THORLABS

OCTP Series and OCT-LKx

User-Customizable Scanner and Scan Lens Kits

User Manual

Original User Manual – not translated

Table of Contents

Chapter 1 Warning Symbol Definitions **1**

Chapter 2 Introduction **2**

2.1. Safety ***2***

2.2. Care and Maintenance ***3***

2.2.1. Optical Cleaning 3
2.2.2. Service 3
2.2.3. Accessories and Customization 3

Chapter 3 Components and Compatibility **4**

3.1. Components ***4***

3.1.1. Fiber Collimation Module 5
3.1.2. Optical Beamsplitter Module (not for OCTP-NR) 5
3.1.3. Reference Arm Module (not for OCTP-NR) 6
3.1.4. OCT Scan Cube Module 7
3.1.5. Objective Holders 8
3.1.6. Lens Kits 9
3.1.7. OCT-STAND 9

3.2. Custom Mounting ***10***

3.2.1. Threaded Holes on Imperial OCTP Scan Cube Module 10
3.2.2. Threaded Holes on Metric OCTP Scan Cube Module 11
3.2.3. Mounting to Thorlabs OCT-STAND 11

3.3. Compatibility between Scanner and Base Units ***12***

Chapter 4 Installation **13**

4.1. OCTP Mounting ***14***

4.2. OCTP Connections ***15***

4.2.1. Connecting the Electrical Control Interface 15
4.2.2. Connecting the Optical Fiber 16

4.3. Optical Alignment ***17***

4.3.1. Alignment to Optical Axis 17
4.3.2. Polarization Adjustment 21

Chapter 5 Description **24**

5.1. Theory ***24***

5.1.1. Signal Generation 24
5.1.2. Limitations 24

5.2. Optical Design ***25***

5.2.1. Common Path Setup (OCTP) 25
5.2.2. Dual Path Setup (OCTP-NR) 25

5.3. Intended Use ***26***

5.3.1. Realization 26

Chapter 6 Troubleshooting **29**

Chapter 7 Certifications and Compliance **30**

Chapter 8 Specifications **31**

8.1. Reflectivity Scanning Mirror ***32***

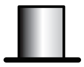
8.2. Transmission Unscanned Optional Port ***32***

Chapter 9 Warranty **33**

9.1. Imaging Systems 33
9.2. Non-Warranty Repairs 33
9.3. Warranty Exclusions 33
Chapter 10 Regulatory 34
10.1. Waste Treatment is Your Own Responsibility 34
10.2. Ecological Background 34
Chapter 11 Thorlabs OCT Support Contact 35
Chapter 12 Thorlabs Worldwide Contacts 36

Chapter 1 Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual or on your device.

Symbol	Description
	Direct Current
	Alternating Current
	Both Direct and Alternating Current
	Earth Ground Terminal
	Protective Conductor Terminal
	Frame or Chassis Terminal
	Equipotentiality
	On (Supply)
	Off (Supply)
	In Position of a Bi-Stable Push Control
	Out Position of a Bi-Stable Push Control
	Caution: Risk of Electric Shock
	Caution: Hot Surface
	Caution: Risk of Danger
	Warning: Laser Radiation
	Caution: Spinning Blades May Cause Harm

Chapter 2 Introduction

2.1. Safety

Please read this manual carefully before operating the OCTP. Please also read any manuals for the systems being connected to the OCTP.

All statements regarding safety and technical specifications will only apply when the unit is operated correctly.

ATTENTION

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

WARRANTY WARNING

There are sensitive electronic and optical parts in the OCTP.

Any modification or servicing of this system by unqualified personnel renders Thorlabs free of any liability.

Any modification of the galvanometer scanners or the camera may cause loss of the factory optical alignment.

This device can only be returned for service when it is packed into the complete original packaging, including all foam packing inserts. Please contact Thorlabs' OCT support (see Chapter 11) for replacement packaging if the original packaging has been lost.

LASER RADIATION WARNING

When a light source (e.g. SLD, laser) is being coupled into the OCTP, please observe the appropriate laser safety precautions for your own protection. The appropriate laser safety precautions depend on the light source coupled into the OCTP.

During normal operations, laser light will be present within the scanner and will also be emitted from the scanner. Laser light may also be emitted from unexpected locations, such as if the fiber has been disconnected from the body or if the reference arm has been disconnected.

In addition, the OCTP is an optical system that can influence the divergence of the beam. This can cause a change of laser class of the light source, especially if the OCTP is used without an objective.

Always turn off the light source before changing or adjusting the OCTP configuration or accessories as the objective, scan lens kit, or sample z-spacer. For Thorlabs OCT base units, turn off the OCT base unit main power to turn off the light source.

2.2. Care and Maintenance

The system should be treated with care, particularly during transportation and unpacking. Hitting or dropping the system can damage the unit and lower system performance. If mishandling occurs, misalignment of the optical components may occur, leading to a decrease in image quality. In this situation, the system should be realigned by qualified personnel.

- 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 the unit away from dust, dirt, and airborne contaminants, such as cigarette smoke. The system is not designed for outdoor use. Protect the equipment from rain, snow, and humidity.
- Do not subject the equipment to mechanical and thermal extremes. Protect the equipment from rapid variations in temperature.
- Handle all electrical and fiber connectors with care. Use of excessive force to form electrical or fiber connections may damage the connectors.

2.2.1. Optical Cleaning

The most common cause of low signal intensity is dirtying of the fiber due to airborne contaminants. To minimize the fiber's exposure to air, avoid unnecessary disconnections of the optical fiber patch cable. Ensure that the connection is tight, and keep the fiber as straight as possible without placing it under tension. It is also advisable to check the fiber when making other adjustments to the optical system, such as changing the objective.

Thorlabs' Fiber Inspection Scope (Item # FS201) can help determine when the fiber needs cleaning. We recommend our Fiber Connector Cleaner (Item # FBC1) for quickly cleaning the fiber tips.

2.2.2. Service

Only trained and approved Thorlabs personnel are allowed to service the system. Please contact Thorlabs' OCT support (see Chapter 11) for more information.

2.2.3. Accessories and Customization

The OCTP series user-customizable scanners are Thorlabs-qualified accessories for Thorlabs' OCT Systems (i.e., Callisto, Ganymede, Telesto, and Vega). In addition to enabling typical imaging applications, the OCTP scanners effectively connect our SM1 lens tubes and 30 mm cage systems to our OCT systems, enabling custom applications. We strongly suggest using Thorlabs' scan lens objectives or OCT-LKx scan lens kits with the OCTP scanners, as they were specifically designed to work together.

In order to achieve the intended performance, this scanner should only be used with qualified parts. Please hold a conversation with Thorlabs' OCT support (see Chapter 11) to determine if other parts you wish to use are compatible. Any modification or servicing of this system by unqualified personnel renders the warranty null and void, leaving Thorlabs free of any liability.

Chapter 3 Components and Compatibility

3.1. Components

The OCTP is intended as an accessory for use with Thorlabs OCT base units. It is assembled from standard Thorlabs opto-mechanics that provide mechanical compatibility with our 30 mm cage systems, SM1 lens tubes, and Ø1" optics, providing a high degree of experimental flexibility.

The major components of the scanner, illustrated in Figure 1 below, include: a fiber collimation module, optical beamsplitter module, reference arm module, and an OCT scan cube module.

These are described in the following sections.

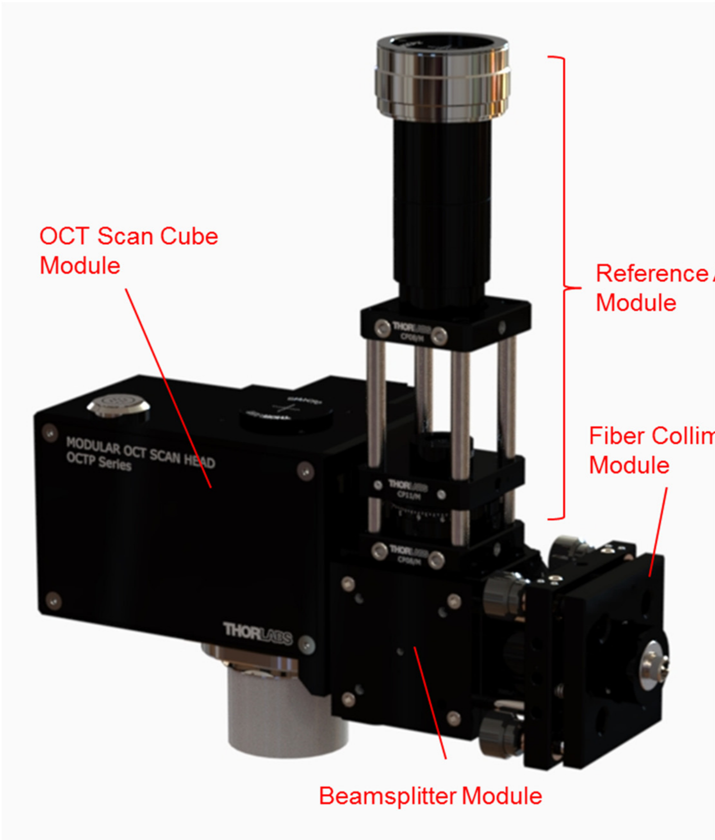


Figure 1 OCTP Modules Common Path

ATTENTION

Always turn off the light source before changing or adjusting OCTP configuration or accessories such as the objective, scan lens kit, reference arm adapter, or sample z-spacer. For Thorlabs OCT base units, turn off the OCT base unit main power to turn off the light source.

3.1.1. Fiber Collimation Module

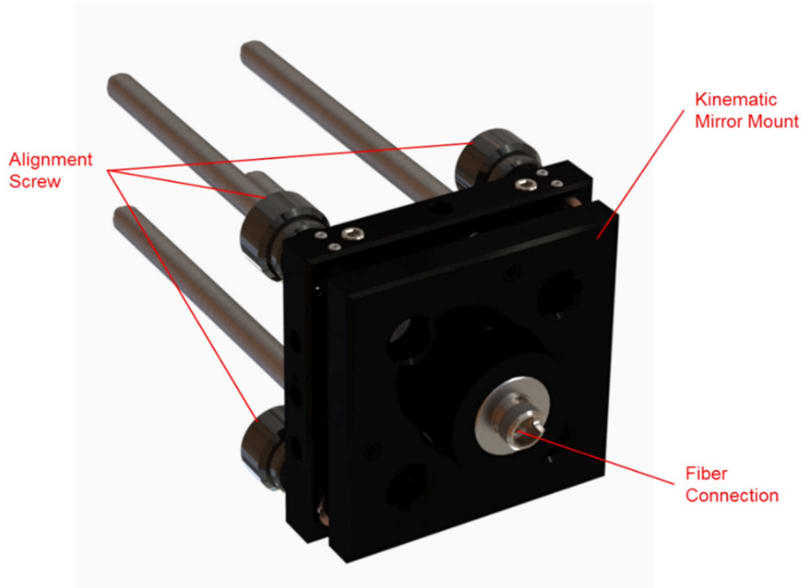


Figure 2 Fiber Collimation Module with Built-In Fiber Collimator

The fiber collimation module has a built-in fiber collimator with 25 mm focal length. The 2.0 mm narrow key FC/APC receptacle is centered within a kinematic mirror mount, which adapts the fiber port to our 30 mm cage system.

The cage compatible design enables the use of different beam diameters and collimator focal lengths, although the clear aperture of the scanner set is limited to Ø6 mm.

