Swept Source OCT System Base Units

VEG200 Series

User Manual

Original User Manual – not translated

Table of Contents

Chapter 1 Introduction

ATTENTION

Please read the instruction manual carefully before operating the SS-OCT system. All statements regarding safety and technical specifications will only apply when the unit is operated correctly.

This equipment is intended for laboratory use only and is not certified for medical applications, including but not limited to life support situations.

Refer to this manual whenever the following symbols are encountered on the SS-OCT system:

Attention symbol indicates that additional information is given in this manual.

Laser Safety symbol indicates that laser radiation is present.

Shock Warning symbol indicates there is possible danger of injury to users.

ATTENTION

Check the supply voltage of the system before plugging in the computer. Make sure the included power cords for the base unit, computer, and monitor are connected to a properly grounded outlet (100 – 240 VAC; 50 – 60 Hz).

Transportation and delivery may cause the SS-OCT system to be warm or cool upon receipt. Please wait for the system to reach room temperature before attempting to operate.

Operate this system on a flat, dry, and stable surface only.

WARRANTY WARNING

Do not open the base unit, imaging scanner or PC. There are no user serviceable parts in this product. Opening the device will void your warranty. Any modification or servicing of this system by unqualified personnel renders Thorlabs free of any liability. This device can only be returned when packed into the complete original packaging, including all foam packing inserts. If necessary, ask for replacement packaging.

The following symbols are used on the device:

	"ON" (power)
	"OFF" (power)
	Stand-by
	Protective earth; protective ground

1.1. Safety

SHOCK WARNING – HIGH VOLTAGE

Before applying power to the system, make sure that the protective conductor of the three-conductor mains power cord is correctly connected to the protective earth contact of the socket outlet. Improper grounding can cause electrical shock resulting in severe injury or even death. Make sure that the line voltage rating agrees with your local supply and that the appropriate fuses are installed. Fuses should only be changed by qualified service personnel. Contact Thorlabs for assistance. Do not operate without cover installed. Refer servicing to qualified personnel.

ATTENTION

Do not obstruct the air-ventilation slots in the computer housing. Do not obstruct air-ventilation into the bottom of the base unit or out of the exhaust fan on the rear of the unit.

Mobile telephones, cellular phones, or other radio transmitters are not to be used within the range of three meters of this unit, since the electromagnetic field intensity may exceed the maximum allowed disturbance values according to IEC 61000-6-1:2005.

The safety of any system incorporating the equipment is the responsibility of the assembler of the system.

If equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

LASER RADIATION WARNING

Laser emission may be emitted

a) from the scan lens of a scanner (intended use)

b) from the back of the base unit when the fiber cap is removed and the fiber disconnected

c) from the output of the fiber when the fiber is not connected to a scanner

Do not look into the optical output when the device is operating. The laser radiation is not visible to the human eye and can cause serious damage to your eyesight.

The laser class information is also stated on the laser safety labels on the back of the housing.

Example given for class 1M LASER product:

INVISIBLE LASER RADIATION

DO NOT STARE INTO BEAM OR VIEW
DIRECTLY WITH OPTICAL INSTRUMENTS

CLASS 1M LASER PRODUCT

CLASSIFIED ACCORDING TO DIN EN 60825-1:2014

1.2. Care and Maintenance

Handle the system with care during transportation and unpacking. Banging or dropping the system can damage the unit or lower system performance. If the system is mishandled during shipment, the optical components may become misaligned, which could lead to a decrease in image quality. If this occurs, the system will need to be realigned by qualified personnel. Please contact Thorlabs technical support for more information.

- Do not store or operate in a damp, closed environment.
- Do not store or operate on surfaces that are susceptible to vibrations.
- Do not expose to direct sunlight.
- Do not use solvents on or near the equipment.
- Keep away from dust, dirt, and air-borne pollutants (including cigarette smoke). The system is not designed for outdoor use. Protect the equipment from rain, snow, and humidity.
- Do not expose to mechanical and thermal extremes. Protect the equipment from rapid variation in temperature.
- Handle all connectors, both electrical and optical, with care. Do not use unnecessary force, as this may damage the connectors.
- Handle the optical fiber with care. Mechanical stress can decrease performance and potentially destroy the fiber. Continual bending of the optical fiber can cause damage. It is important, therefore, to keep the optical fiber patch cable as straight as possible to minimize bending.

Note: The most common cause of low signal intensity is contamination of the fiber due to airborne pollutants. To minimize exposure, avoid unnecessarily disconnecting the optical fiber patch cable. In addition, it is advisable to check the fiber before making other adjustments to the optical system, such as changing the focus or optical path length. Be sure to check the patch cord for a loose connection, and make sure that the fiber is kept as straight as possible.

All lasers, especially lasers with resonator cavities that are defined by mechanical tolerances, are delicate precision instruments and must be handled accordingly. The SS-OCT system is designed to withstand normal transportation and operating conditions. Do not move the system while it is connected and in operation.

1.2.1. Optical Cleaning

Good performance and image quality of the OCT imaging system relies on clean optical connections. Whenever using the Thorlabs OCT system, the following guidelines for optical fiber connection should be followed:

1) Always make sure that the light source is switched off when you clean the fiber.
2) Always inspect and clean the fiber end before plugging it into a receptacle.
3) Always cover the fiber end that is not in use with a fiber cap or dust protection cover.

The cleaning procedure sucess could be visualized using a fiber inspection scope.

Figure 1 Fiber Inspection Scope FS201

1.2.2. Fiber Cleaning Techniques Using the FBC1

This section details how to clean fiber bulkheads and fiber connectors using the FBC1 one-step cleaner.

Using Extended Mode

Figure 2 FBC1 Extended Mode

To use extended mode, pull the tip outward while simultaneously pushing down on the lock button. Extended mode is useful for panels with multiple bulkhead connectors or other tight spaces.

Cleaning Fiber Bulkheads

Figure 3 Cleaning Fiber Bulkheads

Remove the guide cap completely from the device, and insert the tip of the cleaner into the bulkhead connector. Push the case to start the cleaning process; a click indicates that the cleaning is complete.

Cleaning Fiber Connectors

Figure 4 Cleaning Fiber Connectors

Open the cover on the guide cap, and insert the fiber connector over the guide cap. Push the case to start the cleaning process; a click indicates that the cleaning is complete.

1.2.3. Service

Only trained and approved Thorlabs personnel are allowed to service the system. Please contact Thorlabs technical support for more information.

1.2.4. Accessories and Customization

The OCT base unit can easily be adapted for custom interfaces. To achieve the listed specifications however this system should only be used with the accessories that Thorlabs provides. Any modification or maintenance by unqualified personnel will render the warranty null and void, leaving Thorlabs free of liability. Please contact Thorlabs technical support for questions on customization.

Chapter 2 Setup

2.1. Unpacking

Carefully unpack the components from the transport boxes. Make sure that all components are delivered according to the packing list included in the transport box. After unpacking, store the packing cartons and inserts. You may need them in case of a service or upgrade of your OCT system.

2.2. System Connections

2.2.1. Base Unit Connections

All of the base unit connections are located in the rear (see Figure 5).

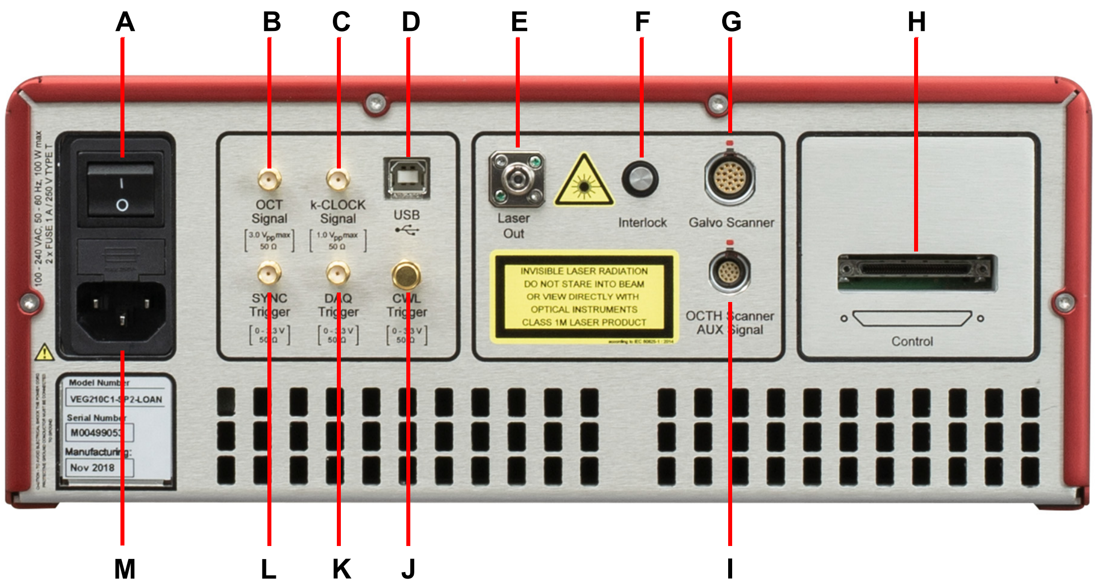

Figure 5 ***Rear View of Base Unit***

A. Main Switch

B. SMA Connector for OCT SIGNAL to connect to Alazar Tech. ATS9351 or ATS9360

C. SMA Connector for DAQ k-CLOCK to connect to Alazar Tech. ATS9351 or ATS9360

D. USB Data Port to Connect PC (USB 2.0 Type B Interface)

E. Probe Fiber Receptacle (FC/APC)

F. Interlock (2.5mm Audio Jack)

G. Scanner Connection Port (LEMO, 19 Pin)

H. VHDCI Data Port to Connect to the NI PCIe-6351

I. Handheld Scanner or Auxiliary Connection Port (LEMO, 14 Pin)

J. SMA Connector for CWL Trigger to Connect to Alazar Tech. ATS9351 or ATS9360

- **Note:** This port remains unused in a default configuration.

K. SMA Connector for DAQ Trigger to Connect to Alazar Tech. ATS9351 or ATS9360

L. SMA Connector for SYNC Trigger to Connect to Alazar Tech. ATS9351 or ATS9360

M. Power Plug and Fuse Storage

2.2.2. Internal Electrical Connections

The USB connection to the PC is used for the control communication between the Software and Base Unit. The acquisition and synchronization of the spectral information is using the SYNC Trigger connection.

2.2.3. Electrical Interfaces to Imaging Scanner

For the connection to a scanner application there are two different interfaces available:

- The scanner connection port is intended to be used together with dedicated Thorlabs imaging scanners OCTG and OCTP.
- The auxiliary connection port is intended to be used together with the dedicated Thorlabs imaging scanner OCTH and furthermore allows the use of a custom scanner. It hosts two analogue signals for driving separate actuators (e.g. Galvanometer scanner), communication lines and supply voltages.

Imaging Scanner – Electrical Interfaces	
Probe Connection Port	Lemo ECG.2B.319.CLL
Auxiliary Connection Port	Lemo ECA.1B.314.CLL

Table 1 Electrical Interfacess

Please contact Thorlabs' tech support for information regarding the pin configuration.

2.3. Optical Interface to Imaging Scanner

The base unit incorporates one FC/APC fiber interface depending on the internal fiber architecture. If not different due to customization, the single mode fiber used in the base units is given in Table 2:

Imaging Scanner - Optical Interface		
Base Unit Series	**Fiber Plug / Receptacle**	**Single Mode Fiber**
Vega	FC/APC	Corning SMF28e+

Table 2 Optical Interface

2.4. System Installation

ATTENTION

Make sure the included power cords for the base unit, computer and monitor are connected to a properly grounded outlet (100 – 240 VAC; 50 – 60 Hz).

Transportation and delivery may cause the OCT system to be warm or cool upon receipt. Please wait for the system to reach room temperature before attempting to operate.

Operate this system on a flat, dry, and stable surface only.

1) Install the PC, monitor, mouse, and keyboard according to the documentation provided by the PC manufacturer.

2) If applicable, assemble the OCT-Stand as described in the documents provided in the OCT-Stand box.

3) If applicable, mount the scanner in the OCT-Stand by sliding the dove tail at the back of the scanner into the dove tail slide of the OCT-Stand.

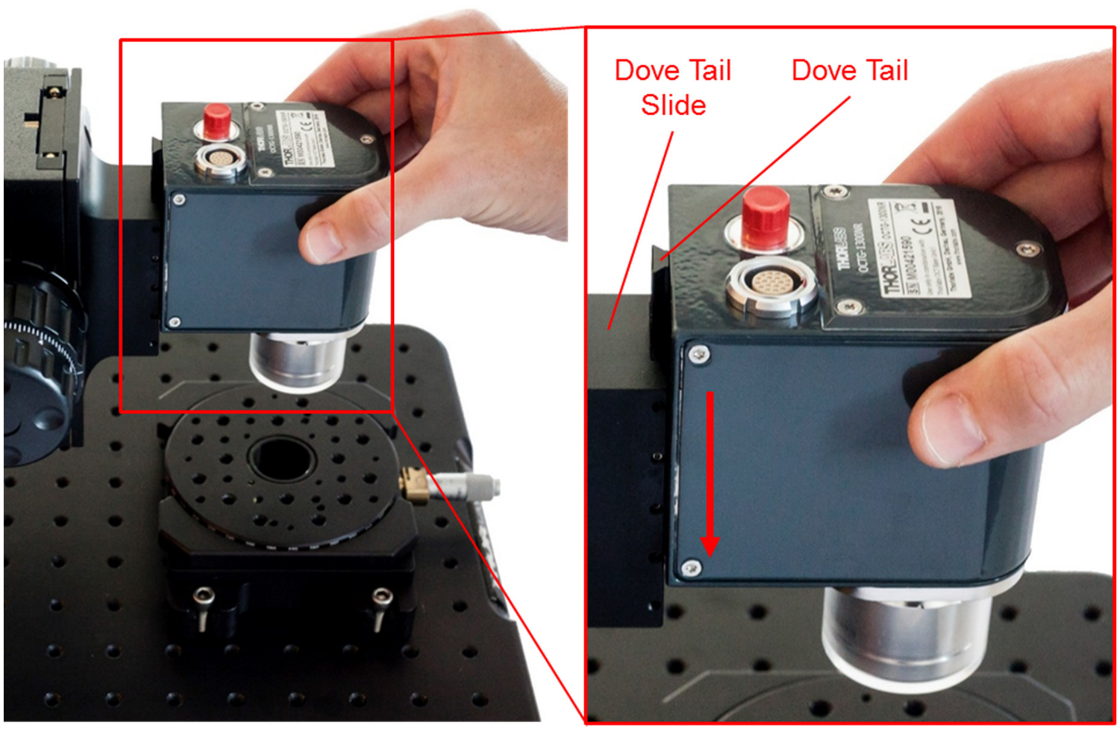

Figure 6 Mounting the Scanner into the Dove Tail Slide of the OCT-Stand

4) Connect the power supply plug to the socket of the base unit and connect the other end to an electrical outlet.

5) Attach the electric connection cable to the imaging scanner.

- Align the red dot of the plug to the alignment mark of the electric connection port of the scanner (e.g. OCTG).

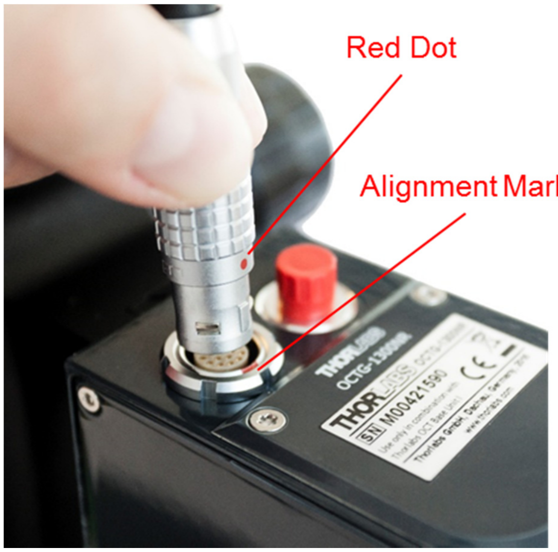

Figure 7 Plugging the Electrical Connector into the Scanner

- Push the connector into the plug until you hear a “click” sound.

Figure 8 Electrical Connector plugged into the Scanner

6) Fiber connection to the imaging scanner:

ATTENTION

When installing the fiber, make sure that the fiber tip does not get contaminated by dust.

Do not touch the fiber tip!

