GANYMEDE - July 8, 2015

Item # GANYMEDE was discontinued on July 8, 2015. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

GANYMEDE Spectral Domain
Optical Coherence
Tomography System

Cross-Sectional and
Volumetric Imaging

OVERVIEW

Thorlabs' GANYMEDE™ OCT Imaging System

Features

- A-Scan Rate of Up to 30 kHz
- General-Purpose OCT System with Video-Rate Imaging Speed
- Three Acquisition Modes for Flexibility in Imaging Speed and Sensitivity
- Ideal for Biological and Industrial Materials Imaging Applications
- Large Field of View: 10 mm x 10 mm x 2.7 mm
- Custom Configurations Available

Thorlabs' GANYMEDE™ OCT Imaging System offers three acquisition speed settings. In the High Speed mode with 30 kHz A-Scan rate, 1024 x 1024 pixel images can be displayed in video rate and with 91 dB sensitivity. In contrast, the High Sensitivity Mode provides the ability to record images with a sensitivity of up to 106 dB at 1.25 kHz A-Scan rate. Increasing sensitivity, at the cost of imaging speed, enables higher contrast during imaging, thereby improving detection of very weakly resolved structures in the sample. The GANYMEDE Spectral Domain OCT System is an excellent general-purpose system for imaging biological samples as well as producing 2D cross-sectional images and 3D volume datasets.

The GANYMEDE utilizes a GigE data connection and is controlled via software preinstalled on a high-performance computer that is capable of online rendering and display of all measured 3D datasets. It also includes a 3D scanning, common path probe with integrated video camera for volume imaging and live video display. The included stand and sample stage provide XY translation and rotation of the sample along with axial travel of the probe. The GANYMEDE system is fully functional right out of the box.

Optical Coherence Tomography (OCT) is a noninvasive optical imaging modality that provides real-time, 1D depth, 2D cross-sectional, and 3D volumetric images with micron-level resolution and millimeters of imaging depth. OCT images provide structural information of a sample, based on light backscattered from different layers of material within that sample. OCT imaging is considered to be the optical analog to ultrasound. OCT, however, achieves higher resolution through the use of near infrared wavelengths, at the cost of decreased penetration depth. In addition to high resolution, the non-contact, noninvasive advantage of OCT makes it well suited for imaging samples such as biological tissue, small animals, and industrial materials.

Click here for a full list of peer-reviewed publications using Thorlabs OCT imaging products.

GANYMEDE System Specifications	
Center Wavelength	930 nm
Imaging Speed (A-Scan Line Rate)	High-Speed Mode: 30 kHz Medium-Speed Mode: 10 kHz High-Sensitivity Mode: 1.25 kHz
Axial (Depth) Resolution (Air)	<5.8 µm
Lateral Resolution	8 µm
Maximum Field of View	10 mm x 10 mm x 2.7 mm
Maximum Pixels Per A-Scan	1024
Optical Power on Sample	1.5 mW

OCT System Comparison ✓

Download a Brochure
77 MB PDF

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OEM and Custom Requests

Thorlabs offers OEM products for easy integration into your imaging system. With ISO9001 certified production facilities and experienced OEM design engineers, we welcome OEM requests.

We also recognize that our customers have unique application requirements. For this reason, we stand ready to discuss how our OCT systems can be adapted to meet your needs. We encourage you to send us samples for product testing so our engineers can customize one of our OCT systems to suit your individual applications. Please use the "Contact Us" button on the upper right-hand side of the page for more information.

PRODUCT DETAILS

Click on the Ganymede OCT Imaging System Components, shown below, for further details.

GANYMEDE Processor

The GANYMEDE OCT System includes a desktop PC and a 22" display. This processing system is set up with all the necessary data acquisition hardware, drive electronics, and software to begin imaging upon arrival.

Computer Specifications*

- Processor: Quad Core
- Processor Speed: ≥ 3.3 GHz
- Memory: ≥ 8 GB
- Hard Drive: ≥ 500 GB
- Data Acquisition: GigE

*Computer Type Subject to Change without Notice

Click Here to return to the top of the page.

GANYMEDE SD-OCT Engine

The GANYMEDE SD-OCT engine is housed in a 420 mm x 320 mm x 149 mm (16.54' x 12.6' x 5.86') unit. It contains a 930 nm Superluminescent Diode Light Source and a Linear Array-Based Spectrometer. It also includes all associated drive electronics and controllers.

