PSY-101
Fiber-Optic Polarization Synthesizer/Analyzer

Operation Manual

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WARRANTY

All of General Photonics’ products have been inspected and found to comply with our stringent quality assurance standards before shipping. If any damage occurs during shipment, please contact the carrier and inform us or our distributors as soon as possible.

Please do not, under any circumstances, attempt user repair of any General Photonics product. To avoid further damage, any repair of defective products must be performed by well-trained engineers.

General Photonics warrants that this product will be free from defects in materials or workmanship for a period of one year from the date of original shipment (listed on the certificate of quality or packing list enclosed with the original shipment). A product found to be defective during the warranty period will be repaired or replaced, at no charge, at General Photonics’ option.

If a problem is found, please contact General Photonics for assistance. If necessary, return the defective product, freight prepaid, clearly labeled with the RMA number, with as complete a description of the problem as possible. The repaired or replacement product will be returned, freight prepaid, as soon as possible.

The above warranty specifically excludes products that have been repaired or modified by non-manufacturer-authorized personnel, as well as damage caused by misuse, abuse, improper storage or handling, or acts of nature.

This warranty is in lieu of all other warranties, expressed or implied. General Photonics will not be liable for any indirect or consequential damages or losses resulting from the use of its products.
SAFETY CONSIDERATIONS

The following safety precautions must be observed during operation, service and repair of this instrument. 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 instrument. General Photonics Corp. assumes no liability for customers’ failure to comply with these requirements.

- **Before operation, the user should inspect the instrument and review the manual carefully.**
  
  - The instrument’s rear panel includes a chassis ground terminal for electrical safety.
  
  - Make sure that the instrument is in a secured work environment (in terms of temperature, humidity, electrical power, hazard due to fire or shock, etc.) for proper operation.
  
  - Standard laser safety procedure should be followed during operation.
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Section 1. Specifications:

Optical Characteristics:

Operating wavelength 1550±50 nm
Insertion loss 1.2 dB typical
Return loss 50 dB
PDL <0.25 dB
PMD <0.1 ps
Operating power range -15 to +10 dBm
SOP tracing accuracy 0.3 degrees
SOP tracing time 2 ms typical, 7 ms max.
SOP measurement accuracy ±1% ¹
Target SOP resolution 0.1°
DOP accuracy ±2% ¹
Input Stokes parameter resolution 0.01
Optical power measurement accuracy ±0.25 dB
Optical power damage threshold 300 mW

Electrical/General Characteristics:

Input fiber type SMF-28
Fiber Input/Output Connectors FC/PC, FC/APC, SC/PC, SC/APC²
Operation temperature 0 °C to 40 °C
Storage temperature -20 °C to 60 °C
Front panel display 2x20 character LCD display
Communications interface RS-232, USB, GPIB, Ethernet
Software PolaView™ display software (included)
Power Supply 100~120 VAC, 50-60 Hz,
or 200~240 VAC, 50-60 Hz
Package Dimensions Standard half-19” rack mount size
14” (L) × 8.5” (W) × 3.5” (H)
Weight 7 lb.

System Specifications:

Polarization Control
SOP mapping Arbitrary (Mapping from any input SOP to any output SOP) or 6 state generation
SOP control Stokes parameter or polarization ellipse angle inputs (Manual or remote control)
Dynamic Tracking
Polarization scan/trace generation
6 state scan Periodic sequence of the following states: 0°, 45°, 90°, -45°, RHC, LHC
Time per step: 1ms to 1 min (60000 ms)
Trace scan Circular trace on Poincaré sphere
Rotation axes: 0°, ±45°, 90°, S3=0 (in sphere coordinates)
Step size range: 0.1° to 99.9°
Time per step: 1ms to 1 min (60000 ms)

**Polarization scrambling**

Scrambling frequency
- Variable: 1-6000 Hz (random mode)
- Variable: 0.1-500 Hz (saw wave mode)

Scrambling waveform
- Saw or random

**Polarimeter**

Display parameters (front panel)
- SOP (Stokes parameters or polarization ellipse angles), DOP, optical power

Notes:

All IL, RL and PDL values are without connectors.
1. Compared with Agilent 8509C polarization analyzer.
2. Per user specification at the time of ordering.
3. Typical SOP tracking time $10 \pi/s$. 
Section 2. Overview:

The PSY-101 is an advanced Polarization Synthesizer/Analyzer instrument designed and manufactured by General Photonics Corporation. The PSY-101 combines General Photonics’ PolaDetect™ high speed in-line polarimeter and award winning PolaRite™ II/III polarization controller with reset-free, proprietary polarization control algorithms to achieve a wide range of polarization control functionalities: the ability to generate and maintain any desired state of polarization (SOP), regardless of the input SOP; real-time SOP and DOP monitoring; generating special SOP points, sequences, and traces; and polarization scrambling. The entire instrument has a microprocessor based electronic control circuit packaged in a rugged 2U-height, half-rack size package, as shown in Figure 1. The all-fiber construction polarization controller provides very wide operation bandwidth with extremely low insertion loss, polarization dependent loss, and activation loss, characteristics that are desirable for most demanding fiber-optic measurements and applications. The PSY-101 is an ideal tool for real-time polarization measurement and control, passive/active component characterization, interferometry, optical remote sensing, RF photonics and other polarization sensitive applications.

![Figure 1 PSY-101 Polarization Synthesizer/Analyzer](image)

A polarization controller can be constructed from either a series of rotatable fixed-retardation plates or a series of variable retardation plates of fixed orientation. An example of the latter scheme, using four variable retardation wave plates, is shown below, in Figure 2a. Figure 2b shows a fiber-based version of this design, which consists of four piezoelectric actuator-driven fiber squeezers oriented 45° from each other. Each fiber squeezer is driven by an applied voltage signal. Squeezing the optical fiber produces a linear birefringence in the fiber, and thus, alters the state of polarization of a light signal passing through it.
Any polarization state of monochromatic light can be represented as a point on the Poincaré Sphere, as shown in Figure 3. In principle, increasing the voltage (increasing the squeezing pressure) on one fiber squeezer (X1 or X3) effectively causes the polarization state to rotate clockwise about the OQ axis while decreasing the voltage causes the point to rotate counter-clockwise. Likewise, increasing the voltage to a fiber squeezer (X2 or X4) oriented 45° from the first one should cause the polarization state to rotate clockwise about an axis (OH axis) orthogonal to the first one, while decreasing the voltage should rotate the polarization counterclockwise. In practice, because of the presence of other birefringences, two parallel fiber squeezers do not always rotate the polarization about the same axis. However, it has been proven to be possible to generate any polarization state from an arbitrary input polarization state using this system.

Strictly speaking, a 3-axis fiber squeezer polarization controller is sufficient to generate any state on the Poincaré sphere. However, adding more fiber squeezers to the system provides more degrees of freedom, enabling reset-free operation, a highly desired feature for many dynamic applications. The PSY-101 uses a 6-axis version of the fiber squeezer based PolaRite™ II/III polarization controller to achieve rapid, reset-free polarization control.
By using different modes of control of the drive voltages, the polarization controller can be made to perform various functions. In the SOP search modes, the instrument uses the embedded polarimeter and feedback control circuit to automatically adjust the DC drive voltages to each of the 6 fiber squeezers to change the output polarization from any initial state to the desired final state.

If the output polarization needs to change with time in a controlled fashion, proprietary polarization control algorithms can compute drive voltage sequences to sweep out a pre-set SOP pattern on the Poincaré sphere. These functions can be used to step periodically through the 6 poles of the Poincaré sphere (0º, 90º, ± 45º, RHC, LHC) or to trace out a circumference of the sphere with one of 5 preferred orientations.

In polarization scrambler mode, the PSY-101 scans the output polarization state evenly over the Poincaré sphere at a user specified frequency, using either a random pattern or a saw wave - based algorithm. This allows the output polarization state to change either in a series of random jumps at defined intervals, or in a continuous fashion, respectively.

In addition to generating the Stokes parameters for the PSY-101’s polarization control functions, the PSY-101’s internal in-line polarimeter, in conjunction with the included PolaView™ data analysis and display software, provides real-time graphic display of polarization state either on a Poincaré Sphere window for viewing SOP traces or on an
oscilloscope window for tracking polarization changes over time. This polarization analysis system allows the user to simultaneously control and monitor the PSY-101’s output polarization. It can also be used alone, with the polarization controller disabled, for monitoring the polarization state in the external system without interrupting data traffic.

Note: Unlike in a free-space optics system, the coordinate system is not maintained during propagation through optical fiber. Therefore, although the relative positions of SOPs generated by the PSY-101 will be maintained, their absolute positions relative to a fixed external coordinate system may change during propagation.
Section 3. Feature Description:

3.1 Optical Features:

The PSY-101 system has two fiber connectors on the front panel to accommodate the input and output optical beams. Each connector is equipped with a universal connector interface (UCI), which features a male-type adapter top piece that can be removed for direct access to the ferrule end for routine cleaning and maintenance without removing the entire adapter from the panel. This feature helps avoid high insertion loss, high return loss and measurement instability caused by dirty or contaminated connectors. In addition, the PSY-101’s universal interchangeable adapter allows the end user to switch to ST, SC, or FC connectors without opening the instrument panel. Although the PSY-101 is shipped with a customer specified fiber adapter, other interchangeable inserts can be purchased from General Photonics. For additional information on different input fiber adapter inserts, please contact General Photonics.

