Manual Fiber Polarization Controllers

User Guide

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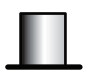
Chapter 1 Warning Symbol Definitions

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

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

Chapter 2 General Description

These manual polarization controllers utilize stress-induced birefringence to alter the polarization in single mode fiber that is looped around two or three independent spools to create two or three independent fractional wave plates (fiber retarders). The amount of birefringence induced in the fiber is a function of the fiber cladding diameter, the spool diameter (fixed), the number of fiber loops per spool, and the wavelength of the light. (NOTE: The desired birefringence is induced by the loop in the fiber, not by the twisting of the fiber paddles). The fast axis of the fiber, which is in the plane of the spool, is adjusted with respect to the transmitted polarization vector by manually rotating the paddles to twist the fiber.

To transform an arbitrary input polarization state into an arbitrary output polarization state, a combination of three paddles (a quarter-wave plate, a half-wave plate, and a quarter-wave plate) or two paddles (quarter-wave plate and a half-wave plate) is used. The retardance of each paddle may be estimated from the following equation:

$$\varphi(Radians) = \frac{2\pi^2 aNd^2}{\lambda D}$$

$$\varphi(Waves) = \frac{\pi aNd^2}{\lambda D}$$

Here, φ is the retardance, a is a constant (0.133 for silica fiber), N is the number of loops, d is the fiber cladding diameter, λ is the wavelength, and D is the loop diameter. While this equation is for bare fiber, the solution for Ø900 µm jacketed fiber will be similar enough that the results for this equation can still be used (i.e., the solution will not vary by a complete loop N for Ø900 µm jacketed fiber).

The FPC020, FPC030, and FPC560 are empty controllers in which the user can install a fiber of their choice. The rest of our fiber polarization controllers have fiber pre-installed to optimize the polarization control at common wavelengths. These controllers can also be customized using the information provided in Sections 2.1 through 2.3.

2.1. 3-Paddle Fiber Polarization Controllers

A 3-paddle polarization controller combines a quarter-wave plate, half-wave plate, and quarter-wave plate in series to transform an arbitrary polarization state into any other polarization state. The first quarter-wave plate would transform the input polarization state into a linear polarization state. The half-wave plate would rotate the linear polarization state, and the last quarter-wave plate would transform the linear state into an arbitrary polarization state. Therefore, adjusting each of the three paddles (fiber retarders) allows complete control of the output polarization state over a broad range of wavelengths from 300 to 2100 nm. The 3-paddle polarization controllers are available with paddles that support either Ø27 mm loops or Ø56 mm loops.

Using FPC030 as an example for the controllers with a Ø27 mm loop diameter, a plot of calcuated retardation per paddle versus wavelength is shown in 0 for a fiber with a cladding diameter of 80 µm. For fiber with a cladding diameter of 125 µm, the retardation per paddle versus wavelength is shown in 0.

