DC1060LEB - July 18, 2024

Item # DC1060LEB was discontinued on July 18, 2024. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

2X2 DOUBLE-CLAD FIBER COUPLERS

- ▶ **Wideband Double-Clad Fiber Couplers for 530 nm, 780 nm, or 1060 nm**
- ▶ **Ideal for OCT or Confocal Microscopy Applications**
- ▶ **Single Mode Core Insertion Loss: ≤0.5 dB**
- ▶ **At Least 60% Multimode Inner Cladding Transfer**

DC780SEB
780 nm Double-Clad Fiber Coupler, No Connectors

DC530SEFA
530 nm Double-Clad Fiber Coupler with Connectors

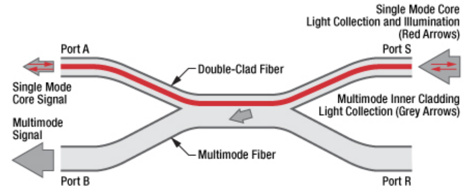
OVERVIEW

Features

- Four Wavelength Ranges
  - 430 - 680 nm
  - 680 - 980 nm
  - 960 - 1260 nm
- ≤0.5 dB Single Mode Core Insertion Loss
- At Least 60% Multimode Inner Cladding Transfer
- All Models Available With Connectors (780 nm and 1060 nm Available Without Connectors)
- 0.5 m or 0.8 m +0.075 / -0.0 m Long Fiber Leads
- Individualized Data Sheet Included with Each Coupler (See the *Verification* Tab; Sample Data Sheets Available for 530 nm, 780 nm, or 1060 nm)

Applications

- Optical Coherence Tomography (OCT)
- Fluorescence Imaging
- Confocal Microscopy
- Spectroscopy
- Surface Plasmon Resonance (SPR) Sensing
- Speckle-Free Single-Fiber Endoscopy
- LIDAR



Click to Enlarge
The schematic above shows the internal structure of a double-clad fiber coupler. Single mode light input at Port A is used to illuminate a sample at Port S. Single mode and multimode light from the sample enters the single mode core (shown in red) and multimode inner cladding (shown in grey) of the DCF at Port S. The single mode signal travels through the core of the DCF and is output at port A; the multimode signal is transferred from the DCF to the multimode fiber and is output at Port B.

Fiber leads containing double-clad fiber are color-coded white (Ports A and S) and fiber leads containing multimode fiber are color-coded orange (Ports B and R).

Thorlabs is collaborating with strategic partner Castor Optics to design and manufacture a family of Double-Clad Fiber Couplers. These 2x2 Double-Clad Fiber Couplers combine a double-clad fiber (single mode core surrounded by a multimode inner cladding) with a standard step-index multimode fiber, as shown in the illustration to the right. Light in the single mode core transmits with virtually no loss over the 430 - 680 nm, 680 - 980 nm, or 960 - 1260 nm wavelength range, depending upon the coupler. The multimode transfer, defined as the ratio of the output signal at Port B to the input signal at Port S, is ≥60% over a wider wavelength range of 400 - 1750 nm, excluding the water absorption region around 1383 nm. The diagram to the right depicts both single mode and multimode signals through a DCF coupler. Double-clad fiber couplers are well suited for applications at 530 nm, 780 nm, or 1060 nm.

These optical properties allow double-clad fiber couplers to function as an alternative to free-space assemblies in many applications, including imaging and sensing. Our 1060 nm couplers are useful for applications such as spectrally encoded scanning laser ophthalmoscope (SESLO) OCT, which enable applications such as non-invasive imaging of the human retina. Our 530 nm and 780 nm couplers feature a small inner cladding (Ø15 µm and Ø26 µm, respectively) that make them ideal for applications in confocal microscopy. Please see the *Applications* tab for more information.

The fiber in each leg is jacketed in a Ø900 µm Hytrel®* tube, color-coded white for the DCF legs (Port A and Port S) and orange for the MM fiber legs (Port B and Port R), as shown in the schematic to the right.

