Fibers and Probes

The Most Flexible Line in the Industry

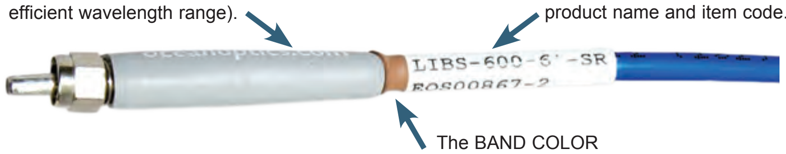
Anatomy of an Assembly

At the fiber's core is pure silica; it's the diameter of the core that you need to consider when purchasing an optical fiber assembly. (The core diameter is often in the product's item code. For example, the P600-UV-VIS has a 600 µm diameter silica core.) Surrounding the core is a doped-fluorine silica cladding. A buffer material is then applied. A buffer coats the core and cladding , strengthens the fiber and reduces stray light even further. In most assemblies polyimide is used as the buffer; other assemblies use aluminum or acrylate. Then a jacketing is applied over the core, cladding and buffer to protect the fiber and provide strain relief.

For off-the-shelf Premium-grade "Q" Optical Fiber Assemblies, the standard jacketing is stainless steel silicone monocoil. There are several other jacketing options when creating a custom assembly. Precision SMA 905 Connectors terminate the assembly and are precisely aligned to the spectrometer's slit to ensure concentricity of the fiber. Finally, captive end caps protect the fiber tips against scratches and contaminants.

Assembly Identifiers

Our optical fiber and probe assemblies are clearly and cleanly labeled in three ways so that you always know the following about your assembly: its name, its core diameter, and its most efficient wavelength region.



Band Colors

The assembly's band color lets you know the fiber type and the most efficient wavelength range in which your fiber will work.

A color band tells you the diameter fiber with which you are working.

8 µm	Purple
50 µm	Blue
100 µm	Green
200 µm	Yellow
300 µm	Gray
400 µm	Red
500 µm	Orange
600 µm	Brown
1000 µm	Clear

Boot Color	Fiber Type	Most Efficient Wavelength Range	Premium-grade Optical Fiber Assembly for each Fiber Type
Gray	UV-VIS XSR Solarization-resistant	180-800 nm	
Gray	UV/SR-VIS High OH content	200-1100 nm	
Blue	UV-VIS High OH content	300-1100 nm	
Red	VIS-NIR Low OH content	400-2100 nm	
Black	Fluoride	400-4500 nm	

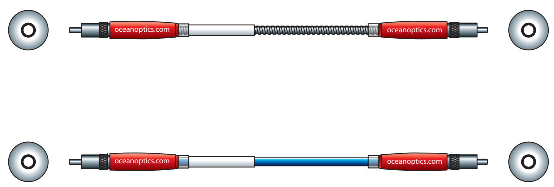
Note: An additional option for mid-IR wavelengths (2000-6000 nm) is Chalcogenide fiber. Standard assemblies are available.

Fibers and Probes: Overview

Standard Assemblies and Probes

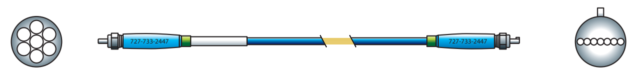
From these half-dozen standard fiber designs, you can tackle an extensive range of absorbance, emission and reflectance spectroscopy needs. All Ocean Optics fibers have SMA 905 terminations for connecting to our spectrometers and accessories. Custom configurations, multiple-fiber bundles and special ferrule designs are also available.

Patch Cord Assemblies



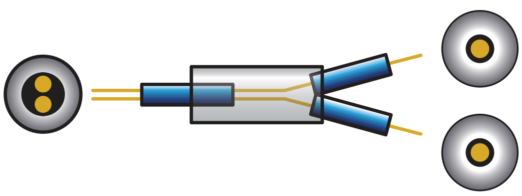
Our patch cord assemblies consist of a single fiber. Our standard, premium-grade options are available with stainless steel BX (top drawing) or silicone monocoil jacketing and PVDF.

Round to Keyed Linear Fiber



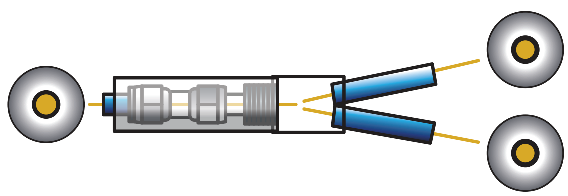
At one end of this seven-fiber assembly, the fibers are aligned linearly to more efficiently direct light into the optical bench and onto the detector. The collection end of the fiber has a six fibers-around-one design.