- Remove the dust caps from one fiber end and from the FC/APC fiber connection at the imaging scanner. Store these with the system packaging.

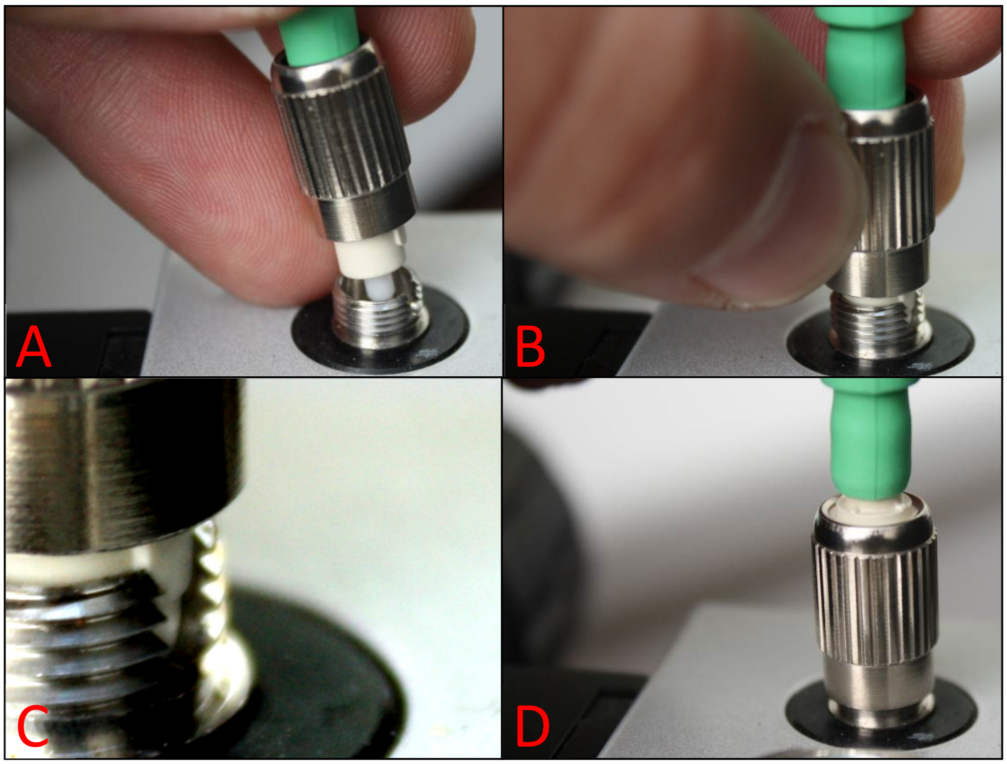

Figure 9 Fiber Connection to the Imaging Scanner

A) Slide the fiber tip into the center bore of the fiber connection.

B and C) The fiber needs to be rotationally oriented so that the alignment nose slides into the mating part of the probe connector as shown in C.
NOTE: If the nose slide is not properly aligned, you will still be able to secure the fiber but there will be significant light losses produced by this incorrect connection.

D) Secure the fiber connection by gently turning the lock cap clockwise.

7) Attach the electric connection cable to the base unit

- Align the red dot upwards, facing the alignment mark in the base unit.
- Push the connector into the plug until a "click" sound is heard.

Figure 10 Installing the Scanner Connection Cable at the Base Unit

8) Fiber connection to the base unit:

ATTENTION

When installing the fiber, make sure that the fiber tip does not get contaminated by dust.

Do not touch the fiber tip!

- Remove the dust caps from the fiber end and from the FC/APC fiber connection at the base unit. The fiber should be installed in a similar fashion as at the scanner. Follow the steps indicated in Figure 9 and make sure not to touch the fiber tip.

ATTENTION

The fiber is slightly longer than the interconnection cable to avoid stress to it. Please be careful not to pull the loop of the fiber at the back of the base unit!

Figure 11 Fiber Connection to the Base Unit

9) Signal, Trigger and USB connections at the Base Unit (see Figure 12):

- Attach the SMA cable labeled “k-CLOCK Signal” to the respective SMA port.
- Attach the SMA cable labeled “OCT Signal” to the respective SMA port.
- Attach the SMA cable labeled “DAQ Trigger” to the respective SMA port. NOTE: The CWLTrigger output can be used as an alternative DAQ Trigger, but this will require modifications of parameters for the data acquisition. By default the output is capped.
- Attach the SMA cable labeled “SYNC TRIGGER” to the respective SMA port. Make sure all the SMA connections are secured tightly.
- Attach the VHDCI cable to the respective port which is labeled “Control”. Make sure both fastening screws which are attached to the connector are bolted tightly.
- Connect the USB cable to the USB port and make sure the connection is tight.

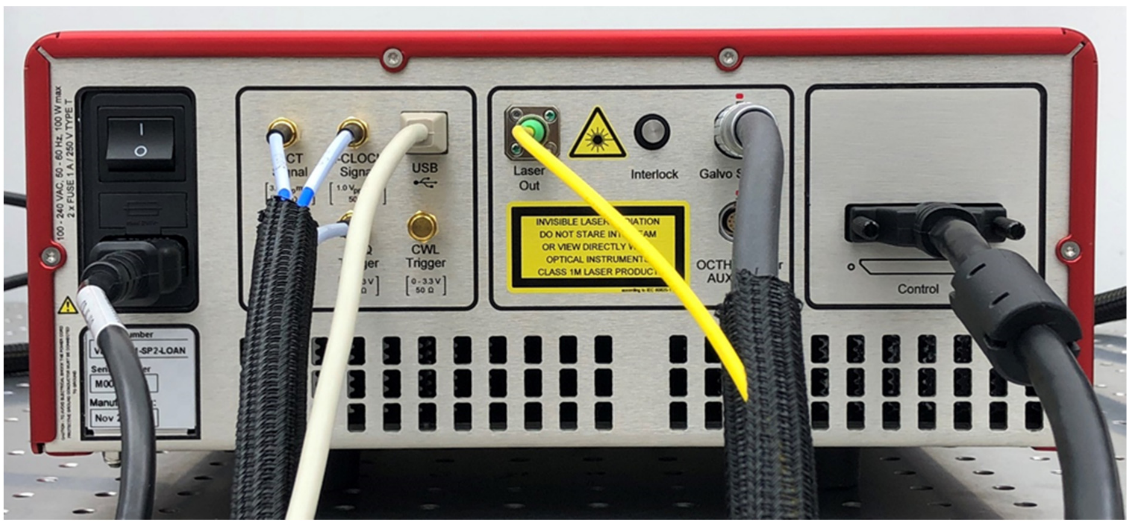

Figure 12 Installation of the Electrical Connections at the Base Unit

10) Connections at the PC (see Figure 13):

- Identify both the ATS9351 or ATS9360 DAQ card, and the NI PCIe-6351 DAQ card at the back of the PC (see Figure 13).
- Connect the VHDCI cable to the NI PCIe-6351 DAQ card. Make sure both fastening screws which are attached to the connector are bolted tightly.
- Attach the SMA end of the cable labeled “ECLK” at the ATS9351 or ATS9360 card marked as “ECLK”.
- Attach the SMA end of the cable labeled “CH B” to the respective SMA port of the ATS9351 or ATS9360 card marked as “CH B”.
- Attach the SMA end of the cable labeled “TRIG IN” to the second SMA port from the left marked as “TRIG IN”.
- Attach the SMA end of the cable labeled “AUX I/O” to the first SMA port from the left marked as “AUX I/O”. Make sure all the SMA connections are secured tightly.
- The SMA port marked as “CH A” is not used!

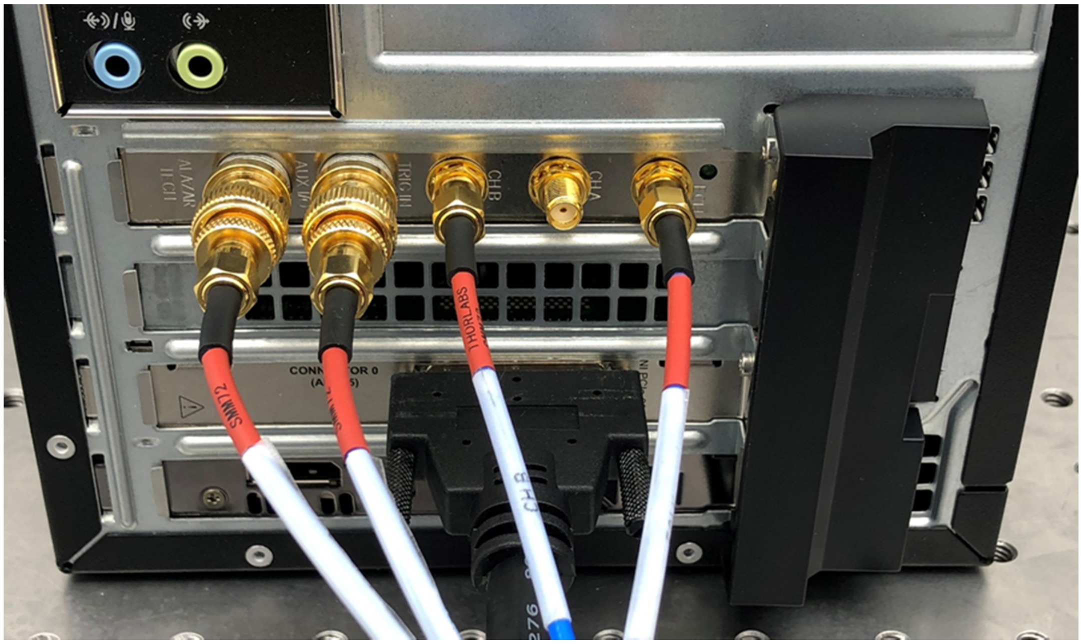

Figure 13 Connections of the Alazar (top) and NI DAQ (bottoms) Cards

15) Removing the protective cap off the scan objective:

Pull the protective cap off the scan objective. Do not rotate the protective cap, as this might loosen the fit of the illumination tube. Do not touch the optical surface of the lens.

Figure 14 Protective Cap Removal

Chapter 3 Description

3.1. Tutorial

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.

To obtain cross-sectional images with micron-level resolution using OCT, an 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: Spatially encoded Frequency Domain OCT (SeFD-OCT) and time encoded Frequency Domain OCT (TeFD-OCT), also named Swept Source OCT (SS-OCT). In both types of systems, light is divided by a fiber coupler into the sample and reference arms of an interferometer setup.

Back-reflected light, attributed to variations in the index of refraction within a sample, recouples into the sample arm fiber and then combines with the light that has traveled a fixed optical path length along the reference arm. The resulting interferogram is measured by either a spectrometer (SeFD-OCT) or balanced photodetectors (SS-OCT).

The frequency of the interferogram measured by the sensor is related to the depth location of the reflector 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; by doing so, 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 is collected to produce a 3D volume dataset.

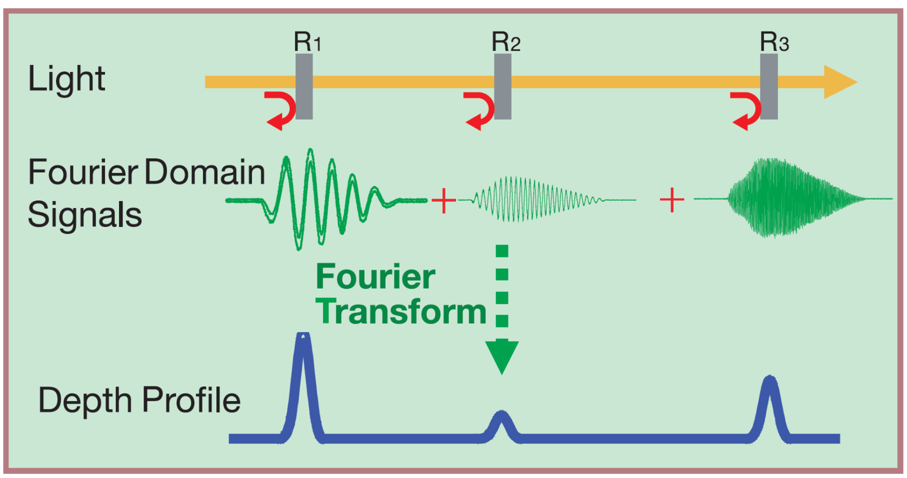

Figure 15 FD-OCT Signal Processing

3.1.1. Theory

The interference equation for the cross-correlated interference term is

$$I_{Interference} \sim 2 \cdot \sqrt{I_{Sample} \cdot I_{Reference}} \cdot \cos(\Delta\varphi)$$

With the phase difference $\Delta\varphi$ being a function of the optical path length difference and the wavenumber

$$\Delta\varphi = k \cdot \Delta \mathrm{z}$$

This optical amplification of a small sample intensity with a strong reference intensity allows the detection of single photons from the sample and is the key to the outstanding sensitivity of OCT.

Due to the reflective character of the measurement modality the optical path length difference is twice the distances in the image. The maximum imaging depth, and so twice optical path length difference, is defined by the wavenumber spacing of the acquisition δk.

$$\Delta z_{max} = \frac{1}{4 \cdot \delta k}$$

In Full-Range OCT setups the image depth could be doubled

The signal width has two limits,

- One limit for the signal width is given by the spectral distribution of the light source. For a fully used light source being Gaussian shaped in k the equation is:

  $$Signal_{FWHM,LightSource,} = \frac{2 \cdot \sqrt{\ln(2)}}{\Delta k_{LightSource}}$$

  with:
  $\Delta k_{LightSource} = Wavenumber\ Difference\ of\ Gaussian\ Shaped\ Light\ Source\ at\ I = I_0 \cdot e^{-1}$

- The other limitation for the signal width is given by the sampling. For a rectangular spectrum the FFT results in a sinc function

  $$Signal_{FWHM,Sampling,} = 1.21 \cdot spacing_z$$

  with:
  $spacing_z = Image\ Depth\ Spacing = \frac{2 \cdot \Delta z_{max}}{N}$
  $N = Number\ of\ aquisition\ points$

A light source is not shaped in a way that the autocorrelation function is clean normally. Therefore the shape should be apodized to get a clean point spread function. A good compromise between resolution and side lobe suppression could be a Hanning window showing a signal width of:

$$Signal_{FWHM,Hanning} = 2 \cdot spacing_z$$

In real mesurements the signal width is furthermore limited by noise, dispersion mismatch between sample- and reference arm of the interferometer, and optical path length distribution of the imaging caused by aberration.

3.1.2. Thorlabs SS-OCT System Technology

Swept Source Optical Coherence Tomography (SS-OCT) technology uses a rapidly tuned broadband source to illuminate the interferometer and records the information with a balanced detector. SS-OCT technology 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.

Advanced data acquisition and digital signal processing techniques are employed in the SS-OCT system to enable real-time video rate OCT imaging. The 2D OCT images are analogous to ultrasound images and show the cross-sectional structure view of the sample. The transverse and axial resolutions of the images are limited by the focusing optics and spectral bandwidth of the light source respectively. The actual imaging depth into the sample is highly dependent on the sample scattering properties at the measurement wavelength. The OCT system 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.

At the heart of the SS-OCT system is a swept laser source that tunes the lasing wavelength over a broad wavelength range, at hundreds of kilohertz repetition rate. Sample depth profile measurements are performed at the high sweeping rate of the laser. The interference signals from the sample are collected using a high-efficiency balanced detection scheme. Each sweep of the laser wavelength provides a depth scan at a sample surface point that yields a depth dependent reflectivity profile along the direction of the laser illumination path.

The SS-OCT system utilizes the latest MEMS-VCSEL swept laser as the light source to perform Fourier domain OCT measurements. The very short cavity length (on the level of a few micrometers) of the MEMS-VCSEL cavity enables very long coherence length (≥100 mm) of the source when sweeping at very high speed (a few hundreds of kHz). The very long coherence length of the MEMS-VCSEL swept laser supports the large depth measurement range in OCT experiments, as its distinctive advantage compared to conventional short external cavity (on the level of a few millimeters) based swept sources. The MEMS-VCSEL SS-OCT system is capable of providing highly detailed, 2D cross-sectional imaging of a sample’s internal structure, as well as computer generated 3D reconstruction of a volume near the sample surface. The internal structure of a sample can be accurately mapped via computer generated tomographic images.