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Click Here to return to the top of the page.

High Performance Software

High-performance ThorImage OCT data acquisition software is included with all SD OCT systems. The Windows-based software performs data acquisition, processing, scan control, and display of OCT images. See the Software tab for more details.
A Software Development Kit (SDK) is also available for C/C++ and LabVIEW-based interfaces. Please contact oct@thorlabs.com for more details.

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Hand-Held Probe and Stand

All Thorlabs OCT systems include a hand-held probe and stand, as shown here. The probe provides X-Y scanning for three-dimensional data acquisition. A camera integrated in the probe provides live video imaging during OCT data acquisition. The probe easily slips onto the stand for imaging of small samples.
The probe stand consists of a post-mounted focus block which is attached to a specially designed 12" x 14" aluminum breadboard using a Ø1.5" P14 Post.

Click to Enlarge

Stand Features

- Ideal for Vibration-Sensitive Studies such as Doppler OCT Imaging
- 3/4" Thick Aluminum Breadboard Provides Increased Stability
- Breadboard Base has Side Grips and Recessed Feet for Easy Lifting and Transportation of the Stand
- Includes a Sample Stage with 1" X and Y Travel as well as Rotation

Click Here to return to the top of the page.

SELECTION GUIDE

Thorlabs offers a wide variety of OCT imaging systems, each with their own special set of specifications. To assist in narrowing down which OCT system(s) is best suited for your application, we have provided the guide below. This information is intended only as a guide. We encourage you to contact us to discuss your specific imaging requirements.

	CALLISTO	GANYMEDE-II	GANYMEDE-II-HR	TELESTO-II	TELESTO-II-1325LR	OCS1310V1
Center Wavelength	930 nm (840 nm option also available)		900 nm	1300 nm	1325 nm	1300 nm
Bandwidth	100 nm[a]	100 nm[a]	150 nm[a]	170 nm[a]	100 nm[a]	100 nm[b]
A-Scan Line Rate	1.2 kHz	36 kHz		Up to 76 kHz		100 kHz
B-Scan Frame Rate[c,d]	2 fps	29 fps		Variable		110 fps
Depth Resolution[e] (Air)	7 µm	6 µm	3 µm	5.5 µm	12 µm	16 µm
Depth Resolution[e] (Water)	5.3 µm	4.3 µm	2.1 µm	4.2 µm	9.0 µm	12 µm
Lateral Resolution	8 µm	8 µm	4 µm	13 µm		25 µm
Sensitivity	105 dB	91 dB		Up to 103 dB		105 dB
Maximum Pixels per A-Scan	512	1024		1024		2048
Max Field of View[e] (L x W x D)	10 x 10 x 1.7 mm	10 x 10 x 2.9 mm	6 x 6 x 1.9 mm	10 x 10 x 3.5 mm	10 x 10 x 7 mm	10 x 10 x 12 mm

- Bandwidth at 3 dB
- Bandwidth at 20 dB
- Actual Frame Rate is dependent on processing and display parameters
- (512 lines/frame)
- Depth Resolution and actual imaging depth are dependent on the optical properties of the sample being imaged.
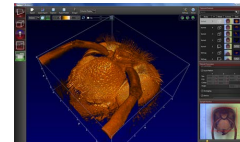
ThorImage OCT Software Index

- Introduction
- 2D Mode for Cross-sectional Imaging
- 3D Mode for Volume Imaging
- Doppler Mode for Doppler Flow Imaging
- Speckle Variance Mode for Angiographic Imaging
- Video Showing Screencast of Rendering Capabilities

ThorImage OCT Software

- Interactive Scan Position Control through Video Display (Draw and Scan)
- Advanced Dataset Management
- High-Speed Volume Rendering of 3D Data
- Doppler and Speckle Variance Imaging
- Versatile Scan and Acquisition Control

Click to Enlarge
The ThorImage OCT window in the Volume Rendering Mode.

ThorImage OCT is high-performance data acquisition software that is included with all Thorlabs Spectral Domain OCT systems. This 64-bit Windows-based software package is capable of data acquisition, processing, scan control, and displaying OCT images. Additionally, NI LabVIEW and C-based Software Development Kits (SDKs) are available, which contain a complete set of libraries for measurement control, data acquisition and processing, as well as storage and display of OCT images. The SDKs provide the means for developing highly specialized OCT imaging software for every individual application.

