
- Pre-Installed ASOM Software (Described on Page 585)

The composite image of the ASM9600 is formed by using the system's fast steering mirror (FSM) to scan only the portion of the sample that is of interest up to the maximum FOV defined by the large 40mm diameter aperture scan lens. As the imaged area on the sample is changed (by changing the orientation of the FSM) the deformable mirror (DM) is used to correct the wavefront error introduced by the scan lens, thus maintaining the diffraction-limited 1.5µm resolution across the extended composite FOV. The scanning system has a wide range of operating modes that include: object tracking, rare event detection, and localized monitoring of specific locations separated spatially by large distances, all in real time. The ASOM, operating at 200 tile frames per second (optional high-speed camera), can complete one full 40mm diameter image less than 20 seconds.

The sample being imaged by the ASOM system can be illuminated via two separate illumination pathways, each with its own light source. A light source mounted under the sample stage is used for transmissive mode illumination while another light source is used for reflective mode illumination (more details on the illumination system are provided on page 586). Only the portion of the sample being imaged is illuminated, when operating in the reflective illumination mode making optimal use of the available light.

The ASM9600 was designed in collaboration with Ben Potsaid, John Wen, and Yves Bellouard at the Center for Automation Technologies and Systems (CATS) at Rensselear Polytechnic Institute (RPI; Troy, NY).

ITEM#	$	£	€	RMB	DESCRIPTION
ASM9600	CALL	CALL	CALL	CALL	Adaptive Scanning Optical Microscope

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ASOM Specific Components

Scan Lens

The ASOM scan lens is based on a reverse telephoto design and has a 76.5mm clear aperture. It is designed to be used with a 44mm diameter light field to facilitate the 40mm composite FOV. For the 44mm light field diameter, the image space NA is 0.2, resulting in a resolution of 1.5µm across the mosaic image after the wave front is corrected by the DM. The use of the DM and its ability to correct up to 14 waves of wave front distortion at 510nm relaxes the need for a complex scan lens design. The scan lens has an on axis wave front error of 0.539 waves peak to valley, and an off axis error of 3.381 waves (all measured at 510nm).

A large working distance of 19mm is provided to allow sufficient room for samples to be easily loaded and manipulated.

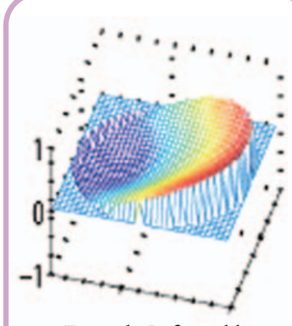
Scan Lens Features
- Large Diameter
- Flat-Field Telecentric Design

ASOM Image Scanning Features
- Moving Object Tracking
- User Defined

Fast Steering Mirror (FSM)

The pitch and yaw fast steering mirror (indicated as FSM in Figure 1) measures 75mm in diameter and is the component that controls the mosaic image formation of the ASOM system. The angular orientation of the fast steering mirror selectively images a particular segment of the sample. Each of these segments is referred to as a tile; each tile measures 0.72mm horizontally by 0.54mm vertically and is comprised of 786,432 pixels (1024 x 768). There are 3215 tiles per composite image when the entire mosaic FOV is imaged. The control system allows both sequential and non-sequential image acquisition, the later provides the ability to track live organisms as they move within the composite FOV.

The total angular range in both pitch and yaw of the FSM is 12°, and the time required to step from one tile to the next is approximately 30ms. As the tile location changes, the system control software automatically updates the shape of the of the DM. To ensure a flat image field, the FSM is located at the back focal plane of the scan lens.



Example Deformable Mirror Profile

Deformable Mirror (DM)

The DM is capable of reconfiguring its surface topography to cancel the wavefront error encountered for each image tile. A factory calibration process ensures that this correction process provides diffraction-limited performance throughout the entire imaged area. See Figure 1 for the location of the DM within the ASOM system.

The DM measures 4.4mm by 4.4mm and is comprised of a 12 x 12 grid of electrostatic actuators on 400µm centers, each with a 3.5µm range. The DM has a broadband enhanced aluminum coating and is capable of operating at approximately 1kHz.

ASOM System Schematic

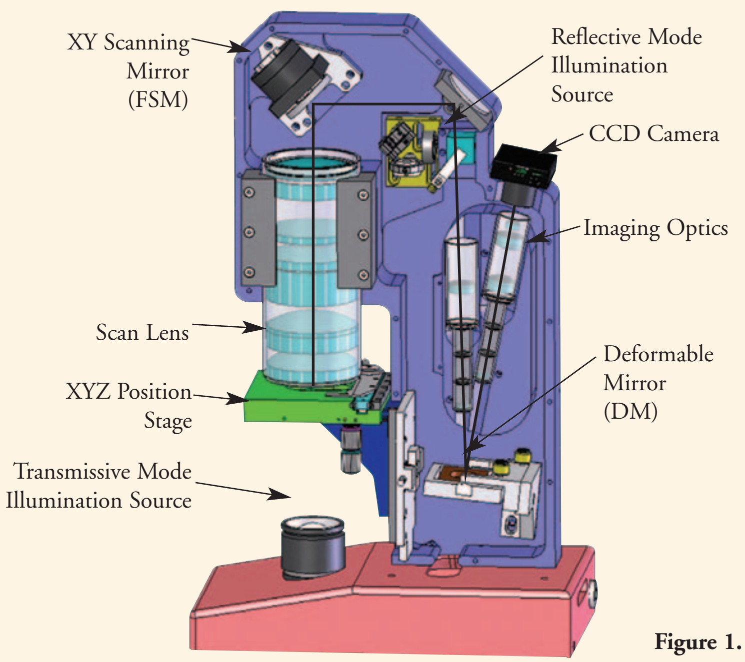
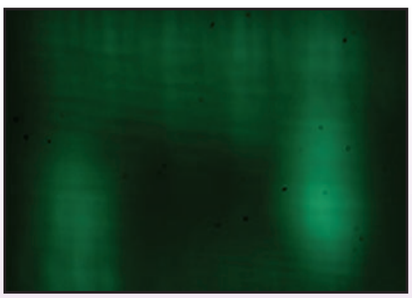
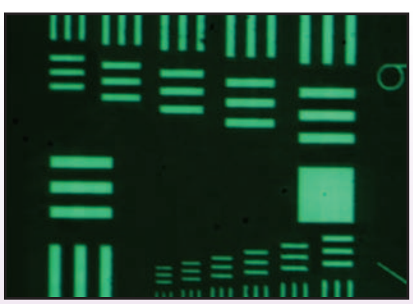


Figure 1.


Air Force target image without the use of the deformable mirror.
Figure 2a.


Air Force target image using the deformable mirror. The smallest lines are separated by 2µm.
Figure 2b.

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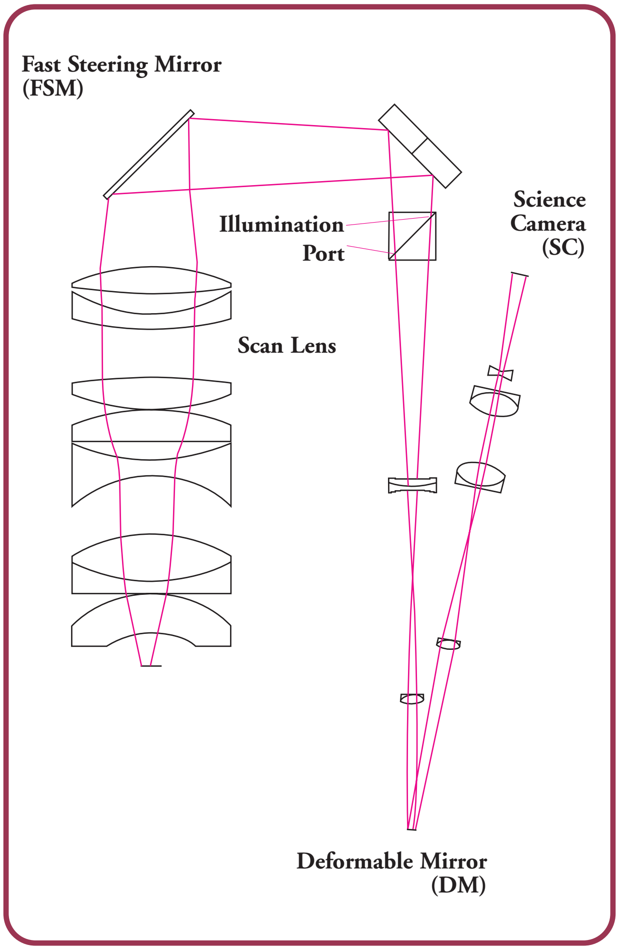
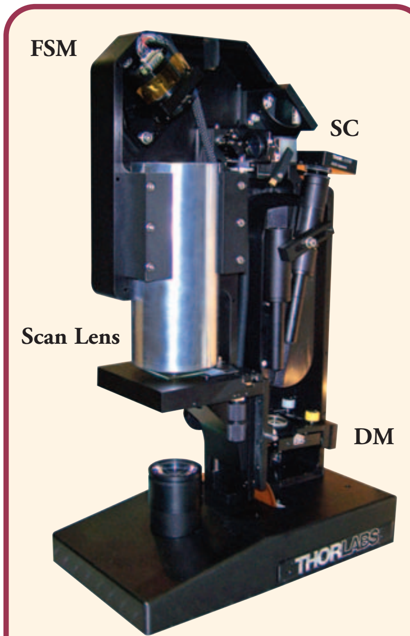


The original ASOM concept was developed in 2005 by Ben Potsaid, John Wen, and Yves Bellouard at the Center for Automation Technologies and Systems (CATS) at Rensselear Polytechnic Institute (RPI; Troy, NY). In November 2006 Thorlabs and RPI researchers initiated a collaborative effort to transform the ASOM design from a research project into a commercial product. The success of the collaboration realized a major milestone in May 2007 when the first fully functional commercial prototype was unveiled as ASOM and was honored with the PhAST/Laser Focus World Innovation Award.

Microscope Conceptual Design

In a traditional microscope, the FOV is small and limited by the objective lens. In order to image large samples at high resolution, the objective must be scanned across the sample (either by moving the microscope or the sample with a moving stage). In contrast, the ASOM uses an FSM to scan across a large diameter objective lens.



First prototype ASOM completed within six months of the initial collaboration with RPI.

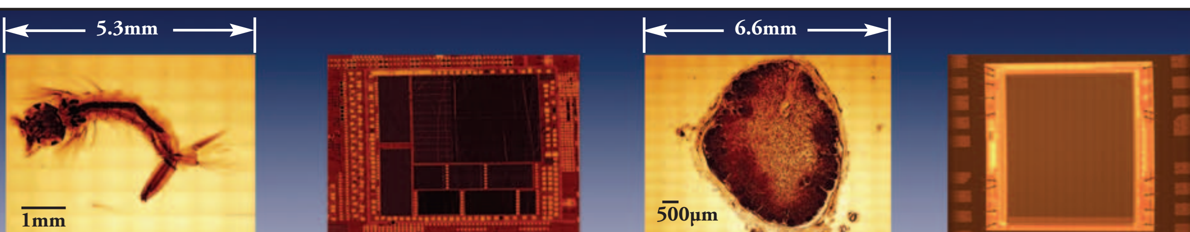
Off-axis light experiences significant wavefront distortions from the objective lens that results in an aberrated image. However, by using a DM with real-time control, the surface of the mirror is optimized to correct these wavefront distortions in order to provide uniform resolution and diffraction-limited imaging over an extended composite FOV.

To image a large sample, the light is scanned across a single square aperture (single tile size is 720 x 540µm). Multi-tile scanning creates an image mosaic providing a high resolution image with a large FOV.

Thorlabs is honored to be recognized by photonics industry professionals who awarded the ASOM First Place in the 2007 PhAST/Laser Focus World Innovation Awards.

ASOM Wins 2007 PhAST/Laser Focus World Innovation Award

Examples of large field images produced by the ASOM.



Mosquito Larva | Microprocessor | Rabbit Lymph Node | CCD Camera Chip

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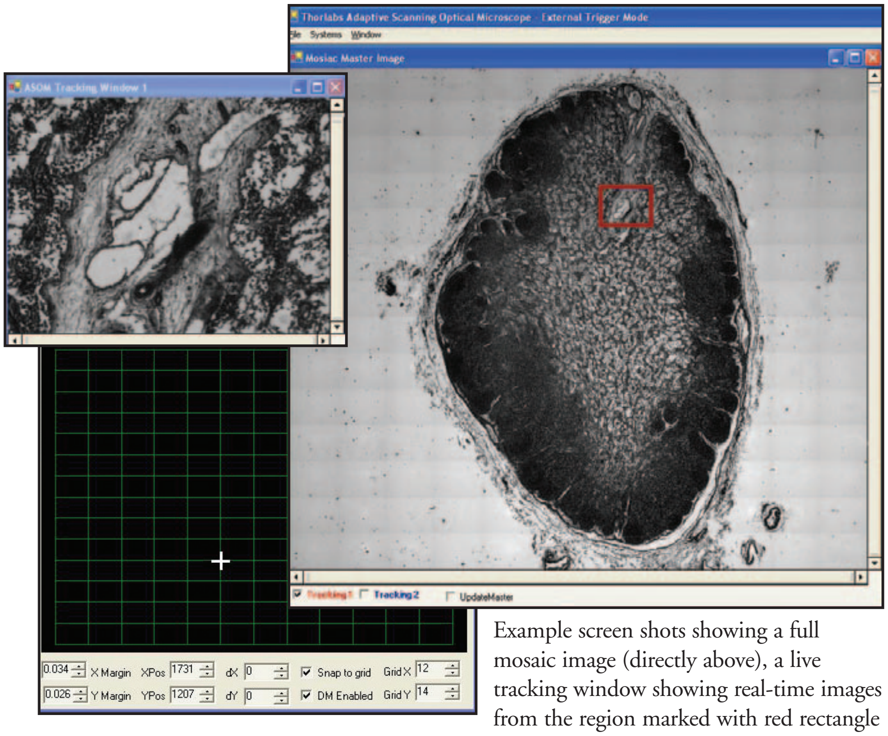
Fully Integrated Software

The ASOM comes as a complete microscopy imaging sytem including scanhead, computer, electronics, and software. The Pentium-class PC running WindowsXP comes with preconfigured software that is loaded and ready for operation.

The software package provides complete system control including self-calibration and self-optimization of the DM and all functions for image scanning, image collection, and data processing. A dynamic display provides detailed information on the FSM position and the DM topography, which provides immediate visual feedback of system functions and performance. An option for manual adjustments of the DM is available for experiment-specific requirements.



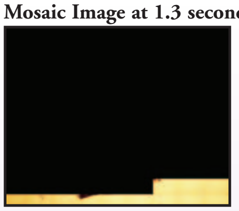
Example screen shots showing a full mosaic image (directly above), a live tracking window showing real-time images from the region marked with red rectangle on mosaic scan (upper left), and the FSM interface (lower left).

Mosaic Image Creation

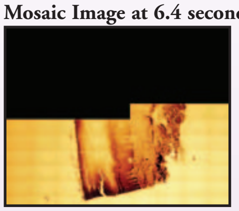
In order to capture the large FOV while maintaining the high resolution, the ASOM software stitches together several sequential camera images (tiles) into a single mosaic image. As a mosaic image is assembled, the ASOM software maintains the full 1024 x 768 pixel CCD data set contained within each tile, preserving the high-resolution data for exploration and analysis. Tile placement within the mosaic image is dictated by the object plane coordinates associated with the angular orientation of the FSM at the time the tile image was captured, the software seamlessly stitches together the composite image.

ASOM Mosaic Imaging

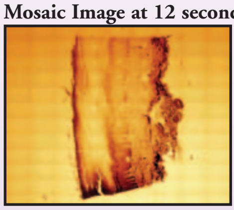
Mosaic Image at 1.3 seconds

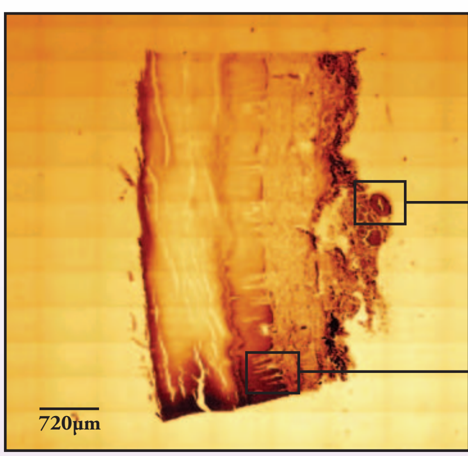


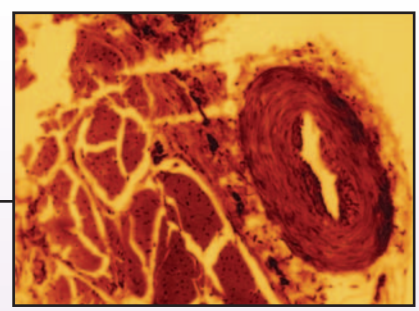
Mosaic Image at 6.4 seconds

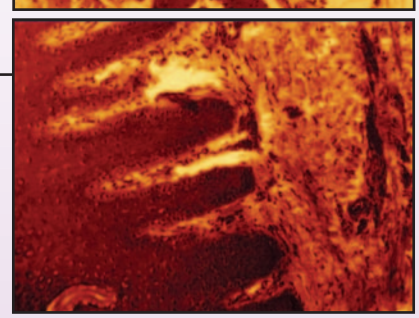


Mosaic Image at 12 seconds*









The images shown here illustrate the tile-scan mosaic data collection, demonstrated with a sample of human skin and sweat gland mounted on a standard microscope slide.

*As the design of the ASOM matures, the acquisition speed is expected to double every 3-6 months.

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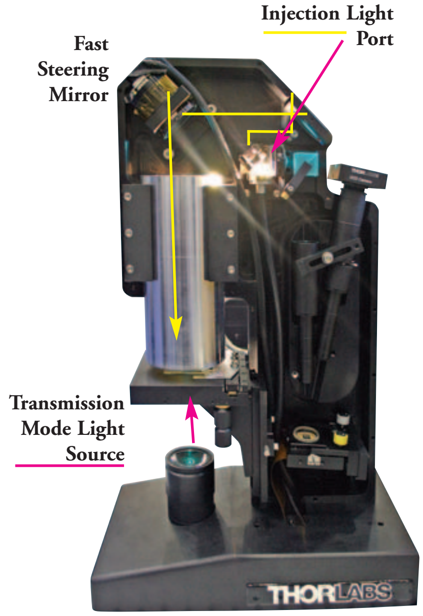
Illumination

The sample being imaged by the ASOM system can be illuminated via two separate illumination pathways, each with a separate light source. The LED light source mounted under the sample stage is used for bright field imaging (transmissive mode), and another internal LED light source is used for epi-illumination (reflective mode). The system comes with standard 528nm illuminators for both illumination modes, but various wavelengths are available (please see our website for details). While the scan lens is designed for operation around 510nm, the use of other wavelengths across the visible spectrum is possible. A substantial change in wavelength (>50nm) will require a small focus adjustment for optimal image quality.

In addition, there is a light injection port that can be used to insert a user supplied light source into the system. The ASM9600 is designed to accept band-pass filters, which can easily be inserted into the illumination pathway to facilitate multi-spectral imaging. Thorlabs is also developing a flexible lighting solution that will be fully compatible with the ASOM system. This light source will feature 6 wavelengths (452nm, 472nm, 498nm, 528nm, 593nm, and 626nm).

When operating in the bright field mode, the entire composite FOV is illuminated from beneath the sample stage. When operating in the epi-illumination mode, the sample illumination is limited to just the active tile. This mode ensures optimal use of the available light, and hence often results in a reduction of the image acquisition time as well as reducing photo-induced damage of live samples.



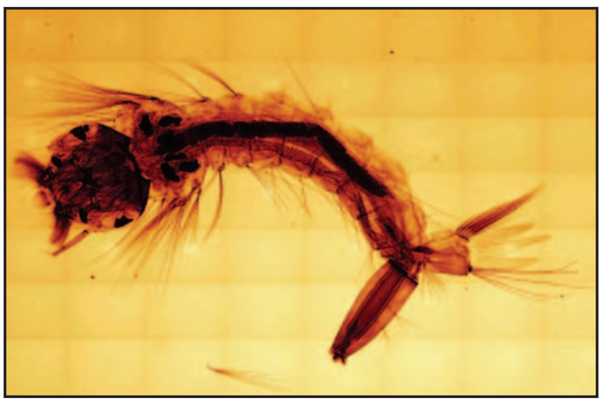


Image of mosquito larva in transmissive configuration, acquired in 8 x 8 tile mosaic scan. Total digital image measures 8,192 x 6,144 pixels.

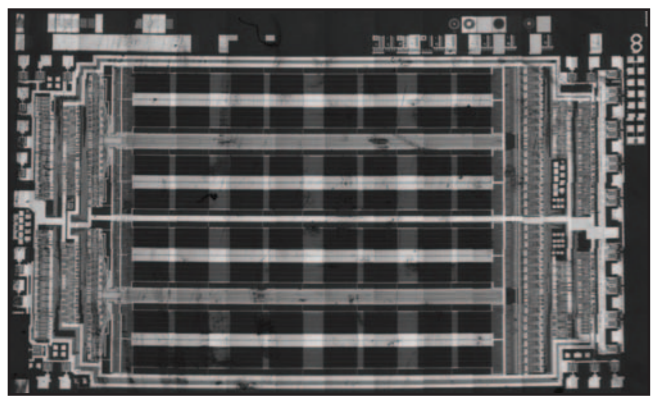
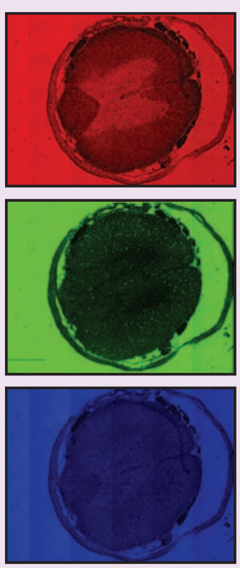
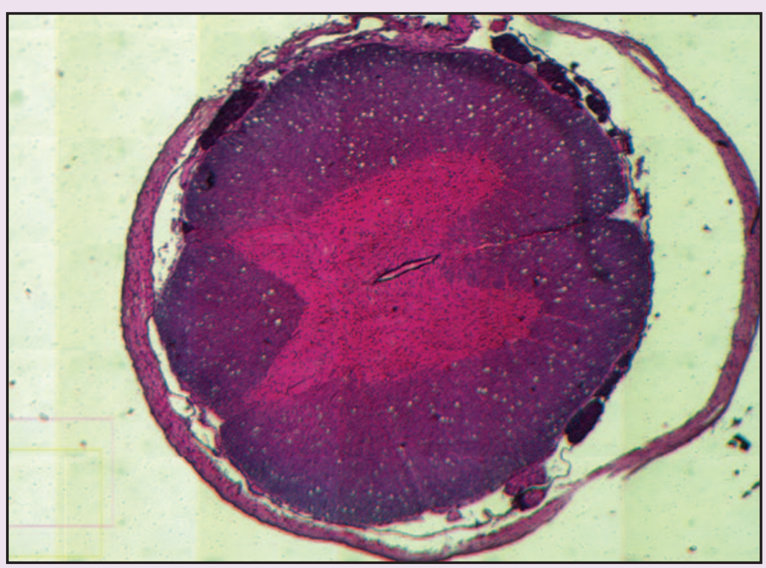


Image of computer memory chip in reflective configuration, acquired in 14 x 8 tile mosaic scan. Total digital image measures 14,336 x 6,144 pixels.

RGB Composite Imaging

This example demonstrates the versatility of the illumination components and software data processing capabilities. Individual images were captured with a black and white CCD camera, each with a discrete dichroic color filter (red, green, and blue). Once the intensity data is captured, the software color adjusts and then combines the RGB data into a single composite image representative of a full-color scan, but without any chromatic effects commonly associated with imaging with a broadband light source.





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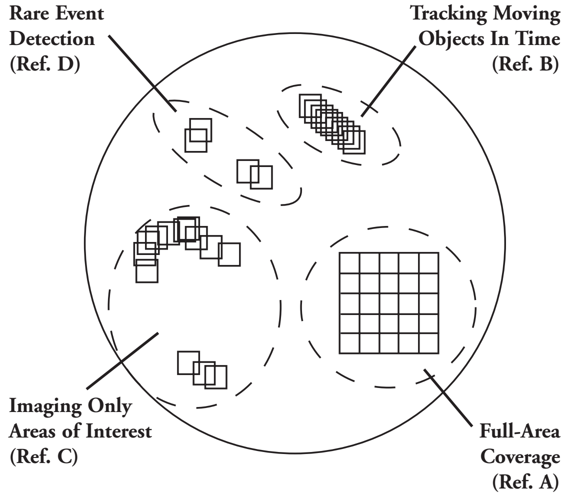
Flexible Scanning Capabilities

The FSM located above the ASOM Scan Lens (see figure on top-right of previous page) is responsible for determining, via its angular orientation, the specific location within the object plane on which the optical system is focused. Since the ASOM software self-optimizes the DM for every unique FSM orientation, diffraction-limited performance is achieved at all times. This dynamic wavefront correction capability allows the ASOM software to generate completely arbitrary scan paths tailored to the specific needs of the individual application. In addition, the software allows the user to adjust the DM topography manually at any location within the FOV so that the wave front may be manually corrected as well.



This dynamically adjustable scan path capability is demonstrated by the schematic to the right, representing four common applications made possible by the FSM. The dashed circles represent possible viewing strategies, while the boxes represent individual scan locations that define the strategy. The standard mosaic image scan mode is ideal for a fast, complete examination of a user-defined area of interest (**Ref. A**). The software may be set for other scan modes such as tracking a moving object (**Ref. B**), viewing multiple spatially separated areas of interest simultaneously (**Ref. C**), and monitoring intermittent processes or rare events over time (**Ref. D**). These scan modes can be used for a wide range of applications, including tracking live samples or micro-robotic grippers in a microelectronic production environment.

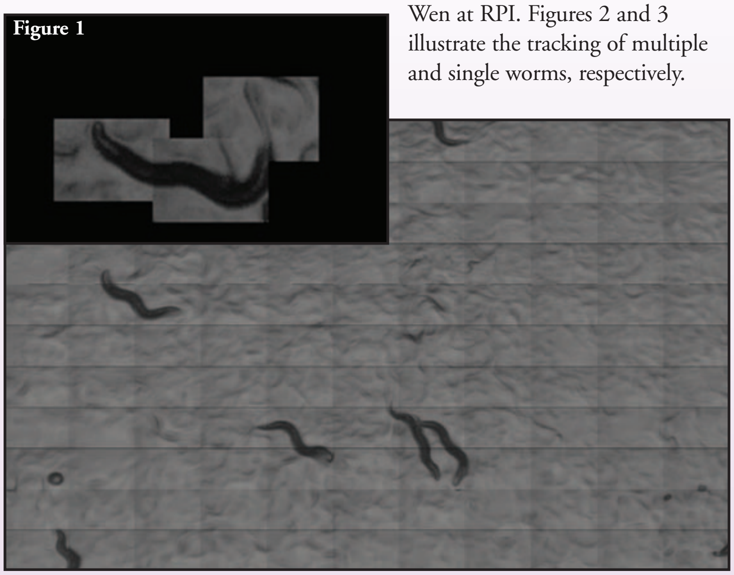
Real-Time Live Sample Mobility Tracking

The ASOM design incorporates an FSM for imaging speeds up to 200 tiles per second. A real-time tracking algorithm allows the user to track live organisms without moving the stage, which can blur the image due to vibrations and can disturb the normal mobility tendencies of living samples. The images shown below were obtained by imaging living *C. elegans* on an agar plate. Figure 1 shows the large FOV imaged to identify an organism of interest. Once this is defined, the software allows the user to zoom in, without changing objectives and track individual organisms that would otherwise move out of the FOV in traditional microscope designs. This application is demonstrated using live *C. elegans*, an organism with a rich body of research literature in molecular biology, developmental biology and neurobiology.

Imaging of Live *C. elegans*

Multiple moving targets can be easily tracked with the ASOM's ability to quickly adjust the focal position with the Fast Steering Mirror. Figure 1 demonstrates three scan "tiles", the first positioned on the head, the second on the midsection, and the third on the tail of a single *C. elegans* worm. These live worm imaging tracking results were obtained by Fern P. Finger, Benjamin Potsaid, and John T. Wen at RPI. Figures 2 and 3 illustrate the tracking of multiple and single worms, respectively.

Figure 1



Back illuminated images of *C. elegans* on agar plate obtained with Thorlabs ASOM-VIS system.

Figure 2

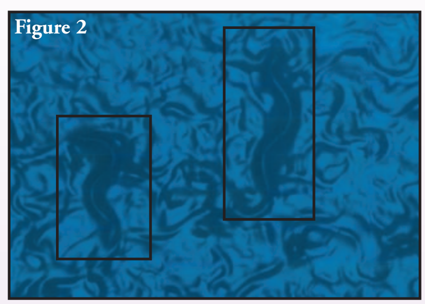
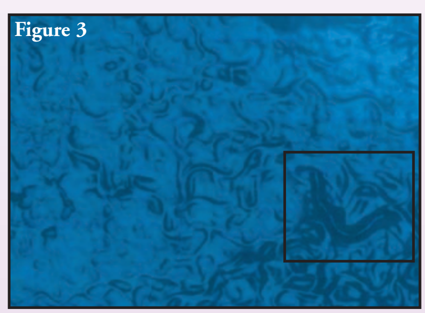


Figure 3



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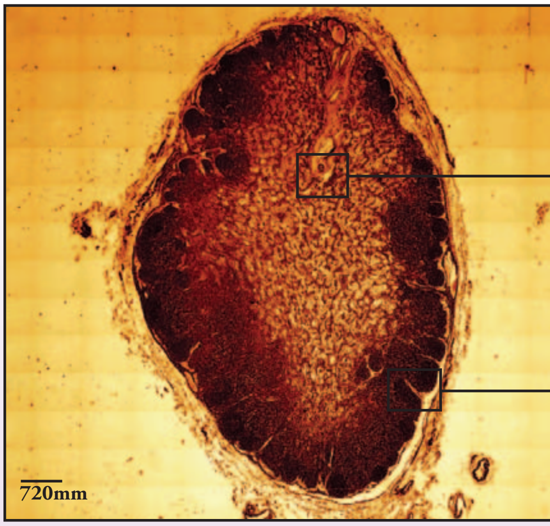


Figure 1

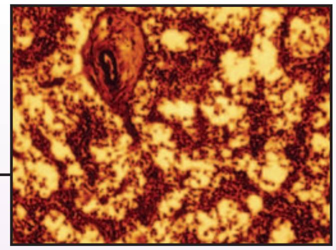


Figure 2

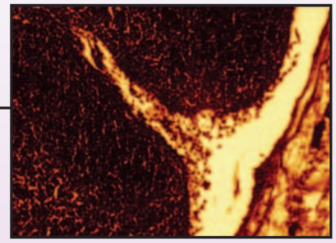
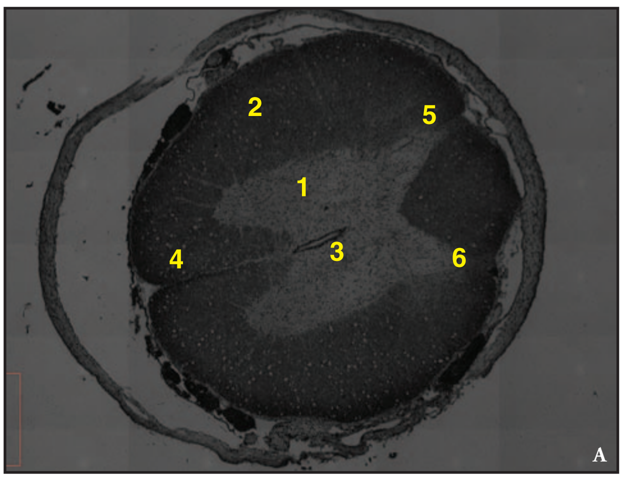
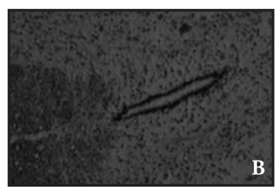


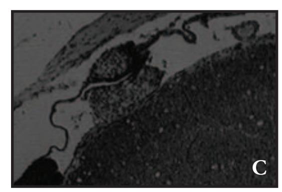
Figure 3

These three images show a slide of rabbit lymph node mounted on a standard microscope slide. The images were taken using the ASOM9600 in transmissive mode. The first image (Fig. 1) shows the entire structure (image size), while the two other images (Figs. 2 and 3) demonstrate cellular-level resolution capabilities of the ASOM, by zooming in on the sinus and a cross-section of a lymphatic vessel.



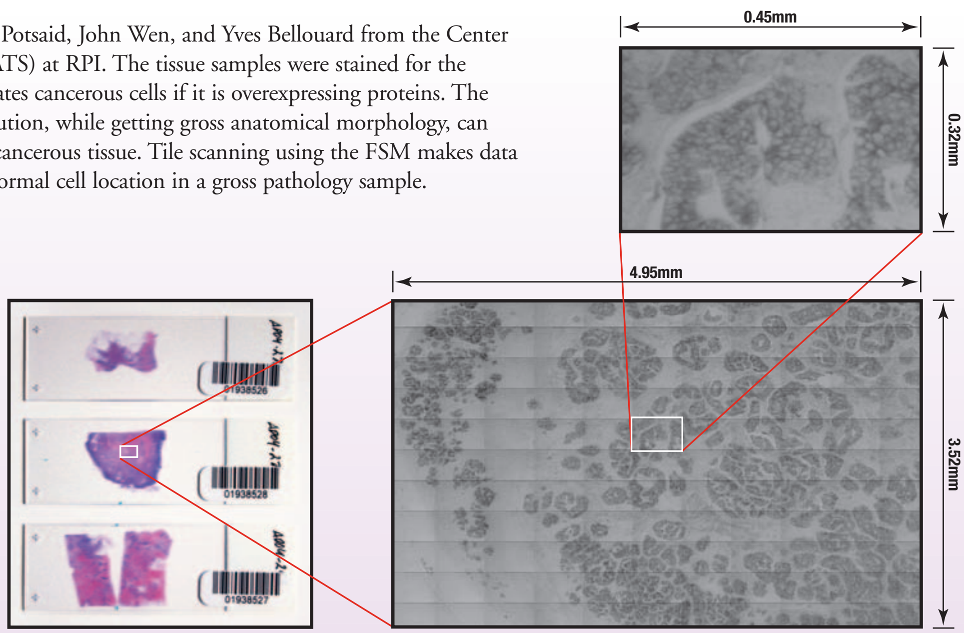
The image shown here is a cross-section of a Rat Anerior Horn (spinal cord) mounted on a standard microscope slide taken with the ASOM9600 in tranmissive mode. Figure A shows the entire sample (4.32mm x 3.24mm), showing the complete structural identification of the gross anatomy and a close-up of the central canal. 1: Gray Matter 2: White Matter, 3: Central Canal, 4: Median Fissure, 5 & 6: Nerve Root. Figures B and C are enlargements of regions 3 and 2 respectively.





Breast tissue slides shown are provided by Ben Potsaid, John Wen, and Yves Bellouard from the Center for Automation Technologies and Systems (CATS) at RPI. The tissue samples were stained for the growth hormone receptor system, which indicates cancerous cells if it is overexpressing proteins. The ability to create images with cellular level resolution, while getting gross anatomical morphology, can greatly aid the detection and identification of cancerous tissue. Tile scanning using the FSM makes data acquisition rapid, while clearly identifying abnormal cell location in a gross pathology sample.

The DM and FSM design incorporated in the new ASOM system makes pathology screening quicker, easier, and more accurate. By providing cellular-level resolution and a large FOV, the full plane of the pathology slide can be rapidly imaged, which eliminates the need for multiple scans with a moving stage, allowing high throughput slide processing. The high resolution (1.5µm) obtained in a single scan enables facile determination of cell abnormalities for accurate clinical diagnoses.