External fiber connectors should be cleaned using industry standard cleaning methods before connection to the PSY-101. If this procedure is followed before each connection, the instrument’s internal connector ferrules should not need regular cleaning. However, high insertion loss or measurement instability that does not improve after cleaning the external connectors may indicate that the instrument’s internal connector ferrules need to be cleaned.

Each connector ferrule is contained in a universal connector interface consisting of a front piece that connects to the external fiber connector, and a base piece that is mounted on the front panel of the instrument, as shown in Figure 4. To clean a connector ferrule, first, make sure no external connector is connected to the universal connector interface. Then, using a Phillips screwdriver, remove the two small screws connecting the front and back parts of the adapter, and carefully pull the front flange straight out. (Note: never remove the adapter base from the front panel). The ferrule end should now be exposed. Clean the ferrule using standard cleaning procedures (compressed air or a fresh lint-free tissue and alcohol). Care must be taken to avoid scratching the ferrule surface. Finally, replace the front flange (position it so that the key notch faces up, and the small alignment pin lines up with the hole in the base piece, before pushing it in) and the screws. For frequent measurements, we recommend that the user prepare a patch cord fiber to avoid inside connector wear.
3.2 Electrical Features:

The PSY-101 uses a standard wall electricity supply. The line voltage is factory-set at 110 VAC or 220 VAC per customer specification. Due to high voltage, safety precautions must be observed during operation.

- The ground pin on the power supply cord must be connected to earth ground of the wall receptacle.
- Never touch the boards inside the package without proper insulation.
- The PSY-101 is not user serviceable and can be serviced only by factory-authorized personnel.

The front panel of the PSY-101 is shown in Figure 5. The power on switch (Power), liquid crystal display (LCD), push button control pad, and input and output optical connectors are mounted on the front panel. The AC power plug, fuse, RS-232, USB, and Ethernet interface connectors are mounted on the back panel, as shown in Figure 6.

The PSY-101 has RS-232, USB, GPIB and Ethernet interfaces for external computer control and communication with the system. RS-232/USB/GPIB control commands, USB driver installation instructions, and descriptions of the LabView and Ethernet control programs are listed in Section 4.4. The PolaView™ data display software is described in section 4.5.
Figure 5  Front Panel layout

Front panel description:

LCD display: displays operation mode and parameters
Power: power on/off switch
Input: universal connector interface adapter for optical fiber input
Output: universal connector interface adapter for optical fiber output
Button functions:
- **MODE**: allows user to choose operational mode.
  1. SOP SETTING – set SOP using Stokes parameters
  2. ANGLE SETTING – set SOP using polarization ellipse angles
  3. SPECIAL SOP – set SOP to one of the poles of the Poincaré sphere, or scan through all 6 states
  4. TRACE SCAN – trace out a circumference of the Poincaré sphere by rotating the polarization state around an axis defined by a radius of the sphere at an angle given in sphere coordinates:
     - 0º (linear horizontal polarization)
     - ±45º (linear polarization at ±22.5º)
     - 90º (linear polarization at +45º)
     - S3=0 (circular polarization)
  5. MANUAL CONTROL: manually control the voltages of each channel of the polarization controller.
  6. SCRAMBLER – polarization scrambler
  7. Polarimeter- Polarization analyzer
  8. WAVELENGTH SEL – select operation wavelength
  9. GPIB SETTING – Set GPIB address

S1- S3: chooses a Stokes parameter to set; pressing any of these buttons automatically returns the PSY-101 to SOP SETTING mode

STORE: stores current SOP setting
RECALL: recalls stored SOP setting
CANCEL: stops current process
STEP: sets scan angle step for a TRACE SCAN
SCAN: starts a 6-point scan between special SOPs (Poincaré sphere poles)
SPEED: set scan speed (dwell time at each step) for trace scan or 6-point scan
ENTER: execute setting
Arrow keys: used to set measurement/control parameters.

Figure 6  Rear Panel layout

Rear panel description:

USB: USB interface port
RS-232: serial communication port
Ethernet: Ethernet interface port
GPIB: GPIB interface port
Line: external AC supply input connector, 110 V or 220 V
BNC: Optional (can be used for external trigger)
\rightarrow: electrical ground connection
Section 4. Operating Instructions:

Warning:

- Never look into the light source fiber connector when light source is turned on. THE OUTPUT LIGHT FROM A HIGH POWER LASER IS HARMFUL TO HUMAN EYES. Please follow industry standard procedures when operating a high power laser source.

- The PSY-101 is designed for indoor use only. Avoid water condensation or liquid spills during PSY-101 storage and operation.

4.1 Unpacking

Inspect PSY-101 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.

4.2 Getting Started

General:

1. Make sure local AC voltage matches the AC voltage requirement of your PSY-101 system. If not, do not proceed. Contact General Photonics Corporation immediately.

2. Connect power cord and plug it into wall receptacle. Make sure the ground pin of the power cord is connected to earth ground.

3. Connect input and output fibers to PSY-101. Make sure that the connector types match those of the instrument. It is important to clean the fiber connectors using industry standard procedures before connecting them. In the case of a high power laser source, turn off optical power source before connector cleaning.

4. Turn on the light source and the PSY-101 power supply.

Instrument Operation

The PSY-101 has 8 operational modes and a wavelength selection function which are governed by the MODE key. In the following sections, the operational modes will be described in turn, using the PolaView™ software display where necessary to illustrate their functions.

At startup, the PSY-101’s LCD will flash two initialization screens:

![Initialization Screens](image)
showing the model number and firmware version (may be different). The initialization
screens are followed by the operational mode selection screen:

![MODE 1. SOP SETTING](image)

The default mode is mode 1: SOP setting using Stokes parameters. The arrow keys can be
used to change the mode. The up arrow decreases the mode number sequentially
(9→8→7…), the down arrow increases the mode number sequentially (1→2→3…), and
the left and right arrows cause the mode number to jump to 1 and 9, respectively. Press
ENTER to confirm mode selection and begin the setup for the selected mode.

The MODE key can be used to exit any operational mode and return to mode selection.

4.2.1. Mode 1: SOP Setting

This mode allows the user to select any desired output polarization state using the
normalized Stokes parameters for that state. The PSY-101 maintains this polarization state
against slow input polarization changes, as shown below. The light input to the PSY-101
was polarization scrambled at 5 Hz with a saw wave based pattern. Figure 7 shows the
polarization trace of the scrambled input alone, with the PSY-101’s polarization controller
disabled. Figure 8 shows the output polarization with the PSY-101 stabilizing the output at
SOP setting (0.40, 0.6, 0.69) against the scrambled input.

![Figure 7 Input polarization pattern: saw wave scramble at 5 Hz, taken over 20 sec.](image)

![Figure 8 Output polarization stabilized by PSY-101 against the same polarization-scrambled input, taken over 20 sec.](image)
1. On entering Mode 1, the LCD will show:

```
S1: +1.00   S2: +0.00
S3: +0.00   SIGN: +
```

where S1-S3 are the Stokes parameters with a default setting as (+1.00, 0.00, 0.00).

2. Set two of the Stokes parameters. The left and right arrow keys change the position of the cursor, and the up and down arrow keys increment the selected digit or toggle the sign between + and -. The S1, S2, and S3 keys can be used to select the Stokes parameter to set, or the ENTER key can be used to set two of the three Stokes parameters one by one ending at the “SIGN” setting.

Note: Pressing S1, S2, or S3 from any operation mode will return the PSY-101 to Mode 1 setup, with the cursor at the selected S parameter.

3. Once two of the Stokes parameters are set, press ENTER.
   a. If the input optical power is too low, the LCD will show “Insufficient Light”. The ENTER key will return the display to the MODE 1 setup screen.
   b. If the light input is sufficient, the polarization synthesizer proceeds to the next step: the three Stokes parameters must satisfy the normalization condition \( S_1^2 + S_2^2 + S_3^2 = 1 \). If the first two Stokes parameters violate this condition (i.e., \( S_1^2 + S_2^2 > 1 \)), the LCD will display “Invalid SOP Value”. Press ENTER to return to the setup screen, or CANCEL to return to the setup screen with default S parameter values.
   c. If the first two Stokes parameters satisfy the condition \( S_1^2 + S_2^2 \leq 1 \), then the normalization condition determines the third, which is automatically calculated by the instrument. After ENTER is pressed the first time, the cursor will move to the “+” or “−” after “SIGN”. Selecting “+” or “−” will set the sign of the third Stokes parameter. Press ENTER again will confirm the settings. At this point, the user can use the arrow keys to change any of the S-parameters following the similar sequence. After the setting is confirmed, the instrument will execute the setting, and the LCD will display

```
S1: +1.00   S2: +0.00
S3: +0.00   SIGN:+   _
```

where the S1-S3 parameters will be the ones just set. The cursor will blink near the end of the second line to indicate that the setting is being executed. The polarization synthesizer will stabilize output polarization at the set value against slow input polarization variations as long as it is in mode 1 operation, as shown in Figs. 7 and 8.
4. To confirm the SOP using the polarimeter, press MODE, use the arrow keys to select MODE 7, and press ENTER. The instantaneous SOP, DOP and power values will be displayed (see 4.2.7 for details).