The VEG200 Series Swept Source OCT systems (Vega) provide simultaneous multiple imaging channels for microscopic viewing of the sample. The *en-face* images, similar to those obtained from a conventional microscope, can be acquired from the video camera channel while the cross-sectional images that show the sample's internal structure are acquired from the OCT channel. Due to the novel data acquisition and signal processing methods employed, real-time video-rate imaging speed has been achieved on both channels.

The system includes a high-speed MEMS-VCSEL swept laser with -10 dB spectral bandwidth larger than 100 nm, and an average output power greater than 20 mW, sweeping at ≥100000 A-scans per second. The swept laser provides an A-scan trigger signal to be connected to the trigger input of the data acquisition device. The laser also has a built-in monitoring interferometer that provides the real-time clock signals to be connected to the external clock input of the data acquisition device. The main output of the laser is coupled into a fiber-based Mach-Zehnder interferometer located inside the imaging module. The light is split into the sample and reference arms using a broadband coupler.

In the reference arm of the interferometer, the light is reflected back into the fiber by a stationary mirror. In the sample arm, the light is fiber-coupled into the imaging scanner, collimated, and then directed by the XY galvanometric scanning mirrors towards the sample. A dichroic mirror is inserted into the beam path to reflect the visible light from the sample onto a CCD camera that records the conventional microscope images of the sample. The axial scans (A-scans) in the depth direction are performed at the sweeping frequency of the laser. The transverse scan (B-scan) is controlled by the galvanometric scanning mirrors and determines the frame rate of the OCT system. The light that exits the imaging scanner is focused onto the sample surface by an objective.

The schematic setup of the Vega swept source OCT system is shown in Figure 16.

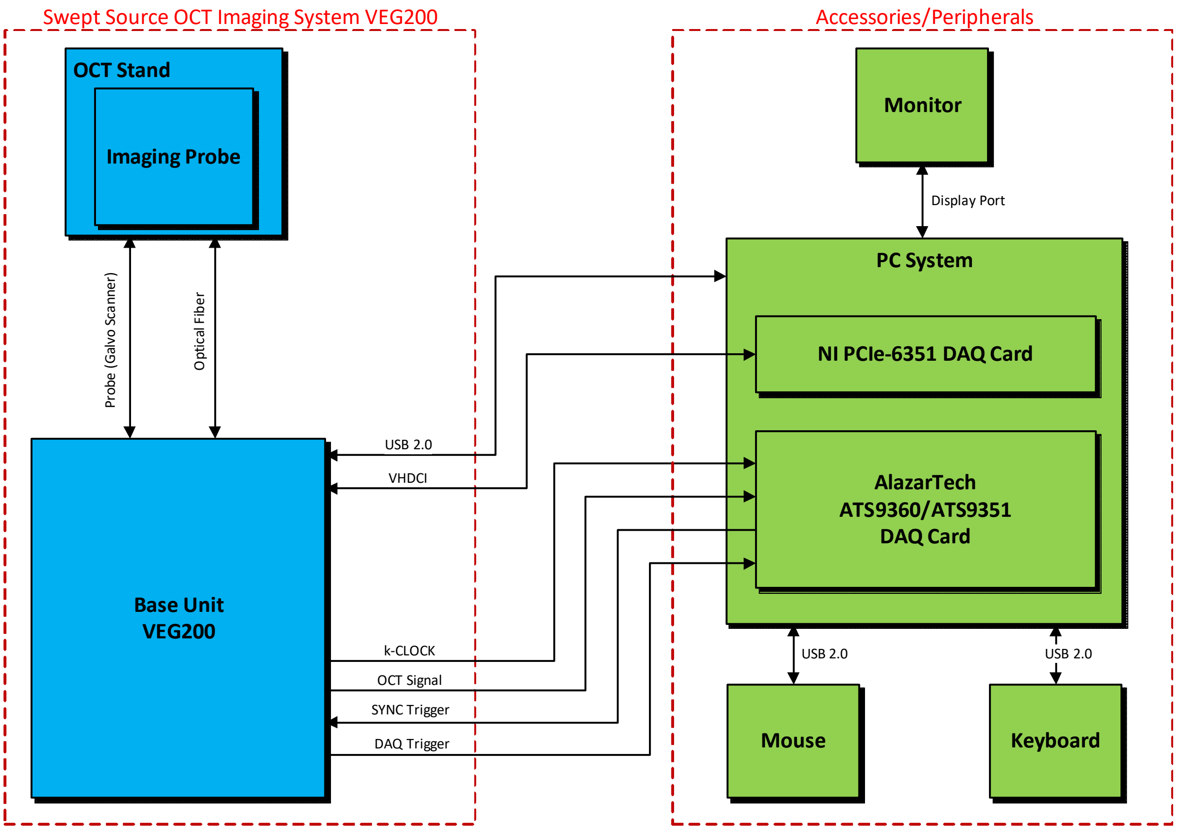

Figure 16 Schematic Diagram of the VEG200-Series Swept Source OCT System

3.1.3. Nomenclature in OCT imaging

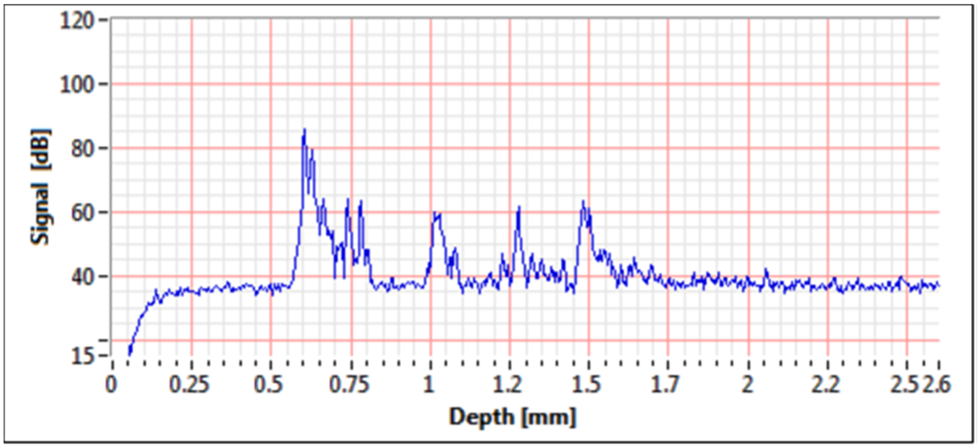

Figure 17 A-Scan Data Set

As described before, the FD-OCT engine creates a depth profile from the interference of photons sent into the sample and received back with photons reflected in the reference arm. This depth profile is referred to as an A-scan. Figure 17 shows a tomato's A-scan data. The ordinate of this graph represents the modulation amplitude based on the number of measured electrons per camera pixel. Other scales do not change the measurement.

The imaging application could make use of up to two scanning directions. When scanning one direction while collecting multiple A-scans, a 2-dimensional image is created. This is referred to as a B-scan. Here, the depth information is typically displayed from top to bottom, while the scan axis is from left to right. Figure 18 shows a B-scan data set.

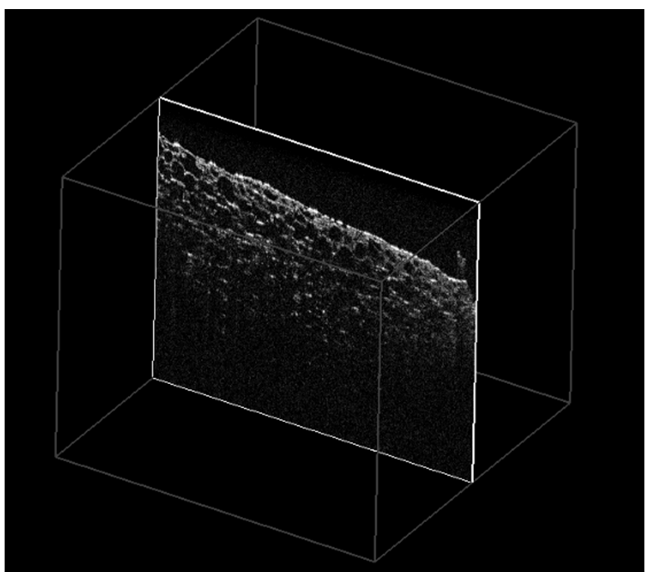

Figure 18 B-Scan Data Set

When scanning both galvanometer mirrors, a volume can be acquired. This can be imaged by movable sections through the volume or by 3D rendering. Please refer to the SD-OCT Software Manual for all features available.

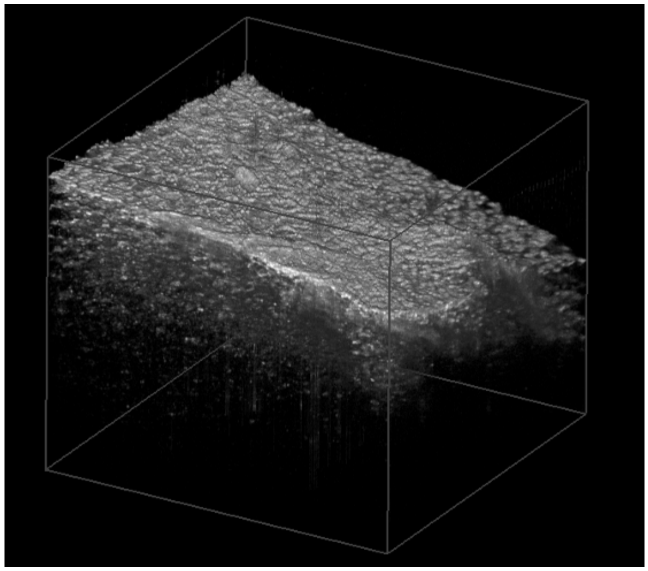

Figure 19 Rendered Volumetric Data Set

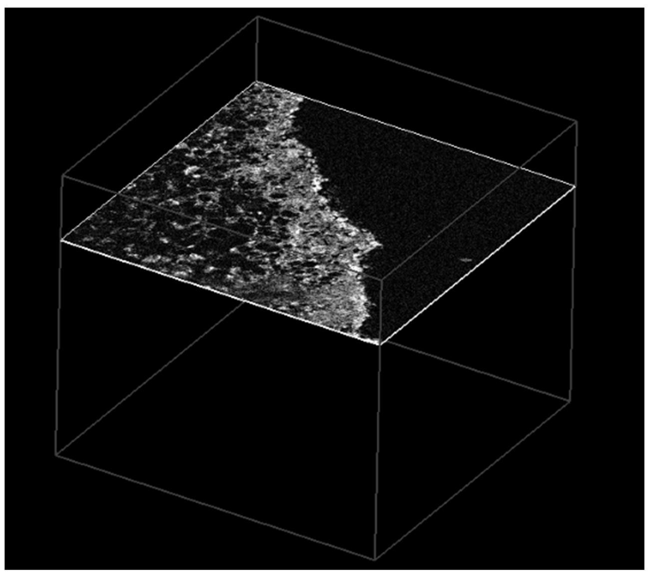

Figure 20 En-Face View or C-Scan

When displaying a plane with both scan directions as axes, an en-face image is created. Here, the viewing plane is parallel to the image plane of the color camera in the scanner. This plane is referred to as C-scan.

3.2. SS-OCT Base Unit Components

The base unit is delivered together with PC that has the ThorImage®OCT software pre-installed. Scanner, stand (OCT-STAND), and stage are not included in the base unit and must be ordered separately. When ordered together with a scanner, the system will be pre-assembled at Thorlabs and the PC settings will already be calibrated and optimized for the usage of the delivered OCT Scanner.

3.2.1. Base Unit

The base unit is the main component of the SS-OCT system. This unit sends light to the application, communicates with the PC through a USB connection, and delivers the measurement data to the PC. The base unit contains a MEMS-VCSEL Swept Source Laser which is directed through a fiber from the back panel of the device. The back-scattered and reflected light from the application is returned through the same optical fiber to an interferometer (as described Figure 16). Other components in the base unit include a balanced detector, analog and digital timing circuitry, analog control signals for the application, and data acquisition hardware.

Figure 21 Base Unit (VEG200 Series)

The central wavelength of the MEMS-VCSEL in the Vega base unit is typically 1300 nm. The use of near-IR broad sweeping bandwidth sources balances the desire for low scattering losses with the need to operate within the wavelength range that will provide higher penetration depth into the sample. Near-IR broadband sources are a perfect compromise between sufficient transparency and a significantly reduced scattering coefficient.

3.2.2. PC with Graphical User Interface

This SS-OCT system is delivered with application software made for the imaging scanners provided by Thorlabs. All required data analysis as well as 2D and 3D display can be performed within the software package. The data can be saved, analyzed and exported for further use.

Detailed operating instructions for the SS-OCT software are provided in the SS-OCT Software User’s Manual.

3.2.3. SDK

A software development kit (SDK) is provided with the system. The SDK gives access to all software routines used to control the units and to process the acquired data. It allows a quick start for application-specific software development. The SDK is implemented in two programming languages, C and LabVIEW. For professional and advanced users, the C interface guarantees a seamless integration into their own object oriented software. For easy access to the functionality we also provide a LabVIEW interface. The LabVIEW interface has the same functionality as the C interface and maintains the same high processing speed achieved with the C interface.

Hardware control through the SDK ranges from low level functions such as setting the galvo scanners to a desired position, to very powerful functions such as initiating full 3D measurements. The programmer can:

- define either a standard scanner provided by Thorlabs or create a software representation of a custom-built device.
- define simple or complex scan patterns.
- acquire simple A-Scans, B-Scans or complete volumetric measurements.

Processing of acquired OCT data ranges from simple A-Scan processing to advanced routines for Doppler speed measurements. The programmer can:

- take the standard processing steps necessary to convert a spectrum measurement into an A-Scan
- set the color scheme, brightness and contrast of images
- calculate the speed of particles in the sample via Doppler OCT
- import and export the different file formats data types

The function library also contains the source code for the LabVIEW software applications supplied with the instrument and other example programs. Often, these can be used as a starting point for software development projects.

The SDK can be installed from the USB device which ships with the system.

A complete documentation of the SDK with a description of all functions can be found in PDF format in the SpectralRadar SDK program group after installation of the SDK.

3.2.4. Imaging Scanner (Accessory)

Thorlabs SS-OCT systems use a dual path OCT setup in which the sample and the reference paths are split at the input of the interferometer. The reference path is set up inside the base unit. Thus, the imaging scanners presented below are “no-reference” (NR) versions.

Various lens kits are available for these scanners. Please note that the reference offers a motorized length adjustment so that changing to different lenses does not require any adapters.

For further detail please refer to the specific manual of the scanner.

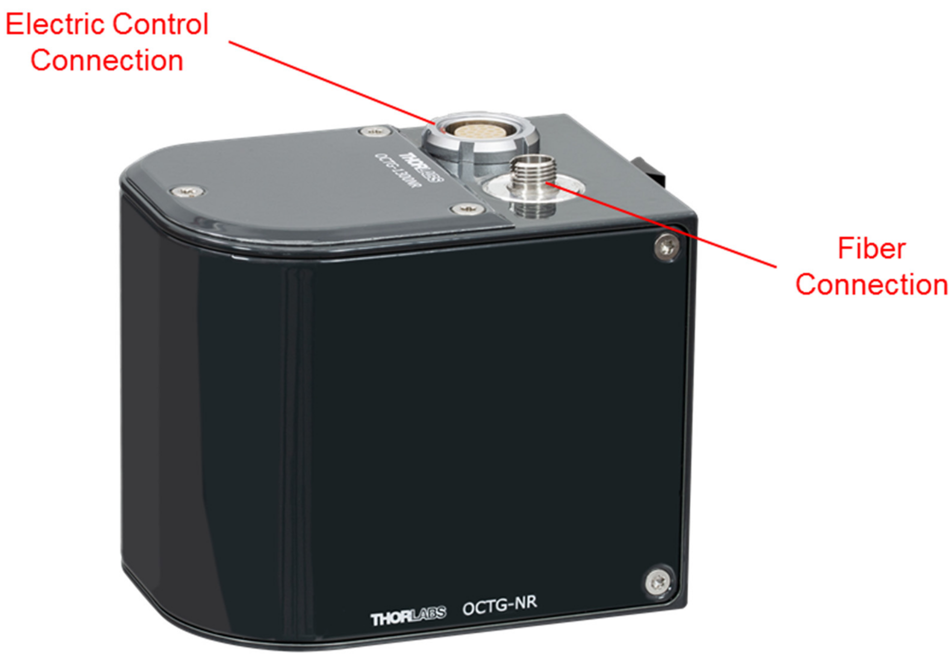

Figure 22 OCTG-NR Rigid Scanner

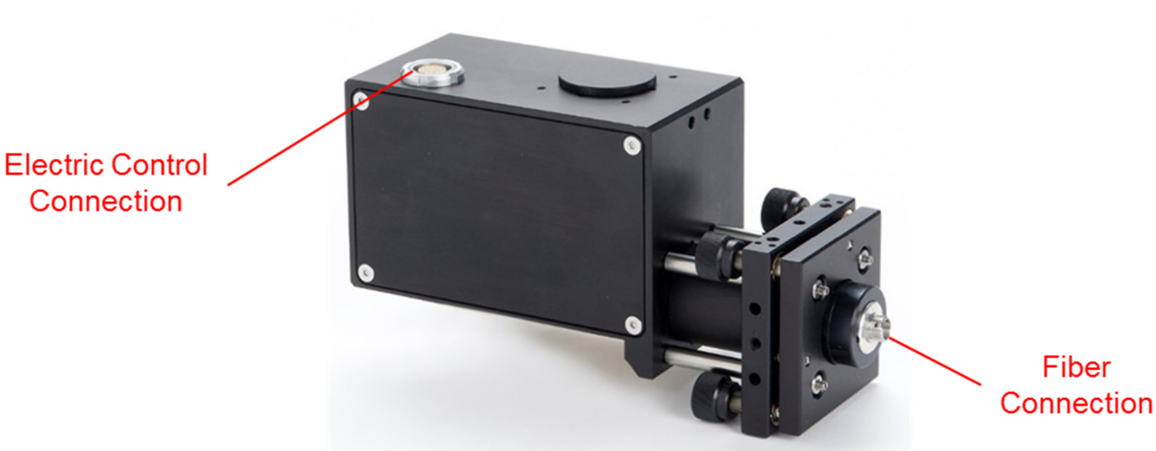

Figure 23 OCTP-NR Adjustable Cage-Compatible Scanner

Figure 24 OCTH-NR Handheld Scanner

3.2.5. OCT-Stand (Accessory)

The Thorlabs OCTG and OCTP scanners can be adapted to an OCT-STAND. For this OCT-STAND the rotation- and translation stage OCT-XYR1 is available.