3.1.2. Optical Beamsplitter Module (not for OCTP-NR)

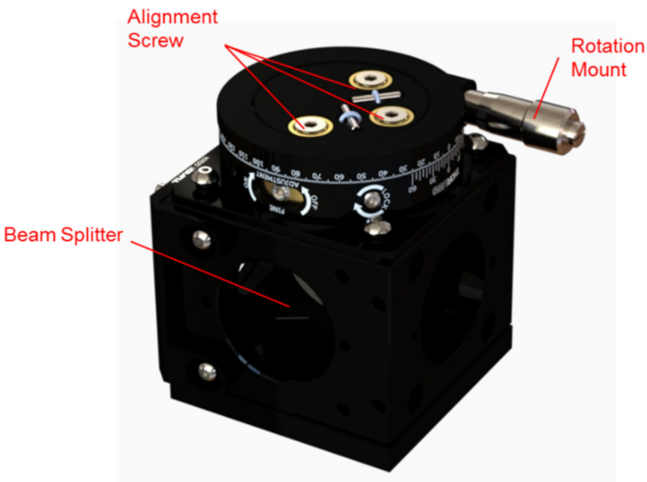


Figure 3 Optical Beam Splitter Module

The optical beamsplitter module consists of a non-polarizing cube beamsplitter that is mounted inside a 30 mm cage cube. This cage cube is secured to a lockable rotation mount. The cube beamsplitter's length, width, and height are 20 mm.

The 30 mm cage cube has four ports, one of which is blocked by an end cap before being shipped. In principle, it is possible to use this last port for asymmetric light coupling, a second detector, or a second input wavelength. Please contact Thorlabs' OCT support (see Chapter 11) for details.

3.1.3. Reference Arm Module (not for OCTP-NR)

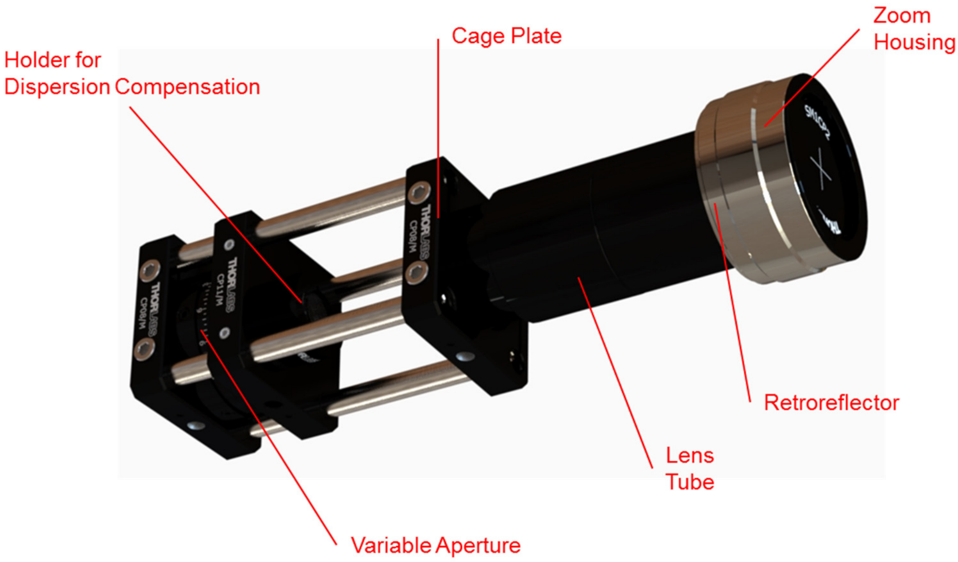


Figure 4 Reference Arm Module

The reference arm module contains a mounted mirror (i.e., retroreflector) that reflects the beam from the light source back into the OCT interferometer.

In order to match the optical path length in this reference arm to the optical path length of the light from the sample, it may be necessary to translate the mirror along the axis of the 30 mm cage system. Coarse length adjustments can be performed by loosening the top cage plate or the variable lens tube. Fine adjustments of the reference length can be performed by moving the retro reflector: ±2 mm (total range of 4 mm) for the OCTP with the non-rotating zoom housing and 12.7 mm for the linear stage of the OCTP-PS.

In order to adjust the reference arm intensity, a zero-aperture iris is located in front of the mirror.

For objective-dependent dispersion compensation, a holder hosting a compensation glass sample is included.

The 30 mm cage system makes it easy to add optomechanical and optical components to the reference arm. For instance, windows for group velocity dispersion (GVD) compensation can be mounted in this arm, as can optical filters.

3.1.4. OCT Scan Cube Module

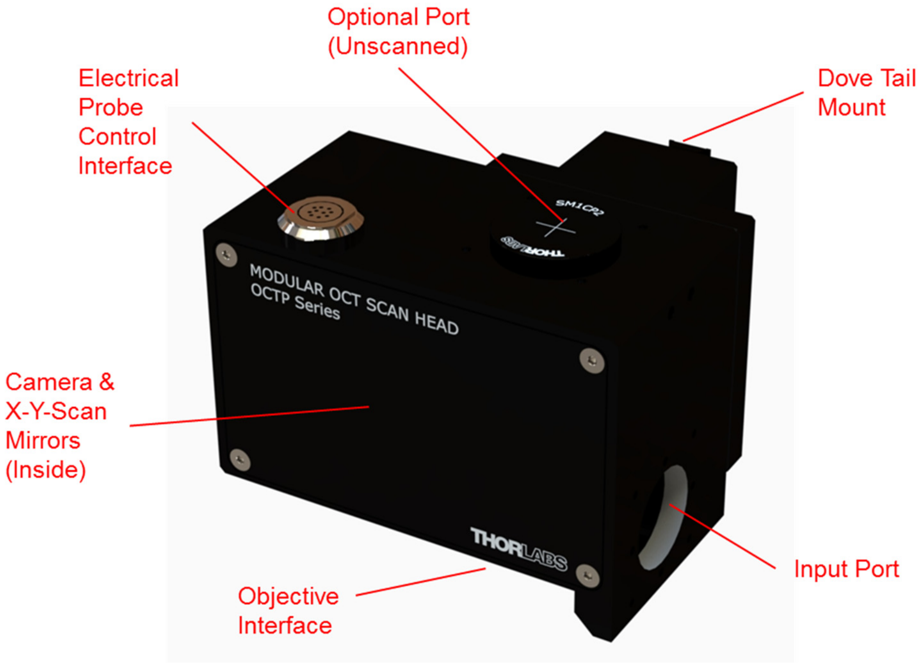


Figure 5 OCT Scan Cube Module

The OCT scan cube module provides high-speed, two-dimensional (X and Y) raster scans of the specimen. The clear aperture of the scan mirrors used within is Ø6 mm. The module also contains a high-resolution video camera for recording the sample during the measurement.

The electrical control interface hosts the included Thorlabs electric control cable to connect the imaging scanner with a Thorlabs OCT base unit. Please contact Thorlabs' OCT support (see Chapter 11) for information regarding the pin configuration.

Should the user wish to view the direct, non-descanned output of the objective (i.e., by passing the primary scan mirror, transmitting the visual wavelength range), the top of the scan cube contains an output port with a removable end cap (Item # SM1CP2). This port can be used for different imaging modalities or additional sample illumination. Unscrewing the end cap exposes an internal SM1 (1.035"-40) threading, which is surrounded by four 4-40 taps that are compatible with our 30 mm cage systems.
A transmission graph of this scan mirror is given in Figure 35.

ATTENTION

Use of the direct output port requires removal of the camera. In addition, a hot mirror with a 2.5 mm circular aperture could be removed. Please contact Thorlabs' OCT support (see Chapter 11) for details.

3.1.5. Objective Holders

There are two different brass plates included that are used to hold the objective to the OCTP:

- The pre-installed objective holder for the use of our OCT-LKx scan lens kits.
  For an OCTP scanner ordered with a scan lens kit, it is pre-installed. These kits include a telecentric scan lens (Item # LSM02, LSM02-BB, LSM03, LSM03-BB, LSM04, or LSM04-BB) and a matched sample illumination light conductor.

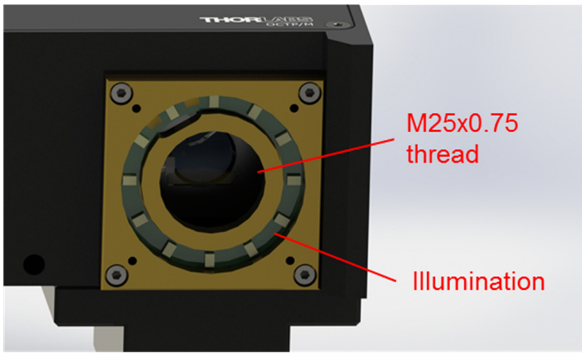


Figure 6 Objective Holder for OCT-LKx Scan Lens Kits or M25-Threaded Objectives

- Alternatively, another brass plate with internal SM1 (1.035”-40) threads and four 4-40 tapped holes for our 30 mm cage systems is included.

Figure 7 Objective Holder for SM1-Threaded Optomechanics and 30 mm Cage System

ATTENTION

The illumination of the pre-installed objective holder for OCT-LKx Scan Lens Kits is connected to a power supply.

When changing the brass plates this connection must be disconnected using the internal electric plug.

3.1.6. Lens Kits

For the case that an OCT scan lens kit is installed, the mechanical dimensions are summarized in the table below.

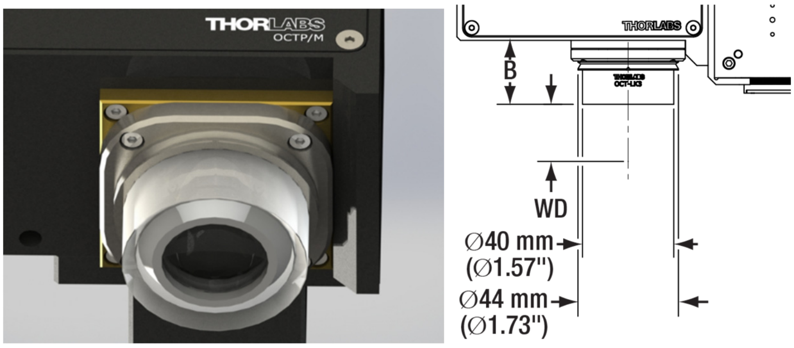


Figure 8 Objective Holder Shown with Scan Lens Kit Installed

OCT Scan Lens Kit	OCT-LK2(-BB)	OCT-LK3(-BB)	OCT-LK4(-BB)
Field of View	6 mm x 6 mm	10 mm x 10 mm	16 mm x 16 mm
Barrel Height (B)	29.5 mm	28.0 mm	41.0 mm
Working Distance (WD)	3.4 mm	24.9 mm	41.6 mm

Table 1 Dimensions for OCT-LKx Scan Lens Kits

Changing the objective of the OCTP requires changing the probe configuration data in the software package ThorImage®OCT. The length of the reference arm must be aligned to match the optical path in the sample arm as well.

This is performed automatically using the built-in calibration procedure of the ThorImage®OCT software package version 4.1.4 and higher. A detailed description of this procedure is given in the ThorImage®OCT operating manual.

3.1.7. OCT-STAND

The OCT-STAND is a dedicated stand for OCTP scanners. The OCTP scanners are attached to the focus block of the OCT-STAND using a spring-loaded mount accepting the dovetail mount of the OCTP. The focus block can be rotated 360° around the Ø1.5" rod, and features 30 mm of travel with fine and coarse adjustment knobs.