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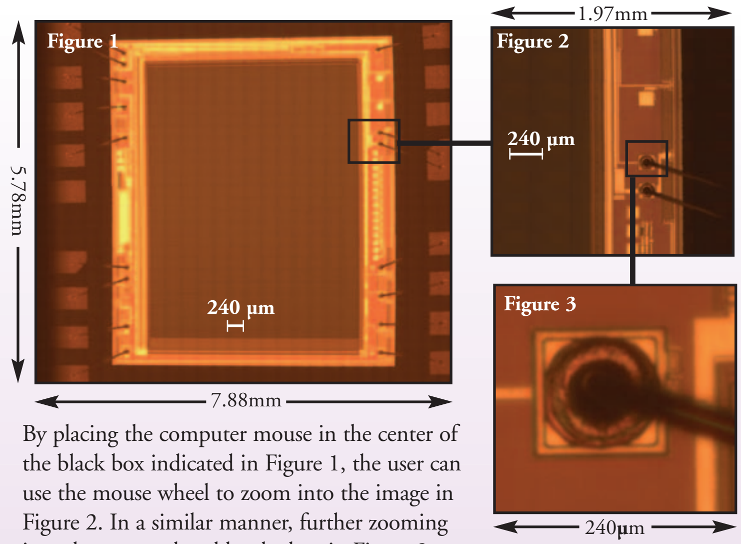
Microelectronics Production and Quality Control

The high-resolution and high FOV provided by the ASOM are ideal for electronic production environments. The image shown is Thorlabs DC310C CCD camera taken with the ASOM in the reflective illumination mode. This technique allows visualization of the entire camera, as well as individual circuit components. The large mosaic scan depicted in Figure 1 contains within it the full data set required to display at a resolution of 1.5µm. By simply zooming into the image with the ASOM software, greater details will be displayed without the need to rescan the sample.



By placing the computer mouse in the center of the black box indicated in Figure 1, the user can use the mouse wheel to zoom into the image in Figure 2. In a similar manner, further zooming into the area enclosed by the box in Figure 2, results in the image shown in Figure 3.

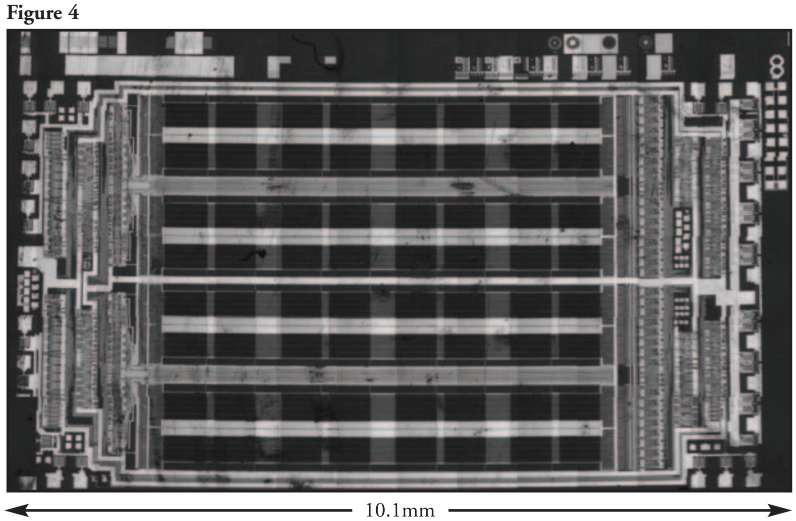
As manufacturing and electronic fabrication advances, larger assemblies can be produced from smaller and smaller components. The ASOM is ideally suited for such applications because of its large FOV and high resolution.

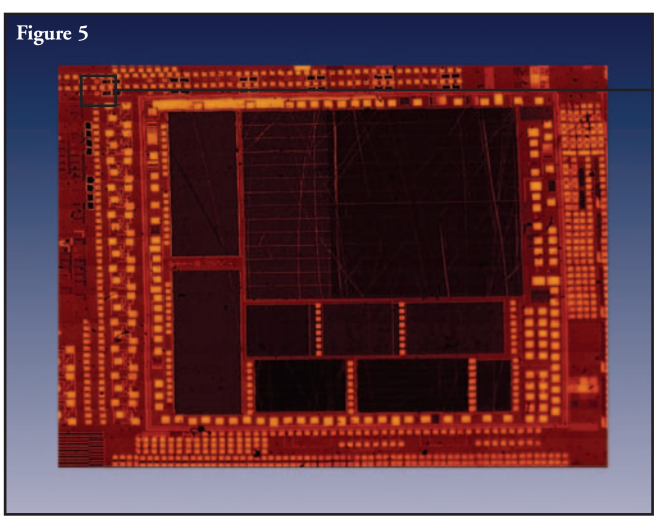
Figure 4 shows an image of an 8-bit memory microchip, showing signs of surface contamination at various locations.

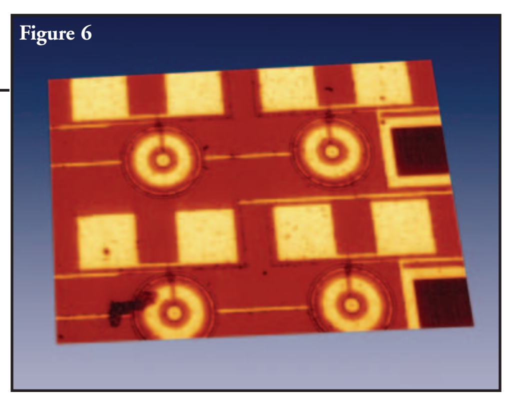
Figure 5 shows an image of an 8-bit microprocessor with signs of surface defects.

Figure 6 shows small surface contaminates on the microchip wafer.

Figure 4







The enlarged image reveals surface defects not readily apparent in the full mosaic scan.

Optical Coherence Tomography Technology Overview

Optical Coherence Tomography (OCT) is the ideal solution for high-resolution visualization of turbid samples. Whether the application is live sample imaging or *in-situ* inspection of microelectronics, this novel optical imaging technique provides real-time 2D and 3D imaging with micron-level image resolution for image depths up to a few millimeters. Thorlabs now offers two different types of OCT systems: the Spectral Radar (SR-OCT) and Swept Source (SS-OCT) systems. We also offer OCT tools for design engineers or OEM integrators, including a complete line of swept source lasers (pages 608-609), inteferometers, detectors, fiber optic components (pages 610-615), and OCT lenses (pages 616-618).

Image of Human Nail Folder

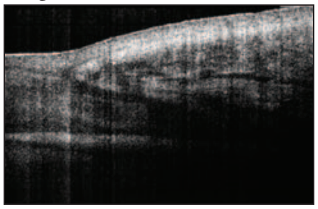


Image of Human Finger Waist

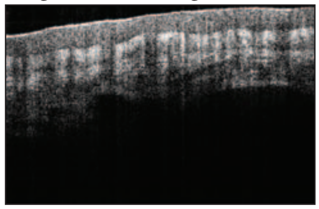


Image of Human Finger Pad

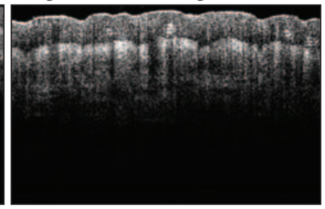
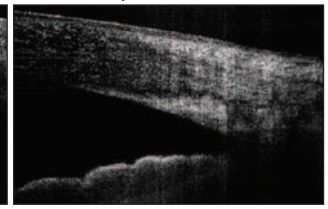
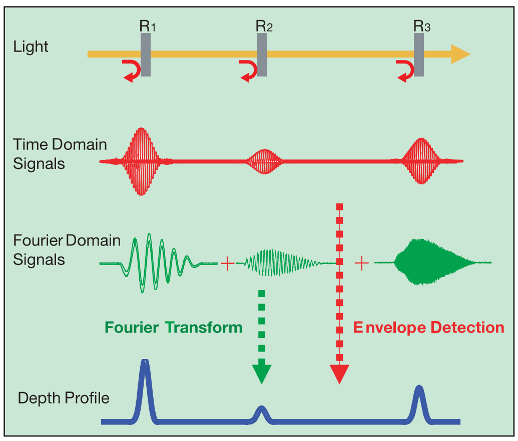


Image of Anterior Chamber of Human Eye





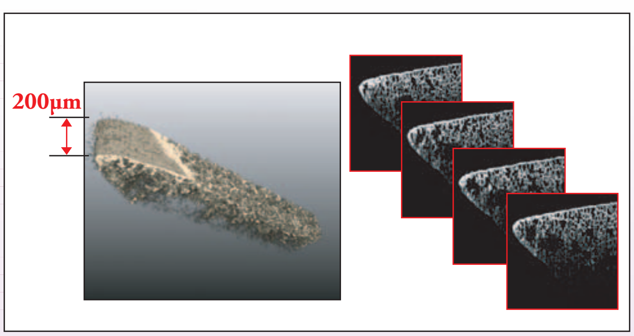
Time Domain and Fourier Domain OCT

In time domain OCT, the interference fringe signals are detected as a function of optical time delay between the sample and reference arms. The envelope of the interference fringe signals yields the depth profile for the sample. In contrast, the interference fringe signals associated with Fourier domain OCT are detected as a function of optical frequency. Since there is a fixed optical delay in the reference arm, light reflected from different sample depths will produce interference patterns with different frequency components. A Fourier transform can then be used to resolve the different depth reflections, thereby generating the depth profile of the sample. This depth profile corresponds to one axial line (i.e. an A-line) in the final OCT image.

Thorlabs' Fourier Domain OCT Systems

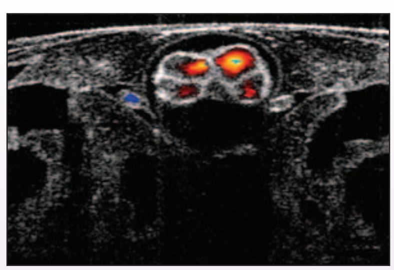
Fourier Domain Optical Coherence Tomography (FD-OCT) achieves greater sensitivity and higher imaging speed than time domain OCT and has become a powerful tool for biomedical and material applications. Thorlabs now offers two types of FD-OCT imaging systems: the Spectral Radar OCT (SR-OCT) and the Swept Source OCT (SS-OCT). The SS-OCT has an optional Doppler Imaging upgrade. Both systems are based on FD-OCT technology but incorporate different technical approaches. The SR-OCT system employs a spectrometer and broadband light source to detect the OCT interference fringe signals as a function of optical frequency, while the SS-OCT system uses a frequency swept light source to generate the same type of interference signals. The signal processing and image construction methods in the two systems are very similar.

Mouse Lung Imaging



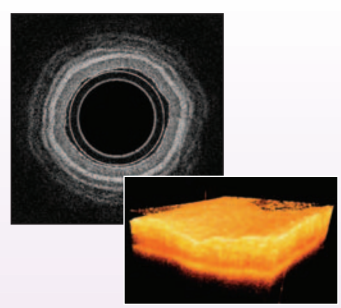
The frames on the right show a sequence of B-scans of a ventilated mouse lung that cover a total of 200µm. These were used to create the 3D reconstruction of the subpleural region of the lung, shown on the left. The image is taken with Thorlabs' **OCP930SR**.

Flow Velocity



This image shows Doppler flow velocity data overlaying an OCT image of an African tadpole. The images were taken with a modified version of Thorlabs' **OCM1300SS**.

Arterial Imaging



These figures show *in-vitro* OCT images of a section of pig artery taken with Thorlabs' OCM1300SS.

Optical Coherence Tomography Technology Overview

Choosing an OCT System

The appropriate OCT system for a given application depends on the desired scan speed and measurement wavelength, since these characteristics ultimately determine the image depth and resolution that can be achieved. In general, the resolution depends on the coherence length of the light source. Shorter coherence lengths, which are associated with broader spectral bandwidths and shorter center wavelengths, lead to better axial (longitudinal) image resolution. For most OCT applications, the axial resolution is ~10µm. Typical image depth for OCT systems can be from 1 – 3mm, depending on the absorption and scattering properties of the sample. For instance, water is most transparent to light in the 600 – 900nm range. Therefore, since the outer portion of the eye (i.e. cornea, vitreous, and lens) is comprised largely of water, it has been shown that for standard ophthalmic applications, an 800 – 900nm light source is ideal. On the other hand, for multilayered biological tissue samples, the 900 – 1400nm range is preferable because most biological materials have lower optical scattering coefficients at these longer wavelengths.

To help our customers choose the appropriate OCT system for their application, a few key parameters of two standard OCT systems (OCP930SR and OCM1300SS) are listed below. In addition to the Standard Spectral Radar 930nm OCT system, we also offer Enhanced Resolution and Deep Imaging SR-OCT Models.

Spectral Radar OCT System

OCP930SR

Swept Source OCT System

OCM1300SS
Cart Not Included

Comparison of Thorlabs' OCT Systems

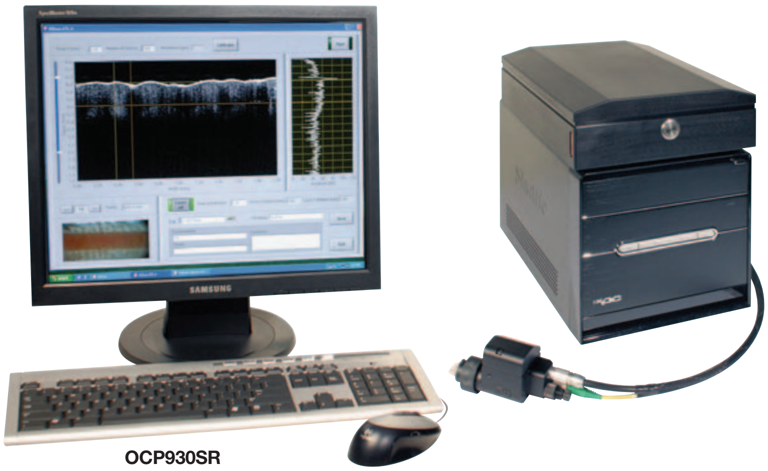
	930nm Spectral Radar OCT (See Page 592)		1300nm Swept Source OCT (See Page 596)	
Optical Specifications				
Center Wavelength (nm)	930.0		1325.0	
3dB Spectral Bandwidth (nm)	100		100	
Imaging Specifications				
Axial Resolution (µm)	6.5		12.0	
Lateral Resolution (µm)	9.0		20.0	
Max. Imaging Depth (mm)[1]	1.6		3.0	
Max. Imaging Width (mm)	6.0		10.0	
A-Scan Rate (kHz)	5.0		16.0	
Imaging Speed (fps)[2]	8		25	
Sample Interface	**Handheld Probe**	**Microscope**[3]	**Handheld Probe**	**Microscope**
Sample Interface Supported	Yes	Yes	Yes	Yes
3D Imaging Capability	No	Yes	Yes	Yes
CCD Camera Integrated	Yes	Yes	No	Yes

[1] Max. imaging depth is defined as the maximum range of reflected signals that can be resolved by the OCT system. Many materials and biological samples are highly light scattering; actual imaging depth may vary.
[2] Real-time frame rate based on 512 A-scans per frame.
[3] Application specific microscope versions of the spectral radar OCT systems are available from our design team at Thorlabs HL AG. Please contact: info@thorlabs-hl.de.

NEW

Thorlabs Now Offers Swept Source OCT Systems with a Central Wavelength of 850nm, 1050nm, 1325nm, or 1550nm.

Spectral Radar OCT Systems — Page 1 of 4



OCP930SR

Real-Time 2D and 3D OCT Imaging

Application-specific versions of the spectral radar OCT systems are available from our design team at Thorlabs HL AG.

Please contact: info@thorlabs-hl.de.

Spectral Radar OCT System Features

- Integrated Michelson Interferometer in Probe Minimizes Mode Dispersion
- Telecentric Optics Keep the Beam Perpendicular, Eliminating Image Distortion Over a Broad Scanning
- Compact System Design Ready for OEM Applications
- Real-Time *In-situ* Imaging of Biological and Industrial Samples

The Thorlabs Spectral Radar OCT system was developed in collaboration with Thorlabs (USA) and two German-based organizations: Thorlabs Lübeck AG and the Medical Laser Center Lübeck. This system combines a broadband light source with a high-speed spectrometer to perform Fourier domain detection of the OCT interference fringe signals. The Spectral Radar OCT System is available with two imaging options: the standard handheld probe or an application-specific microscope design (info@thorlabs-hl.de). Both systems have an integrated CCD camera for sample monitoring. The handheld OCT provides high-resolution 2D imaging, while the microscope version is capable of providing 3D images. The system can be fully operational within minutes of being received.

Standard SR Model

OCP930SR

- General Purpose
- Imaging Depth ~1.6mm
- Axial Resolution 6.2µm

Enhanced Resolution SR Model

OCP900SR

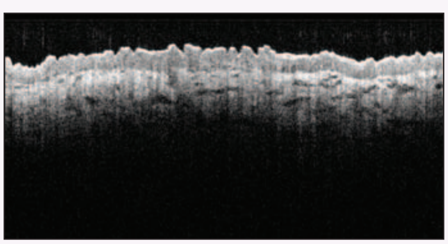
- Ideal for Imaging Small Features Close to the Surface
- Imaging Depth ~1.1mm
- Axial Resolution 4.5µm

Deep Imaging SR Model

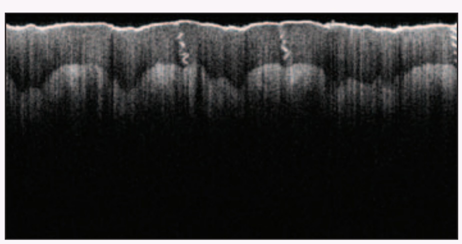
OCP840SR

- Ideal for Larger Features and for Deep Imaging
- Imaging Depth ~3.2mm
- Axial Resolution 15µm

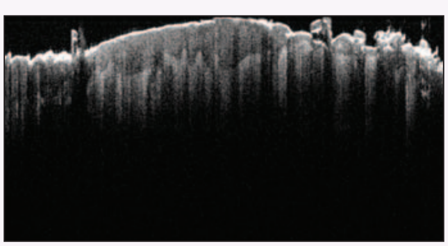
OCT Images of Human Skin



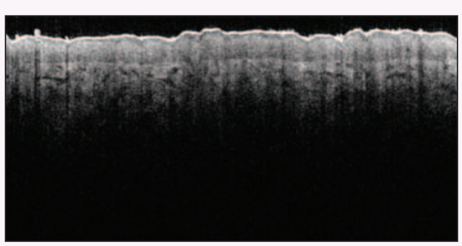
Palm



Finger Pad



Skin With Callous



Back of Hand

Application of the Handheld Probe for *In Vivo* Human Skin Imaging

Spectral Radar OCT Systems — Page 2 of 4

Introduction

Fourier Domain Optical Coherence Tomography (FD-OCT) is used to obtain subsurface cross-sectional images with micron-level resolution by analyzing the interference pattern created by the mixing of light in a Michelson interferometer (see Figure 1). FD-OCT systems are able to obtain a direct measurement of the scattering amplitude along a vertical axis within a bulk sample. One exposure provides the complete scattering profile from the surface into the bulk of the sample; this measurement is commonly referred to as an "A-scan." A series of A-scans can be combined to form a cross-sectional image, which is commonly referred to as a "B-scan." Adjacent cross-sectional images (B-scans) can then be combined to reconstruct a 3D image. Typical scan depths for highly scattering biological samples range from 1mm to several millimeters, depending on the scattering properties of the sample.

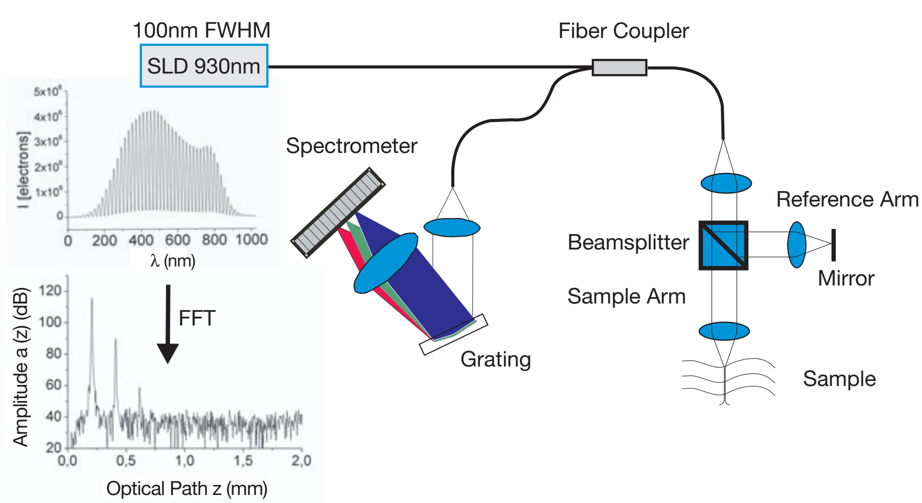
FD-OCT is more sensitive than earlier OCT systems, which were based on time-domain optical coherence tomography (TD-OCT). This increase in sensitivity significantly improves the data acquisition speed and image quality. The current spectral radar FD-OCT system offered by Thorlabs operates at a maximum speed of 8 frames per second, which makes it a feasible solution for real-time imaging in clinical, surgical, industrial, and material science applications. For even higher frame rates, see the section on swept source OCT systems starting on page 596.

The spectral radar OCT is a complete imaging system that can be easily installed without any special requirements. The system includes a handheld probe, an OCT engine, a computer, a monitor, and an integrated software suite, which provides a graphical interface for the control of the hardware and image processing functions. The system was developed collaboratively with the Medical Laser Center Lübeck and the University of Lübeck located in Germany as well as the Thorlabs engineering labs in the US and Germany.

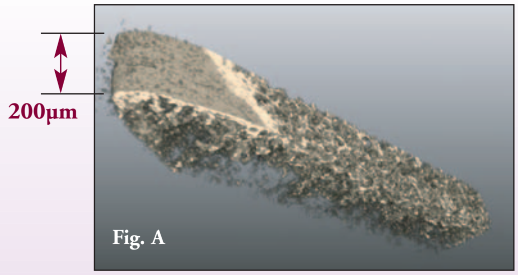
Simplified Operating Principle of Spectral OCT

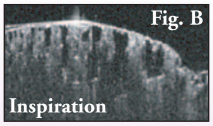
Figure 1 (see below) graphically depicts the basic design of the Thorlabs OCP930SR spectral OCT engine and probe. The output of a broadband Super Luminescent Diode (SLD) light source is guided into a handheld Michelson interferometer probe, which splits the light into two separate optical paths. The reference arm path is terminated with a mirror, while the other path contains an imaging lens that focuses the light onto the sample. This same imaging lens is also used to collect light that is backscattered or reflected from the sample. The light returning from the end of both paths is recombined and directed into a spectrometer, which spatially separates the light to form the interference pattern that is then analyzed to yield the spectral OCT image. If the length of the sample arm were fixed, the interference pattern would be a simple sinusoidally-varying function of wavelength, for which the Fourier transform is a single peak. However, due to the fact that the backscattered and reflected light originates from various depths within the sample, a modulation in the amplitude of the sinusoidally varying interference pattern arises. Since the amplitude modulation is depth dependent, the Fourier transform yields the intensity of the backscattered or reflected light as a function of depth (i.e. an A-scan).

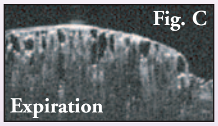
Figure 1 Schematic Spectral Radar With Handheld Probe



Spectral Radar Application







The 3D reconstruction of the sub-pleural area (Fig. A) and cross-sectional images of a ventilated mouse lung (Figs. B and C) are shown. These images were taken with Thorlabs' 930nm spectral radar system.

Image courtesy of Prof. Stefan Uhlig (Department of Pulmonary Pharmacology, Research Center Borstel, Germany) and E. Lankenau and G. Hüttmann (Institute of Biomedical Optics, University of Luebeck, Germany).

Spectral Radar OCT Systems — Page 3 of 4

System Description

The Thorlabs **OCP930SR** Spectral Radar OCT imaging system is depicted schematically in Figure 2. It comes standard with a handheld probe, but a microscope model is available upon request (see the price box on page 595 for all available models and wavelengths). The base unit includes the broad super luminescent diode (SLD) light source, the spectrometer, analog and digital timing circuitry, and drive electronics for the galvanometer scanner within the handheld probe.

A fiber optic coupler is used to direct light from the broadband SLD source into a handheld probe, which contains a Michelson interferometer. Both the probe and reference light travel back through the same fiber to the spectrometer and imaging sensor, both of which are located in the base unit. The spectrometer has 0.14nm resolution, which corresponds to a theoretical (calculated) imaging depth of 1.63mm, but actual results will depend on individual sample characteristics.

Data Acquisition and Software

The base unit is connected to the PC, which is equipped with two high-performance data acquisition cards. All required data acquisition and processing is performed via the integrated software package, which contains a complete set of functions for controlling data measurement, collection, and processing as well as for displaying and managing OCT image files. The resulting 2D or 3D images (in the microscope model) can be displayed on the PC at rates of up to 8 frames per second.

The software packaged with the OCP390SR includes a library of parameters for sample applications. In addition, this system offers a high degree of flexibility by allowing the user to modify experimental parameters to suit experimental needs; for example, the lateral scanning range and the step width are both user controlled. In addition, the data sets are easily accessed off-line for further image processing and data analysis.

Applications of Spectral Radar OCT

The center wavelength of our standard model Spectral Radar OCT system is 930nm. Thorlabs also offers other wavelengths to accommodate special imaging requirements (see the application descriptions and the price box on the next page). The choice of a near-IR broadband source is ideal for most biological samples due to the low scattering losses associated with IR radiation.

Spectral-based OCT can be applied to a wide range of biological and industrial imaging applications. Cross-sectional and 3D images of samples ranging from the human retina or cochlea (see the figure to the right) to laminated packaging films or mechanical parts can be obtained in real time, making this system ideal for many clinical and industrial applications. Please visit our homepage and click on the link to our online Image Gallery for up-to-date applications (www.thorlabs.com).

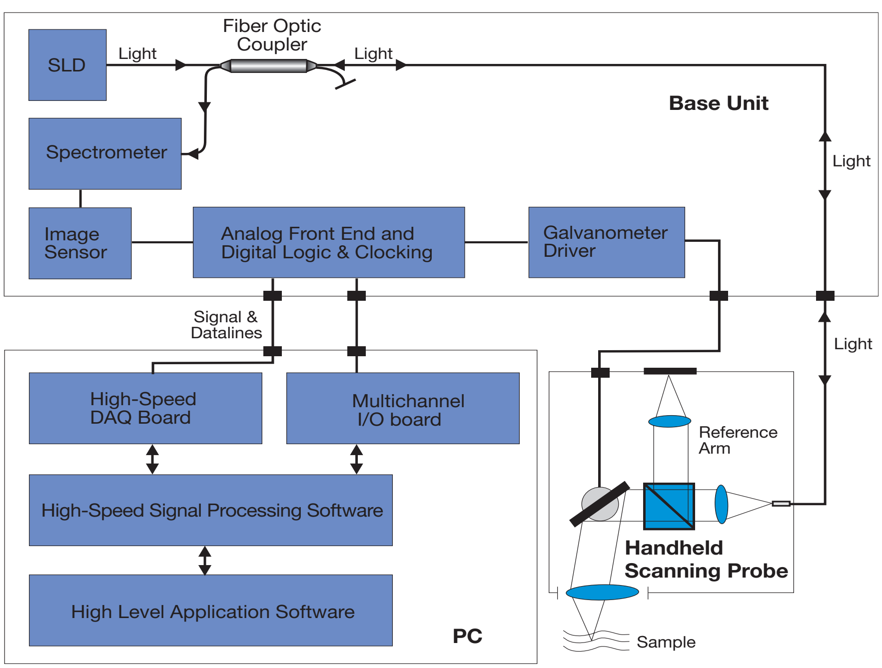
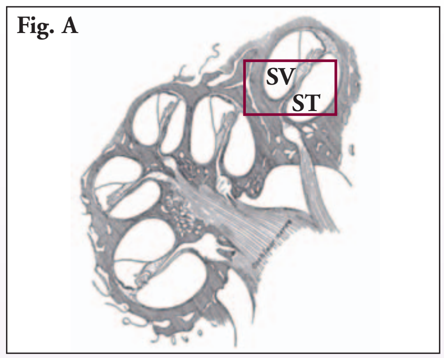
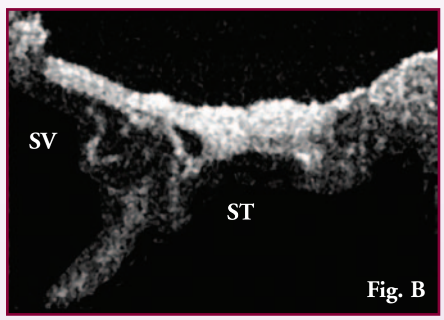


Figure 2 Schematic showing all the major component parts of the SR-OCT system

Spectral Radar Application





An anatomical drawing of human cochlea (Fig. A) and the OCT scan of the lateral part of an exposed cochlea (Fig. B) imaged with a modified Thorlabs' spectral radar system and a Möller-Wedel HR1000 microscope.

Ref: Pau, H. W., Lankenau, E., Just, T., Behrend, D., and Hüttmann, G. *Acta Oto-Laryngologica* accepted, 2007.

Spectral Radar OCT Systems — Page 4 of 4

Effect of Wavelength for Imaging Applications

The selection of a particular OCT system depends on the specific application requirements. Image quality depends both on the type of sample as well as the design of the system. For example, water is more transparent to light in the 600 to 800nm wavelength range. Since the outer portion of the eye (cornea, vitreous, and lens) is mostly water, OCT imaging at 800nm has become the industry standard in many ophthalmic applications. For multilayered biological tissue (skin, brain, GI tract, etc.), the 900 to 1400nm range is appropriate, since longer wavelengths typically provide better penetration depth.

Choice of Axial Resolution to Match Your Application Requirements

Aside from wavelength, one of the more significant parameters for choosing an OCT system is the resolution requirements for a given application. In general, the resolution is determined by the spectral bandwidth of the light source. The broader the spectral bandwidth, the better the resulting axial (longitudinal) resolution of the image (see specifications table below).

The **Standard** (930nm) spectral radar system has a 100nm spectral bandwidth, which yields a typical imaging depth of ~1.6mm and an axial resolution of 6.2µm. Overall, this multi-purpose system provides a balanced optimization of both resolution and measurement depth. To accommodate special imaging requirements, Thorlabs offers two additional spectral radar OCT systems: the **Enhanced Resolution** and the **Deep Imaging Models**.

The **Enhanced Resolution** (900nm) model provides superior resolution at the surface when compared with either the **Standard** (930nm) or **Deep Imaging** (840nm) system. Due to its axial resolution of 4.5µm, this system is ideal for creating high-resolution images near the surface. For example, this system can be used to identify cancer cell boundaries during surgical procedures. However, the image quality will degrade more quickly with depth than it would with either the **Standard** system or the **Deep Imaging** system.

The **Deep Imaging** (840nm) Spectral Radar System's prime advantage is its ability to provide a larger imaging depth (3.2mm) than any of the other spectral radar systems. A modified version of the OCP840SR has been used to provide real-time images of the inner ear during a surgical operation; these images have sufficient axial resolution to provide distinct structural determination of the cochlea (see the figure on the previous page).

Spectral Radar System Specifications by Model

Optical:	**Standard**	**Enhanced Resolution**	**Deep Imaging**
Center Wavelength:	930 ± 5nm	900 ± 5nm	840 ± 5nm
Spectral Width (FWHM):	100 ± 5nm	140 ± 5nm	50 ± 5nm
Axial Scan Rate:		~5kHz	
Spectrometer Resolution:	0.14nm	0.18nm	0.06nm
Optical Power:	~2mW	~1.5mW	~1.5mW
Imaging:	**Standard**	**Enhanced Resolution**	**Deep Imaging**
Imaging Speed:		8 fps	
Maximum Image Size:		1024 x 512 Pixels	
Maximum Imaging Width:		6.0mm	
Maximum Imaging Depth:	1.6mm	1.1mm	3.2mm
Axial Resolution:[1]	6.2µm	4.5µm	15µm
Dynamic Range:[1]		>90dB	

[1] Axial resolution and dynamic range are specified in air. This value may vary depending on the absorption and scattering characteristics of the sample.

Common Spectral Radar System Specifications

Electric

- **Analog/Digital Conversion Rate:** 100MS/s*
- **Analog/Digital Resolution:** 14 Bit
- **Analog/Digital Channels:** 2
- **Analog Output Rate:** 1MS/s*
- **Analog Output Resolution:** 16 Bit
- **Analog Output Channels:** 4

Computer

- **CPU:** Intel® Processor
- **Memory:** 2GB Memory
- **Operating System:** Windows® XP Professional, SP2
- **Hard Drive:** 250GB SATA
- **Optical Drive:** 16x DVD+/-RW
- **Monitor:** 19" LCD 1280 x 1024

2D *En-face* Microscope Imaging Capability (not available on handheld probe)

- **CCD Camera:** Color CCD Camera (NTSC format)
- **Maximum Resolution:** 510 x 492Pixels
- **Imaging Speed:** 24fps

3D Volumetric Imaging (Microscope Only)

- **Maximum Volume Size:** 6.0(L) x 6.0(W) x 3.0(D)mm
- **Maximum Sampling Resolution:** 512(L) x 512(W) x 512(D) Pixels
- **Imaging Time:** ~60 seconds

*MS/s = 1x10^6 samples per second

Note: For those familiar with our OCT systems, you will find new part numbers due to our on-going engineering improvements.

ITEM#	$	£	€	RMB	DESCRIPTION
OCP930SR	$ 35,000.00	£ 19,650	€ 29.000,00	¥ 301,600.00	Standard 930nm SROCT System With Handheld Probe

Built Upon Order

ITEM#	$	£	€	RMB	DESCRIPTION
OCP840SR	$ 35,000.00	£ 19,650	€ 29.000,00	¥ 301,600.00	Deep Imaging 840nm SROCT System With Handheld Probe
OCP900SR	$ 35,000.00	£ 19,650	€ 29.000,00	¥ 301,600.00	Enhanced Resolution 900nm SROCT System With Handheld Probe

Swept Source OCT Systems: Video Rate OCT Imaging – Page 1 of 6

OCM1300SS
* Cart Not Included

Swept Source OCT (SS-OCT), like optical frequency domain reflectometry, measures the magnitude and time delay of reflected light in order to construct depth profiles (A-scans) of the sample being imaged. Adjacent A-scans are then synthesized to create an image. Thorlabs now has a complete family of SS-OCT systems ready for research and industrial applications.

Thorlabs' SS-OCT Systems support both 2D and 3D high-speed, high-resolution imaging of turbid media. The design integrates a broadband high-speed swept laser, a fiber-based Michelson interferometer with a balanced detection scheme, and a multifunctional microscope to provide simultaneous *en-face* microscope imaging and cross-sectional OCT imaging of the sample. The system is also available with a handheld probe option.

Advanced data acquisition and digital signal processing techniques are employed in the SS-OCT system to enable real-time video rate OCT imaging. Optical 3D volumetric imaging and surface profiling capabilities are included in the standard software. An optional Doppler OCT imaging upgrade is available (see page 599). This OCT system can provide coherence gated *en-face* images similar to optical coherence microscopy and also enables the generation of images similar to confocal microscopy by summing signals in the axial direction. High-speed 3D OCT imaging provides comprehensive data that combines the advantages of surface microscopy and structural OCT imaging in a single system.

Video Rate OCT Imaging Applications

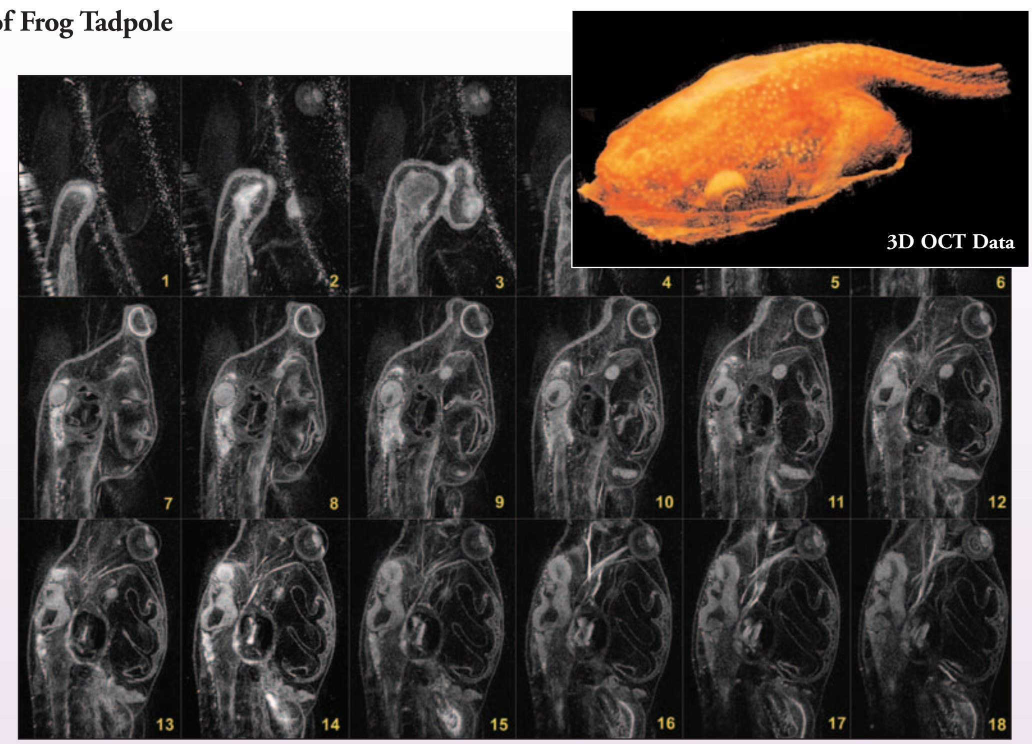
- Biomedical Imaging
- Real-Time Surgical Screening
- Material Inspection and Quality Control
- Thin Film Test and Measurement
- 3D Optical Profilometry and Volumetric Imaging

Biological Imaging

Three-Dimensional Imaging of Frog Tadpole

The data shown represent a series of *en-face* images of an African frog tadpole and a 3D image reconstruction. The data was acquired using the Thorlabs **OCM1300SS** OCT microscope system. All images are 6mm x 8mm and were taken from the posterior to the anterior of the tadpole in 100µm depth increments.