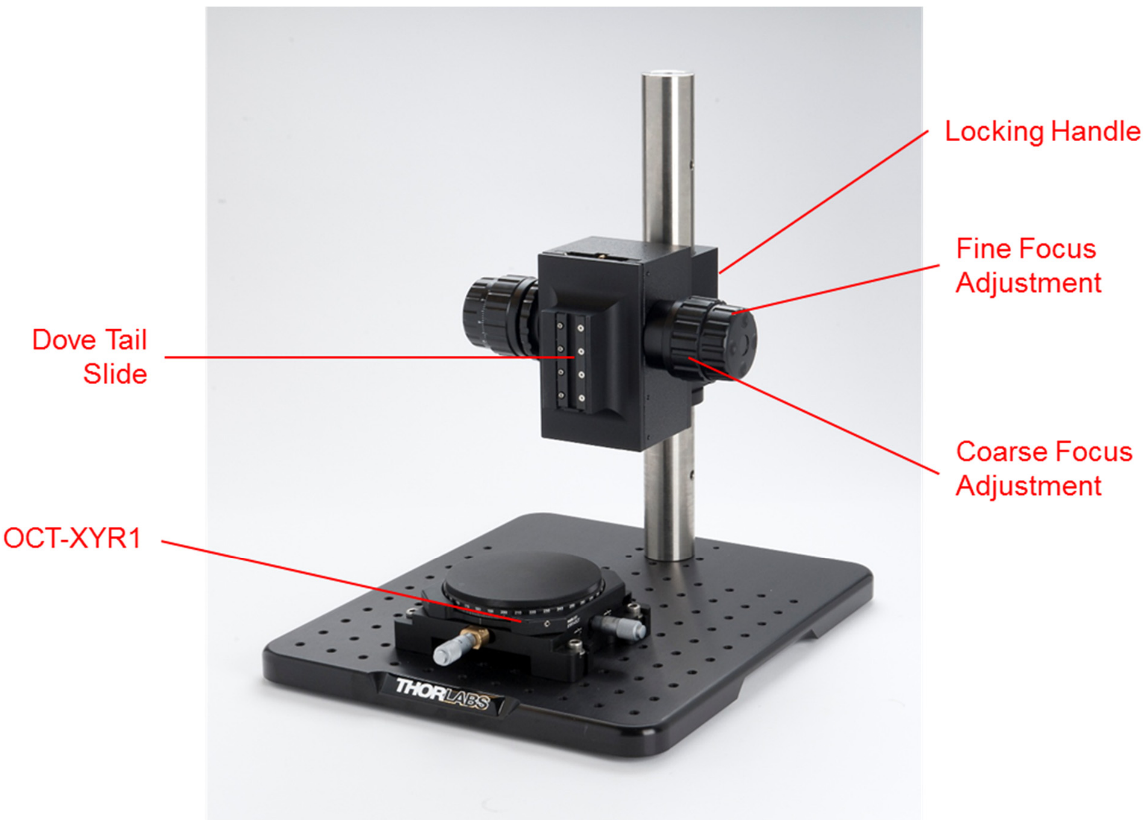

Figure 25 OCT-STAND with OCT-XYR1

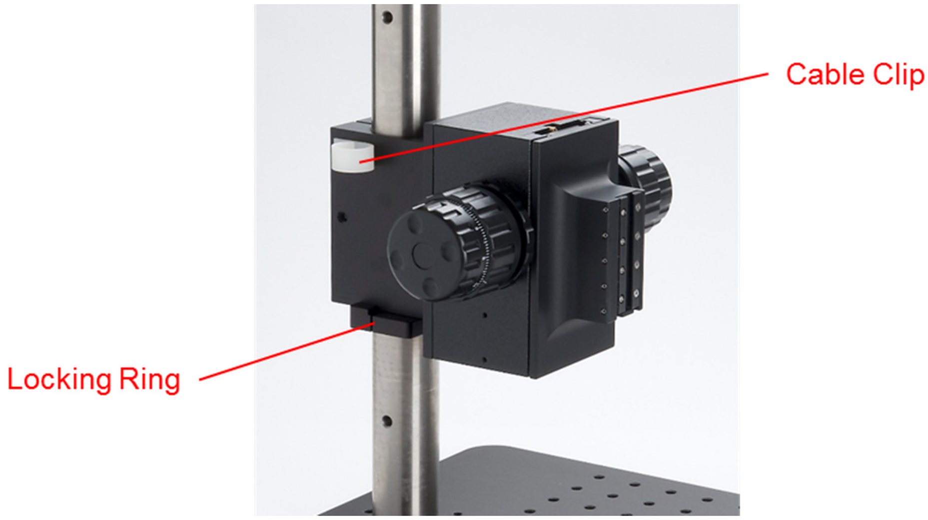

Figure 26 OCT-STAND Adjuster

Figure 27 OCT-XYR1 Sample Rotation Stage

For further details on the OCT-STAND and the OCT-XYR1 please refer to the Thorlabs web page.

Chapter 4 System Operation

4.1. Starting the System

Follow the steps described in the next three subchapters for proper initialization of the system. Your PC system should already be running.

4.1.1. Turning on the Base Unit

The following turn ON procedure is required for proper operation of the base unit.

1) Turn on the base unit by placing the main switch to the "|" Position. Verify that the power button indicator at the front panel turns red as shown in Figure 28. This indicates that you are in the "STANDBY MODE".

Figure 28 Base Unit Turn ON Step 1: Main Switch

2) Press the power button to power up the base unit. Verify that the power button indicator at the front panel turns green as shown in Figure 29. This indicates that the base unit is enabled.

Figure 29 Base Unit Turn ON Step 2: Power Button

4.1.2. Starting the Software

1) Start the ThorImageOCT software (see Software User's Manual for details). The system will be switched on via remote control from the computer. Wait for about 10 seconds until the PC has recognized the hardware. The green "Sys OK" LED should turn on indicating that the system is ready for use as shown in Figure 30. Furthermore, the ring-light illumination on the scanner should be turned on.

2) The laser source will be enabled with a short delay once the ThorImageOCT software was started. Verify that the green "Laser ON" LED is turned on as shown in Figure 30. In case something is wrong with the laser source or the system is not connected correctly, the software will show the respective error message.

Figure 30 Software Start: Indicator LEDs

3) In case the interlock pin was removed, a red "Interlock" LED will be turned on as shown in Figure 31. You will not be able to turn on the laser source. To enable the laser source again, push the interlock pin into the respective port and depower the base unit (the laser module requires a power cycle for a reset). The base unit can be powered up again. The "Interlock" LED should be turned off now and the system is ready for use.

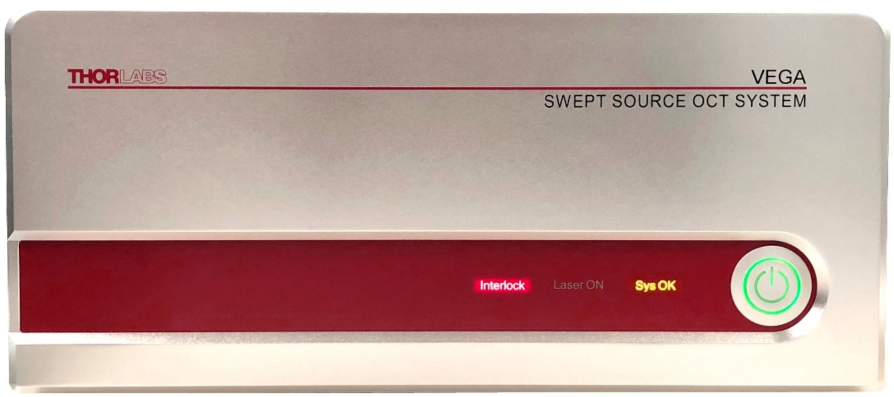

Figure 31 Interlock Error

4.2. Basic Adjustments

When receiving the SS-OCT system from Thorlabs, the reference length is adjusted so that OCT imaging in air is possible simply by adjusting the focus to the region of interest. If the reference arm length no longer matches the sample arm length, the following procedure will aid you to a good basic adjustment. For OCT imaging through refractive media, e.g. water or glass, please refer to chapter 4.3.2.

4.2.1. Adjusting the Focus

For a coarse adjustment of the focus, place a suitable sample, e.g. the IR viewing card delivered with the system, underneath the scanner. Using the OCT software, a fraction of the card can be seen in the sample monitor. Now adjust the height of the imaging scanner with respect to the card by adjusting the focus block of the OCT-Stand (see Figure 32) to obtain a sharp image.

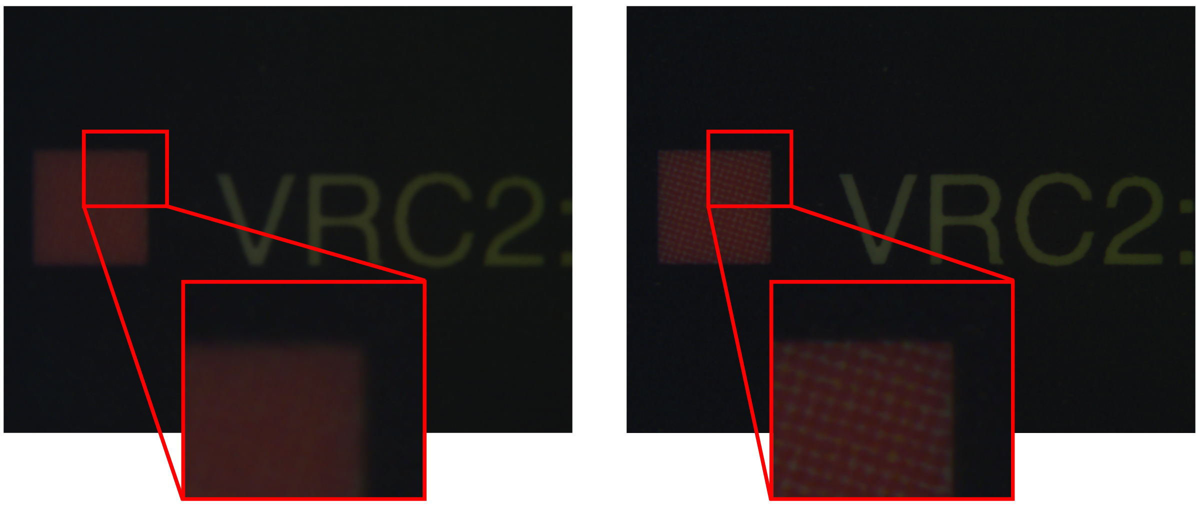

Figure 32 Basic Focus Adjustment

4.2.2. Adjusting the Reference Length

The Vega Swept Source OCT System is preset so that the “zero-delay” line is set to a depth position of 0 mm. This means that when the surface of the sample under test is placed in the focus of the objective in use, it will be shown at 0 mm of the imaging depth. However, in case of any misalignment due to shipping, etc., corrections can be made by adjusting the length of the reference path. Also, when using a different objective, the reference path length will have to be changed accordingly. The reference path in the Vega system is motorized and controlled through the GUI (ThorImageOCT) as indicated in Figure 33.

Figure 33 Reference Length Controls

For detailed information, please refer to the respective Software Manual section (Chapter 3: OCT Imaging → 3.1 Reference Length). Adjustment of the reference length may be done in combination with focus height adjustment (using the OCT stand), so that the focus position in the OCT data is shifted. Also, this adjustment is necessary when imaging in a refractive material.

The following steps will guide you to a basic adjustment of the reference length:

- Start B-scan acquisition. When significantly misadjusted, you will get an incorrect OCT image or no image of your sample, irrespective of the focus position.

- Use the jog buttons or the input field in the reference stage control to move the reference stage in both directions so that you can see how the image position is shifted.
- Find a value for the reference stage control so that the image is not “flipped” (upside-down). Use a sample where you know for sure what the top surface looks like.
- Hit the auto-adjust button (see software Manual) to adjust the dynamic range of your B-scan.
- When using the IR card for adjustment, your B-scan image should look as shown in Figure 34.

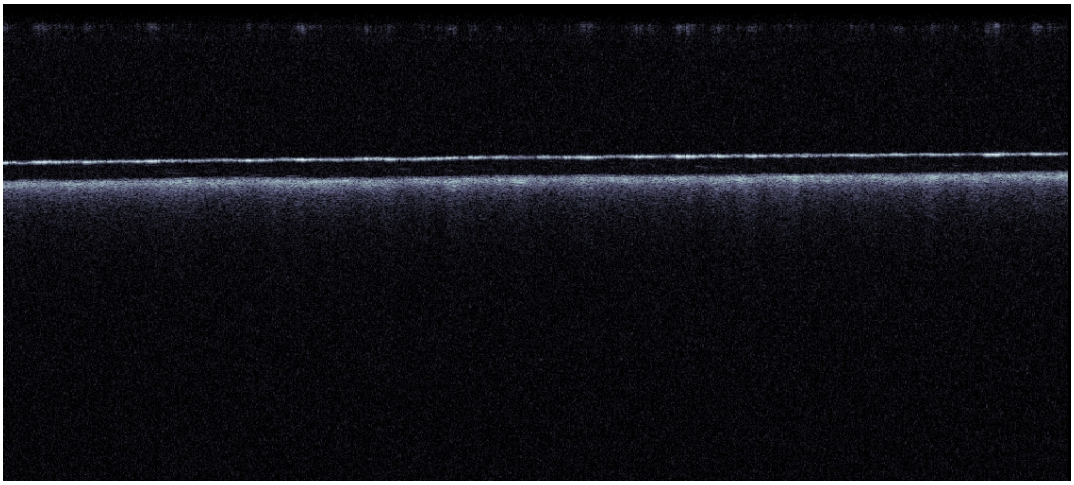

Figure 34 B-Scan of an IR Viewing Card

After basic alignment, you need to adjust the focus position inside your sample by use of the fine focus adjuster (see Figure 25) of the OCT-Stand. Then, the final position of the OCT image in the B-scan or volume scan can be set using the reference stage control again. Vary the value to move the image up and down until you achieve the desired location. Next time the system is restarted, the reference length will be set according to the last modifications made.

