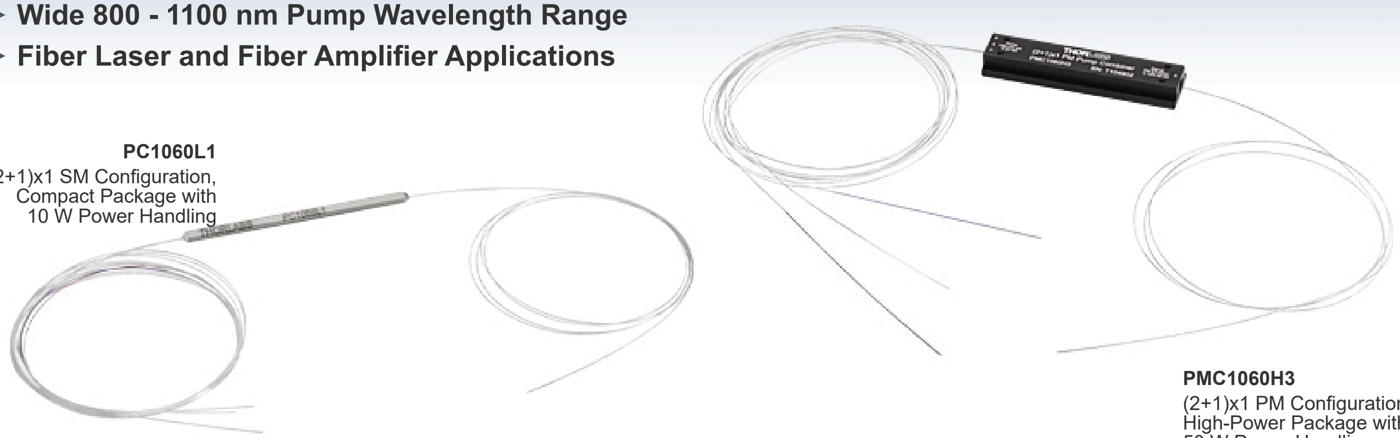
PMC1060H1 - October 17, 2024

Item # PMC1060H1 was discontinued on October 17, 2024. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

(2+1)X1 PUMP AND SIGNAL COMBINERS

- ► **Combine Two High-Power Multimode Sources with One SM or PM Signal Source**
- ► **Fused Fiber Design for Minimal Loss**
- ► **Wide 800 - 1100 nm Pump Wavelength Range**
- ► **Fiber Laser and Fiber Amplifier Applications**



OVERVIEW

Features

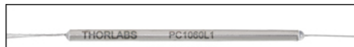
- Pump Light Couples into 1st Cladding of Double Clad Fiber
- Signal Light Propagates Through Core of Double Clad
- Fiber Single Mode (SM) or Polarization-Maintaining (PM) Signal and Output Fiber
- High Power Handling for Fiber Laser and Fiber Amplifier Applications
- Individual Test Report Available for Each Combiner; Click Here for a Sample Test Report

General Specifications	
Signal Wavelength Range[a]	1040 - 1080 nm
Pump Wavelength Range	800 - 1100 nm
Signal Insertion Loss	≤0.5 dB (Typ.)
Fiber Lead Length and Tolerance	0.8 m +0.075 m / -0.0 m
Fiber Termination	No Connectors, Scissor Cut
Pigtail Tensile Load	10 N
Operating Temperature Range	0 to 75 °C
Storage Temperature Range	-40 to 85 °C

a. Signal Optimized for Fundamental Mode Transmission

As part of Thorlabs' sustainability efforts, we are transitioning from distributing paper copies of unit-specific test reports with these products to offering them digitally. For devices supported by digital download, test results can be accessed by clicking on the red Docs icon ( ) next to the Item # and entering your device's serial number under "Download Serial Item Data." If your device was provided with a paper copy of the test results and you prefer an electronic version, please contact Tech Support.

Click to Enlarge
Light from the pump legs, which are color-coded in this simplified diagram, is coupled into the first cladding of double-clad fiber with signal light in the core.