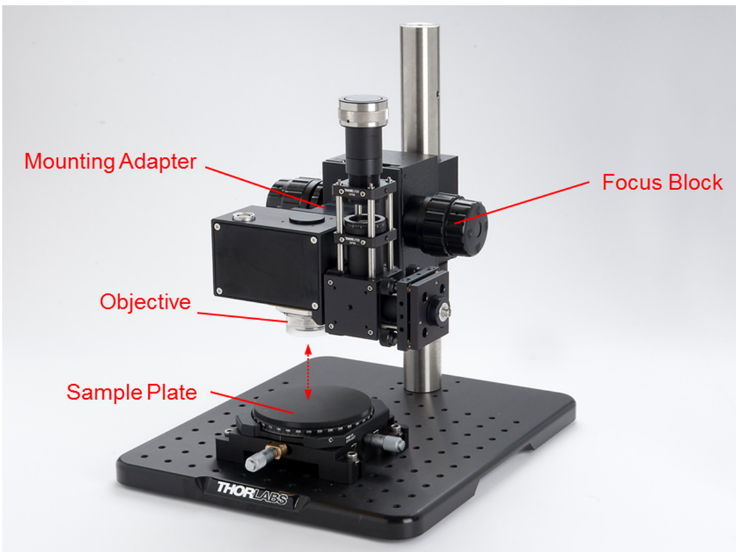


Figure 9 OCTP in Thorlabs OCT-STAND

3.2. Custom Mounting

The mechanical drawings shown below depict several threaded holes that can be used to secure the scanner to an optical breadboard or an application-specific mount. The tap depth is twice the diameter.

3.2.1. Threaded Holes on Imperial OCTP Scan Cube Module

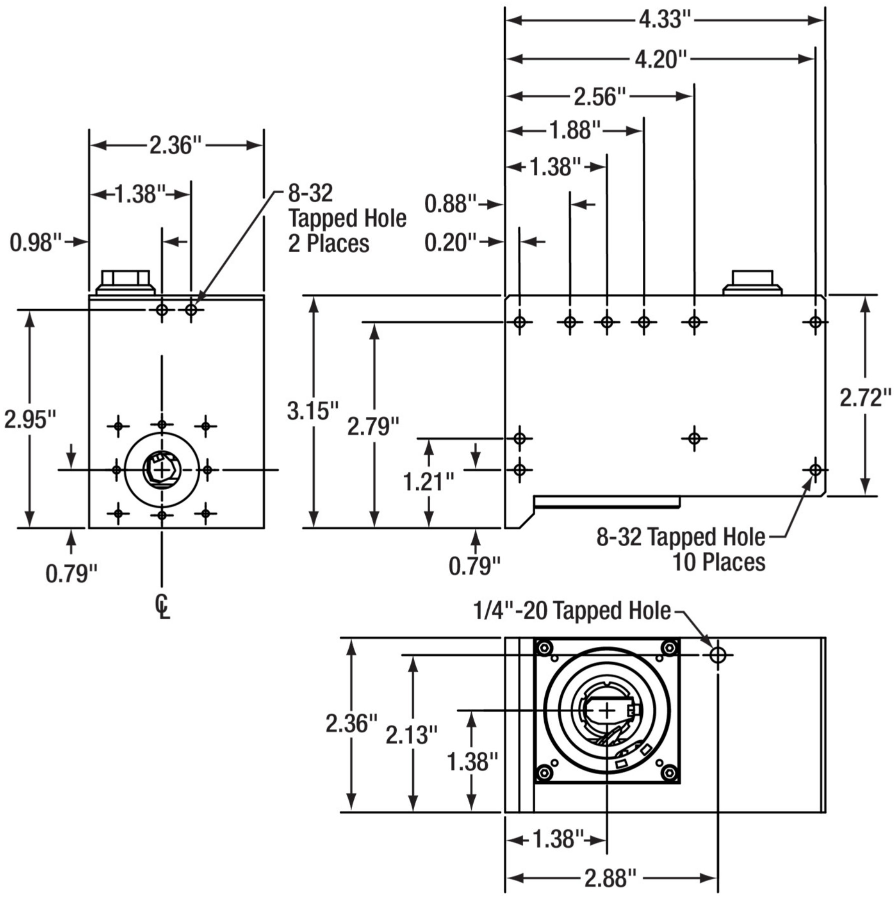


Figure 10 Drawing of Threaded Holes in an Imperial OCTP Scan Cube Module

3.2.2. Threaded Holes on Metric OCTP Scan Cube Module

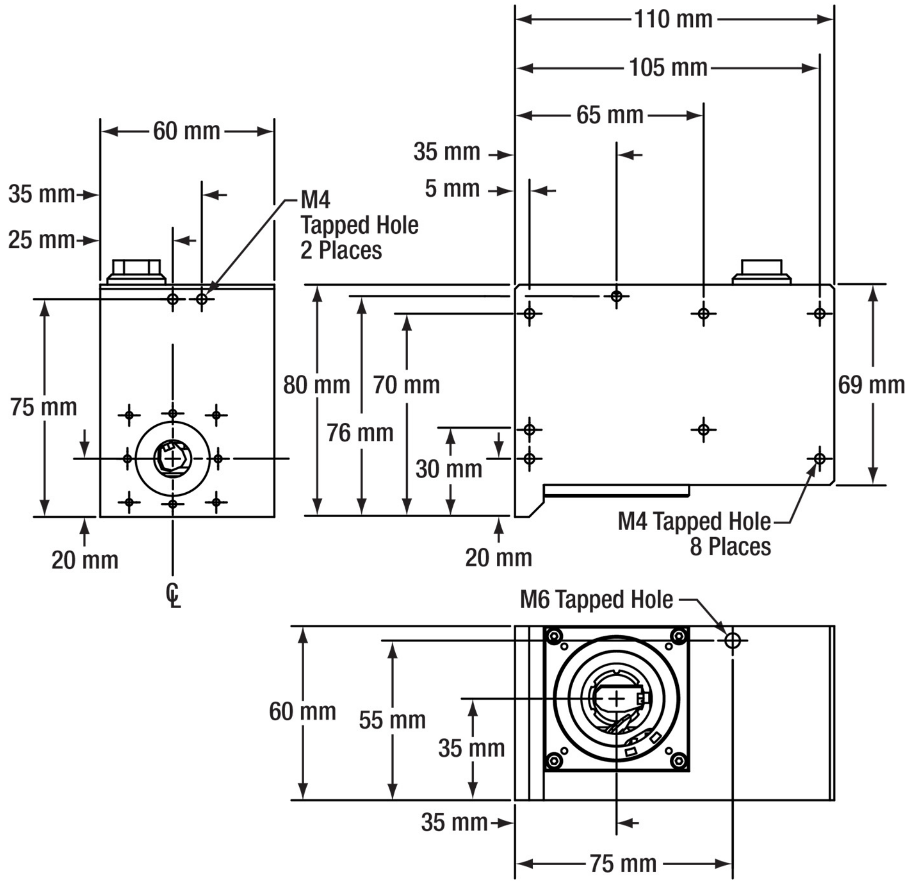
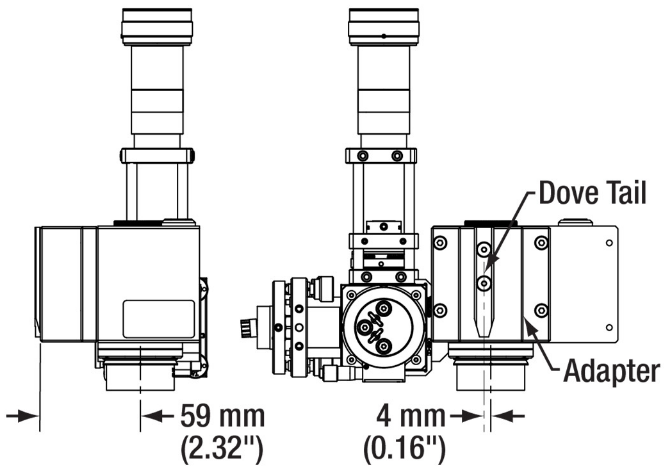


Figure 11 Drawing of Threaded Holes in a Metric OCTP Scan Cube Module

3.2.3. Mounting to Thorlabs OCT-STAND

The OCTP ships with a mounting adapter and a dovetail mount, as shown in **Error! Reference source not found.**. These accessories allow the scanner to be mounted to a Thorlabs OCT-STAND which ensures that the objective is directly centered above the sample plate.



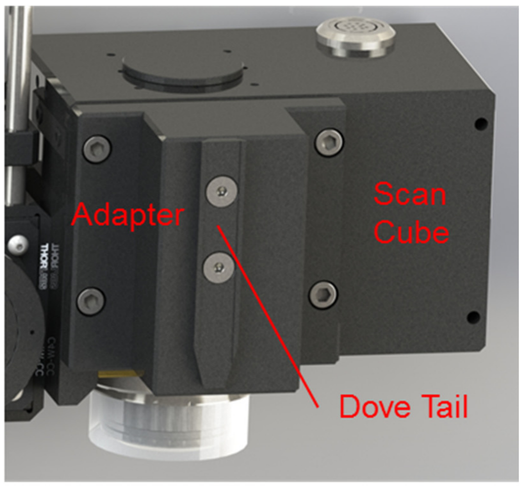


Figure 12 Scanner Mounting Adapter for the OCTP

3.3. Compatibility between Scanner and Base Units

The OCTP User-Customizable Scanner is a standalone, preassembled, integrated scanner intended for use together with a Thorlabs OCT base unit.

This scanner is available in versions for different wavelength ranges.

- The OCTP-900 for OCT systems working in the 900 nm regime (i.e., Ganymede or Callisto).
- The OCTP-1300, OCTP-1300NR, and the OCTP-1300PS for OCT systems working in the 1300 nm regime (i.e., Telesto or Vega).

In this manual we will use abbreviations for the OCTP scanner as follows:

- OCTP OCTP-900, OCTP-1300, OCTP-1300NR, or OCTP-1300PS
- OCTP-PS OCTP-1300PS
- OCTP-NR OCTP-1300NR

All these scanners are also available in a version with metric threads for interface. The part number of these devices is followed by a separated “M”, e.g. OCTP-900/M.

For common statements, the abbreviation “OCTP” is used for all setups.

The OCTP scanners are fully compatible with all Thorlabs OCT base units of the Callisto, Ganymede, and Telesto series. The OCTP-NR scanner is intended to be used with the Vega series base units.

The table below gives a short overview of the different user-customizable scanners, their usable wavelength range and lists preferred OCT base units.

Standard Scanner	Wavelength Range	Fiber Receptacle	Single Mode Fiber	OCT Base Unit
OCTP-900	**800 nm – 1000 nm**	FC/APC	Nufern 780	**CALxxx** **GANxxx**
OCTP-1300	**1200 nm – 1400 nm**	FC/APC	Corning SMF28 Ultra or Corning HI-1060	**TELxxx**
OCTP-1300PS	**1200 nm – 1400 nm**	FC/APC (Narrow Key)	Corning PANDA PM13-U25A Key Aligned to Slow Axis (Included in Base Unit)	**TELxxxPS**
OCTP-1300NR	**1200 nm – 1400 nm**	FC/APC	Corning SMF28 Ultra	**VEGxxx**

Table 2 Usable Wavelength Range of OCT Scanner

The optical component with the most significant wavelength dependency is a mirror mounted on the Y-axis galvanometric scanner of the scanner set. A reflectivity graph of the scanning mirror is given in Figure 34.