Reference: R. Huber, *et al.*, *Optics Express*. **13**, 10523 (2005)



African Frog Tadpole

Swept Source OCT Systems — Page 2 of 6

System Description

Figure 1 shows the schematic of Thorlabs' **OCM1300SS** OCT system. This system incorporates a high-speed frequency swept external cavity laser (Thorlabs **SL1325-P16**), which has a 3dB spectral bandwidth (larger than 100nm). The swept source has a built-in Mach-Zehnder Interferometer (MZI, Thorlabs **INT-MZI-1300**) that provides the frequency clock for the laser. The main output of the laser is coupled into a fiber-based Michelson interferometer and split into the reference and sample arms using a broadband 50/50 coupler (Thorlabs **FC1310-70-50-APC**). In the reference arm of the interferometer, the light is reflected back into the fiber by a stationary mirror. The reflectivity is controlled by a variable optical attenuator. In the sample arm, the light is fiber coupled into the microscope head and focused onto the sample surface by an objective with a long working distance. The sample is placed on a stage, providing XY and rotational translation. An integrated CCD camera in the microscope head provides a conventional microscopic view of the sample, which aids sample alignment. A pair of XY galvo mirrors scans the beam across the sample surface, creating 1D, 2D, or 3D images. The optional handheld probe includes similar 2D and 3D imaging capabilities.

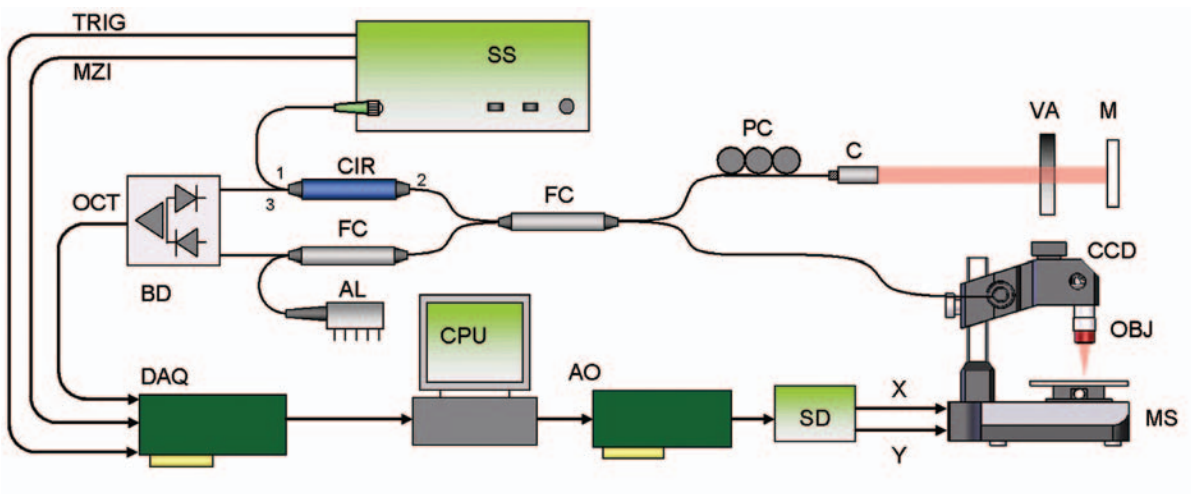


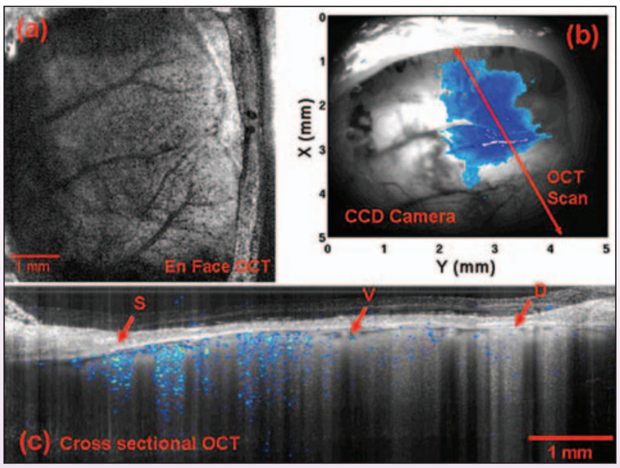
Figure 1. Schematic of **OCM1300SS** Swept Source OCT Microscope: swept source (SS), fiber coupler (FC), polarization controller (PC), circulator (CIR), collimator (C), variable attenuator (VA), mirror (M), balanced detector (BD), data acquisition board (DAQ), XY scanners driver (SD), CCD camera (CCD), objective (OBJ), microscope (MS), analog output (AO), aiming laser (AL). A Mach-Zehnder interferometer (MZI), which is built in the swept light source, provides the frequency clock signals for the laser.

Brain Functional Imaging

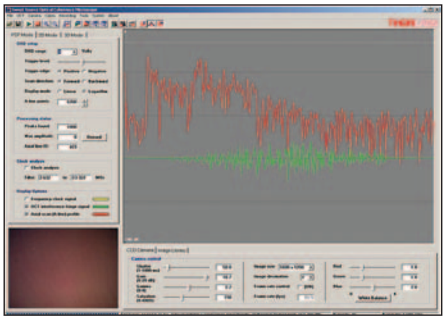
The images to the right show OCT images collected in the functionally activated region of a rat brain. Images were taken by researchers at MIT and Massachusetts General Hospital using a modified Thorlabs Swept Source OCT system.

The OCT scan is directed to the region of interest using a video microscope. The OCT image enables identification of the skull (S), surface vasculature (V), and meningeal layers, including the dura mater (D). The blue colored areas show the functionally active regions of the cortex, which were co-registered on the CCD camera and OCT channels.

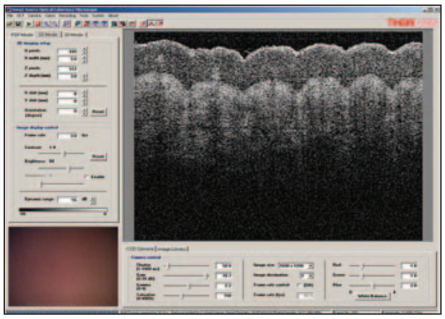
Reference: A. D. Aguirre, *et al.*, *Optics Letters.* **31**, 3459 (2006).



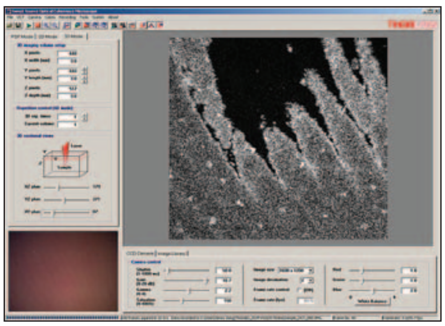
Swept Source OCT Systems — Page 3 of 6



1D Mode: OCT Interference Fringe Diagnosis



2D Mode: Cross-Sectional Imaging



3D Mode: Volume and *En-Face* Imaging

Signal Processing

In the Thorlabs SS-OCT, the interference signal is detected using a high-transimpedance gain-balanced photodetector (**PDB145C**) that suppresses the DC and autocorrelation noise in the interference signals. A 14-bit, high-speed digitizer is used to sample the OCT interference fringe signals, which are first converted from time to frequency space using a fast Fourier transform (FFT) and then recalibrated. The FFT of the interference signal yields the depth-dependent reflectivity profile for the OCT image.

Software

The screen captures for three different imaging modes of the software GUI are shown to the left. In the 1D imaging mode, there is no transverse scanning of the probe beam in the sample arm. The recalibrated interference fringe signals and the Fourier transformed point spread functions are displayed in real time, which aids optimization of the signal and system parameters. In the 2D imaging mode, the probe beam is scanned in one direction and cross-sectional OCT images are displayed in real time. The software provides flexible control of image size, brightness, contrast, and the A-line average. For the 3D imaging mode, the probe beam is sequentially scanned across the sample surface area, and the 3D volume data set under this area is acquired, processed, and stored. 3D volume rendering capability of the data is provided with the preinstalled software. The OCT data may be displayed in 2D or 3D mode.

The software allows real-time recording of 2D or 3D data into disk files at full imaging speed. The recorded binary data files can be exported into standard image files (jpeg, bmp) or converted to movie files (avi). A software program that provides 3D graphics rendering of acquired OCT data is also provided in the software package.

Thorlabs Research- and OEM-Ready OCT Systems

Thorlabs' swept source OCT systems are highly customizable. The basic OCT engine includes the swept light source, optional interferometer module, and the software development kit (SDK). The OCT engines are readily adapted to various industrial and biomedical applications. Customers can choose one of our standard microscope or probe options, or they can engineer application-specific probes, which may be directly interfaced with Thorlabs' OCT systems.

Vascular

The data shown here demonstrate a current application in our development lab using the Thorlabs **OCM1300SS** OCT system. These images represent *in vitro* pig artery sections. Figure 1 was acquired from a rotational catheter within the vessel, while Fig. 2 reveals the 3D layered structure within the blood vessel wall. A critical requirement in blood vessel imaging is the successful identification of the boundary between media and adventitial layers in the vessel wall. We developed new techniques to address this challenge and demonstrate our results in the figures to the right. Figure 3A represents the raw OCT image data, which was digitally processed, to show more clearly the layer boundary (Fig. 3B). Figures 4A and 4B demonstrate the power of the polarization-sensitive OCT (PSOCT) technique and show the standard OCT and PS-OCT phase retardation images of the blood vessel wall, respectively. The collagen-rich adventitial layer exhibits a strong birefringence, which aids image definition in the PSOCT technique.

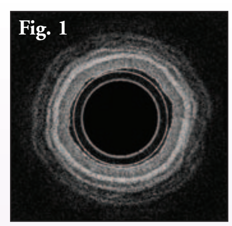


Fig. 1

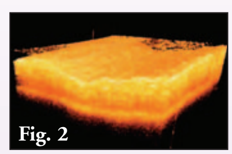


Fig. 2

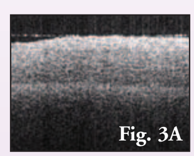


Fig. 3A

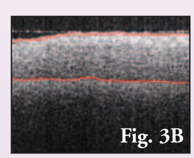


Fig. 3B

Fig. 4A

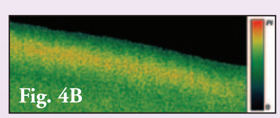
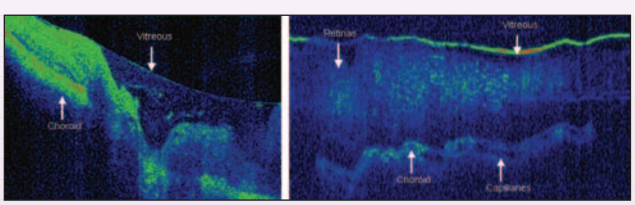


Fig. 4B

Endosco

Yang and his research group at CalTech have developed a new forward-looking endoscopic probe for OCT imaging applications and demonstrated this probe using a modified Thorlabs SS-OCT system. The images shown below (2.5 x 2.3mm) represent *in vitro* procine retinal images acquired using their paired-angle rotating scanner (PARS). This probe was developed because standard side-imaging probes do not provide the real-time cross-sectional imaging capability desirable for guiding retinal surgery.



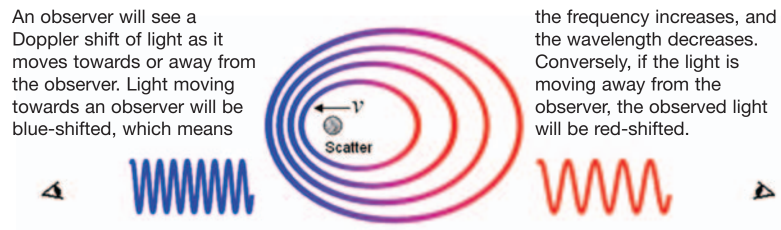
References:
1. M. V. Sarnic, *et al.*, BIOS 2007.
2. J. Wu, *et al.*, *Optics Letters.* 13, 1265 (2006).

Swept Source OCT Systems — Page 4 of 6

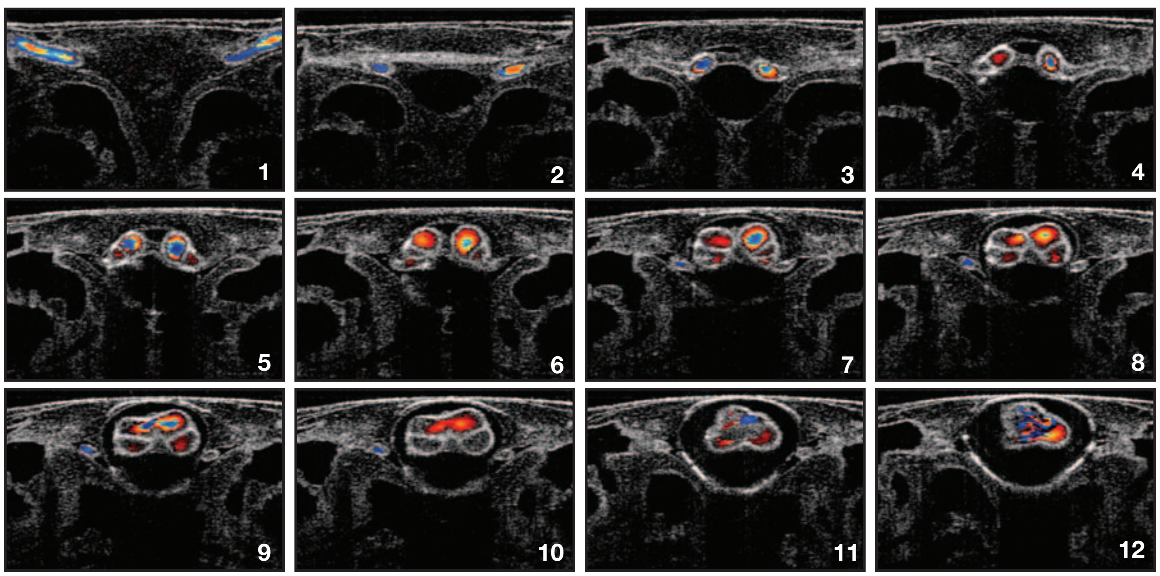
New Doppler Upgrade Option for Swept Source OCT

Doppler OCT, also known as ODT (Optical Doppler Tomography), is a noninvasive imaging technique that provides relative flow velocity measurements in the sample. This enhanced imaging capability was developed in collaboration with Adrian Mariampillai and Victor Yang at the University of Toronto.

As a functional extension of OCT, Doppler OCT relies on the low coherence detection of the light interference signals but uses the laser-induced Doppler frequency shift as the contrast mechanism for image construction. When combined with standard OCT imaging, the high-spatial resolution (2-10µm) of OCT and high velocity sensitivity of Doppler OCT (50-100µm/s) provide simultaneous structural imaging and flow velocity measurements in the sample, which can be useful in studying embryo cardiac dynamics, vascular functional imaging, or vascular treatment response. It is also ideal for general flow velocimetry used in microfluidic channel monitoring.



In Doppler OCT, this small observable frequency shift of the reflected (scattered) light from a moving object is measured in the OCT interference fringe signal, allowing the relative object motion in the light probing direction to be measured.



Normalized Flow Velocity

Images above represent *in vivo* cross-sectional images of a beating African tadpole heart superimposed with Doppler velocimetry data. The data shows structural information, while also showing heart beat motion and relative blood flow velocity. These images were taken using a Thorlabs **OCM1300SS** OCT with the Doppler software upgrade.

Developmental Biology

The images here show how the Thorlabs swept source OCT was used by researchers at the University of Toronto to study the cardiovascular system of living embryos. An optical Doppler cardiogram was obtained using a gated technique to increase the effective frame rate and improve the signal-to-noise ratio. The gating technique provides ultra high-speed visualization of the heart blood flow pattern in developing African frog embryos in both 3D and 4D (i.e. 3D + time) modes. This allows detailed visualization of the complex cardiac motion and hemodynamics in the beating heart.

Reference: A. Mariampillai, *et al.*, *Optics Express.* 15, 1627 (2007).

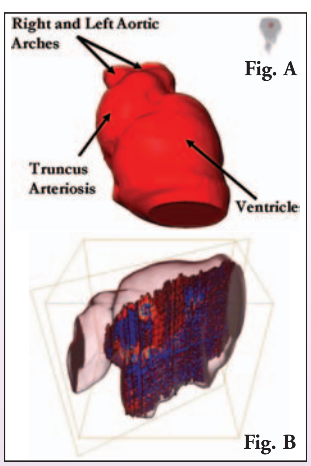


Fig. A

Fig. B

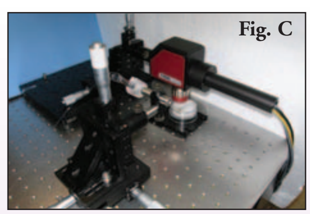
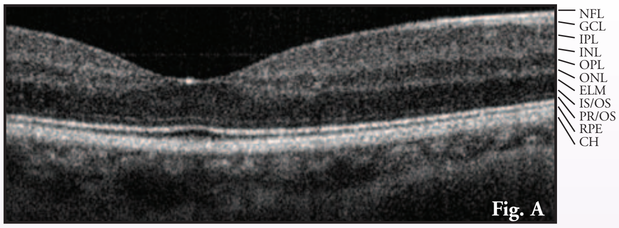


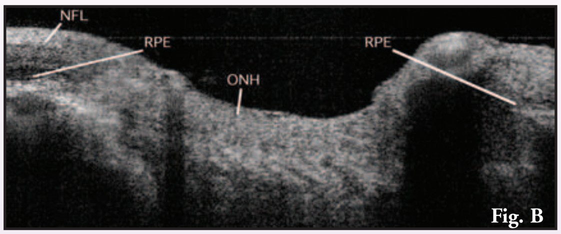
Fig. C

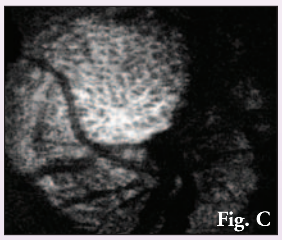
Fig. A shows the 3D surface reconstruction of the tadpole heart, while Fig.B demonstrates the complex blood flow pattern of the heart via a 3D color Doppler map. Fig.C shows the experimental apparatus using Thorlabs' handheld probe, which is mounted into the Doppler imaging setup.

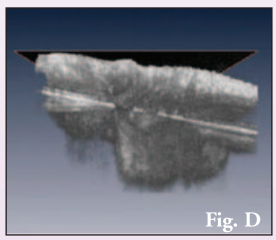
Swept Source OCT Systems — Page 5 of 6

SS-OCT Application - 850nm Retinal Imaging









Swept source OCT is a promising technique for *in vivo* human retinal imaging. The human retina images shown here were taken using an 850nm SS-OCT imaging system jointly developed with researchers at MIT. These high-resolution *en-face* images of the macular and the optic nerve head (Figs. A and B, respectively) allow the identification of major intra-retinal layers and optical nerve structures.

This OCT imaging system provides high-speed data collection (16 - 24kHz A-scan rate) and excellent axial resolution (~7µm) in tissue samples.

Fig. A: High-definition OCT image of the human macular.
Fig. B: High-definition OCT image of the human optic nerve.
Fig. C: Virtual image of the lamina cribrosa, created from 3D OCT data.
Fig. D: 3D OCT data consisting of 512 images x 512 axial scans (acquired in 16s).

Nerve fiber layer (NFL), ganglion cell layer (GCL), inner plexiform layer (IPL), inner nuclear layer (INL), outer plexiform layer (OPL), outer nuclear layer (ONL), external limiting membrane (ELM), photoreceptor inner segment/outer segment junction (IS/OS), photoreceptor outer segments (PR OS), retinal pigment epithelium (RPE), choroid (CH), optic nerve head (ONH).

Reference: V. J. Srinivasan, *et al.*, *Optics Letters.* **32**, 261 (2007)

Adaptive Optics Enhanced Retinal Imaging

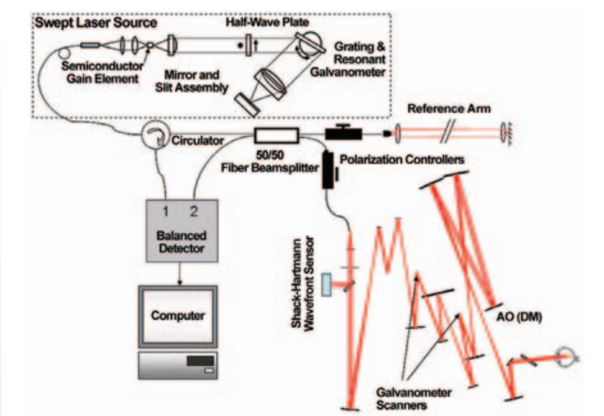


Figure 1. AO swept source OCT system

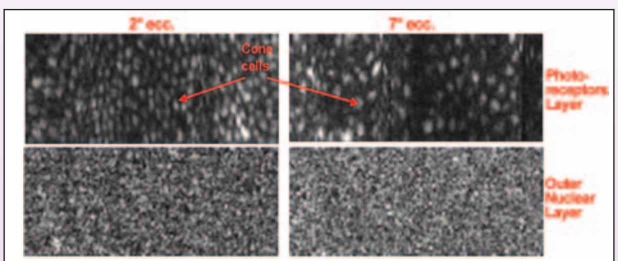


Figure 2. Adaptive Optics enhanced *en-face* OCT imaging of human retina reveals cone cells

Researchers at the University of Indiana recently demonstrated enhanced transverse resolution and improved signal-to-noise ratio in ophthalmic retinal imaging using adaptive optics (AO) and a Thorlabs 850nm swept source laser (**SL850-P16**, center wavelength = 850nm, BW = 35nm) integrated into an experimental OCT system. The schematic of the AO camera is shown in Figure 1. The AO OCT subsystem includes a Shack-Hartmann wavefront sensor and a deformable mirror (DM) that dynamically corrects the wavefront aberrations over the 6.6mm human pupil at up to 25Hz. The large stroke of the deformable mirror provides quick focusing in the retina. The reference arm of the interferometer included a vial of water for partial chromatic dispersion compensation in order to compensate for the fact that the human eye is mostly water..

Figure 2 shows the *en-face* images extracted from the OCT volume data recorded with the AO SS-OCT system. The images are acquired at 2° and 7° eccentricity, thus providing the definition needed to resolve individual cone photoreceptors. The images are displayed using a linear intensity scale.

References:

1. B Cense, *et al.*, "Retinal Imaging at 850nm with Swept Source Optical Coherence Tomography and Adaptive Optics," ARVO 2007.

2. Y. Zhang, *et al.*, *Optics Express.* **14**, 4380 (2006)

Swept Source OCT Systems — Page 6 of 6

Swept Source OCT System Specifications

Optical	**OCM850SS**	**OCM1050SS**	**OCM1325SS**	**OCM1550SS**
Center Wavelength	850nm	1050nm	1325nm	1550nm
Spectral Bandwidth	30nm	50nm	100nm	110nm
Axial Scan Rate	16kHz	16kHz	16kHz	16kHz
Coherence Length	5.0mm	5.0mm	6.0mm	6.0mm
Average Output Power	3.0mW	5.0mW	10.0mW	10.0mW
Electric				
A/D Conversion Rate	100MS/s			
A/D Resolution	14bit			
A/D Channels	2			
Analog Output Rate	1MS/s			
Analog Output Resolution	16Bit			
Analog Output Channels	4			
Computer				
CPU	Dual-Core Intel Processor			
Memory	2GB SDRAM			
Operating System	Windows® XP Professional, SP2			
Hard Drive	250GB SATA 3.0Gb/s			
Optical Drives	48X/32X CD-RW and 16X DVD+/-RW			
Monitor	Dell 19" UltraSharp™ Flat Panel, VGA/DVI			
Imaging Specifications				
2D Cross Sectional OCT Imaging Capability Imaging Speed (on 512 A-Scans Per Frame)	25fps			
Maximum Imaging Size	4000 (H) x 512 (D) Pixels			
Maximum Imaging Width	10mm	10mm	10mm	10mm
Maximum Imaging Depth	2.5mm	2.5mm	3.0mm	3.0mm
Transverse Resolution	10µm	10µm	15µm	20µm
Axial Resolution (Air/Water)	8/6µm	10/7.5µm	12/9µm	15/11.3µm
2D *en-face* Microscope Imaging Capability CCD Camera Pixel	2.0 Mega, 24 Bit RGB			
Maximum Resolution Pixels	1600 x 1200			
Imaging Speed	100fps @ 640 x 480 pixels; 20fps @ 1600 x 1200			
3D volumetric imaging capability Maximum Volume Size	10(L) x 10(W) x 3(D)mm			
Maximum Sampling Resolution	640(L) x 640(W) x 512(D) Pixels			
Imaging Time	~30 Seconds			

Microscope Included With OCM1300SS

Handheld Probe Included With OCP1300SS

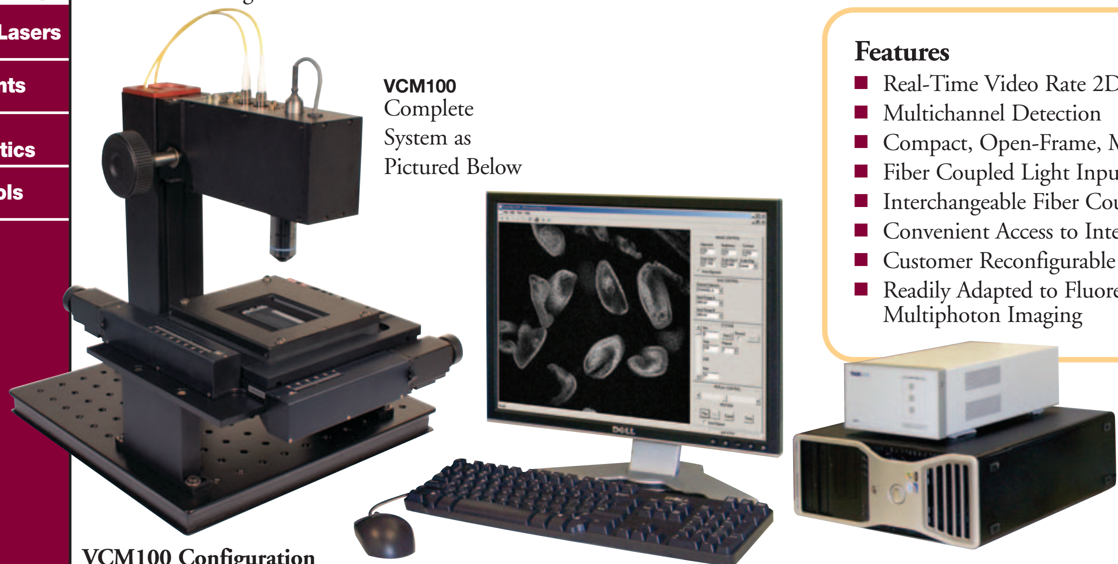
Note: For those familiar with our OCT systems, you will find new part numbers due to our on-going engineering improvements.

ITEM#	$	£	€	RMB	DESCRIPTION
OCM850SS	$ 60,000.00	£ 37,800.00	€ 55.800,00	¥ 573,000.00	850nm SS-OCT Imaging System With Microscope
OCP850SS	$ 57,500.00	£ 36,225.00	€ 53.475,00	¥ 549,125.00	850nm SS-OCT Imaging System With Handheld Probe
OCMP850SS	$ 70,000.00	£ 44,100.00	€ 65.100,00	¥ 668,500.00	850nm SS-OCT Imaging System With Microscope & Handheld Probe
OCM1050SS	$ 60,000.00	£ 37,800.00	€ 55.800,00	¥ 573,000.00	1050nm SS-OCT Imaging System With Microscope
OCP1050SS	$ 57,500.00	£ 36,225.00	€ 53.475,00	¥ 549,125.00	1050nm SS-OCT Imaging System With Handheld Probe
OCMP1050SS	$ 70,000.00	£ 44,100.00	€ 65.100,00	¥ 668,500.00	1050nm SS-OCT Imaging System With Microscope & Handheld Probe
OCM1300SS	$ 60,000.00	£ 37,800.00	€ 55.800,00	¥ 573,000.00	1300nm SS-OCT Imaging System With Microscope
OCP1300SS	$ 57,500.00	£ 36,225.00	€ 53.475,00	¥ 549,125.00	1300nm SS-OCT Imaging System With Handheld Probe
OCMP1300SS	$ 70,000.00	£ 44,100.00	€ 65.100,00	¥ 668,500.00	1300nm SS-OCT Imaging System With Microscope & Handheld Probe
OCM1550SS	$ 60,000.00	£ 37,800.00	€ 55.800,00	¥ 573,000.00	1550nm SS-OCT Imaging System With Microscope
OCP1550SS	$ 57,500.00	£ 36,225.00	€ 53.475,00	¥ 549,125.00	1550nm SS-OCT Imaging SystemWith Handheld Probe
OCMP1550SS	$ 70,000.00	£ 44,100.00	€ 65.100,00	¥ 668,500.00	1550nm SS-OCT Imaging System With Microscope & Handheld Probe

ITEM#	$	£	€	RMB	DESCRIPTION
OCDSS	$ 8,500.00	£ 5,355.00	€ 7.905,00	¥ 81,175.00	Doppler Upgrade Option for Swept Source OCT
OCM-CART	$ 2,125.00	£ 1,338.80	€ 1.976,30	¥ 20,293.80	Instrument Cart for Swept Source OCT Microscope System

Real-Time Video-Rate Laser Scanning Microscope

Thorlabs' new **VCM100** Video Rate Laser Scanning Microscope System offers real-time confocal imaging in a customizable open platform. The fiber coupled design of this system ensures a spatially filtered input beam, which is essentially a perfect Gaussian. In addition, the two single mode fibers that are used to deliver the illuminating light as well as collect the back-scattered signal replace the pinhole that is used in traditional confocal systems. The confocal arragement of the fiber position rejects out of focus light thus creating a true confocal image.



VCM100 Complete System as Pictured Below

Features

- Real-Time Video Rate 2D Confocal Imaging
- Multichannel Detection
- Compact, Open-Frame, Modular Design
- Fiber Coupled Light Input/Output
- Interchangeable Fiber Coupled Laser Diode
- Convenient Access to Internal Optics
- Customer Reconfigurable
- Readily Adapted to Fluorescence and Multiphoton Imaging

All bold part numbers are Thorlabs part numbers and can be found in the index at the back of this catalog.

VCM100 Configuration

The **VCM100** comes as a complete imaging system which includes the microscope head (**VCM100H**), laser light source, photodetector, **MAX201** XY-stepper motor stage and controller, **SCZ100** MicroScan piezo driven Z-stage and controller, plus the computer and software (see page 605 for a labelled diagram of the microscope hardware). Simply put, the **VCM100** system includes everything required to collect 2D and 3D images using point-wise backscattering (see sample images on next page). Perhaps more significant is the flexibility with which the **VCM100** system can be completely reconfigured for custom imaging applications.

The user may purchase the **VCM100H** head alone for use in constructing customized systems. The optomechanics allow for easy modifcation via interchangable optics and an internal mounting surface that contains a matrix of tap holes (see the photograph of the **VCM100H** below). By changing fibers and beamsplitters, adding dichroics or changing detectors, the user can easily reconfigure this confocal scan head for custom applications, such as confocal fluorescence microscopy (see sample setup and images on page 604) or multiphoton excitation microscopy.

Backscattering Configuration

In the standard backscattering configuration, a single mode fiber is used to couple the 660nm laser source into the microscope head. The light hits a turning mirror and is directed through a beamsplitter into a pair of scanning mirrors (one resonant scanner and one galvo scanner) used to raster scan the laser across the sample. The light is focused onto the sample using a 40X objective (**RMS40X**), and the resulting backscattered light is collected back through this same objective. This backscattered signal is directed to the fiber coupled high-speed photodetector via the beamsplitter as shown in Figure 1.

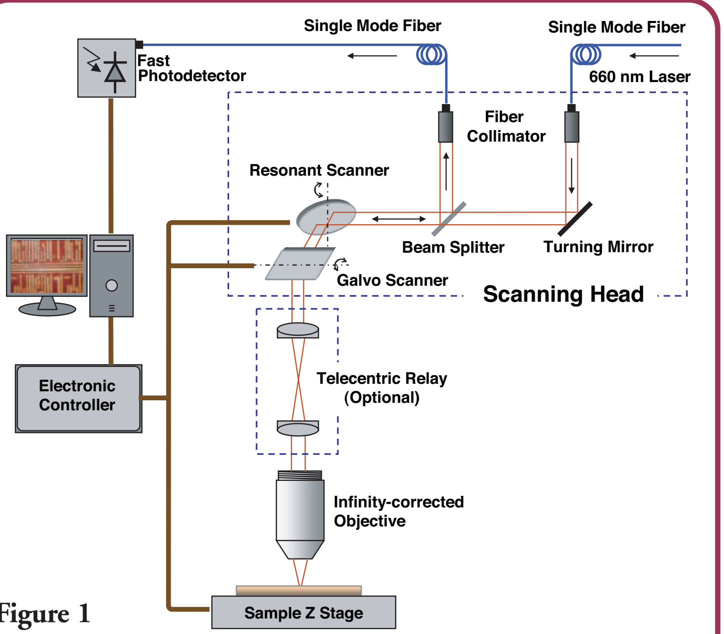
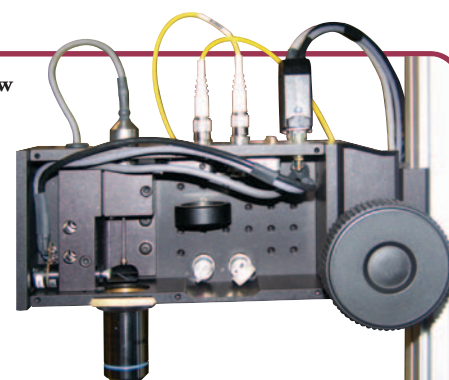


Figure 1
Thorlabs' new **VCM100** Video-Rate Laser Scanning Microscope System includes the scan head (**VCM100H**) with a RMS40X objective, a 660nm laser diode, a fast photodetector, a computer, DAQ and control electronics, and piezo stage. The system is configured for confocal back scattering mode and can be switched to fluorescence imaging mode by adding a filter and PMT.

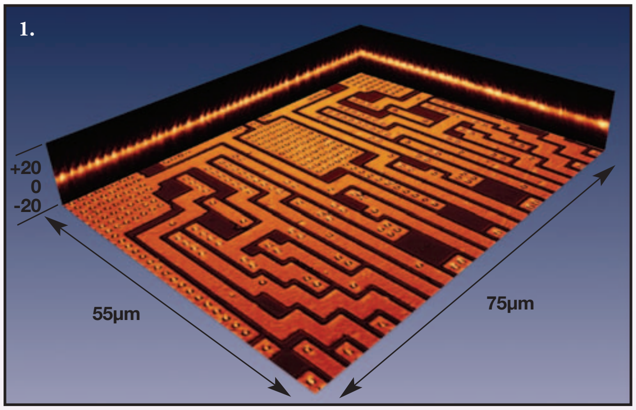
VCM100H Internal View

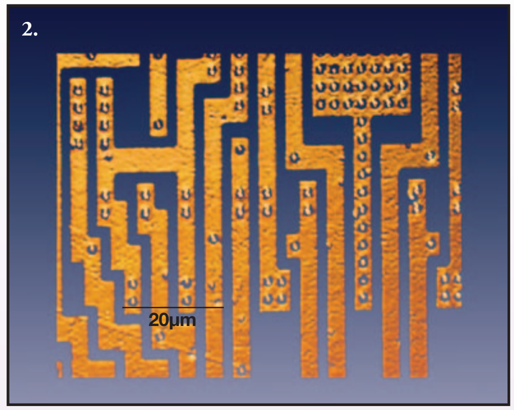
Optical design of the **VCM100H** is easily customizable. The internal face has tap holes to add or remove optics for different applications.