5. To set a new polarization state:
   From Mode 7 (step 4): press MODE, select MODE 1, press CANCEL to clear parameter values, and proceed from step 1. Or:
   From Mode 1 operation mode (after step 3): press CANCEL to clear parameter values, then repeat steps 2-3.

6. Pressing CANCEL at any point during setup or execution in MODE 1 returns the display to the default setting screen. The output polarization setting stays (but is not actively stabilized) at the last state set. Using the LEFT arrow key can stop the SOP control without back to the default settings.

4.2.2 Mode 2: Angle Setting

This mode allows the user to select any desired output polarization state by specifying the orientation ($\theta$) and elliptic ($\phi$) angles of the polarization ellipse of that state.

![Figure 9 Polarization ellipse](image)

For a light beam with propagation direction z (out of the paper) and polarization ellipse as shown in Figure 9, with semimajor axis $a >$ semiminor axis $b$, the orientation angle $\theta$ is defined as the angle between the x axis and the semimajor axis of the ellipse. The elliptic angle $\phi$ is defined by

$$\tan \phi = \pm \frac{b}{a}$$

where the positive sign is used for right-handed rotation, and the negative sign for left-handed rotation. The range for $\theta$ is $0^\circ$ to $180^\circ$, while the range for $\phi$ is $-45^\circ$ to $+45^\circ$. 
1. On entering Mode 2, the LCD shows the default setting screen:

![Default Setting Screen](image)

2. Set the values for $\theta$ and $\phi$. The left and right arrow keys change the position of the cursor (including moving between parameters), and the up and down arrow keys increment the selected digit or toggle the sign between + and -.

3. Press ENTER to accept and apply the setting. If the values entered are out of range, the display will show “Invalid Data” after ENTER is pressed. Pressing CANCEL will return the display to the default setting screen (Similarly to the SOP setting, using the LEFT arrow key can stop the control without back to the default settings). If the values are within range, after ENTER is pressed, the PSY-101 will execute the setting and switch to Mode 1 to display the Stokes parameters for the selected polarization state. Again, this output polarization will be stabilized against changes in input polarization.

   a. Note: if $\phi$ is set to $\pm 45^\circ$, the SOP will be set to (0 0 ±1), regardless of the value set for $\theta$.

4. As described for Mode 1, to confirm the SOP using the polarimeter, press MODE, use the arrow keys to select MODE 7, and press ENTER. The instantaneous SOP, DOP and power values will be displayed.

### 4.2.3 Mode 3: Special SOP

In Mode 3, the synthesizer generates any of 6 distinct polarization states that are used for Mueller Matrix calculations ($0^\circ$, $90^\circ$, $\pm 45^\circ$, RHC and LHC). It can also step sequentially through all 6 states. The 6 states are represented by the poles of the Poincaré sphere, as shown in Figure 10.

![Poincaré Sphere Representation of a 6-Point Scan](image)
The Mode 3 selection screen is shown below:

1. To select a single state, use the arrow keys to move the cursor to the desired state, and then press ENTER to select it. The PSY-101 will stabilize the output SOP at the selected state. The display will show:

   SOP SEARCH...
   0°

   In this example, the output polarization state is linear horizontal.

2. Press CANCEL to return to the selection screen.

3. To step sequentially through the 6 states:
   a. Press the SPEED button to set the dwell time at each step. (Dwell time is defined as the time that each individual SOP is maintained once it is found. The time needed to search for an SOP is 2 ms typical, 7 ms max.) The LCD will show:

   SPEED: 00100 ms

   The default dwell time value is 100 ms/SOP. Use the left and right arrow keys to move the cursor position, and the up and down arrow keys to increase or decrease the selected digit. The range is 0-60000 ms. Press the ENTER key to execute the dwell time selection. The cursor will blink at the far right of the screen to indicate that the setting has been executed.
   b. Press SCAN to start the sequence. The cursor will flash on each state as the output polarization moves to that state. Note: Pressing the SCAN button from any operation mode will put the PSY-101 into Mode 3 and start a 6-state scan at the currently set speed.
   c. Pressing CANCEL will stop the scan. The SOP setting will stay in the state it was in at the time CANCEL was pressed.

4.2.4 Mode 4: Trace Scan

In Mode 4, the generated polarization state follows one of 5 preset traces, with a defined step size and dwell time at each step. Each trace is a circumference of the Poincaré sphere, rotating about an axis defined by its angle from the S1 axis.
0º: The rotation axis is the S1 axis
+45º: The rotation axis is in the S1-S2 plane, midway between the S1 and S2 axes
-45º: The rotation axis is in the S1-S2 plane, midway between the S1 and –S2 axes.
90º: The rotation axis is the S2 axis.
S3=0: The rotation axis is the S3 axis; i.e., the polarization state stays linear, with the inclination angle changing.

The traces and their corresponding rotation axes are illustrated in Figs. 11-12. The first 4 traces intersect at the (0 0 ±1) points (RHC and LHC), and the S3=0 trace perpendicularly bisects the others.

On entering Mode 4, the LCD shows the trace scan setup screen:
1. Use the arrow keys to move between rotation axes selections (0°, ±45°, 90°, or S3=0, as described above). Pressing ENTER starts a scan about the selected axis using the latest set values of the step size and dwell time.

2. Once the scan is started, the LCD displays:

   ![TRACE SCAN ...](XX°)

3. Pressing CANCEL while a scan is in progress will stop the scan at the SOP it was in when CANCEL was pressed, and return the LCD to the trace scan setup screen, with the cursor flashing on the most recently selected rotation axis.

4. To monitor a scan in progress, press the MODE key, choose Mode 7, and press ENTER.

5. To change the dwell time at each step (time during which each individual SOP is maintained once it is found), press SPEED. The LCD will show

   ![SPEED: 00100 ms](XX°)

   The default value is 100 ms/SOP. Use the left and right arrow keys to move the cursor position and the up and down arrow keys to increase or decrease the selected digit. Press the ENTER key to execute the dwell time selection. The cursor will blink at the far right of the screen to indicate that the time setting is being executed.

6. To change the angle step size, press STEP. The LCD will show

   ![STEP: 01.0°](XX°)

   The default value is 1.0°. Use the left and right arrow keys to move the cursor position and the up and down arrow keys to increase or decrease the selected digit. Press the ENTER key to execute the angle step selection. The cursor will blink at the far right of the screen to indicate that the step size setting is being executed.
7. Use the MODE button to return to the MODE 4 setup screen after setting the speed or step size.

4.2.5 Mode 5: Manual Control

Mode 5 allows the user to change the output polarization state through direct control of the control voltages applied to all the six channels of the polarization controller. In all of the other control modes, the user selects a desired polarization state, and then the PSY-101 determines and applies the control voltages required to achieve that state. This direct control mode allows for quick, almost continuous tuning of the polarization state, and is especially convenient when the output polarization state can be simultaneously monitored using the PolaView™ display software. As mentioned in the introduction, changing the voltage on channel 1 causes the polarization state to rotate about a particular axis on the Poincaré sphere, while changing the voltage on channel 2 will cause it to rotate about an axis orthogonal to that of channel 1, and so on. By independently tuning the control voltages on the 6 channels of the polarization controller, the user can change the output polarization to any state on the Poincaré sphere. Figure 13 shows an example. Point A is the initial SOP. From there, the voltages on the 4 channels were sequentially changed in 1-volt steps as follows:

$\Delta V_1 = 20\text{V} \rightarrow \text{pt B}$
$\Delta V_2 = 10\text{V} \rightarrow \text{pt C}$
$\Delta V_3 = 15\text{V} \rightarrow \text{pt D}$
$\Delta V_4 = 10\text{V} \rightarrow \text{pt E}$

Figure 13 Manual polarization control example

On entering manual control mode, the LCD will show:

$V1: \text{xxx}.x\text{V}$
$V2: \text{xxx}.x\text{V}$
$V3: \text{xxx}.x\text{V}$
$V4: \text{xxx}.x\text{V}$

The underlined digit is the one being controlled, and “xxx.x”’s show the current control voltages on different channels. Once enter this mode, the four arrow keys can be used to
select different channels (i.e. V1~V6). Pressing ENTER key will confirm the channel selection and enter the voltage control mode of that channel. Then use the following keys to adjust the desired control voltages:

▲: increases or decreases selected channel voltage by the selected increment
▼: moves the cursor to different digit position.
◄ ►: moves the cursor to different digit position.
ENTER: press ENTER again will confirm the current setting of the channel and move to the next channel.
CANCEL: Pressing the cancel button in this mode sets all channel voltages to 0.

After setting V4 (the fourth channel), pressing ENTER will show the following display, where V5 and V6 correspond to the fifth and sixth channels.

The range of control voltages on each channel is 0-150V. The control voltages change in real time as the UP and DOWN arrow keys are pressed.

4.2.6 Mode 6: Scrambler

In Mode 6, the PSY-101 functions as a variable speed polarization scrambler, changing the output polarization state based on a random pattern or combination of saw waves of user specified frequency. If the saw wave based pattern is selected, the polarization will change continuously at a constant speed determined by the frequency, in a pattern that will cover the entire Poincaré sphere. This function can be used for such applications as PDL measurement, in which the maximum and minimum light output power as a function of input polarization state is measured: for maximum accuracy, all polarization states need to be covered, but each power reading should be taken at a distinct polarization state. Since the photodetector in such a measurement often cannot follow a fast polarization scrambler, a function in which the polarization changes continuously allows the photodetector to average over states that are close to each other for each reading. Figure 14 shows the SOP trace for a saw scramble at 1 Hz after 1 minute.

