OTS-1000
Optical Transmission Scanner
-OptiScan™

User Guide

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General Photonics Corporation is located in Chino California. For more information visit the company's website at: www.general photonics.com or call 909-590-5473
SAFETY CONSIDERATIONS

The following safety precautions must be observed during operation of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the product. General Photonics assumes no liability for customers’ failure to comply with these requirements.

Before operation, the user should inspect the product and review the manual carefully.

Use only in a safe work environment in terms of temperature, humidity, electrical power and risk of fire or shock. The product is designed for indoor use. Avoid exposure to liquids or water condensation. Provide adequate ventilation for cooling.
Operate the product on a stable surface. Avoid excess vibration.
Standard laser safety procedures should be followed during operation.

Never look into the light source fiber connector when the light source is turned on. THE OUTPUT LIGHT FROM A HIGH POWER LASER IS HARMFUL TO HUMAN EYES. Follow industry standard procedures when operating a high power laser source. Since the light from the OTS-1000 may be invisible (depending on light source), it is safer to turn it off when making adjustments to the setup and when the light source is not in use.

OPERATION CONSIDERATIONS

- The software program should be closed before powering off the instrument.
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Section 1.0 Overview

Non-destructive evaluation (NDE) techniques that can measure both surface and subsurface defects are of critical importance in evaluating the integrity of composites and plastics. The OTS-1000 is a high resolution (lateral), rapid, non-contact optical transmission scanning system specifically designed for quantitative NDE of such components. Materials with low attenuation in the ultraviolet (FUV to NUV), visible, or infrared (NIR to FIR) spectra are suitable for inspection. Unlike ultrasonic testing (UT) methods, the OTS-1000 has a simpler system design and does not require coupling or sophisticated electronics, thus allowing for rapid scanning and significant cost reduction. The system comes with integrated software, which provides advanced post-processing capabilities.

Figure 1 OTS-1000 Optical Transmission Scanner

The OTS system consists of a translation stage that moves the sample, a laser source and a photodetector. The light is normally incident on the sample.
1.1 Principle of Operation

The operating principle of optical transmission scanning (OTS)\(^2\) is based on measuring the transmission properties of the sample being tested. When radiation interacts with a material, the following effects can occur: transmission, absorption, chromatic dispersion, diffraction, scattering, reflection, refraction and conversion\(^3\). Conversion of radiation occurs due to the medium’s nonlinearity (dielectric polarization responds nonlinearly to the electric field of the light) and can be neglected if the medium is fairly linear. Refraction affects the direction of radiation propagation and can be neglected if the incident radiation is normal to the interface. Diffraction mainly occurs at the edges and is insignificant in the bulk of a material. Dispersion effects will be insignificant if the radiation is quasi-monochromatic. Note that the former three effects influence the direction of radiation propagation rather than the energy or the power of radiation.

Power losses are partially due to reflection, which occurs whenever there is a mismatch between the refractive indexes of two materials (e.g., an interface such as a delamination). In order to calculate the reflection coefficients for s-polarized (\(R_s\)) and p-polarized (\(R_p\)) light at the interface between non-magnetic materials, the Fresnel equations are used\(^1\):

\[
R_s = \frac{n_1 \cos \theta_i - n_2 \sqrt{1 - \left(\frac{n_1}{n_2}\right)^2 \sin^2 \theta_i}}{n_1 \cos \theta_i + n_2 \sqrt{1 - \left(\frac{n_1}{n_2}\right)^2 \sin^2 \theta_i}}
\]

\[
R_p = \frac{n_1 \sqrt{1 - \left(\frac{n_1}{n_2}\right)^2 \sin^2 \theta_i} - n_2 \cos \theta_i}{n_1 \sqrt{1 - \left(\frac{n_1}{n_2}\right)^2 \sin^2 \theta_i} + n_2 \cos \theta_i}
\]

where \(\theta_i\) is the angle of incidence, \(n_1\) is the refractive index of the material from which light is incident on the interface, and \(n_2\) is the refractive index of the material into which nonreflected light is transmitted. In the case of normal incidence (\(\theta_i = 0\)) these equations reduce to the following formula:

\[
R = R_s = R_p = \left|\frac{n_1 - n_2}{n_1 + n_2}\right|^2
\]

For instance, at a normal incidence angle, the specular reflection coefficient for an air (\(n = 1\))/glass (\(n \approx 1.5\)) interface is around 0.04, meaning that approximately 4% of incident radiation is reflected. If the interface is optically rough, diffuse reflection can take place. In such a case, the
interaction of radiation with material becomes more complex; and the reflection coefficient can change drastically\textsuperscript{4,5}.