Detailed information about the spectral performance of the different mirrors are available upon request. Please contact Thorlabs’ OCT support (see Chapter 11) for details.

Chapter 4 Installation

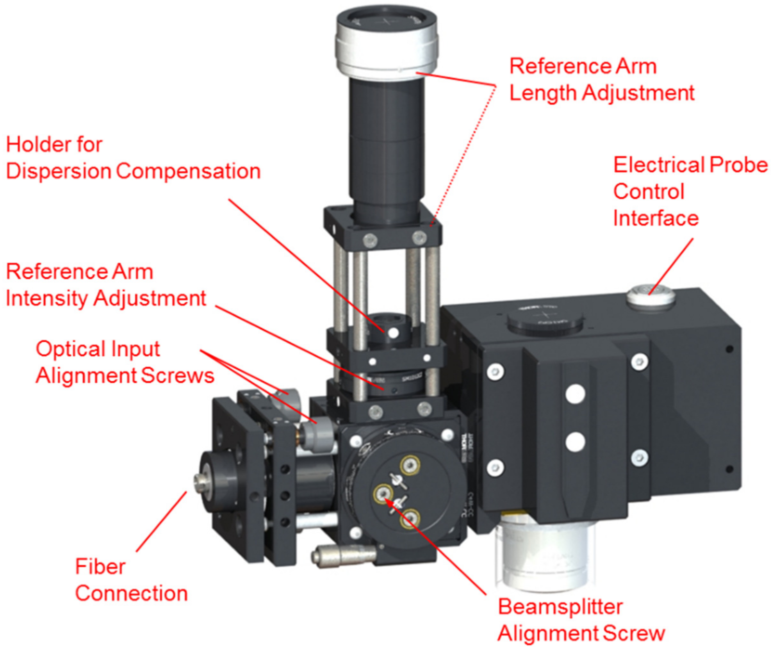


Figure 13 OCTP

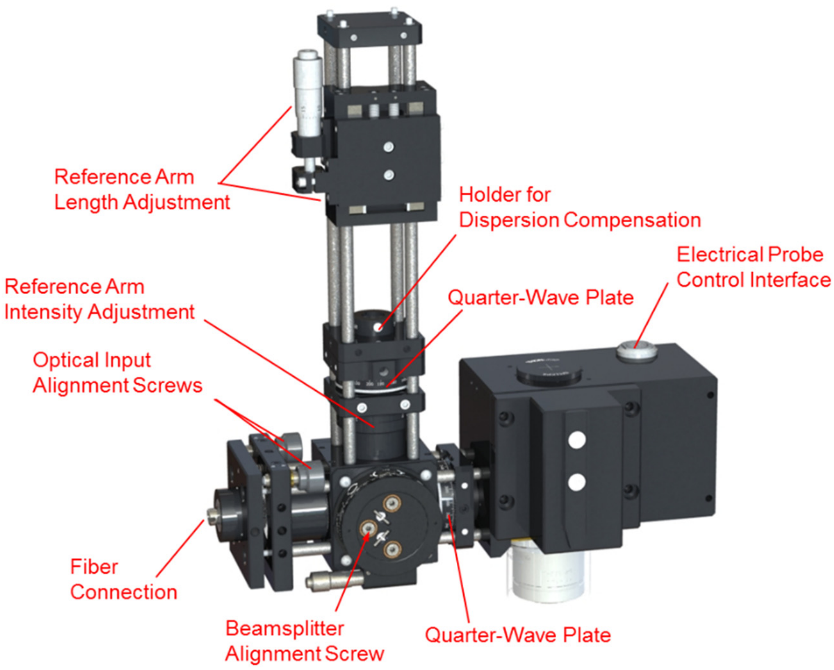


Figure 14 OCTP-PS

The OCTP(-PS) scanner is a preassembled, integral accessory to an OCT base unit. It should be securely mounted to an optical table or breadboard with minimal vibrations. We recommend mounting the OCTP(-PS) in a Thorlabs OCT-STAND. The OCTP-PS is composed of a linear stage instead of the lens tube system used in the OCTP. Hence, adjustments of the reference length are possible. In addition, it consists of two quarter-wave plates in the sample arm and the reference arm to adjust the polarization state.

4.1. OCTP Mounting

To mount the OCTP in the OCT-STAND, gently slide the dovetail of the OCTP into the slide of the OCT-STAND.

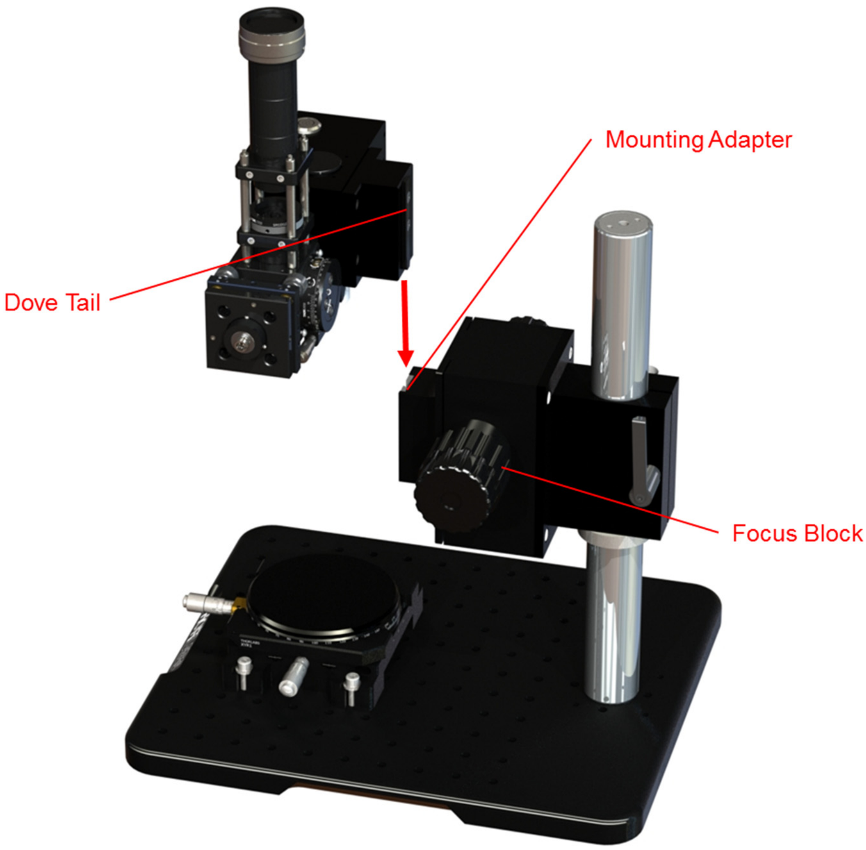


Figure 15 Mounting the OCTP in the OCT-STAND

4.2. OCTP Connections

4.2.1. Connecting the Electrical Control Interface

Attach the electric control cable from the OCT base unit to the OCTP. You may use either side of the cable since the plugs are identical. The OCTP's electrical control interface is located at the top of the scan cube, as shown in Figure 16. Align the red dot of the plug to the alignment mark of the port.

Figure 16 Installation of the Electrical Control Connector at the OCTP

Next, attach the remaining plug of the electrical connection cable to the base unit. The connection is located at the rear of the base unit, as shown in Figure 17. For installation, align the red dot upwards, facing the alignment mark in the base unit. Push the connector into the plug marked "Control" until a "click" sound is heard. This click indicates that the connector is locked.

Figure 17 Installation of the Electrical Control Connector at the Base Unit

4.2.2. Connecting the Optical Fiber

ATTENTION

When installing the fiber, make sure that the fiber tip does not get contaminated by dust. Thorlabs' Fiber Inspection Scope (Item # FS201) and Fiber Connector Cleaner (Item # FBC1) are useful for keeping the optical path clean.
Do not touch the fiber tip!

Attach the optical fiber from the OCT base unit to the OCTP, as illustrated in Figure 18. Either end of the fiber patch cable may be used to connect to the OCTP. Remove the dust cap from each fiber end and store these with the system packaging. The OCTP's FC/APC fiber connection is located at the fiber collimation module, as shown in Figure 13. Insert the fiber tip into the center bore of the fiber connection, then secure the tip by rotating the locking cap clockwise.

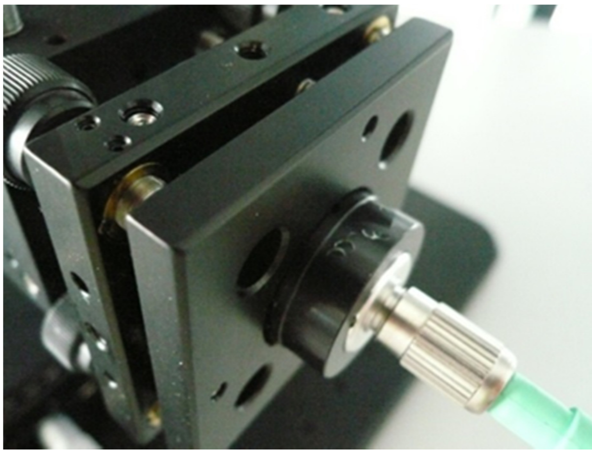


Figure 18 Installation of the Fiber at the OCTP

The fiber connector needs to be oriented such that the alignment key slides into the key slot of the fiber connector. If the key is NOT properly aligned with respect to the key slot, you will still be able to screw in the fiber connector, but significant light intensity losses will result from this incorrect connection. The position of the fiber connector also affects the OCT focal position (and the state of polarization for the OCTP-PS).

Follow the same procedure to connect the fiber to the OCT base unit. This step is not applicable for OCTP-PS scanner. A step-by-step procedure is shown in Figure 19.

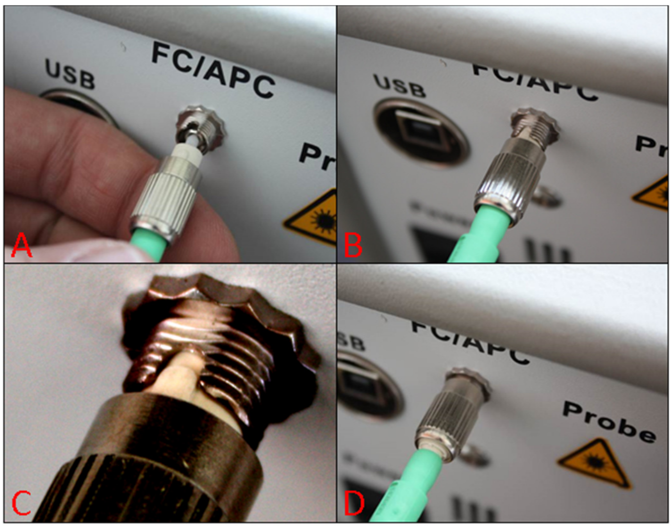


Figure 19 Installation of the Fiber at the Base Unit

4.3. Optical Alignment

The system comes preassembled. Additionally, the galvo scan mirrors and the camera inside the scan cube are aligned with regard to the focusing optics. However, for final installation, it is necessary to align the collimator orientation, the scan cube, and the reference arm to generate an optimal interference signal. These steps are described in Section 4.3.1. Furthermore, the polarization adjustments for OCTP-PS Systems are detailed in Section 4.3.2.

The OCTP is often used with near-infrared light, which is invisible to the eye. Hence, for alignment purposes, it is necessary to use a CCD camera or the included IR viewing card (item # VRC2) to visualize the NIR light. Alternatively, a visible, fiber based light source may be connected to the scanner for alignment purposes only.