These couplers are housed inside of a protective tube and are available with either all four legs unterminated (780 nm and 1060 nm only) or with a mix of 2.0 mm narrow key FC/PC and FC/APC connectors. In general, FC/APC connectors reduce back reflections from the single mode core of the double-clad fiber leg of the coupler; reflection is not an issue for the multimode output port, so an FC/PC connector is used for easier integration with other fiber components. The DC530SEFA, DC780SEFA, and DC1060LEFA include an FC/PC connector on port R to allow for connection to a beam trap when used with a mating sleeve. Please refer to the diagrams in the tables below for specific connector configurations.

Custom connector configurations and different performance characteristics may be available; please contact info@castoroptics.com with all custom inquiries.

*Hytrel® is a registered trademark of DuPont Polymers, Inc.

Webpage Features	
(i)	Clicking this icon below will open a window that contains specifications and drawings.

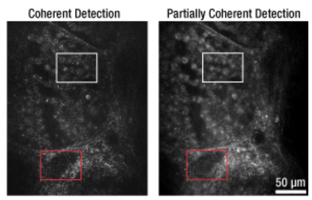
APPLICATIONS

Double-Clad Fiber Coupler (DCFC) Applications

Double-Clad Fiber Couplers can be implemented in many imaging, photonics, and LIDAR applications. The examples below specifically illustrate how DCFCs can be used in confocal microscopy, OCT, and endoscopy applications.

Confocal Microscopy and Partially Coherent Detection[a]

In a free-space confocal microscope, pinhole apertures only allow coherent light at the focal plane to reach the detector, which enables optical sectioning and high-resolution images over a narrow focal plane. Widening the detection aperture allows a small amount of partially coherent light to reach the detector, creating images with reduced speckle noise and increased contrast, but slightly reduced resolution.



Click to Enlarge
Figure 1. Comparison of confocal images taken using a single mode fiber coupler (left) and DC780SEFA DCFC (right).

Figure 2. Sequence of confocal images of swine muscle tissue using single mode fiber coupler (left) and DC780SEB DCFC(right).

This same effect can be achieved using a small-diameter DCFC, such as the DC780SEFA or DC780SEB. In this scenario, the single mode core acts as an illumination pinhole while the small inner cladding (Ø26 µm) serves the purpose of the detection pinhole. Together, the core and inner cladding enable optical sectioning of the image just as in free space confocal microscopy. Using a DCFC in this manner ensures that the pinholes are always conjugate, because the detection pinhole surrounds the illumination pinhole. Finally, because the inner cladding diameter is just slightly larger than the core diameter, a small amount of partially coherent light is accepted, which reduces speckle noise and increases contrast.

Figure 1 compares images taken of a swine thyroid tissue section using a 50:50 single mode fiber coupler and a DC780SEFA DCFC, respectively. As seen in comparing the white and red boxed sections in the left and right images, using a DCFC reduces speckle artifacts in the image while increasing contrast of cellular features within the tissue sample. Figure 2 shows a series of confocal images taken of swine muscle tissue at depths from 15 µm to 105 µm using a single mode fiber coupler and a DC780SEB double-clad fiber coupler.

Optical Coherence Tomography and Fluorescence Imaging[b]

DCFCs can also be used instead of traditional dichroic beamsplitters to allow both OCT and fluorescence imaging of a sample using the same objective and scanning optics. The OCT signal (Figure 3) is collected in the single mode core of the double-clad fiber (DCF), while the fluorescence signal (Figure 4) is collected in the cladding. The core and cladding signals can be combined to produce a detailed image that distinguishes between bronchioles and blood vessels, as shown in Figure 5.

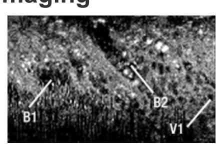


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Figure 3. OCT Image

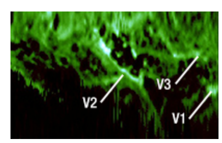

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Figure 4. Fluorescence Image

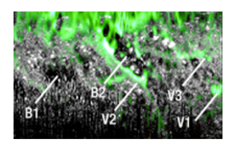

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Figure 5. Combined OCT and Fluorescence Image

Speckle-Free Endoscopy[c]

DCFCs can be used instead of traditional single mode 2x2 couplers in single-fiber endoscopy systems. When imaging a sample (Figure 6) with single mode fiber, laser speckle is present (Figure 7). Using both the single mode core and multimode cladding of the DCF for signal collection generates a higher quality image (Figure 8). Data from the core and inner cladding can also be used to create a three dimensional rendering of the subject as shown in Figure 9.