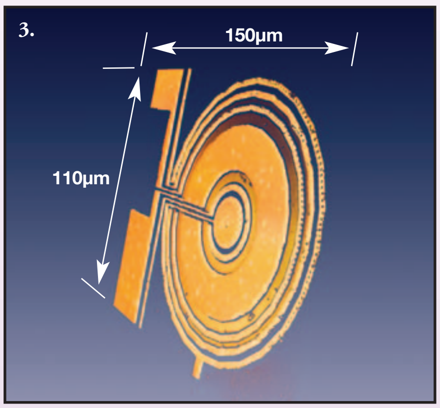


Microelectronics

Confocal scattering images of a memory chip taken with **VCM100** using a 660nm incoming light source. A photodiode is used to detect the backscattered light that is collected and coupled into the single mode fiber.



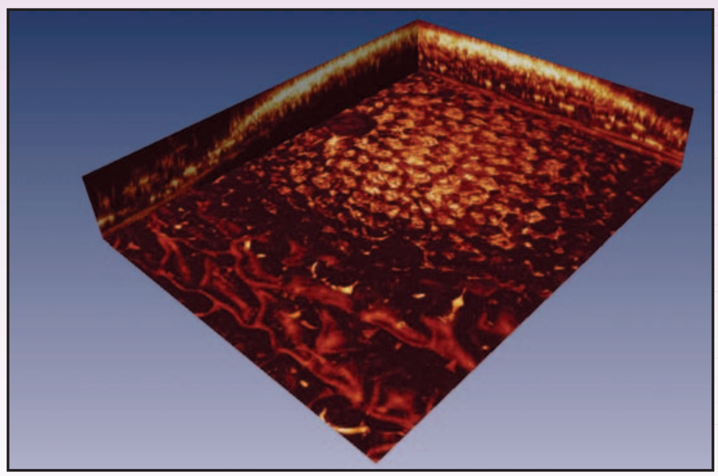




1. Confocal scattering image of memory chip with XZ and YZ cross-sectional images taken with a 60X objective. The total image size is 75 x 55µm.

2. Confocal scattering image of a memory chip taken using a 100X objective with 3D projection. Each microcircuit is 2.5µm wide. Total image size is 55 x 35µm.

3. Reconstructed 3D projection model of confocal backscattering signal from a portion of the circuit of microchip, using a 100X objective. Original image size is 150 x 110µm.



Psuedo-color 3D projection and cross-sectional confocal scattering image of a green leaf obtained with **VCM100** using a 60X objective. The image was taken using a fiber coupled 660nm laser diode. (250 x 185µm, Z-depth is 80µm)

Leaf

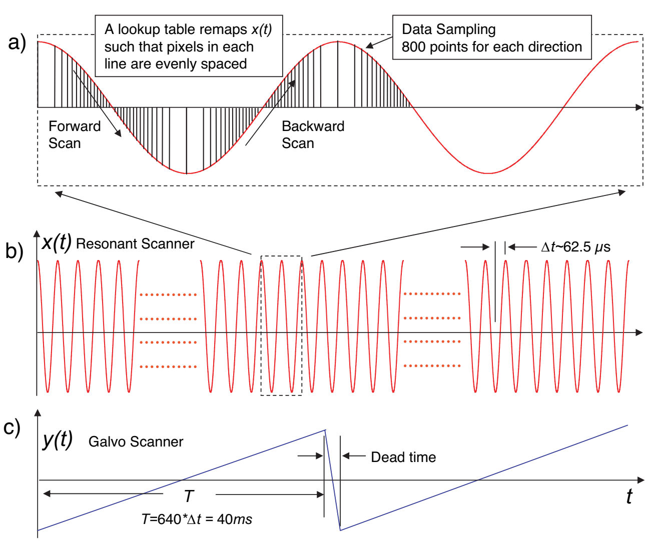


Figure 2

Graphs Showing Synchronization between Galvo and Resonant Scanners

Scanning Data Collection

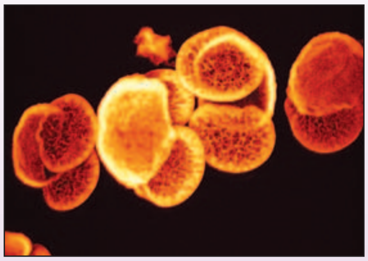
For the **VCM100**, the frame rate is determined by the resonant scanner (8kHz) and galvo scanner pair. As shown in Figure 2 to the left, data is collected during the forward and backward scan of the resonant scanner but only on the forward scan of the galvo mirror. A dead time of about 2-3ms exists for each cycle of the galvo (each frame) as it flys back. The data set is recalibrated given the sinusoidal motion of the resonant scanner, and the corrected image is displayed. The result is a video-rate image displayed at ~ 23fps.

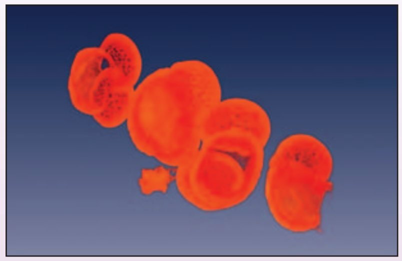
Real-Time Video-Rate Laser Scanning Microscope

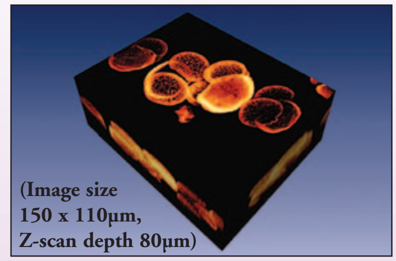
The VCM100 is Easily Reconfigured for Florescence Imaging

Pollen

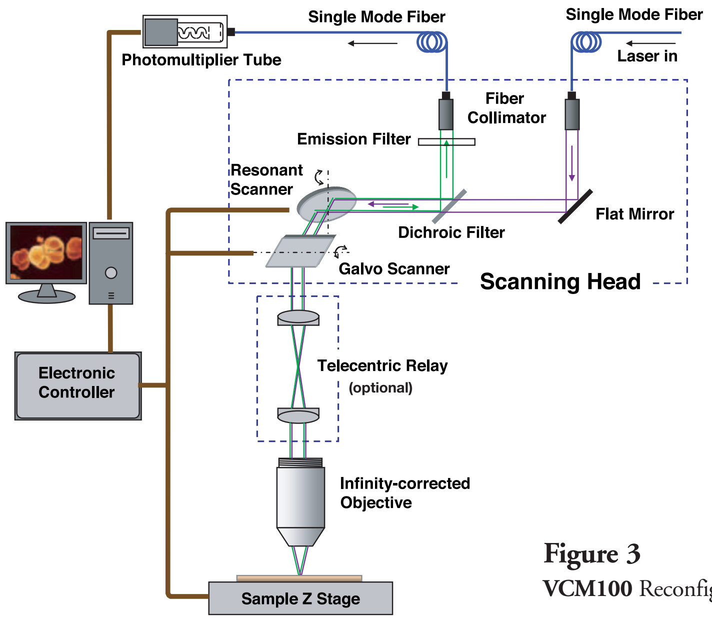
The figures shown below are pseudo-color 2D projections and 3D confocal fluorescent images of pollen taken with **VCM100** using a 60X objective. Pollen grains were mounted on a standard microscope slide and excited with 405nm light from a laser diode (**DL5146-152**). The emission signal was selected using a dichroic mirror (**FD05D**) with a cut-off wavelength 505 ±15nm. The signal was collected through a single mode fiber (**P1-460A-FC-5**) with a cut-off wavelength of 410 to 450nm and directed to a PMT for detection.







(Image size 150 x 110µm, Z-scan depth 80µm)



Fluorescence Mode Configuration

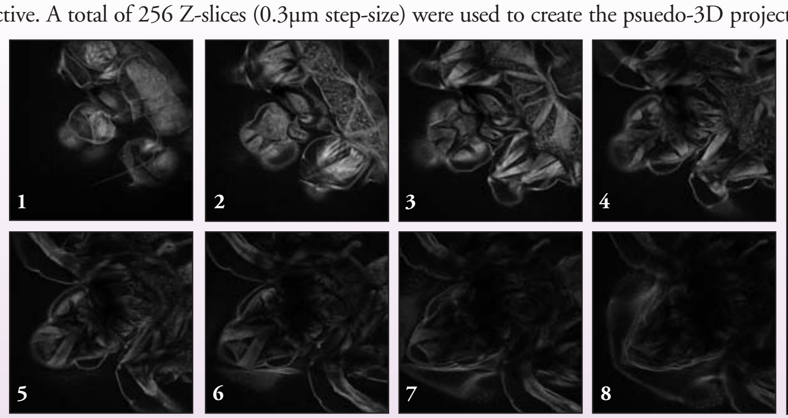
Figure 3 shows the **VCM100** reconfigured for fluorescence imaging. By changing the beamsplitter to a dichroic in the standard **VCM100H** setup and adding the appropriate excitation and emission filters, the system is now a powerful fluorescence imaging tool. In most situations, a PMT should also replace the fast photodetector.

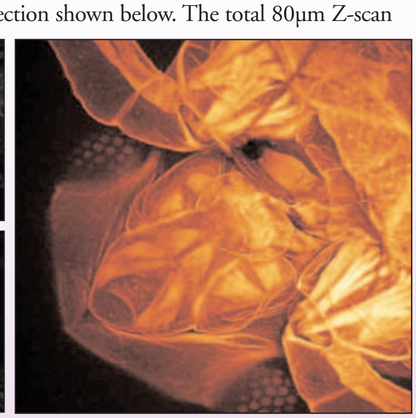
Check on-line at www.thorlabs.com to find new filter options and for information on choosing an appropriate filter for your dye.

Figure 3
VCM100 Reconfigured For Confocal Fluorescence

Peach Worm

These images represent psuedo-color confocal fluorescence images of a peach worm taken with the **VCM100** reconfigured for fluorescence using a 60X water immersion objective. A total of 256 Z-slices (0.3µm step-size) were used to create the psuedo-3D projection shown below. The total 80µm Z-scan is represented by the selection of data images shown in Figures 1 – 8, which are individual Z-slices at 10µm increments. Each individual image is 440 x 430µm.



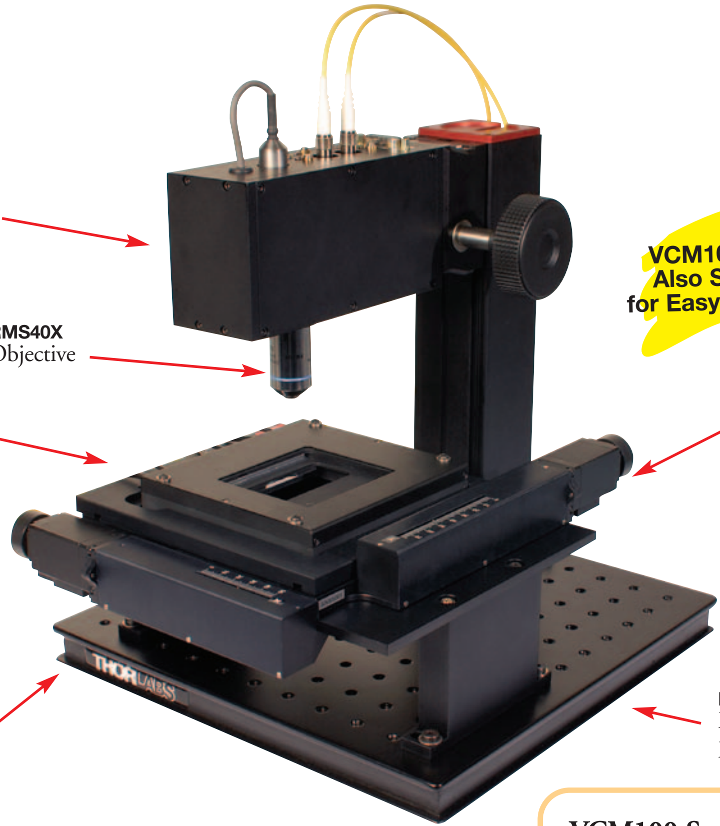


Real-Time Video-Rate Laser Scanning Microscope

VCM100H
Scanning Head
Includes Resonant Scanner, Glavo Sanner, Fiber System, and Enclosure as Shown.

RMS40X
Objective

SCZ100
Piezo Z Stage



VCM100H Scan Head Also Sold Separately for Easy Custom Designs

MAX201
XY Stepper Motor Stage
MAX200 Series

MAX200P5
Mounting Bracket Set for MAX200 Series

PBG11101
Breadboard

Please visit our website for information on accessories to reconfigure your VCM100 system: www.thorlabs.com

VCM100 System Includes:

- VCM100H Microscope Head
- 660nm Fiber Coupled Laser Diode
- RMS40X Objective
- MAX201 Encoded XY Stepper Motor Stage (Travel: 3" x 2", 75mm x 50mm)
- SCZ100 Piezo Controlled Z-stage (100µm Range)
- BPS103 APT 3-Channel (2 Stepper, 1 Piezo) Benchtop Controller
- Photodetector
- Breadboard With Mounting Bracket
- Computer
- Data Aquisition Card
- Control Electronics and Software

VCM100 System Specifications

Imaging:

- Resolution:[1] 1µm
- Frame Rate: 23 fps @ 800 (X) x 640 (Y) Pixels (2-Channel Detection)
- 3D Acquisition:[2] 800 x 640 x 256 (X, Y, Z) Pixels for 11 seconds

Optical:[3]

- Output Power: ~2mW
- Beam Diameter: ~ 4.5mm

Electronics:

- Analog Input: 2 Channels, 14 Bit, 100MS/s*
- Analog Output: 4 Channels, 12 Bit, 1MS/s*, +/-10V
- Digital I/O: 8 Ports

Hardware:

- CPU: Intel® Processor
- Memory: 2GB Memory
- Operating System: Windows® XP Professional, SP2
- Hard Drive: 250GB SATA
- Optical Drive: 16X DVD+/-RW
- Monitor: 19" LCD 1280 x 1024

[1] Resolution specified using a RMS40X objective and 660nm diode. Actual resolution will vary with objective used.

[2] When a piezo stage SCZ100 is used.

[3] Output power and beam diameter measured at exit port of VCMH with no objective using a 660nm laser diode light source (included).

*MS/s= Megasamples per Second

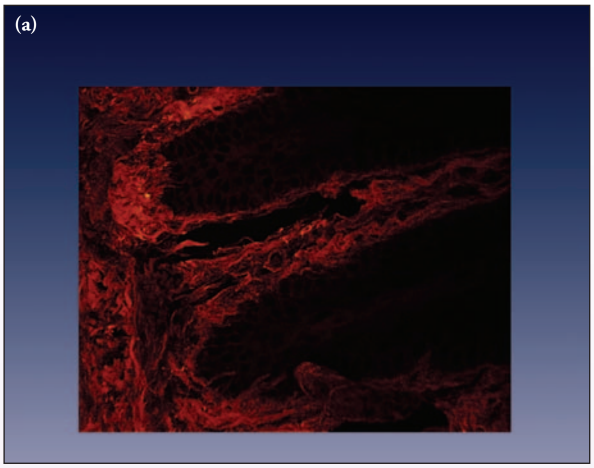
ITEM#	$	£	€	RMB	DESCRIPTION
VCM100	CALL	CALL	CALL	CALL	Video-Rate Laser Scanning Microscope System
VCM100H	CALL	CALL	CALL	CALL	Video-Rate Laser Scanning Microscope Scan Head Only

Confocal Application Images Page 1 of 2

The true power of confocal microscopy is the ability to spatially filter the reflected light so that only the signal that is generated from close to the focal plane is imaged onto the detector. This technique allows optical sectioning along the Z-plane. Optically sectioned images can be post-processed to create different renderings of the confocal raw data which can aid in visualization of different features within a given sample, as shown by the figures on these two pages.

For each of the images shown, the raw data consisted of a series of black and white tiff files that are easy to manipulate with standard image processing programs. The data was collected using the **VCM100** in flourescence mode with a 405nm fiber coupled laser diode used for the illumination. These images were imported into an image processing program that created the psuedo-color slices, projections, 3D cross-sections, and psuedo-3D images (a 3D reconstruction projected onto a 2D computer screen) shown here.

Human Skin and Sweat Gland


(a)

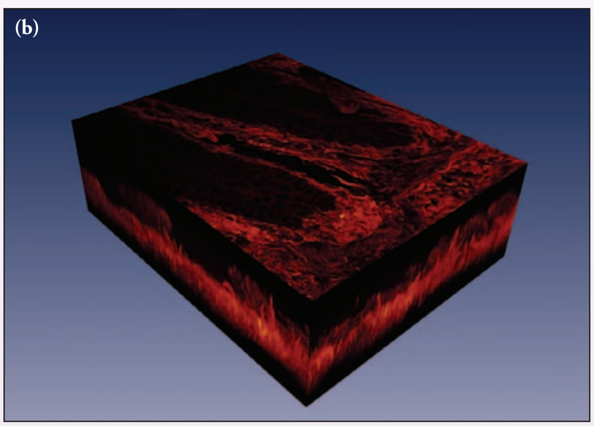
These figures show different views of a sample slice of human skin and sweat gland that was mounted on a standard microscope slide taken with the VCM100 using an infinity corrected 60X water immersion objective.

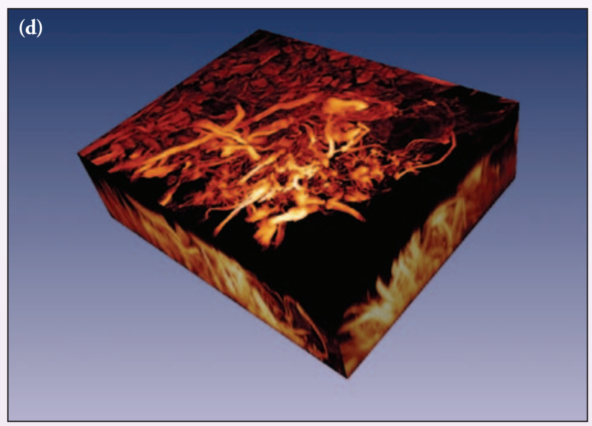
Figure (a), (b), and (c) are generated from the same set of data, whereas (d) and (e) are from another set.

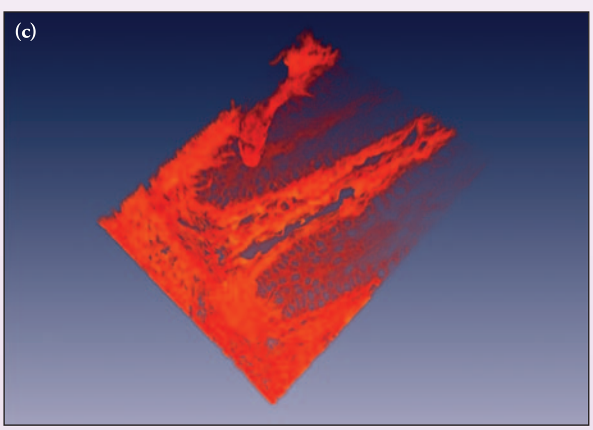
Figure (a) shows a psuedo-color projection that was created from a series of individual Z-slices.

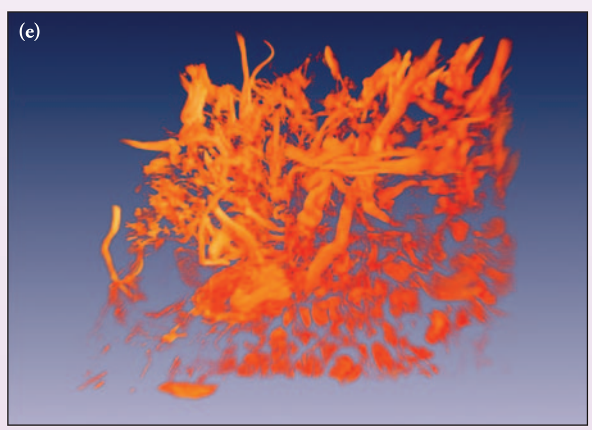
Figures (b) and (d) show 3D cross-sectional views. The 3D images can be rotated on the computer screen, and the contrast and intensity can be changed to help identify individual features within a sample.

Figures (c) and (e) show the psuedo-3D reconstruction of small portions of the human skin.


(b)

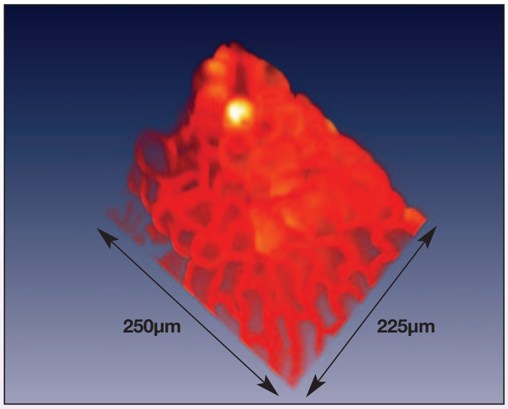

(d)


(c)


(e)

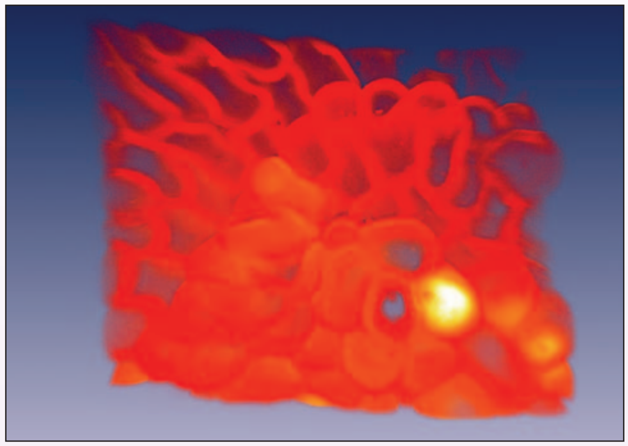
Confocal Application Images Page 2 of 2

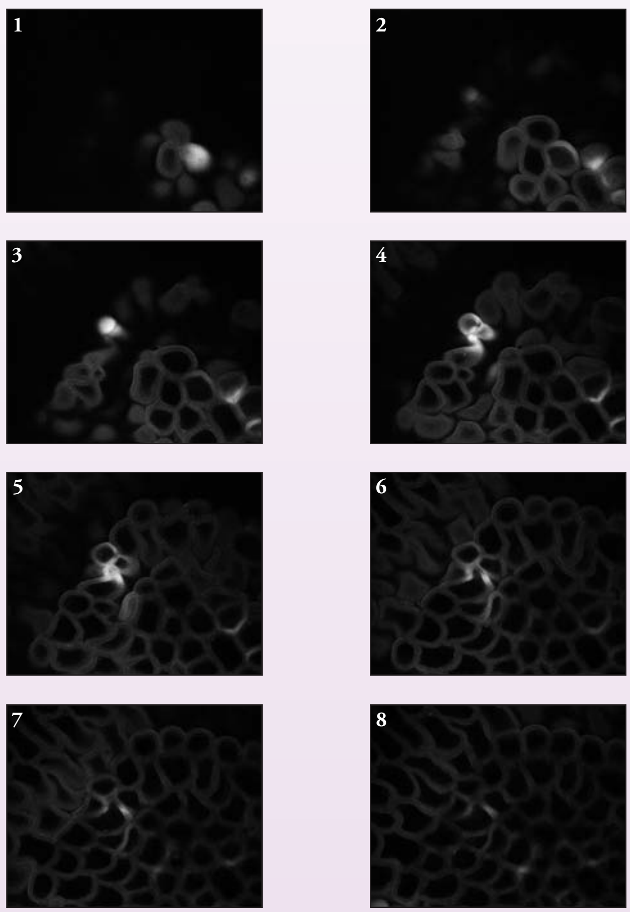
Fern Leaf



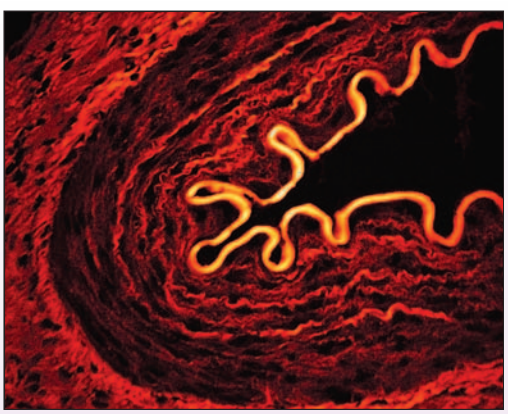
This image shows a 3D representation of a fern leaf created from fluorescent Z-section images taken with a **VCM100**. The leaf was mounted on a standard microscope slided and excited with 405nm light. The emitted light was collected, coupled into a single mode fiber, and detected with a PMT. The total image depth is 80µm.

The images shown here represent a confocal flourescence data of fern leaf. The black and white images (Figures 1-8) shown here are individual images taken with the **VCM100**. A total of 1024 frames were collected, each representing a single XY-frame (Z-slice). 4 frames were averaged at each Z-depth to create the individual black and white Z-slices (256 optical slices) from an 80µm thick sample. The black and white images shown here are a selection of those slices separated by 10µm each. Total data acquisition time for all 1024 frames (4 x 256 slices) was approximately 45 seconds.





Rabbit Artery



This image shows the top view projection of a slice of rabbit artery mounted on a standard microscope side. This figure represents a psuedo-color confocal fluorescent image taken with the **VCM100** in fluorescence mode using a 60X infinity corrected objective. Total image size is 250 x 210um.

Frequency Swept Laser Source

Thorlabs' Frequency Swept Tunable Lasers are specifically designed for Swept Source Optical Coherence Tomography (SS-OCT) and Optical Frequency Domain Reflectometry (OFDR) applications. These applications provide real-time, high resolution, cross-sectional imaging of turbid media and require a specially designed laser source that can sweep a wide wavelength range at very high speeds. A wide spectral tuning range is required for high axial resolution OCT images, and a high sweep-speed is needed to obtain real-time 2D and 3D OCT imaging speeds. Thorlabs now offers a variety of frequency swept laser sources based on a tunable external cavity semiconductor laser, designed and optimized for SS-OCT and OFDR applications.

Now available with center wavelengths at 850nm, 1050nm, 1325nm, and 1550nm, these broadband frequency swept lasers are a versatile family of specialty laser sources covering the spectral regions most often used in OCT applications. The compact design, robust alignment and high repetition rate make these systems ideal for both OEM and research applications. Recently redesigned, these lasers now offer even greater stability in a smaller desktop housing.

SL1325-P16

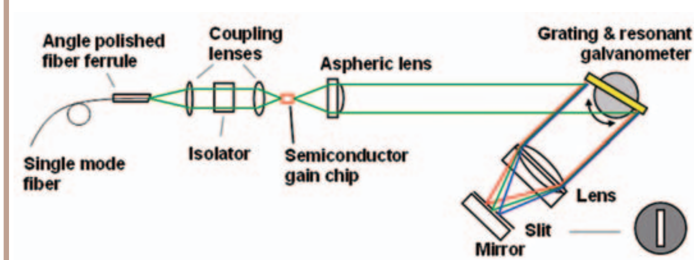
The swept source lasers are easily integrated into OEM systems and are available in the key wavelengths used in many biological and material science applications. For ophthalmic systems, the sample is mostly water, making the **SL850-P16** and the **SL1050-P16** ideal due to the minimal absorption of water in the 700 to 1000nm spectral range. In many other biological tissue samples, wavelengths of 1000nm or longer provide enhanced imaging and deeper penetration depths. In addition, the availability of optics and components optimized for telecom wavelengths make the **SL1325-P16** and **SL1550-P16** lasers ideal for other imaging and OEM system applications.

The external cavity laser consists of a single gain element where one facet of the element serves as an end mirror for the cavity. The extended cavity is comprised of a single collimating lens and a Cat-Eye wavelength selection device.

The intra-cavity side of the semiconductor gain element is AR coated, providing a residual reflectivity of less than 10^{-4} thus allowing for the efficient formation of an extended cavity. Wavelength selection is achieved using a diffraction grating mounted onto a scanner with a focusing lens, mirror, and slit assembly providing active wavelength selection. The focusing lens and slit/mirror assembly are separated by the focal length of the lens. This configuration is commonly referred to as a Cat-Eye and is highly insensitive to angular misalignment. Output from the laser cavity is coupled into a fiber using a lens system containing an isolator that prevents optical feedback into the cavity.

This design enables a robust alignment due to the cat's eye configuration of the back-reflector which provides superior long-term stability compared to designs with a quasi-collimated beam on the laser cavity back-reflector.

Patent Pending



Cat-Eye External Cavity Laser

Figure 1 - Schematic of the Swept Source Laser

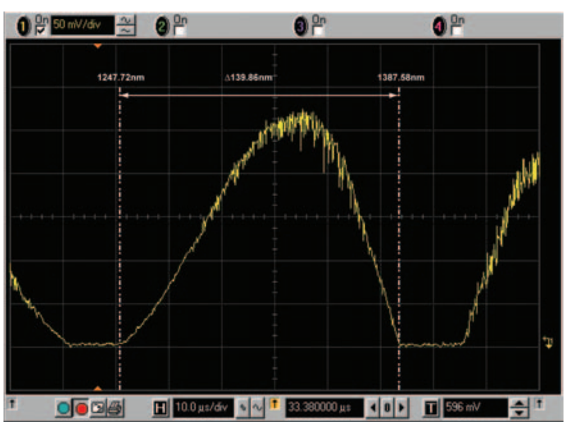


Figure 2 - the power monitoring signal, accessible from the rear panel of the laser.

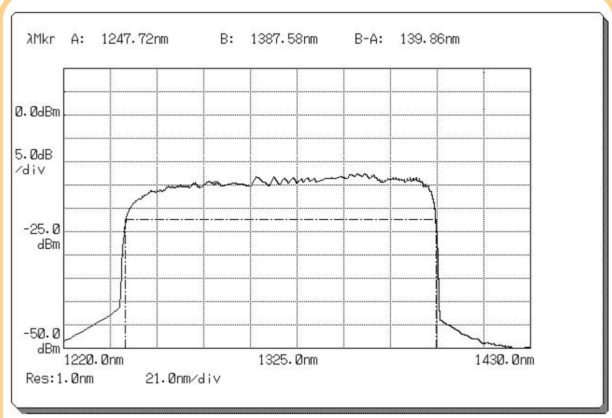


Figure 3 - the spectrum of the SL1325-P16 swept laser with an active wavelength tuning range of 155nm centered at 1325nm.

Frequency Swept Laser Source

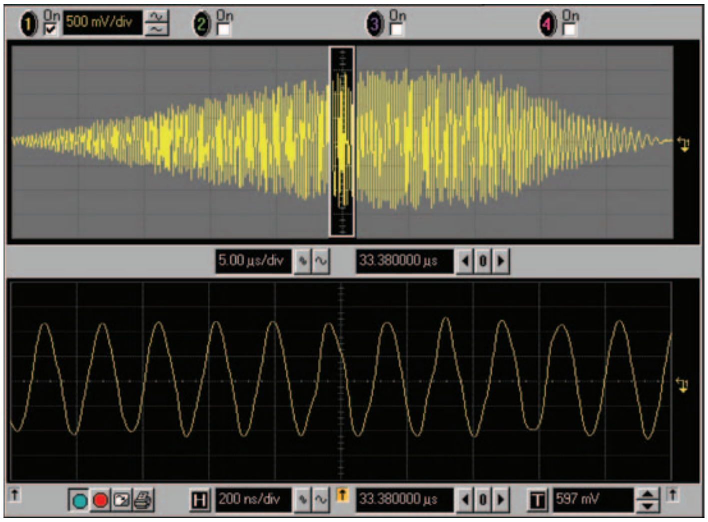


Figure 4 - At fast frequency sweep speeds, the laser frequency varies sinusoidally in time. For OCT imaging, accurate and reliable recalibration of the interference output is required so that the samples are equidistant in frequency. Thorlabs' swept source laser is ideal for this application. The laser features a built-in Mach-Zehnder Interferometer (MZI) with balanced detector output, which can be used as a frequency clock because the zero crossings of the interference fringe signal are equally spaced in optical frequency (k-space). This 'clock', while useful for resampling OCT data sets, can also be used to synchronize other measurements.

Key Features:

- Multiple Wavelength Versions: 850nm, 1050nm, 1325nm & 1550nm
- Fast Wavelength Sweep Rate: 16kHz
- Single Mode Fiber Output
- Compact Housing: 12.4" x 11.6" x 5.8" (315 x 295 x 146mm)

Rear Panel of Swept Source Laser

315 x 295 x 146mm (WxDxH)

The rear panel provides connections for the power monitor signal, the MZI clock, the sweep trigger, and the RS232 port.

OCT Swept Laser Source Specifications

Parameter	SL850-P16	SL1050-P16	SL1325-P16	SL1550-P16
Center Wavelength (nm) Typical	850	1050	1325	1550
Center Wavelength Range (nm)	835 - 855	1040 - 1060	1310 - 1340	1535 - 1565
Tuning Range (nm) @ -10dB cut off point	60 - 80	70 - 90	120 - 150	140 - 180
Repetition Rate (kHz) ± 200Hz	16	16	16	16
Average Optical Output Power (mW) Scanning	3	3	12	10
Optical Output Power (mW) Static	6	6	24	20
Signal Source Spontaneous Emission (dB)	25	25	25	25
Coherence Length Range (mm)	5 - 7	5 - 7	6 - 8	6 - 8
Laser Classification (per IEC 60825-1)	Class 1M	Class 1M	Class 1M	Class 1M
Operating Temperature (°C)	10 - 40			
Physical Size Width x Depth x Height	12.4" x 11.6" x 5.8" (315 x 295 x 146mm)			
Weight	21Lbs (9.5kg)			
Input Voltage	100 - 240VAC 50 - 60Hz			
Optical Output	Single Mode Fiber			
Output Connector	FC/APC			
Electrical Output Connectors	BNC			
RS232 Interface	DB9-F			

Note: Specifications subject to change due to on-going engineering improvements.

ITEM#	$	£	€	RMB	DESCRIPTION
SL850-P16	$ 35,000.00	£ 22,050.00	€ 32.550,00	¥ 334,250.00	16kHz Frequency Swept Laser Source @850nm
SL1050-P16	$ 35,000.00	£ 22,050.00	€ 32.550,00	¥ 334,250.00	16kHz Frequency Swept Laser Source @1050nm
SL1325-P16	$ 35,000.00	£ 22,050.00	€ 32.550,00	¥ 334,250.00	16kHz Frequency Swept Laser Source @1325nm
SL1550-P16	$ 35,000.00	£ 22,050.00	€ 32.550,00	¥ 334,250.00	16kHz Frequency Swept Laser Source @1550nm

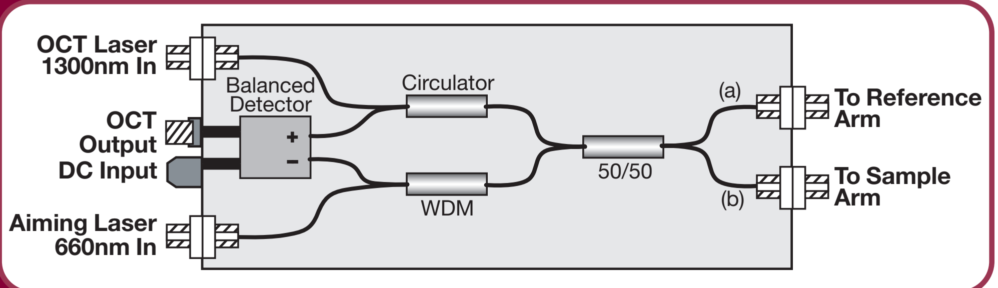
INT-MSI-1300 Michelson-Type Interferometer

Features

- Low Insertion Loss
- Flat Wavelength Response
- Integrated Balanced Signal Detection with Active Aliasing Filter
- Compact Design
- Input for Aiming Beam (660nm)to Aid Alignment

The Michelson-type INT-MSI-1300 interferometer subassembly is designed to be used inside an OCT system with a balanced detection scheme. It contains a fiber coupler network for a Michelson interferometer and has outputs for a reference and sample arm. Internally used couplers are optimized for flat wavelength response and very low polarization dependant coupling losses. The fiber length is matched on both arms of the interferometer to within 0.2mm while the housing includes FC/APC angled fiber adapters for robustness and ease of use.

The integrated, high-gain balanced detector (PDB145C) includes an active aliasing filter to suppress the generation of aliasing frequencies in the digitized fringe signals, which degrade the quality of the image if present. In order to simplify the optical alignment of a system using an INT-MSI-1300 an additional input for a 660nm aiming laser and a specially designed WDM-coupler that combines the swept laser source (1300nm) and the alignment laser (660nm) was included in the subassembly.