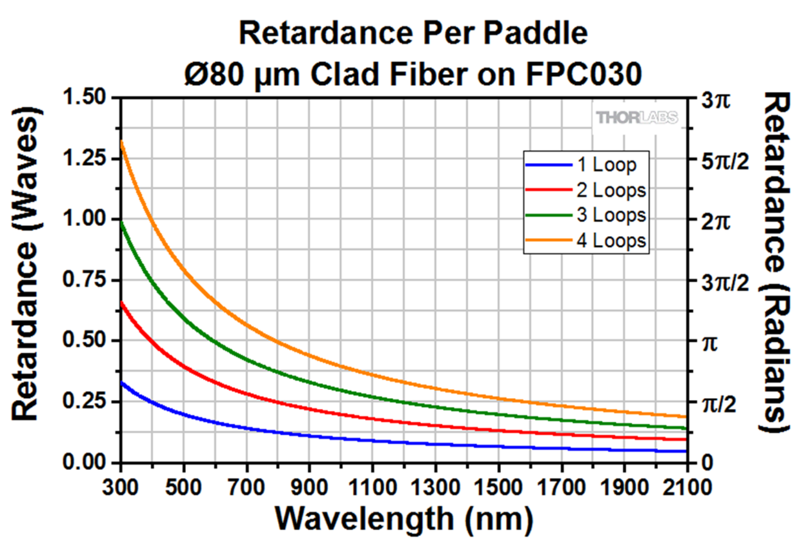


Figure 1

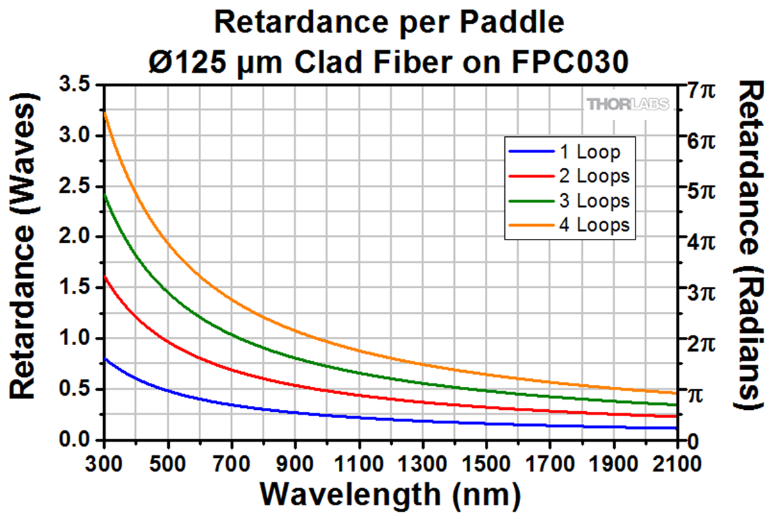


Figure 2

Figure 3 and Figure 4 show the results for Ø80 µm and Ø125 µm clad fiber, respectively, for the FPC560 controller, which has three paddles with a loop diameter of 56 mm. The larger loop diameter is ideal for fibers with higher bend loss.

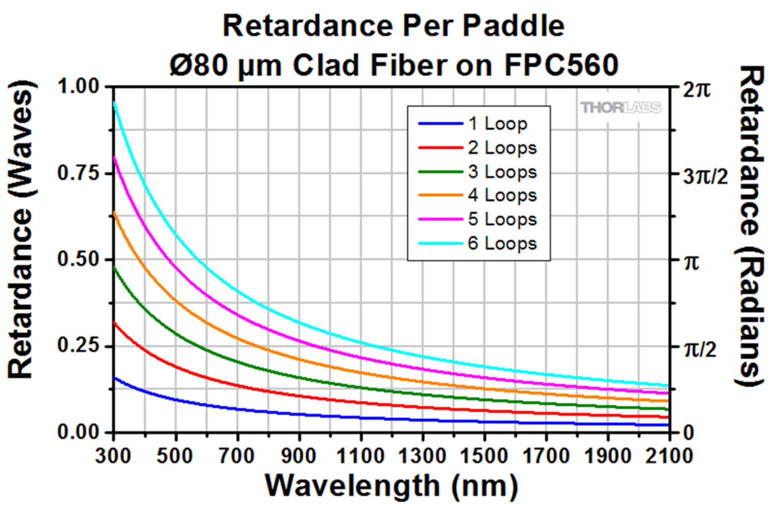


Figure 3

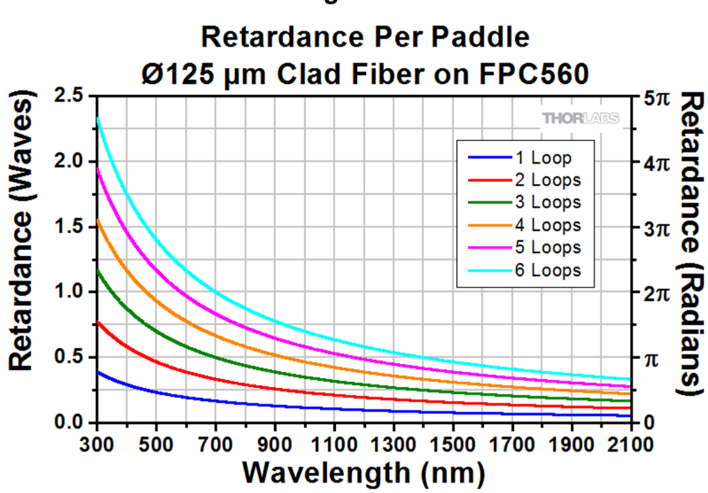


Figure 4

2.2. Miniature 2-Paddle Fiber Polarization Controllers

The 2-paddle polarization controllers use a quarter-wave plate and a half wave plate to transform an arbitrary polarization state into any other polarization state. In this configuration, however, the control of the polarization will be coupled between the two paddles. These controllers allow complete control of the output polarization state over a broad range of wavelengths (300 to 2100 nm).