For collimated monochromatic radiation in homogeneous media, the material’s effect on the transmitted light, including the effects of absorption and scattering, but excluding the effects of reflection from internal layer interfaces, can be calculated from:

\textbf{Equation 4}

\[ P_T = P_0 \cdot T_{as} = P_0 \cdot \exp\left[-\sum_{i=1}^{N} (\mu_a^i + \mu_s^i)l_i\right] = P_0 \cdot \exp\left[-\sum_{i=1}^{N} \mu_i l_i\right] \]

where \( P_0 \) is the incident power, \( P_T \) is the transmitted power, \( T_{as} \) is the transmission coefficient in the absence of reflection, \( N \) is the number of attenuating species of the material sample, and \( \mu_a^i, \mu_s^i, \mu_i \) and \( l_i \) are the absorption coefficient, scattering coefficient, attenuation coefficient, and thickness of the \( i \)th specie, respectively.

The transmitted power detected after the sample, including the effects of reflections from internal interfaces, can be approximated as follows:

\textbf{Equation 5}

\[ P = P_T \cdot (1 - R_1) \cdot (1 - R_2) \cdot \ldots \cdot (1 - R_M) = P_T \cdot T_{R_1} \cdot T_{R_2} \cdot \ldots \cdot T_{R_M} \]

where \( P \) is the power of the transmitted radiation, \( P_T \) is the power calculated using Equation 4, \( R_1, R_2, \ldots, R_M \) are the reflection coefficients from \( M \) interfaces in the sample, and \( T_{R_1}, T_{R_2}, \ldots, T_{R_M} \) are the corresponding transmission coefficients for the \( M \) interfaces. However, if a collimated beam propagates through a scattering medium, the transmitted radiation is no longer collimated, in which case the sample geometry significantly affects the angular distribution of the transmitted radiation. Thus, the size of a delamination/air gap inside a sample and the distance between the detector and the output interface might affect the amount of transmitted radiation received.

Equation 5 provides a self-referencing capability for the system. The thickness of a composite sample and the delamination depth do not affect the transmission coefficient for a single interface (delamination), which is defined as the ratio of the radiation transmitted through the region with delamination (\( P \)) to the radiation transmitted through a healthy region of the sample (\( P_T \)).

Section 2.0 Features

2.1 Light Path and Sample Holder

Figure 2 Sample holder

Figure 2 shows the sample holder. It holds a 100×100mm sample, which is held in place by 3 spring-loaded clips.

Figure 3 Light path
An SM fiber patchcord with FC/PC connectors is used to direct the light from the laser to a connector holder at the top of the assembly. The connector holder and photodetector are prealigned so that the light beam travels directly between them. During the setup for a scan, the sample holder is positioned to place the sample in the path of the beam such that the beam enters the sample at normal incidence.
2.2 Control Box

The control box contains the laser, power supply, and control electronics for the OTS-1000 system. The power switch, power cable connection, and USB connector are on one side, and the laser and photodetector connections are on the other side.

![Control box, with cables connected](image)

**Figure 4 Control box, with cables connected**

![Control box PD/laser/gantry connections](image)

**Figure 5 Control box PD/laser/gantry connections**
The system power switch is the main power switch for the entire system (laser, PD, motors, control electronics). The gantry control and PD also have separate on/off switches. Once all three switches are turned on, the control program can be run to initialize the system and set up for scanning.

Figure 6 Control box external power/communication connections

The system power switch is the main power switch for the entire system (laser, PD, motors, control electronics). The gantry control and PD also have separate on/off switches. Once all three switches are turned on, the control program can be run to initialize the system and set up for scanning.
Section 3.0      Operation Instructions

3.1 Unpacking

Inspect OTS-1000 for any physical damage due to shipping and transportation. Contact carrier if any damage is found. Check the packing list to see if any parts or accessories are missing.

Packing List

<table>
<thead>
<tr>
<th>Item #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OTS-1000 system</td>
</tr>
<tr>
<td>2</td>
<td>SM fiber patchcord with FC/PC connectors</td>
</tr>
<tr>
<td>3</td>
<td>PD power cable</td>
</tr>
<tr>
<td>4</td>
<td>Power cord</td>
</tr>
<tr>
<td>6</td>
<td>USB cable</td>
</tr>
<tr>
<td>7</td>
<td>M6×12 Pan head screws (x2) to mount the control box to the gantry</td>
</tr>
<tr>
<td>8</td>
<td>4 angle brackets</td>
</tr>
<tr>
<td></td>
<td>¼-20 (½” long) screws (x4) to mount beam with light source connector holder</td>
</tr>
<tr>
<td>9</td>
<td>User guide</td>
</tr>
<tr>
<td>10</td>
<td>Software</td>
</tr>
</tbody>
</table>

3.2 Assembly and Setup

System Assembly

The complete OTS system is very large. To reduce the size of the package and the possibility of damage during shipping, the main control box and the light source output support beam are detached from the main system assembly for shipping. They must be reassembled before use.