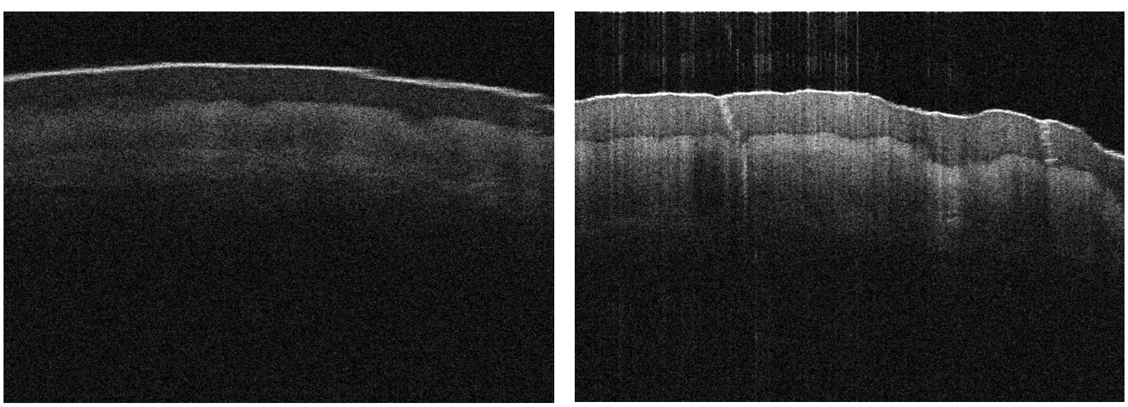

Figure 35 B-Scan of a Fingertip Out of Focus and In Focus

In Figure 35, two images of a fingertip are shown, the left is out of focus and the right is in focus.
The focus can usually be identified by one or more of the following features:

- Sharp (thin) features in lateral direction.
- Higher contrast (i.e. a strong signal). Note, that the focus does not always have to be on the top surface of your sample, but needs to be adjusted to the layer of interest in your sample.
- If the sample that you are using to find the focus is highly reflective, you are likely to get saturation resulting in strong horizontal lines in the image.

4.2.3. Adjusting the Polarization

If necessary, polarization in the reference path can be modified with the reference polarization controllers in the "Device Settings" tab as indicated in Figure 36.

Figure 36 Polarization Adjustment in the Reference Path

In order to adjust polarization in the reference path, there are two motorized controllers available, one acting as a QWP and the other as a HWP. By moving the sliders, the respective single and double fiber loops are rotated, thus changing the state of polarization. The principle of operation is identical to a paddle polarization controller offered by Thorlabs, as shown in Figure 37.

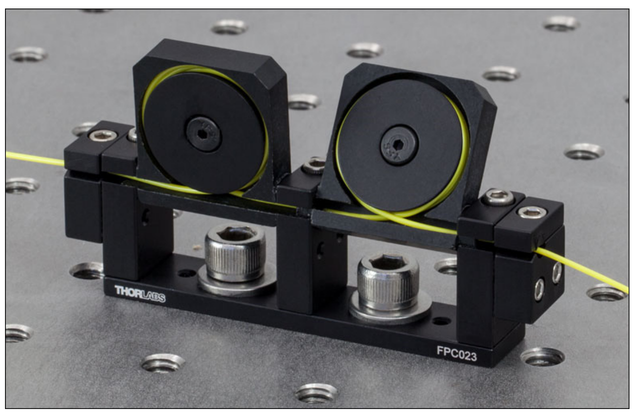

Figure 37 Padddle Polarization Controller by Thorlabs

4.2.4. Adjusting the Reference Light Intensity and Amplification

If required, the reference light intensity can be modified with the reference intenstity controller in the “Device Settings” tab. Especially when analyzing highly reflective samples, attenuation of the reference light may be necessary. In the unlikely case that no reference light is needed (e.g.: examination of auto-correlated signals in the sample path), the reference light can be blocked completely.

Moreover, the amplification level for the OCT signal can be modified as well. Depending on the characteristics of the sample under test, the amplification level and the reference light intensity should be adjusted in a way that the image is optimal. There are 7 amplification levels available, each level providing an additional amplification of roughly 6 dB.

Figure 38 Reference Intensity Adjustment and Amplification

For proper settings of your application, please refer to the respective section in the Software Manual (Chapter 3: OCT Imaging → 3.2 Sensor Saturation).

4.3. Advanced Adjustments

4.3.1. Focus and Choice of Objective Lens

In OCT, an objective lens is used to focus the light beam on and into the sample and also to collect the backscattered light. The focused nature of the beam means that the lateral extension of the beam is different along the depth axis. Since OCT records signals along this depth axis, the collected signal corresponds to different lateral extensions of the beam and therefore the resolution is different along the depth axis. The best resolution can be obtained from the axial focus plane; the further away from the focal plane the light is backscattered from, the more blurred out the signal will appear.

The length of the axial focus depends on the optics of the OCT system, especially on the choice of the objective lens. For samples with a small axial focus length, an objective lens with a high numerical aperture can be chosen. This will grant a small lateral and axial focus, hence allowing a more in-depth analysis of the sample but also restricting the axial depth that can be investigated. For samples with a deep region of interest it is helpful to choose an objective with a low numerical aperture, thus being able to collect signals from a large focus band. However, low numerical aperture objective lenses will decrease the lateral resolution of the image.

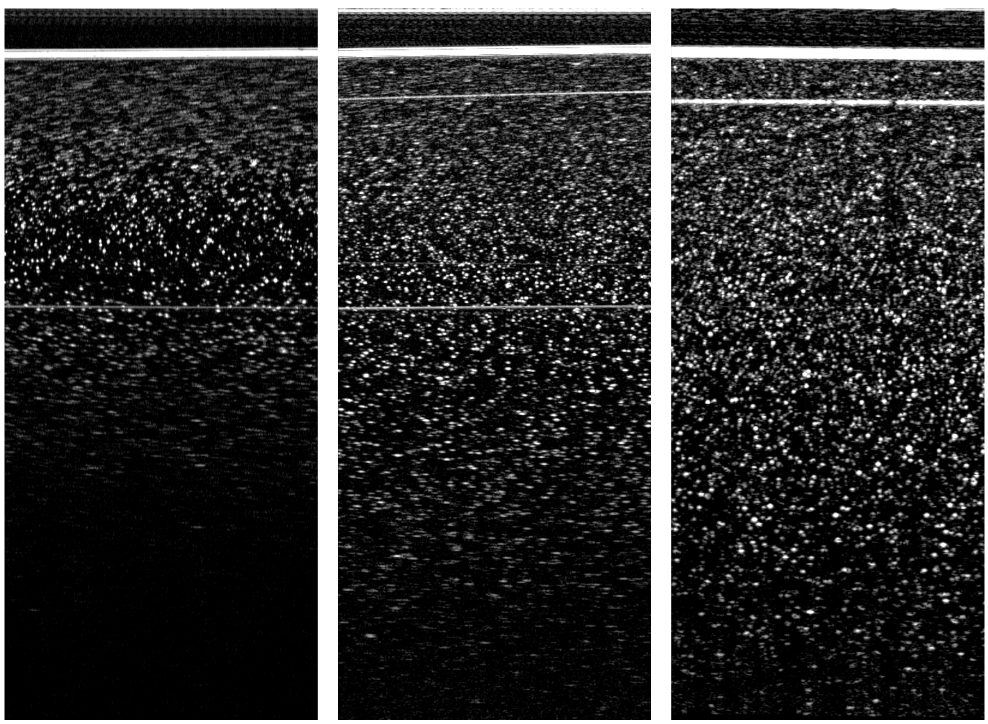

Figure 39 ***OCT B-Scans of scattering particles taken with LSM02, LSM03, and LSM04***

Thorlabs offers three objective lenses for different purposes. Figure 39 shows the difference in lateral resolution and depth of focus for the LSM02 (high resolution imaging), LSM03 (general purpose), and LSM04 (high depth of focus). Note the change in signal strength and lateral resolution over depth caused by an increasing focus band.

Please contact Thorlabs for more information on how to incorporate different objective lenses in your OCT system.

4.3.2. Imaging through Refractive Media

To acquire OCT images, the optical path lengths of the sample arm and reference arm have to be matched. When imaging through refractive media,

- The optical path length of the sample arm is increased, which has to be compensated in the reference arm (for more details see chapter 5.6).
- The amount of dispersion changes, which can be compensated using the ThorImageOCT software.

Every time the amount of refractive media is changed, this procedure has to be repeated in order to achieve a good image quality.

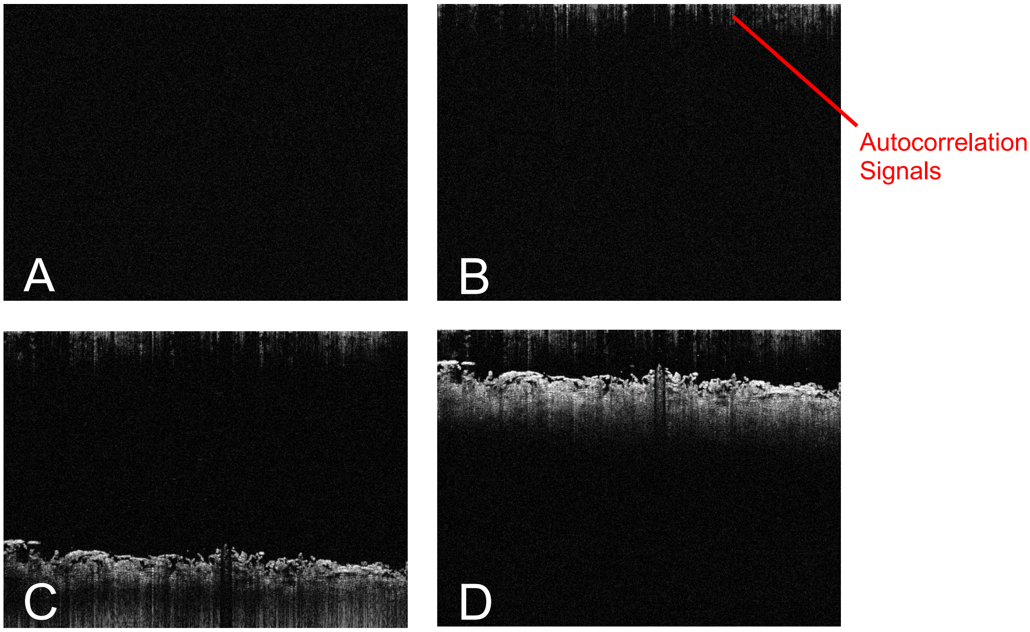

Figure 40 Step by Step Adjustments when Imaging through Refractive Media

Instead of adjusting focus and reference arm length at the same time, it is often helpful to first find the focus and then adjust the reference arm length. Figure 40 shows this procedure step by step, starting with a sample that is out of focus and with a misaligned reference arm, so that no sample can be seen in the B-scan (Figure 40 A). After finding the focus, autocorrelation terms will appear in the upper part of the image even without any reflecting surface in the field of view of the B-scan. When these artifact signals are the strongest stop focusing and adjust the reference arm length so that the image appears in the top half of the window.

Furthermore, the refractive media will introduce dispersion effects, i.e. washing out due to a dependence of the phase velocity on the wavelength. This can be compensated using the ThorImageOCT software (for more details see the software manual). Note that the amount of dispersion depends on the thickness of the refractive media, hence, the dispersion compensation has to be changed every time the thickness of the refractive media is changed.

Note: If you are able to identify autocorrelation signals but are not able to move the OCT image into the observable window, the optical path length of the sample arm is likely increased to an extent that cannot be adjusted by the reference arm anymore. Thorlabs offers a special reference arm adapter to further increase the reference arm length, please contact Thorlabs for more information.

4.3.3. Reflecting Surfaces and Interfaces

Reflecting surfaces and interfaces might lead to a saturation of the detector and in turn lead to artifacts described in more detail in chapter 5.1. The influence of the artifacts can be decreased by tilting the probe or the sample. By doing that, the reflections from the sample are directed back at a different angle than the incident beam and are not collected by the objective lens.

4.3.4. Rough Surfaces

Rough interfaces between two layers with different refractive indices will lead to reduced sensitivity. The reason is that the sample light is scattered at the interface and directed in various directions. Here, it is often helpful to use an immersion gel and a flat surface (e.g. a glass slide) to reduce scattering.

Thorlabs offers sample z-spacers that provide a glass plate at a fixed distance to reduce scattering effects and to keep the sample in focus, please contact Thorlabs for more information.

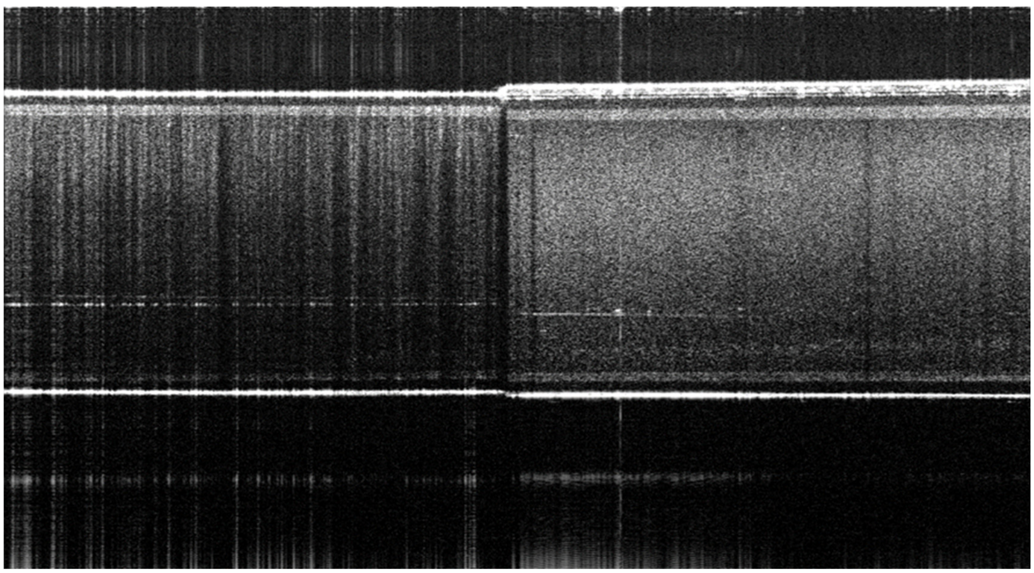

Figure 41 Plastic with Matte Surface, Partially Covered with Clear Adhesive Tape

Figure 41 shows a B-scan of a plastic substrate with a matte surface. The right part of the surface was covered with a strip of adhesive tape to make the rough surface smoother. Due to this smooth surface, the OCT image is much more consistent and the contrast in deeper layers is much better compared to the plain matte surface that is shown on the left. This is the same effect that can be seen when looking through a transparent material with a matte surface. As an example, frosted glass becomes more transparent with water.

4.4. Shutting Down the System

The following steps should be followed when shutting down the system:

1) Save any important data.

2) Stop imaging by ceasing the scan. Close the ThorImageOCT software. The indicator LEDs “Laser ON” and “Sys OK” should turn off when the software is closed.

3) Press the power button at the front panel to disable the system. The power button should turn from green to red indicating that the system is in standby.

4) You can leave the Base Unit in the standby mode (the power consumption is minimal), or

5) you can turn off the Base Unit completely using the main power switch at the back panel.

6) Shut down the PC.

4.5. Example Images

Spectral Domain OCT can be used for a wide range of real-time monitoring applications in biological and clinical fields as well as in manufacturing and materials science. This technology is ideal for in-line industrial imaging applications ranging from laminated packaging films to 3D visualization of mechanical parts.

Skin Imaging

SS-OCT provides real-time high resolution surface and sub-surface imaging of human skin, making this system ideal for many dermal and sub-dermal applications, including burn-depth monitoring, wound healing, and cancer detection.