The retardation per paddle is a function of loop number and the cladding diameter of the fiber if the loop diameter is fixed. The retardation, in radians, is plotted for 1, 2, 3, and 4 loops per paddle for a fiber with cladding diameters of 80 µm and 125 µm (Figure 5 and Figure 6). Due to its small size, the FPC020 cannot accommodate more than 4 loops per paddle.

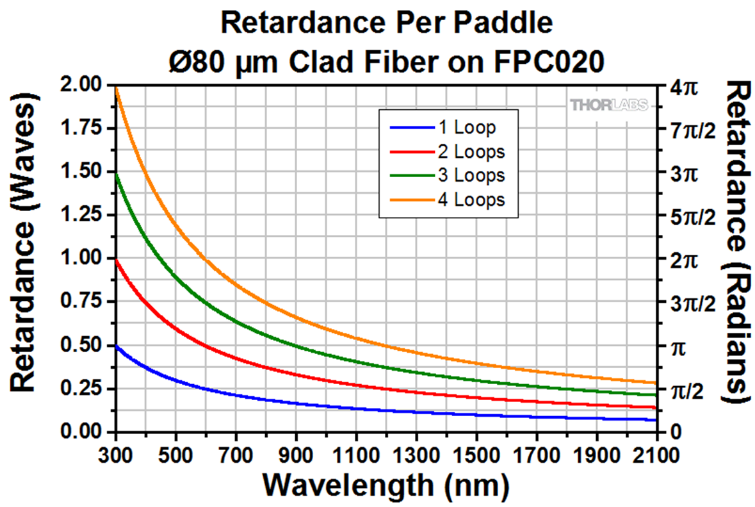


Figure 5

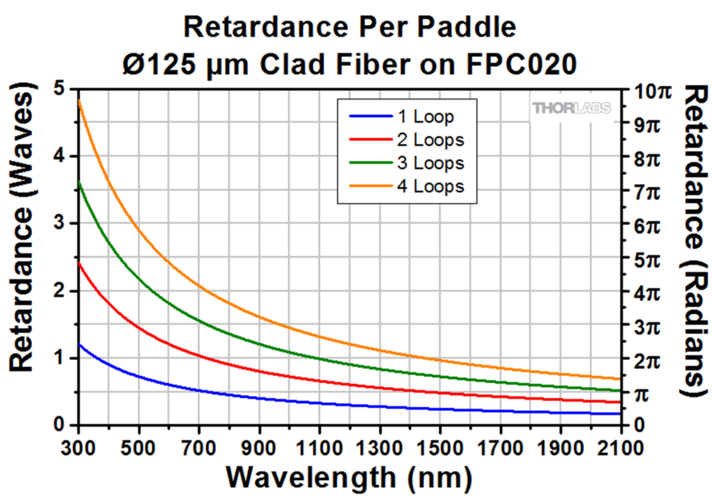


Figure 6

2.3. Recommended Number of Loops

The retardation of multi-order (including zero order) quarter-wave plate is given by the following equation:

$$\frac{(2m+1)\pi}{2}$$

where *m* is an integer. Similarly, the retardation of multi-order (including zero order) half-wave plate is given by:

$$(2m+1)\pi$$

See the table below for several solutions to the equations:

Order	m	Quarter-Wave Plate Retardation	Half-Wave Plate Retardation
Zero	0	$\frac{\pi}{2} \approx 1.57$	$\pi \approx 3.14$
1st	1	$\frac{3\pi}{2} \approx 4.71$	$3\pi \approx 9.42$
2nd	2	$\frac{5\pi}{2} \approx 7.85$	$5\pi \approx 15.71$
3rd	3	$\frac{7\pi}{2} \approx 11.00$	$7\pi \approx 21.99$
4th	4	$\frac{9\pi}{2} \approx 14.14$	$9\pi \approx 28.27$
5th	5	$\frac{11\pi}{2} \approx 17.28$	$11\pi \approx 35.56$

The retardation of each paddle should be close to any number above. The paddle rotation sensitivity should also be taken into consideration when determining the number of fiber loops. In creasing the number of loops increases the sensitivity to rotation. One loop is usually too insensitive for most applications and is rarely used.

