56 Sparta Avenue • Newton, New Jersey 07860
(973) 300-3000 Sales • (973) 300-3600 Fax
www.thorlabs.com

THORLABS

## PLC-900 - DEC 4, 2017

Item # PLC-900 was discontinued on DEC 4, 2017. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

# IN-LINE OPTICAL FIBER POLARIZATION CONTROLLER

- ► **Converts An Arbitrary Input Polarization State to Any Desired Output Polarization State**
- ► **All-Fiber Design with No Intrinsic Loss or Back Reflections**
- ► **Compatible with Ø900 µm Tight Buffer Fiber**


**PLC-900**


PLC-900 with Ø900 µm Tight-Buffer Fiber Mounted on an Optical Table

OVERVIEW

## Features

- Fiber Squeezer Design Creates an In-Fiber Variable Waveplate
- Insensitive to Wavelength Variations, Vibrations, and Fiber Variations
- Compact 1" x 3" (25.4 mm x 76.2 mm) Footprint
- OCT-Proven Design
- For Use with Ø900 µm Tight-Buffer Jacketed Fiber

The PLC-900 is a compact, in-line polarization controller for Ø900 µm tight-buffer fiber. The device consists of a rotatable fiber squeezer and two fiber holding blocks. It creates stress-induced birefringence within the fiber by mechanically compressing a cross-sectional axis of the fiber. This creates a variable, rotatable wave plate. Both the angle and retardance of the wave plate can be continuously, independently adjusted, which allows any arbitraty input polarization state to be converted to any desired output polarization state.

| Item # | PLC-900 |
|---|---|
| Insertion Loss | <0.05 dB[a] |
| Return Loss | >65 dB[a] |
| Extinction Ratio | >40 dB[a] |
| Operating Temperature | −40 to 85 °C |
| Storage Temperature | −40 to 85 °C |
| Fiber Jacket | Ø900 µm Tight-Buffer Jacket[b] |

- Specified for bare fiber without connectors.
- Not compatible with bare fiber or Ø900 µm loose-tube jacketing.

The PLC-900's all-fiber design produces no intrinsic loss or back reflections, making it a good alternative to traditional free-space polarization controllers, which consist of two quarter-wave plates and one half-wave plate. Fiber can be dropped into the PLC-900 without disconnecting either end from a setup. The polarization controller has a compact, 1" x 3" (25.4 mm x 76.2 mm) footprint with four 1/4" (M6) clearance slots for securing to an optical table. Please note that this controller is not intended for use with bare fiber or Ø900 µm loose-tube furcation tubing.

Thorlabs also offers paddle-style fiber polarization controllers, which create several fixed-retardance, rotatable wave plates using looped fiber to create birefringence.

| Fiber Polarization Control Selection Guide | | | |
|---|---|---|---|
|  |  |  |  |
| Paddle Fiber Polarization Controllers | In-Line Fiber Polarization Controller | In-Line Fiber Polarizers | Polarizing Fiber |

O P E R A T I O N

## Fiber Polarization Controller Operation

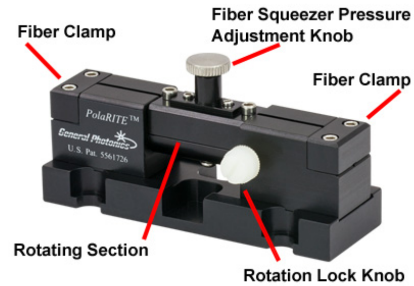


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**Figure 1:** PLC-900 Polarization Controller

The PLC-900 Fiber Polarization Controller consists of two fiber holding clamps with a rotatable fiber squeezer mounted between them. The pressure applied by the fiber squeezer produces a linear birefringence in a short section of the fiber, which creates a fiber wave plate. The amount of birefringence per unit length, δ, is proportional to the applied pressure and is given by

$$\delta \sim 6 \times 10^{-11} \frac{F}{\lambda d} \ rad \ m^{-1}$$

where *F* is the applied force in newtons, *λ* is the wavelength of light in meters, and *d* is the diameter of the fiber in meters.[1, 2]

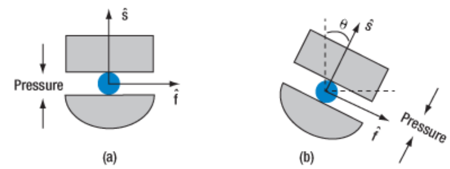


**Figure 2:** $\hat{s}$ and $\hat{f}$ Correspond to the Fast and Slow Axes, Respectively, of the Fiber Wave Plate. They Define a Coordinate System Used in the Calculations Below. (a) Force Squeezing the Fiber Creates Stress-Induced Birefringence, Creating a Wave Plate. (b) The Fiber can be Twisted to Rotate the Fast and Slow Axes of the Wave Plate.

The fiber's core acts as a birefringent wave plate with a slow axis that is defined by the direction of the applied pressure, as shown in Figure 2a. By changing the applied pressure, the retardation of the fiber wave plate can be continuously varied between 0 and 2π.