Bifurcated Fiber



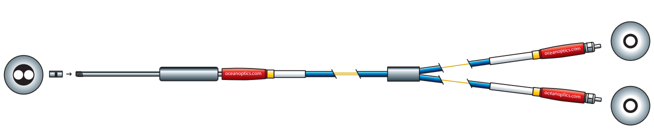
Bifurcated assemblies have two fibers side-by-side in the common end and break out into two legs at the other end. Each leg can be UV-VIS or VIS-NIR or mixed.

Splitter



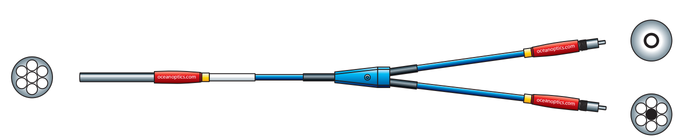
A splitter comprises three fibers – two fibers at one end that deliver light into the third fiber at the common end. All the fibers are epoxied together at the nexus of the assembly.

Transmission Dip Probe



We offer several versions of this standard two-fiber transmission probe, designed for immersion in process streams and solutions. Various pathlength tips are available.

Premium Reflection Probe



Our standard reflection probe arrangement has seven optical fibers – six illumination fibers around one read fiber – in a stainless steel ferrule. Additional configurations are available.

Fibers and Probes: Overview

Transmission Characteristics of UV-VIS Options

Ocean Optics offers fiber material types with wavelength ranges to best match your application. On these pages are the attenuation curves for each of the fiber types we offer. High OH, or high water content fiber, is optimized for transmission in the UV-VIS. For work in the UV, especially <300 nm, our XSR and UV/SR-VIS fibers are a fine choice. These silica-core fibers are doped with fluorine to mitigate the solarizing effects of UV radiation. An Applications Scientist can provide additional assistance.

Transmission Efficiency of Optical Fibers

Transmission efficiency is the ratio of light energy exiting an optical fiber to the energy that is projected onto the other end. Transmission of light by optical fibers, however, is not 100% efficient. Energy is lost by reflection when light is launched into the fiber and at the other end when it exits the fiber. This is called Fresnel reflection and occurs when light travels across an interface between materials with different refractive indices.

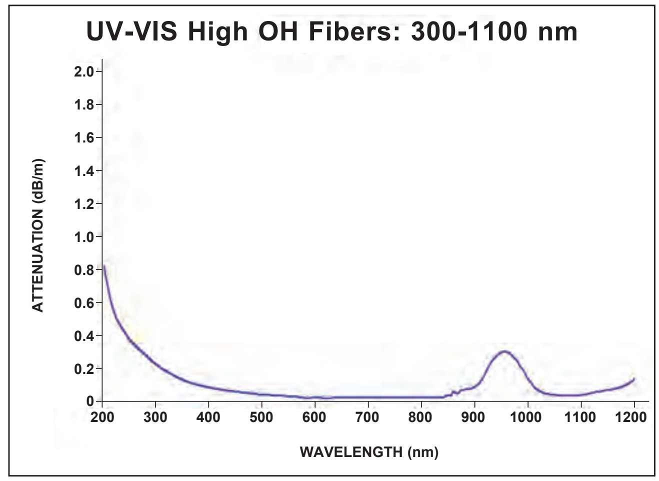
Ideally, light would travel inside the fiber by total internal reflection without any loss of energy. However, several factors can degrade the light during transmission and cause attenuation or absorption of light in the fiber.

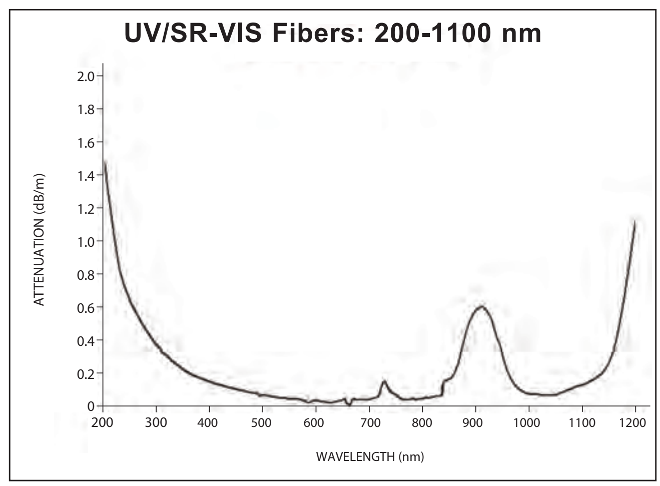
One reason for degradation of light is the presence of tiny imperfections in the fiber material, causing light at lower wavelengths to scatter. The fiber is also not completely transparent at all wavelengths. For example, high OH fiber is designed to transmit as much light as possible in the UV. However, the extra water has an absorption band that leads to dips in transmission efficiency in the NIR. To achieve good transmission in the NIR, the fiber material must be low OH.