Specifications

- Insertion Loss of 1300nm Light into the Sample Arm: < 4.0dB
- Insertion Loss of 660nm Light into the Sample Arm: < 4.0dB
- Path Length Difference Between Sample and Reference Arms: <± 0.2mm
- Bandwidth: DC to 15MHz

ITEM#	$	£	€	RMB	DESCRIPTION
INT-MSI-1300	$ 2,300.00	£ 1,449.00	€ 2.139,00	¥ 21,965.00	INT-MSI-1300 Michelson-Type Interferometer

INT-COM-1300 Common-Path OCT Interferometer

Features

- Low Insertion Loss
- Flat Wavelength Response
- Integrated Balanced Signal Detection with Active Aliasing Filter
- Compact Design
- Input for 660nm Alignment Beam

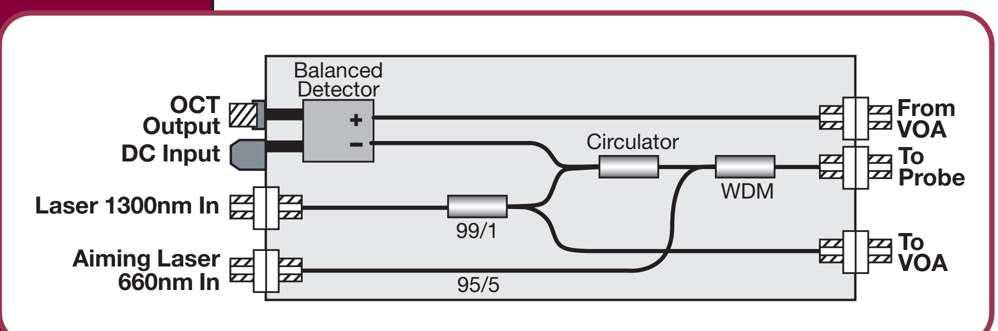
Specifications

- Insertion Loss: < 2dB
- Bandwidth: DC to 15MHz

Thorlabs' INT-COM-1300 interferometer is designed to be used inside a swept source OCT system for common-path OCT applications. Internally used couplers are optimized for flat wavelength response and very low polarization dependant coupling losses. The module also includes FC/APC angled fiber adapters.

The integrated high-gain balanced detector (PDB145C) includes an active aliasing filter, that minimizes the generation of aliasing frequencies in the digitized fringe signals for improved image quality.

Alignment is made easier due to an additional input for a 660nm aiming laser and a specially designed WDM coupler that combines the swept laser source (1300nm) and the alignment laser (660nm).



ITEM#	$	£	€	RMB	DESCRIPTION
INT-COM-1300	CALL	CALL	CALL	CALL	INT-COM-1300 Common-Path OCT Interferometer

INT-MZI-1300 and INT-MZI-850 Mach-Zehnder Interferometer

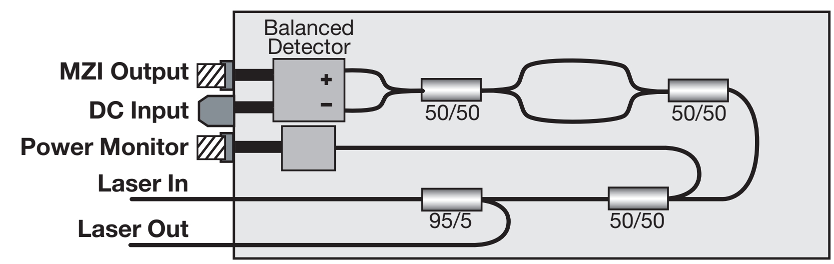
Features

- Two Center Wavelength Models Available: 850nm or 1300nm
- Ideal for Swept Source Output Frequency Monitoring with Balanced Detection Output
- Low Insertion Loss
- Flat Wavelength Response
- Integrated Signal Detection for Power Monitor and *k*-Clock Signals
- Compact Design
- **Fiber:** 780HP (INT-MZI-850)
  SMF28 (INT-MZI-1300)
  Both 0.5m long, FC/APC Connectorized

Thorlabs' MZI series of clock box subassemblies are designed to be used inside a swept source OCT system with a central wavelength of either 850nm or 1300nm. The clock box contains two detectors that provide a power monitor signal and a *k*-clock signal that monitors the output frequency of the swept source. The internal fiber couplers are optimized for flat wavelength responses and very low polarization dependent coupling losses, which makes the output signals independent of input polarization changes.

Specifications

- Free Spectral Range: 103.3GHz (±5%)
- Insertion Loss: < 1dB
- Power Monitor Bandwidth: DC-200MHz
- MZI Output Bandwidth: DC to 200MHz
- Custom Free Spectral Range and Center Wavelength Versions Available



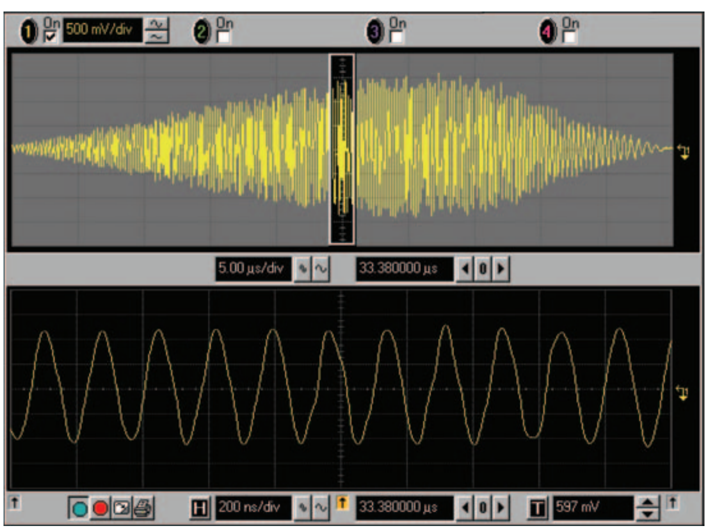
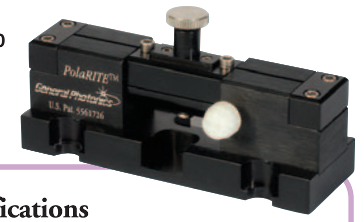


Figure 1 – Rapidly swept laser sources typically use sinusoidal tuning elements to achieve the very fast optical frequency sweep speeds required for OCT imaging applications. Hence accurate and reliable re-calibration of the OCT signal is required so that the final data points are equidistant in frequency. The Thorlabs swept source laser features a built-in Mach-Zehnder Interferometer (MZI) with balanced detector output that can be used for just this purpose. A frequency clock is derived from the zero crossings of the MZI interference fringe signal; these zero crossings are equally spaced in optical frequency (k-space). While this clock is intended for re-sampling OCT data sets, it can also be used to synchronize other measurements.

ITEM#	$	£	€	RMB	DESCRIPTION
INT-MZI-850	$ 1,800.00	£ 1,134.00	€ 1.674,00	¥ 17,190.00	850nm Mach-Zehnder Interferometer Clock Box
INT-MZI-1300	$ 1,800.00	£ 1,134.00	€ 1.674,00	¥ 17,190.00	1300nm Mach-Zehnder Interferometer Clock Box

In-line Fiber Polarization Controllers

PLC-900



The PLC-900 polarization controller is ideal for applications that require a stable, compact, manual controller. It is designed to be used with 900µm jacketed single mode fiber. The fiber is simply placed in a channel, and end-clamps hold it in place. One knob is adjusted to squeeze the fiber and rotate it, allowing one to convert an arbitrary input state of polarization into any other state of polarization; any point on the Poincare sphere may be set. A separate knob is used to lock the controller into position.

Features

- For 900µm Jacketed Fiber
- Compact
- Insensitive to Wavelength Variations

Specifications

- **Operating Wavelength:** 780-1550nm
- **Insertion Loss:** 0.05dB
- **Return Loss:** 65dB
- **Extinction Ratio:** >40dB

ITEM#	$	£	€	RMB	DESCRIPTION
PLC-900	$ 500.00	£ 315.00	€ 465,00	¥ 4,775.00	Inline Fiber Polarization Controller for 900 µm Fiber Jacket

Application Note - OCT Interferometer Modules

Thorlabs now offers three types of interferometer modules for OCT applications. The Michelson type and common path type Mach-Zehnder interferometers can be used to generate the OCT interference fringe signals. The Mach-Zehnder type interferometer (MZI) can be used as the frequency clock (k-clock) for tunable laser sources. The MZI is essentially an optical etalon with a balanced detection output and very high optical throughput, which improves signal quality.

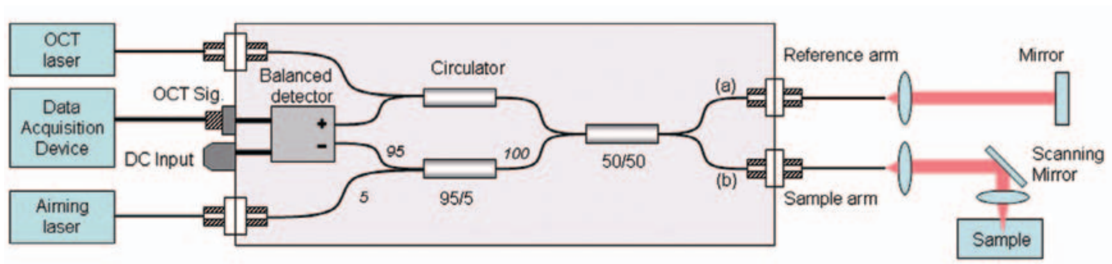


Figure 1. INT-MSI-1300 used in an OCT system with Michelson interferometer

The **INT-MSI-1300** can be used in both Fourier domain and time domain OCT systems. Since the fiber lengths are well matched (within 0.2 mm) internally for the sample and reference arms, the user only needs to construct the two external arms with matched optical path lengths and dispersion and plug the FC/APC terminated sample and reference arms into the module. A broadband 50/50 coupler optimized for both the 1300nm OCT wavelength and the 660nm aiming laser wavelength and a balanced detector equivalent to Thorlabs **PDB145C** are integrated into the module.

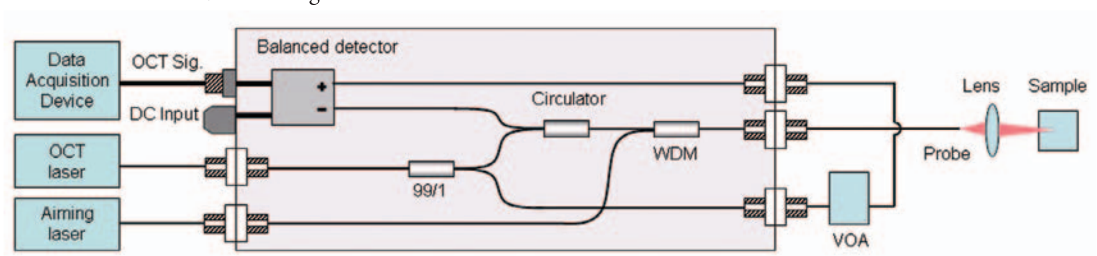


Figure 2. INT-COM-1300 used in an OCT system with common path interferometer

The **INT-COM-1300** is designed for swept source Fourier domain OCT systems that require a common path interferometer configuration. The probe interfaced with this module should have a reference arm and a sample arm. The reflections from both arms are combined to produce the interference fringes detected by one channel of the integrated balanced detector inside the **INT-COM-1300**, which is equivalent to the Thorlabs' **PDB145C**. The second channel of the balanced detector is available to be used to offset any DC component in the interference signal. This requires that the optical pathway to this channel be completed with a variable optical attenuator (VOA) that can be used to control the intensity of the light reaching the second detector channel. Removing the DC component of the detector output signal maximizes the utilization of the dynamic range of the data acquisition device used to record the interference signal.

OCT Proven Balanced Detectors

PDB145C

Features

- Operating Wavelength:
  - 320 to 1000nm (PDB120A, PDB140A, or PDB145A)
  - 800 to 1700nm (PDB120C, PDB140C, or PDB145C)
- Bandwidth: DC 75MHz (PDB120); DC to 15 MHz (PDB140, or PDB145)
- High Transimpedance Gain
- Low DC Offset
- Excellent Common Mode Rejection (>35dB)
- Ultra-Low Noise
- Active Low-Pass Filter to Suppress Aliasing (Not Available on PDB120 Series)

Image quality in an OCT system can be dramatically improved by utilizing a balanced detection scheme. A balanced detection scheme improves the signal to noise ratio by allowing for common-mode noise rejection and autocorrelated noise suppression.

Thorlabs now offers a broad range of balanced detectors to cover different bandwidth and wavelength regions. All the units are optimized for low DC offset and high transimpedance gain. The active low-pass anti-aliasing filter helps to remove the frequency aliasing effect associated with high-frequency signal digitization processes. These balanced detectors are widely used in Thorlabs' swept source OCT imaging systems and produce superior image quality.

Please see page 938 for specifications on these and other balanced photodetectors.

ITEM#		$	£	€	RMB	DESCRIPTION
PDB120A	PDB120A-EC	$ 1,176.00	£ 740.90	€ 1.093,70	¥ 11,230.80	Bal. Amplified Photodetector, 75MHz, Si, 320-1000nm, 180kV/A Gain
PDB120C	PDB120C-EC	$ 1,260.00	£ 793.80	€ 1.171,80	¥ 12,033.00	Bal. Amplified PD, 75MHz, InGaAs, 800-1700nm, 180kV/A Gain
PDB140A	PDB140A-EC	$ 1,276.00	£ 803.90	€ 1.186,70	¥ 12,185.80	Fixed Gain Bal. Detector, 15MHz, Si, 320-1000nm, 560kV/A Gain
PDB140C	PDB140C-EC	$ 1,360.00	£ 856.80	€ 1.264,80	¥ 12,988.00	Fixed Gain Bal. Detector, 15MHz, InGaAs, 800-1700nm, 560kV/A Gain
PDB145A	PDB145A-EC	$ 1,276.00	£ 803.90	€ 1.186,70	¥ 12,185.80	Fixed Gain Bal. Detector, 15MHz, Si, 320-1000nm, 51kV/A Gain
PDB145C	PDB145C-EC	$ 1,360.00	£ 856.80	€ 1.264,80	¥ 12,988.00	Fixed Gain Bal. Detector, 15MHz, InGaAs, 800-1700nm, 51kV/A Gain

Balanced Detectors, See Pages 938-939

PDB150 with Switchable Gain

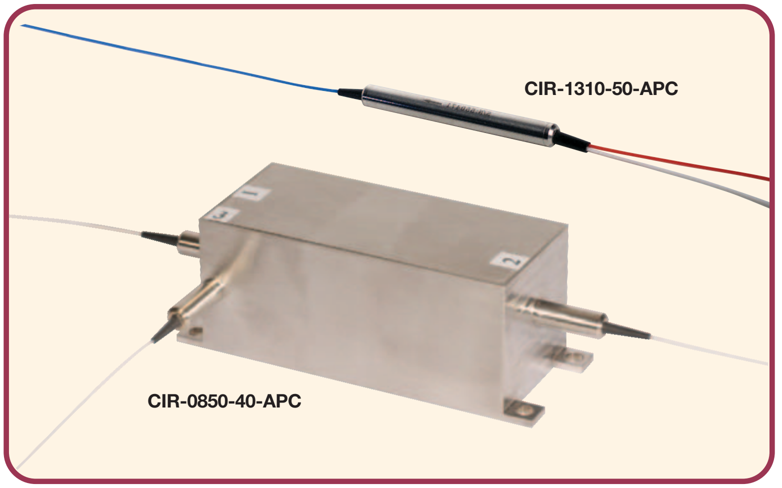
Thorlabs has many options for balanced detectors.

The PDB100 Balanced Detector Series acts as a balanced receiver by subtracting the two optical input signals from each other resulting in the cancellation of common mode noise. This allows small changes on the signal path to be extracted from the interfering noise floor. Versions with different transimpedance gains, bandwidths and photodiodes are offered to suit a variety of applications.

- Ultra Low Noise
- Two Inputs Allows Differential Signal Detection and Increased SNR
- Various Models Available From 320 to 1700nm
- Excellent Common Mode Rejection
- High Bandwidth: DC to 350MHz
- Detector Types: Si or InGaAs
- Free Space & Fiber Input

NEW! Switchable Gain PDB150

OCT Proven Broadband Circulators



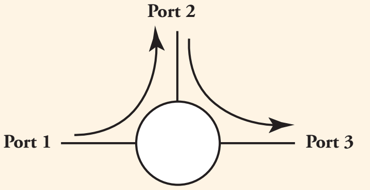
Optical Coherence Tomography (OCT) systems require components that operate over a broad spectral range, with minimal spectral dependency. Thorlabs OCT proven circulators are tested to ensure minimal wavelength dependent insertion loss variations, making them an ideal choice for integrating into many OCT systems.

Features

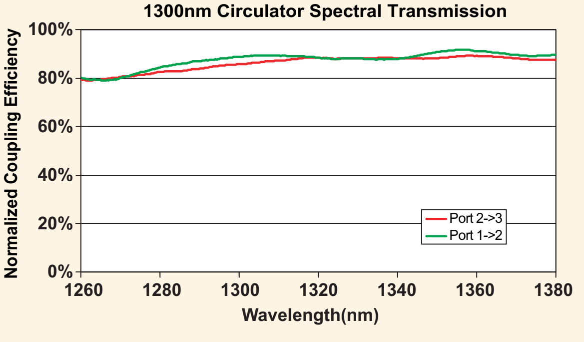
- Wide Operating Wavelength Range
- Low Insertion Loss

Specifications

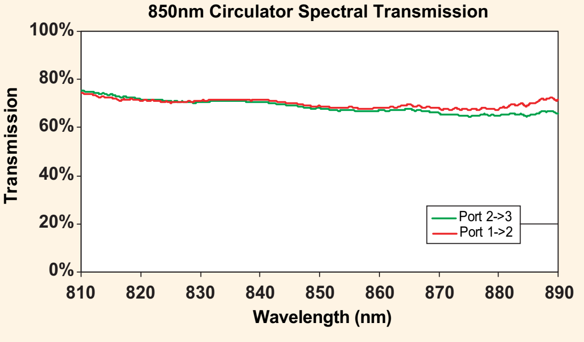
PARAMETERS	CIR-1310-50-APC	CIR-0850-40-APC
Wavelength Range	1280-1400nm	810-890nm
Isolation	28dB	≥15dB
Insertion Loss	1.6dB	1.5dB
Directivity	50dB	≥40dB
Return Loss	45dB	≥45dB
Polarization-Dependent Loss	0.2dB	0.5dB Max / 0.25dB Typ.
Polarization Mode Dispersion	0.05ps	–
Max. Optical Power	500mW	500mW
Operating Temperature	0 to 70°C	10 to 50°C
Storage Temperature	–40 to 85°C	–



Insertion Loss (1➛2, 2➛3)
Isolation (2➛1, 3➛2)
Directivity (1➛3)



The plot above shows the normalized coupling efficiency for the two beam propagation paths of a typical OCT-proven 1310nm circulator (CIR-1310-50-APC) versus wavelength. Port 1-to-2 shows a mean coupling efficiency of 88% and a standard deviation of 10%. Port 2-to-3 shows a mean coupling efficiency of 86% and a standard deviation of 12%.



The plot above shows the normalized coupling efficiency for the two beam propagation paths of a typical OCT-proven 850nm circulator (CIR-0850-40-APC) versus wavelength. Port 1-to2 shows a mean coupling efficiency of 70% and a standard deviation of 4%. Port 2-to-3 shows a mean coupling efficiency of 70% and a standard deviation of 4%.

ITEM#	$	£	€	RMB	DESCRIPTION
CIR-0850-40-APC	CALL	CALL	CALL	CALL	Broadband Fiber Circulator, 810-890nm
CIR-1310-50-APC	$ 700.00	£ 441.00	€ 651,00	¥ 6,685.00	Broadband Fiber Circulator, 1280-1400nm

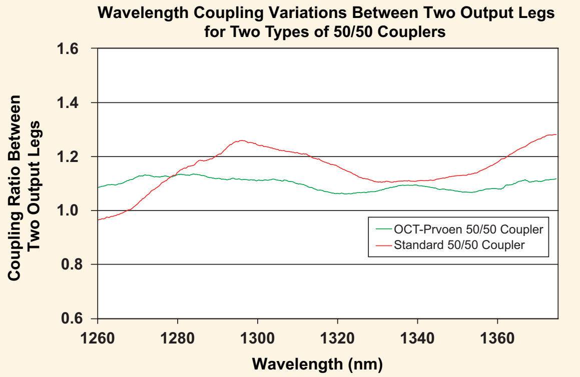
Broadband Fiber-Optic Couplers for OCT

FC1310-70-01-APC

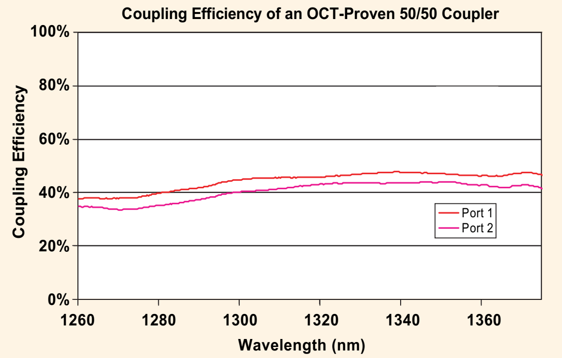
Optical Coherence Tomography (OCT) systems require components that operate over a broad spectral range, with minimal spectral dependency. Thorlabs OCT proven couplers are tested to ensure minimal wavelength dependent insertion loss variations, making them an ideal choice for integrating into many OCT systems.

Features

- **Operating Wavelengths:** 1310 ± 40nm, 850 ± 40nm
- Broadband Wavelength Flattened Coupling
- Low Insertion Loss
- **Different Coupling Ratios:** 1:99, 10:90, and 50:50
- FC/APC Connectors
- Customized Fiber Length Available



The plot above shows, for a standard and an OCT-proven 50/50 coupler, the ratio of transmitted intensity between the two output ports versus wavelength. The standard coupler shows a ratio of 1.14 and a standard deviation of 12.6%, while the OCT-proven coupler shows a ratio of 1.10 and a standard deviation of 5.0%. This shows the OCT proven coupler with ~2.5x improvement in split ratio performance.



The plot above shows the coupling efficiency for each of the two output ports of a typical OCT-proven 50/50 coupler versus wavelength. Port 1 shows a mean coupling efficiency of 39% and a standard deviation of 5%. Port 2 shows a mean coupling efficiency of 43% and a standard deviation of 5%.

FC850-40-XX-APC Series

PARAMETERS	850 +/-40nm		
Fiber Type (nm)	SM-800, 900µm diameter		
Coupling Ratio	1/99	10/99	50/50
Insertion Loss (dB)	0.25/20	0.75/10	3.7/3.7
Polarization Dependent Loss (dB)	≤0.2		
Excess Loss (dB)	≥0.5		
Directivity (dB)	≥55		
Port Configuration	2 x 2		
Operating Temperature Range (°C)	0 ~ +70°		
Storage Temperature Range (°C)	-40 ~ +85°		
Lead Length and Tolerance (cm)	100 +/- 10		
Connectors	FC/APC		

FC1310-70-XX-APC Series

PARAMETERS	1310 +/-40nm		
Fiber Type (nm)	Corning SMF-28e, 900µm diameter		
Coupling Ratio	1/99	10/90	50/50
Insertion Loss (dB)	0.4/21.6	0.8/12.7	3.8/3.8
Polarization-Dependent Loss (dB)	<0.15		
Excess Loss (dB)	0.2		
Directivity (dB)	>60		
Port Configuration	2 x 2		
Connectors	FC/APC		

ITEM#	$	£	€	RMB	DESCRIPTION
FC1310-70-01-APC	$ 250.00	£ 157.50	€ 232,50	¥ 2,387.50	Broadband Fiber Optic Coupler, 1310nm ± 40nm, 1:99
FC1310-70-10-APC	$ 250.00	£ 157.50	€ 232,50	¥ 2,387.50	Broadband Fiber Optic Coupler, 1310nm ± 40nm, 10:90
FC1310-70-50-APC	$ 250.00	£ 157.50	€ 232,50	¥ 2,387.50	Broadband Fiber Optic Coupler, 1310nm ± 40nm, 50:50
FC850-40-01-APC	$ 250.00	£ 157.50	€ 232,50	¥ 2,387.50	Broadband Fiber Optic Coupler, 850nm ± 40nm, 1:99
FC850-40-10-APC	$ 250.00	£ 157.50	€ 232,50	¥ 2,387.50	Broadband Fiber Optic Coupler, 850nm ± 40nm, 10:90
FC850-40-50-APC	$ 250.00	£ 157.50	€ 232,50	¥ 2,387.50	Broadband Fiber Optic Coupler, 850nm ± 40nm, 50:50

Laser Microscopy Objectives

Introduction to Objective Lenses

Traditional microscope objective lenses were used to create visible images of small objects. As a result, they were engineered to minimize spherical and chromatic aberrations with other parameters like the numerical aperture and working distance chosen for the specific imaging application. However, more recently objective lenses have been found to be useful in an increasing number of applications. In response to this, new objective lenses have been designed with parameters optimized for their intended purpose. Since Thorlabs has recently expanded the number and types of objectives that it offers, the discussion below has been included to help select the proper objective for your application; it provides a coarse overview of each type of objective offered by Thorlabs. Detailed information can be found on the page where the product is listed for sale (see below).

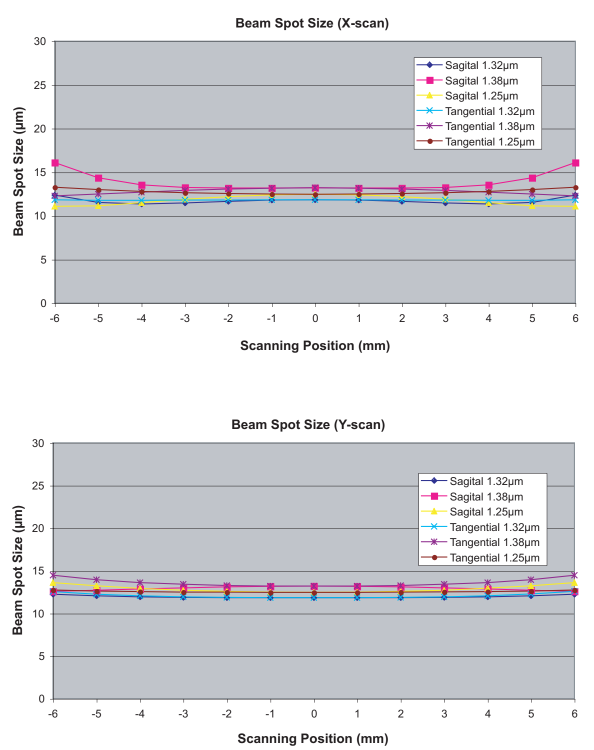
Objective Lens Selection Guide

The RMS, LMU, or LMH series of objective lenses should be used in applications like traditional microscopy, confocal imaging, and fiber coupling. In these applications, the imaged area or focal spot is intended to be coincident with the optical axis of the objective lens. If the application involves using light over a broad spectral range, consider using one of the lenses on page 619. For applications using a single wavelength of light at 193, 248, 266, 351/354, 532, or 1064nm, Thorlabs carries specialized objectives (see pages 620-621).

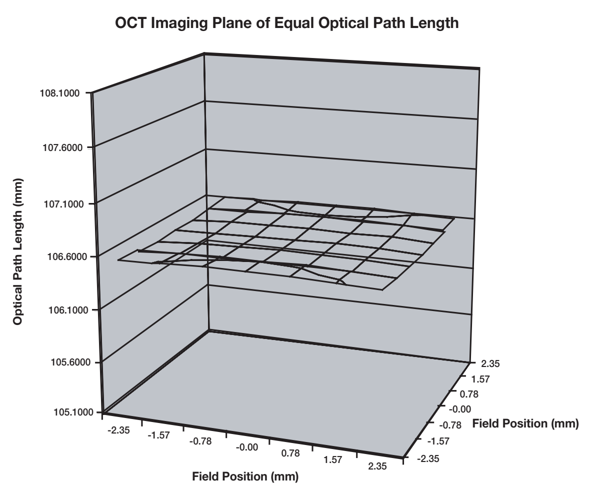
The LSM series of objectives has been recently designed to improve the performance of Thorlabs' OCT imaging systems. These objective lenses are sometimes referred to as scan lenses because a laser beam is scanned across the back aperture of the lens. This results in a focal spot that is not coincident with the optical axis of the scan lens. The specifications of these scan lenses can be found on page 618 while some performance plots and application information follows. As a side note, the scan lens used in the ASOM system offered by Thorlabs was specially designed to image a spot that was not coincident with the optical axis. The ASOM system contains a specialized scan lens, a fast steering mirror, and an adaptive optical element (deformable mirror) that allow it to create high resolution (1.5µm) images with a field of view greater than 40mm in diameter (see pages 582-589).

Theoretical Performance Plots for the LSM02 Scan Lens

These plots are also representative of the performance characteristics of the LSM03 and LSM04 scan lenses; please see Thorlabs website for details on these other scan lenses.



These plots show the calculated beam spot size at the focal plane for different wavelength components. The mean spot size is 13µm for both X and Y scans. A non-zero scanning position indicates that the imaged point is not coincident with the intersection of the scan lens optical axis with the sample.



This plot shows the calculated equal OPL plane of an LSM02 lens. The maximum variation of the equal OPL plane from a perfect plane is 50µm. (The OPL was calculated from the fiber end in the sample arm of an OCT system.)

Laser Microscopy Objectives

Scan Lens Applications

The LSM series of scan lenses were designed for Thorlabs' OCT imaging systems. Figure 1 shows a simplified setup of the sample arm in the OCT imaging system. For a more detailed presentation, please refer to page 594. As you can see in Fig. 1, a galvo mirror is used to scan a beam of light over the back aperture of the scan lens. The LSM series of scan lenses were designed and manufactured to prevent image degradation and distortion during scanning. The LSM series of OCT objectives are designed with a large diameter barrel that has a relatively low NA and a focal spot size that is uniform over the entire Field of View (FOV). In addition, the scan lenses have a telecentric design that minimizes the image distortions over the entire scan range.

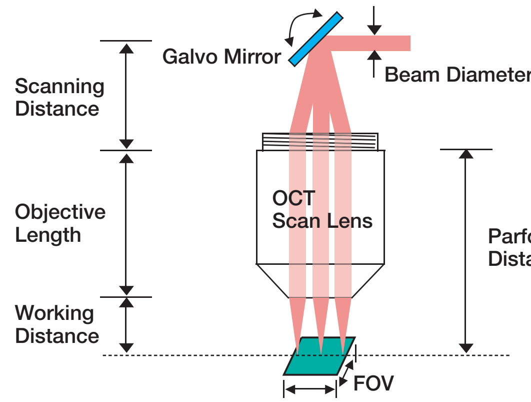
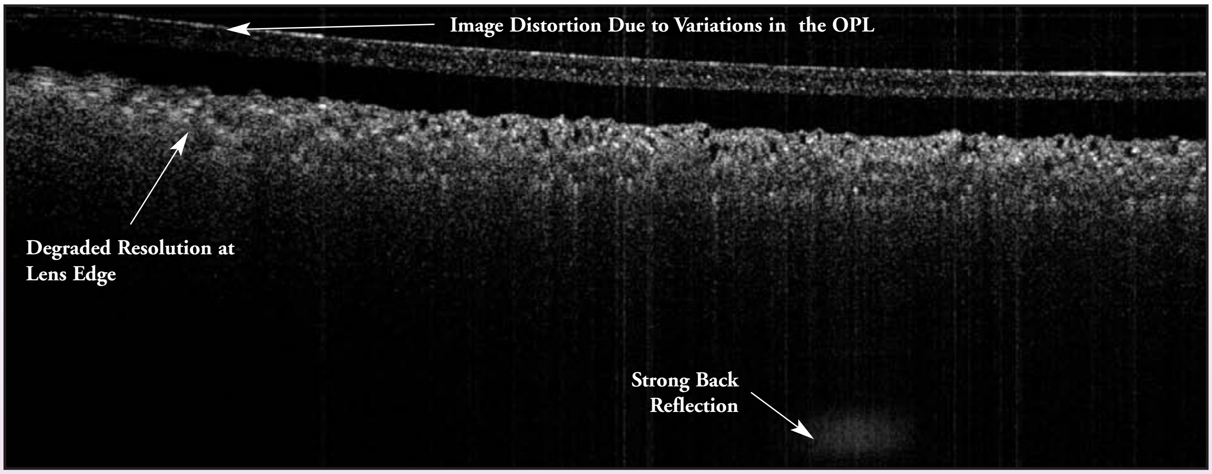


Figure 1
Typical OCT Scan Lens Application Setup

IR Card



This image shows the typical image artifacts that occur when using a standard achromatic lens for OCT imaging.

When designing an imaging system using an LSM scan lens, the following parameters should be considered. (See page 618 for the specifications of the LSM series of lenses):

- **Field of View (FOV):** The FOV is the total imaging area size at the focal plane of the lens as the beam is scanning a sample.
- **Resolution:** The minimal distance between two points that can be identified as two distinct features. In the case of the LSM OCT objectives, the resolution of the lens is the mean value of the beam spot size within the FOV.
- **Depth of View (DOV):** In traditional objectives the larger the NA, the smaller the DOV. In OCT applications a good approximation is that the DOV is the distance between the two planes on both sides of the focal plane where the beam spot size becomes $\sqrt{2}$ times larger than the spot size at the focal plane.
- **Scanning Distance (SD):** The SD is the distance between the galvo mirror pivot point and the back mounting plane of the lens. The OCT lens is designed to be telecentric. This requires the galvo mirror pivot point to be located at the back focal plane of the lens, thus determining the scanning distance.
- **Parfocal Distance (PD):** The PD is the distance from the lens mounting plane to the focus plane in the sample.
- **Working Distance (WD or LWD):** The WD distance is the distance between the front surface of the lens and the front focal plane of the lens.
- **Field Curvature:** The field curvature is the maximum deviation of the front focal plane from an ideal plane.
- **Scan Angle (SA):** The scan angle is the maximum angle of the beam as it is scanned away from the center axis of the lens. For OCT applications, the scan angle is 7.5°, which means the full optical scan angle of 15° can be accepted by the OCT lens.
- **Beam Diameter (BD):** The beam diameter is defined as the diameter of the beam at the point when the optical field intensity reaches $1/e^2$ of its maximum value. For OCT, the scan lens is designed to accept a beam diameter of 4mm.
- **Optical Path Length (OPL):** The optical path length is the travel distance of the beam from the galvo scan mirror to the focal spot. The OCT lens is designed such that this value varies minimally over different scanning angles.

LSM Series Objective Lenses

Features

- Optomized for OCT Applications
- Telecentric Design
- Long Working Distance

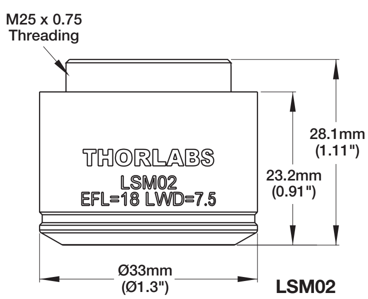
LSM02

LSM03

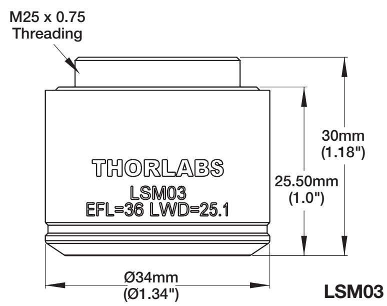
LSM04

The LSM series of objective lenses were designed for use with Thorlabs' OCT microscope. As a result, these infinity corrected laser scanning objectives are optimized to maintain a small focal spot and constant optical path length as the laser beam is scanned over the entrance aperture of the LSM objective. In addition, the LSM series of OCT objectives have a telecentric design that minimizes image distortion. The low NA allows for a large depth of focus (DOF), which is preferable for OCT applications. Finally, these lenses have also been designed to minimize both lateral and axial chromatic aberrations. Combined, these features enable the OCT microscope to create a high resolution 3D image with a wide field of view. These objective lenses have M25-0.75 threading. For more information on the LSM objectives, please see the two previous pages. For information on Thorlabs' OCT systems. please see the section beginning on page 590.