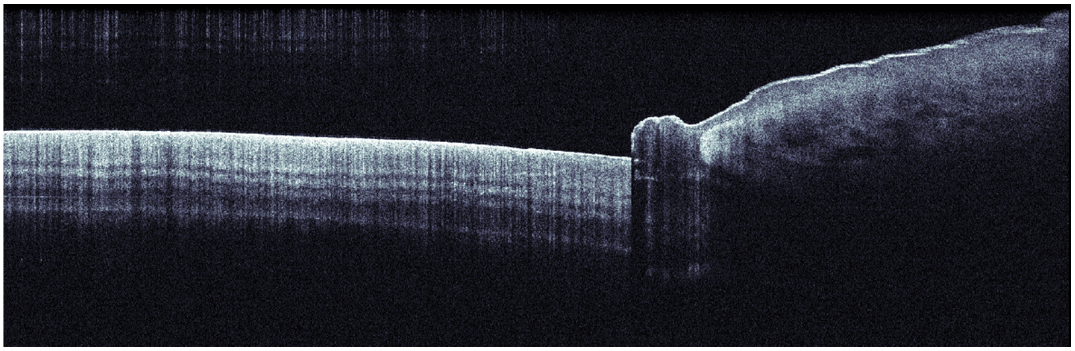

Figure 42 B-Scan of a Nailfold

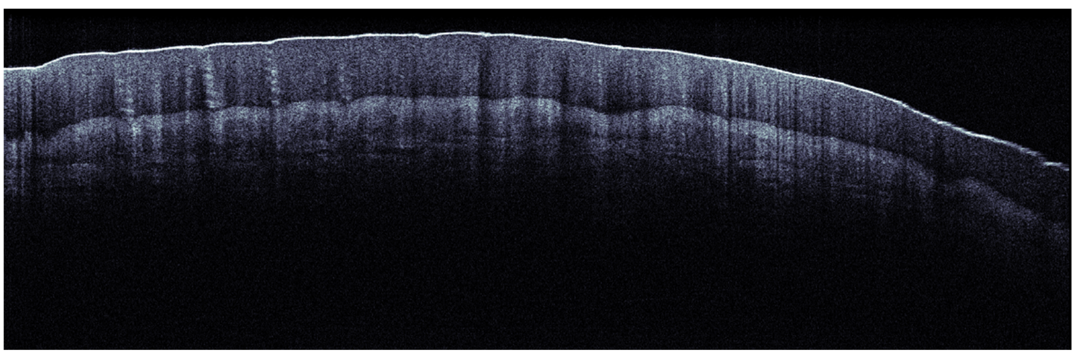

Figure 43 B-Scan of a Fingertip

Material Imaging

SS-OCT can also be used for non-biological material science applications. SS-OCT is ideal for monitoring surface topography and layered structures.

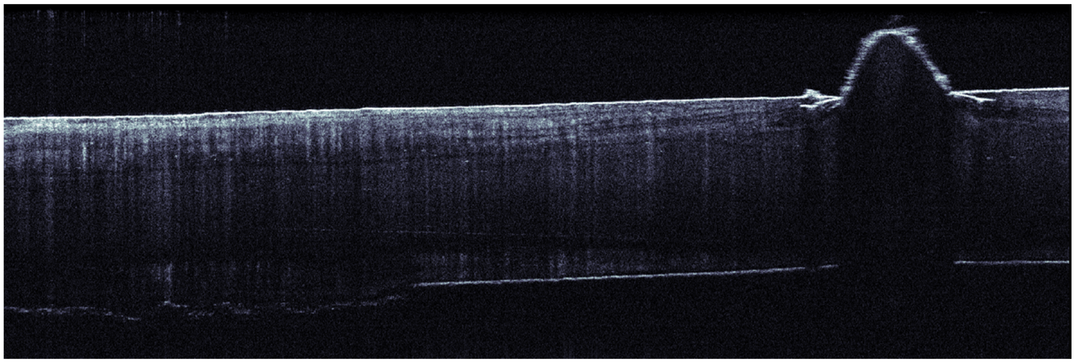

Figure 44 B-Scan of a Semi-Transparent Molded Plastic Cap

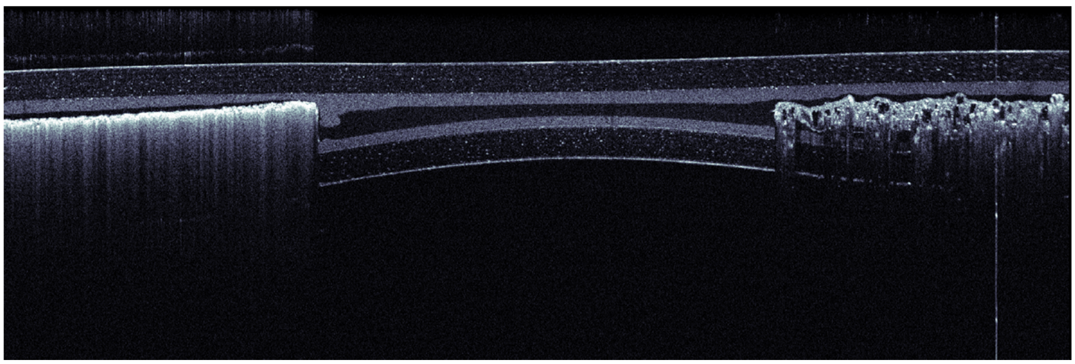

Figure 45 B-Scan of a Laminated IR Card

Biological Imaging

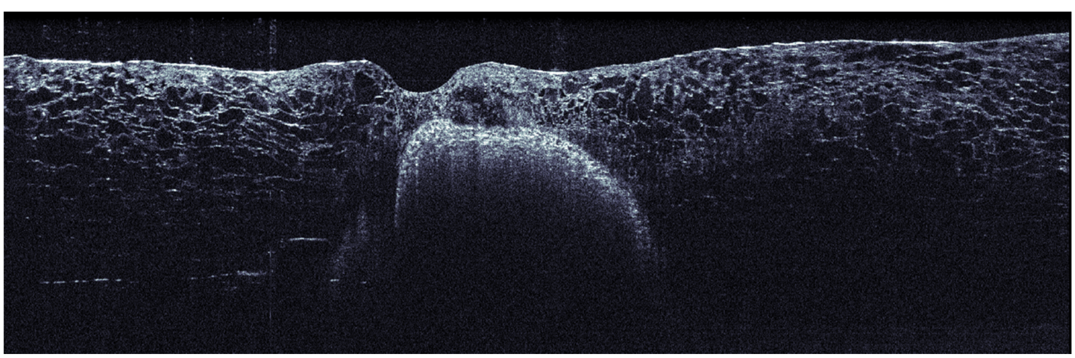

Figure 46 B-Scan of a Section of a Grape

Chapter 5 Imaging Artifacts

5.1. Saturation and Non-Linearity

The OCT A-scan data is created by frequency analysis of the spectral data generated by the spectrometer. Intense reflection from the sample can saturate the sensor of the spectrometer or illuminate very close to saturation. This effect broadens the signal and leads to a nonlinear response. For example, a sinusoidal optical signal is interpreted as partially rectangular. Consequently, additional harmonic frequencies of the root signal appear.

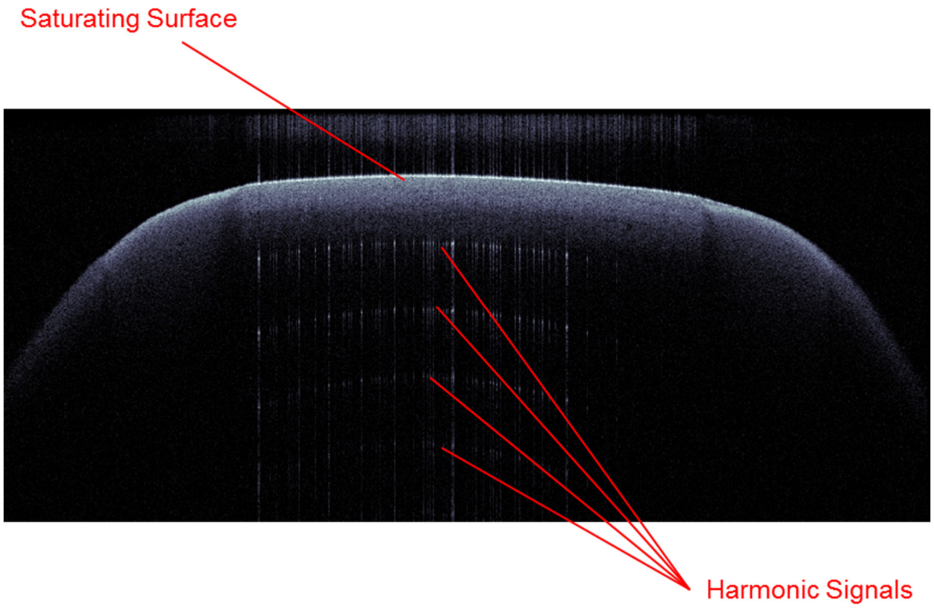

Figure 47 ***High Surface Reflection Causing Saturation and Nonlinear Response of the Spectrometer***

A typical example of this effect is shown in Figure 47. Saturation can be reduced or avoided by:

- Changing focus position
- Tilting the sample with respect to the A-scan axis
- Introduction of a wedge into the optical path (first reflex reflecting outside of NA) and immersion (see Figure 48)

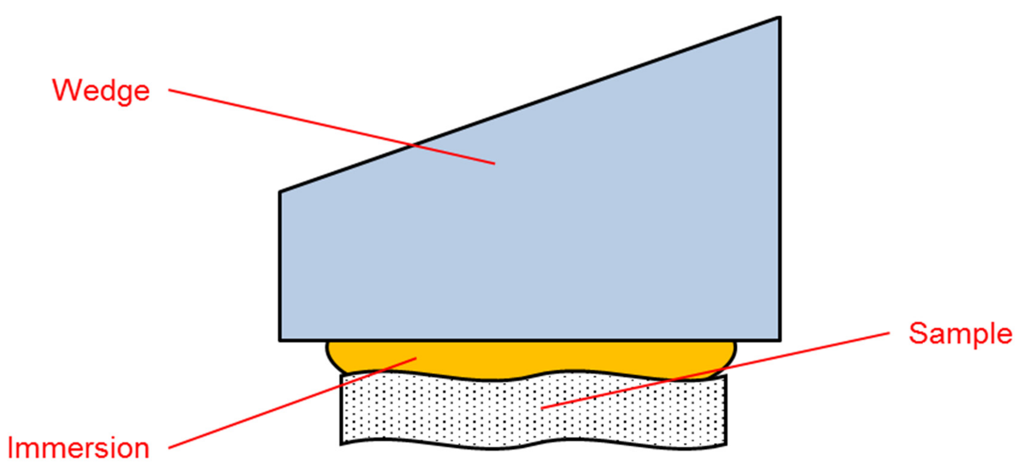

Figure 48 ***Avoiding Strong Surface Reflection by Use of an Immersed Wedge***

When operating with a wedge, the image will be tilted in the direction of the wedge angle. When scanning in the orthogonal direction, no tilt occurs.

5.2. Multiple Scattering

When imaging highly scattering material, a large portion of the photons returned to the detection system have been scattered multiple times from travelling into the sample until exiting. Since OCT visualizes the relative travelled path lengths of photons, signals from multiple scattered photons are shown deeper in the image than physically present.

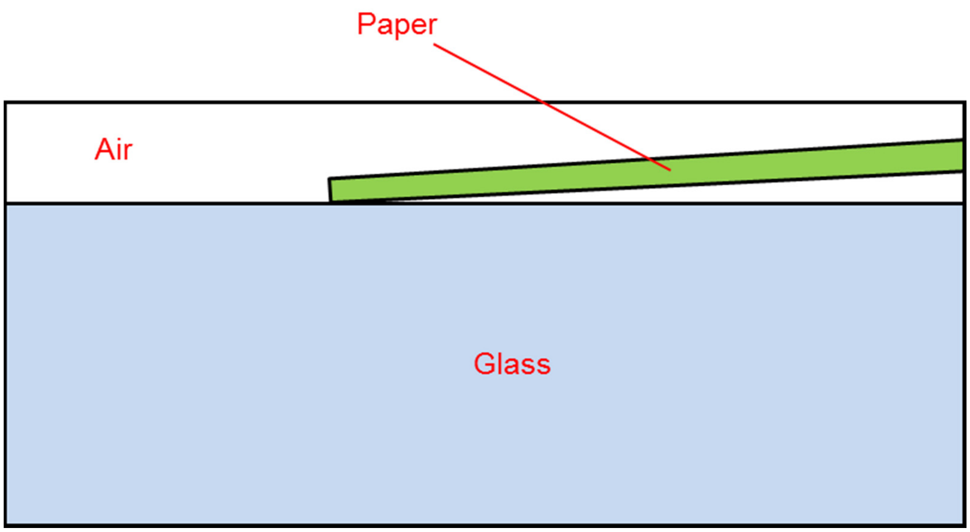

Figure 49 Schematic of a Setup to Show the Influence of Multiple Scattering

Multiple scattering is intense in paper. For illustration of this artifact, a setup as depicted in Figure 49 is imaged. Here, a piece of paper is placed over a glass substrate.

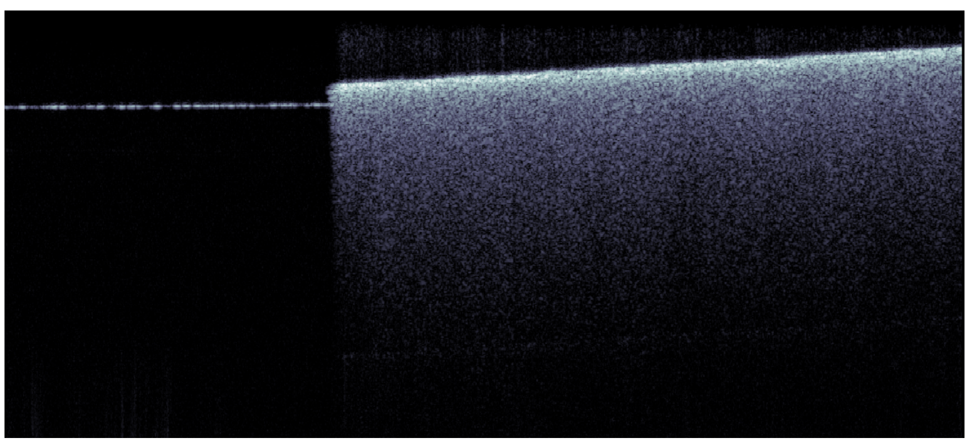

Figure 50 OCT Image Showing Multiple Scattering

In the OCT image (see Figure 50), one can clearly see that the paper appears to be very thick. This apparent thickness is induced by the relatively long travel of photons that are scattered multiple times before finding their way back into the detecting aperture.

5.3. Phase Wrapping and Fringe Washout

The A-scan data created by the SD-OCT system is produced from spectral information of an optical interference. Depending on the system setting, a certain integration time is applied for acquisition of each A-scan. Certain movement of the sample or parts of it can well be detected by comparing the phase information of adjacent A-scans. This Doppler Imaging mode is provided by the SD-OCT Software (please refer to the SD-OCT Software Manual for details). Sample movements of more than ¼ of the detected wavelength λ (from A-scan to A-scan) lead to misleading results. The maximum detectable speed (in direction of the A-scan axis) is

$$v_{\max} = f \cdot \frac{\lambda}{4}$$

For an A-scan rate of f = 1.25 kHz at 930nm, the maximum detectable speed v (in the direction of the A-scan axis) is 290µm/s. When the direction of the movement occurs at an angle with respect to the A-scan axis, larger speeds can be imaged.

For larger movements within the integration time of the detector, a complete washout of the interference will occur.

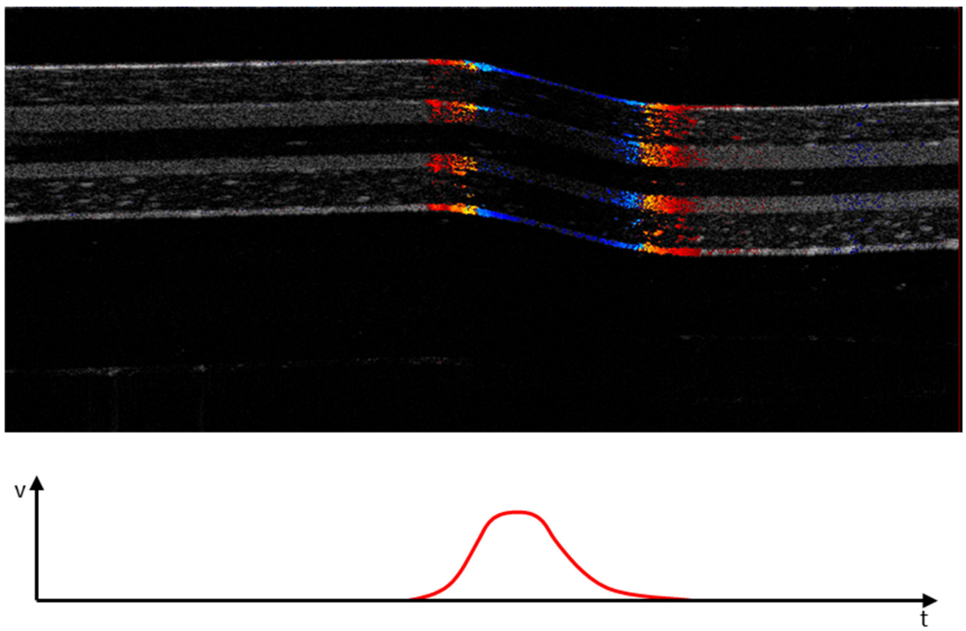

Figure 51 Sample Image Showing Fringe Washout and Phase Wrapping

To illustrate these effects, a sample has been moved quickly while slowly acquiring a B-scan. Figure 51 shows the result. The intensity data is shown in black and white, while the Doppler information is displayed red to blue. When the movement starts, the Doppler information is displayed red which means that the sample moves down. Now at increasing speed, the Doppler information turns blue. This means that the phases of the signal have wrapped and an inverse speed is shown. In the middle of the movement where the speed is at its maximum almost no OCT data is displayed (fringe washout).