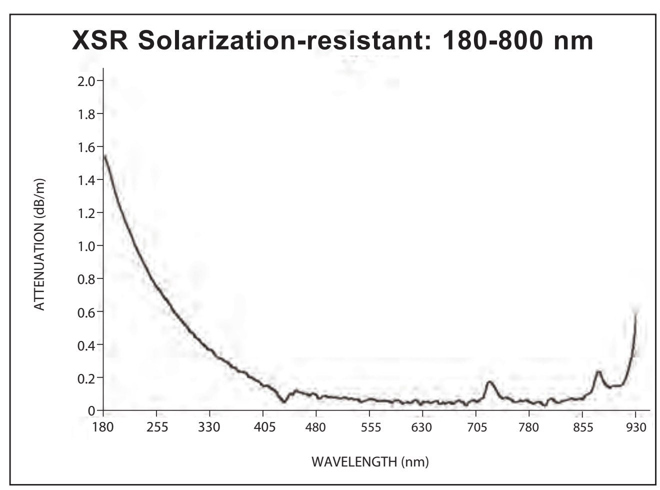
Another loss in transmission efficiency results from the evanescent field. When the light bounces off the interface between the core and cladding inside the fiber, its electric field penetrates the cladding. If the cladding material absorbs the light, the fiber will lose some of its energy.

Bending of fibers also contributes to attenuation. As the fiber is bent, it changes the angle at which light rays are striking the surface between the core and cladding. If the fiber is bent enough, light that had been below the critical angle will now exceed the critical angle and leak out of the fiber. Most of the bending occurs where a flexible fiber meets a rigid connector. To spread the bending along the length of the fiber, strain relief boots are added to the connectors.

Ocean Optics builds its fibers into assemblies that are cleaved, epoxied into precise SMA 905 or other connectors and polished with a very fine lapping film to reduce Fresnel reflection. The fiber is encased in mechanical sheathing to protect it and to provide good strain relief at the ends. As a result, the improvement in performance between Ocean Optics premium assemblies and ordinary telecom grade assemblies is quite significant.





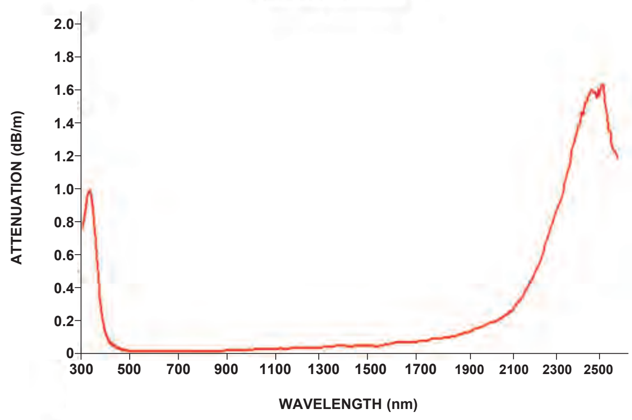


Fibers and Probes: Overview

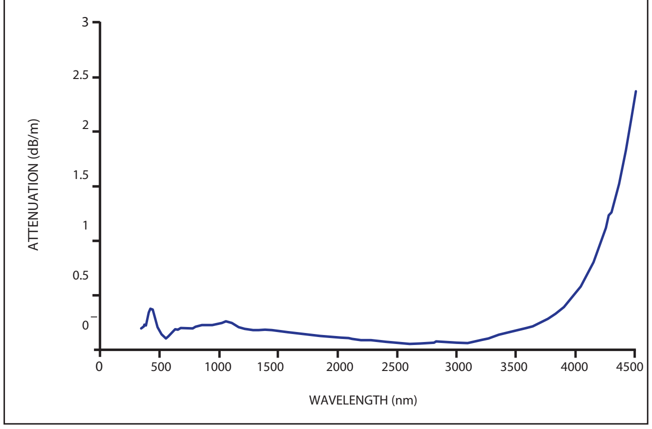
Transmission Characteristics of VIS-NIR and Mid-IR Options

Ocean Optics offers several options for applications at higher wavelengths. For most Visible and Shortwave NIR setups, our low OH VIS-NIR fibers are a convenient, affordable option. If your work takes you farther into the NIR and mid-IR, consider our fluoride and chalcogenide fiber options. ZBLAN heavy-metal fluoride fibers are responsive to 4500 nm and distinguished by excellent IR transmittance performance. Chalcogenide fibers are responsive from 2000-6000 nm and characterized by low optical loss and great flexibility.