Figure 14 Saw wave scramble trace, 1 Hz after 1 minute.
If the random scramble pattern is selected, random combinations of drive voltages are input to the fiber squeezers, causing the polarization to jump to random states at time intervals determined by the selected frequency. This pattern also generates even coverage of the Poincaré sphere, and can be used at high frequency for applications requiring unpolarized light. Figure 15 shows the results of a random scramble at 100 Hz after 1 minute.

Note: The PolaView™ software was used to generate the figures illustrating the scramble function. The number of points shown in the figures is limited by data transfer rate. The sphere coverage generated by the PSY-101 under the given scramble conditions is much greater than that shown in the figures.

On entering Mode 6, the LCD shows the scrambler setup screen:

1. Random Scrambling
2. Saw Wave Scrambling

1. Use the up and down arrow keys to move to the desired scrambling mode, and press ENTER to select it.

2. The instrument will then show the frequency selection screen for the chosen scrambling mode. The displayed frequency is the last frequency set or, if the instrument has just been turned on, the default frequency for that mode. The frequency selection screens for both random and saw scrambling are shown below:
Use the left and right arrow keys to move the cursor position and the up and down arrow keys to increase or decrease the selected digit. The frequency range is 1-6000 Hz for random scrambling (default is 500 Hz), and 0.1-500 Hz for saw wave scrambling (default is 100 Hz). Once the frequency is set, press the ENTER key to accept it and begin scrambling. The frequency selection screen will remain displayed, and the cursor will blink at the bottom right corner of the screen during operation.

3. To change the scrambling frequency in the current mode, use the left and right arrow keys to move the cursor to the digit to be changed. Scrambling will stop as soon as the cursor is moved to a frequency setting position. The frequency can then be set and entered as in step 2.

4. Pressing CANCEL during frequency selection will return the frequency setting to its default value. Pressing CANCEL during operation will stop the scramble and return the frequency setting to its default value. The LEFT key can also stop the scrambling without back to the default frequency settings.

4.2.7 Mode 7: Polarimeter

In Mode 7, the PSY-101 functions as a polarization analyzer. With the polarization controller disabled, the instrument uses its internal polarimeter to monitor the input SOP, DOP, and optical power, and displays the results on the LCD screen. The display is the same as in Monitor mode.

1. To go to polarimeter mode, use the MODE button to bring up the mode selection screen, use the arrow keys to select MODE 7, and press ENTER. The default display screen is shown below:

```
P:XX.XXmW  DOP:XXX.X%
θ: XXX.XX°  ϕ: +XX.XX°
```

with the optical power, DOP and the \((θ, ϕ)\) display. If the input optical power is too small, the screen will show “Insufficient Light”.

2. Press ENTER key again to switch to SOP display shown below (use ENTER key to toggle between the previous display mode and the SOP display mode), where optical power is displayed in dBm.
4.2.8 Mode 8: Wavelength Selection

Mode 8 is not an operational mode. It allows the user to set the operation wavelength, which determines the calibration matrix used for the calculation of SOP parameters. When Mode 8 is selected, the LCD will display

![Wavelength: 1550 nm]

The default wavelength is 1550 nm. The wavelength range is 1550 ± 50 nm. Use the left and right arrows to move the cursor position, and the up and down arrows to change the value of the selected digit. Then, press ENTER to apply the wavelength setting.

Pressing CANCEL will reset the display to the default value.

4.2.9 Mode 9: GPIB Setting

Mode 9 is used to set the GPIB address for the remote control through GPIB port. Selecting Mode 9 will display as

![GPIB ADDRESS: 05]

Using arrow key to set the GPIB address from 1-30 and pressing ENTER to confirm the setting.

4.2.10 Storage and Recall of SOP Settings

SOP setting storage:

The PSY-101 has 100 storage locations for SOP settings. Once an SOP setting has been set and executed under any operational mode (usually 1 or 2), it can be stored in memory. When the STORE button is pressed, the LCD will show:

![ID: 00]
Choose a location to store the current SOP setting. Use the left and right arrows to choose the digit to be changed, and the up and down arrows to set the value. Available storage locations are 0 to 99. After the storage location number is set, press ENTER to store the data there. After the data is stored, the cursor will blink at the right of the screen. Use the MODE button to return to the previous operational mode.

Pressing CANCEL returns the display ID to its default value of 00.

**SOP setting recall:**

A stored SOP setting can be recalled from within any operational mode or SOP setting selection screen. Press the RECALL button. The LCD will show:

```
ID: 00  R
```

As for the “store” function, use the arrow keys to set the storage location number, then press ENTER to recall and apply the SOP setting stored there. At this point, the LCD will display the Mode 1 interface to indicate the currently set SOP.

If a selected location has no stored data, the screen will display “Invalid Data” after ENTER is pressed. Press CANCEL to clear the error screen and return to storage location selection. Pressing CANCEL during storage location selection (before pressing ENTER) will reset the displayed location number to 00.

**4.3 Testing and Characterization:**

The PSY-101 can be serviced only by manufacturer authorized personnel. There are no user serviceable components in this system.

The polarization control functions of the PSY-101 can be monitored using the internal polarimeter either from the front panel display in Mode 7 (Monitor mode), or from a PC using the PolaView™ software display.

**4.4 Remote control and programming:**

**4.4.1 RS-232 control**

**4.4.1.1 RS-232 connection**

The RS-232 serial interface port allows the user to remotely control the PSY-101. Any program that supports RS-232 communication protocols can be used to send ASCII commands to the PSY-101 to remotely access the system.

The RS-232 connector on the back panel of the PSY-101 is a DB9 male connector. Use a straight connection RS-232 cable to connect the PSY-101 to the RS-232 port of a
To ensure proper communication, use a serial cable with direct pin-to-pin connected wires (see Figure 16) at both ends of the cable.

![RS-232 connector pin assignment on PSY-101 back panel.](image)

**Figure 16** RS-232 connector pin assignment on PSY-101 back panel.

### 4.4.1.2 Remote operation and commands

General Photonics provides a test program for remote control of the PSY-101. The control software is included with the package. Installation and application procedures for the control software are described in section 4.4.3.

If users write their own control programs, the following steps and commands are recommended for remote operation of the PSY-101 using the RS-232 communication port.

2. Turn the power switch on.
3. Table 1 on the following page lists the available control commands. Many programming languages support serial communications, including Visual Basic, LabView and C.

#### Table 1  RS-232 / USB/GPIB Command List:

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>*IDN?</td>
<td>Query PSY101 identification</td>
<td>*IDN GP-PSY-101#</td>
</tr>
<tr>
<td>*VER?</td>
<td>Query PSY101 firmware version</td>
<td>*VER 3.0.070801F# (may vary)</td>
</tr>
<tr>
<td>*ADR nn#</td>
<td>Set GPIB address Range: 0 to 30</td>
<td>*E00# if successful else *Enn# error message Example: *ADR 5#</td>
</tr>
<tr>
<td>*ADR?</td>
<td>Query GPIB address</td>
<td>*ADR 30#</td>
</tr>
<tr>
<td>*SAV nn#</td>
<td>SOP values saved to memory location nn Range 0 to 99</td>
<td>Will not save if sum of square not equal 1. Example: *SAV 2#</td>
</tr>
<tr>
<td>*REC nn#</td>
<td>Load SOP values from memory location Range 0 to 99</td>
<td>Display jumps to mode SOP with loaded settings. Example: *REC 2#</td>
</tr>
<tr>
<td>*IND ON</td>
<td>OFF#</td>
<td>Turn on/off the variable name when return</td>
</tr>
</tbody>
</table>
### Data transmit divider : $2^n$
- **Range**: 0 to 10
- **Default**: 6

### System reset to its default value
- **Response**: *E00# if successful
- **Error**: *Enn# error message

### Turn on or off LCD refresh
- **Response**: *E00# if successful
- **Error**: *Enn# error message

### Set the max of a channel to the maximum
- **n**: AD channel number (1～4)
- **Response**: *E00# if successful
- **Error**: *Enn# error message

### Manual control voltage on channel n
- **n**: 1～6
- **xxx.x**: 0-150.0
- **Response**: *E00# if successful
- **Error**: *Enn# error message

---

## Basic Optical Value Commands

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>*POW?</td>
<td>Query power</td>
<td>*POW -6.7#</td>
</tr>
<tr>
<td>*POW:UNT?</td>
<td>Query unit of Power returned.</td>
<td>*UNT dBm# or *UNT mW#</td>
</tr>
<tr>
<td>*POW:UNT MW</td>
<td>DBM#</td>
<td>Set power unit to mW or dBm for returned value</td>
</tr>
<tr>
<td>*DOP?</td>
<td>Query DOP value.</td>
<td>Example: *DOP 98.6#</td>
</tr>
<tr>
<td>*SOP?</td>
<td>Query SOP value</td>
<td>*S1 -0.60,S2 0.60,S3 0.53# or *THA thetavalue,PHI phivalue#</td>
</tr>
<tr>
<td>*SOP:SSS#</td>
<td>SOP displays s1,s2,s3 Only affects *SOP? returning value.</td>
<td>*E00# if successful else *Enn# error message</td>
</tr>
<tr>
<td>*SOP:ANG#</td>
<td>SOP displays theta:phi Only affects *SOP? returning value.</td>
<td>*E00# if successful else *Enn# error message</td>
</tr>
<tr>
<td>*WAV?</td>
<td>Query wavelength of light, Range: 1500 to 1600 Default: 1550 nm</td>
<td>*WAV 1550#</td>
</tr>
<tr>
<td>*WAV nnnn#</td>
<td>Set wavelength of light source Range: 1500 to 1600 Default: 1550 nm</td>
<td>*E00# if successful else *Enn# error message Example: *WAV 1550#</td>
</tr>
</tbody>
</table>