ATTENTION

The galvanometer scanners and the camera are factory aligned to the optical axis of the focusing optics. Any modification to the scanners or the camera may cause loss of alignment.

The optical alignment cannot be retrieved with the standard procedure described in this manual if the scanners and/or the camera are misaligned! When optical alignment failure persists please contact OCT support (see Chapter 11) for assistance.

Always turn off the base unit before changing or adjusting OCTP configuration or accessories such as the objective, scan lens kit, reference arm adapter, or sample z-spacer. For Thorlabs OCT base units, turn off the OCT base unit main power to turn off the light source.

4.3.1. Alignment to Optical Axis

We recommend aligning the OCTP using the OCT light source and the camera-based control equipment to be used with the scanner (e.g., a Thorlabs OCT base unit and ThorImage®OCT software).

Alignment consists of the following steps:

1. If the OCTP is already installed, remove the objective. First, unmount the illumination part of the scan lens kit by unscrewing the four screws that hold the steel plate in the brass adapter plate. This will remove the ring light conductor from around the objective, and it will also expose a printed circuit board (PCB) and the LEDs of the ring light, which should not be touched. Then unscrew the objective.

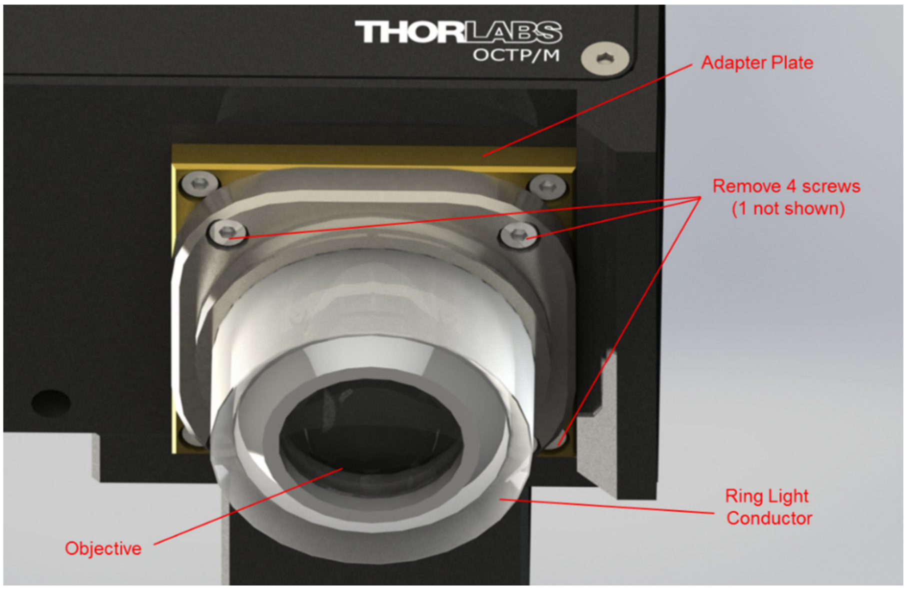


Figure 20 Removing the Objective

2. The ports should look like one of the two images below (Figure 21).

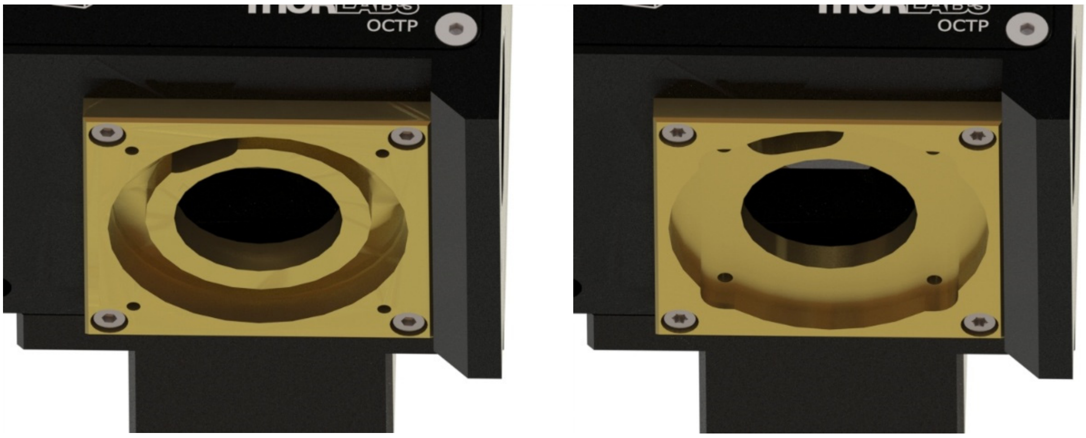


Figure 21 Optics Output Port, left for OCT-LKx, right for SM1

3. Install the provided alignment target (shown in Figure 22) in the objective mount of the scanner cube. For the brass plate on the left (used with the OCT-LKx scan lens kits), please use the included SM1A11 adapter to insert the alignment target. Place the IR viewing card (item # VRC2) delivered with the system on the sample plate underneath the alignment target.

Figure 22 Alignment Target

4. Turn on the Thorlabs OCT base unit to power up the galvanometer scanners in the OCTP and start the ThorImage®OCT software. To make sure that the mirrors are in their assigned initial position and the light source is turned on, choose the 2D Scan mode and simply "Start" and then "Stop" a measurement.

5. Use the knobs indicated in Figure 23 to align the fiber collimation module such that light is centered on the alignment target. A good starting point for the procedure is a parallel orientation of the kinematic mirror mount that comprise the fiber collimator mount. The alignment can be monitored on the IR viewing card.

   Using this target it is possible to align a non-focused beam by controlling the shadow of the central cross. The alignment is good when the four open segments of the alignment target are completely visible on the IR viewing card and the beam fills the segments identically. If the beam is centered on the alignment disk, it is also centered on the optical axis of the scan cube's output port.

   Turn off the ring light if necessary using the light bulb slider under the camera window. It might be necessary to occasionally move the IR viewing card when its fluorescence intensity becomes low.

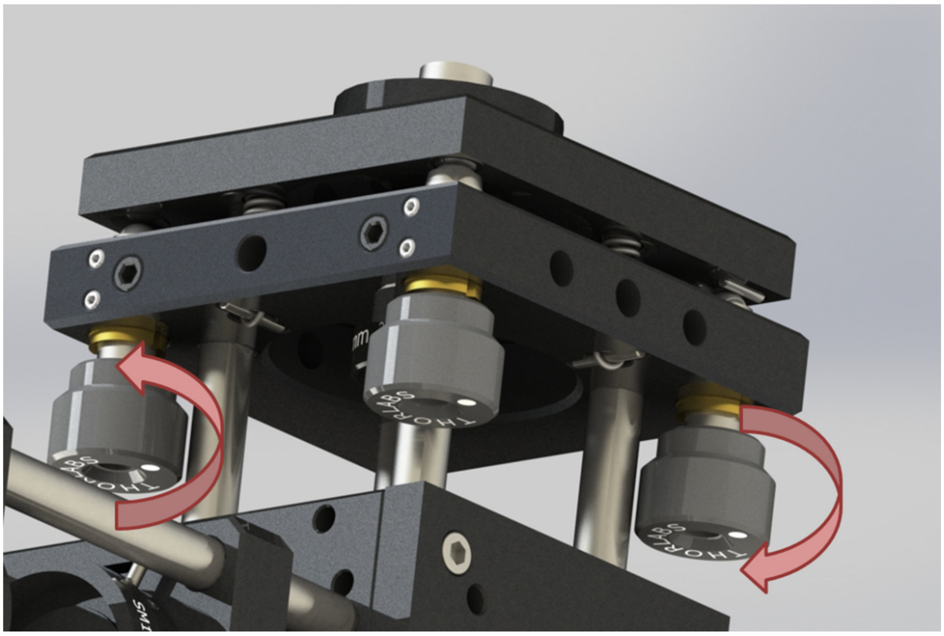


Figure 23 Adjustment of Collimator

When configuring an OCTP-NR for dual path measurement e.g. when used together with a Vega series OCT system, the alignment ends here.

6. Align the optical beamsplitter module with respect to the reference arm module. The goal of this step is to maximize the intensity of the light in the reference arm that returns to the collimator and is collected by the fiber. To monitor the power in the reference arm, use the reference light intensity monitor as shown in Figure 24. It turns red if the camera is saturated by the reference light. Then, the iris needs to be closed to reduce the reference intensity.

Figure 24 Reference Light Intensity Monitor

Before starting adjustment of the beamsplitter, loosen the locking screw of the micrometer and tighten the fine adjustment screw of the rotation plate. Note that overtightening the fine adjustment control screw may prevent proper operation of the micrometer driven stage. Use the knob and hex slot indicated in Figure 25 to align the optical beamsplitter module such that the beam going into the reference arm module is centered on the reference arm mirror. (It should not be necessary to use the hex slots that are not indicated.)

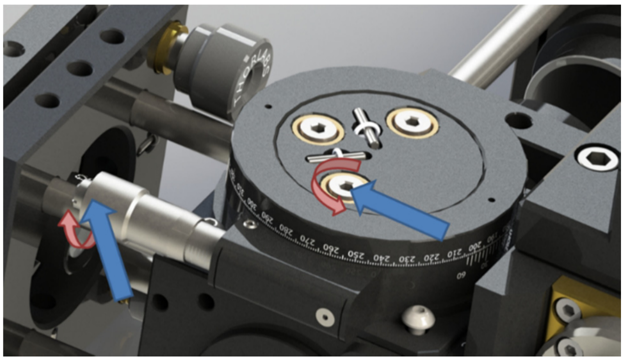


Figure 25 Adjustment of Beam Splitter

Align the beamsplitter for maximum intensity. If the display reaches its limit (very high reference light; see Figure 24), it does not necessarily indicate that maximum intensity is being collected by the fiber; it can simply indicate that the intensity exceeds the dynamic range of the detector. If this occurs, use the variable aperture to return the measurement within the usable dynamic range, then continue aligning the beamsplitter to see if the intensity can still be increased. Use both the aperture and the beamsplitter iteratively maximize the back reflected light.

7. After changing the beamsplitter orientation, it is necessary to check the centration of the beam on the alignment target. If the beam through the objective aperture is not well centered along an optical axis (i.e., the beam is coming out at an angle), it is necessary to repeat steps 5 and 6 iteratively.

8. Close the software program ThorImage®OCT to turn off the light from the OCT base unit. Check that the SLD light indication LED at the base unit is no longer lit. Remove the alignment target and re-install the objective and illumination part.

9. Place a suitable sample for adjusting the focus under the OCTP, like the IR viewing card delivered with the system. Then use ThorImage®OCT to visualize the card. Adjust the height of the OCTP with respect to the card by adjusting the focus block of the OCT-STAND until you get a sharp image of the sample, turning on the ring light if necessary.

10. The length of the reference arm can be adjusted by starting a B-scan acquisition. When the length of the arm is significantly incorrect, no OCT image will appear on the screen. The OCTP is shipped with the reference arm length pre-adjusted to match the selected objective.

- For OCTP:
  To coarsely adjust the length of the reference arm, translate the mirror along the axis of the 30 mm cage system, either by loosening the top cage plate or the variable lens tube. Fine adjustments of ±2 mm (total range of 4 mm) can be performed by tweaking the non-rotating zoom housing, as shown in Figure 26. We recommend aligning the reference arm such that when the sample is present, the non-rotating zoom housing is centered within its adjustment range. In addition, if coarse adjustment of the reference arm length is necessary, we recommend making the reference arm length slightly shorter than the sample arm length.