PC1060L1
Click for Details
Each compact pump and signal combiner is engraved with the Item #, Serial Number, and fiber specifications.

PMC1060H3
Click to Enlarge
Each high-power pump and signal combiner is engraved with the Item #, Serial Number, and fiber specifications on the input and output ports.

Thorlabs' (2+1)x1 Pump and Signal Combiners couple the power from two multimode (MM) pump sources to the first cladding of a double clad fiber with a signal propagating through the core of that single mode or polarization-maintaining fiber. A schematic of this operation is shown in the diagram to the right. These devices are unidirectional, offering high power throughput for splicing into a fiber laser or fiber amplifier. For system integration, Thorlabs offers precision cleavers and fusion splicers for low-loss splicing of single mode, multimode, and specialty fiber types.

The fused fiber construction of these combiners is essential for the power handling needs of industrial, defense, medical, and telecom applications. A compact, stainless steel housing similar to Thorlabs' couplers is offered for minimal footprint and 10 W of power handling. A high-power housing is also offered to enable optimal heat transfer and up to 50 W of power in each pump port. Both housing types are engraved with the Item #, Serial Number, and fiber specifications. Five signal fiber types are offered for each form factor: Ø5 µm core, Ø130 µm cladding SM or PM fiber with 0.12/0.46 NA; Ø10 µm core, Ø125 µm cladding SM fiber with 0.08/0.46 NA; Ø7 µm core, Ø125 µm cladding PM fiber with 0.12/0.48 NA; or Ø11 µm core, Ø125 µm cladding PM fiber with 0.075/0.46 NA. Fiber leads are 0.8 m long and both ends are scissor cut with no connectors. A test report detailing the results of extensive testing is availble for each device, with the pump ports color-coded for easy association. A sample test report for the combiners can be viewed here.

DAMAGE THRESHOLD

Quick Links
Damage at the Air / Glass Interface
Intrinsic Damage Threshold
Preparation and Handling of Optical Fibers

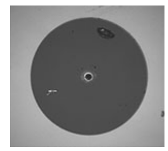
Laser-Induced Damage in Silica Optical Fibers

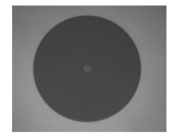
The following tutorial details damage mechanisms relevant to unterminated (bare) fiber, terminated optical fiber, and other fiber components from laser light sources. These mechanisms include damage that occurs at the air / glass interface (when free-space coupling or when using connectors) and in the optical fiber itself. A fiber component, such as a bare fiber, patch cable, or fused coupler, may have multiple potential avenues for damage (e.g., connectors, fiber end faces, and the device itself). The maximum power that a fiber can handle will always be limited by the lowest limit of any of these damage mechanisms.

While the damage threshold can be estimated using scaling relations and general rules, absolute damage thresholds in optical fibers are very application dependent and user specific. Users can use this guide to estimate a safe power level that minimizes the risk of damage. Following all appropriate preparation and handling guidelines, users should be able to operate a fiber component up to the specified maximum power level; if no maximum is specified for a component, users should abide by the "practical safe level" described below for safe operation of the component. Factors that can reduce power handling and cause damage to a fiber component include, but are not limited to, misalignment during fiber coupling, contamination of the fiber end face, or imperfections in the fiber itself. For further discussion about an optical fiber's power handling abilities for a specific application, please contact Thorlabs' Tech Support.

Damage at the Air / Glass Interface

There are several potential damage mechanisms that can occur at the air / glass interface. Light is incident on this interface when free-space coupling or when two fibers are mated using optical connectors. High-intensity light can damage the end face leading to reduced power handling and permanent damage to the fiber. For fibers terminated with optical connectors where the connectors are fixed to the fiber ends using epoxy, the heat generated by high-intensity light can burn the epoxy and leave residues on the fiber facet directly in the beam path.