Scan Control

ThorImage OCT provides numerous scan and acquisition controls. The camera integrated in the probe of our OCT system provides live video images in the application software. Defining the scan line for 2D imaging or the scan area for 3D imaging is accomplished through the easy-to-use "Draw and Scan" feature by clicking on the video image. The scan pattern can also be adjusted by specifying parameters in the controls of the software. Additionally, one can further set processing parameters, averaging parameters, and the speed and sensitivity of the device using device presets. By using a high-speed preset, video-like frame rates in 2D and fast volume rendering in 3D are possible, whereas high-sensitivity acquisition is enabled by choosing a preset with a lower acquisition speed.

Click to Enlarge
Various acquisition parameters can be adjusted in ThorImage OCT.
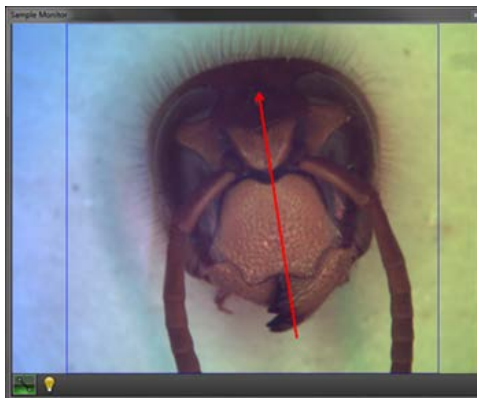
Click to Enlarge
The Sample Monitor can be used to define the scan pattern using the "Draw and Scan" feature.
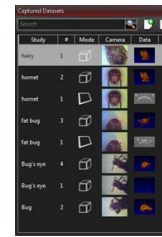
Dataset Management

ThorImage OCT provides advanced dataset management capabilities, which allow opening several datasets simultaneously. Datasets are uniquely defined using an identifier consisting of study (or test series) name and an experiment number. Grouping of datasets is possible using the same study name. The "Captured Datasets" list shows an overview of all open

datasets, including the study name, the acquisition mode, and preview pictures of the still video image and the OCT data.

Datasets can be exported in various image formats, such as PNG, BMP, JPEG, PDF, or TIFF. Formats suited for post-processing purposes, such as RAW/SRM, FITS, VTK, VFF, and 32-bit floating-point TIFF, are also supported.

The OCT file format native to ThorImage OCT allows OCT data, sample monitor data, and all relevant metadata to be stored in a single file. ThorImage OCT can also be installed and run on computers without an OCT system installed in order to view data.

Click to Enlarge
The Dataset Management
Window of ThorImage OCT.

Third Party Applications

If ImageJ is installed on the computer with ThorImage OCT installed, opening acquired OCT data in ImageJ is one mouse click away, as shown in the image below. This enables a flawless workflow when requiring the advanced image processing functionality provided by ImageJ. Clicking the Explorer button shown below will open the folder and select the file in Windows Explorer where the currently active dataset is stored.
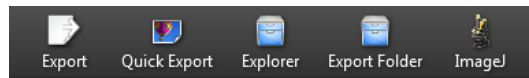
Export buttons are accessible in the Action Toolbar of ThorImage OCT.

2D Mode

In the 2D imaging mode the probe beam scans in one direction, thus acquiring cross-sectional OCT images, which are then displayed in real time. Line averaging before or after the Fast Fourier Transform (FFT) is available as well as B-Scan averaging. Image display parameters, such as color mapping, can be controlled in this mode. We have also implemented an option for automatic calculation of the optimum contrast and brightness of the displayed OCT images.
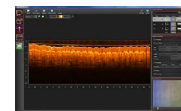
Click to Enlarge
The ThorImage OCT window in
the 2D Mode.

3D Mode

In the 3D imaging mode, the OCT probe beam scans sequentially across the sample to collect a series of 2D cross-sectional images, which are then processed to build a 3D image.

In the ThorImage OCT software, 3D volume datasets can be viewed as orthogonal cross-sectional planes (see below) and volume renderings.

The Sectional View features cross-sectional images in all three orthogonal planes, independent of the orientation in which the data was acquired. The view can be rotated as well as zoomed in and out.