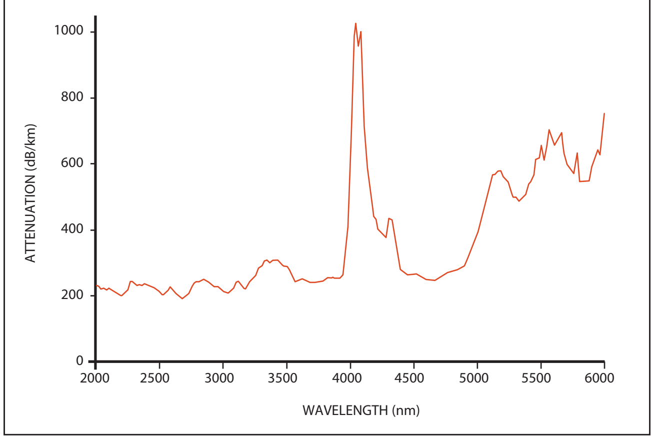
VIS-NIR Low OH Fibers: 400-2100 nm



Flouride: 300-4500 nm



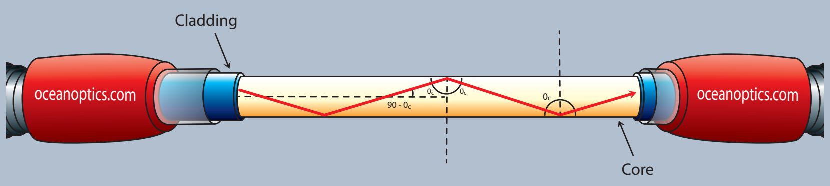
Chalcogenide: 2000-6000 nm



Numerical Aperture of Optical Fibers

Optical fibers are designed to transmit light from one end of the fiber to the other with minimal loss of energy. The principle of operation in an optical fiber is total internal reflection. When light passes from one material to another, its direction is changed. According to Snell's Law, the new angle of the light ray can be predicted from the refractive indices of the two materials. When the angle is perpendicular (90º) to the interface, transmission into the second material is maximum and reflection is minimum. Reflection increases as the angle gets closer to parallel to the interface. At the critical angle and below the critical angle, transmission is 0% and reflection is 100% (see figure below).

Light Passing Through an Optical Fiber



Snell's Law can be formulated to predict critical angle and also the launch or exit angle θ_{max} from the index of refraction of the core (n1) and cladding (n2) materials. The angle also depends on the refractive index of the media (n). Equation (1)

$$n \sin \theta_{max} = \sqrt{n_1^2 - n_2^2}$$

The left side of the equation is called the numerical aperture (NA), and determines the range of angles at which the fiber can accept or emit light.

Ocean Optics fibers have a numerical aperture of 0.22. If the fiber is in a vacuum or air, this translates into an acceptance angle θ_{max} of 12.7° (full angle is ~25°). When light is directed at the end of an optical fiber all the light rays or trajectories that are within the +/-12.7° cone are propagated down the length of the fiber by total internal reflection. All the rays that exceed that angle pass through the cladding and are lost. At the other end of the fiber, light exits in a cone that is +/- 12.7°.

There are many types of fibers available, with a variety of numerical apertures. While a fiber with a larger numerical aperture will collect more light than a fiber with a smaller numerical aperture, it is important to look at both ends of the system to ensure that light exiting at a higher angle can be used. In optical sensing, one end is gathering light from an experiment and the other is directing light to a detector. Any light that does not reach the detector will be wasted.

Premium Grade Optical Fiber Assemblies

Our premium-grade fibers are durable, high quality fibers optimized for spectroscopy and enhanced with extra strain relief for use even in demanding environments. We have a full range of standard patch cords and can customize assemblies (see pages 136-137 for options). Also available are assemblies (see table at bottom) consisting of multiple fibers stacked in a linear arrangement at one end to deliver light more efficiently into the spectrometer.