Click to Enlarge
Damaged Fiber End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Undamaged Fiber End

Damage Mechanisms on the Bare Fiber End Face

Damage mechanisms on a fiber end face can be modeled similarly to bulk optics, and industry-standard damage thresholds for UV Fused Silica substrates can be applied to silica-based fiber. However, unlike bulk optics, the relevant surface areas and beam diameters involved at the air / glass interface of an optical fiber are very small, particularly for coupling into single mode (SM) fiber. therefore, for a given power density, the power incident on the fiber needs to be lower for a smaller beam diameter.

The table to the right lists two thresholds for optical power densities: a theoretical damage threshold and a "practical safe level". In general, the theoretical damage threshold represents the estimated maximum power density that can be incident on the fiber end face without risking damage with very good fiber end face and coupling conditions. The "practical safe level" power density represents minimal risk of fiber damage. Operating a fiber or component beyond the practical safe level is possible, but users must follow the appropriate handling instructions and verify performance at low powers prior to use.

Estimated Optical Power Densities on Air / Glass Interface[a]		
Type	**Theoretical Damage Threshold[b]**	**Practical Safe Level[c]**
CW (Average Power)	~1 MW/cm^2	~250 kW/cm^2
10 ns Pulsed (Peak Power)	~5 GW/cm^2	~1 GW/cm^2

a. All values are specified for unterminated (bare), undoped silica fiber and apply for free space coupling into a clean fiber end face.
b. This is an estimated maximum power density that can be incident on a fiber end face without risking damage. Verification of the performance and reliability of fiber components in the system before operating at high power must be done by the user, as it is highly system dependent.
c. This is the estimated safe optical power density that can be incident on a fiber end face without damaging the fiber under most operating conditions.

Calculating the Effective Area for Single Mode Fibers
The effective area for single mode (SM) fiber is defined by the mode field diameter (MFD), which is the cross-sectional area through which light propagates in the fiber; this area includes the fiber core and also a portion of the cladding. To achieve good efficiency when coupling into a single mode fiber, the diameter of the input beam must match the MFD of the fiber.

As an example, SM400 single mode fiber has a mode field diameter (MFD) of ~Ø3 µm operating at 400 nm, while the MFD for SMF-28 Ultra single mode fiber operating at 1550 nm is Ø10.5 µm. The effective area for these fibers can be calculated as follows:

SM400 Fiber: Area = Pi x $(\text{MFD}/2)^2$ = Pi x $(1.5\ \mu\text{m})^2$ = 7.07 µm^2 = 7.07 x 10^{-8} cm^2

SMF-28 Ultra Fiber: Area = Pi x $(\text{MFD}/2)^2$ = Pi x $(5.25\ \mu\text{m})^2$ = 86.6 µm^2 = 8.66 x 10^{-7} cm^2

To estimate the power level that a fiber facet can handle, the power density is multiplied by the effective area. Please note that this calculation assumes a uniform intensity profile, but most laser beams exhibit a Gaussian-like shape within single mode fiber, resulting in a higher power density at the center of the beam compared to the edges. Therefore, these calculations will slightly overestimate the power corresponding to the damage threshold or the practical safe level. Using the estimated power densities assuming a CW light source, we can determine the corresponding power levels as:

SM400 Fiber: 7.07×10^{-8} cm^2 x 1 MW/cm^2 = 7.1×10^{-8} MW = 71 mW (Theoretical Damage Threshold)
7.07×10^{-8} cm^2 x 250 kW/cm^2 = 1.8×10^{-5} kW = 18 mW (Practical Safe Level)

SMF-28 Ultra Fiber: 8.66×10^{-7} cm^2 x 1 MW/cm^2 = 8.7×10^{-7} MW = 870 mW (Theoretical Damage Threshold)
8.66×10^{-7} cm^2 x 250 kW/cm^2 = 2.1×10^{-4} kW = 210 mW (Practical Safe Level)

