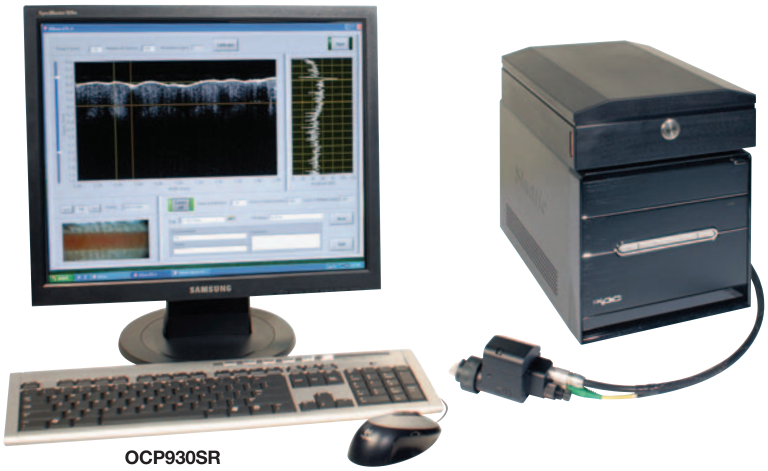
Spectral Radar OCT Systems — Page 1 of 4



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

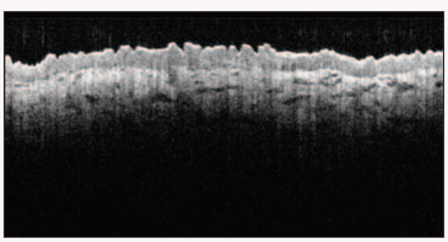
- Ideal for Imaging Small Features Close to the Surface
- Imaging Depth ~1.1mm
- Axial Resolution 4.5µm

Deep Imaging SR Model

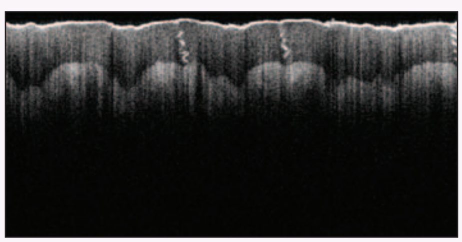
OCP840SR

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

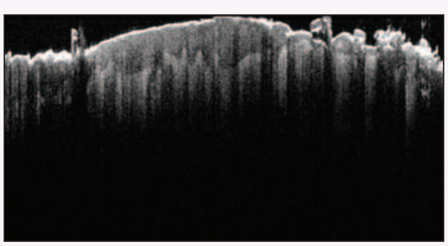
OCT Images of Human Skin



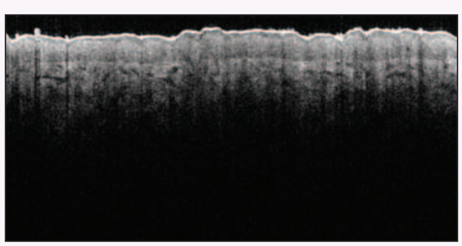
Palm



Finger Pad

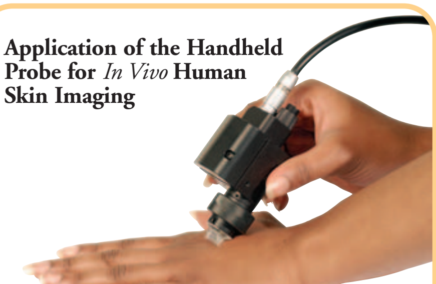


Skin With Callous



Back of Hand

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



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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.

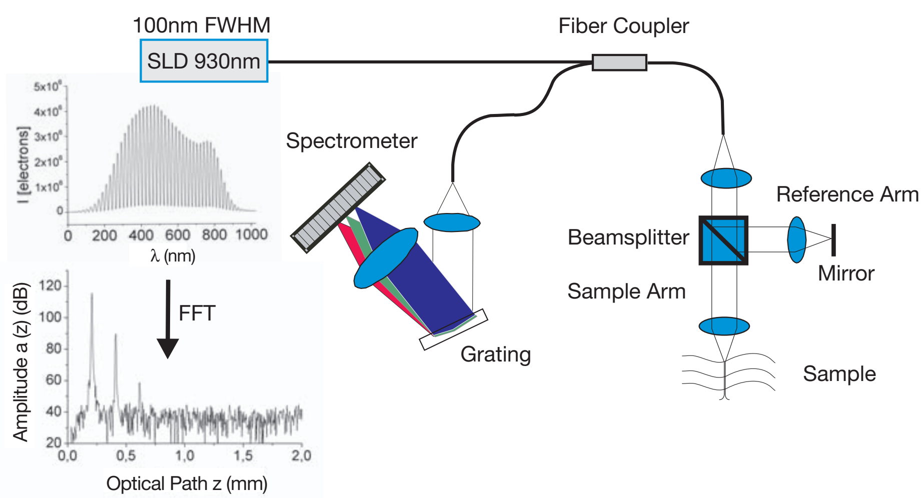
FD-OCT is more sensitive than earlier OCT systems, which were based on time-domain optical coherence tomography (TD-OCT). This increase in sensitivity significantly improves the data acquisition speed and image quality. The current spectral radar FD-OCT system offered by Thorlabs operates at a maximum 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.