Rotating the fiber squeezer while applying pressure causes the birefringent portion of the fiber to rotate. This also causes the fiber at the left and right sides of the birefringent section to twist. This twisted fiber rotates the incident polarization in the direction of the twist by an angle given by

$$\theta' = \eta\theta$$

where θ is the physical rotation angle shown in Figure 2b and η is a coefficient of twist-induced optical activity. For single mode fibers, η is on the order of 0.08[3, 4, 5]. For a physical rotation of θ degrees, the net change of the incident angle between the slow axis of the fiber wave plate and the input polarization, in degrees, is

$$(1 - \eta)\theta$$

For coarse angular adjustments, the fiber squeezer should be rotated without twisting the fiber. This can be accomplished by releasing the pressure from the fiber squeezer before rotating it. Once the desired rotation is achieved, pressure can be reapplied by the fiber squeezer. Thus, for a physical rotation of θ degrees, the net change of the incident angle between the slow axis of the fiber wave plate and the input polarization is also θ degrees.

We recommend this procedure for the coarse adjustment of the output polarization state. When the output polarization is close to that desired, the fiber squeezer can be rotated slightly while applying pressure in order to fine tune the output polarization angle.

## Achieving the Desired Output Polarization State

The rotatable fiber squeezer allows the optical fiber to act as a wave plate of variable retardation and rotatable birefringent axes. This is equivalent to a Soleil-Babinet compensator[6]. Using the slow and fast axes of fiber wave plate as a coordinate system, as shown in Figure 2, the Jones matrix describing the birefringence of the fiber wave plate can be written as

$$\begin{bmatrix} e^{-i\frac{\Gamma}{2}} & 0 \\ 0 & e^{i\frac{\Gamma}{2}} \end{bmatrix}$$

where $\Gamma \equiv 2\pi\Delta nl/\lambda = \delta l$ is the phase retardation of the fiber. In this expression, l is the length of the birefringent fiber and Δn is the index of refraction difference between the slow and fast axes. In the same coordinate system, the Jones vector of an arbitrary input polarization is

$$\vec{E}_{in} = \begin{bmatrix} E_s \\ E_f e^{i\phi} \end{bmatrix} = E \begin{bmatrix} cos(\alpha) \\ sin(\alpha)e^{i\phi} \end{bmatrix}$$

where $E_s$ and $E_f$ are the amplitudes of the light field projected on the slow and fast axes, respectively, φ is the phase retardation between $E_s$ and $E_f$, $E \equiv \sqrt{E_f^2 + E_s^2}$, and $\alpha \equiv tan^{-1}(E_f/E_s)$.

After propagation through the squeezed fiber, the Jones vector of the output polarization state is

$$\vec{E}_{out} = E\begin{bmatrix} e^{-i\frac{\Gamma}{2}} & 0 \\ 0 & e^{i\frac{\Gamma}{2}} \end{bmatrix}\begin{bmatrix} cos(\alpha) \\ sin(\alpha)e^{i\phi} \end{bmatrix} = Ee^{-i\Gamma/2}cos(\alpha)\begin{bmatrix} 1 \\ \chi \end{bmatrix}$$

where $\chi = tan(\alpha)e^{i(\phi+\Gamma)}$. The birefringent axis of the fiber can be rotated, and thus α can be continuously varied from 0 to π/2. Similarly, the phase retardation, Γ, can be continuously varied from 0 to 2π by changing the pressure on the fiber. Thus, χ can take any value on the complex plane Re(χ) vs. Im(χ). Because each point of the complex plane is associated with a polarization state[7], the rotatable fiber squeezer is capable of generating any output polarization from any arbitrary input polarization.

## Recommended Adjustment Procedure

The procedure below details how to convert an unknown, arbitrary elliptical input polarization state (common in single mode fiber) to a linear output polarization state, to be input into a polarization-sensitive optical device.

1. Apply pressure to the center portion of the fiber by tightening the knob on the rotatable fiber squeezer while monitoring the output polarization state with, for instance, a polarizer and a power meter. Alternatively, a polarimeter can be used for more direct monitoring of the output polarization state. If applying pressure causes a significant increase in the monitored optical power, then increase pressure until the optical power starts to decrease.
2. Rotate the fiber squeezer while keeping the pressure on to fine tune the output polarization. Adjust the pressure and orientation of the rotatable fiber squeezer iteratively until a maximum optical power is obtained. This is the indication that the desired polarization is achieved.
3. If applying a pressure causes little change in monitored optical power, or causes the optical power to decrease, then release the pressure and rotate the center portion to a new position. Repeat steps 1 and 2 if turning the knob causes a significant increase in monitored visibility or optical power.