Effective Area of Multimode Fibers

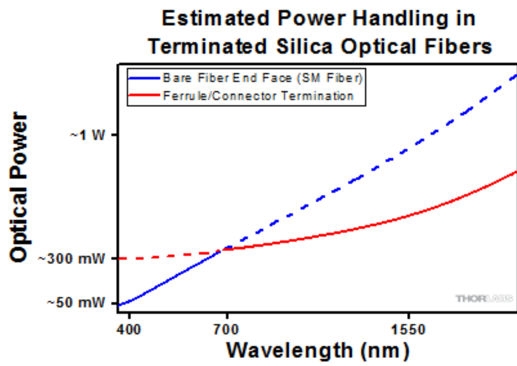
The effective area of a multimode (MM) fiber is defined by the core diameter, which is typically far larger than the MFD of an SM fiber. For optimal coupling, Thorlabs recommends focusing a beam to a spot roughly 70 - 80% of the core diameter. The larger effective area of MM fibers lowers the power density on the fiber end face, allowing higher optical powers (typically on the order of kilowatts) to be coupled into multimode fiber without damage.

Damage Mechanisms Related to Ferrule / Connector Termination

Fibers terminated with optical connectors have additional power handling considerations. Fiber is typically terminated using epoxy to bond the fiber to a ceramic or steel ferrule. When light is coupled into the fiber through a connector, light that does not enter the core and propagate down the fiber is scattered into the outer layers of the fiber, into the ferrule, and the epoxy used to hold the fiber in the ferrule. If the light is intense enough, it can burn the epoxy, causing it to vaporize and deposit a residue on the face of the connector. This results in localized absorption sites on the fiber end face that reduce coupling efficiency and increase scattering, causing further damage.

For several reasons, epoxy-related damage is dependent on the wavelength. In general, light scatters more strongly at short wavelengths than at longer wavelengths. Misalignment when coupling is also more likely due to the small MFD of short-wavelength SM fiber that also produces more scattered light.

To minimize the risk of burning the epoxy, fiber connectors can be constructed to have an epoxy-free air gap between the optical fiber and ferrule near the fiber end face. Our high-power multimode fiber patch cables use connectors with this design feature.



Click to Enlarge

Plot showing approximate input power that can be incident on a single mode silica optical fiber with a termination. Each line shows the estimated power level due to a specific damage mechanism. The maximum power handling is limited by the lowest power level from all relevant damage mechanisms (indicated by a solid line).

Determining Power Handling with Multiple Damage Mechanisms

When fiber cables or components have multiple avenues for damage (e.g., fiber patch cables), the maximum power handling is always limited by the lowest damage threshold that is relevant to the fiber component. In general, this represents the highest input power that can be incident on the patch cable end face and not the coupled output power.

As an illustrative example, the graph to the right shows an estimate of the power handling limitations of a single mode fiber patch cable due to damage to the fiber end face and damage via an optical connector. The total input power handling of a terminated fiber at a given wavelength is limited by the lower of the two limitations at any given wavelength (indicated by the solid lines). A single mode fiber operating at around 488 nm is primarily limited by damage to the fiber end face (blue solid line), but fibers operating at 1550 nm are limited by damage to the optical connector (red solid line).

In the case of a multimode fiber, the effective mode area is defined by the core diameter, which is larger than the effective mode area for SM fiber. This results in a lower power density on the fiber end face and allows higher optical powers (on the order of kilowatts) to be coupled into the fiber without damage (not shown in graph). However, the damage limit of the ferrule / connector termination remains unchanged and as a result, the maximum power handling for a multimode fiber is limited by the ferrule and connector termination.

Please note that these are rough estimates of power levels where damage is very unlikely with proper handling and alignment procedures. It is worth noting that optical fibers are frequently used at power levels above those described here. However, these applications typically require expert users and testing at lower powers first to minimize risk of damage. Even still, optical fiber components should be considered a consumable lab supply if used at high power levels.

Intrinsic Damage Threshold

In addition to damage mechanisms at the air / glass interface, optical fibers also display power handling limitations due to damage mechanisms within the optical fiber itself. These limitations will affect all fiber components as they are intrinsic to the fiber itself. Two categories of damage within the fiber are damage from bend losses and damage from photodarkening.