1. Assemble the system on a stable surface that is not subject to vibrations.
2. Mount the light source output support beam to the rest of the frame, as shown below. The beam is held to each side of the frame by 3 angle brackets (one on each side of the beam and one on top of the side bar to which the beam is to be attached). Each angle bracket requires two ¼-20 button head screws.
   Two of the six angle brackets (one on top of the bar on each side of the frame) are already attached to the frame with one screw each. The beam has 3 screws attached on each side.
   The remaining 4 screws are provided separately with the remaining 4 angle brackets.
3. Mount the control box to the frame using M6×12 pan head screws. One screw on each side is used to hold the control box angle brackets to the frame.

4. Connect the fiber patchcord between the laser output connector on the control box and the fiber connector holder on the horizontal beam. The cable holders on some of the beams in the frame can be used to hold the fiber in place (see Figure 3).

5. Connect the PD power supply and output cables between the control box and the PD. The cable holders on some of the beams in the frame can be used to hold the cables in place.
6. Connect the gantry power and communication (USB) cables between the main control box and the gantry control box, which is attached to the slider.
Measurement Setup

1. Connect the main power cable to the control box and plug it into the wall power supply.
2. Connect the control computer to the control box with a USB cable. See Section 3.3 for details on software installation.
3. The first time the system is used after assembly, position the gantry such that neither the x nor y limit switches touch the wall. If either limit position sensor is tripped when the system is turned on, it will not initialize.
4. Power on the system (power switch on control box).
5. Turn on the switch for the gantry (switch on cable connecting control box to gantry).
6. Turn on the switch on the photodetector.
7. After initial assembly, the light source must be aligned to the detector (see next section) before the system can be used for measurement.
8. Insert the sample in the sample holder (see Figure 3).
9. Run the control program.

**Light Source-Detector Alignment**

The light source-detector alignment is performed using a 2-angle kinematic mount to adjust the light source output and a 2-axis translation stage to adjust the detector position. Fine adjustment using micro steps is not required. The procedure for light source-detector adjustment is provided below:

1. Turn on the detector and monitor the detector output using NI Measurement & Automation Explorer (alignment utility software can be provided on demand). By default, NI Measurement & Automation Explorer is installed along with DAQ drivers from the DAQmx package.
2. Remove the detector pinhole and position the detector so that the laser beam is in the vicinity of the detector center.
3. Using the provided alignment pinhole, sequentially tune the light source output angle alignment as shown in Figure 7 to position the reflected beam in the center of the pinhole:
   a. Position the provided pinhole so that the output light source radiation passes through the center of the alignment pinhole.
   b. Note the relative position of the reflected incident beam.
   c. Tilt the light source output end in the opposite direction of the reflected beam offset from the center of the pinhole.
4. Insert and secure the detector pinhole with provided retaining ring.
5. Adjust the X and Y axes of the detector stage to achieve maximum detector output.

Figure 7 Laser output angle alignment
3.3 Software Installation

System Requirements
Operating system: Windows 7 32-bit, Windows 7 64-bit, Windows 10 32-bit, Windows 10 64-bit
CPU: Intel i-5 2.3 GHz or better
RAM: 4 GB or more
Free disk space: 1 GB or more
Communication port: USB 2.0 or better

Driver and Software Installation

Driver Installation
Before running the main software installer, several driver packages must be installed.

1. Gantry USB driver.
   This driver is provided with the OTS software package. It can also be downloaded from the manufacturer’s official website here: Carbide Motion V3 Build 366 for Windows. Install the required driver by running the executable file “CarbideMotion-366.exe” and restart the computer if necessary.

2. NI-VISA driver package version 15.5.
   This driver is provided with the OTS software package. It can also be downloaded from the National Instruments official website here: NI-VISA 15.5. Install the required driver package by running the executable file ”NIVISA1550full.exe” and restart the computer if necessary.

3. NI-DAQmx driver package version 15.5.1.
   This driver is provided with the OTS software package. It can also be downloaded from the National Instruments official website here: NI-DAQmx 15.5.1. Install the required driver package by running the executable file ”NIDAQ1551f0.exe” and restart the computer if necessary.