Premium-Grade Assemblies				Assembly Length					Jacketing				Bend Radius	
Wavelength Range	Item Code	Core Diameter	Buffer/ Coating	0.25 m	0.5 m	1 m	1.5 m	2 m	Silicone monocoil	Stainless-steel BX	PVDF Furcation	PEEK	LTBR	STBR
UV-VIS High OH Content 300-1100 nm	QP50-2-UV-VIS QP50-2-UV-BX	50 µm	Polyimide					X	X	 X			4 cm	2 cm
	QP100-2-UV-VIS QP100-2-UV-BX	100 µm	Polyimide					X	X	 X			4 cm	2 cm
	QP200-2-UV-VIS QP200-2-UV-BX	200 µm	Polyimide					X	X	 X			8 cm	4 cm
	QP400-1-UV-VIS QP400-1-UV-BX QP400-2-UV-VIS QP400-2-UV-BX	400 µm	Polyimide			X X		 X X	X X	 X X			16 cm	8 cm
	QP600-025-UV-VIS QP600-025-UV-BX QP600-1-UV-VIS QP600-1-UV-BX QP600-2-UV-VIS QP600-2-UV-BX	600 µm	Polyimide	X X		 X X		 X X	X X X	 X X X			24 cm	12 cm
	QP1000-2-UV-VIS QP1000-2-VIS-BX	1000 µm	Acrylate					X X	X	 X			40 cm	20 cm
VIS-NIR Low OH content 400-2100 nm	QP8-2-VIS-NIR	8 µm	Acrylate					X	X				4 cm	2 cm
	QP50-2-VIS-NIR QP50-2-VIS-BX	50 µm	Polyimide					X X	X	 X			4 cm	2 cm
	QP100-2-VIS-NIR QP100-2-VIS-BX	100 µm	Polyimide					X X	X	 X			4 cm	2 cm
	QP200-2-VIS-NIR QP200-2-VIS-BX	200 µm	Polyimide					X X	X	 X			8 cm	4 cm
	QP400-1-VIS-NIR QP400-1-VIS-BX QP400-2-VIS-NIR QP400-2-VIS-BX	400 µm	Polyimide			X X		 X X	X X	 X X			16 cm	8 cm
	QP600-025-VIS-NIR QP600-025-VIS-BX QP600-1-VIS-NIR QP600-1-VIS-BX QP600-2-VIS-NIR QP600-2-VIS-BX	600 µm	Polyimide	X X		 X X		 X X	X X X	 X X X			24 cm	12 cm
	QP1000-2-VIS-NIR QP1000-2-VIS-BX	1000 µm	Acrylate					X X	X	 X			40 cm	20 cm
Fluoride 300-4500 nm	P450-0.5-FLUORIDE P450-1.5-FLUORIDE P450-1-FLUORIDE	450 µm	Acrylate		X	 X	 X				X X X		15 cm	8 cm
Chalcogenide 2000-6000 nm	P500-0.5-CHAL P500-1-CHAL	500 µm	Fluoropolymer and PVC		X	 X						X X	7.5 cm	7.5 cm

Keyed SMA Optical Fiber Assemblies

Keyed SMA Optical Fiber Assemblies, Round to Keyed Linear				Assembly Length					Jacketing					
Wavelength Range	Item Code	Core Diameter	Buffer/ Coating	0.25 m	0.5 m	1 m	1.5 m	2 m	Silicone monocoil	Stainless-steel BX	PVDF Furcation	PEEK	LTBR	STBR
300-1100 nm	PL100-2-UV-VIS	100 µm ± 3 µm	Polyimide					X	X				4 cm	2 cm
400-2100 nm	PL100-2-VIS-NIR	100 µm ± 3 µm	Polyimide					X	X				4 cm	2 cm
300-1100 nm & 400-2100 nm	PL100-2-MIXED	100 µm ± 3 µm	Polyimide					X X	X X				4 cm	2 cm
300-1100nm & 400-2100 nm	PL200-2-MIXED	200 µm ± 4 µm	Polyimide					X	X				8 cm	4 cm

Note: Fiber bend radius is expressed as Long Term (LTBR) and Short Term (STBR).

Bifurcated Optical Fiber Assemblies

Premium-grade bifurcated assemblies have two fibers in the common end of the assembly that break out into separate legs. Splitters comprise three fibers epoxied at the nexus of a Y-shaped assembly and have lower transmission efficiency than bifurcated fibers.