Bend Losses

Bend losses occur when a fiber is bent to a point where light traveling in the core is incident on the core/cladding interface at an angle higher than the critical angle, making total internal reflection impossible. Under these circumstances, light escapes the fiber, often in a localized area. The light escaping the fiber typically has a high power density, which burns the fiber coating as well as any surrounding furcation tubing.

A special category of optical fiber, called double-clad fiber, can reduce the risk of bend-loss damage by allowing the fiber's cladding (2nd layer) to also function as a waveguide in addition to the core. By making the critical angle of the cladding/coating interface higher than the critical angle of the core/clad interface, light that escapes the core is loosely confined within the cladding. It will then leak out over a distance of centimeters or meters instead of at one localized spot within the fiber, minimizing the risk of damage. Thorlabs manufactures and sells 0.22 NA double-clad multimode fiber, which boasts very high, megawatt range power handling.

Photodarkening

A second damage mechanism, called photodarkening or solarization, can occur in fibers used with ultraviolet or short-wavelength visible light, particularly those with germanium-doped cores. Fibers used at these wavelengths will experience increased attenuation over time. The mechanism that causes photodarkening is largely unknown, but several fiber designs have been developed to mitigate it. For example, fibers with a very low hydroxyl ion (OH) content have been found to resist photodarkening and using other dopants, such as fluorine, can also reduce photodarkening.

Even with the above strategies in place, all fibers eventually experience photodarkening when used with UV or short-wavelength light, and thus, fibers used at these wavelengths should be considered consumables.

Preparation and Handling of Optical Fibers

General Cleaning and Operation Guidelines

These general cleaning and operation guidelines are recommended for all fiber optic products. Users should still follow specific guidelines for an individual product as outlined in the support documentation or manual. Damage threshold calculations only apply when all appropriate cleaning and handling procedures are followed.

1. All light sources should be turned off prior to installing or integrating optical fibers (terminated or bare). This ensures that focused beams of light are not incident on fragile parts of the connector or fiber, which can possibly cause damage.

2. The power-handling capability of an optical fiber is directly linked to the quality of the fiber/connector end face. Always inspect the fiber end prior to connecting the fiber to an optical system. The fiber end face should be clean and clear of dirt and other contaminants that can cause scattering of coupled light. Bare fiber should be cleaved prior to use and users should inspect the fiber end to ensure a good quality cleave is achieved.

3. If an optical fiber is to be spliced into the optical system, users should first verify that the splice is of good quality at a low optical power prior to high-power use. Poor splice quality may increase light scattering at the splice interface, which can be a source of fiber damage.

4. Users should use low power when aligning the system and optimizing coupling; this minimizes exposure of other parts of the fiber (other than the core) to light. Damage from scattered light can occur if a high power beam is focused on the cladding, coating, or connector.

Tips for Using Fiber at Higher Optical Power

Optical fibers and fiber components should generally be operated within safe power level limits, but under ideal conditions (very good optical alignment and very clean optical end faces), the power handling of a fiber component may be increased. Users must verify the performance and stability of a fiber component within their system prior to increasing input or output power and follow all necessary safety and operation instructions. The tips below are useful suggestions when considering increasing optical power in an optical fiber or component.

1. Splicing a fiber component into a system using a fiber splicer can increase power handling as it minimizes possibility of air/fiber interface damage. Users should follow all appropriate guidelines to prepare and make a high-quality fiber splice. Poor splices can lead to scattering or regions of highly localized heat at the splice interface that can damage the fiber.

2. After connecting the fiber or component, the system should be tested and aligned using a light source at low power. The system power can be ramped up slowly to the desired output power while periodically verifying all components are properly aligned and that coupling efficiency is not changing with respect to optical launch power.

3. Bend losses that result from sharply bending a fiber can cause light to leak from the fiber in the stressed area. When operating at high power, the localized heating that can occur when a large amount of light escapes a small localized area (the stressed region) can damage the fiber. Avoid disturbing or accidently bending fibers during operation to minimize bend losses.