The number of recommended loops and recommended fiber for several wavelengths is given in the following tables. These combinations come close to the desired quarter-wave retardation:

Wavelength	# of Loops for ~1/4λ Retardation			Recommended Fiber
	Ø18 mm	Ø27 mm	Ø56 mm	
480 nm	3 loops	N/A	3 loops	460HP, SM450
630 nm	3 loops	2 loops	4 loops	630HP, S630-HP
780 nm	4 loops	1 loop	2 loops	780HP, S630-HP, SM600
850 nm	4 loops	1 loop	2 loops	780HP, SM800-5.6-125
980 nm	2 loops	3 loops	2 loops	980HP, HI1060-J9, 1060XP
1060 nm	2 loops	3 loops	2 loops	980HP, HI1060-J9, 1060XP
1310 nm	1 loop	4 loops	3 loops	SMF-28-J9, CCC1310-J9
1550 nm	1 loop	2 loops	3 loops	SMF-28-J9, CCC1310-J9

These combinations come close to the desired half-wave retardation:

Wavelength	# of Loops for ~1/2λ Retardation			Recommended Fiber
	Ø18 mm	Ø27 mm	Ø56 mm	
480 nm	2 loops	3 loops	2 loops	460HP, SM450
630 nm	1 loop	4 loops	3 loops	630HP, S630-HP
780 nm	1 loop	2 loops	4 loops	780HP, S630-HP, SM600
850 nm	1 loop	2 loops	4 loops	780HP, SM800-5.6-125
980 nm	4 loops	2 loops	4 loops	980HP, HI1060-J9, 1060XP
1060 nm	4 loops	2 loops	4 loops	980HP, HI1060-J9, 1060XP
1310 nm	2 loops	3 loops	6 loops	SMF-28-J9, CCC1310-J9
1550 nm	2 loops	3 loops	6 loops	SMF-28-J9, CCC1310-J9

Chapter 3 Setup

3.1. Loading the Fiber

3.1.1. 3-Paddle Fiber Polarization Controllers

The FPC030 and FPC560 do not come with fiber. When installing fiber in these units be sure to take into account the length of the loops required to achieve the desired retardation (see tables on page 5), the overall length of the device (0.2 m), and any additional working length needed on either side of the device for external connections. We recommend at least 0.5 m length of each side for typical applications. The controller can accept bare fiber or a jacket up to Ø900 µm.

1. Loosen the spool covers on each paddle. Each end of the fiber polarization controller (FPC) also has a rectangular clamp held in place by two phillips head screws (Figure 7). Remove one screw and loosen the other. This should allow a jacketed fiber to be slipped into the clamp.
2. Position the paddles horizontally so that the groove loops are facing up. The straight parts of the grooves in the paddles should be aligned with the grooves in the top of the paddle supports of the base.
3. Lay the fiber in one end of the FPC and continue to lay the fiber along the grooved path, with the number of desired loops per paddle, until the fiber is through the other end of the FPC. The fiber should be in contact with the inside of the groove loops, but not be pulled too snug against the groove as this will cause optical losses due to induced birefringence as the paddles are rotated with respect to each other.
4. Make sure that the fiber is sitting in the groove inside each clamp, replace the second screw, and gently tighten the clamp to hold the fiber in place.

   NOTE: The ends of the FPC are designed to 'clamp' onto 900 µm diameter protective tubing. If the fiber placed into the FPC does not have a protective jacket, pieces of a soft material, such as foam, can be inserted into the end clamps to prevent the fiber from loosening in the paddles. The fiber should be held 'gently' enough so that the fiber is not drawn into the FPC, but there should be minimal force applied to the fiber such that additional birefringence is not induced.
5. Gently tighten the screws that hold the spool covers in place.

Figure 7 Top View of FPC030

3.1.2. Miniature 2-Paddle Fiber Polarization Controllers

The FPC020 does not come with fiber and we recommend using at least 2 m of fiber. The controller can accept bare fiber or a jacket up to Ø900 µm.

1. Position both paddles vertically and align the grooves (see Figure 8).
2. Loosen the 4-40 clamp screws (marked a in Figure 8) at each end. If you are having problems getting the fiber into the spool, you can loosen the 4-40 screw holding the spool cover in place (b), but this should not be necessary.
3. Lay the fiber in one end of the FPC and route the fiber along the grooved path. Lay the desired number of loops into each paddle. End by bringing the fiber out the other end of the FPC. Make sure to wind the fiber snuggly against the inner wall of each spool but do not make the fiber taught.