The Rendering View provides a volumetric rendering of the acquired volume dataset. This view enables quick 3D visualization of the sample being imaged. Planes of any orientation can be clipped to expose structures within the volume. The 3D image can be zoomed in and out as well as rotated. Furthermore, the coloring and dynamic range settings can be adjusted.

Utilizing the full potential of our high-performance software in combination with our high-speed OCT systems, we have included a Fast Volume Rendering mode in ThorImage OCT, which serves as a preview for high-resolution 3D acquisitions. In this mode, high-speed volume renderings can be displayed in real-time, providing rapid visualization of samples in three dimensions.
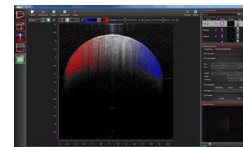

Click to Enlarge
Rendering
View

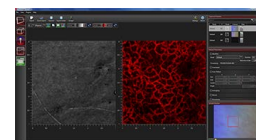Click to Enlarge
Sectional View

Doppler Mode

Doppler OCT imaging comes standard with all OCT systems. In the Doppler mode, phase shifts between adjacent A-scans are averaged to calculate the Doppler frequency shift induced by particle motion or flow. The number of lateral axial pixels can be modified to change velocity sensitivity and resolution during phase shift calculation. The Doppler images are displayed in the main window with a color map indicating forward- or backward-directed flow, relative to the OCT beam.

Click to Enlarge
Doppler dataset showing the velocity of a
rotated plastic stick.

Speckle Variance Mode

ThorImage OCT 4.0 introduces a new acquisition mode, which uses the variance of speckle noise to calculate angiographic images. It can be used to visualize three dimensional vessel trees without requiring significant blood flow and without requiring a specific acquisition speed window. The speckle variance data can be overlaid on top of intensity pictures providing morphological information. Different color maps can be used to display the multimodal pictures.

Click to Enlarge
Speckle variance measurement showing blood
vessels of a hand.

Video Showing Screencast of ThorImage OCT Rendering Capabilities

In this video, OCT images of a finger are acquired and manipulated in the 3D volume and cross section modes.

Doppler OCT Imaging

Doppler OCT is an extension of OCT that enables imaging of particle motion within a sample. In Fourier Domain OCT (FD-OCT) systems, there are no additional hardware requirements for implementation of Doppler imaging. Doppler OCT imaging capability is embedded in the software provided with all Thorlabs' OCT systems and is ideal for functional vascular imaging, studying embryonic cardiac dynamics, or monitoring vascular treatment response. It is also useful for general flow velocimetry used in microfluidic channel monitoring.

Principles of Doppler OCT

The Fourier transform of the interferogram acquired in FD-OCT imaging (A-scan) produces a complex signal [I(z) + iQ(z)], where the magnitude of that signal is used to create the structural OCT image. The complex portion of the signal contains information based on the phase of the interferogram. Any change in phase between consecutively acquired A-scans can be attributed to a Doppler frequency shift induced by particle motion.

In Thorlabs' implementation of Doppler OCT, Doppler frequency shifts are calculated based on spatially averaging phase shifts within a sliding 2D window and using a Kasai autocorrelation function (see reference below). The Doppler frequency shift f_D caused by moving particles is related to the phase shift between A-scans, as described in the following expression:

$$f_D = \frac{\Delta\varphi}{2\pi} f_A$$

where $\Delta\varphi$ is the average phase shift within the sliding 2D window and f_A is the A-scan rate of the OCT system. The Thorlabs Doppler Imaging Mode displays the phase shift induced by moving particles using a standard Doppler colormap where red to yellow (violet to blue) indicates flow in the direction toward (away from) the OCT sample beam.

The mean velocity <v> of the moving particles, at any depth, can be quantified by knowing θ, the angle between the OCT sample beam and flow vector:

$$\langle v \rangle = \frac{\lambda_o f_D}{2n\cos(\theta)}$$

Here, λ_o is the center optical wavelength of the OCT sample beam and n is the index of refraction of the sample.

Reference:
C. Kasai, K. Namekawa, A. Koyano, R. Omoto et al . "Realtime two-dimensional blood flow imaging using an autocorrelation technique," IEEE Trans. Sonics. Ultrason. 32 458-464 (1985).