4. Users should always choose the appropriate optical fiber for a given application. For example, large-mode-area fibers are a good alternative to standard single mode fibers in high-power applications as they provide good beam quality with a larger MFD, decreasing the power density on the air/fiber interface.

5. Step-index silica single mode fibers are normally not used for ultraviolet light or high-peak-power pulsed applications due to the high spatial power densities associated with these applications.

(2+1)x1 Pump and SM Signal Combiners, 10 W Compact Package

Item #	Info	Max Power Level[a]	Pump Transmission Efficiency	Signal Fiber Specifications			Pump Fiber Specifications			Housing Dimensions
				Type	Core/Cladding Diameter	NA[b]	Type	Core/Cladding Diameter	NA	
PC1060L1	i	10 W per Pump Port	≥95%	SM	5/130 µm	0.12/0.46	MM	105/125 µm	0.22	Ø0.12" x 2.36"
PC1060L2	i				10/125 µm	0.08/0.46				

a. Combiner performance and reliability under high-power conditions must be determined within the user's setup.
b. NA is specified for the fiber core and, if the fiber is double-clad, for the cladding layer.

Please note: Once current inventory is depleted, newly placed orders for these pump and signal combiners will have a 6 month lead time resulting from upgrades to the fiber fusion station used in the manufacturing process.

Part Number	Description	Price	Availability
PC1060L1	**(2+1)x1 Pump and SM Signal Combiner, Ø5 µm Core Signal, Compact Package**	**$412.07**	**Today**
PC1060L2	**(2+1)x1 Pump and SM Signal Combiner, Ø10 µm Core Signal, Compact Package**	**$412.07**	**Today**

(2+1)x1 Pump and PM Signal Combiners, 10 W Compact Package

Item #	Info	Max Power Level[a]	Pump Transmission Efficiency	Signal Extinction Ratio	Signal Fiber Specifications			Pump Fiber Specifications			Housing Dimensions
					Type	Core/Cladding Diameter	NA[b]	Type	Core/Cladding Diameter	NA	
PMC1060L1	i	10 W per Pump Port	≥92%	≥20 dB	PM	5/130 µm	0.12/0.46	MM	105/125 µm	0.22	Ø0.12" x 2.36"
PMC1060L3	i					7/125 µm	0.12/0.48				
PMC1060L2	i		≥90%	≥19 dB		11/125 µm	0.075/0.46				

a. Combiner performance and reliability under high-power conditions must be determined within the user's setup.
b. NA is specified for the fiber core and, if the fiber is double-clad, for the cladding layer.

Please note: Once current inventory is depleted, newly placed orders for these pump and signal combiners will have a 6 month lead time resulting from upgrades to the fiber fusion station used in the manufacturing process.

Part Number	Description	Price	Availability
PMC1060L1	**Customer Inspired! (2+1)x1 Pump and PM Signal Combiner, Ø5 µm Core Signal, Compact Package**	**$615.83**	**Today**
PMC1060L3	**(2+1)x1 Pump and PM Signal Combiner, Ø7 µm Core Signal, Compact Package**	**$615.83**	**7-10 Days**
PMC1060L2	**Customer Inspired! (2+1)x1 Pump and PM Signal Combiner, Ø11 µm Core Signal, Compact Package**	**$641.33**	**Today**

(2+1)x1 Pump and SM Signal Combiners, 50 W High-Power Package

Item #	Info	Max Power Level[a]	Pump Transmission Efficiency	Signal Fiber Specifications			Pump Fiber Specifications			Housing Dimensions (L x W x H)
				Type	Core/Cladding Diameter	NA[b]	Type	Core/Cladding Diameter	NA	
PC1060H1		50 W per Pump Port	≥95%	SM	5/130 µm	0.12/0.46	MM	105/125 µm	0.22	2.36" x 0.59" x 0.28"
PC1060H2					10/125 µm	0.08/0.46				

a. Combiner performance and reliability under high-power conditions must be determined within the user's setup.
b. NA is specified for the fiber core and, if the fiber is double-clad, for the cladding layer.