Software Installation

The software installation package is in the folder “OTS GUI installer”. Locate and run “setup.exe” to install all required components. The installer also creates a desktop shortcut to the OTS GUI software. Restart the computer if necessary.

After installation is completed, connect the OTS system to the control computer with a USB cable, power on the system and run the file “OTS GUI.exe” using the desktop shortcut or from the folder specified during the installation process.
3.4 Software Interface

General Photonics’ optical transmission scanner (OTS) graphical user interface (GUI) is the control software for OTS system operation and sample transmittance measurements. The software has a user-friendly interface and includes self-diagnostics features. Since the software requires extensive hardware communication, it is not recommended to run other programs or use other communication ports (e.g., undedicated USB or Ethernet ports, VGA or HDMI, etc.) on the control computer at the same time, in order to avoid data interruptions.

Initialization and Main Interface Screen-Overview

When the OTS system is initialized, it performs a homing sequence. During homing, most control interfaces are inactive. The status indicator is solid red (Figure 8, item 1) and only the “QUIT” button is active (Figure 8, item 2). After the homing sequence is completed, the sample fixture is set to (0, 0) XY coordinates, and the software switches to the ready state display (Figure 9).

![Figure 8 OTS GUI during homing procedure: 1-status indicator is red during homing 2-“QUIT” button](image)

1-status indicator is red during homing
2-“QUIT” button
The ready state interface contains several sections, labeled as follows in Figure 9:

1. Sample fixture motion and status indicator - used to position the sample holder
2. Progress status - shows scan status
3. Scan settings - controls to set up and run a scan
4. B-scan plot window
5. C-scan plot window
6. "Save data" button – allows user to save data after a scan
7. "QUIT" button – terminates the program operation and parks the sample stage

The GUI window can be minimized and moved freely on the screen.

The functions of each section are described below.

**Sample Fixture Motion Control and Status**

Figure 10 shows an exploded view of the sample fixture motion control and status indicator section of the OTS GUI. These controls are used to set the initial position of the sample before scanning. Usually, the initial position is a corner of the sample.
Figure 10 OTS GUI: sample fixture motion and status indicator: 1-status indicator, 2-XY coordinate display, 3-step size field, 4-step towards negative X button, 5-10× steps towards negative X button, 6-step towards positive X button, 7-10× steps towards positive X button, 8-step towards negative Y button, 9-10× steps towards negative Y button, 10-step towards positive Y button, 11-10× steps towards positive Y button.

The functions of the numbered items in Figure 10 are as follows:

1. Status indicator: The status indicator light (in the middle of the virtual keypad) indicates the system status. It is red while the OTS system is performing a task, green while the OTS system is idle, and blinks while the OT-scan is paused.

2. XY coordinate display: The X and Y coordinates, in mm, of the sample fixture are shown in the display boxes immediately below the virtual keypad. The X axis is the motion direction along the sample fixture arch with one stepper motor, and the Y axis is the motion direction perpendicular to the sample fixture arch, along the rails with two stepper motors (see Figure 11). The positive direction of motion for both axes is towards the parking/homing switch positions of the OTS system (the direction of the arrows in Figure 11).

3. Step size control: Use this field to control the step size for fixture motion. Minimum step size is 0.1mm

4. Move one step in the negative X direction.

5. Move ten steps in the negative X direction.

6. Move one step in the positive X direction.
7. Move ten steps in the positive X direction.
8. Move one step in the negative Y direction.
9. Move ten steps in the negative Y direction.
10. Move one step in the positive Y direction.
11. Move ten steps in the positive Y direction.

Figure 11 X and Y axis directions in OTS system gantry. The arrows indicate the positive direction of motion.

Scan Settings

Figure 12 OTS GUI: scan settings: 1-“Home” button, 2-B-scan axis selector, 3-scan range in X direction, 4-scan range in Y direction, 5-resolution in X direction, 6-resolution in Y direction, 7 “Start scan” button.
Once the sample stage has been positioned at the start point for the scan, the scan settings controls can be used to set scan parameters and start/stop the scan. Figure 12 shows an exploded view of the scan settings for the OTS GUI. Numbered items are as follows:

1. Home: The “Home” button returns the sample fixture to the (0, 0) XY coordinates.
2. B-scan axis: Use the pull-down to set the B-scan axis of the raster scan to X or Y.
3. X travel range: Set scan range in X direction, in mm.
4. Y travel range: Set scan range in Y direction, in mm.
5. X resolution: Set step size in X direction for scan. Default/minimum value 0.1mm
6. Y resolution: Set step size in Y direction for scan. Default/minimum value 0.1mm
7. Start scan: Initiates the raster scan sequence.