---

## Mode Commands

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
<th>Response</th>
</tr>
</thead>
</table>
| *MOD? | Query the current mode. | *SOP#: SOP setting
<p>|         |              | *ANG#: angle setting     |
|         |              | *SPE# special sop        |
|         |              | *TRA# trace scan         |
|         |              | *VCT# volt setting       |
|         |              | *SCR# scramble mode select |
|         |              | *RAN# random scramble    |
|         |              | *SAW# sawth scramble     |</p>
<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>*MOD:zzz#</td>
<td>*MOD:zzz# represents setting a mode, where *MOD is the command prefix, and zzz is the mode number.</td>
</tr>
<tr>
<td>SOP:SS1 sf.fff#</td>
<td>Set S1 value, where sf.fff specifies a value within the range of -1.000 to +1.000.</td>
</tr>
<tr>
<td>SOP:SS2 sf.fff#</td>
<td>Set S2 value, where sf.fff specifies a value within the range of -1.000 to +1.000.</td>
</tr>
<tr>
<td>SOP:SS3 sf.fff#</td>
<td>Set S3 value, where sf.fff specifies a value within the range of -1.000 to +1.000.</td>
</tr>
<tr>
<td>SOP:THA fff.ff#</td>
<td>Set the theta value, where fff.ff specifies a value within the range of 0.00 to 180.00.</td>
</tr>
<tr>
<td>SOP:PHA sff.ff#</td>
<td>Set the PHI value, where sff.ff specifies a value within the range of -45.00 to 45.00.</td>
</tr>
<tr>
<td>SOP:ENA ON</td>
<td>Start SOP CONTROL, where ON is the command to start the control.</td>
</tr>
<tr>
<td>SOP:ENA OFF</td>
<td>Stop SOP CONTROL, where OFF is the command to stop the control.</td>
</tr>
<tr>
<td>SPE:SCN nnnnn#</td>
<td>Set the special SOP scanning speed, where nnnnn specifies a value within the range of 1 to 60000. Example: *SPE:SCN 4000#.</td>
</tr>
<tr>
<td>SPE:SCN?</td>
<td>Query the special SOP scanning speed.</td>
</tr>
<tr>
<td>SPE:STA?</td>
<td>Query the special SOP control state.</td>
</tr>
<tr>
<td>SPE:STA N#</td>
<td>Special SOP polarization control, where N# specifies a polarization mode (N= 1: 0°, N= 2: 45, N= 3: 90, N= 4: -45, N= 5: RHC, N= 6: LHC, N= 7: Scan).</td>
</tr>
<tr>
<td>TRA:SCN?</td>
<td>Query the trace scanning speed.</td>
</tr>
<tr>
<td>TRA:STE n.f#</td>
<td>Set the trace step size, where n.f specifies a value within the range of 1 to 99. Default 1°.</td>
</tr>
<tr>
<td>TRA:STA?</td>
<td>Query the trace scan state, where N= 1: 0°, N= 2: 45.</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>*TRA:STA N#</td>
<td>Set the trace scan state</td>
</tr>
<tr>
<td>*RAN:ENA?</td>
<td>Query if the random scrambling is ON or OFF</td>
</tr>
<tr>
<td>*RAN:FRQ?</td>
<td>Query the random frequency</td>
</tr>
<tr>
<td>*RAN:FRQ nnnn #</td>
<td>Set the random scrambling frequency. Range: 1 to 6000</td>
</tr>
<tr>
<td>*RAN:ENA ON</td>
<td>OFF#</td>
</tr>
<tr>
<td>*SAW:FRQ?</td>
<td>Query the saw wave scrambling frequency</td>
</tr>
<tr>
<td>*SAW:FRQ FFF.F#</td>
<td>Set the saw wave scrambling frequency. Range: 0.1 to 500.0 Default-units: Hz</td>
</tr>
<tr>
<td>*SAW:ENA ON</td>
<td>OFF#</td>
</tr>
</tbody>
</table>

**Communication commands**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
<th>Response / Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>*COM:POW</td>
<td>STK</td>
<td>P+S</td>
</tr>
<tr>
<td>*COM?</td>
<td>Query frame data structure</td>
<td>*POW# or *STK# or *P+S# or *VTG#</td>
</tr>
<tr>
<td>*COM:AUT ON</td>
<td>OFF#</td>
<td>Start or stop auto communication</td>
</tr>
<tr>
<td>*COM:CNT nnnn#</td>
<td>The count number of frames. Default:250 Range: 1-8192</td>
<td>*E00# if successful else *Err# error message</td>
</tr>
<tr>
<td>*COM:GRP ON#</td>
<td>Start the group communication</td>
<td></td>
</tr>
<tr>
<td>*COM:TRG ON</td>
<td>OFF#</td>
<td>Ready or cancel for trigger</td>
</tr>
<tr>
<td>*RAT n?</td>
<td>Query Gain-Ratio of n Range: 0 to 15</td>
<td>*RAT n, n…n# If nnnnn&gt;134217728 Gain_ratio[n] = n…n - 134217728 Else Gain_ratio[n] = n…n / 1000</td>
</tr>
<tr>
<td>*GAN?</td>
<td>Query gain value</td>
<td>*GAN 12#</td>
</tr>
<tr>
<td>*RSX?</td>
<td>Query RS232 Baud Rate</td>
<td>*5, 9600#</td>
</tr>
<tr>
<td>*CAP#</td>
<td>PSY DATA transmit mode: default mode</td>
<td></td>
</tr>
<tr>
<td>*CNO#</td>
<td>PSY can not transmit during SOP control</td>
<td></td>
</tr>
</tbody>
</table>
**Error Definition**

E00  No error (State OK)
E01  Undefined command
E06  Parameter outside the allowed range
E07  String of characters too long (>buffer limit)
E08  Light power too high
E09  Light power too low
E11  Error loading stored values
E12  Unable to store values
E13  Storage location invalid
E14  Recall location doesn’t exist
E16  Not in setup mode
E17  Mode setup error.
E18  Failed self test
E50  Stoke values square sum is out of range.

Notes:

a. If the beginning ("*”) or ending identifiers ("#” or “?”) of a command are missing, or the command string is too long, the instrument will ignore the communication and will not respond.

b. Sometimes an error may occur during communication due to hardware control (measurement interruptions). The typical response from the instrument in this case is E01. If this occurs, the user should resend the command until he receives the correct response.

c. Sometimes the communication may freeze (overflow) due to port conflict (this mainly happens during ETHERNET control). In this case, the user may need to restart the instrument to re-enable remote control.

d. Demo LabView programs (both source code and executable programs) have been provided with the PSY-101. These programs can be used as references for instrument control (see section 4.4.3.)

**4.4.1.3 RS-232 troubleshooting**

If a problem occurs during RS-232 control, please check the following:

1. Cable should be straight-wired: Select a straight-wired (pin-to-to pin wired) cable;
2. Verify active Comm Port (COM1, COM2, etc.);
3. Verify Comm Port settings: 8 data bits, 1 stop bit, no parity bits;
4. Check baud rate: must be 9600 bps;
5. Check commands: a correct command should begin with “*” and end with “#” or “?”.

**4.4.2 USB control**
The procedure for USB control is almost the same as that for RS-232 control, but requires the installation of a USB driver.

4.4.2.1 Procedure for Installing USB VCP driver

1. Copy VCP driver from CD-ROM to your computer.
2. Turn on power supply and plug in USB cable; this should bring up the “Found New Hardware Wizard”:

![Found New Hardware Wizard](image)

Welcome to the Found New Hardware Wizard

This wizard helps you install a device driver for a hardware device.

To continue, click Next.

3. Click “Next”:
4. Click “Next”:

5. Check “Specify a location”, then click “Next”: 
6. Use “Browse” to locate the file directory where the VCP driver is. Click “OK” to proceed to the next screen:

7. Click “Next”: 
8. Click “Finish”. This completes the first part of the installation, during which the USB to serial converter is installed. The second part consists of the installation of the serial port driver. This should follow automatically once the converter installation is completed:

9. Click “Next”:
10. Click “Next”:

11. Use “Browse” to locate the file directory where the VCP driver is. Click “OK” to proceed to the next screen:
12. Click “Next”:

13. Click “Finish”.
Depending on the system software and the location of the driver, the sequence of screens between the “found new hardware” screen and the “completion” screen may be slightly different, but in all cases, the result will be the installation first of the USB serial converter and then the USB serial port.

Once the installation of the serial port driver has been completed, confirm that the installation has been successful by looking under “Device Manager” on the “System Properties” screen: select Control Panel → System Properties → Hardware → Device Manager, then Select View → Device by type. The resulting screens are shown below. The device should have installed as a USB Serial Port (COMx) attached to USB High Speed Serial Converter. Note the port number that the device is using; it will need to be entered in the control program.