5.4. Flipped Image

Without the introduction of additional techniques not provided by the standard SS-OCT system, there is no distinguishing between photons that traveled a distance Δd shorter or longer from the beam splitter to the sample compared to the reference arm length. When adjusting the reference length to be too long, the image appears flipped.

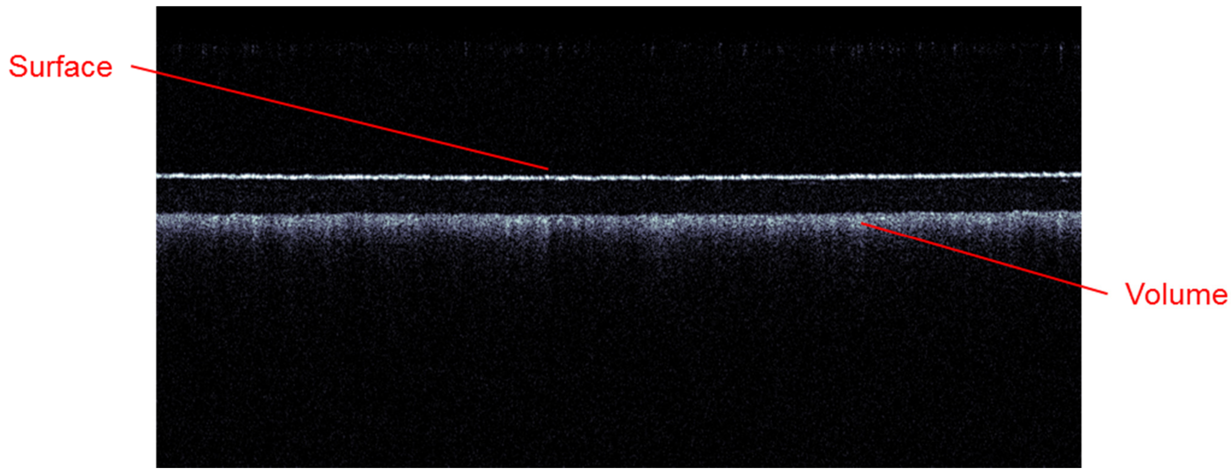

Figure 52 Right Orientation Up Reference Length Adjustment for Imaging of an IR Viewing Card

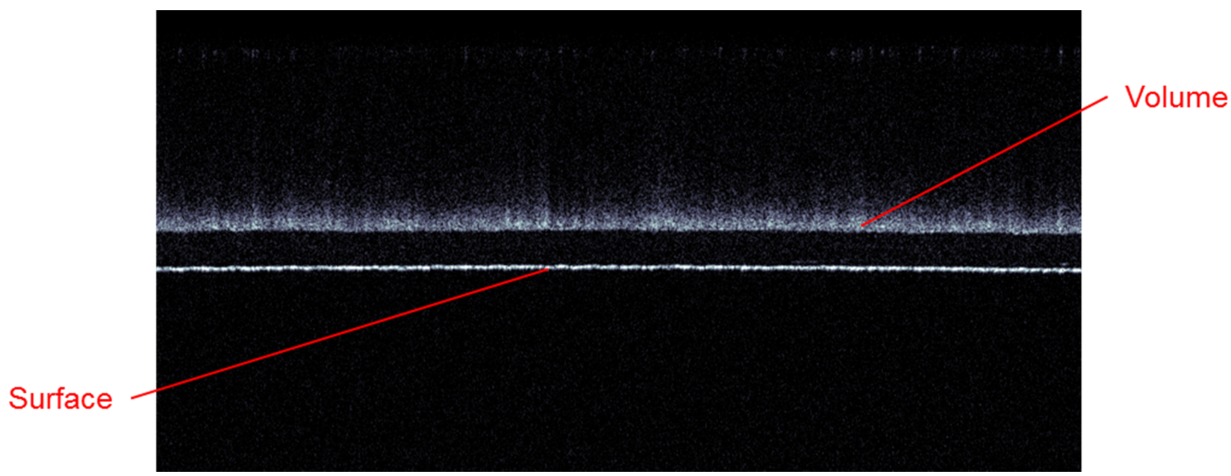

Figure 53 Upside Down Reference Length Adjustment Showing a Flipped Image

Figure 52 and Figure 53 show the different adjustments of the reference length when imaging the IR viewing card provided with the system.

5.5. Shadowing

Since the SS-OCT imaging uses light for detection of depth information, one can only see information from regions in the sample where photons are transmitted to and allowed back into the sampling aperture. Reflections, strong scattering and absorption lead to shadows in the depth distribution of the data acquired.

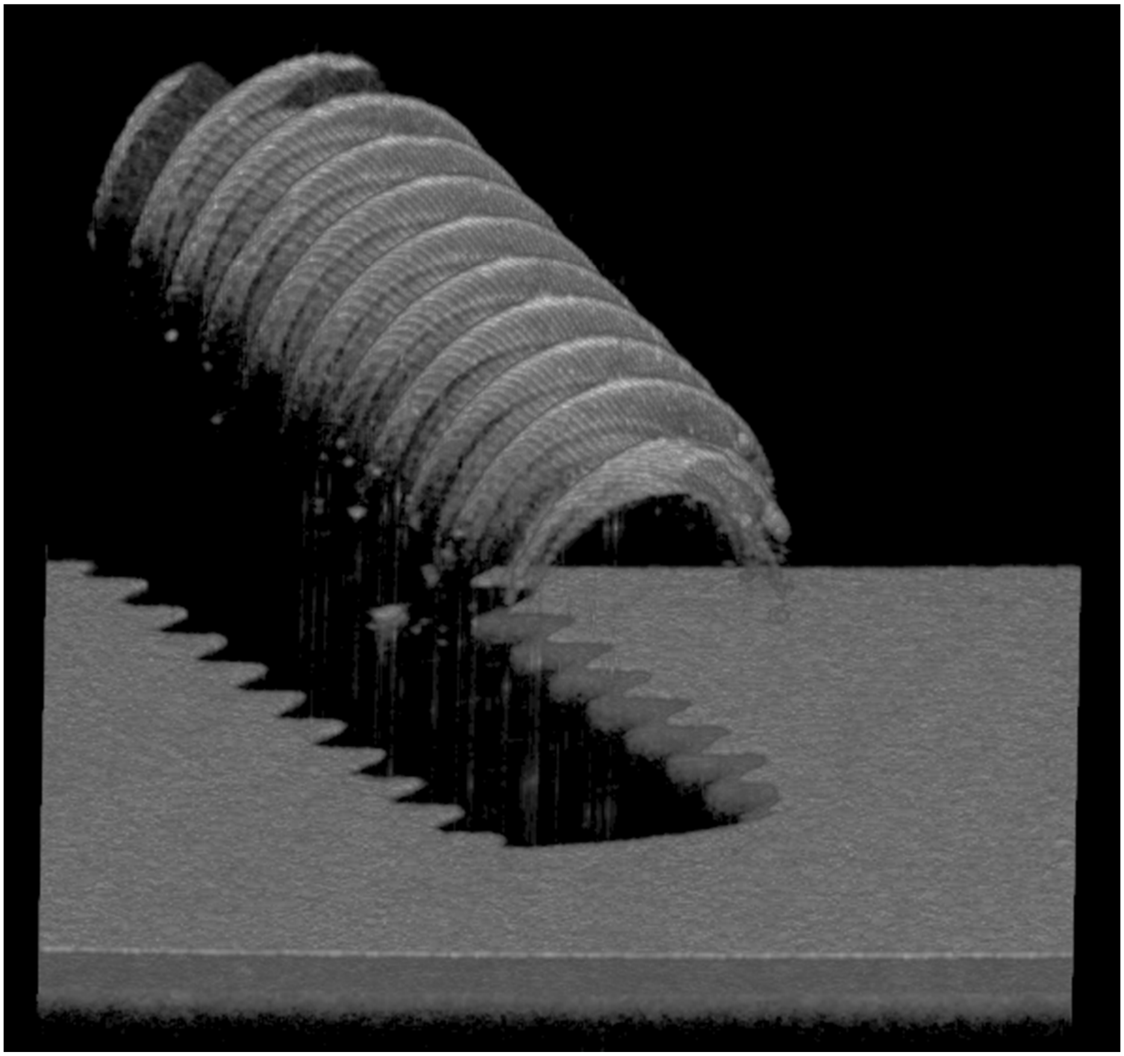

Figure 54 Rendered Volume of a Screw on an IR Viewing Card Displaying the Shadowing Effect

5.6. Image Distortion by Refractive Media

OCT images display path length differences between reference arm length and sample arm length (distance from the beam splitter to the scattering or reflecting object). These path lengths are optical path lengths, calculated from the physical path length multiplied by the group refractive index of the sample.

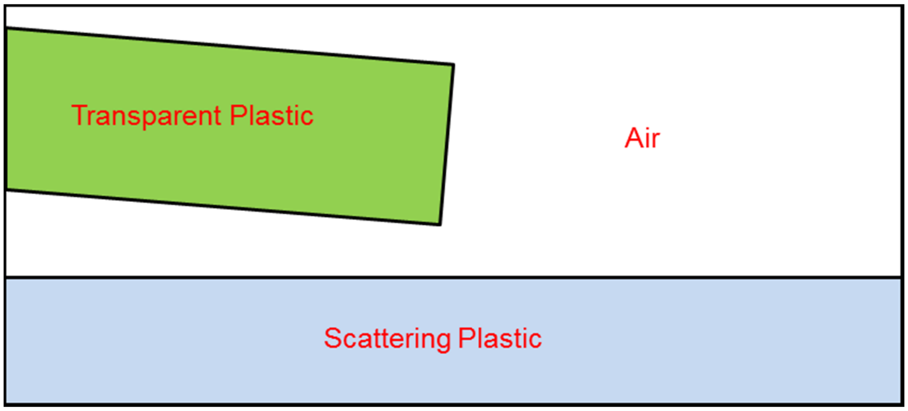

Figure 55 Schematic of a Setup to Show Distorsion from Refracting Media

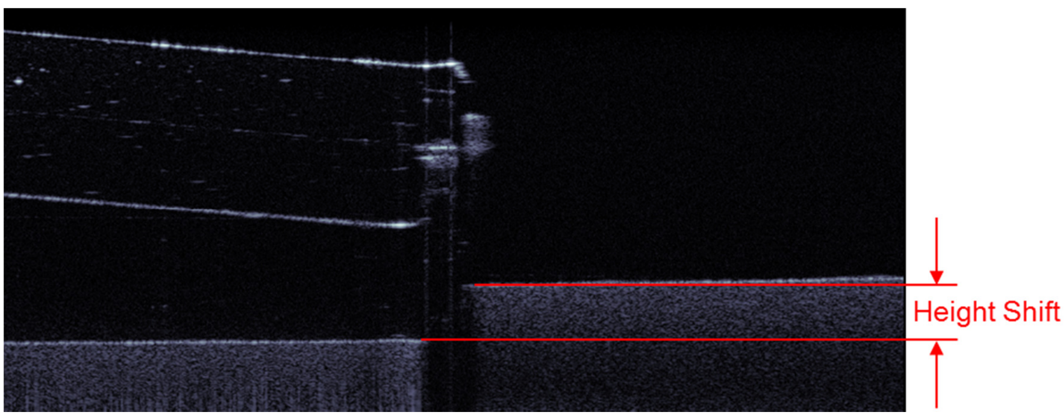

Figure 56 Height Shift of OCT Image Through Refractive Media

5.6.1. The Group Refraction Index

The principle of optical coherence tomography is the detection of optical path length differences between the two arms of an interferometer. The optical paths within these arms are defined by the mechanical path lengths and the refractive indices of the materials.

When talking about the refractive index of an optical material, most of the time it refers to the phase velocity index. As the name indicates, this is a factor for the velocity of the phase when travelling through the material in relation to the vacuum speed of light. The standard abbreviation of the Phase refractive index is n .

The group velocity of a wave is the velocity with which the overall shape of the wave's amplitudes - known as the modulation or envelope of the wave - propagates through space. This velocity usually is different from the speed of the phases of the single wavelengths. This velocity is calculated by using the group refractive index n_g of a material.

The relation of these two values is: $$n_g = n - \lambda_0 \frac{dn}{d\lambda_0}$$

In OCT systems, the group refractive index defines the optical path lengths.

In the table below, some materials and their phase refractive indices n_p as well as their group refractive indices n_g are given.

Material	λ = 900nm		λ = 1050nm		λ = 1310nm	
	n_p	n_g	n_p	n_g	n_p	n_g
Water 24°C	1.327	1.340	1.324	1.340	1.320	1.343
Water 37.6°C	1.324	1.341	1.321	1.339	1.316	1.339
Quartz	1.452	1.465	1.450	1.463	1.447	1.462
N-BK7	1.510	1.523	1.507	1.521	1.504	1.519
N-LAK22	1.640	1.659	1.638	1.655	1.634	1.651
N-SF11	1.760	1.798	1.754	1.786	1.748	1.775
N-SF57	1.818	1.861	1.812	1.847	1.805	1.834

In vacuum, the values for n_p as well as for n_g are 1 for all wavelengths. The difference for the performance in air is negligible for most instances.

5.6.2. Measurement Depth in OCT Systems

The spectral resolution of a frequency domain OCT system defines its possible measurement depth. This depth is the maximum detectable optical path length difference limited by the Nyquist criteria. In real materials the measurement depth of OCT systems as well as the axial resolution is reduced. The reduction of the resolution depends on the material properties between the two measured interface signals used. The reduction of the imaging depth is a result of the materials in the sample image as visualized in the graphic below:

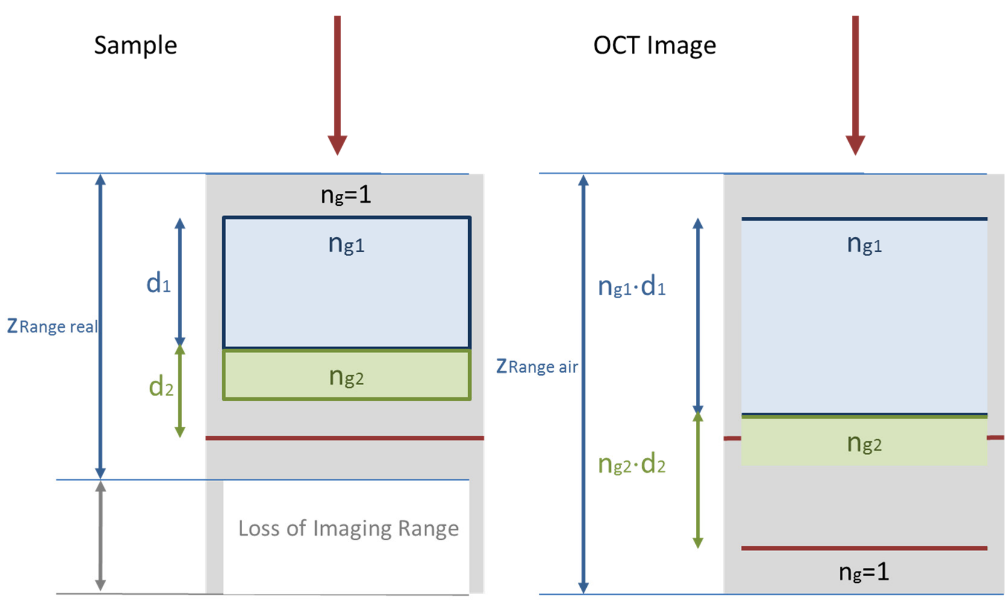

Figure 57 Measurement Depth With Refractive Media

In the image the incoming beam from above is scanned over a structure made of two different materials named one (d_1, n_{g1}) and two (d_2, n_{g2}) stacked on a flat surface (red line). The imaging range is displayed as a light grey area. Vertical structures are barely visible.