By default, the increment of travel range and resolution is 0.1 mm, and the minimum resolution is the value of a travel range.

**Progress Status**

Figure 13 OTS GUI: progress status: 1-scan progress bar and display, 2-elapsed time display, 3 remaining

Figure 13 shows an exploded view of the progress status section of the OTS GUI. This display allows the user to track the progress of a scan. Numbered items are as follows:

1. Scan progress bar: Shows the percentage of the scan completed.
2. Time elapsed: Shows the time elapsed since the start of the scan, in hh:mm:ss format.
3. Time remaining: Shows the estimated time remaining before the scan is completed, in hh:mm:ss format.

**B-scan Plot**

The B-scan plot is shown in the lower left of the screen (Figure 9, item 4). A B-scan represents the transmittance of the sample over the travel range of the selected scan axis in 1D. The horizontal axis of the B-scan is the coordinate in the selected scan axis, in mm (Y, in the example below). The vertical axis represents the transmittance (in arbitrary units). An example of a B-scan taken during the scan sequence is illustrated in Figure 14.
C-scan Plot

The C-scan plot is shown in the center section of the OTS GUI (Figure 9, item 5). A closeup is shown in Figure 15a. A C-scan represents the transmittance of the sample over the scan area in 2D. The cursor (see Figure 15a, item 1) can be moved using the mouse at any time; the XY coordinates of the cursor and the sample’s transmittance at the chosen location are provided in the lower left corner of the C-scan plot window (Figure 15a-2). The C-scan plot area during and after scan completion is illustrated in Figure 15b. During and after the scan, a color bar representing the sample’s transmittance becomes visible on the right side of the C-scan plot (Figure 15b, item 1). When the scan is paused or completed, the software switches to review mode, which provides advanced controls for the C-scan plot (Figure 15b, item 2). The review mode and its controls are described in more detail in the “Review mode with advanced C-scan controls” section.

Figure 15 OTS GUI: C-scan plot. (a) before the scan: 1-cursor, 2-information display; (b) during and after the scan: 1-transmittance color bar, 2-advanced C-scan controls.
System Shutdown Procedure

Before closing the GUI, the program must be stopped using the “QUIT” button (Figure 9, item 7). This ensures the correct termination of communication sessions with the OTS system. The software will stop, and the sample fixture will be parked. After the program is stopped, it can be closed using the CTRL+Q key combination, the “X” button in the top right corner of the screen (Figure 16, item 1), or the “Exit” option under the File menu (Figure 16, item 2). Failure to follow this sequence when exiting the program may result in improper system functioning.

![Figure 16 Closing the OTS GUI: 1-“X” button, 2-“Exit” option in “File” menu.](image)

After the control program is closed, the system control box can be powered off.

Raster Scanning

The OTS system raster scans the sample in a snake (rectangular) pattern. The B-scan axis corresponds to the axis scanned with a continuous movement of the fixture, while the other axis corresponds to the step-wise motion. During the scan, the B scan plot window is updated with the data from the most recently completed B-scan, while the C-scan plot shows the image of the scanned portion of the sample in real-time. The software automatically takes care of data flow interruptions and amends the scan sequence on the fly. Hence, there is no need to re-scan the sample if the OTS software data flow is interrupted during scanning.
Scan Setup

**B-scan Axis Selection**

The B-scan axis can be selected using the corresponding pull-down menu (see Figure 17). The default B-scan axis is the Y-axis, as shown in Figure 17. Figure 18 illustrates the case where X is chosen as the B-scan axis; the horizontal axis of the B-scan plot is changed to "X, mm", and the X-cursor is highlighted in red on the C-scan plot window. Proper selection of the B-scan axis may provide better results in applications where sample features have distinct 1D geometry, e.g., cracks, fibers, lines, wires, etc.

![Figure 17 B-scan axis selection in OTS GUI](image)

B and C-scan windows are configured for B-scan axis = Y.
Figure 18 OTS GUI display with B-scan axis switched to X.

Scan Start Point

After the B-scan axis is selected, the scan start point can be set using the sample fixture motion controls (arrow keypad and step size selector, see Figure 9 and Figure 10). The offset of the sample fixture position from the (0, 0) XY coordinates can be monitored in the coordinate display section (see Figure 10, item 2).

Once the internal safety limits are reached, the sample fixture will not move further in the selected direction, and the OTS software will display a limit warning message.