Doppler Effect

Click to Enlarge

A stationary observer will observe a Doppler shift in the frequency of light emitted from a source moving toward or away from the observer. When the light source is moving toward the observer, the observed frequency of light will be blue-shifted, meaning the perceived frequency of the light will be higher than the actual frequency emitted by the source. Higher frequencies correspond to shorter wavelengths. Conversely, if the light source is moving away from the observer, the observed frequency of light will be redshifted to lower frequencies. In Doppler OCT, the Doppler effect caused by moving particles in a sample is determined by measuring a shift in the phase between consecutive OCT interference fringe signals.
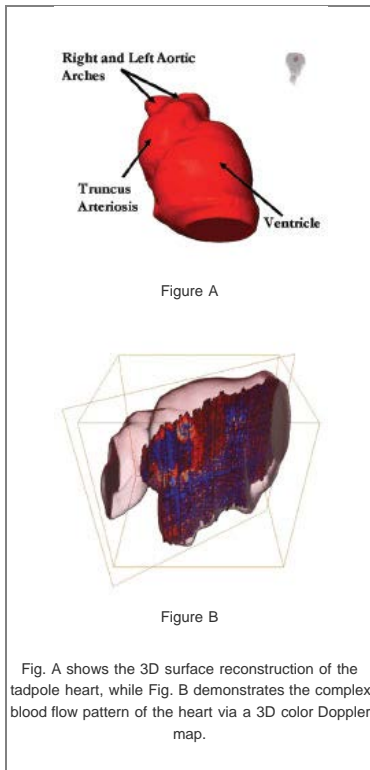
Developmental Biology

A Thorlabs Swept Source OCT Imaging System with Doppler Imaging was used by researchers at the University of Toronto to study the cardiovascular system of living tadpoles. The series of images below show *in vivo* cross-sectional SS-OCT images of a beating tadpole heart superimposed with Doppler blood flow images. 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.

(1) (2) (3)
(4) (5) (6)

Reference:
A. Mariampillai, B.A. Standish, N.R. Munce, C. Randall, G. Liu, J.Y. Jiang, A.E. Cable, I.A. Vitkin, V.X.D. Yang, "Doppler optical cardiogram gated 2D color flow maging at 1000 fps and 4D in vivo visualization of embryonic heart at 45 fps on a swept source OCT system", Optics Express 15 , 1627 (2007).

Right and Left Aortic Arches

Truncus Arteriosis

Ventricle

Figure A

Figure B

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.

Optical Coherence Tomography Tutorial

Optical Coherence Tomography (OCT) is a noninvasive optical imaging modality that provides real-time, 1D depth, 2D cross-sectional, and 3D volumetric images with micron-level resolution and millimeters of imaging depth. OCT images consist of structural information from a sample based on light backscattered from different layers of material within the sample. It can provide real-time imaging and is capable of being enhanced using birefringence contrast or functional blood flow imaging with optional extensions to the technology.

Thorlabs has designed a broad range of OCT imaging systems that cover several wavelengths, imaging resolutions, and speeds, while having a compact footprint for easy portability. Also, to increase our ability to provide OCT imaging systems that meet each customer's unique requirements, we have designed a highly modular technology that can be optimized for varying applications.

Application Examples

Art Conservation | Drug Coatings | 3D Profiling | In-vivo | Small Animal | Biology | Tissue Birefringence | Mouse Lung

Retina Cone Cells

OCT is the optical analog of ultrasound, with the tradeoff being lower imaging depth for significantly higher resolution (see Figure 1). With up to 15 mm

imaging range and better than 5 micrometers in axial resolution, OCT fills a niche between ultrasound and confocal microscopy.

In addition to high resolution and greater imaging depth, the non-contract, noninvasive advantage of OCT makes it well suited for imaging samples such as biological tissue, small animals, and materials. Recent advances in OCT have led to a new class of technologies called Fourier Domain OCT, which has enabled high-speed imaging at rates greater than 700,000 lines per second.[1]

Fourier Domain Optical Coherence Tomography (FD-OCT) is based on low-coherence interferometry, which utilizes the coherent properties of a light source to measure optical path length delays in a sample. In OCT, to obtain cross-sectional images with micron-level resolution, and interferometer is set up to measure optical path length differences between light reflected from the sample and reference arms.