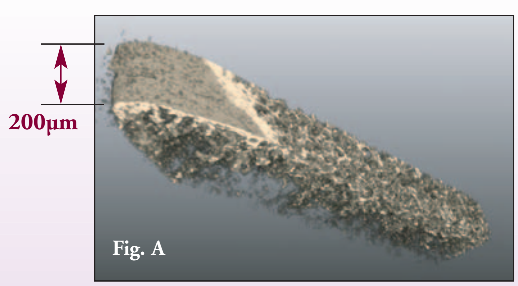
Simplified Operating Principle of Spectral OCT

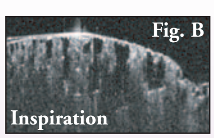
Figure 1 (see below) graphically depicts the basic design of the Thorlabs OCP930SR spectral OCT engine and probe. The output of a broadband Super Luminescent Diode (SLD) light source is guided into a handheld Michelson interferometer probe, which splits the light into two separate optical paths. The 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).

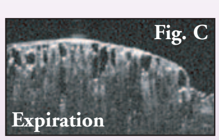
Figure 1 Schematic Spectral Radar With Handheld Probe



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).

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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.

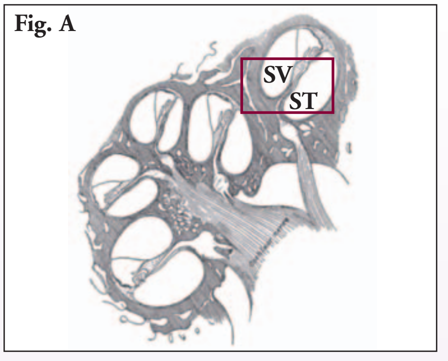
Applications of Spectral Radar OCT

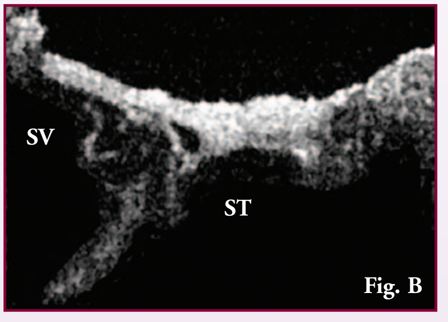
The center wavelength of our standard model Spectral Radar OCT system is 930nm. Thorlabs also offers other wavelengths to accommodate special imaging requirements (see the application descriptions and the price box on the next page). The choice of a near-IR broadband source is ideal for most biological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

Spectral Radar Application

Fig. A





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.

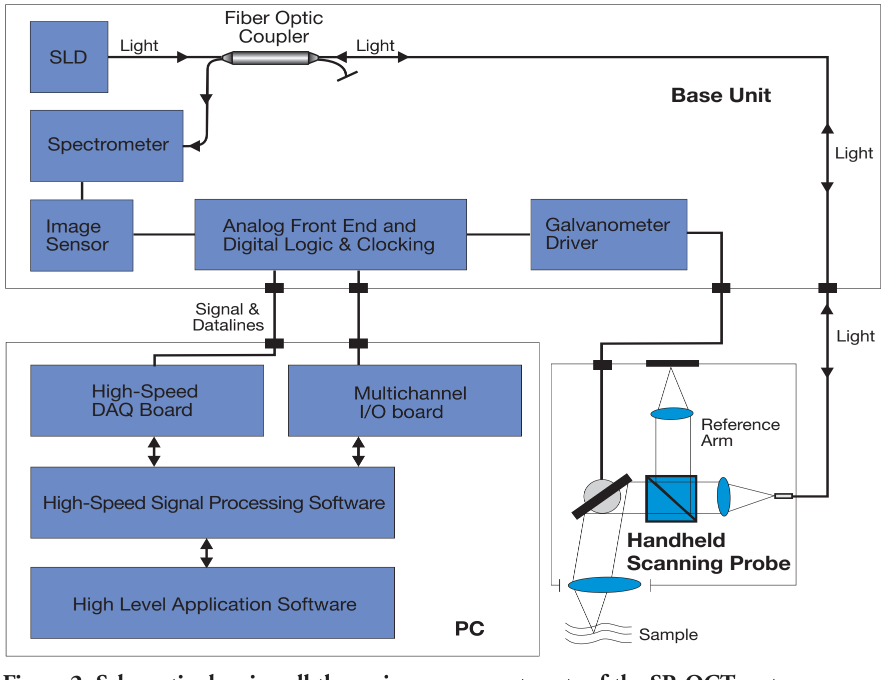


Figure 2 Schematic showing all the major component parts of the SR-OCT system

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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