Figure 19 Safety limit warning messages in OTS GUI. (a) in X direction, (b) in Y direction

Scan Range

After the sample fixture is positioned at the start point for the scan, the scan ranges can be set by entering the desired values in the “X travel” and “Y travel” fields in the Scan Settings area of the screen. The software has safeguards in place to prevent scanning beyond the limits. It automatically checks the available scan range in the selected direction, relative to the current sample stage position, and limits the scan range to its maximum allowed value if the user inputs a value exceeding the limit. Examples of this scan range thresholding in the X and Y directions are shown in Figure 20 and Figure 21, respectively. The scan range will be reduced further if the sample fixture is moved in the positive direction, as shown in Figure 22 and Figure 23 for X and Y scan ranges, respectively.
Figure 20 X scan travel range thresholding in OTS GUI.
With the sample stage position at (0,0), X scan range is limited to 472.5mm.

Figure 21 Y scan travel range thresholding in OTS GUI.
With the sample stage position at (0,0), the Y-scan range is limited to 510mm.
Scan Resolution

The X and Y step sizes used for the scan can be set by entering the desired values in the "X resolution" and "Y resolution" fields in the Scan Settings area of the screen. The total scan length in the X or Y direction must be an integer multiple of the corresponding step size (resolution). If division of the travel range by the resolution is a fractional number, the OTS software provides a notification (Figure 24) and rounds the travel range down to the nearest integer number of steps. Figure 25 and Figure 26 show the resulting range adjustments in the X and Y directions, respectively, for the case where a range of 100 mm is entered, and then the
resolution is changed to 0.3 mm. The corresponding ranges are rounded down to 99.9 mm (the nearest integer multiple of 0.3 mm).

The resolution setting of the B-scan axis does not affect the scanning time.

Figure 24 Travel range rounding notifications. (a) in X direction, (b) in Y direction.

Figure 25 X scan travel range rounded down from 100 to 99.9mm for resolution setting of 0.3mm.

Figure 26 Y scan travel range rounded down from 100 to 99.9mm for resolution setting of 0.3mm.
**Start Scan**

After completing the scan setup, click the "Start scan" button to start the scan sequence.

During scanning, the status indicator turns solid red, and most controls are disabled. Only the "Pause", "Stop scan", and "Quit" buttons are active. The scan progress and scan time estimates are displayed in the progress status area (see Figure 27 and Figure 28, item 2), and the C-scan display starts filling in from bottom to top or from left to right, depending on which axis is selected as the B-scan axis.

![Figure 27 Running scan with B-scan axis=X](image1)

![Figure 28 Running scan with B-scan axis=Y](image2)
If the scan is paused, the status indicator blinks from red to yellow (see Figure 29, item 1); and the OTS software switches to review mode with the advanced C-scan controls active, (Figure 29, item 2). Please refer to the “Error! Reference source not found.” section for descriptions of the advanced C-scan controls. To continue a paused scan, click the “Resume” button (Figure 29, item 3).

![Figure 29 Paused scan in OTS GUI: 1-status indicator, 2-advanced C-scan controls, 3-“Resume” button](image)

If the scan is stopped, the sample fixture will return to the start scan point, and measured data will be available for saving.

**Data Options after Scan Completion**

Once the scan was completed (see Figure 30), the status indicator will change to solid green (Figure 30, item 1). The OTS software switches to review mode, and the advanced C-scan controls become active (Figure 30, item 2). Please refer to the “Error! Reference source not found.” section for descriptions of the advanced C-scan controls. After scan completion “Active B-scan axis resolution” mode (Figure 30, item 3) and the “Save data” button (Figure 30, item 4) become available. These features are described below.
Figure 30 Completed C-scan in OTS GUI: 1-status indicator, 2-advanced C-scan controls, 3 “Active B-scan axis resolution” mode, 4-“Save data” button.

**Active B-scan Axis Resolution**

Active B-scan axis resolution mode allows the user to change the resolution of the linescan along the original B-scan axis direction of a completed scan without having to rescan the sample. This is particularly useful if, after viewing the results of a completed scan, the user determines that higher resolution in the B-scan axis direction is required. Figure 31 shows the interface with active B-scan axis resolution mode enabled. In this mode, all scan settings except the B-scan axis selector and the resolution setting of the B-scan axis for the completed scan are disabled.

Note that the ”B-scan axis” selector in reviewing mode only controls the B-scan direction and has no effect on the parameters of an already performed scan.
Figure 31 Completed scan data with active B-scan resolution controls enabled in OTS GUI

Figure 31 and Figure 32 show the effects of changing the active B-scan axis resolution from 0.1 to 10mm for a completed scan taken with the Y-axis as the B-scan axis. Observe that both the B-scan and C-scan plots are adjusted accordingly.