Please note: Once current inventory is depleted, newly placed orders for these pump and signal combiners will have a 6 month lead time resulting from upgrades to the fiber fusion station used in the manufacturing process.

Part Number	Description	Price	Availability
PC1060H1	**(2+1)x1 Pump and SM Signal Combiner, Ø5 µm Core Signal, High-Power Package**	**$508.82**	**Today**
PC1060H2	**(2+1)x1 Pump and SM Signal Combiner, Ø10 µm Core Signal, High-Power Package**	**$508.82**	**Today**

(2+1)x1 Pump and PM Signal Combiners, 50 W High-Power Package

Item #	Info	Max Power Level[a]	Pump Transmission Efficiency	Signal Extinction Ratio	Signal Fiber Specifications			Pump Fiber Specifications			Housing Dimensions (L x W x H)
					Type	Core/Cladding Diameter	NA[b]	Type	Core/Cladding Diameter	NA	
PMC1060H1		50 W per Pump Port	≥92%	≥20 dB	PM	5/130 µm	0.12/0.46	MM	105/125 µm	0.22	2.36" x 0.59" x 0.28"
PMC1060H3						7/125 µm	0.12/0.48				
PMC1060H2			≥90%	≥19 dB		11/125 µm	0.075/0.46				

a. Combiner performance and reliability under high-power conditions must be determined within the user's setup.
b. NA is specified for the fiber core and, if the fiber is double-clad, for the cladding layer.

Please note: Once current inventory is depleted, newly placed orders for these pump and signal combiners will have a 6 month lead time resulting from upgrades to the fiber fusion station used in the manufacturing process.

Part Number	Description	Price	Availability
PMC1060H1	**Customer Inspired! (2+1)x1 Pump and PM Signal Combiner, Ø5 µm Core Signal, High-Power Package**	**$696.15**	**7-10 Days**
PMC1060H3	**(2+1)x1 Pump and PM Signal Combiner, Ø7 µm Core Signal, High-Power Package**	**$696.15**	**Lead Time**
PMC1060H2	**Customer Inspired! (2+1)x1 Pump and PM Signal Combiner, Ø11 µm Core Signal, High-Power Package**	**$721.65**	**Lead Time**

PMC1060H1 - (2+1)x1 Pump and PM Signal Combiner, Ø5 µm Core Signal, High-Power Package

Specifications

Combiner Specifications			
Port Configuration	(2+1)x1		
Signal Wavelength Range[a]	1040 - 1080 nm		
Pump Wavelength Range	800 - 1100 nm		
Signal Insertion Loss	≤0.5 dB (Typ.)		
Signal Extinction Ratio	≥20 dB		
Pump Transmission Efficiency	≥92%		
Pump Max Power Level per Port[b]	50 W		
Pump Optical Return Loss (ORL) per Port	≥35 dB		
Fiber Lead Length and Tolerance	0.8 m +0.075 m/-0.0 m		
Connectors	No Connectors, Scissor Cut		
Package Size (L x W x H)	2.36" x 0.59" x 0.28" (60.0 mm x 15.0 mm x 7.0 mm)		
Pigtail Tensile Load	10 N		
Operating Temperature	0 to 75 °C		
Storage Temperature	-40 to 85 °C		
Fiber Specifications[c]			
Port	**Pump**	**Signal Input**	**Output**
Fiber	FG105UCA or Equivalent	Coherent® PM-GDF-5/130	
Core Diameter	105 µm	5 µm	
Cladding Diameter	125 µm	130 µm	
Core NA	0.22	0.12	
Cladding NA	-	0.46	

a. Signal Optimized for Fundamental Mode Transmission
b. Combiner performance and reliability under high-power conditions must be determined within the user's setup. See Usage Tips on the Spec Sheet for safety and handling information.
c. Other fiber types may be available upon request. Contact techsales@thorlabs.com with inquiries.