Figure 10 shows a sequence of 99 images of a wasp head obtained using a DCFC. Speckle-free reflectance maps are acquired using light collected from the multimode cladding of the DCF (left panel of the video). The right panel of the video shows an overlay of the interferometric height profiles collected using the DCF single mode core on top of the reflectance maps. This technique enables the construction of a 3-D profile of the specimen and requires no special sample preparation.

Figure 6. Photo of Sample

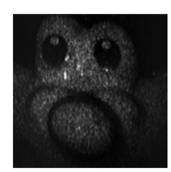

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Figure 7. Endoscopy Image Obtained Using an SM Fiber Coupler

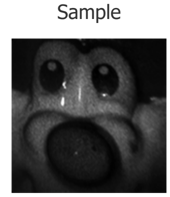

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Figure 8. Speckle-Free Endoscopy Image Obtained Using a Double-Clad Fiber Coupler

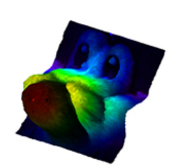

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Figure 9. 3D Image Generated from Speckle-Free Endoscopy Using a Double-Clad Fiber Coupler

Figure 10. Speckle-free reflectance map using the multimode output of a DCFC (left) and an overlay of the interferometric height profile from the single mode output (right).

References

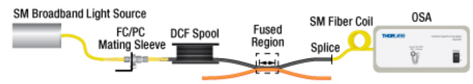
a. De Montigny et al., "Double-clad fiber for partially coherent detection." Opt. Express, 23, 9040-9051 (2015). Images used with permission.
b. Lorenser *et al.*, "Dual-modality needle probe for combined fluorescence imaging and three-dimensional optical coherence tomography." *Opt. Lett.*, **38**, 266-268 (2013). Images used with permission.
c. Lemire-Renaud *et al.*, "Double clad fiber coupler for endoscopy." *Opt. Express*, **18**, 9755-9764 (2010). Images used with permission. Video adapted with permission.

VERIFICATION

Double-Clad Fiber Coupler Verification

Our double-clad fiber couplers undergo stringent verification testing during production. The setups shown below are used to obtain a single mode transmission spectrum, insertion loss, and the multimode inner cladding transfer specification. Each coupler is shipped with an individualized data sheet providing a summary of the results of these tests. Click for a sample data sheet for 530 nm, 780 nm, or 1060 nm.

Step 1: Single Mode Insertion Loss/Transmission Measurement



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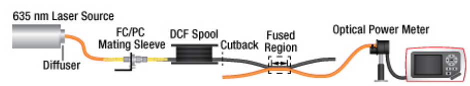
Single Mode Insertion Loss and Transmission Measurement

The single mode input of the coupler is connected to a Broadband Light Source (BBS) through a single mode fiber and a spool of double-clad fiber (DCF). The SM coupler output is spliced to a coiled SM patch cable (to ensure cladding modes are stripped) that is connected to an Optical Spectrum Analyzer (OSA). A spectrum is recorded before and after the fibers are fused to create the coupler. The difference between the two spectra can be defined as either Insertion Loss (dB) or Transmission (%).

Step 2: Multimode Transfer Measurement



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Multimode Transfer Measurement

The multimode input of the coupler is connected to a diffused 635 nm laser source through a Ø105 µm core / Ø125 µm cladding multimode fiber and a spool of DCF. Doing so ensures that the inner cladding modes are filled. The Ø200 µm core / Ø220 µm cladding multimode fiber output of the coupler is connected to a silicon photodiode optical power meter. A first optical power is recorded. The coupler is then removed from the measurement setup and the DCF spool is connected directly to the same power meter. A second optical power is recorded. The Multimode Inner Cladding Transfer is defined as the ratio of the first to second power measurements (%).