Figure 32 Completed scan data with B-scan axis resolution changed from 0.1 to 10mm.

Figure 33 shows the effect on the plots in Figure 32 of changing the B-scan axis from Y to X. The B-scan plot in Figure 33 now shows an X-axis linescan. Note, however, that although the B-scan plot axis can be changed after a scan is completed, only the original B-scan axis resolution (Y-axis, in this example), can be modified after the scan is completed.
Saving Data

Measured C-scan data can be saved in csv format by clicking the “Save data” button at the bottom left of the screen. The user will be prompted to enter the filename and location to which to save the data (Figure 34). Please note that saved data takes into account X and Y resolutions, i.e., a single scan can be saved with multiple resolutions, which can be changed in “Active B-scan axis resolution” mode. The first row of the data file is a header row, in the following format: “B-scan axis”; selected B-scan axis: X or Y; “X:”; 0; “:”; X resolution value; “:”, X scan range value; “mm”; “Y:”; 0; “:”; Y resolution value; “:”, Y scan range value; “mm”. The rest of the data is the actual C-scan, where rows correspond to linescans in the X direction, while columns correspond to linescans in the Y direction.
Review Mode with Advanced C-scan Controls

After a scan is paused, stopped, or completed, the OTS software switches to review mode, with advanced plot controls enabled for more detailed analysis of the C-scan plot. The advanced C-scan control toolbar appears to the bottom right of the C-scan plot (Figure 15b). It includes cursor, zoom, and pan options (Figure 35).

Figure 34 Prompted saving dialog window in OTS GUI

Figure 35 Advanced C-scan controls: 1-cursor option, 2-zoom option, 3-pan option.

In review mode, the minimum and maximum values of the X, Y, and Z (color bar) axes of the C-scan can also be changed manually.
Figure 36 Plot axis limits can be manually edited.

Cursor

With the cursor option selected, the cursor can be moved freely in the C scan window; and the current cursor position and transmittance at that location are displayed below the C-scan plot. Examples of cursor control and position display for paused and completed scans are shown in the following figures.

Figure 37 Review mode in paused scan in OTS GUI: cursor function.
B-scan Axis Selection

In review mode, the B-scan plot actively tracks the linescan at the cursor position along the axis chosen with the “B-scan axis” selector. The B-scan axis can be changed post-scan, as demonstrated in Figure 39 and Figure 40.

Figure 38 Review mode in completed scan in OTS GUI: cursor function.

Figure 39 Review mode in paused scan in OTS GUI: same data as in Figure 37, but with B-scan axis changed from Y to X. The B-scan plot now shows the transmission vs. X position at the Y position of the cursor.
Figure 40 Review mode in completed scan in OTS GUI: same data as in Figure 38, but with B-scan axis changed from Y to X. The B-scan plot now shows the transmission vs. X position at the Y position of the cursor.

Zoom

The zoom option has multiple self-explanatory subcategories shown in Figure 41. The subcategories are (from the left to the right and from the top to the bottom): zoom-in area, zoom-in vertical section, zoom-in horizontal section, zoom-out to full scale, zoom-in at cursor position, and zoom-out at cursor position. An example of a zoomed-in C-scan section is shown in Figure 42.
Pan

The pan option allows the user to drag the plot in the C-scan plot window, which is particularly useful for viewing different sections of a zoomed-in image. An example of panning is demonstrated in Figure 43.

Figure 43 Review mode in paused scan in OTS GUI: panned C-scan. This is the same scan data as in Figure 41 and Figure 42, but by dragging the plot, a different section of the plot becomes visible.
### 3.5 Troubleshooting