The USB driver can drive more than one instrument, but the correct port number must be set in the control programs for each of the instruments.

![Device Manager Screenshot](image-url)
In this example, the USB device is connected to COM3.

4.4.2.2. VCP Uninstall Procedure:

Unplug device. Run “Add/Remove Programs” from Control Panel: The following screens will be displayed.
4.4.2.3. USB Commands

The command list for USB control is the same as for RS-232 (see table 1 in section 4.4.1.2).

4.4.2.4. USB Troubleshooting:

Sometimes, for unknown reasons, the USB Serial Port cannot be found in Device Manager. To troubleshoot this issue, run “Add/Remove Programs” from the Control Panel, click
FTDI USB Serial Converter Drivers, and then click the Change/Remove button. A warning window will tell you that you have to unplug the USB cable if you want to remove the drives. Unplug USB cable, then press “Continue” button. Restart computer, then run VCP installation procedure again.
4.4.3 LabView control software

LabView programs are provided for computer control of the PSY-101 via different computer interfaces. Before running these programs, the user should determine whether the LabView developing environment is installed in the control computer. If the LabView environment (version 8.2 or above) is present, either the source code (vi) or the executable versions of the remote control programs can be used without installing further drivers. To control the instrument through the USB port, the USB drivers must be installed (see section 4.4.2)

Note: For simple control of the instrument, it is often easier to use the executable versions of the program than the source code. However, the executable versions will not run properly while LabView is running. If using the executable versions of the program on a computer with LabView installed, the user should quit LabView before running them.

If LabVIEW is not installed on the control computer, the user should set up the LabVIEW Run-Time engine by running the programs under “\LVRunTimeEng_8.2” (on the CD-ROM), and install the driver program for VISA (used for RS-232, distributed by National Instruments) by running the program named “Visa400runtime.exe” (under the root directory). To use the USB programs, the USB drivers also need to be installed (see section 4.4.2). Once the necessary drivers and other setup parameters are in place, the executable programs in the application directory can be run.

After the necessary drivers are installed, the programs (executable and/or source code) should be copied to the hard drive and run from there.

There are several versions of the control program on the CD_ROM. Here is the list of the programs and their corresponding directories:

A. Under “LabView_SourceCode” directory
   • PSY_REMOTE.vi – The source code for the control program using either RS232 or USB.
   • PSY ETHERNET.vi – The source code for the control program through ETHERNET.
   • GP_SET ETHERNET.vi – The source code for ETHERNET setup (see section 4.4.4)
   • GP_GPIB_ADDRESS.vi – The source code for querying/changing GPIB address (see section 4.4.5)

B. Under “LabView_Application” directory
   • Executable programs with the same names (ending in “.exe”) and functions as those contained in the “LabView_SourceCode” folder.

Note: Always close the control program (and LabView as well if using the VI version of the control program) before turning off the instrument. During remote control section, the front panel LCD may be disabled or not work properly. To resume the front panel control, restart the instrument if necessary.
Note: The control program described in this section is compatible with RS-232 and USB interfaces. The program auto-senses which interface is being used and displays the appropriate port configuration option. The program is for demo only, users can design own programs using the demo program as reference.

The control program screen layouts are shown below.

![Screen Layout](image)

Port Configuration: Displays the selected port for the RS-232, USB or GPIB connection. If the selected port and the actual connection do not match, the program will not function correctly. Set the correct port number here. The port number can be determined from the Device Manager (see section 2.4.2) or from National Instruments’ Measurement & Automation program. Note that the port number cannot be set while the program is executing (trying to control the instrument). Stop the program first by clicking the STOP button, then choose the correct port if necessary.

Notes: (a) ASRL1:INSTR is the same as COM1 for RS-232.
(b) GPIB:XX:INSTR means the GPIB port with an address of XX.

Use this screen to set an SOP using Stokes parameters. Set all 3 parameters by typing them into the boxes or using the arrows, then click the “Set” button to execute the setting.

Note: Stokes parameters must satisfy the normalization condition $S_1^2 + S_2^2 + S_3^2 = 1$. If they do not, the setting will be ignored.
Figure 18 Mode 2 (ellipse angle) control interface

Use this screen to set an SOP using polarization ellipse angles. Enter the desired values in the boxes, then click “Set” to execute the setting.
This screen is used to set the dwell time per point (in ms) for a 6-point or trace scan and the angle step size (in degrees) for a trace scan. The parameters will be applied as soon as they are entered in the boxes.
Use this screen to select one of the 6 poles of the Poincaré sphere as the output SOP. The desired SOP will be applied as soon as it is selected. If “Scan” is selected, the PSY-101 will scan sequentially through all 6 states in the order listed, using the dwell time at each point set from the parameter screen.
Select the desired rotation axis (0°, +45°, 90°, -45°, or S3) from the pull-down menu. The trace scan will begin as soon as the axis is selected, using the angle step and dwell time selected from the parameter screen.
Use this screen to directly set the control voltages for each channel of the polarization controller (only four channels are used in the demo program). Voltages are applied as soon as they are set, either in the box or using the dials.
The random scramble will begin as soon as this tab is selected. A new frequency is applied as soon as it appears in the box.

The saw wave scramble functions the same way. Frequency range for saw wave scramble is 0.1 to 500 Hz.
This screen shows the current output SOP Stokes parameters and the current measured power in dBm.

If “Monitor Polarization Control” is selected in the monitor mode pull-down menu, the SOP displayed reflects the action of the polarization controller, i.e., if an SOP was set from mode 1 or 2, the displayed SOP should match that setting.

If “Polarimeter Only” is selected in the monitor mode pull-down menu, the polarization controller is disabled, and the PSY-101 acts as a polarimeter only, showing the polarization state without any action from the PSY-101.

For the current version, there is no difference between these two modes.
To set the operation wavelength, either use the arrows or type it in the box, then click the "Set" button to apply the setting.
Use this screen to save the SOP currently being maintained by the PSY-101. Select the desired save point, then click “Save” to save the setting there.

The recall function works in the same way as the save function.
4.4.4 Ethernet control

The PSY-101 includes a small server. The following steps describe how to use it.

1. Connect Instrument
   There are two connection configurations for Ethernet control:

   a) Connect the instrument directly to the PC, as shown in figure 27.
   b) Connect the instrument with a DHCP server (router or exchange server), as shown in figure 28.

2. There are two ways of assigning the instrument an IP address:

   a) Static IP: the administrator assigns the instrument a fixed IP address.
   b) Dynamic IP: the DHCP server assigns the instrument an available address when requested.

3. Set Ethernet configuration and get IP address:
   Open the LabVIEW program (GP_SET_ETHERNET.vi or GP_SET_ETHERNET.exe) to set the Ethernet configuration.

   NOTE: This program was designed for an RS-232 interface, so the instrument should be connected to the computer via RS-232 before running it. Please see the instructions at the beginning of section 4.4.3 for preparations to run an RS-232 LabView program. The program interface is shown below.

   a) To use a static IP configuration, click the “fixed IP mode” tab, as shown in figure 29. Set the 5 parameters shown in figure 29. They can be obtained from your network administrator. The default values are those shown in Figure 29. Once the parameters are set, click the “Set” button to confirm.
b) To use dynamic IP address assignment, click the “DHCP MODE” tab, as shown in figure 30. Click the “OK” button to confirm. Note: this is the default mode.

After IP address configuration, select the “GET IP ADDRESS” tab to determine the IP address of the instrument, as shown in figure 31. Write down the IP address; it will be needed to access the PSY-101’s server.
4. Ethernet control of the PSY-101:
   Open the LabVIEW programs `PSY_Ethernet.vi` or `PSY_Ethernet.exe` for PSY-101 control through ETHERNET. The program interface is shown in figure 32. Input the IP address obtained in the previous step (see Figure 31). If the `SET-ETHERNET.vi` program’s static IP configuration was used, the Port number is the one set from that screen (see Figure 29). The default value is 23.

From this point, the program interfaces are very similar to those of the RS-232/USB/GPIB control programs. See section 4.4.3 for more detailed descriptions of the control program interfaces.
4.4.5 GPIB Control

Setting the GPIB address

The GPIB address of PSY-101 can be set through front panel control (mode 9).

Alternatively, the GPIB address can be changed by remote control either by sending individual control commands through one of the control interfaces (table 1 in section 4.4.1) or by using the LabView programs “GP_GPIB_ADDRESS.vi” or “GP_GPIB_ADDRESS.exe” to read or set the GPIB address through the RS-232 or USB port, as shown in figure 33.

![GPIB ADDRESS SETTING](Image)

Figure 33 Retrieve or change the GPIB address via LabView program

GPIB Control

Connect the instrument to the computer with a GPIB cable. After determining/setting the PSY-101’s GPIB address, select the corresponding port number in the corresponding box of the LabView control program (see section 4.4.3) and run the control program.

In addition to using the provided control programs, individual commands can be sent through the GPIB port. Enter the GPIB address in the communication program being used. The instrument will then be ready to receive commands. The command list is given in Table 1 at the beginning of section 4.4.1.