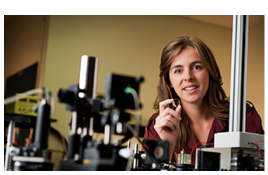
RESEARCH TEAM

castor

Castor Optics, a Montreal-based leading manufacturer of double-clad fiber couplers, has been a key strategic partner of Thorlabs since 2013. Castor was founded by Caroline Boudoux, Nicolas Godbout, Normand Brais, and Alex Cable to commercialize the innovative fiber coupler technology developed in the laboratory by Caroline Boudoux and Nicolas Godbout. The team at Castor works closely with Thorlabs' Montreal office to bring to market a broad range of fiber-based optical components for next-generation medical imaging devices and advanced instrumentation for use in the physical sciences.

About Caroline Boudoux
Caroline Boudoux earned her PhD from the Harvard-MIT Division of Health Sciences and Technology in 2007. She is an associate professor of engineering physics and principal investigator for the Laboratory for Optical Diagnoses and Imaging at École Polytechnique Montréal, a researcher at Sainte-Justine Hospital Research Center, and a visiting professor in the Department of Otology and Laryngology at Harvard Medical School. Her areas of research include biomedical imaging, optical coherence tomography, confocal and nonlinear microscopy, and endoscopic imaging.

About Nicolas Godbout
Nicolas Godbout earned his PhD in Engineering Physics from École Polytechnique de Montréal in 2000. Follwing this, he led the optical design team at ITF Optical Technologies. He is currently a professor and principal investigator for the Optical Fibers Laboratory at École Polytechnique Montréal. His research interests include nonlinear and quantum optics, fiber lasers, fiber-optic design and fabrication, characterization techniques, and biophotonics.



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Professor Boudoux in the Laboratory
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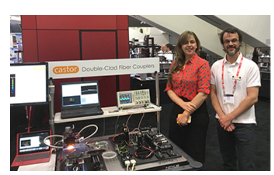

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Castor Optics at Photonics West 2016 Tradeshow

PUBLICATIONS

2015 Conference Presentations

L. Hariri, L. Bernstein, D. C. Adams, W.-J. Madore, A. J. Miller, M. Strupler, E. De Montigny, K. Beaudette, N. Godbout, C. Boudoux, and M. J. Suter. "Multimodal optical coherence tomography and fluorescence spectroscopy MEMS probe to assess inflammation in acute lung injury," in SPIE Photonics West, San Francisco, CA, 2015.

L. Bernstein, L. Hariri, W.-J. Madore, D. C. Adams, M. Strupler, E. De Montigny, K. Beaudette, Y. Wang, N. Godbout, M. J. Suter, and C. Boudoux. "Multimodal dual-clad fiber MEMS probe for simultaneous OCT and fluorescence imaging of inflammation in the lung," in SPIE Photonics West, San Francisco, CA, 2015.

K. Beaudette, M. L. Villiger, M. Strupler, M. Shishkov, J. Ren,W.-J. Madore, N. Godbout, B. E. Bouma, and C. Boudoux. "Double clad fiber devices for combined optical coherence tomography and laser tissue coagulation," in SPIE Photonics West, San Francisco, CA, 2015.

Combined OCT and Fluorescence Imaging

D. Lorenser, B. C. Quirk, M. Auger,W.-J. Madore, R.W. Kirk, N. Godbout, D. D. Sampson, C. Boudoux, and R. A. McLaughlin. "Dual-modality needle probe for combined fluorescence imaging and three-dimensional
optical coherence tomography," *Optics Letters*, **38**, 266 - 268 (2013).

L. Scolaro, L. Dirk, W.-J. Madore, A. Kramer, G. C. Yeoh, N. Godbout, D. D. Sampson, C. Boudoux, and R. A. McLaughlin, "Dual-modality Imaging Needle for Combined Optical Coherence Tomography and Fluorescence Imaging of Fluorescently Labelled Tissue," in Biomedical Optics 2014, OSA Technical Digest (online) (Optical Society of America, 2014), paper BS2B.7.

Surface Plasmon Resonance (SPR) Sensing

M. D. Baiad, M. Gagné, S. Lemire-Renaud, E. De Montigny, W.-J. Madore, N. Godbout, C. Boudoux, and R. Kashyap. "Capturing reflected cladding modes from a fiber Bragg grating with a double-clad fiber coupler," *Optics Express*, **21**, 6873 - 6879 (2013).