- For OCTP-PS:
  The coarse length adjustment is performed by changing the postion of the cage translation stage. The fine adjustment of ±6 mm (total range of 12.7 mm) can be performed by using the micrometer screw.

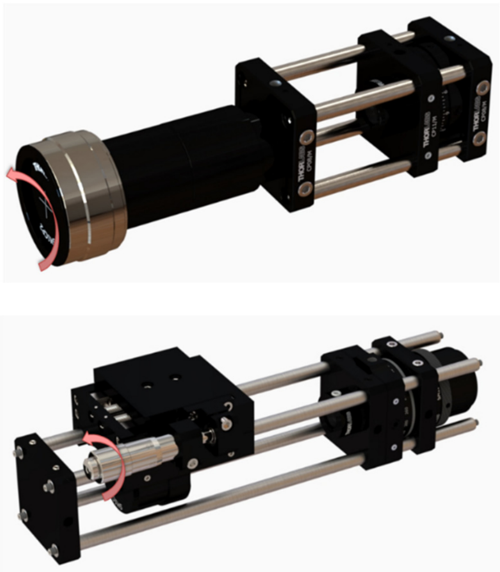


Figure 26 Fine Adjustment of Reference Arm Length OCTP (top) and OCTP-PS (bottom)

If no signal appears, check that the sample is at the focus of the objective and that the beam is not blocked anywhere along its beam path. When using the IR card for adjustment, your B-scan image should be similar to Figure 27.

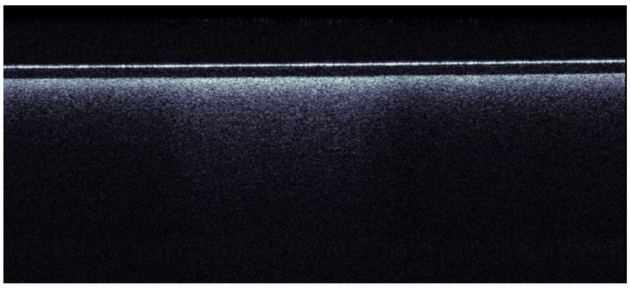


Figure 27 OCT Image of IR Viewing Card

When not configured for a polarization-sensitive SD-OCT system, the alignment ends here.
Please continue below for adjusting the OCTP-PS.

4.3.2. Polarization Adjustment

In polarization-sensitive OCT, the polarization state of the incident light is adjusted in both the reference arm and the sample arm. The incident light on the sample is circularly polarized light to achieve a sensitivity to all polarization axes in the sample and to be independent on sample rotation in plane. In contrast, the light coming from the reference arm is linearly polarized light rotated by 45° with respect to the light going into the OCTP-PS. That way it is able to interfere with both polarization axes.

The polarization state in both arms can be adjusted by unlocking the screw of the quarter-wave plate mounts, as shown in Figure 28. Note that the polarization state of the light of each arm is traversed twice through the corresponding quarter-wave plate.

Please note that changing the orientation of the collimator and hence also that of the polarization maintaining fiber, requires a readjustment of the quarter-wave plates detailed below.

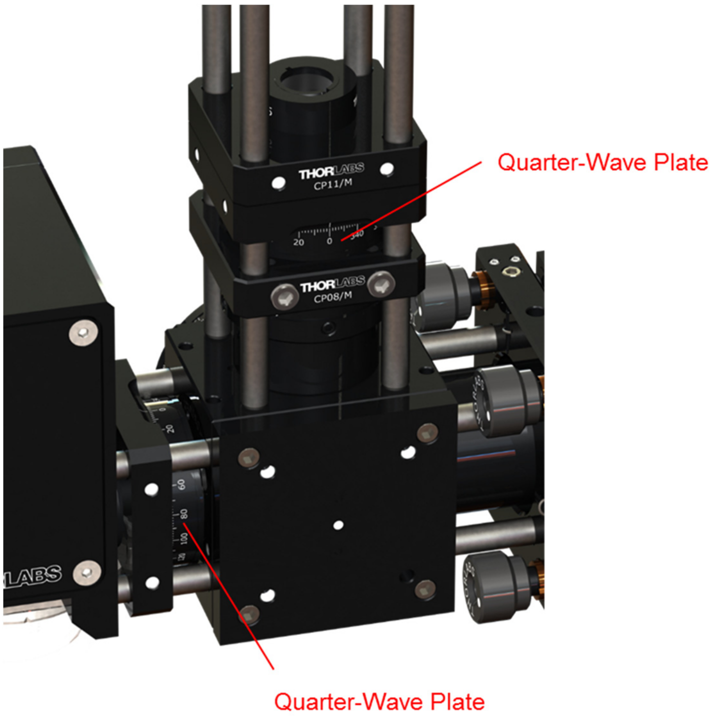


Figure 28 Polarization Adjustment by Quarter-Wave Plates in OCTP-PS

ATTENTION

The quarter-wave plates are adjusted in both arms with respect to the orientation of the polarization axis of the optical fiber (key aligned to slow axis) in the collimator. All positions are marked in red.

In this configuration the main intensity from the sample arm is collected on Camera 0. If this is NOT the case, please check if the CameraLink cables are interchanged.

The OCTP-PS comes prealigned and further alignment should not be necessary. Perform the following steps only when you are certain that realignment is necessary. When using the OCTP-PS together with a Telesto PS-Series OCT system, the polarization adjustment can be performed by following these steps:

1. Start ThorImage®OCT software and select the 1D Mode to display the intensity spectra of the two cameras.

2. To detect the polarization state of the sample arm the reference arm has to be blocked, e.g. by closing the zero-aperture iris.

3. Place a mirror in the focus of the sample arm. Rotate the quarter-wave plate such that the intensity on Camera 0 is maximum and the intensity on Camera 1 is minimum. The corresponding spectra are shown in Figure 29 on the top.

4. To determine the polarization state in the reference arm, the light in the sample arm has to be blocked, e.g. by removing any sample from under the objective. Make sure to either block the light completely or to have a sufficiently large gap between the objective and the substrate.

5. Rotate the quarter-wave plate in the reference arm such that the spectra on both Camera 0 and Camera 1 overlap exactly. The corresponding spectra are shown in Figure 29 on the bottom.

   Note that a good agreement between the two spectra can be obtained several times when rotating the quarter-wave plate by a full 360°. However, the agreement between the spectra will vary slightly and the quarter-wave plate should be rotated such that the agreement is best (at 22.5° with respect to the incident linearly polarized light).

6. Once the adjustment is complete, tighten the screws of the quarter-wave plate mounts.

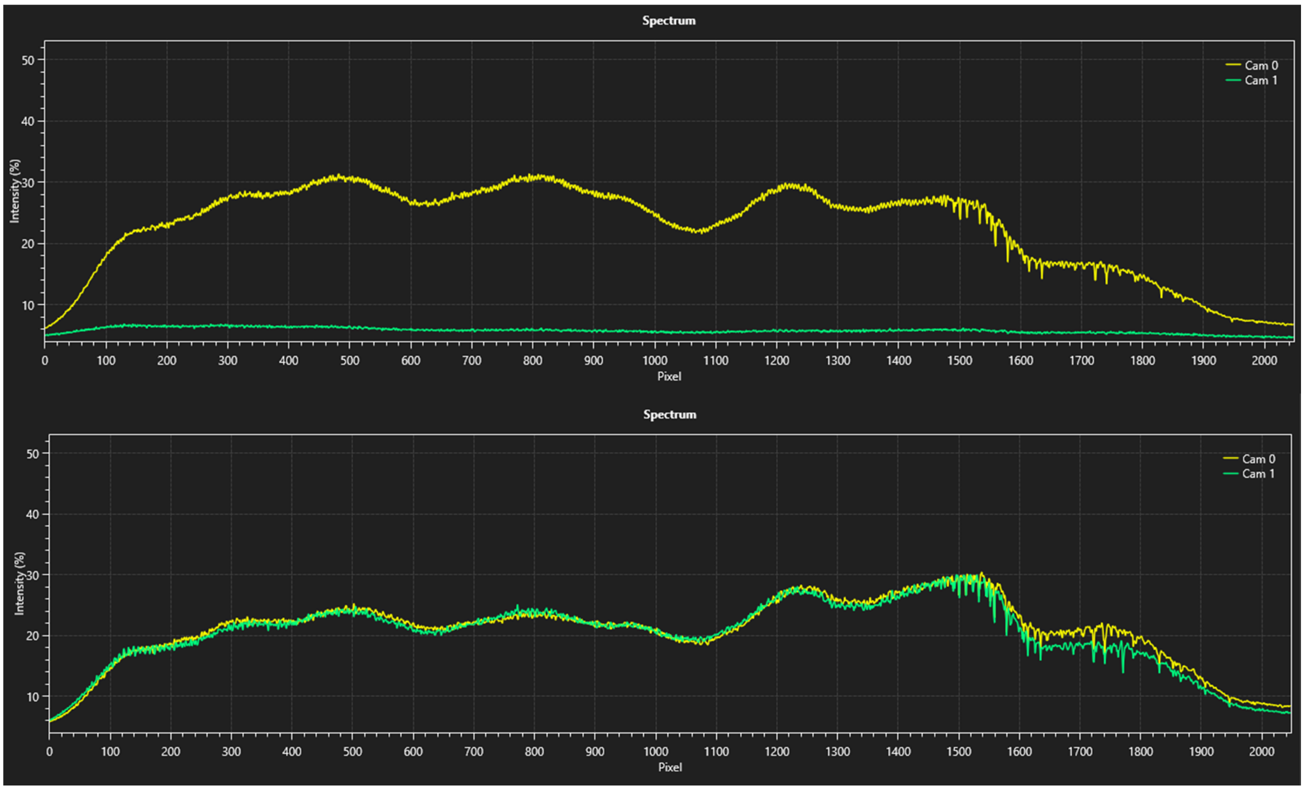


Figure 29 Spectral distribution on the two cameras during the adjustment of the sample beam (top) and the reference beam (button)

Chapter 5 Description

5.1. Theory

5.1.1. Signal Generation

Optical coherence tomography (OCT) generates cross-sectional images up to several millimeters deep into tissue. The images are assembled by a series of adjacent depth profiles, allowing 2D and 3D reconstruction of the specimen.

Therefore the interference between the light coming back from the specimen and from a reference is sampled for a broad range of different wavelengths. This is performed either by using a broadband light source divided into separate wavelengths using a spectrometer or by a laser with small bandwidth quickly tuned over a broad wavelength range.

The phase delay of the back-reflected and back-scattered light (with respect to the stationary reference) is recorded as a function of wavenumber, and a Fast Fourier Transform (FFT) yields the cross-sectional images as a function of sample depth.

5.1.2. Limitations

The spatial resolution and sensitivity of the OCTP depends on several parameters, including the following:

- **Wavelength Range:** The optical components within the OCTP are optimized for a specific wavelength range, depending upon the model. For the usable wavelength range please refer to Table 2.

- **Optical Power:** The sensitivity of the OCTP is directly related to the intensity of the light returning from the sample. Factors that can reduce the collected light intensity from the sample fiber include: dirty fibers, blocked/cropped beams, and condensed water in the environment.

- **Physical Movements:** OCT systems use a camera to detect the phase relation of the light returning from the sample. Even small movements of the specimen in relation to the optical reference arm can ”wash out” the wavenumber-resolved phase contrast, affecting the image.