The materials are displayed in the OCT image with an axial dimension corresponding to the optical path lengths.

In most cases the sample is not well known. The measurement depth in air (vacuum) is known and the optical path lengths of the materials are obtained – only with the knowledge of the material properties it is possible to determine the real physical thickness.

The loss of imaging depth depends on the thickness and the group refractive indices of the materials displayed within the image. It is calculated as follows:

$$loss = \sum_i (n_{gi} - 1) d_i$$

5.6.3. Distortions in the Image

In complex structures, distortions occur in the OCT image which require a close look to be understood.

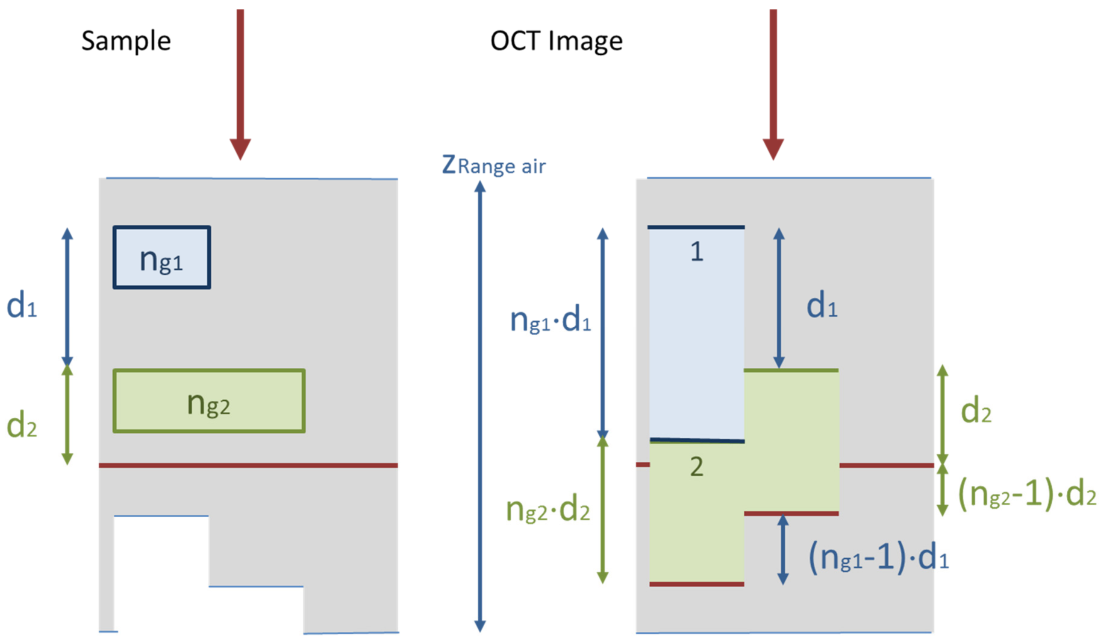

Figure 58 Different Materials in One Measurement

The loss of imaging depth depends on the amount of material through which the beam passes. As a result, the measured depth in the sample changes throughout the scan.

In the setup shown in Figure 58, one can determine the properties of the materials assuming the underlying surface to be flat and horizontal in the image. In the OCT image on the right, the physical thicknesses d_i , optical path lengths $n_{gi} d_i$ as well as the resulting shifts of underlying structures $(n_{gi} - 1) d_i$ can be determined directly.

The real imaging areas are displayed in the graphic for real sample dimensions on the left.
When the physical structure becomes more complex, the resulting OCT image becomes more difficult to interpret.

Especially when the surface is not horizontal or curved, effects like shadowing, diffraction on interfaces and possible multiple measured structures may occur in addition to the changes in optical path length.

As an example a material with a wedge is analyzed:

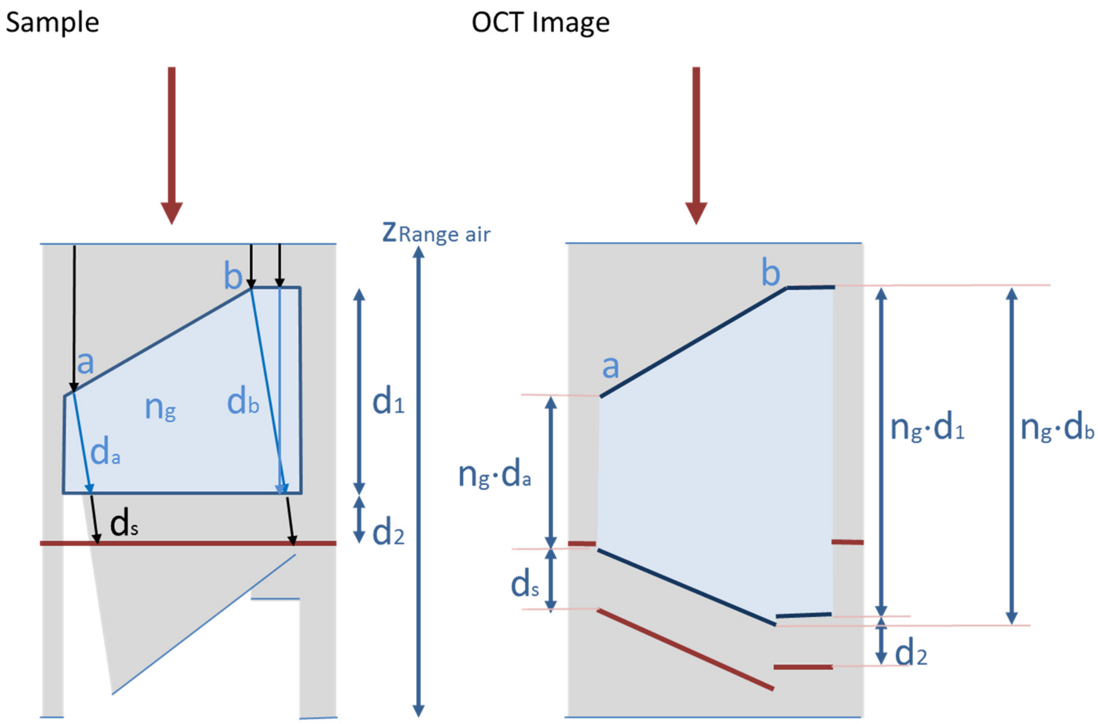

Figure 59 Complex Structure in Image

The block shows “standard” behavior on the right side where the surface is perpendicular to the incoming beam.

In the chamfered area, there is diffraction and the beam travels under an angle through the block. The real angled physical path is enlarged a little (d_a and d_b), and d_s is not in-line with d_a.

These paths are displayed strictly vertical in the OCT image showing the expected optical path lengths $n_{gi}d_i$. The beam is displayed without rotation.

This difference between the real diffracted optical path and the displayed OCT image makes it difficult to perform an inverse ray tracing because all the diffractive interfaces need to be determined in 3D.
Even this determination needs to be undertaken step after step, since the first interface affects the OCT image of the second interface and so on.

The most challenging part is the light grey area in the sample marking the imaged field. In the left edge of the chamfered block, there is an area which is not reached by OCT light and therefore cannot be visualized at all. On the other hand, there are structures that are measured twice because of the two different optical paths leading to these structures.

In very complex structures these effects become more and more difficult to handle, e.g. spherical or curved interfaces, bubbles, inhomogeneous materials, possible imaging aberrations in the sample etc.

Chapter 6 Troubleshooting

Symptom	Possible Cause	Solution
System Does Not Start	No power is supplied to the unit	Connect the power supply
	Power cord is broken	Change power cord
	Other reason	Call Thorlabs[1]
System Does Not Make Measurements	PC crashed	Restart PC
	Poor connection of USB cable	Check USB connection
	Data acquisition cables not inserted	Connect data acquisition cables
	Optical path length not matched	Adjust optical path length
	Beam is blocked	clean fiber tip
	Other reason	Call Thorlabs[1]
No Signal in Image	Fiber not connected	Connect fiber patch cable
	Fiber tip is dirty	Clean fiber tip
	Scanner not connected	Connect Scanner
	Focus is out of imaging area	Adjust reference length, readjust focus
	Other reason	Call Thorlabs[1]
Bad Image Quality	Mirrored image shown	Observe the OCT image while adjusting the distance of the scanner to the sample
	Distance to the sample is too short	When decreasing the distance, the image needs to move towards the top of the OCT image
	Other reason	Call Thorlabs[1]
Flipped Image	Reference length set incorrectly	Adjust reference length

Table 3 Troubleshooting

[1] *Please refer to Chapter 12 for Thorlabs contact information.*

6.1. Changing the Input Fuses

If for some reason you need to replace a broken fuse in the base unit, you must perform the following procedure:

- Remove the AC input cable that may be connected to the unit.
- Slide open the cover of the fuse holder located at the rear panel of the either the Laser Module or the Imaging Module. Remove the existing fuse and install the appropriate replacement fuse for the respective unit.
    1. Use only IS 1A 250VAC Type T 5x20mm style fuses (IEC 60127-2/III, low breaking capacity, slow blow) for the Base Unit.
- Slide the fuse cover closed.

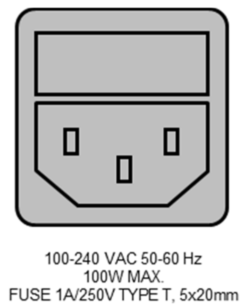

Figure 60 Fuse Cover on Rear Panel

If for some reason you need to replace the mains lead, the power connection is made using the IEC 60320 C14 plug. When choosing the cord, ensure to choose a cord following local applicable standards. The cord must be specified for 10 A, 250 V.

To avoid electrical shock, the power cord protective ground conductor must be connected to ground.

Chapter 7 Certifications and Compliance

7.1. Declaration of Conformity Vega Series Base Units

THORLABS
www.thorlabs.com

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs GmbH

Of: Hans-Boeckler-Str. 6, 85221 Dachau/München, Deutschland

in accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: ***VEG2xy***

Equipment: ***VEG200-Series OCT Base Unit***

is in conformity with the applicable requirements of the following documents:

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.	2010
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013
EN 60825-1	Safety of laser products	2014

and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive

I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed: *On:* 29 November 2018

Name: Bruno Gross

Position: General Manager

EDC - VEG2xy -2018-11-29

CE

THORLABS
www.thorlabs.com

EU Konformitätserklärung

In Übereinstimmung mit EN ISO 17050-1:2010

Wir: Thorlabs GmbH

Hans-Boeckler-Str. 6, 85221 Dachau/München, Deutschland

erklären hiermit, in Übereinstimmung mit den folgenden Richtlinien:

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

dass:

Artikel (der Serie): ***VEG2xv***

Artikelbeschreibung: ***VEG200-Series OCT Base Unit***

den geltenden Anforderungen der folgenden harmonisierten Normen entspricht / entsprechen:

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.	2010
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013
EN 60825-1	Safety of laser products	2014

Aus dem unten angegebenen Grund, wobei die alleinige Verantwortung für die Ausstellung dieser Konformitätserklärung der Hersteller trägt, sind alle genannten Artikel auch konform mit der Richtlinie 2011/65/EU des Europäischen Parlaments und des Rates vom 8. Juni 2011 über die Beschränkung der Verwendung bestimmter gefährlicher Stoffe in elektrischen und elektronischen Geräten:

Die maximalen Konzentrationen, bezogen auf das Gewicht homogener Materialien, für die im Anhang II der Richtlinie aufgeführten Stoffe, werden nicht überschritten.

Ich erkläre hiermit, dass die genannten Artikel so entwickelt wurden, dass sie den wesentlichen Abschnitten der oben angegebenen Spezifikationen entsprechen, und alle geltenden Anforderungen der Richtlinien erfüllen.

Unterschrift: *Datum:* 29 November 2018

Name: Bruno Gross

Funktion: Geschäftsführer

EDC - VEG2xy -2018-11-29

CE

Chapter 8 Warranty

8.1. Lasers and Imaging Systems

Thorlabs offers a one year warranty on all lasers and imaging systems, with the exceptions of laser diodes.

8.2. Non-Warranty Repairs

Products returned for repair that are not covered under warranty will incur a standard repair charge in addition to all shipping expenses. This repair charge will be quoted to the customer before the work is performed.

8.3. Warranty Exclusions

The stated warranty does not apply to products which are (a) specials, modifications, or customized items (including custom patch cables) meeting the specifications you provide; (b) ESD sensitive items whose static protection packaging has been opened; (c) items repaired, modified, or altered by any party other than Thorlabs; (d) items used in conjunction with equipment not provided by or acknowledged as compatible by Thorlabs; (e) subjected to unusual physical, thermal, or electrical stress; (f) damaged due to improper installation, misuse, abuse, or storage; (g) damaged due to accident or negligence in use, storage, transportation, or handling.

Chapter 9 Specifications

General Performance Specifications – Vega Series Base Unit	
Supply Voltage for Base Unit*	100 V – 240 V / AC
Maximum Power Consumption	100 W
Weight of Base Unit (Approx.)	11.5 kg
Storage/Operating Temperature	10 °C to 35 °C
Dimensions of OCT-Stand (L x W x H)	206 mm x 305 mm x 248 mm
Dimensions of Base Unit (L x W x H)	361.8 mm x 305.0 mm x 143.0 mm
Airborne Noise Emission	<70 dB_A

*Base unit has universal AC input.

Table 4 General Specifications

Optical Performance Specifications – Vega Series Base Unit		
Base Unit	**VEG210**	**VEG220**
Central Wavelength	1300 nm	1300 nm
Axial Scan Rate	100 kHz	200 kHz
Minimum Pixels per A-Scan	1312	960
Sensitivity	102 dB (with OCT-LK4)	98 dB (with OCT-LK4)
Maximum Imaging Depth Air/Water (typical)	11 mm / 8.3 mm	8.0 mm / 6.0 mm
Axial Resolution Air/Water (typical)	16 µm / 12 µm	16 µm / 12 µm
Lateral Resolution at Focus with OCT Scan Lens Kit	20 µm (OCT-LK4)	20 µm (OCT-LK4)

Table 5 Vega Specifications

Some specifications depend on the actual type of accessory used.

Chapter 10 Mechanical Drawings

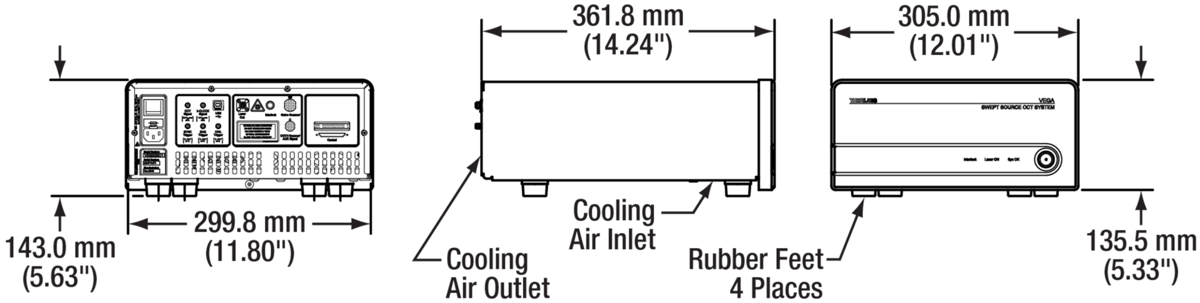

Figure 61 Base Unit Dimensions

Chapter 11 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

- This offer is valid for Thorlabs electrical and electronic equipment:
- Sold after August 13, 2005
- Marked correspondingly with the crossed out "wheelie bin" logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated

Wheelie Bin Logo

As the WEEE directive applies to self-contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:

- Pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

Waste Treatment is Your Own Responsibility

If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

Chapter 12 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at www.thorlabs.com/contact for our most up-to-date contact information.

USA, Canada, and South America
Thorlabs, Inc.
sales@thorlabs.com
techsupport@thorlabs.com

Europe
Thorlabs GmbH
europe@thorlabs.com

France
Thorlabs SAS
sales.fr@thorlabs.com

Japan
Thorlabs Japan, Inc.
sales@thorlabs.jp

UK and Ireland
Thorlabs Ltd.
sales.uk@thorlabs.com
techsupport.uk@thorlabs.com

Scandinavia
Thorlabs Sweden AB
scandinavia@thorlabs.com

Brazil
Thorlabs Vendas de Fotônicos Ltda.
brasil@thorlabs.com

China
Thorlabs China
chinasales@thorlabs.com


UNLEASHED