4. Making sure the fiber is seated in the groove, tighten the clamp screws (a) at each end. Be careful not to clamp too tightly or make the fiber too taught as this will introduce extra loss into the fiber. Tighten the paddle screws (b) if they were loosened.

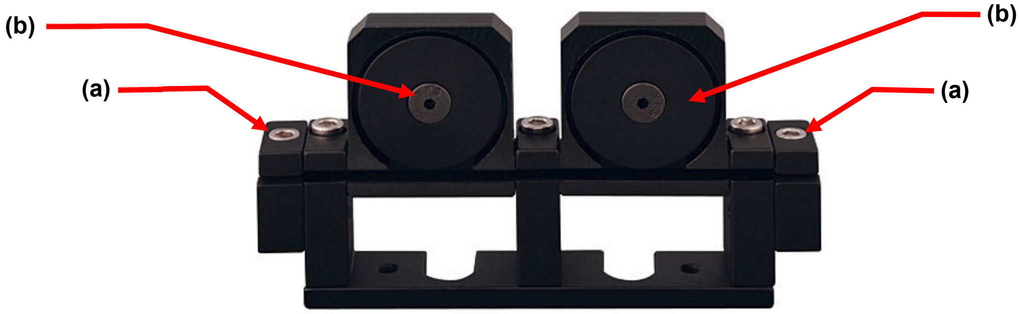


Figure 8 Front View of FPC020

3.2. Removing the Fiber (All Models)

1. Loosen the clamp screws as described in the fiber installation instructions.
2. Remove the paddle spool covers. For the 2-paddle polarization controllers, use a 4-40 hex key or ball drive to loosen the screws. On the 3-paddle controllers, knobs on the screws holding the spool covers in place allow them to be loosened by hand.
3. Remove the fiber and replace the spool covers and clamps when done.

Chapter 4 Specifications

4.1. 3-Paddle Polarization Controllers, Ø56 mm Loop

Item #	FPC560	FPC563	FPC564	FPC561	FPC562
Paddle Material	Black Delrin				
Number of Paddles	3				
Loop Diameter	2.2" (56 mm)				
Paddle Rotation	±117.5°				
Footprint (L x W)	12.50" x 1.00" (317.5 mm x 25.4 mm)				
Fiber	None	780HP	HI1060-J9	SMF-28-J9	
Operating Wavelength Range[a]	N/A	780 - 970 nm	980 - 1650 nm	1260 - 1625 nm	
Design Wavelength[b]	N/A	780 nm and 850 nm	980 nm and 1064 nm	1310 nm and 1550 nm	
Mode Field Diameter	N/A	5.0 ± 0.5 µm @ 850 nm	5.9 ± 0.3 µm @ 980 nm 6.2 ± 0.3 µm @ 1060 nm	9.2 ± 0.4 µm @ 1310 nm 10.4 ± 0.5 µm @ 1550 nm	
Cladding Diameter	N/A	125 ± 1 µm	125 ± 0.5 µm	125 ± 0.7 µm	
Coating Diameter	N/A	245 ± 15 µm	245 ±10 µm	242 ± 5 µm	
Numerical Aperture	N/A	0.13	0.14	0.14	0.14
Jacketing	N/A	Ø900 µm Hytrel Tubing	Ø900 µm Tight Buffer		
Loop Configuration[c]	N/A	2-4-2		3-6-3	
Connectors	N/A	FC/APC		FC/PC	FC/APC
Bend Loss	N/A	≤0.1 dB			

a. Retardance varies as a function of wavelength. Refer to Chapter 2 for more information.
b. Devices with preloaded fiber are optimized for this wavelength.
c. For polarization controllers with fiber preinstalled.