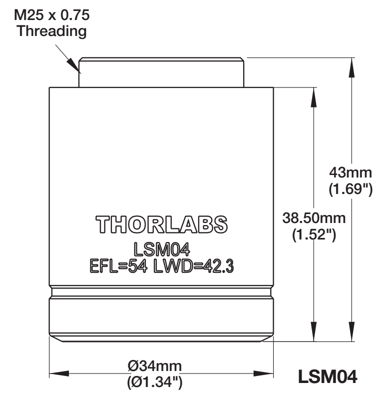
FOR MORE INFORMATION ON THORLABS OCT PRODUCTS, SEE PAGE 590



LSM02



LSM03



LSM04

Specifications	LSM02	LSM03	LSM04
Scanning Distance (Dist. from Pupil Position to Mounting Plane) [SD]:	15mm	15mm	15mm
Pupil Size ($1/e^2$)[EP]:	4mm	4mm	4mm
Working Distance [LWD]:	7.5mm	25.1mm	42.3mm
Lens Numerical Aperture [NA]:	0.11	0.055	0.037
Effective Focal Length [EFL]:	18mm	36mm	54mm
Depth of View [DOV]:	0.12mm	0.58mm	1.15mm
Variation of Spot Size Over FOV [dS]:	11µm	4µm	13.5µm
Distance Between First Lens Surface and Mounting Plane:	-4.0mm	-3.1mm	-3mm
Field of View [FOV]:	4.7 x 4.7mm	9.4 x 9.4mm	14.1 x 14.1mm
Parfocal Distance [P]:	32mm	55mm	80.7mm
Mean Spot Size (Diameter, $1/e^2$) (in Field of Focus) [S]:	13µm	25µm	35µm
Curvature (Maximum Error) of FOV from Planar [C]:	48µm	300µm	320µm
Maximum Difference for Optical Path Length (OPL) From Center to the Corner of the Image: (<50 µm difference from a plane OPL field with 8mm separation between X and Y scan mirrors)	< 1µm	< 1µm	< 1µm
Transmission Efficiency (Beam Energy Into Spot Energy) $1/e^2$:	> 93%	93%	93 %
Linearity (of Conversion From Scan Angle Into Spot Position):	< 2.0%	< 1.4%	< 2%
Magnification:	10x 5x 3x	10x 5x 3x	10x 5x 3x
Center Wavelength:	1315nm	1315nm	1315nm
Wavelength Range:	± 65nm	± 65nm	± 65nm
Lateral Color (Maximum Shift Permitted):	< 6.0µm	< 8.3µm	< 19µm
Vertical Color, Axial Color or Chromatic Focal Shift (Maximum Shift Permitted) [VC]:	< 20µm	<1µm	< 46µm
Lens Operating Temperature Range [TA]:	10 to 50°C	10 to 50°C	10 to 50°C

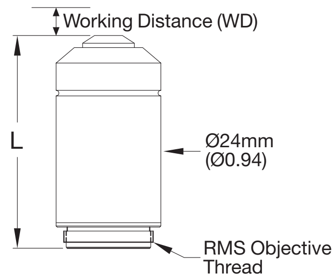
Note: The specifications above assume a diffraction-limited beam and are valid assuming that the scanner 1/2 angle is 7.5 degrees, and the distance between scanner(s) is 8mm.

ITEM#	$	£	€	RMB	DESCRIPTION
LSM02	$ 1,600.00	£ 1,008.00	€ 1.488,00	¥ 15,280.00	Laser Scanning Objective, EFL 18mm
LSM03	$ 1,100.00	£ 693.00	€ 1.023,00	¥ 10,505.00	Laser Scanning Objective, EFL 36mm
LSM04	$ 980.00	£ 617.40	€ 911,40	¥ 9,359.00	Laser Scanning Objective, EFL 54mm

Visible Imaging Objectives

Features
- Infinity Corrected
- 4X, 10X, 20X, or 40X Magnification
- Achromatic Objective

Thorlabs offers a line of infinity corrected Plan Apo imaging objectives. Optimized for brightfield imaging, these objectives provide superb field flatness. The achromatic objectives have an ultra wide antireflection coating and standard RMS threading.



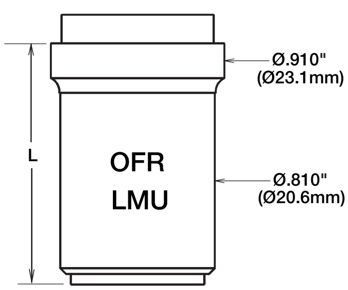
ITEM #	MAGNIFICATION	NA	EFL	WD	LENGTH	$	£	€	RMB
RMS4X	4X	0.10	45mm	22mm	28mm	$ 172.00	£ 108.40	€ 160,00	¥ 1,642.60
RMS10X	10X	0.25	18mm	10.5mm	39mm	$ 364.00	£ 229.30	€ 338,50	¥ 3,476.20
RMS20X	20X	0.40	9mm	1.2mm	48.5mm	$ 422.00	£ 265.90	€ 392,50	¥ 4,030.10
RMS40X	40X	0.65	4.5mm	0.56mm	49mm	$ 764.00	£ 481.30	€ 710,50	¥ 7,296.20

UV MicroSpot Focusing Objectives

Broadband AR Coatings for Maximum Versatility

The all-refractive UV Achromatic MicroSpot Focusing Objectives made by OFR, a division of Thorlabs, are designed for use with UV excimer lasers and other ultraviolet sources. The lens elements comprising the objectives are made from the highest quality, lowest absorption excimer grade fused silica and CaF_2 available. These lenses have broadband AR coatings and are ideal for use in multi-wavelength applications like UV fluorescence spectroscopy or confocal microscopy.

Features
- Air-Spaced Design
- Achromatic UV Lens Elements
- RMS Threaded
- Infinite Conjugate



COATING DESIGNATION	SPECTRAL RANGE	DAMAGE THRESHOLD (20ns PULSES @ 20Hz)	MAX REFLECTIVITY PER SURFACE
UVB	240-360nm	50MW/cm^2	1.5%
NUV	325-500nm	50MW/cm^2	1.0%

M	Magnification	**NA**	Numerical Aperture
WD	Working Distance	**TFS**	Theoretical Focal Spot Size
EFL	Effective Focal Length	**EA**	Entrance Aperture

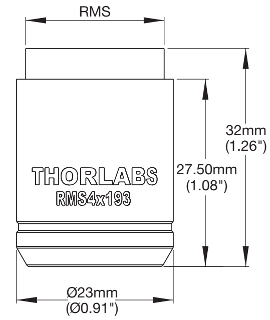
ITEM #	COATING	$	£	€	RMB	WD	EFL	NA	TFS[1]	EA	L	DESIGN SPECTRUM
LMU-3X-UVB	UVB	$ 1,095.00	£ 689.90	€ 1.018,40	¥ 10,457.30	49mm	60mm	0.08	5µm	10mm	26mm	193-450nm
LMU-3X-NUV	NUV	$ 1,095.00	£ 689.90	€ 1.018,40	¥ 10,457.30	49mm	60mm	0.08	5µm	10mm	26mm	193-450nm
LMU-5X-UVB	UVB	$ 1,095.00	£ 689.90	€ 1.018,40	¥ 10,457.30	35mm	40mm	0.13	3µm	10mm	24mm	193-450nm
LMU-5X-NUV	NUV	$ 1,095.00	£ 689.90	€ 1.018,40	¥ 10,457.30	35mm	40mm	0.13	3µm	10mm	24mm	193-450nm
LMU-10X-UVB	UVB	$ 1,675.00	£ 1,055.30	€ 1.557,80	¥ 15,996.30	15mm	20mm	0.25	2µm	10mm	32mm	193-450nm
LMU-10X-NUV	NUV	$ 1,675.00	£ 1,055.30	€ 1.557,80	¥ 15,996.30	15mm	20mm	0.25	2µm	10mm	32mm	193-450nm
LMU-15X-UVB	UVB	$ 1,825.00	£ 1,149.80	€ 1.697,30	¥ 17,428.80	8.5mm	13mm	0.32	1µm	8.5mm	36mm	193-450nm
LMU-15X-NUV	NUV	$ 1,825.00	£ 1,149.80	€ 1.697,30	¥ 17,428.80	8.5mm	13mm	0.32	1µm	8.5mm	36mm	193-450nm
LMU-20X-UVB	UVB	$ 2,095.00	£ 1,319.90	€ 1.948,40	¥ 20,007.30	4mm	10mm	0.40	1µm	8mm	35mm	193-450nm
LMU-20X-NUV	NUV	$ 2,095.00	£ 1,319.90	€ 1.948,40	¥ 20,007.30	4mm	10mm	0.40	1µm	8mm	35mm	193-450nm
LMU-39X-NUV	NUV	$ 1,825.00	£ 1,149.80	€ 1.697,30	¥ 17,428.80	2mm	5mm	0.50	1µm	5mm	34mm	325-650nm
LMU-40X-UVB	UVB	$ 2,200.00	£ 1,386.00	€ 2.046,00	¥ 21,010.00	1mm	5mm	0.50	1µm	5mm	34mm	193-450nm
LMU-40X-NUV	NUV	$ 2,200.00	£ 1,386.00	€ 2.046,00	¥ 21,010.00	1mm	5mm	0.50	1µm	5mm	34mm	193-450nm

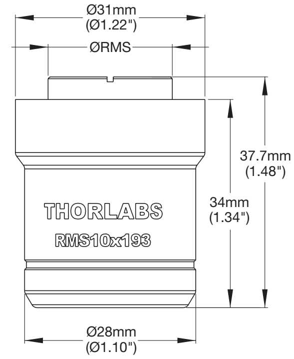
[1] The theoretical focal spot size is calculated assuming that the entrance aperture is filled and the beam profile is Gaussian.

UV Focusing Objectives, RMS Series

The RMS series of focusing objectives has now been extended to include two infinity corrected objectives designed to provide diffraction-limited performance at 193nm. The objectives are made out of high-quality, certified Excimer-Grade fused silica with a transmission >99.5%/cm @193nm. The optical elements in the UV focusing objectives are air-spaced so that they are suitable for use with high-power UV lasers. The lenses have a large entrance aperture to ensure that the laser beam is not clipped and a long working distance so that ablated material is not deposited on the front lens surface.

RMS4X193





ITEM #	MAGNIFICATION	NA	EFL	WD	ENTRANCE APERTURE[1]	$	£	€	RMB
RMS4X193	3.7X	0.11	42mm	24mm	10mm	$ 980.00	£ 617.40	€ 911,40	¥ 9,359.00
RMS10X193	10X	0.24	17.8mm	14.3mm	9mm	$ 1,600.00	£ 1,008.00	€ 1.488,00	¥ 15,280.00

[1] Maximum beam diameter for diffraction-limited performance.

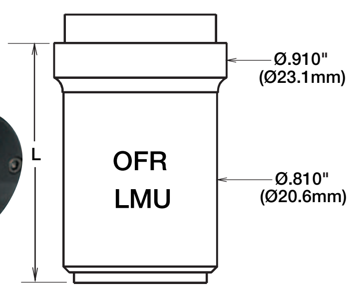
UV MicroSpot Focusing Objectives

Narrowband AR Coatings for High-Power Industrial Applications

The all-refractive UV Achromatic MicroSpot Focusing Objectives made by OFR, a division of Thorlabs, are designed for use with high-power, UV excimer lasers and other ultraviolet sources. The lens elements comprising the objectives are made from the highest quality, lowest-absorption, excimer-grade fused silica and CaF_2 available. The MicroSpot lenses with the narrow band AR coatings are specifically designed for high-power industrial applications such as micromachining, microlithography, laser scribing, and photoablation.

Features

- Air-Spaced Design
- Achromatic UV Lens Elements
- RMS Threaded
- Infinite Conjugate



COATING DESIGNATION	SPECTRAL RANGE	DAMAGE THRESHOLD (20ns PULSES @ 20Hz)	MAX REFLECTIVITY PER SURFACE
193	192-194nm	100MW/cm²	1.5%
248	240-260nm	200MW/cm²	0.5%
266	255-280nm	500MW/cm²	0.35%
351	340-370nm	500MW/cm²	0.25%

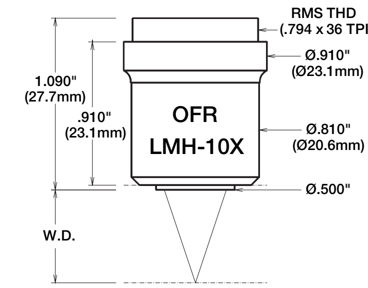
M	Magnification	**NA**	Numerical Aperture
WD	Working Distance	**TFS**	Theoretical Focal Spot Size
EFL	Effective Focal Length	**EA**	Entrance Aperture

ITEM #	COATING	$	£	€	RMB	WD	EFL	NA	TFS[1]	EA	L
LMU-3X-193	193	$ 1,195.00	£ 752.90	€ 1.111,40	¥ 11,412.30	49mm	60mm	0.08	5µm	10mm	26mm
LMU-3X-248	248	$ 1,095.00	£ 689.90	€ 1.018,40	¥ 10,457.30	49mm	60mm	0.08	5µm	10mm	26mm
LMU-3X-266	266	$ 1,095.00	£ 689.90	€ 1.018,40	¥ 10,457.30	49mm	60mm	0.08	5µm	10mm	26mm
LMU-3X-351	351/354	$ 1,095.00	£ 689.90	€ 1.018,40	¥ 10,457.30	49mm	60mm	0.08	5µm	10mm	26mm
LMU-10X-193	193	$ 1,775.00	£ 1,118.30	€ 1.650,80	¥ 16,951.30	15mm	20mm	0.25	2µm	10mm	32mm
LMU-10X-248	248	$ 1,675.00	£ 1,055.30	€ 1.557,80	¥ 15,996.30	15mm	20mm	0.25	2µm	10mm	32mm
LMU-10X-266	266	$ 1,675.00	£ 1,055.30	€ 1.557,80	¥ 15,996.30	15mm	20mm	0.25	2µm	10mm	32mm
LMU-10X-351	351/354	$ 1,675.00	£ 1,055.30	€ 1.557,80	¥ 15,996.30	15mm	20mm	0.25	2µm	10mm	32mm
LMU-15X-193	193	$ 1,925.00	£ 1,212.80	€ 1.790,30	¥ 18,383.80	8.5mm	13mm	0.32	1µm	8.5mm	36mm
LMU-15X-248	248	$ 1,825.00	£ 1,149.80	€ 1.697,30	¥ 17,428.80	8.5mm	13mm	0.32	1µm	8.5mm	36mm
LMU-15X-266	266	$ 1,825.00	£ 1,149.80	€ 1.697,30	¥ 17,428.80	8.5mm	13mm	0.32	1µm	8.5mm	36mm
LMU-15X-351	351/354	$ 1,825.00	£ 1,149.80	€ 1.697,30	¥ 17,428.80	8.5mm	13mm	0.32	1µm	8.5mm	36mm

[1] The theoretical focal spot size is calculated assuming that the entrance aperture is filled and the beam profile is Gaussian.

High-Power MicroSpot Focusing Objectives

The High-Power Nd:YAG MicroSpot Focusing Objectives made by OFR, a division of Thorlabs, are designed to transmit the high-power, 1064nm radiation emitted by industrial Nd:YAG lasers and to focus it to a diffraction-limited spot. The transmission window of the objective extends from 250nm to 1.6µm, and the objective is capable of producing a nearly diffraction-limited spot throughout the visible and near-infrared spectral range.

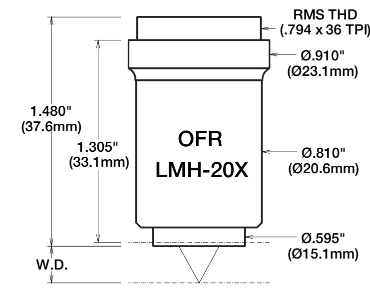


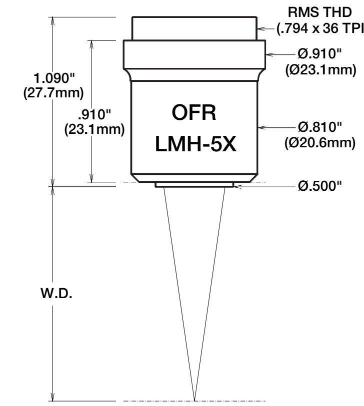
Specifications

- Lens Element Material: Fused Silica
- Energy Throughput: >96-98% Within Design Spectral Region
- Damage Threshold: 500MW/cm² for 20ns Pulses @ 20Hz (532 or 1064nm)

Convert RMS Threading to SM1 Threading with the SM1A3 Adapter

See Page 215





M	Magnification	NA	Numerical Aperture
WD	Working Distance	EA	Entrance Aperture
EFL	Effective Focal Length		

ITEM#	METRIC ITEM#	COATING RANGE	WD	EFL (mm)	NA	EA	DAMAGE THRESHOLD	$	£	€	RMB
LMH-5X-532	LMH-5X-532/M	532nm	35mm	40mm	0.13	10mm	500MW/cm² The power rating is based on a 20ns pulse with a 20Hz repetition rate at either 532nm or 1064nm.	$ 790.00	£ 497.70	€ 734,70	¥ 7,544.50
LMH-5X-1064	LMH-5X-1064/M	1064nm	35mm	40mm	0.13	10mm		$ 790.00	£ 497.70	€ 734,70	¥ 7,544.50
LMH-10X-532	LMH-10X-532/M	532nm	15mm	20mm	0.25	10mm		$ 975.00	£ 614.30	€ 906,80	¥ 9,311.30
LMH-10X-1064	LMH-10X-1064/M	1064nm	15mm	20mm	0.25	10mm		$ 975.00	£ 614.30	€ 906,80	¥ 9,311.30
LMH-20X-532	LMH-20X-532/M	532nm	6mm	10mm	0.40	8mm		$1,445.00	£ 910.40	€ 1.343,90	¥ 13,799.80
LMH-20X-1064	LMH-20X-1064/M	1064nm	6mm	10mm	0.40	8mm		$1,445.00	£ 910.40	€ 1.343,90	¥ 13,799.80

Fast Steering Mirror

Fast Steering Mirror and Controller

Applications

- Laser Scanning
- Laser Beam Stabilization
- Image Stabilization
- Laser Tracking
- Laser Pointing
- Field Tested in Our ASOM Microscope (See Page 582)

Thorlabs' FSM3 Fast Steering Mirror offers a high precision, closed-loop solution for single and multi-axis optical applications. The FSM3 is ideally suited for general purpose beam steering, auto-alignment systems, remote beam control, and image capture applications. The Fast Steering Mirror is incorporated into Thorlabs' new Adaptive Scanning Optical Microscope (ASOM) System, which provides the ability to view large areas of a sample in a high resolution image without sacrificing image resolution.

The FSM3 incorporates four voice coils into a compact flexure bearing support frame for fast and stable positioning. The FSM3 mirror contains an internal continuous position sensitive photodetector (PSD) to provide accurate and repeatable positioning of the mirror.

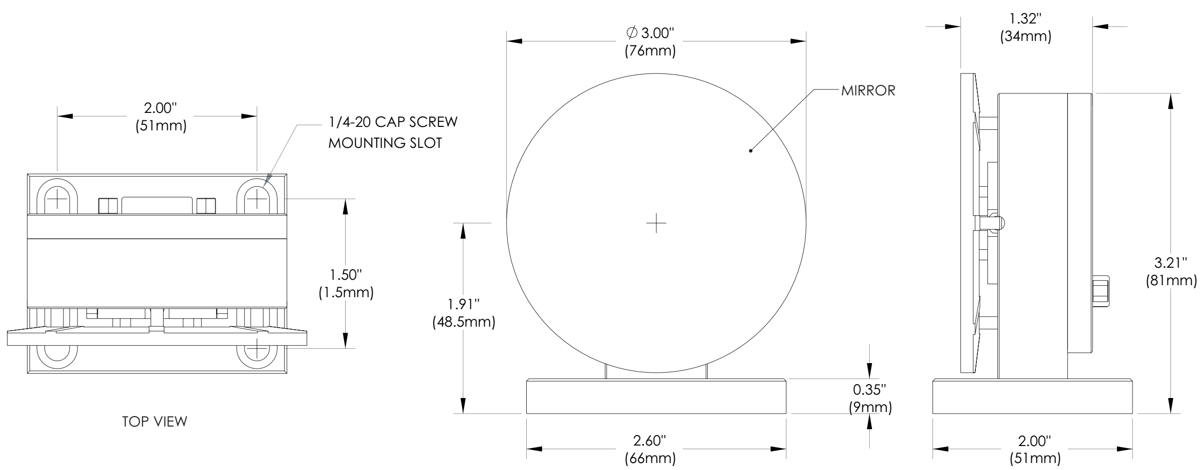
Features

- 3" Mirror Diameter
- ±6° Angular Adjustment Range
- 30ms Position Response (5mrad)
- 2-Axis X and Y Rotation
- 2 Driver Channels
- Flexure Bearing mirror suspension
- Automatic PID Feedback
- USB 2.0 Interface
- Remote or Local Control

The FSM3 controller allows the user to position the mirror locally using the front panel keypad, as well as remotely via an USB 2.0 interface. The front panel of the FSM3 controller also features an LED that reveals the Enable status of the voice coils as well as an interactive LCD display that provides access to the control parameters X and Y coordinates and local/remote mode. An internal closed-loop feedback is built into the FSM3 mirror head to provide precise and repeatable position sensing with reference to the default zero position.

When using the USB 2.0 interface of the FSM3, control is possible through the included FSM3 ActiveX™ Application Program or by using a simple command line interface from any terminal window.

When used with our PDQS1, four-channel quadrant detector system, the FSM3 can quickly auto-align and lock to the center of the detector for high-speed laser beam control and stabilization.

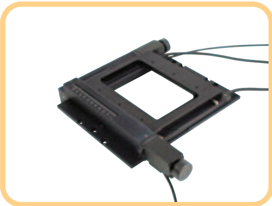


The Fast Steering Mirror Used in the ASOM System

ITEM#	$	£	€	RMB	DESCRIPTION
FSM3	CALL	CALL	CALL	CALL	3" Fast Steering Mirror System

Microscopy Tools Selection Guide

Pages 624-645




Motorized Stages and Controllers

- Motorized XY Stages
- Motor Controllers
- Closed-Loop Piezo Controller

See Pages 626-631


LED Light Sources and Drivers

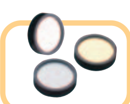
- LED Driver
- Mounted LEDs
- Collimated LEDs

See Pages 632-635

Photomultiplier Module

- Photomultiplier Module

See Page 637



Motorized Filter Wheels and Filters

- Fast Changing Filter Wheel
- Dichroic Filter Wheel
- Fluorescence Filters

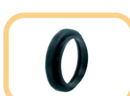
See Pages 638-641


Rotating Turret Mount

- Turret Mount
- Microscope Objectives

See Page 642





Thread Adapters

- Olympus to SM Series
- RMS to SM1 Series
- M25-0.75 to SM1 Series

See Page 643

Microscopy Science Desks™

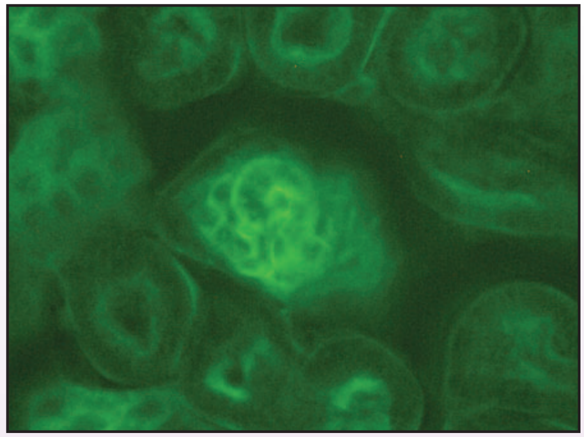
- Configurable Workstation
- IsoPlate Vibration Damping

See Pages 644-645

Thorlabs is excited to offer a vastly expanded line of components that were developed specifically for use in microscopy applications. The new components were designed to be compatible with the lens tube and cage system components as well as many of the other popular optomechanical components built by Thorlabs. As a result, the components can not only be used to enhance the design and functionality of an existing microscope but also to construct a complete microscope imaging system that is tailored to the particular requirements of a given experiment. In addition, due to the interchangeable nature of the components, it is possible to reconfigure easily or to upgrade the capabilities of an imaging system constructed using Thorlabs components.

To overcome compatibility issues with the different industry standards created by companies such as Nikon, Zeiss, and Olympus, Thorlabs has expanded its line of adapters in an effort to simplify the customization of the imaging systems produced by these companies.

Mouse Kidney



A wide field of view image of a slice of mouse kidney dyed with Alexa 488 is shown. The image was taken with the microscope pictured on the next page. This microscope was constructed in its entirety from parts available for purchase from Thorlabs. A detailed list of parts for the Inverted Wide-Field Epifluorescence Microscope is available on the Thorlabs web site (www.thorlabs.com).

Dear Colleagues and Customers,

The Microscopy and Laser Imaging section of the catalog is a result of the symbiotic relationship Thorlabs tries to cultivate with the community of innovative researchers, engineers, and manufacturers that we serve in the photonics industry. In this section of the catalog, you will find numerous new and redesigned components and even entire imaging systems that were the direct result of feedback and collaborations with our colleagues and customers.

Thorlabs is eager to participate in licensing agreements with industrial researchers in order to expedite the advancement of scientific instrumentation. For example, our ASOM imaging system, which received the 2007 PhAST/Laser Focus Innovation Award, is a result of a licensing agreement with university researchers at RPI. With a collaboration in place, it took less than a year to reengineer every major component of the imaging system. Most notably, a new, high-performance scan lens was designed and manufactured and a new algorithm was created to control the adaptive optic in the ASOM system. Our diverse personal base, experience, and resources allow Thorlabs to develop solutions to the myriad of issues that arise during the development of innovative new systems. This not only reduces the time a system spends in the development stage but also improves the quality and functionality of the final product.

Please contact us with suggestions, whether it is a new product or a change to an existing product. The feedback we have received in the past has been instrumental in shaping the growth of Thorlabs, and we hope that you will continue to be a stimulus for future changes that will help us to serve you.

Sincerely,

Alex Cable
President of Thorlabs

Pictured below is a wide-field epifluorescence microscope that was constructed entirely from parts sold by Thorlabs and demonstrates the versatility of our microscope related optomechanical components. The microscope is constructed from one possible stage, a sample illumination system, and an imaging system, all assembled in the same configuration that is used by many major microscope manufacturers.

Sample Stage

The sample stage consists of the MAX200 XY stepper motor stage (for coarse adjustments) combined with the SCXYZ100 XYZ piezo stage (for fine adjustments). The XY stepper motor stage allows the sample to be positioned precisely to within 5µm over a 3" range in the X direction and a 2" range in the Y direction. The SCXYZ100 piezo stage, which is designed to mount directly to the MAX200 stage, allows the sample position to be controlled with a resolution of 25nm in the X, Y, and Z directions. The travel range for the X and Y directions is 100µm whereas it is 80µm in the Z direction.

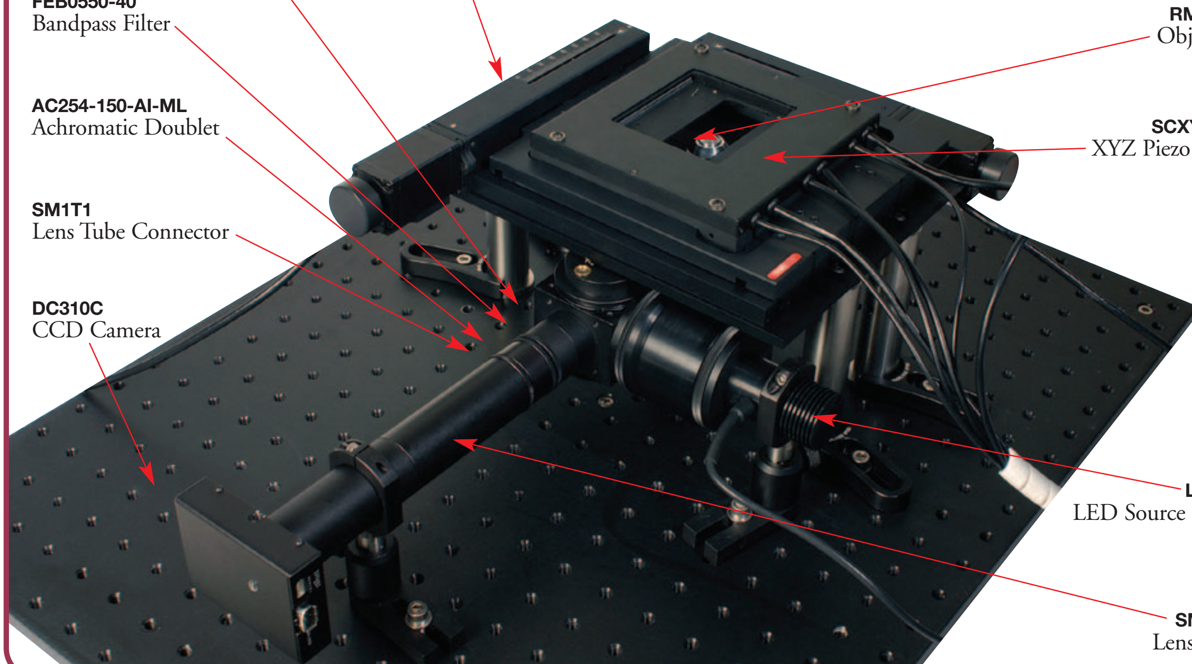
Sample Illumination

The sample is illuminated using an LEDC1, which is a collimated blue LED source (other emission wavelengths are also available). For this particular microscope, the LEDC1 is held in a SM1RC; however, the same LED is available in housings that are compatible with many standard commercial microscopes. The light from the LED is directed along the imaging optical path using a dichroic beamsplitter mounted inside of a C4W cage cube with a B3C base. The cage cube could be replaced easily with a FW104 dichroic filter wheel, which can hold up to six filters.

Imaging System

The imaging system consists of an objective lens, a steering mirror, an emission filter, a tube lens, and a CCD camera. The RMS20X objective lens, which is an infinity corrected objective, collects the light emitted from the sample. Next, the steering mirror, which is obscured from view in the picture below, directs the collected emission light toward a CCD detector. The emission light is then transmitted through the dichroic filter. The transmitted emission light travels through an emission filter (FEB0550-40), which further eliminates unwanted light, and then a tube lens (AC254-150-A1-ML) is used to image the light onto the DC310C CCD camera. The entire optical path is enclosed inside of lens tubes to minimize the effects of stray and scattered light.

Inverted Wide-Field Epifluorescence Microscope



Motorized XY Stages

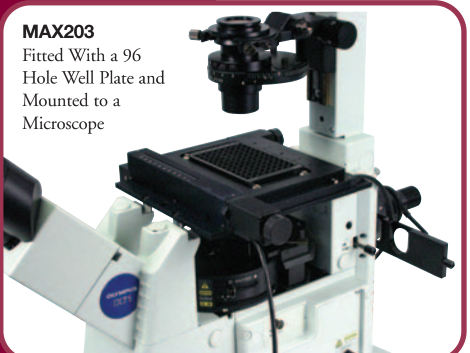
Features

- Compact, Low Profile Design
- Compatible With Zeiss Axiovert 200, Olympus IX, and Nikon TE2000 (Using the MAX200A1, Sold Separately) Microscopes
- Uses High-Precision Leadscrew & Bearings
- Encoded and Non-Encoded Versions Available
- Simplified Mounting to Microscope
- Easy Integration of Accessories

MAX203

The MAX200 Series of dual-axis motorized stages and accessories have been specifically designed for automated XY positioning of microscopy samples. The stages can easily hold standard microscope slides, 35mm diameter Petri dishes, or the standard well-plate footprint (e.g. 96 hole well plates). Thorlabs also provides convenient mounting options for attaching these stages to many commercially available microscopes from Olympus, Nikon, and Zeiss as well as third-party or custom-designed imaging systems.

The MAX200 series of stages offers a long travel range (>70mm) and fast, accurate, and repeatable positioning of the region of interest with submicron resolution.



MAX203
Fitted With a 96 Hole Well Plate and Mounted to a Microscope

The MAX200 (standard) and MAX201 (encoded) stages have been designed to be compatible with our MicroScan series of piezo scanning stages. The MicroScan family consists of three stages, offering high-speed, piezo-actuated motion in Z, XY, and XYZ (see page 630 for more details). The MAX202 (standard) and MAX203 (encoded) have longer travel ranges and are compatible with standard 96 hole well plates. Accessory plates are available for all stages to allow the positioning of standard microscope slides and Petri dishes, which can be found on the next page.

All stages fit the Olympus IX71 microscopes with no additional hardware. Mounting adapters for the Nikon TE2000 may be purchased separately (part number MAX200A1 – see page 627), while the Zeiss Axiovert 200 microscopes are only compatible with the MAX202 and MAX203 stages.

All MAX200 series stages are driven by high-resolution microstepping stepper motors. The positional accuracy of the MAX200 and MAX202 stages is determined by microstep counting, which results in a positional accuracy of 5µm and a unidirectional repeatability of one micron. The MAX201 and MAX203 stages include a precision glass scale linear encoder that improves the linearity, accuracy, and precision to one micron.

To drive the MAX200 series, we recommend the apt™ BCS102 precision 2-channel controller. This controller operates with both open- and closed-loop versions of the MAX200 stages (see page 628 for more details).

However, if the MAX200 stage is to be used in conjunction with a MicroScan series piezo stage, we offer a hybrid controller (BPS103) that contains 2 channels of stepper motor control and a channel of piezoelectric control (see page 629). This makes a particularly convenient solution for motorized XY control and piezoelectric Z control.

Specifications

- **Travel:** MAX200 & MAX201: 3"x 2" (75mm x 50mm)
  MAX202 & MAX203: 2.75" X 4.13" (70 x 105mm)
- **Maximum Speed:** 10mm/s
- **Resolution:** 40nm
- **Accuracy:** MAX200 & MAX202: 5µm
  MAX201 & MAX203: 1µm
- **Unidirectional Repeatability:** 1µm
- **Repeatability:** 1µm in X and Y (Typical Error Over Full Travel)
- **Load Capacity:** 5kg
- **Straightness of Travel:** 400arcsec (0.1°) Maximum Pitch Error for Both Axes; 100arcsec (0.025°) Maximum Yaw Error for Both Axes

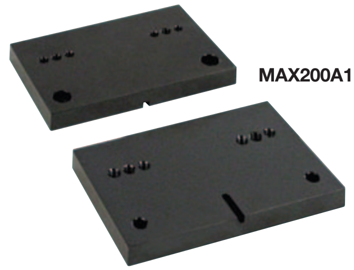
MAX200
With MAX200P1 Microscope Sample Holder

Save by Buying the Stage and Controller Together (See Page 628)

ITEM#	$	£	€	RMB	DESCRIPTION
MAX200	$ 3,391.50	£ 2,136.60	€ 3.154,10	¥ 32,388.80	3"x 2" (75mm x 50mm) Travel XY Stage
MAX201	$ 6,460.00	£ 4,069.80	€ 6.007,80	¥ 61,693.00	3"x 2" (75mm x 50mm) Travel Encoded XY Stage
MAX202	$ 3,950.00	£ 2,488.50	€ 3.673,50	¥ 37,722.50	2.75" X 4.13" (70 x 105mm) Travel XY Stage
MAX203	$ 7,950.00	£ 5,008.50	€ 7.393,50	¥ 75,922.50	2.75" X 4.13" (70 x 105mm) Travel Encoded XY Stage

Mounting Adapter for MAX200 Series Stages for Nikon TE2000 Microscope

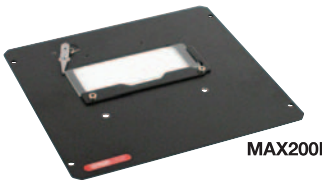
Features
- Pre-Drilled Tap Holes for Easy Mounting of Motorized Sample Stage
- Mounts MAX200 Stages to the Nikon TE2000 Microscope



MAX200A1

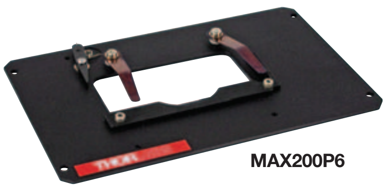
The MAX200A1 is an adapter for easy mounting of our MAX200 series stages to the Nikon TE2000 microscope.