To ensure proper communication, use a GPIB cable that is fully compatible with the IEEE 488.1 standard. All GPIB/IEEE 488 interface connections must be made before turning on the instruments.
4.5 PolaView display software

In addition to displaying output polarization state on the LCD screen, the PSY-101 can be used in conjunction with the PolaView™ data analysis and display software, which provides real-time graphic display of polarization state either on a Poincaré Sphere window for viewing SOP traces or on an oscilloscope window for tracking polarization changes over time.

SOP, DOP, and DSOP (the angle between the current SOP and the reference SOP) of the input light can be calculated using the following formulas:

\[
\begin{bmatrix}
S_0 \\
S_1 \\
S_2 \\
S_3
\end{bmatrix}
= M
\begin{bmatrix}
V_0 \\
V_1 \\
V_2 \\
V_3
\end{bmatrix}
= \begin{bmatrix}
m_{11}, m_{12}, m_{13}, m_{14} \\
m_{21}, m_{22}, m_{23}, m_{24} \\
m_{31}, m_{32}, m_{33}, m_{34} \\
m_{41}, m_{42}, m_{43}, m_{44}
\end{bmatrix}
\begin{bmatrix}
V_0 \\
V_1 \\
V_2 \\
V_3
\end{bmatrix}
\]

(1)

\[
DOP = \sqrt{S_1^2 + S_2^2 + S_3^2} / S_0
\]

(2)

\[
DSOP = \frac{180}{\pi} \cos^{-1} \frac{S_1 * S_1^{\text{ref}} + S_2 * S_2^{\text{ref}} + S_3 * S_3^{\text{ref}}}{\sqrt{S_1^2 + S_2^2 + S_3^2} * \sqrt{S_1^{\text{ref}}^2 + S_2^{\text{ref}}^2 + S_3^{\text{ref}}^2}}
\]

(3)

where \(V_0 - V_3\) are analog output voltages from the polarimeter, \(M\) is a calibration matrix, \(S_0 - S_3\) are the Stokes parameters corresponding to \(V_0 - V_3\), and \(S_1^{\text{ref}}, S_2^{\text{ref}}, S_3^{\text{ref}}\) are the Stokes parameters of a reference polarization state specified by the user, normalized such that \((S_1^{\text{ref}})^2 + (S_2^{\text{ref}})^2 + (S_3^{\text{ref}})^2 = 1\).

4.5.1 System requirements

Pentium II or higher processors are recommended for running PolaView™. The software performed well in a Pentium III 800MHz test system.

PolaView™ is compatible with current Windows operating systems, and has been tested under Windows 98/NT/2000/XP. If the Poincaré sphere does not display correctly, it is usually due to a problem with the monitor’s display resolution or the graphics card configuration. Contact General Photonics for technical support.
4.5.2 Software installation

The PolaView™ software uses a USB connection to the PSY-101, so it requires that the USB driver be installed (see section 4.4.2).

To install the PolaView™ software, run the file “setup.exe” on the provided CD. Follow the setup screens until the following window will appear:

![Image of setup window]

After “finish” is clicked, the program is ready to be executed: the program should appear under “General Photonics” in the “Programs” section of the Start menu.

4.5.3 Software removal

To uninstall the PolaView™ software, go to Start → Programs → General Photonics → Uninstall.

4.5.4 Software operation instructions

Getting Started:
2. Start program.
3. Open the port: choose “COMPort” from the “Option” menu, and select the active port number (which can be found from Device Manager).
4. The PolaView has two monitoring modes for PSY-101: Select the “Sampling Rate” under the “Option” menu, then the two modes – “Polarimeter mode” and “PSY Polarimeter mode”, will appear. Polarimeter mode is used to monitor the polarization state without any polarization control inside PSY-101 (i.e. a passive monitor). PSY Polarimeter mode is used to monitor the polarization variation during the polarization control (i.e. an active monitor). Due to these two monitor mechanisms, the Polarimeter mode can have high sampling rate, while the PSY Polarimeter mode has limited bandwidth due to the timing conflicts between different hardware interrupts (polarization detection, active polarization control and high-speed data communication). Therefore, the sampling rate should be optimized under PSY Polarimeter mode for better detection using PolaView, otherwise, the accuracy of the polarization control may be sacrificed.

- Choose Polarimeter mode if using PSY-101 as a high-speed polarization analyzer and set the sampling rate;
- Choose PSY Polarimeter mode if polarization analyses are required during polarization control (either dynamic tracking or pre-determined generation), and set the sampling rate;

As an example, Figures 35 and 36 show the setting sequences for PSY Polarimeter mode.
5. The wavelength of the input light determines the calibration matrix used by the PSY-101 to calculate the Stokes parameters. Make sure that the wavelength set from the PSY-101’s front panel (Mode 8) matches that of the input light, and set the corresponding wavelength under the “Option” menu when running the PolaView (Figure 37).

![Figure 37 Set the wavelength](image)

6. Always exit the PolaView™ program before turning off the PSY-101.

4.5.4.1 Data Acquisition

There are two modes for polarization data acquisition: Sphere display mode and oscilloscope mode (Under the “Measurement” menu). Measurement must be stopped (click “Stop” in the lower right hand corner of the screen) to change display modes or use any of the menu functions. Sphere mode is the default data display mode when the software is started.

4.5.4.2. Sphere Display Mode

Figure 38 illustrates the user interface for sphere display mode. A data point’s location on the 3-D sphere is determined by vector \( (S_1, S_2, S_3) \). \( R (0,0,1) \), and \( L (0,0,-1) \) denote the sphere poles corresponding to right hand circular and left hand circular polarizations, respectively. Values of \( S_0, S_1, S_2 \) and \( S_3 \) are updated in the edit boxes once per 100 data points appearing on the sphere in POD mode, and once per data point in non-POD mode. (Note: The edit boxes each have pull-down menus, and can display azimuth, ellipticity, DLP, DCP, dREF, and DOP as well as S-parameters.) The \( S_0 \) (Power) value is also shown in the progress bar under the 2D circle display (scale ranges between –40 and 15 dBm).
Sphere display mode operates in continuous data acquisition mode. The data acquisition process begins and data points appear on the sphere when the user clicks the “Start” button. The process runs until the “Stop” button is clicked. “Clear” clears all displayed data points from the sphere. The display can also be switched between “Point” (displays individual points) and “Trace” (links consecutive data points on the sphere to display a trace). Points on the front of the sphere are displayed in red, and points on the back of the sphere in blue.

The sphere can be rotated for different vantage points using the green arrow buttons at the bottom of the screen. The magnifying glass buttons at the bottom of the screen zoom the sphere in or out. Both the house button at the center bottom of the screen and the “Home” button at the right bottom section of the screen return the sphere to its default position and size.

- Data Logging

In addition, PSY has a function as data logging under the sphere display mode, choose “Data Logging” from the “Option” menu, the display will be like Figure 39 (lower right). There are two options for data logging: Free Run and Timed.

In the Free Run mode, press “Start” will start the data logging function and all the measured data will be kept in a temporary file. Once the “Save” is pressed, the data can be stored to a specified file named by the user. This file can also be recalled to display all the saved data on the sphere using the “Load” button. Pressing “Start” again will rewrite the temporary file and start the new measurement again.

In the Timed mode, the measured data number is set by “point#”, and the measurement (data acquisition) interval is set by the “Period” in millisecond (ms). “Start”, “Save” and “Load” buttons have similar functions to the Free Run mode.

In both modes, pressing “Exit” will stop the data logging function and back to the normal/default sphere display mode.
4.5.4.3. Oscilloscope Mode

Figure 40 illustrates the user interface in oscilloscope display mode. In this mode, the user can specify more parameters than in sphere display mode. Again, measurement must be stopped (click “Stop” in the lower right hand corner of the screen) to change display modes or function parameters, or to use any of the menu functions. In the upper-right corner of the display, the “Numbers” box specifies the number of points per data frame displayed by the scope traces. “Data average” is the number of consecutive values used to compute the running average for each displayed point (e.g., if the data average is 10, the current value and the 9 previous measured values are used to compute the average.)

In the middle right section of the display, “SOP Ref.” specifies the values of the reference Stokes parameters ($S_{1\text{ref}}$, $S_{2\text{ref}}$, $S_{3\text{ref}}$ used in formula (3) to compute the DSOP). The DSOP relative to this reference is denoted as $d_{\text{REF}}$. The default SOP reference point is (1, 0, 0).
The “Clear”, “Start” and “Stop” buttons have the same functions as in Sphere mode. The “Var Track” button is used to initiate the variation tracking process, which will be discussed in section 4.5.4.4.

The left side of the screen contains the oscilloscope and data display areas. The oscilloscope display area is similar to that of a real oscilloscope. The x-scale unit is sample point number. The pull-down menu at the top right of each data display area is used to select the parameter displayed in the corresponding oscilloscope trace and data display area. Parameters that can be monitored include $S_0$ (power), $S_1$, $S_2$, $S_3$ (Stokes parameters), Azimuth, Ellipticity, DOP (degree of polarization), DLP (degree of linearity), DCP (degree of circularity) and dREF (angle variation of the current point from the reference point). The “Time/Numbers” button at the bottom of the screen toggles the x-scale unit between sample point number and time in ms.

When the measurement is stopped, a cursor can be used to find measurement parameters for a particular point on the oscilloscope traces. Left-click on the oscilloscope traces to make the cursor appear as a green line on the oscilloscope display, and then use the “L” and “R” keys on the keyboard to move the cursor.