There are two types of FD-OCT systems, each characterized by its light source and detection schemes: Spectral Domain OCT (SD-OCT) and Swept Source OCT (SS-OCT). In both types of systems, light is divided into sample and reference arms of an interferometer setup, as illustrated in Fig 2. SS-OCT uses coherent and narrowband light, whereas SD-OCT systems utilize broadband, low-coherence light sources. Back scattered light, attributed to variations in the index of refraction within a sample, is recoupled into the sample arm fiber and then combined with the light that has traveled a fixed optical path length along the reference arm. A resulting interferogram is measured through the detection arm of the interferometer.
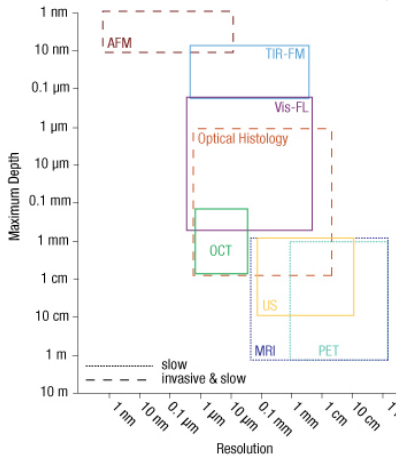
The frequency of the interferogram measured by the sensor is related to depth locations of the reflectors in the sample. As a result, a depth reflectivity profile (A-scan) is produced by taking a Fourier transform of the detected interferogram. 2D cross-sectional images (B-scans) are produced by scanning the OCT sample beam across the sample. As the sample arm beam is scanned across the sample, a series of A-scans are collected to create the 2D image.

Similarly, when the OCT beam is scanned in a second direction, a series of 2D images are collected to produce a 3D volume data set. With FD-OCT, 2D images are collected on a time scale of milliseconds, and 3D images can be collected at rates now below 1 second.

Click to Enlarge
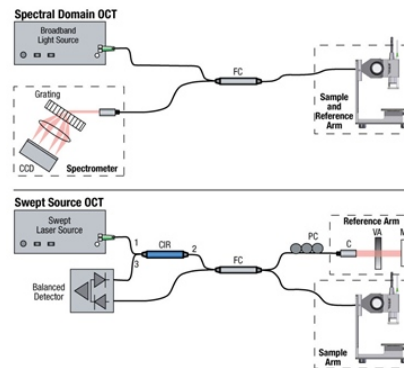**Figure 1**

Click to Enlarge
Figure 2

Spectral Domain OCT vs. Swept Source OCT

Spectral Domain and Swept Source OCT systems are based on the same fundamental principle but incorporate different technical approaches for producing the OCT interferogram. SD-OCT systems have no moving parts and therefore have high mechanical stability and low phase noise. Availability of a broad range of line cameras has also enabled development of SD-OCT systems with varying imaging speeds and sensitivities.
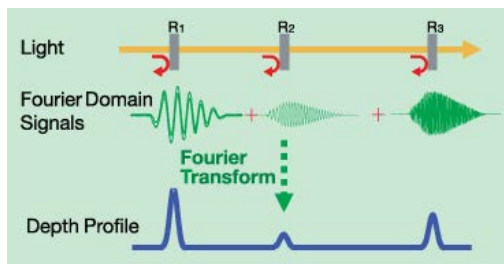
SS-OCT systems utilize a frequency swept light source and photodetector to rapidly generate the same type of interferogram. Due to the rapid sweeping of the swept laser source, high peak powers at each discrete wavelength can be used to illuminate the sample to provide greater sensitivity with little risk of optical damage.

Click to Enlarge

FD-OCT Signal Processing

In Fourier Domain OCT, the interferogram is detected as a function of optical frequency. With a fixed optical delay in the reference arm, light reflected from

different sample depths produces interference patterns with the different frequency components. A Fourier transform is used to resolve different depth reflections, thereby generating a depth profile of the sample (A-scan).

[1] V.Jayaraman, J. Jiang, H.Li, P. Heim, G. Cole, B. Potsaid, J. Fujimoto, and A. Cable, "OCT Imaging up to 760 kHz Axial Scan Rate Using Single-Mode 1310 nm MEMs-Tunable VCSELs with 100 nm Tuning Range," CLEO 2011 - Laser Applications to Photonic Applications, paper PDPB2 (2011).

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Part Number	Description	Price	Availability
GANYMEDE	Video-Rate Spectral Domain OCT Imaging System	$50,000.00	Lead Time