ITEM#	$	£	€	RMB	DESCRIPTION
MAX200A1	$ 125.00	£ 78.80	€ 116,30	¥ 1,193.80	Mounting Adapter for Nikon TE2000 Microscope



MAX200P1

MAX200P1 Features
- Compatible With the MAX200 and MAX201 Motorized Stages
- Fits Standard Microscope Slides and Ø35mm Petri Dishes
- Clip Holder to Secure Samples
- Size: 128mm x 136mm x 2mm (5.04" x 5.35" x 0.08")



MAX200P6

MAX200P6 Features
- Compatible With the MAX202 and MAX203 Motorized Stages
- Fits Standard Microscope Slides and Ø35mm Petri Dishes
- Clip Holder to Secure Samples
- Size: 86mm x 143mm x 2mm (3.4" x 5.65" x 0.08")

MAX200P2

MAX200P2 Features
- Compatible With the MAX200 and MAX201 Motorized Stages
- Accepts Standard Microscope Slides and Ø35mm Petri Dishes
- Tapped Holes: 63 x 1/4"-20 (M6) and 86 #4-40 (M3) Tapped Holes, 1/2" (12.5mm) Pitch
- Size: 129mm x 137mm x 6mm (5.1" x 5.4" x 0.24")

MAX200P3

MAX200P3 Features
- Compatible With the MAX200 and MAX201 Motorized Stages
- Accepts Standard Microscope Slides
- Compatible With Ø35mm Petri Dishes
- Magnetic Steel Platform
- Size: 129 x 137 x 2mm (5.1" x 5.4" x 0.08")

ITEM#	$	£	€	RMB	DESCRIPTION	COMPATIBILITY
MAX200P1	$ 200.00	£ 126.00	€ 186,00	¥ 1,910.00	Microscope Slide Platform for MAX200 & MAX201 Stages	MAX200 & MAX201
MAX200P6	$ 200.00	£ 126.00	€ 186,00	¥ 1,910.00	Microscope Slide Platform for MAX202 & MAX203 Stages	MAX202 & MAX203
MAX200P2	$ 125.00	£ 78.80	€ 116,30	¥ 1,193.80	Tapped Hole Microscope Sample Platform (1/4-20 & 4-40)	MAX200 & MAX201
MAX200P2/M	$ 125.00	£ 78.80	€ 116,30	¥ 1,193.80	Tapped Hole Microscope Sample Platform (M6 & M3)	MAX200 & MAX201
MAX200P3	$ 95.00	£ 59.90	€ 88,40	¥ 907.30	Magnetic Microscope Sample Platform	MAX200 & MAX201

Positioning Component Compatibility

POSITIONING STAGE	OPTIONAL PIEZO STAGES	COMPATIBLE SAMPLE TYPE/PLATFORM	Olympus IX71	Zeiss Axiovert 200	Nikon TE2000
MAX202	N/A	**Well Plate:** No Platform Required **Slide or Petri Dish Holder:** MAX200P6	yes	yes	yes*
MAX203	N/A	**Well Plate:** No Platform Required **Slide or Petri Dish Holder:** MAX200P6	yes	yes	yes*
MAX200 MAX201	MicroScan Series Stages SCXY100, SCZ100, SCXYZ100 (See Page 630)	**Slide or Petri Dish Holders:** MAX200P1 Sample Holder MAX200P2 Threaded Sample Platform MAX200P3 Magnetic Sample Platform	yes	no	yes*

* The MAX200A1 is needed to mount the MAX200 series XY stepper stages to the Nikon TE2000 microscope.

Benchtop apt™ Stepper Motor Controllers

See our full line of motor controllers, starting on page 347.

BSC102
50W Drive Capability

Features

- Two-Channel Control
- Supports Two Phase Bipolar Steppers up to 50W
- Differential Encoder Feedback (QEP Inputs) for Closed-Loop Positioning
- Auto-Configure Function for All Thorlabs' Stages
- USB 2.0 Interface Plus Multiaxis Expansion
- Motor Control I/O Port (Jogging, Interlocks)
- Full Software GUI Control Suite
- High-Resolution Microstepping Control (For Very Fine Positioning Applications)
- Stable and Predictable Low-Speed Operation (For Velocity Sensitive Applications)
- ActiveX® Programming Interfaces
- Seamless Software Integration With apt™ Family

Introduction

The BSC102 apt™ stepper-motor controller is designed to provide two channels of stepper motor control, with or without encoder feedback. These units are capable of delivering 48V/50W peak powers (25W average) and are ideally suited for driving the stepper motor actuators incorporated in the MAX200 series stages.

The controllers combine the latest high-speed digital signal processors (DSP) with low-noise analog electronics and ActiveX® software technology for effortless motion control. A full suite of software support tools is included. The intuitive graphical instrument panel allows immediate control and visualization of the operation of the controller. See pages 380-382 for a full description of the apt™ system software.

Driver Functionality

The apt™ stepper unit operation is fully configurable (parameterized) with key settings readily available through graphical interface panels. Motor step resolution and leadscrew pitch can be set for a particular motor/actuator combination, phase currents can be limited to suitable peak powers, and the limit switch configuration can be customized through a flexible set of limit switch logic settings.

Moreover, relative and absolute moves can be initiated with move profiles that are set using velocity profile parameters. Similarly, home sequences have a full set of associated parameters that can be adjusted for a particular stage or actuator. For simplicity, the apt™ software will automatically load pre-configured settings for any Thorlabs' stepper motor or stepper motor stage. For non-Thorlabs stepper motors, the apt™ software allows the users to set each parameter manually via the graphical interface.

Full Support for Encoder Feedback The apt™ stepper unit also supports encoder feedback through dedicated quadrature-encoded pulse (QEP) inputs, one for each channel of operation. A built-in algorithm can be enabled to allow the stepper system to reach and maintain an encoded position through an iterative move sequence.

Specifications

- **Input/Output:**
  - **Motor Drive Channel (15-Pin D-Type Female)**
    - 2-Phase Bipolar Motor Drive Output
    - Differential Quadrature-Encoder Interface
    - Forward, Reverse Limit Switch Inputs
  - **Motor Control (15-Pin D-Type Female)**
    - Jog Forward/Back
    - Enable/Disable Interlock
    - (Future Use)
    - User Logic Outputs/Inputs
    - Single-Ended Analog Input (0-10 Volt)
    - Trigger In/Out
- **Motor Power:** Up to 48V/50W (peak)
- **Resolution:**
  - 128 Microsteps per Full Step
  - 200 Step Motor – 25,600 Microsteps per Revolution
- **Input Power Requirements:**
  - Voltage: 85-264VAC
  - Power: 200W (100W BSC101)
  - Fuse: 3.15A
- **Motor Speeds:** Up to 600RPM (for 200 Full Step Motor)
- **Encoder Feedback Bandwidth:** 500,000 counts/sec
- **Housing Dimensions (W x D x H):**
  - BSC101: 152 x 244 x 104mm (6" x 9.6" x 4.1")
  - BSC102, BSC103: 240 x 360 x 133mm (9.5" x 14.2" x 5.2")
- **Instrument Weight:**
  - BSC101: 3.18kg (7lbs)
  - BSC102, BSC103: 6.7kg (14.75lbs)

ITEM#	$	£	€	RMB	DESCRIPTION
BSC102	$ 2,203.20	£ 1,388.00	€ 2.049,00	¥ 21,040.60	Two-Channel apt™ Stepper Motor Controller
MAX200B	$ 5,322.70	£ 3,353.30	€ 4.950,10	¥ 50,831.80	Kit Including MAX200 and BSC102
MAX201B	$ 8,228.70	£ 5,184.10	€ 7.652,70	¥ 78,584.10	Kit Including MAX201 and BSC102
MAX202B	$ 5,950.00	£ 3,748.50	€ 5.533,50	¥ 56,822.50	Kit Including MAX203 and BSC102
MAX203B	$ 9,950.00	£ 6,268.50	€ 9.253,50	¥ 95,022.50	Kit Including MAX204 and BSC102

Combined Piezo and Stepper Controller

BPS103

This new three-channel apt™ controller features two channels of stepper motor control and one channel of piezo control. The controller is ideal for controlling the MAX200 Series XY stepper motor stage and a Z-axis nanopositioning piezoelectric stage.

Features

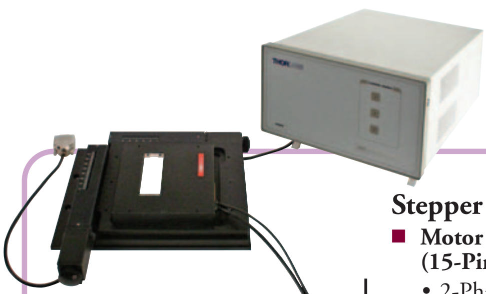
- Integrated Software Support for Other apt™ Controllers
- Software Control Suite Supports LabVIEW
- Intuitive Software Graphical Control Panels
- Extensive ActiveX® Programming Interfaces

Stepper Controller Features

- High-Resolution Microstepping Control for Very Fine Positioning Applications
- Stable and Predictable Low-Speed Operation (for Velocity-Sensitive Applications)
- Differential Encoder Feedback (QEP Inputs) for Closed-Loop Positioning
- Auto-Configure Function for All Thorlabs Stages
- Motor Control I/O Port (Jogging, Interlocks)

Piezo Controller Features

- High Power – 75V, 500mA Continuous
- Closed-Loop PID Position via Strain Gauge Feedback Circuit
- High-Resolution Position Control for Very Fine Positioning Applications
- Voltage Ramp/Waveform Generation Capability for Scanning Applications
- High Bandwidth (10kHz) Piezo Positioning
- Auto-Configure Function for Thorlabs' Ident-Equipped Piezo Actuators



BPS103 Controller with MAX200 XY stage and SCZ100 piezo scanning stage

Controller Specifications

- **User I/O Connector (15-Pin D-Type Female):**
  - 4 User-Logic Inputs: Open Collector
  - 4 User-Logic Outputs: Open Collector
- **Input Power Requirements:**
  - Voltage: 85-264 VAC
  - Power: 200W (peak)
  - Fuse: 3.15A
- **General:**
  - Housing Dimensions (W x D x H): 240 x 360 x 133mm (9.5 x 14.2 x 5.2")
  - Weight: 6.7kg (14.75lbs)

Stepper Controller Specifications

- **Motor Drive Connector (15-Pin D-Type Female):**
  - 2-Phase Bipolar Motor Drive Output
  - Differential Quadrature Encoder (QEP) Input
  - Forward, Reverse Limit Switch Inputs
  - User 5V (With Ground) 100mA Max.
- **I/O Control Connector (Keyed 15-Pin D-Type Female)**
  - Jog Forward/Back Input: TTL
  - User Logic Input: TTL
  - User Logic Output: Open Collector
  - Analog Input: Single Ended 0-10V
  - User 5V (With Ground) 100mA Max
  - Trigger Input/Output: TTL
- **Motor Resolution:**
  - 128 Microsteps per Full Step
  - For 200 Step Motor: 25,600 Microsteps/Rev
  - For 24 Step Motor: 3072 Microsteps/Rev
- **Motor Drive Voltage:** 48V
- **Motor Drive Power:** Up to 50W(peak)/25W(ave)
- **Motor Speeds:** Up to 600RPM (200 full step motor)
- **Encoder Feedback Bandwidth:** 500,000 counts/sec

Piezo Controller Specifications

- **Piezoelectric Output (SMC Male)**
  - Voltage (Software Control): 0V to 75 V DC
  - Voltage (External Input): -10V to 90V DC
  - Current: 500mA Max. Continuous
  - Stability: 100ppm over 24 Hours (After 30 Mins. Warm up Time)
  - Noise: <3mV RMS
  - Typical Piezo Capacitance: 1µF to 10µF
  - Bandwidth: 10kHz (1µF Load, 1V p-p)
- **Position Feedback (9-Pin D-type Female)**
  - Feedback Transducer Type: Strain Gauge
  - Detection Method: AC Bridge (18kHz Excitation)
  - Typical Resolution: 5nm (for 20µm Actuator, e.g. PAZ020)
  - Auto-Configure: Identification Resistance in Actuator
- **User Input/Output (15-Pin D-Type Female)**
  - 4 Digital Inputs: TTL Levels
  - 4 Digital Outputs: Open Collector
  - Trigger Input/Output: TTL
  - Trigger Input Functionality: Triggered Voltage Ramps/Waveforms
  - Trigger Output Functionality: Trigger Generation During Voltage Ramp Output
  - User 5V (With Ground) 250mA Max.

ITEM#	$	£	€	RMB	DESCRIPTION
BPS103	$ 3,561.00	£ 2,243.40	€ 3.311,70	¥ 34,007.60	apt™ 3-Channel Benchtop (2x Stepper + 1x Piezo) Controller

MicroScan Series of Microscopy Scanning Stages

These low-profile, piezo-driven stages have been designed specifically for microscopy applications. For visualizing specimens or samples on standard microscope slides (1" x 3"), the Thorlabs MicroScan piezo scanning stages provide a convenient mechanism for precise position control of a sample with submicron repeatability. When combined with a piezo controller, this system is all that is needed for complete computer control of positioning with active location feedback. For scanning purposes, this means the user can scan a sample, add reagents, wait for a physiological process, and then rescan and be assured that the same point in the sample is being imaged. The closed-loop active feedback ensures correct positioning with a resolution on the order of 25 to 30nm (see specifications) and submicron repeatability. These stages provide active feedback to compensate for thermal changes and other factors that might lead to stage drift. These stages are ideal for laser scanning microscopy setups for 2D or 3D data collection.

MicrosScan Family Features

- Compact, Low Profile
- Accurate, Reliable Sample Positioning
- Compatible With a Wide Range of Microscope Slides and Petri Dishes
- Fully Compatible With MAX200 and MAX201 XY Long Travel Stages
- Allows Fast Optical Scanning
- Closed-Loop Control Based on Strain Gauge Feedback

There are three models of piezo stages available: vertical scanning (SCZ100), 2D scanning (SCXY100), or 3D scanning (SCXYZ100). Alternatively, these piezo stages may be used with the MAX200 series (see page 626) long travel stages to yield precise sample positioning over a long range of travel.

These stages are compatible with our piezo controllers: BPC202, BPC203, or BPC103 (see pages 364-370 for the full line of piezo controllers).

SCZ100

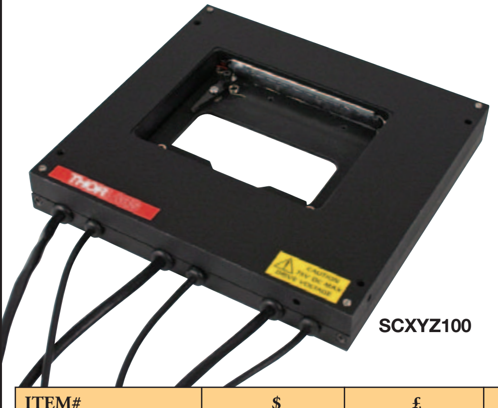
SCZ100 Specifications

- **Travel:** 100µm (Z)
- **Positioning Resolution:** 25nm
- **Feedback:** Strain Gauges
- **Load Capacity:** 100g Centered on Top Surface
- **Resonant Frequency:** >70Hz
- **Drive Voltage:** 75V
- **Dimensions:** 123mm x 134mm x 22mm (4.8" x 5.3" x 0.9")
- **Weight:** 0.5kg Nominal

SCXY100

SCXY100 Specifications

- **Travel:** 100µm (x, y)
- **Max Load:** 100g (Centered on Top Surface)
- **Positioning Resolution:** 25nm
- **Resonant Frequency:** >150Hz Allows High-Speed Scanning
- **Thermal Stability:** 1µm/°C
- **Feedback:** Strain Gauges
- **Weight:** 0.25kg Nominal
- **Recommended Controllers:** BPC201, BPC202, or PBC203



SCXYZ100

SCXYZ100 Specifications

- **X- and Y-Axis Travel:** 100µm
- **Z-Axis Travel:** 80µm
- **Positioning Resolution:** 25nm
- **Feedback:** Strain Gauges
- **Load Capacity:** 100g on Top Surface
- **Stiffness:** 0.4N/µm in X or Y
- **Resonant Frequency:** >70Hz
- **Max Voltage:** 75V

ITEM#	$	£	€	RMB	DESCRIPTION
SCZ100	$ 3,230.00	£ 2,034.90	€ 3.003,90	¥ 30,846.50	MicroScan 100µm Z Scanning Stage
SCXY100	$ 4,709.00	£ 2,966.70	€ 4.379,40	¥ 44,971.00	MicroScan XY Microscopy Scanning Stage
SCXYZ100	$ 6,120.00	£ 3,855.60	€ 5.691,60	¥ 58,446.00	MicroScan XYZ Microscopy Scanning Stage
SCXYZ100B	$ 9,990.00	£ 6,293.70	€ 9.290,70	¥ 95,404.50	Kit Including SCXYZ100 and BPC203

Benchtop apt™ Closed-Loop Piezo Controller

BPC203

Features

- Front-Panel Controls
- Two Control Channels
- High Current Output
- Closed-Loop PID Position Via Strain Gauge Feedback Circuit
- Quiet High-Resolution Position Control (for Very Fine Positioning Applications)
- Voltage Ramp/Waveform Generation Capability (for Scanning Applications)
- High Bandwidth (10kHz) Piezo Positioning (Open Loop)
- Auto-Configure Function for Thorlabs' Ident-Equipped Piezo Actuators
- Full Software Control Suite Supplied
- Extensive ActiveX® Programming Interfaces

The BPC203 three-channel apt™ piezo controller is ideal for use with the MicroScan SCXYZ stage (see page 630). Flexible software settings make this unit highly configurable, and therefore, it is suitable for driving a wide range of piezo elements in third-party products. A waveform generation capability, combined with triggering outputs, makes this unit particularly well-suited for piezo scanning applications.

Controls are located on the front face of the unit to allow manual adjustment of the piezo position using the digitally encoded adjustment pot. The display is easy to read and can be set to show either applied voltage or position in microns. Open- or closed-loop control and zeroing of the piezo can also be selected from the front panel.

By coupling these features with user-friendly apt™ software the user is able to get up and running in a short period of time – for example, all relevant operating parameters are set automatically for Thorlabs' piezo actuator products. Advanced custom motion control applications and sequences are also possible using the extensive ActiveX® programming environment, which is described in more detail on pages 381-382.

It is often convenient to make adjustments to the piezo output while closely watching the device being positioned, which can prove difficult when using the front panel keys or a remote PC.

To allow this kind of use, Thorlabs has developed the PHS101 handset, which enables the piezos to be positioned remotely from the controller and PC (i.e. without using the front panel buttons, GUI, or software method calls). It is supplied with a 3m (9.75') cable.

PHS101

Specifications (Per Channel)

- **Piezoelectric Output (SMC Male)**
- **Voltage (Software Control):** 0V to 75VDC
- **Voltage (External Input):** -10V to 90VDC
- **Current:** 500mA Max. Continuous
- **Stability:** 100ppm Over 24 Hours (After 30 Mins. Warm up Time)
- **Noise:** <3mV RMS
- **Typical Piezo Capacitance:** 1-10µF
- **Bandwidth:** 10kHz (1µF Load, 1V p-p)
- **Position Feedback (9-Pin D-Type Female):**
  - Feedback Transducer Type: Strain Gauge
  - Detection Method: AC Bridge (18kHz Excitation)
  - Typical Resolution: 5nm (for 20µm Actuator, e.g. PAZ005)
  - Auto-Configure: Identification Resistance in Actuator
- **User Input/Output (15-Pin D-Type Female)**
  - 4 Digital Inputs: TTL Levels
  - 4 Digital Outputs: Open Collector
  - Trigger Input/Output: TTL
  - Trigger Input Functionality: Triggered Voltage Ramps/Waveforms
  - Trigger Output Functionality: Trigger Generation During Voltage Ramp Output
  - User 5V (With Ground): 250mA Max.
- **USB Port**
  - Version 1.1
- **Power Input**
  - Voltage: 85-264VAC
  - Power: 100W
  - Fuse: 2A
- **Housing Dimensions:** (W x D x H) 152 x 244 x 104mm (6" x 9.6" x 4.1")
- **Weight:** 3.18kg (7lbs)

ITEM#	$	£	€	RMB	DESCRIPTION
BPC203	$ 4,550.00	£ 2,866.50	€ 4.231,50	¥ 43,452.50	3-Channel Benchtop Closed-Loop Piezo Controller/Driver
PHS101	$ 270.00	£ 170.10	€ 251,10	¥ 2,578.50	Remote Handset for BPC Series Benchtop Piezo Controllers

700mA, 7V Benchtop LED Driver

LEDD1
Benchtop LED Driver
With Cable Included

Features

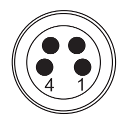
- Easy-to-Use LED Driver
- Constant Current and Pulsed Current Modes
- Adjustable Brightness
- Pulsewidth and Frequency Controllable via External 0-5V Signal
- Compact T-Cube Footprint

The LEDD1 T-Cube is a variable intensity LED driver for the most recent generation of high-power, low-compliance voltage LEDs (such as those manufactured by Philips/Lumiled). This provides a lightsource for brightfield or fluoresence microscopy when combined driver with Thorlabs' collimated LEDs. The brightness is controlled via a potentiometer, which regulates the current flowing to the LED, up to a maximum of 700mA. The power output of the LED can be controlled by one of two selectable modes: continuous (CW) or externally modulated (pulsed). The CW mode is ideal for imaging with CCD cameras or photodiodes. Pulsed mode operation is controlled from user-generated 0-5V signals. These signals can be used to strobe the LED or to control the average power by way of pulsewidth modulation.

Specifications

- **Output Current:** 700mA
- **Maximum Flash Frequency:** 10kHz
- **Minimum Strobe Pulse Width:** 50µs
- **Strobe Turn-On / Turn-Off Time:** <25µs
- **Power Supply:** 9-32VDC / 1A
- **Operating Temperature:** -0 to +40°C
- **Storage Temperature:** -40 to +70°C
- **Size:** 60 x 60 x 47mm (2.4" x 2.4" x 1.8")

The LEDD1 T-Cube requires an external power supply. The TPS001 is suitable for powering a single LEDD1 unit while the TCH002 can power up to eight T-Cube units.



Pin	Description
1	LED +ve
2	LED -ve
3	N/C
4	N/C

NOTE: LEDD1 Driver Requires a Power Supply (Sold Separately)

ITEM#	$	£	€	RMB	DESCRIPTION
LEDD1	$ 249.00	£ 156.90	€ 231,60	¥ 2,378.00	T-Cube LED Driver
TPS001	$ 25.50	£ 16.10	€ 23,70	¥ 243.50	15V Power Supply Unit for a Single T-Cube
TCH002	$ 765.00	£ 482.00	€ 711,50	¥ 7,305.80	T-Cube™ Controller Hub and Power Supply Unit

New T-Cube Laser Source

- Compact T-Cube Laser Source: 4.8" x 2.4" x 1.8" (120 x 60 x 47mm)
- Two Models: 635nm or 1550nm
- Safety Interlock

See Page 567

TLS001

Mounted LEDs

Features

- Up to 700mW Continuous Power Output
- Compact, Energy Efficient, Longer Lifetime Than Traditional Light Source
- Output can be Modulated (With Suitable Cntroller)
- Compatible With LEDD1 Driver
- Compatible With Thorlabs' SM1 Lens Tube and 30mm Cage Systems

LED Colors Available

- Royal Blue (455nm)
- Blue (470nm)
- Cyan (505nm)
- Green (530nm)
- White

Connector Diagram

Pin	Description
1	LED +ve
2	LED -ve
3	Not Connected
4	Not Connected

LEDs offer several advantages over traditional light sources, including better stability, longer life (up to 100k hours), lower risk (no glass bulbs to break), and lower energy use than traditional light sources. These mounted LEDs are compatible with all the SM1 construction mechanics and optical components.

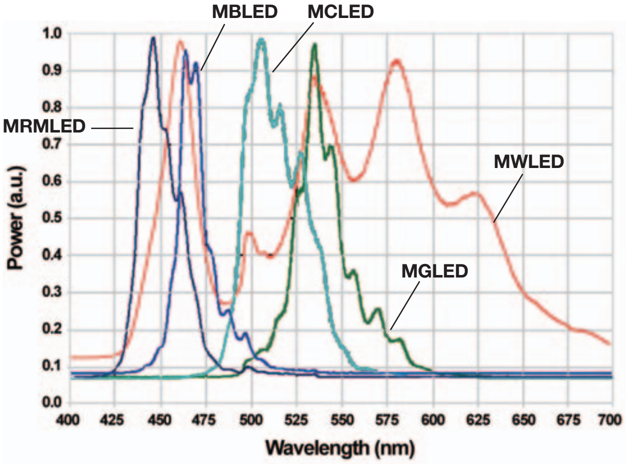
Each high-power LED is mounted to the end of a heatsink, which has an internal SM1 thread and accepts SM1 lens tubes directly. A low-voltage, high-current power cable is connected to the LED and has a feedout from the side of the heatsink tube. The end of the power cable is terminated in a circular 4-pin, M8 plug. This plug is compatible with the socket of the Thorlabs LED controller (LEDD1) and with other industry standard connections. See page 632 for details of the LEDD1 LED Driver and associated power supply.

Specifications

COLOR	DOMINANT WAVELENGTH (nm)	LOWER WAVELENGTH LIMIT (nm)	UPPER WAVELENGTH LIMIT (nm)	POWER (mW)	LUMINUS FLUX (lm)
Royal Blue	455	430	470	730	200
Blue	470	450	500	625	50
Cyan	505	485	450	420	160
Green	530	510	585	275	160
White	N/A	435	675	500	120

Notes

1. Measurements made on typical LEDs at room temperature, using Thorlabs' calibrated spectrometer SP1-USB, our calibrated integrating sphere IS236A, and our power meter head PM30.
2. Upper and lower wavelengths of emission taken at threshold of 10% of peak power.



Graph of Typical Emissions Spectra

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.
Operation Voltage	V_{op}	5.43V	6.84V	8.31V
DC Forward Current	I_{fw}	–	–	700mA
Peak Pulsed Forward Current	$I_{fw\text{-}pls}$	–	–	1000mA
Temperature Coefficient of Dominant Wavelength	$d\lambda_p/dT_j$	–	0.04nm/°C	–
Viewing Angle	–	–	150°	–
Dynamic Resistance	R_D	–	1.0	–
Operating Temperature	T_{op}	-40°C	–	120°C
Storage Temperature	T_{st}	-40°C	–	120°C

ITEM#	$	£	€	RMB	DESCRIPTION
MBLED	$ 127.50	£ 80.30	€ 118,60	¥ 1,217.60	Uncollimated Blue LED, 470nm
MCLED	$ 127.50	£ 80.30	€ 118,60	¥ 1,217.60	Uncollimated Cyan LED, 506nm
MGLED	$ 127.50	£ 80.30	€ 118,60	¥ 1,217.60	Uncollimated Green LED, 530nm
MRMLED	$ 127.50	£ 80.30	€ 118,60	¥ 1,217.60	Uncollimated Royal Blue LED, 455nm
MWLED	$ 127.50	£ 80.30	€ 118,60	¥ 1,217.60	Uncollimated White Light LED

Collimated LEDs

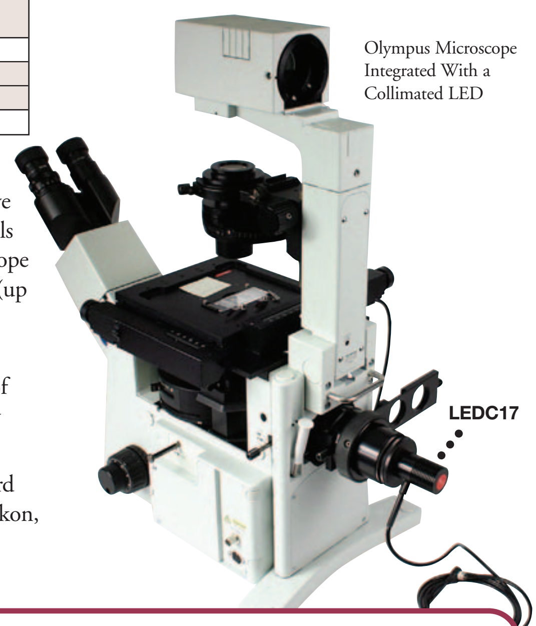

LEDC1

Features

- Compact, Energy Efficient
- Longer Lifetime Than Traditional Light Sources
- Adjustable Focus
- Easily Interchangeable LEDs
- Output can be Modulated (With Suitable Controller)
- Compatible With LEDD1 Controller
- In-Stock Models Fit Many Commercially Available Microscopes
- Custom Designs for Other Microscope Setups (Contact Tech Support)

Characteristics Common to All LEDs (Ta=25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.
Operation Voltage	V_{op}	5.43V	6.84V	8.31V
DC Forward Current	I_{fw}	–	–	700mA
Peak pulsed Forward Current	$I_{fw\text{-}pls}$	–	–	1000mA
Temprature Coefficient of Dominant Wavelength	$d\lambda_p/dT_j$	–	0.04nm/°C	–
Dynamic Resistance	R_D	–	1.0	–
Divergence	–	–	5°	–
Operating Temprature	T_{op}	-40°C	–	120°C
Storage Temprature	T_{st}	-40°C	–	120°C



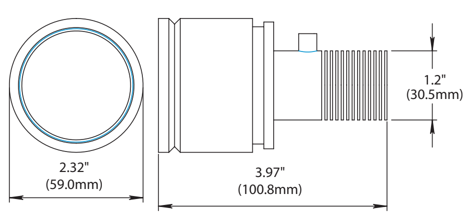
Olympus Microscope Integrated With a Collimated LED

Developments in Light Emitting Diodes (LEDs) have resulted in devices that have significantly more power than halogen lamps and gas discharge lamps. Power levels are now high enough for LEDs to be a practical alternative to traditional microscope light sources. LEDs offer several advantages, including better stability, longer life (up to 100k hours), lower risk (no glass bulbs to break), and lower energy use than traditional light sources.

We offer several different colors of high-power LEDs, including white. The rear of the collimator accepts our mounted LEDs, which can be quickly interchanged by unscrewing the LED housing and replacing it with an alternative LED.

Thorlabs' collimated LED assemblies are designed for integration into the standard and epi-illumination ports found on most commercial microscopes, including Nikon, Zeiss, Leica, and Olympus. (LEDD1 controller sold separately, see page 632.)

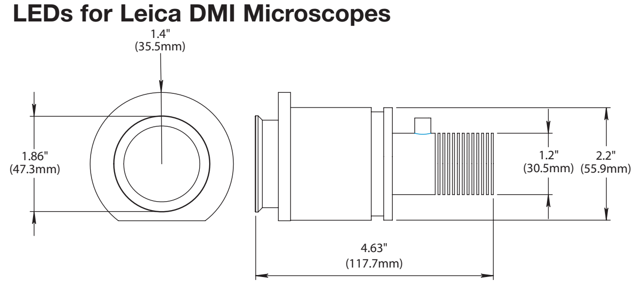
LEDs for Olympus IX & BX Microscopes



Specifications

Part Number	Wavelength (Color)	Total Power	Beam Diameter	Beam Area	Lens Efficiency	Total Beam Power
LEDC1	455nm	730mW	50mm	1963.49mm²	0.6	438mW
LEDC5	470nm	625mW	50mm	1963.49mm²	0.6	375mW
LEDC9	505nm	420mW	50mm	1963.49mm²	0.6	252mW
LEDC13	530nm	275mW	50mm	1963.49mm²	0.6	165mW
LEDC17	White	500mW	50mm	1963.49mm²	0.6	300mW

LEDs for Leica DMI Microscopes



Specifications

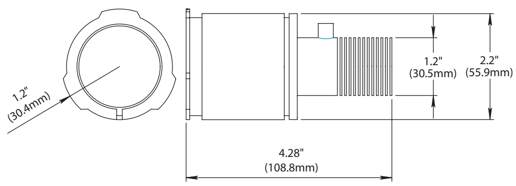
Part Number	Wavelength (Color)	Total Power	Beam Diameter	Beam Area	Lens Efficiency	Total Beam Power
LEDC2	455nm	730mW	37mm	1075.21mm²	0.6	240mW
LEDC6	470nm	625mW	37mm	1075.21mm²	0.6	205mW
LEDC10	505nm	420mW	37mm	1075.21mm²	0.6	138mW
LEDC14	530nm	275mW	37mm	1075.21mm²	0.6	90mW
LEDC18	White	500mW	37mm	1075.21mm²	0.6	164mW

Collimated LEDs

LEDs for Nikon F Mount Microscopes

Specifications

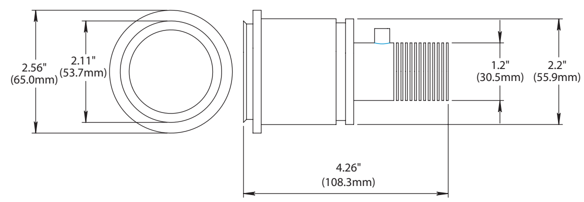
Part Number	Wavelength (Color)	Total Power	Beam Diameter	Beam Area	Lens Efficiency	Total Beam Power
LEDC3	455nm	730mW	43mm	1452.20mm²	0.6	323.94mW
LEDC7	470nm	625mW	43mm	1452.20mm²	0.6	277.35mW
LEDC11	505nm	420mW	43mm	1452.20mm²	0.6	186.38mW
LEDC15	530nm	275mW	43mm	1452.20mm²	0.6	122.03mW
LEDC19	White	500mW	43mm	1452.20mm²	0.6	221.88mW



LEDs for Zeis Axioskop Microscopes

Specifications

Part Number	Wavelength (Color)	Total Power	Beam Diameter	Beam Area	Lens Efficiency	Total Beam Power
LEDC4	455nm	730mW	44mm	1520.53mm²	0.6	339mW
LEDC8	470nm	625mW	44mm	1520.53mm²	0.6	290mW
LEDC12	505nm	420mW	44mm	1520.53mm²	0.6	195mW
LEDC16	530nm	275mW	44mm	1520.53mm²	0.6	128mW
LEDC20	White	500mW	44mm	1520.53mm²	0.6	232mW



ITEM#	$	£	€	RMB	DESCRIPTION
LEDC1	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Royal Blue LED (455nm) for Olympus BX & IX Microscopes
LEDC2	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Royal Blue (455nm) LED for Leica DMI Microscopes
LEDC3	$ 374.00	£ 235.60	€ 347,80	¥ 3,571.70	Collimated Royal Blue (455nm) LED for Nikon F Microscopes
LEDC4	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Royal Blue (455nm) LED for Zeiss Axioskop Microscopes
LEDC5	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Blue LED (470nm) for Olympus BX & IX Microscopes
LEDC6	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Blue (470nm) LED for Leica DMI Microscopes
LEDC7	$ 374.00	£ 235.60	€ 347,80	¥ 3,571.70	Collimated Blue (470nm) LED for Nikon F Microscopes
LEDC8	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Blue LED (470nm) for Zeiss Axioskop Microscope
LEDC9	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Cyan (505nm) LED for Olympus Microscope
LEDC10	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Cyan (505nm) LED for Leica DMI Microscope
LEDC11	$ 374.00	£ 235.60	€ 347,80	¥ 3,571.70	Collimated Cyan (505nm) LED for Nikon F Microscope
LEDC12	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Cyan (505nm) LED for Zeiss Axioskop
LEDC13	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Green (530nm) LED for Olympus BX & IX Microscopes
LEDC14	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Green (530nm) LED for Leica DMI Microscope
LEDC15	$ 374.00	£ 235.60	€ 347,80	¥ 3,571.70	Collimated Green (530nm) LED for Nikon F Microscope
LEDC16	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated Green (530nm) LED for Zeiss Axioskop Microscope
LEDC17	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated White LED for Olympus BX & IX Microscopes
LEDC18	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated White LED for Leica DMI Microscope
LEDC19	$ 374.00	£ 235.60	€ 347,80	¥ 3,571.70	Collimated White LED for Nikon F Microscope
LEDC20	$ 331.50	£ 208.80	€ 308,30	¥ 3,165.80	Collimated White LED for Zeiss Axioskop Microscope

Light Detection

Cooled EMCCD Camera

Features

- High-Resolution B/W EM Vacuum-Cooled CCD Camera
- Real-Time Video Imaging With Single Photon Detection Capability
- User-Friendly Software and External Triggering for Versatile Imaging Options

Our new high-resolution, real-time CCD camera is designed for extremely sensitive imaging applications. The high signal amplification enables single photon detection. The low dark current allows for long exposure times, thus leading to an excellent signal-to-noise ratio. These features, combined with user-friendly software for data collection, make this an ideal high-sensitivity camera for low-light biological applications.

Applications

- Multiphoton Microscopy
- FRET/FLIM
- Uncaging and Ca^{++} Imaging
- Low Level Fluorescent Protein Expression

NEW

Thorlabs' new cooled CCD camera is ideal for single photon detection. Please check details on our website at www.thorlabs.com.

New High-Resolution CCD Cameras

Features

- 1024 x 768 or 1280 x 1024 Pixel Resolution
- Color and B&W Versions Available
- 1/3" or 1/2" Image Sensor With Square Pixels
- 30fps or 15fps (Full Frame Mode)

DCU223M

See Page 964

Slim Photodiode Sensor Heads

- For Optical Power Measurements in Narrow Places
- Wavelength Range: 400-1800nm
- Slim Design: 5mm Thickness at Detector Side

When combined with an optical power meter (see page 946), this sensor allows the user to measure the optical power hitting a sample in microscopy or imaging setups. The slim design fits easily under an objective turret.