## References


1. A. M. Smith, "Single-mode fiber pressure sensitivity," Electronics Letters, Vol. 16, No 20, pp 773-774 (1980).
2. J. Sakai and T. Kimura, "Birefringence and Polarization Characteristics of Single-Mode Optical Fibers under Elastic Deformations," IEEE Journal of Quantum Electronics, Vol. QE-17, No. 6, pp 1041-1051 (1981).
3. R. Ulrich and A. Simon, "Polarization optics of twisted single-mode fibers," Applied Optics, Vol. 18, No. 13, pp 2241-2251 (1979).
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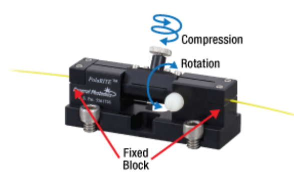
5. M. Monerie and L. Jeunhomme, "Polarization mode coupling in long single-mode fibers," Optical and Quantum Electronics, Vol. 12, pp 449-461 (1980).
6. M. Born and E. Wolf, *Principles of Optics*, New York: Pergamon Press, Sixth edition, 1980, pp. 693-694.
7. A. Yariv and P. Yeh, *Optical Waves in Crystals*, New York: John Wiley & Sons, 1984, pp. 61-62.


LAB FACTS

### Thorlabs Lab Fact: Using the PLC-900 to Manipulate Polarization




Click to Enlarge
**Figure 1:** Forces produced by the PLC-900.

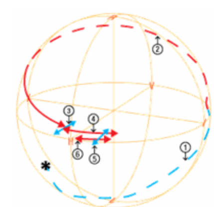


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**Figure 2:** Poincaré sphere showing the polarization rotation from a PLC-900.

We present laboratory measurements of the influence on the output polarization state from a fiber due to rotational and compression forces from the PLC-900 polarization controller. This controller utilizes the effects of stress-induced birefringence to create changes in the polarization of light traveling through a fiber under stress. The stress can be caused either through compression [1] or rotation [2], as shown in Figure 1. It was found that the stress-induced birefringence can be adjusted continuously, thus allowing any arbitrary input polarization state to be rotated into any desired output polarization state. We detail the procedures necessary to achieve a desired output polarization, and plot the change in the polarization on a Poincaré sphere to illustrate the steps necessary in reaching a desired polarization state.

For our experiment, we used the S1FC1310 Fabry-Perot Benchtop Laser (1310 nm) as the light source and couple it into a Ø900 µm tight-buffer fiber. The fiber is mounted through the PLC-900, and the output was collimated into a free-space beam with a fiber collimator. From here the beam was measured, either directly by a polarimeter or through an analyzer assembly consisting of a λ/4 wave plate, a linear polarizer, and a power meter.

**Lab Facts**

Click for full Lab Facts summary

Figure 2 summarizes the measured results for manipulating the polarization of light in a fiber as a function of rotational and compression forces and is shown on the Poincaré sphere. The blue lines represent compression and the red lines represent rotation of the PLC-900 (see Fig. 1); the numbers indicate the step. As shown in Fig. 2, starting at any arbitrary polarization state, it is possible to achieve any desired polarization state through a series of rotations and compressions. This manipulation of the polarization by the PLC-900 does not produce intrinsic loss nor back reflections; instead stress-induced birefringence is utilized as a mechanism for rotating the polarization of light in fiber. Data is presented for both compression and rotation forces, and the polarization changes due to these are mapped out on Poincaré spheres. For details on the experimental setup employed and the results obtained, please click here.


[1] A.M. Smith, “Single-mode fibre pressure sensitivity,” Electron Lett. 16, 773-774 (1980).
[2] R. Ulrich, A. Simon, “Polarization optics of twisted single-mode fibers” Appl Opt 18, 2241-2251 (1979).

SMART PACK

## Smart Pack

- Reduce Weight of Packaging Materials
- Increase Usage of Recyclable Packing Materials
- Improve Packing Integrity
- Decrease Shipping Costs

| Item # | % Weight Reduction | $CO_2$-Equivalent Reduction[a] |
|---|---|---|
| PLC-900 | 44.94% | 10.92 kg |

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PLC-900 Packaging

Thorlabs' Smart Pack Initiative is aimed at waste minimization while still maintaining adequate protection for our products. By eliminating any unnecessary packaging, implementing packaging design changes, and utilizing eco-friendly packaging materials for our customers when possible, this initiative seeks to improve the environmental impact of our product packaging. Products listed above are now shipped in re-engineered packaging that minimizes the weight and the use of non-recyclable materials.[b] As we move through our product line, we will indicate re-engineered packages with our Smart Pack logo.

- Travel-based emissions reduction calculations are estimated based on the total weight reduction of packaging materials used for all of 2013’s product sales, traveling 1,000 miles on an airplane, to provide general understanding of the impact of packaging material reduction. Calculations were made using the EPA’s shipping emissions values for different modes of transport.
- Some Smart Pack products may show a negative weight reduction percentage as the substitution of greener packaging materials, such as the Greenwrap, at times slightly increases the weight of the product packaging.

| Part Number | Description | Price | Availability |
|---|---|---|---|
| **PLC-900** | **In-Line Fiber Polarization Controller for Ø900 µm Tight Buffer Fiber** | **$536.00** | **Today** |

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