Y-Scale Range

The range of the Y-scale in the oscilloscope display area can be either automatically adjusted or manually set. The Y scale can only be changed when measurement is stopped. To set the Y scale, choose “Y-scale range” from the “Option” menu. The following window will pop up:

![Y-scale control window](image)

Figure 41 Y-scale control window

The Y scale control options are:
1. Auto Scale: When a value exceeds the current Y-scale range limit, the Y-scale range automatically rescales to accommodate new values.

2. Manual Scale: The user sets the range separately for each of the 4 oscilloscope graphs. Note that data values may exceed the range limits. However, the display is more stable in this mode.

Note: In Auto Scale mode, the range for S1, S2, and S3 is set as ±10% of the current value. Manual Scale mode should be used to change to another range; for example, if the variation is small, a smaller range will show more detail.

4.5.4.4 Data Acquisition in Oscilloscope mode

The default data acquisition mode is continuous mode. To change to another mode, select the desired measurement mode from the “Measurement” menu. This can only be done when measurement is stopped.

To use the various modes under Oscilloscope mode:

Continuous scan: The oscilloscope trace and data display area continuously update. To use this mode, select “continuous scan” from the “Option” menu.

Trigger (Optional): To use this mode, select “trigger” from the “Option” menu and input a TTL trigger signal to the BNC connector on the back panel of the instrument. If there is no signal, the oscilloscope will continue to display the results of the last set of data measured.

Burst: this mode will only measure X samples at the current speed, where X is specified by the “Numbers” located at the right upper corner of the screen.

Variation Tracking: This mode tracks changes in SOP larger than a specified value. When starting variation tracking, the user specifies a reference SOP and a DSOP tolerance value. If the current DSOP is greater than the specified DSOP value, the polarization data are recorded in a file on the hard disk, and the reference SOP with respect to which DSOP is calculated is updated to the current SOP (i.e., the next set of DSOP values will be calculated relative to the current SOP, rather than the original user-set reference, until the DSOP again exceeds the specified value, at which point the reference will update again, etc.).

Figures 42, 43, and 44 illustrate variation tracking dialog screens. The screen shown in Figure 42 appears when the “Var. Tracking” button on the main oscilloscope interface is clicked. The sample rate (Figure 42, top line) can be between 0.1 and 10-KHz for PSY Polarimeter mode. The DSOP tolerance value to be used (Figure 42, middle line, specified in degrees) can be between 0 and 180°. The period (Figure 42, bottom line) specifies the period over which polarization variation is to be tracked, in hours (maximum 1000 hours). The filename and location of the file in which variation tracking data is stored should be input in the next “save as” dialog box. Finally, a confirmation dialog shows before the variation tracking process starts. “Cancel” can be used to cancel the variation tracking at
any point during setup, and the “Stop” button on the oscilloscope interface can be used to stop a variation tracking run in progress.

![Variation Tracking Setup Parameters](image1)

Figure 42 Variation Tracking Setup Parameters

![Save DSOP data in a file](image2)

Figure 43 Save DSOP data in a file
Figure 44 Confirmation: Clicking “OK” starts the variation tracking run.

The saved data file stores the time (in ms), and the $S_0$, $S_1$, $S_2$, and $S_3$ of the polarization states that match the required DSOP condition. The data file can be loaded by choosing “Load” in the “File” menu.

4.6 Polarization Extinction Ratio (PER) Measurement

To minimize polarization dependent effects, it is often desirable to maintain a constant state of polarization as light propagates through an optical system. With regard to such systems, polarization extinction ratio (PER), or polarization crosstalk, is a measure of the degree to which the light is confined in the principal polarization mode. It is defined as the ratio of the power in the principal polarization mode to the power in the orthogonal polarization mode after propagation through the system, expressed in dB. The crosstalk measured at any point in the system is the result of the cumulative effects of the polarization properties of the light source (light not fully polarized or not linearly polarized), misalignments at fiber connections or splices, and propagation through the fiber itself up to the measurement point.

Polarization maintaining optical fibers have an optical (slow) axis defined by a strong linear birefringence. If light input to an ideal PM fiber is polarized along its optical axis, the polarization state will be maintained during propagation through the fiber. However, if it is misaligned, or is not fully polarized, the component polarized along the slow axis propagates at a different speed than the component polarized along the fast axis. Thus, the polarization state of the light changes with the relative phase delay between the two components as it propagates through the fiber.

For the case of a linearly polarized light beam launched into a PM fiber with its polarization axis rotated by an angle $\theta$ from the PM fiber’s slow axis, as shown in Figure 45, the extinction ratio due to the misalignment can be calculated as

$$PER = -10\log(\tan^2 \theta)$$

(1)
The misalignment angle is difficult to measure directly, as it depends on the determination of the orientation of the fiber’s slow axis.

Changes in the fiber length due to temperature changes or mechanical stress change the relative phase delay between the two orthogonal polarization components, causing the state of polarization of the output light to rotate along a circle on the Poincaré sphere. The rotation axis of the circle is defined by the optical (slow) axis of the PM fiber, and the radius of the circle by the misalignment of the light to the slow axis, as shown in Figure 46.
The polarization extinction ratio, then, can be calculated directly from the size of the circle:

\[
PER = -10\log\left(\frac{\sin^2 \frac{\alpha}{2}}{\cos^2 \frac{\alpha}{2}} \right) = -10\log\left(\frac{1 - \cos \alpha}{1 + \cos \alpha} \right) = -10\log\left(\frac{1 - \sqrt{1 - R^2}}{1 + \sqrt{1 - R^2}} \right)
\] (2)

For complete confinement in one mode, \(R \rightarrow 0\) (the circle collapses to a point), corresponding to \(PER \rightarrow \infty\). At the other extreme, if the light is evenly distributed between the two orthogonal polarization modes, \(R \rightarrow 1\) (the circle becomes a circumference of the sphere), corresponding to \(PER \rightarrow 0\).

Since this is a relative measurement, dependent only on the size of the circle and not on its absolute position on the Poincaré sphere, the PM fiber under test does not need to be directly connected to the polarimeter. Intermediate sections of SM fiber will change the position of the circle, but not its size, as long as the fiber does not move during the measurement.

4.6.1. PER measurement using the PSY-101
1. Connect the system under test to the PSY-101. Some sample test setups will be described in the next section. Make sure that all of the fiber sections except the section under test are immobilized.

2. If the system ends at the PSY-101 (i.e., no further components are connected to the output of the PSY-101), terminate the output to prevent backreflections. This can be done by connecting the output port to an isolator or absorber, or to a fiber jumper with an APC connector on the other end.

3. From the Poincaré sphere display mode, click “Stop” in the box at the bottom right corner of the screen to stop data acquisition. Make sure that “Point” rather than “Trace” is selected.

4. Select “PER Measurement” from the “Options” menu.

5. Click “Start” to start data acquisition for the PER measurement.

6. Slowly heat or stretch the section of PM fiber under test until the SOP traces out close to a full circle on the Poincaré sphere. If stretching the fiber, make sure that it does not bend, as this can cause mode coupling.

7. Once sufficient data points are present (close to a full circle), click “Stop” to stop data acquisition and begin the PER calculation. The software will perform a curve fitting to fit a circle (shown in green) to the measured data points, and then use the radius of the circle to calculate the PER. When it is finished, a small window with the calculated PER will pop up. Some sample measurements are shown in Figures 47 and 48.

![Figure 47 PER measurement results: Blue points are measured data; green circle is the fitted curve. Smaller circle corresponds to higher ER.](image)
8. When the PER measurement is finished, deselect “PER Measurement” in the “Options” menu to return to normal Poincaré sphere SOP monitoring mode.

4.6.2. Application examples

The following examples show some of the applications for this kind of measurement. For accurate results, the light source should be narrowband and polarized, fiber segments should be stationary during measurement, and the polarizer or polarization controller used should have a higher extinction ratio than the fiber sections/connections under test. In these examples, the PM fiber segment under test is shown in red.

1. Aligning light source input to a PM fiber:

   ![Diagram 1]

   As the PM fiber segment under test (red) is heated or stretched, the polarization controller can be used to change the input polarization to minimize the size of the circle trace. The PER measurement function can then be used to characterize the best alignment.

2. Testing alignment between different segments/components in a system

   ![Diagram 2]
Using PM segment 1 as the test segment, follow the procedure in example 1 to align the light source to the slow axis of fiber/component 1. Then, with segment 1 immobilized, do a measurement with segment 2 as the test segment. The result of this measurement indicates the crosstalk in segment 2 due to the misalignments at connections A and B. The difference between the measurement results obtained using segments 1 and 2, respectively, as the test segment gives an idea of the alignment quality of connection B. The crosstalk at points further along the system can be tested by heating or stretching subsequent sections of PM fiber.

3. A similar setup can be used for active alignment of PM fibers before splicing or to test alignment during connectorization.
Section 5. Technical Support

General Photonics is committed to high quality standards and customer satisfaction. For any questions regarding the quality and use of the PSY-101, calibration services, or future suggestions, please contact General Photonics Corporation at (909)-590-5473 (telephone) or (909)-902-5536 (fax), or by e-mail at info@general photonics.com. General Photonics will respond to all customer questions within 24 hours during regular business hours. General Photonics can also be contacted by mail at:

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