- **Imaging:** In a fiber-based OCT setup, the light returning from the sample is focused into the core of an optical fiber. Hence, the fiber can be thought of as a spatial filter for the light. This filter has an effective diameter, referred to as the “mode field diameter. For single mode propagation, mode field diameter is larger than the fiber core diameter. Poor focusing, caused by optical aberration or misalignment, therefore leads to loss of contrast and sensitivity.

5.2. Optical Design

5.2.1. Common Path Setup (OCTP)

As shown below, the OCTP is factory-configured such that the sample beam and reference beam are generated after the beam leaves the fiber. This allows us to use single-mode optical fiber to transport the beam into the scanner while minimizing the use of free-space propagation.

This approach avoids problems that can degrade image quality, related to optical phenomena like polarization mode dispersion (PMD) and birefringence, and makes the performance of the system independent from the length of the single-mode fiber.

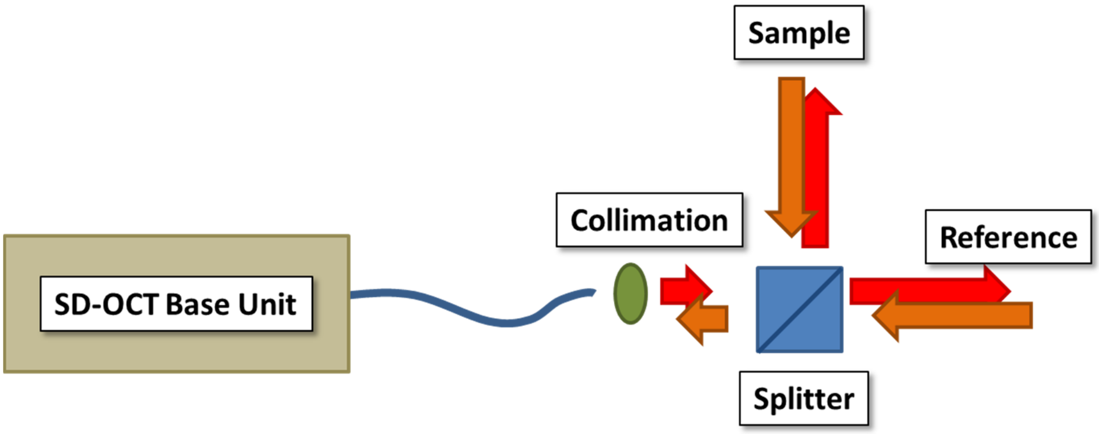


Figure 30 Diagram of the Common Path Setup

5.2.2. Dual Path Setup (OCTP-NR)

Shown below is an alternative beam geometry to the common path setup when the scanner is ordered in a configuration without reference (OCTP-NR). The sample beam and reference beam are generated within different fibers, before the beam exits into free space. In this configuration, the scanner becomes the sample arm of the interferometer. By using two different fibers, the beamsplitter cube used in the common path setup is no longer needed.The flexible cage compatible design of the OCTP allows the removal of the beamsplitter cube and the reference module.

While this approach is able to provide greater sensitivity due to the absence of the beamsplitter cube (which reduces the intensity of the light that returns to the fiber), it is significantly more sensitive to the optical phenomena mentioned before. Please contact Thorlabs' OCT support (see Chapter 11) for details.

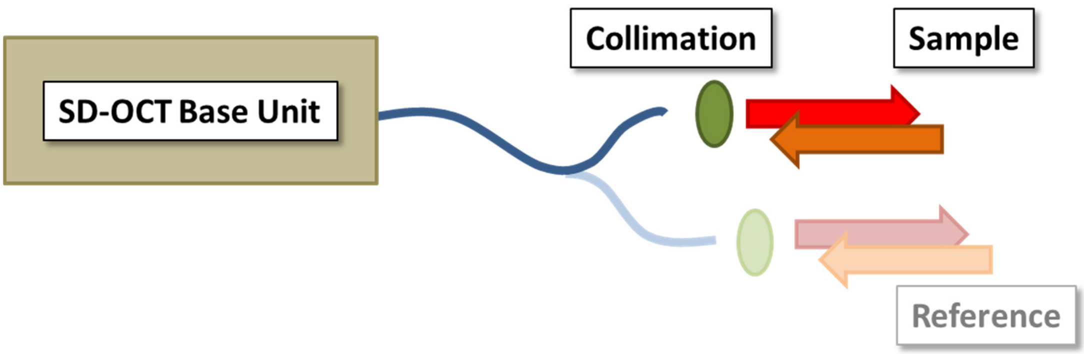


Figure 31 Diagram of the Dual Path Setup

5.3. Intended Use

The OCTP is designed for simple and rapid installation. It contains mechanical features that enable compatibility with Thorlabs' SM1 lens tube and 30 mm cage system standards, permitting simple, easy system modifications that improve and optimize the performance. The scanner allows integration of additional components for adaptation to a specific application.

Please contact a member of the Thorlabs' OCT support team to determine if other parts you wish to use are compatible (see Chapter 11). Any modification or servicing of this system by unqualified personnel renders the warranty null and void, leaving Thorlabs free of any liability.

5.3.1. Realization

The basic optical layout of the OCTP scanner in common path layout is illustrated below in Figure 32.

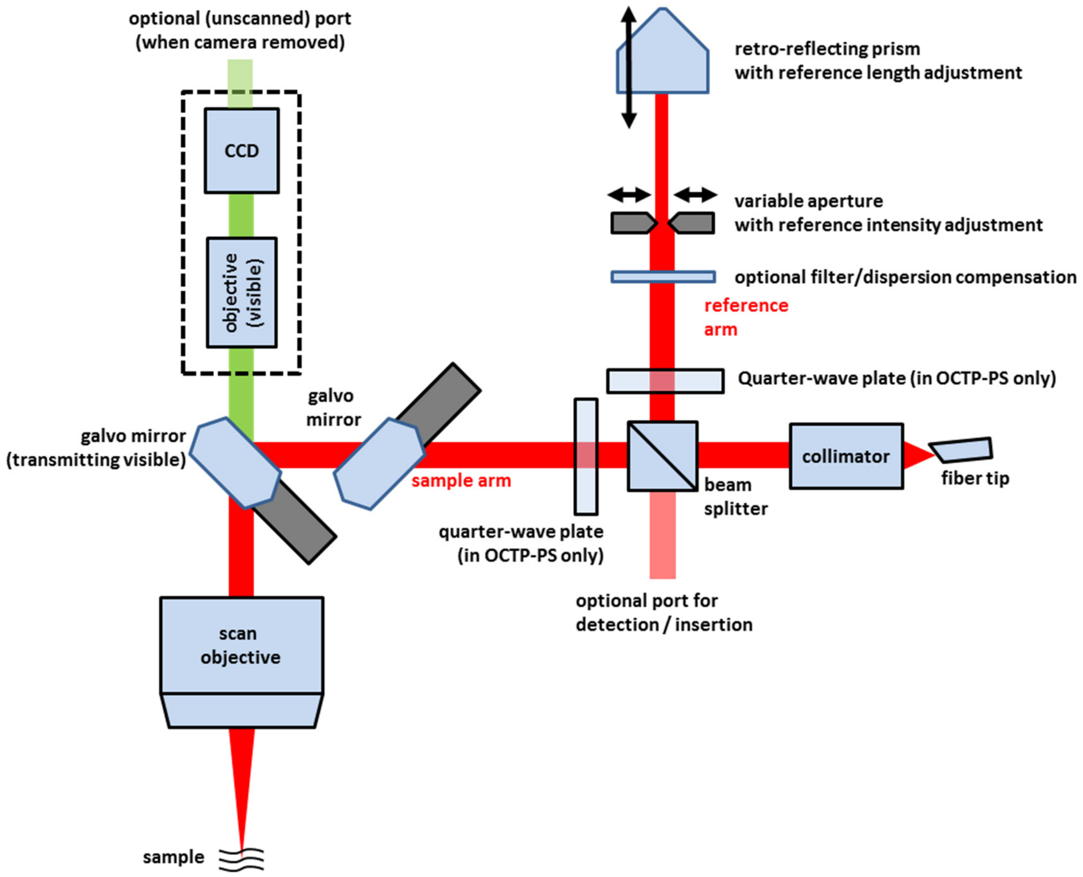


Figure 32 Optical Layout of the OCTP

The broadband light output from an FC/APC-terminated fiber is collimated and directed into a cube beamsplitter. The beamsplitter divides the broadband light into a sample arm and a reference arm, similar to a Michelson interferometer.

The sample arm is propagated onto two galvanometric mirrors to allow for scanning in two axes. The scan objective then focuses the beam into the sample. Backscattered and back-reflected light is collected by the scan objective and travels back into the fiber. The light propagated into the reference arm is reflected back into the fiber. The interference between the beams in these two arms generates the OCT signal.

Reference Arm Tweaks

- There is an optimal intensity for the reference light that can be found using the zero-aperture iris. For the best contrast, the intensity in the reference arm should be roughly equal to the intensity of the backscattered and back-reflected light returning from the sample.
- The length of the reference arm can be adjusted by translating the retroreflector along the cage rods, by rotating the variable lens tube (a coarse adjustment), or by using the non-rotating zoom housing (a fine adjustment). Adjustment of the reference arm length can be done in combination with adjustment of the focus height (using the OCT-STAND), so that the focal point in the OCT data is shifted. This adjustment is also necessary when imaging in a refractive medium.
- Filters and dispersion-compensating optics can be mounted in the reference arm.

In the dual path configuration of the OCTP-NR, the reference path components are not included.

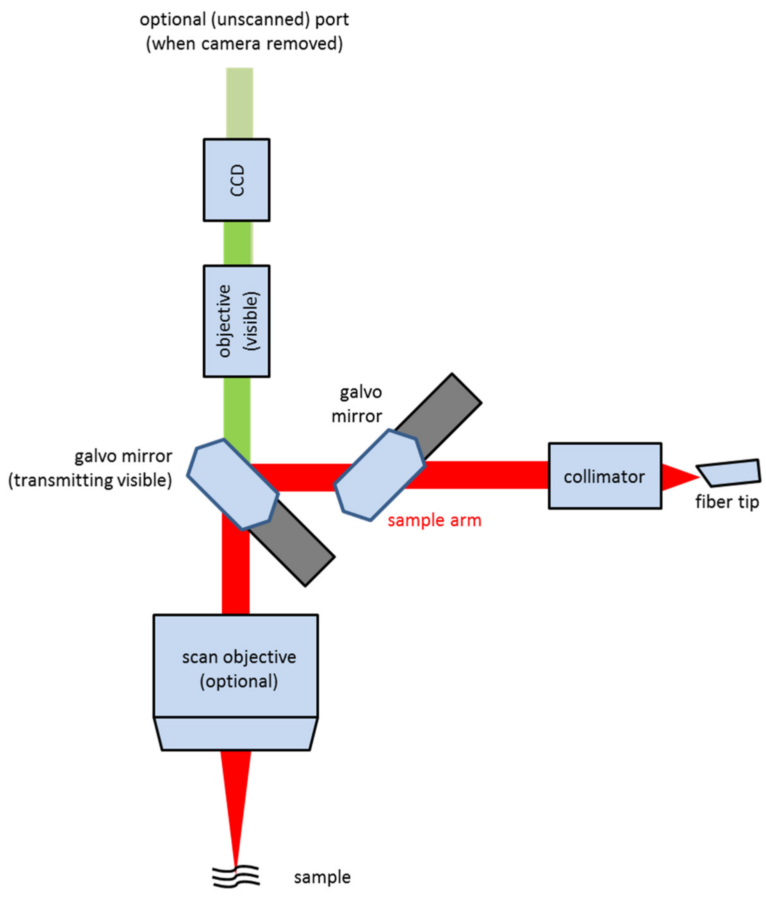


Figure 33 Optical Layout OCTP-NR

Optional Optical Ports

In the two figures above, optional optical ports are marked.