4.2. 3-Paddle Polarization Controllers, Ø27 mm Loop

Item #	FPC030	FPC033	FPC034	FPC031	FPC032
Paddle Material	Black Delrin				
Number of Paddles	3				
Loop Diameter	1.06" (27 mm)				
Paddle Rotation	±117.5°				
Footprint (L x W)	8.50" x 1.00" (215.9 mm x 25.4 mm)				
Fiber	None	780HP	HI1060-J9	CCC1310-J9	
Operating Wavelength Range[a]	N/A	780 - 970 nm	980 - 1650 nm	1260 - 1625 nm	
Design Wavelength[b]	N/A	780 nm and 850 nm	980 nm and 1064 nm	1310 nm and 1550 nm	
Mode Field Diameter	N/A	5.0 ± 0.5 µm @ 850 nm	5.9 ± 0.3 µm @ 980 nm 6.2 ± 0.3 µm @ 1060 nm	8.6 ± 0.4 µm @ 1310 nm 9.7 ± 0.5 µm @ 1550 nm	
Cladding Diameter	N/A	125 ± 1 µm	125 ± 0.5 µm	125 ± 0.7 µm	
Coating Diameter	N/A	245 ± 15 µm	245 ± 10 µm	242 ± 5 µm	
Numerical Aperture	N/A	0.13	0.14	0.14	0.14
Jacketing	N/A	Ø900 µm Hytrel Tubing	Ø900 µm Tight Buffer		
Loop Configuration[c]	N/A	1-2-1	3-2-3	4-3-4	
Connectors	N/A	FC/APC		FC/PC	FC/APC
Bend Loss	N/A	≤0.1 dB			

a. Retardance varies as a function of wavelength. Refer to Chapter 2 for more information.
b. Devices with preloaded fiber are optimized for this wavelength.
c. For polarization controllers with fiber preinstalled.

4.3. 2-Paddle Polarization Controllers, Ø18 mm Loop

Item #	FPC020	FPC021	FPC022
Paddle Material	Black Delrin		
Number of Paddles	2		
Loop Diameter	0.71" (18 mm)		
Paddle Rotation	±143°		
Footprint (L x W)	3.06" x 0.50" (77.6 mm x 12.7 mm)		
Fiber	None	SM450	SM600
Operating Wavelength Range[a]	N/A	488 - 633 nm	633 - 780 nm
Design Wavelength[b]	N/A	488 nm	633 nm
Mode Field Diameter	N/A	2.8 - 4.1 µm @ 488 nm	3.6 - 5.3 µm @ 633 nm
Cladding Diameter	N/A	125 ± 1.0 µm	
Coating Diameter	N/A	245 ± 15 µm	245 ± 15 µm
Numerical Aperture	N/A	0.10 - 0.14	0.10 - 0.14
Jacketing	N/A	Ø900 µm Hytrel Tubing	
Loop Configuration[c]	N/A	3-2	3-1
Connectors	N/A	FC/APC	
Bend Loss	N/A	<0.1 dB	

a. Retardance varies as a function of wavelength. Refer to Chapter 2 for more information.
b. Devices with preloaded fiber are optimized for this wavelength.
c. For polarization controllers with fiber preinstalled.

Item #	FPC023	FPC024	FPC025
Paddle Material	Black Delrin		
Number of Paddles	2		
Loop Diameter	0.71" (18 mm)		
Paddle Rotation	±143°		
Footprint (L x W)	3.06" x 0.50" (77.6 mm x 12.7 mm)		
Fiber	780HP	HI1060-J9	CCC1310-J9
Operating Wavelength Range[a]	780 - 970 nm	980 - 1650 nm	1260 - 1625 nm
Design Wavelength[b]	780 nm and 850 nm	980 nm and 1064 nm	1310 nm and 1550 nm
Mode Field Diameter	5.0 ± 0.5 µm @ 850 nm	5.9 ± 0.3 µm @ 980 nm 6.2 ± 0.3 µm @ 1060 nm	8.6 ± 0.4 µm @ 1310 nm 9.7 ± 0.5 µm @ 1550 nm
Cladding Diameter	125 ± 1.5 µm	125 ± 0.5 µm	125 ± 0.7 µm
Coating Diameter	245 ± 15 µm	245 ± 10 µm	242 ± 5 µm
Numerical Aperture	0.13	0.14	0.14
Jacketing	Ø900 µm Hytrel Tubing	Ø900 µm Tight Buffer	Tubing
Loop Configuration[c]	4-1	2-4	1-2
Connectors	FC/APC		
Bend Loss	<0.1 dB		

a. Retardance varies as a function of wavelength. Refer to Chapter 2 for more information.
b. Devices with preloaded fiber are optimized for this wavelength.
c. For polarization controllers with fiber preinstalled.

Chapter 5 Regulatory

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

This offer is valid for Thorlabs electrical and electronic equipment:

- Sold after August 13, 2005
- Marked correspondingly with the crossed out "wheelie bin" logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated

Wheelie Bin Logo

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

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

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

Waste Treatment is Your Own Responsibility

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

Ecological Background

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

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

Chapter 6 Thorlabs Worldwide Contacts

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

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