The following table lists some common issues and probable causes.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Symptoms/Warning</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTS software does not progress</td>
<td><img src="image1.png" alt="Error Icon" /> &lt;br&gt;<strong>No USB connection with OTS DAQ. Please restart the OTS system and the software.</strong></td>
<td>• If running, close National Instruments Measurement &amp; Automation Explorer. &lt;br&gt;• Check the USB connection between the OTS system and the PC. &lt;br&gt;• Check whether the OTS DAQ is recognized by the PC. Please use provided National Instruments Measurement &amp; Automation Explorer (NI MAX): go to &quot;My System&quot;=&gt;&quot;Devices and Interfaces&quot; and check if NI USB 6002 is present. &lt;br&gt;• Contact General Photonics Corporation if the problem persists.</td>
</tr>
<tr>
<td>OTS data flow has stopped unexpectedly</td>
<td><img src="image2.png" alt="Error Icon" /> &lt;br&gt;<strong>No USB-VISA connection with gantry microcontroller. Please restart the OTS system and the software.</strong></td>
<td>• Check whether the OTS system is turned on. &lt;br&gt;• Check the USB connection between the OTS system and the PC. &lt;br&gt;• Check whether the homing switches are not activated, i.e., not locked in pressed state. &lt;br&gt;• Check whether the gantry microcontroller is recognized by the PC. Please use provided National Instruments Measurement &amp; Automation Explorer (NI MAX): go to &quot;My System&quot;=&gt;&quot;Devices and Interfaces&quot; and check if ASRL device is present. &lt;br&gt;• Contact General Photonics Corporation if the problem persists.</td>
</tr>
<tr>
<td>OTS data flow has been lost unexpectedly</td>
<td><img src="image3.png" alt="Error Icon" /> &lt;br&gt;<strong>USB connection with OTS DAQ has been lost. Please restart the OTS system and the software.</strong></td>
<td>• Check whether any USB devices were connected or updated during the OTS system operation. &lt;br&gt;• If running, please close National Instruments Measurement &amp; Automation Explorer.</td>
</tr>
<tr>
<td>OTS-1000 User Guide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>OTS gantry has stopped unexpectedly</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Check the USB connection between the OTS system and the PC.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- (For laptops): disable sleep option in power settings. Sleep mode interrupts the USB connection between the OTS system and the PC.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Contact General Photonics Corporation if the problem persists.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="USB-VISA connection with gantry microcontroller has been lost" /></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Scanning time is notably longer than expected</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- OTS system gantry is moving but the scan does not progress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- OTS system has notable lags between the linescans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Check whether other programs are running on the PC. The applications which use significant amounts of CPU, RAM, or bandwidth, e.g. graphics/video or communication, may interfere with proper OTS system operation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Contact General Photonics Corporation if the problem persists.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Section 4.0 Specifications

### Optical

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection wavelength¹</td>
<td>IR: 1060 nm, 1310 nm, or 1550 nm</td>
</tr>
<tr>
<td></td>
<td>VI: 400 nm – 700 nm</td>
</tr>
<tr>
<td>Collimated Beam Diameter</td>
<td>&lt;1 mm</td>
</tr>
<tr>
<td>Optical Fiber Type</td>
<td>SM</td>
</tr>
<tr>
<td>Laser Output Power²</td>
<td>≥5 mW</td>
</tr>
<tr>
<td>Lateral Resolution⁴</td>
<td>100 µm</td>
</tr>
<tr>
<td>Scanning Speed</td>
<td>200 mm/s max.</td>
</tr>
</tbody>
</table>

### Electrical/Communication

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply</td>
<td>100-240 VAC, 50-60 Hz</td>
</tr>
<tr>
<td>Communication Interfaces</td>
<td>USB 2.0</td>
</tr>
<tr>
<td>Software</td>
<td>OTS GUI software</td>
</tr>
</tbody>
</table>

### Physical and Environmental

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
<td>100×100 mm</td>
</tr>
<tr>
<td>Sample Thickness³⁴</td>
<td>Up to 7 cm</td>
</tr>
<tr>
<td>Sample Weight</td>
<td>2 kg max.</td>
</tr>
<tr>
<td>Scanning Range</td>
<td>24: 20.32 × 40.64 cm</td>
</tr>
<tr>
<td></td>
<td>44: 40.64 × 40.64 cm</td>
</tr>
<tr>
<td></td>
<td>48: 40.64 × 81.28 cm</td>
</tr>
<tr>
<td>System Dimensions</td>
<td>24: 72.1 × 61.0 × 36.1 cm</td>
</tr>
<tr>
<td></td>
<td>44: 113.7 × 61.0 × 36.1 cm</td>
</tr>
<tr>
<td></td>
<td>48: 113.7 × 102.2 × 36.1 cm</td>
</tr>
<tr>
<td>Weight</td>
<td>24: 24.9 kg</td>
</tr>
<tr>
<td></td>
<td>44 or 48: 52.2 kg</td>
</tr>
<tr>
<td>Operation temperature</td>
<td>10 to 50 °C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>−20 to 60 °C</td>
</tr>
</tbody>
</table>

Notes:
1. Wavelength will be selected based on customer requirements.
2. Lasers with higher power may be available, depending on customer requirements.
3. Dependent on transparency of sample material.
4. With diameter of pinhole = 100µm, wavelength = 640nm, rear face of sample flat, and sample transmission > 10%.