- A non-descanned optical port (i.e., a port that bypasses the partially transmitting galvo scan mirrors) is accessible by removing the camera.

- The cage cube holding the beamsplitter ships with a port that is blocked by an end cap. By removing the end cap, the exposed port can be used for additional sample detection or laser illumination. This second port is not available in OCTP-NR.

Chapter 6 Troubleshooting

Problem	Possible Cause	Recommended Solution
Poor Reference Light Intensity	Fiber Not Connected	Remove and Reconnect Fiber, Ensuring that Alignment Key is Inserted into Key Slot
	Aperture is Too Small	Open Aperture (See 4.3)
	Reference Arm is Not Aligned	Align Optical Beamsplitter to Make Beam To and From the Reference Mirror Collinear with Cage System Axis (See 4.3)
	Fiber Tip is Dirty	Clean Fiber Tip (Thorlabs' FBC1 Bulkhead and Connector Cleaner Recommended)
	Other Reason	Contact OCT Service (See Chapter 11)
No Image is Obtained	Optical Path Length of Reference and Sample Arms is Not Matched	Adjust Reference Arm Length Using Cage Plate and/or Non-Rotating Zoom Housing (See 4.3)
	Beam is Blocked	Check for Obstructions in Fiber Collimation Module and Reference Arm Module
	USB Cable is Loose	Reconnect USB Cable
	PC Crashed	Restart PC
	Other Reason	Contact OCT Service (See Chapter 11)
Low Scan Resolution	Dispersion in Reference and Sample Arms is Not Matched	Add Compensating Optics to One or Both Arms
Bad Image Quality	Image Obtained is Being Mirrored	Adjust the Distance Between the Objective and the Sample. The Image Should Move Towards the Top of the Computer Window
	Optical Path Length of Sample Arm is Too Short	Move Sample Away From Objective
	Reference Intensity is Too High or Too Low	Close or Open Zero-Aperture Iris to Adjust Intensity (See 4.3)
	Other Reason	Contact OCT Service (See Chapter 11)
Flipped Image	Optical Path Length of Reference Arm is Incorrect	Adjust Reference Arm Length Using Cage Plate and/or Non-Rotating Zoom Housing (See 4.3)

Table 3 Troubleshooting

Chapter 7 Certifications and Compliance

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):

2006/42/EC	Machinery Directive (MD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: ***OCTP-xxxx(NR/M)***

Equipment: ***OCTP User-Customizable Scanner***

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

EN ISO 12100	Safety of Machinery. General Principles for Design. Risk Assessment and Risk Reduction	2010
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013

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: D. Jennrich *On:* 15 February 2017

Name: Dorothee Jennrich

Position: General Manager

EDC - OCTP-xxxx(NR/M) -2017-02-15

CE

Chapter 8 Specifications

OCTP Series Scanner	
Optical Specifications	
Center Wavelength	900 nm, 1050 nm, or 1300 nm
Clear Aperture	Ø6 mm (Max)
Clear Aperture Unscanned Optional Port (with Hot Mirror)	Ø2.5 mm
Clear Aperture Unscanned Optional Port (w/o Hot Mirror)	Ø6 mm (Max)
Reference Length Fine Adjustment	±2 mm
Scan Distance	10.0 mm / 20.8 mm
General Specifications	
Video Camera	Color CMOS
Weight of Scanner	1 kg (2.2 lbs)
Storage / Operating Temperature	10 °C to 35 °C
Dimensions of Imaging Module (L x W x H) Common Path	~230 mm x 65 mm x 250 mm
Dimensions of Imaging Module (L x W x H) Dual Path	~170 mm x 65 mm x 90 mm
Airborne Noise Emission	<70 dB_A

Table 4 OCTP Specifications

Compatible Scan Lens Kits			
Objective Item #	**OCT-LK2(-BB)**	**OCT-LK3(-BB)**	**OCT-LK4(-BB)**
Field of View	6 mm x 6 mm	10 mm x 10 mm	16 mm x 16 mm
Barrel Height (B)	29.5 mm	28.0 mm	41.0 mm
Working Distance	3.4 mm	24.9 mm	41.6 mm

Table 5 Scan Lens Kits Specifications

8.1. Reflectivity Scanning Mirror

The OCTP series user-customizable scanners are equipped with a semitransparent galvo mirror to enable video camera imaging.*

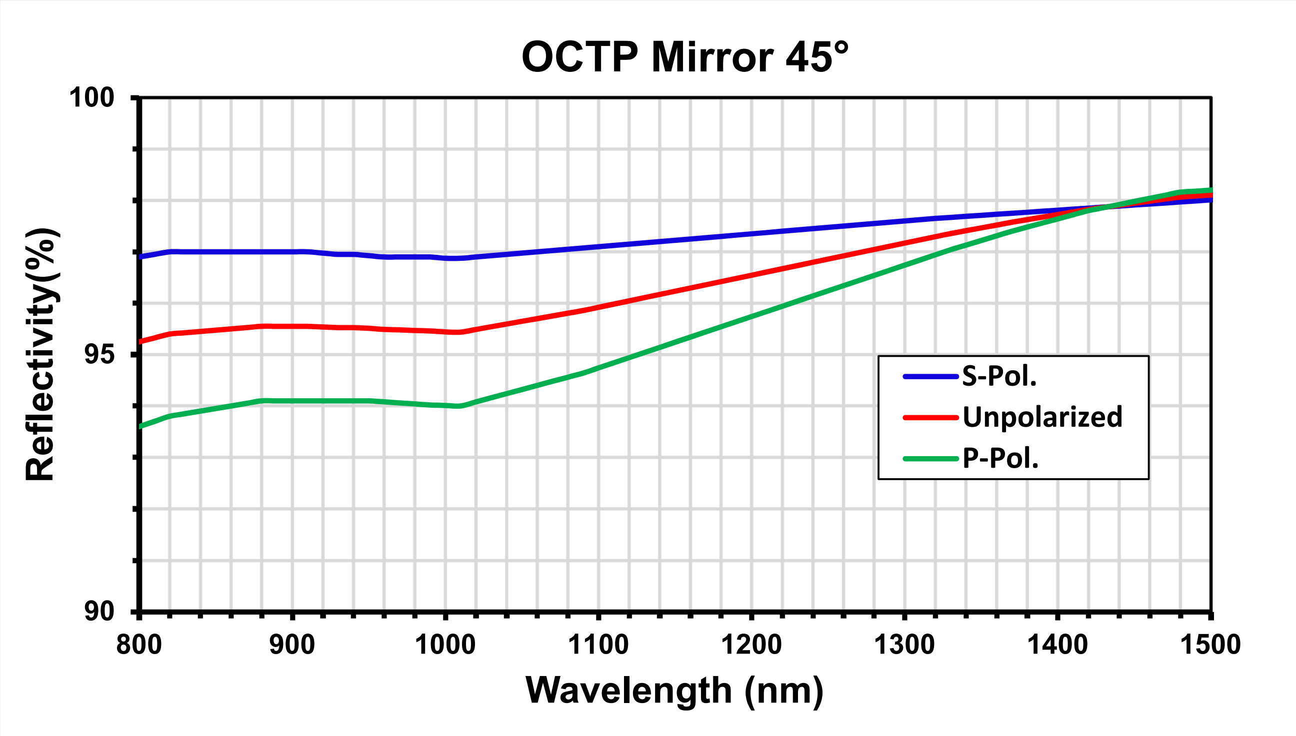


Figure 34 Reflectivity of Scanning Mirror

8.2. Transmission Unscanned Optional Port

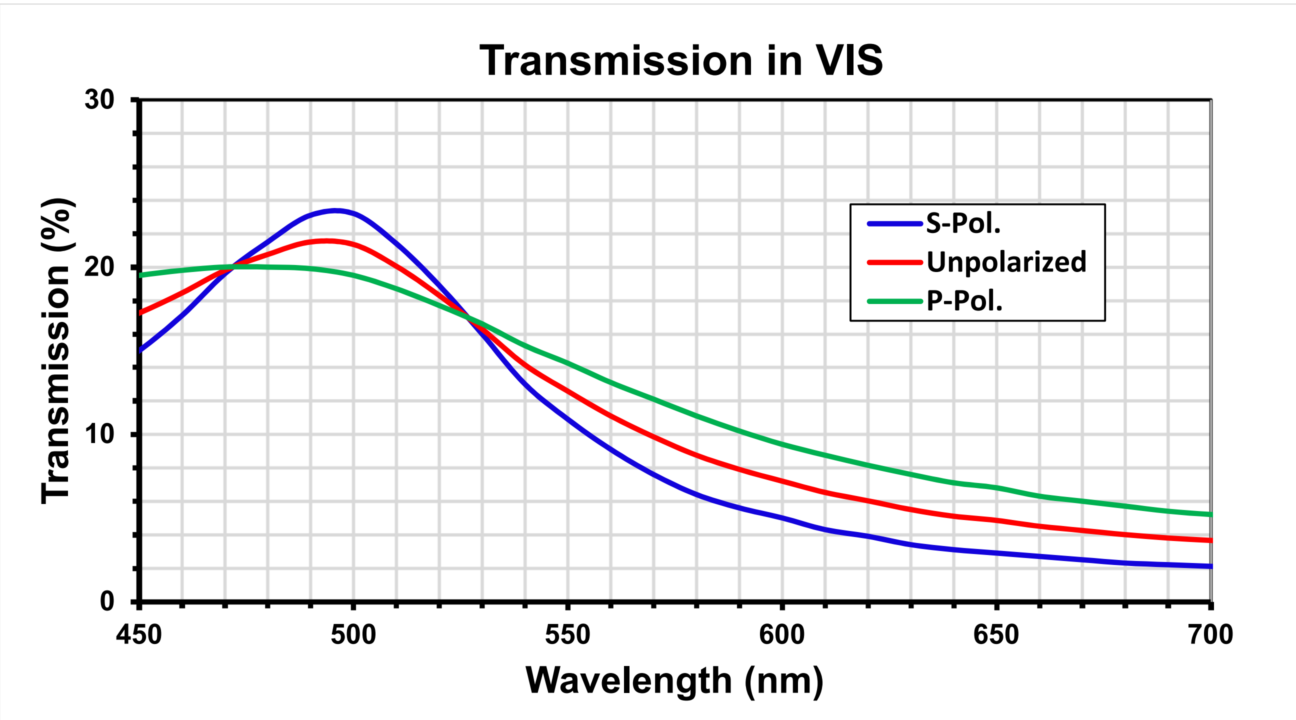


Figure 35 Transmission of Unscanned Optional Port

*In systems delivered prior to February 2017 a coating with different characteristics was used. For further information about their performance, please contact Thorlabs' OCT support (see Chapter 11).

Chapter 9 Warranty

9.1. Imaging Systems

Thorlabs offers a one-year warranty on the OCTP.

9.2. 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.

9.3. 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 10 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.

10.1. 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.

10.2. 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 11 Thorlabs OCT Support Contact

If you have a technical question or issue on Thorlabs OCT products, please refer directly to the OCT Support team located in Luebeck, Germany.

OCT Support

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Fax: +49-(0)8131-5956-99
www.thorlabs.de
Email: oct-support@thorlabs.com

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.

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