Premium-grade Bifurcated Optical Fiber Assemblies				Assembly Length	Jacketing		Bend Radius	
Wavelength Range	Item Code	Core Diameter	Buffer/ Coating	2 m	Silicone monocoil	Stainless-steel BX	LTBR	STBR
VIS-NIR Low OH content 400-2100 nm	QBIF50-VIS-NIR	50 µm	Polyimide	X	X			
	QBIF200-VIS-NIR	200 µm	Polyimide	X	X		8 cm	4 cm
	QBIF200-NIR-BX			X		X		
	QBIF400-VIS-NIR	400 µm	Polyimide	X	X		16 cm	8 cm
	QBIF400-NIR-BX			X		X		
	QBIF600-VIS-NIR	600 µm	Polyimide	X	X		24 cm	12 cm
	QBIF600-NIR-BX			X		X		
UV-VIS High OH Content 300-1100 nm	QBIF50-UV-VIS	50 µm	Polyimide	X	X		4 cm	2 cm
	QBIF200-UV-VIS	200 µm	Polyimide	X	X		8 cm	4 cm
	QBIF400-UV-VIS	400 µm	Polyimide	X	X		16 cm	8 cm
	QBIF600-UV-VIS	600 µm	Polyimide	X	X		24 cm	12 cm
300-1100 nm & 400-2100 nm (Mixed)	QBIF200-MIXED	200 µm	Polyimide	X	X		8 cm	4 cm
	QBIF400-MIXED	400 µm	Polyimide	X	X		16 cm	8 cm
Splitter Optical Fiber Assemblies								
VIS-NIR Low OH content 400-2100 nm	SPLIT200-VIS-NIR	200 µm	Polyimide	X	X		8 cm	4 cm
	SPLIT400-VIS-NIR	400 µm	Polyimide	X	X		16 cm	8 cm
UV-VIS High OH Content 300-1100 nm	SPLIT200-UV-VIS	200 µm	Polyimide	X	X		8 cm	4 cm
	SPLIT400-UV-VIS	400 µm	Polyimide	X	X		16 cm	8 cm

Solarization Resistant Optical Fiber Assemblies

We offer two types of solarization-resistant fiber assemblies, which prevent transmission degradation in the UV: polyimide-buffer fibers for applications <300 nm and aluminum-buffer fibers that offer enhanced UV transmission (signal will transmit to 180 nm) and resistance to UV degradation.

Extreme Solarization-Resistant												
Wavelength Range	Item Code	Core Diameter	Buffer/ Coating	0.25 m	0.5 m	1 m	1.5 m	2 m	Silicone monocoil	Stainless-steel BX	LTBR	STBR
UV/SR-VIS High OH content 200-1100 nm	QP200-2-SR-BX	200 µm	Polyimide					X		X	8 cm	2 cm
	QP300-1-SR	300 µm	Polyimide			X			X		12 cm	6 cm
	QP300-1-SR-BX					X				X		
	QP400-025-SR	400 µm	Polyimide	X					X		16 cm	8 cm
	QP400-025-SR-BX			X						X		
	QP400-2-SR							X	X			
	QP400-2-SR-BX							X		X		
	QP600-025-SR	600 µm	Polyimide	X					X		24 cm	12 cm
	QP600-025-SR-BX			X						X		
	QP600-1-SR					X			X			
	QP600-1-SR-BX					X				X		
	QP600-2-SR							X	X			
	QP600-2-SR-BX							X		X		
UV-VIS XSR Solarization-resistant 180-900 nm	QP115-025-XSR-BX	115 µm	Aluminum (Primary)	X						X	4 cm	2 cm
	QP115-1-XSR-BX					X				X		
	QP115-2-XSR-BX							X		X		
	QP230-025-XSR-BX	230 µm	Aluminum (Primary)	X						X	4 cm	2 cm
	QP230-1-XSR-BX					X				X		
	QP230-2-XSR-BX							X		X		
	QP455-025-XSR-BX	455 µm	Aluminum (Primary)	X						X	8 cm	4 cm
	QP455-1-XSR-BX					X				X		
	QP455-2-XSR-BX							X		X		
	QP600-025-XSR-BX	600 µm	Aluminum (Primary)	X						X	24 cm	12 cm
	QP600-1-XSR-BX					X				X		
	QP600-2-XSR-BX							X		X		

Note: Fiber bend radius is expressed as Long Term (LTBR) and Short Term (STBR).