See Page 949

See Other Power Meter Options on Page 946

Photomultiplier Module

Features

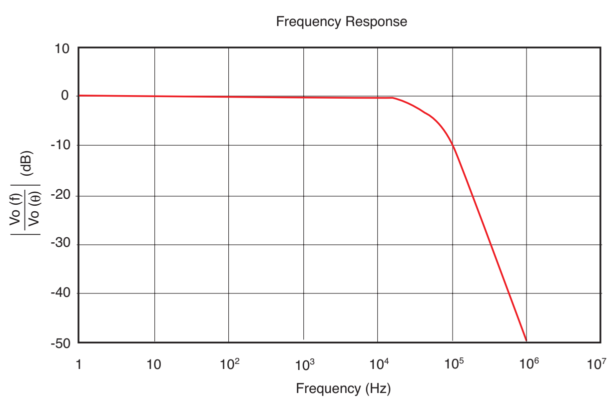
- Stable Performance
- Wide Bandwidth
- Easy to Use
- Electromagnetic Shielding

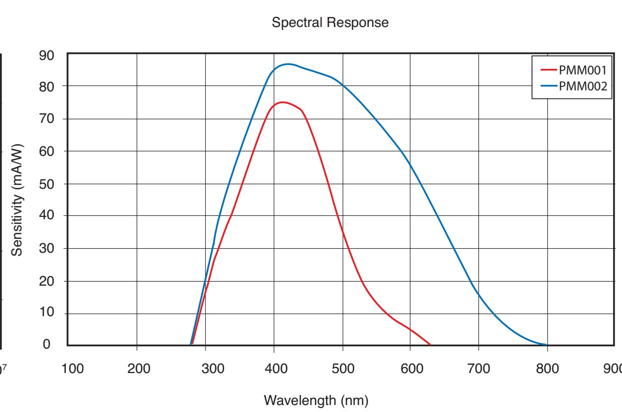
Photomultiplier Tubes (PMTs) are sensitive, high-gain devices that provide a current output that is proportional to the incident light. When light is incident on the photocathode of a PMT, electrons are ejected from the surface. The electrons then cascade down a chain of dynodes, each at a successively higher electric potential, until reaching the anode. As the electrons cascade, they free electrons from each dynode surface, resulting in a measurable output current upon reaching the anode.

Thorlabs now offers two photomultiplier modules, each with a different PMT. The PMT in the PMM01 module has the advantage of a smaller dark current and a larger gain; however, the PMT in the PMM02 module can be used to detect light over a greater spectral range. Both modules come with a high-gain, dc coupled, transimpedance amplifier. Since these modules are compatible with our 30mm cage systems and SM1 lens tubes, imaging optics and filters can be easily mounted and centered on the photocathode of the PMT. Stray and scattered light can be prevented from reaching the detector by utilizing lens tubes to mount the optical components; this is particularly advantageous when working with weak or noisy signals.

Specifications

- **Photocathode Type:**
  - PMM01: Bialkali
  - PMM02: S20
- **Photocathode Active Diameter:** 22mm
- **Wavelength Range:**
  - PMM01: 280-630nm
  - PMM02: 280-850nm
- **Peak Responsivity at 400nm:** 80mA/W Typical
- **Amplifier Conversion Gain:** 1V/µA
- **Sensitivity at 400nm, pmt g = 105:** 8V/nW
- **Dark Current:**
  - PMM01: 0.3-3nA
  - PMM02: 0.5-5nA
- **Gain (Max.):**
  - PMM01: 7.1 x 10^6
  - PMM02: 3.1 x 10^6
- **Bandwidth, 6dB:** 0-20kHz
- **Amplifier Noise:** 2mV RMS Typical
- **Amplifier Offset:** 1mV Typical
- **Output Rise and Fall Times:** 15µs
- **Output Impedance:** 50Ω
- **Output Signal:**
  - Unterminated: 0-10V
  - Terminated Into 50Ω: 0-5V
- **Power Input:**
  - +12V (+12 to +15): 40mA
  - -12V (-12 to -15): 10mA
- **HV Control Sensitivity:** -1000V/V
- **HV Control Volts:** 1.8V Max.
- **Warm Up Time:** <10s
- **Operating Temperature:** 5°C to 55°C
- **Storage Temperature:** -40°C to 55°C
- **Weight:** 200g





ITEM#	$	£	€	RMB	DESCRIPTION
PMM01	$ 2,100.00	£ 1,323.00	€ 1.953,00	¥ 20,055.00	Photomultiplier Module, 280-630nm
PMM02	$ 2,400.00	£ 1,512.00	€ 2.232,00	¥ 22,920.00	Photomultiplier Module, 280-850nm

Motorized Fast-Change Filter Wheel

FW103

Thorlabs FW103 motorized fast-change filter wheel is designed to hold our fluorescence filters (see page 640) and our general purpose laser line and bandpass filters (pages 842-843). It is also compatible with our SM1 and 30mm cage system for customized imaging designs.

Designed to hold up to six Ø1" round filters, this wheel allows for rapid filter changing in multi-wavelength fluorescent imaging applications that require sequential wavelength observation. The FW103 wheel is designed with four tapped holes for easy mounting and has a removable cover that allows changing of filters without removing the wheel from the optical path.

Choosing the proper electronic controller for the FW103 depends on the required speed of operation. The BSC101 apt™ stepper motor controller (page 366) should be used for <60ms switching between adjacent filters, and the TST001 T-Cube stepper motor controller (page 350) should be used for 250ms switching. Both controllers provide the ability to fine tune filter wheel speed for optimum performance.

Features

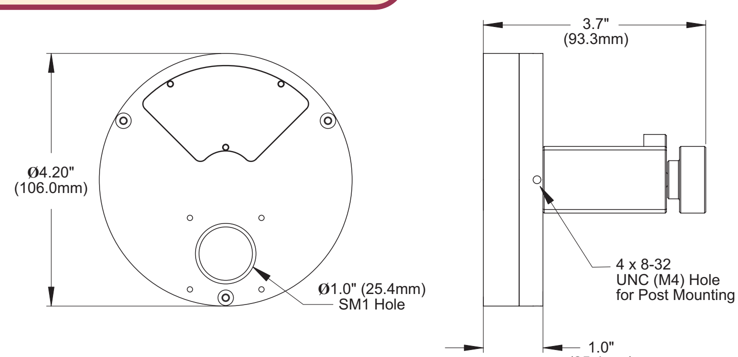
- Holds Up to Six 25mm (1") Diameter Filters
- Light Tight Design
- Easy Integration With the Thorlabs SM1 Lens Tube System, 30mm Cage System, and Post Mounting System
- Easy Access to Add/Remove Filters From the Wheel
- Hall Effect Sensor to Indicate Successful Completion of Position Change

FW103

Shown With Thorlabs' Cage Systems Accessories (Sold Separately, See Page 227)

Specifications

- 55-60ms Transition Time Between Adjacent Filters Using BSC101 Controller
- 250ms Transition Time Between Adjacent Filters Using TST001 T-Cube Controller



ITEM#	METRIC ITEM #	$	£	€	RMB	DESCRIPTION
FW103	FW103/M	$ 350.00	£ 220.50	€ 325,50	¥ 3,342.50	Fast Motorized Transition Filter Wheel
FW103H	FW103H/M	$ 1,650.00	£ 1,039.50	€ 1.534,50	¥ 15,757.50	Fast Motorized Filter Wheel and High-Current BSC101 Controller
FW103S	FW103S/M	$ 850.00	£ 535.50	€ 790,50	¥ 8,117.50	Motorized Filter Wheel and Low-Current TST001 Controller

Dichroic Filter Wheel

Similar to the FW103 High-Speed Filter Wheel on the previous page, the FW104 is designed to hold multiple optical filters for microscopy applications but is specifically designed to hold rectangular dichroic mirrors (see page 846). This fast filter wheel allows the user to assemble a custom fluorescence imaging system easily. Fitting SM1 lens tubes or 30mm cage systems to the input and output ports of the filter wheel housing allows rapid prototype setup of custom imaging systems. This dichroic wheel is easily mounted using the four tapped holes (either 8-32 UNC or M4).

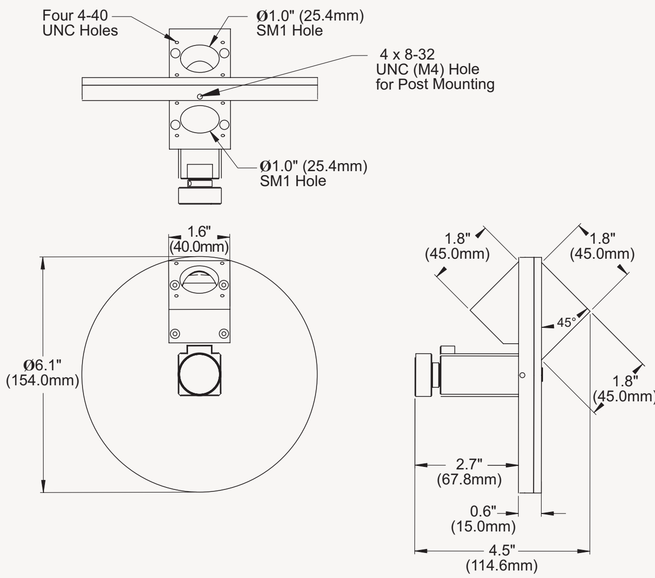
Up to six 1" x 1.4" (25mm x 35.5mm) filters (e.g. Thorlabs FDF Series – see page 641) can be fitted into the wheel, which are easily accessed through the removable cover without needing to remove the filter wheel from the optomechanical setup.

This filter wheel can be used on its own, or in conjunction with two FW103 high-speed filter wheels, to make a powerful, high-speed fluorescence filter system capable of sequentially imaging samples at different wavelengths at close to video rates.

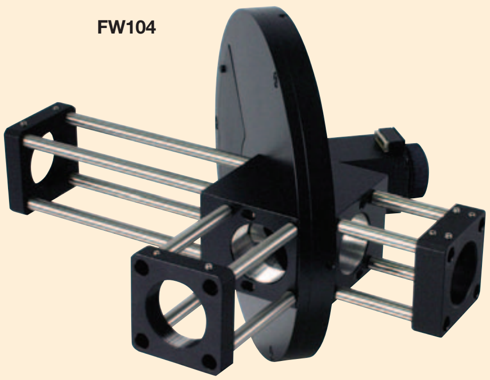
Choosing the proper electronic controller for the FW104 depends on the required speed of operation. For high-speed (50-60ms) switching between adjacent filters, the BSC101 apt™ stepper motor controller should be used (see page 366). For 250ms switching, the TST001 T-cube stepper motor controller should be used (see page 350). Both controllers provide the ability to fine tune filter wheel acceleration and speed for optimum performance. The T-cube stepper controller front panel can also be used to control the filter wheel without the need for an external PC connection.

Features

- Holds Up to Six 1" x 1.4" Planar Dichroic Mirrors
- High-Speed Operation Compatible With BSC101 Controller
- Easy Integration With Thorlabs' SM1 Lens Tube System, 30mm Cage System, and Post Mounting System
- Easy Access to Add or Remove Filters Without Removing Wheel From Setup
- Hall Effect Switches for Home & Position Indexing



FW104



Shown With Thorlabs Cage Systems Accessories (Sold Separately, See Page 227)

Specifications

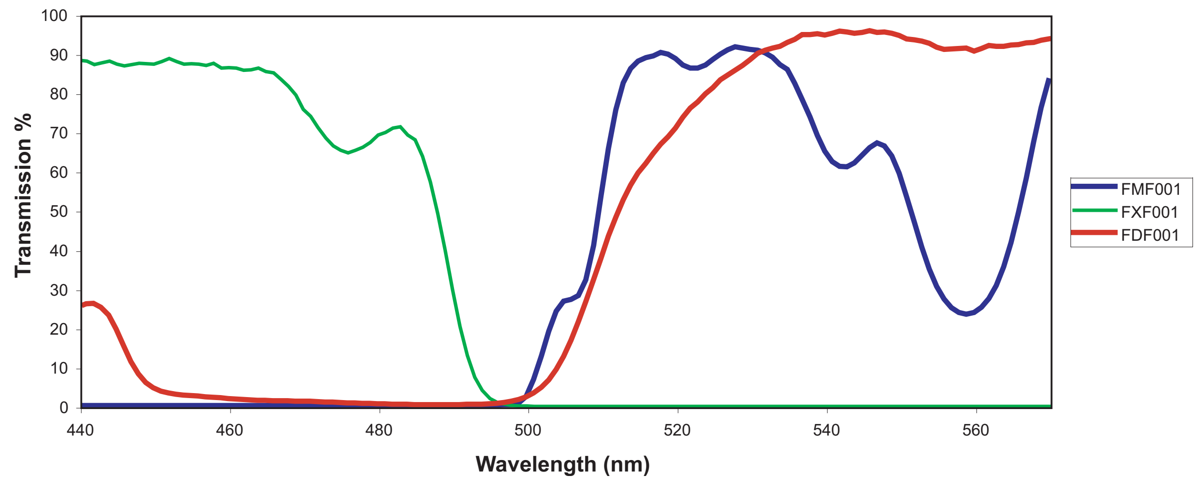
- 55-60ms Transition Time Between Adjacent Filters Using BSC101 Controller
- 250ms Transition Time Between Adjacent Filters Using TST001 T-Cube Controller

ITEM#	METRIC ITEM #	$	£	€	RMB	DESCRIPTION
FW104	FW104/M	$ 530.00	£ 333.90	€ 492,90	¥ 5,061.50	Dichroic Filter Wheel
FW104H	FW104H/M	$ 1,630.00	£ 1,026.90	€ 1.515,90	¥ 15,566.50	Dichroic Filter Wheel and High-Current BSC101 Controller
FW104S	FW104S/M	$ 1,030.00	£ 648.90	€ 957,90	¥ 9,836.50	Dichroic Filter Wheel and Low-Current TST001 Controller

Fluorescence Filters

Introduction

Thorlabs now offers a selection of filters specifically designed and manufactured for fluorescence imaging applications. Standard fluorescence imaging applications generally incorporate three different filters: an excitation filter, a dichroic mirror, and an emissions filter. Thorlabs offers these three types of filters to accommodate the key wavelength ranges for many common fluorophores (or their alternatives), including Alexa 488, Rhodamine, Cy5, Cy3, and GFP.



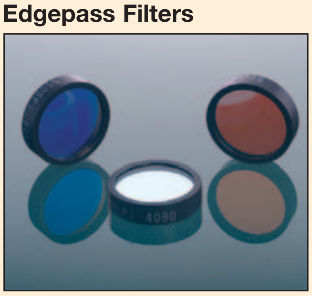
EXCITATION	ALEXA 488 (FXF001)	GFP (FXF002)	CY3 (FXF003)	RHOD (FXF005)	CY5 (FXF004)
Transmission Wavelength (>85%)(nm)	430-470	455-490	505-555	535-585	605-650
Wavelength Cutoff (<0.1%)(nm)	380-415, 500-680	400-455, 490-650	450-505, 555-700	500-535,585-750	550-605, 650-800

EMMISION	ALEXA 488 (FMF001)	GFP (FMF002)	CY3 (FMF003)	RHOD (FMF005)	CY5 (FMF004)
Transmission Wavelength (>85%)(nm)	515-535	500-540	570-620	600-655	655-720
Wavelength Cutoff (>0.1%)(nm)	430-505	400-500,540-650	450-570, 600-700	500-535,585-750	550-665, 720-800

DICHROIC	ALEXA 488 (FDF001)	GFP (FDF002)	CY3 (FDF003)	RHOD (FDF005)	CY5 (FDF004)
Transmission Wavelength (>85%)(nm)	530-610	500-650	575-700	600-750	675-720
Reflection Wavelength (>85%)(nm)	460-500	400-475	450-550	500-580	550-650

Edgepass and Bandpass Filters

Edgepass Filters



- Both Long and Short Pass Versions
- Hermetically Sealed for Humidity Protection
- Custom Filtering Available

See Page 844

Bandpass Filters

- From 340-1650nm
- <0.01% Out-of-Band Transmission
- From 1nm to 70nm Full Width Half Max. Bandpass

See Page 843

Filter Design

The excitation and emission filters are mounted in a black anodized housing while Thorlabs' dichroic filters are unmounted. These filters are manufactured to high-performance optical specifications and designed for durability. They are produced with multiple dielectric layers deposited on a high-precision glass substrate, which is ground and polished to ensure that the highest possible image quality is maintained. This manufacturing technique produces filter layers that are more dense than those obtained from electron beam deposition techniques. The dense filter layers reduce water absorption and greatly enhance durability, stability, and performance of the filter. Each filter layer is monitored during growth to ensure minimal deviation from design specification thickness, ensuring overall high-quality filter performance.

All filters conform to MIL-F-48616 for adhesion and resistance to humidity, moderate abrasion, solubility, and cleanability. They also conform to MIL-C-675 and MIL-E-12397 resistance to severe abrasion.

Fluorescence Filters

General Specifications
- 25mm Outer Diameter
- 21mm Clear Aperture
- 5mm Thick
- 20-10 Scratch-Dig

FXF Series Excitation Filters & FMF Series Emissions Filters

These fluorescent filters are specifically designed to be used in microscopy and imaging. With a selection of excitation and emissions filters for specific fluorophores, these filters, along with the fast filter wheels, allow for the construction of custom microscopy setups. Each filter is deposited on a 5mm thick round substrate and mounted in a black anodised housing. These filters provide excellent transmission of the desired excitation wavelength (>85%), with a sharp spectral cutoff and low transmission at other wavelengths (<0.1%). These filters may be mounted into our Fast Filter Wheel (FW103) to allow rapid wavelength changes (see page 638).

ITEM#	$	£	€	RMB	DESCRIPTION
FXF001	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	Alexa 488 Excitation Filter
FXF002	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	GFP Excitation Filter
FXF003	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	CY3 Excitation Filter
FXF004	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	CY5 Excitation Filter
FXF005	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	Rhodamine Excitation Filter
FMF001	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	Alexa 488 Emission Filter
FMF002	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	GFP Emission Filter
FMF003	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	CY3 Emission Filter
FMF004	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	CY5 Emission Filter
FMF005	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	Rhodamine Emission Filter

FDF Series Dichroic Filters

Thorlabs Dichroic Filters are designed to separate light of different wavelengths. With a 45° angle of incidence, they reflect excitation light and its associated back reflection while passing the longer wavelength fluorescence signal. These filters are unmounted and may be used directly with the Thorlabs Dichroic Filter Wheel (FW104) for rapid filter changing of up to six different configurations (see page 639).

General Specifications
- 25 x 36mm
- 1.1mm Thick
- 20-10 Scratch-Dig

ITEM#	$	£	€	RMB	DESCRIPTION
FDF001	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	Alexa 488 Dichroic Filter
FDF002	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	GFP Dichroic Filter
FDF003	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	CY3 Dichroic Filter
FDF004	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	CY5 Dichroic Filter
FDF005	$ 220.00	£ 138.60	€ 204,60	¥ 2,101.00	Rhodamine Dichroic Filter

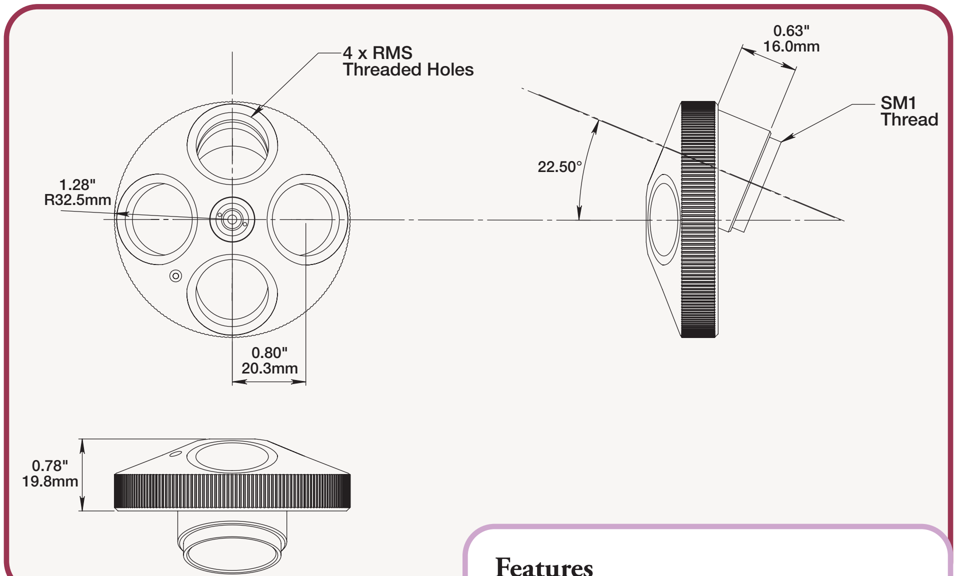
Save 10% By Ordering a Dye Filter Set:
Set includes one excitation, one emission, and one dichroic filter


ITEM#	$	£	€	RMB	DESCRIPTION
FST001	$ 594.00	£ 374.20	€ 552,40	¥ 5,672.70	Alexa 488 Filter Set (Set of 3)
FST002	$ 594.00	£ 374.20	€ 552,40	¥ 5,672.70	GFP Filter Set (Set of 3)
FST003	$ 594.00	£ 374.20	€ 552,40	¥ 5,672.70	CY3 Filter Set (Set of 3)
FST004	$ 594.00	£ 374.20	€ 552,40	¥ 5,672.70	CY5 Filter Set (Set of 3)
FST005	$ 594.00	£ 374.20	€ 552,40	¥ 5,672.70	Rhodamine Filter Set (Set of 3)

Rotating Lens Turret

OT1 LENS TURRET

OT1 Lens Turret With Microscope Objectives Fitted



Features

- RMS Threaded (0.8", 36TPI Whitworth)
- Compact Volume
- 4 Objective Lens Mounting Ports
- SM1 Lens Tube Interfaces Provided
- Aluminum Construction

This lens turret holds up to four standard microscope objective lenses and is designed to be used with an SM1 or 30mm cage setup. This turret allows easy magnification changes without adjusting the optical setup.

A detent ensures any given lens returns to the same location with high accuracy.

ITEM#	$	£	€	RMB	DESCRIPTION
OT1	$ 150.00	£ 94.50	€ 139,50	¥ 1,432.50	Objective Lens Turret for Four RMS Threaded Objectives

Microscope Objectives: Infinity Corrected

RMS10X
0.25NA
Working Distance = 10.5mm

RMS4X
0.10NA
Working Distance = 22mm

RMS20X
0.40NA
Working Distance = 1.2mm

RMS40X
0.65NA
Working Distance = 0.56mm

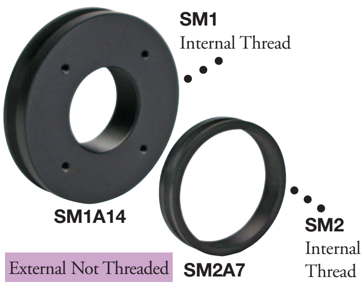
Olympus infinity-corrected microscope objectives are ideal for producing high-quality, high-magnification images. These objectives also find many applications in focusing or collimating laser light.

- Allows for Conversion of Instrument to Microscope
- Ideal for Image Examination
- Lenses are Infinity Corrected
- PLAN Achromat Design

ITEM #	$	£	€	¥	DESCRIPTION
RMS4X	$ 172.00	£ 108.40	€ 160,00	¥ 1,642.60	4X Microscope Objective
RMS10X	$ 364.00	£ 229.30	€ 338,50	¥ 3,476.20	10X Microscope Objective
RMS20X	$ 422.00	£ 265.90	€ 392,50	¥ 4,030.10	20X Microscope Objective
RMS40X	$ 764.00	£ 481.30	€ 710,50	¥ 7,296.20	40X Microscope Objective

For More Microscope Objectives, See Pages 659-661

Olympus Microscope Adapters



- Support for SM1, SM2, and 30mm Cage Systems
- Easy-to-Use Mechanical Interface
- Allows Versatility of Thorlabs Construction Systems to be Applied to Microscopes
- Mates Directly to Olympus Lamphouse Fittings on Current Generation Upright (BX) and Inverted (IX) Microscopes

These SM1A14 and SM2A7 adapters allow Olympus Microscope epifluorescence (or reflected light) lamphouse ports to mate to Thorlabs' systems of optomechanical construction: the Ø1" lens tube (SM1) system, the Ø2" lens tube (SM2) system, and the 30mm cage system. See lens tube systems (page 207) and cage systems (page 226) for more details.

ITEM#	$	£	€	RMB	DESCRIPTION
SM1A14	$ 37.83	£ 23.80	€ 35,20	¥ 361.30	Olympus to Internal SM1 Lens Tube and 30mm Cage Adapter
SM2A7	$ 37.83	£ 23.80	€ 35,20	¥ 361.30	Olympus to Internal SM2 Lens Tube Adapter

Microscope Objective Adapters

The SM1A3 can be used to convert external RMS threads on a part to external SM1 threads. The SM1A4 can be used to convert external SM1 threads on a part to external RMS threads.

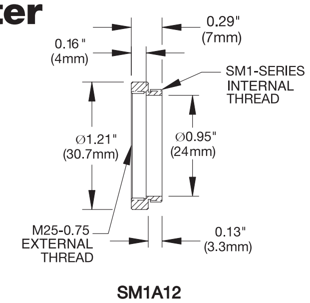
ITEM #	$	£	€	RMB	DESCRIPTION
SM1A3	$ 18.40	£ 11.60	€ 17,10	¥ 175.70	RMS to SM1 Adapter
SM1A4	$ 23.00	£ 14.50	€ 21,40	¥ 219.70	SM1(Internal) to RMS (External) Thread Adapter

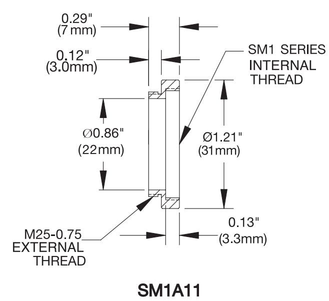
Retaining Rings & Adapter for Objective Turret

This SM05RMS adapter allows any SM05 compatible products to be integrated into applications fitted with RMS (Royal Microscopy Society) threads. The adapter has an SM05 internal thread and an RMS external thread.

ITEM#	$	£	€	RMB	DESCRIPTION
SM05RMS	$ 14.30	£ 9.00	€ 13,30	¥ 136.60	SM05 to RMS Adapter

SM1 to M25-0.75 Thread Adapter





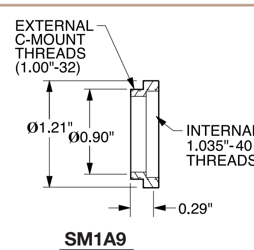
- SM1A11 Adapter Designed With SM1 (1.035"-40) Internal Threads and M25-0.75 External Threads
- SM1A12 Adapter Designed With M25-0.75 Internal Threads and SM1(1.035"-40) External Threads

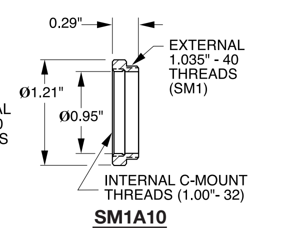
Our new M25-0.75 thread adapters make our SM1 threaded optical mounts compatible with the thread.

ITEM#	$	£	€	RMB	DESCRIPTION
SM1A11	$ 18.40	£ 11.60	€ 17,10	¥ 175.70	SM1 Internal to M25-0.75 External Microscope Objective Adapter
SM1A12	$ 18.40	£ 11.60	€ 17,10	¥ 175.70	SM1 External to M25-0.75 Internal Microscope Objective Adapter

Camera C-Mount Adapter

These C-mount adapters are ideal for either integrating camera lenses into the SM1 Series system or adapting the SM1 Series optical assemblies to camera systems.





ITEM#	$	£	€	RMB	DESCRIPTION
SM1A9	$ 18.90	£ 11.90	€ 17,60	¥ 180.50	Internal SM1 to External C-Mount Thread Adapter
SM1A10	$ 18.40	£ 11.60	€ 17,10	¥ 175.70	Internal C-Mount to External SM1 Thread Adapter

ScienceDesk™ Configurable Workstation

MSD502

Complete With Breadboard as Pictured

Features

- Ergonomic Workplace System for Microscopy
- Modular Design
- Allows Workplace Customization
- Wide Range of Accessories Available
- No Need for Constant Air Supply
- Heavy-Duty Casters for Easy Movement
- ESD Safe With Grounding Kit (PSX105)
- Lightweight Aluminum Frame
- Three Standard Frame Sizes
- Three Independent Shrader Valves for Easy Inflation
- Three Point Stability
- Custom Options Available

Specifications

- **Load Capacity (Including Breadboard):** 45-180kg (100-400lbs)
- **Frame Size:** 195mm Deeper and Wider Than the Work Surface Size
- **Frame Height:** 765mm (30.1")
- **Height Adjustment Range Leveling Feet:** ±20mm (0.8")
- **Isolation Type:** Passive
- **Vertical Resonant Frequency:** <4.5Hz
- **Horizontal Resonant Frequency:** <4.5Hz
- **Vertical Transmissibility (at Resonance):** <9dB
- **Horizontal Transmissibility (at Resonance):** <9dB
- **Vertical Transmissibility (at 10Hz):** <0.2dB
- **Horizontal Transmissibility (at 10Hz):** <0.2dB
- **Air Pressure Required:** 415kPa (60psi) Maximum
- **Finish:** Dark Gray
- Ergonomics in Accordance With BS527 and BS1335

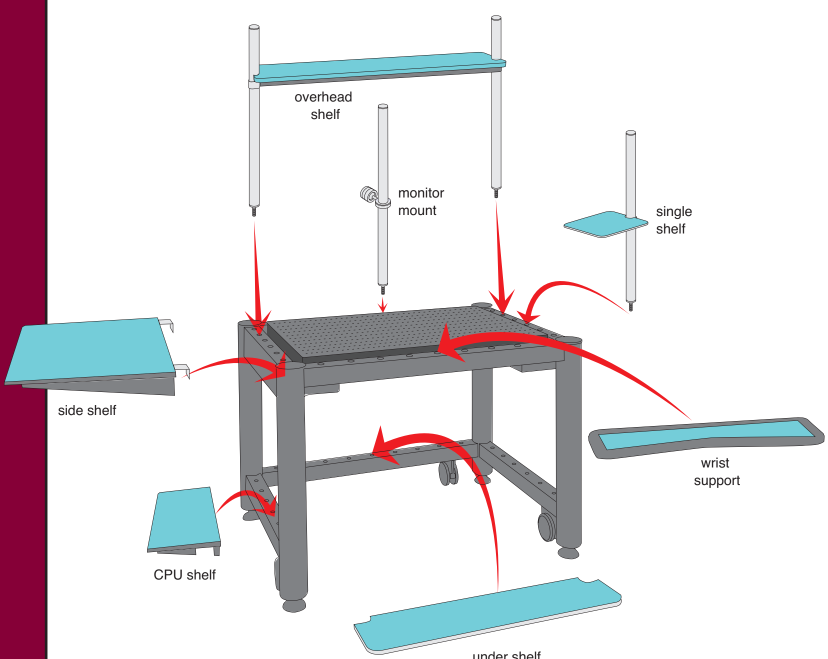
ScienceDesk™ is a modular system designed to provide an ergonomic alternative to conventional workstations. The specially designed ScienceDesk for Microscopy is a high-performance solution that allows users to operate sensitive high-power microscopes conveniently and comfortably. By using ScienceDesk, today's high-power widefield and confocal microscopes are able to achieve their design/published resolution and performance specifications.

The ScienceDesk system constructed from a pneumatically damped aluminum support frame and a stainless steel honeycombed work surface. Vibration damping components inside the tabletop remove locally generated vibrations (such as those induced by beam choppers or equipment fans).

The pneumatic isolators in the support frame absorb vibrations coming from the floor and prevent them from reaching the tabletop. Both vertical and horizontal vibrations are damped by these isolators. The frame also features heavy-duty casters for ease of movement.

Three standard work-surface sizes are available, ranging from 2.5' x 2.5' (750 x 750mm) to 3' x 4' (900 x 1200mm), all at a standard frame height upon 30.6" (765mm). Custom sizes are available upon request, and tapped holes (to accommodate a camera mounted to the base port of a microscope) can be specified. Please call Tech Support for assistance in customizing a ScienceDesk.

A full array of accessories is also available to allow the design of customized workstations, including shelving options, keyboard holders, monitor holders, and grounding kits – see pages 11-14 for more details. The shelving accessories are ESD compliant. In addition to standard accessories, Thorlabs also offers custom accessories such as furniture modules.



ITEM#	$	£	€	RMB	DESCRIPTION
MSD502	$ 2,495.00	£ 1,571.90	€ 2.320,40	¥ 23,827.30	750 x 750mm (2.5 x 2.5ft) Microscope Desk
MSD503	$ 2,850.00	£ 1,795.50	€ 2.650,50	¥ 27,217.50	750 x 900mm (2.5 x 3ft) Microscope Desk
MSD506	$ 2,995.00	£ 1,886.90	€ 2.785,40	¥ 28,602.30	900 x 1200mm (3 x 4ft) Microscope Desk

IsoPlate Vibration Damping System

PTT300600

The Thorlabs IsoPlate Vibration Damping System is designed to offer a moderate amount of benchtop vibration isolation. This system consists of two products:

- A honeycomb plate with stainless steel top that is designed to support the imaging system and provide broadband damping of acoustic vibrations
- A light but strong steel IsoPlate Base with a pneumatic system designed to isolate the honeycomb plate from vibrations coupled to the bench or table

The pneumatic system comprises four inflated cushions, of which one pair has a coupled air reservoir and the other two are independently inflated. This arrangement provides stable, three-point dynamics to the system.

The standard IsoPlate System includes a size-matched base and a honeycomb plate. If there is a need for a traditional optical breadboard surface with an array of 1/4"-20 or M6 threaded holes, the required breadboard can be selected from our line of optical breadboards, and then the IsoPlate Base can be purchased separately.

Features

- Three Independent Shrader Valves for Easy Inflation
- No Need for a Constant Air Supply
- Three Point Stability

PART NUMBER	ISOPLATE SIZE	MICROSCOPE COMPATIBILITY
MIP1	600mm x 300mm	Olympus CX21/31/41
MIP2	600mm x 600mm	Leica DMI Series Olympus BX41/45A/51/61 CKX31/41 IX51/71 Nikon Eclipse 50i/55i/ 80i/90i TE2000 Zeiss Axioskop/Imager Axiovert 40/200
MIP3	600mm x 900mm	Leica DMI Series Olympus BX41/45A/51/61 CKX31/41 IX51/71 Nikon Eclipse 50i/55i/ 80i/90i TE2000 Zeiss Axioskop/Imager Axiovert 40/200

Specifications

- **Load Capacity:** 45-180kg (100-400lbs)
- **Air Connection:** Shraeder Valve
- **Air Pressure Required:** 415kPa (60psi) maximum
- **Finish:** Two Tone Gray

VIBRATION ISOLATION DATA			
Resonant Frequency		Transmissibility (Isolation Efficiency) in dB	
Vertical	Horizontal	Vertical	Horizontal
<3.5Hz	<3.5Hz	<9 at Resonance	<9 at Resonance
<3.5Hz	<3.5Hz	<0.2 (> 80% Isolation) at 10Hz	<0.2 (> 80% Isolation) at 10Hz

Choice of vibration isolation options for delicate imaging and photonics setups.

See Pages 1-14

Thorlabs' Performance™ Optical Breadboards provide high performance at an economical price. These 60mm (2.4") thick optical breadboards offer the same construction techniques as our standard Performance Series range but with no holes drilled into the top plate. They provide high stiffness and standard damping, making them an ideal solution for microscopy applications.

MIP1

MIP1 Shown With Plate

IsoPlate Vibration Damping System

ITEM#	$	£	€	RMB	DESCRIPTION
MIP1	$ 1,300.50	£ 819.30	€ 1.209,50	¥ 12,419.80	300 x 600mm (11.8" x 23.6") Base & Plate
MIP2	$ 1,524.90	£ 960.70	€ 1.418,20	¥ 14,562.80	600 x 600mm (23.6" x 23.6") Base & Plate
MIP3	$ 1,674.50	£ 1,054.90	€ 1.557,30	¥ 15,991.50	900 x 600mm (35.4" x 23.6") Base & Plate

ITEM	$	£	€	RMB	DESCRIPTION
PTT300600	$ 875.00	£ 551.30	€ 813,80	¥ 8,356.30	IsoPlate Passive Isolation Base 300 x 600 x 90mm (11.8" x 23.6" x 3.5")
PTT600600	$ 950.00	£ 598.50	€ 883,50	¥ 9,072.50	IsoPlate Passive Isolation Base 600 x 600 x 90mm (23.6" x 23.6" x 3.5")
PTT900600	$ 1,000.00	£ 630.00	€ 930,00	¥ 9,550.00	IsoPlate Passive Isolation Base 900 x 600 x 90mm (35.4" x 23.6" x 3.5")