M. D. Baiad, M. Gagné, W.-J. Madore, E. De Montigny, N. Godbout, C. Boudoux, and R. Kashyap. "Surface plasmon resonance sensor interrogation with a double-clad fiber coupler and cladding modes excited by a tilted fiber Bragg grating," *Optics Letters*, **38**, 4911 - 4914 (2013).

Speckle-Free Imaging

W.-J. Madore, E. De Montigny, O. Ouellette, S. Lemire-Renaud, M. Leduc, X. Daxhelet, N. Godbout, and C. Boudoux. "Asymmetric double-clad fiber couplers for endoscopy," *Optics Letters*, **38**, 4514 - 4517 (2013).

S. Lemire-Renaud, M. Rivard, M. Strupler, D. Morneau, F. Verpillat, X. Daxhelet, N. Godbout, and C. Boudoux. "Double-clad fiber coupler for endoscopy," *Optics Express*, **18**, 9755 - 9764 (2010).

Confocal Microscopy

E. De Montigny, W.-J. Madore, O. Ouellette, G. Bernard, M. Leduc, M. Strupler, C. Boudoux, N. Godbout, "Double-clad fiber for partially coherent detection," *Optics Express*, **23**, 9040 - 9051 (2015).

2x2 Double-Clad Fiber Couplers, 530 nm

Item #	Info	Wavelength Range	Core Insertion Loss[a] (Click for Plot)	Multimode Inner Cladding Transfer[b]	DCF Core NA	DCF Inner Cladding Diameter	DCF Inner Cladding NA	MM Fiber Core NA	Termination[c] (Click for Diagram)
DC530SEFA		430 - 680 nm	≤0.5 dB	≥70%	0.11	15 µm	0.19	0.22	Ports A and S: FC/APC Ports B and R: FC/PC

a. Measured over the wavelength range from Port A to the core of Port S, as defined in the illustration on the *Overview* tab above. Performance from Port S to Port A will be similar.
b. Specified for light transfer from the inner cladding of Port S to Port B from 400 nm to 1750 nm, as described in the *Overview* tab. This specification excludes the water absorption region around 1383 nm.
c. All connectors are 2.0 mm narrow key. Additional lead lengths and connector options available upon request. Please contact Tech Support with inquiries.

Part Number	Description	Price	Availability
DC530SEFA	**2x2 Double-Clad Fiber Coupler, 530 nm, Connectors**	**$1,240.34**	**Today**

2x2 Double-Clad Fiber Couplers, 780 nm

Item #	Info	Wavelength Range	Core Insertion Loss[a] (Click for Plot)	Multimode Inner Cladding Transfer[b]	DCF Core NA	DCF Inner Cladding Diameter	DCF Inner Cladding NA	MM Fiber Core NA	Termination[c] (Click for Diagram)
DC780SEB		680 - 980 nm	≤0.5 dB	≥70%	0.12	26 µm	0.19	0.22	Unterminated, Scissor Cut
DC780SEFA									Ports A and S: FC/APC Ports B and R: FC/PC

a. Measured over the wavelength range from Port A to the core of Port S, as defined in the illustration on the *Overview* tab above. Performance from Port S to Port A will be similar.
b. Specified for light transfer from the inner cladding of Port S to Port B from 400 nm to 1750 nm, as described in the *Overview* tab. This specification excludes the water absorption region around 1383 nm.
c. All connectors are 2.0 mm narrow key. All unterminated fiber ends are scissor cut.

Part Number	Description	Price	Availability
DC780SEB	**2x2 Double-Clad Fiber Coupler, 780 nm, No Connectors**	**$1,192.58**	**Today**
DC780SEFA	**2x2 Double-Clad Fiber Coupler, 780 nm, Connectors**	**$1,240.34**	**Today**

2x2 Double-Clad Fiber Couplers, 1060 nm

Item #	Info	Wavelength Range	Core Insertion Loss[a] (Click for Plot)	Multimode Inner Cladding Transfer[b]	DCF Core NA	DCF Inner Cladding Diameter	DCF Inner Cladding NA	MM Fiber Core NA	Termination[c] (Click for Diagram)
DC1060LEB		960 - 1260 nm	≤0.5 dB	≥60%	0.19	102 µm	0.24	0.26	Unterminated, Scissor Cut
DC1060LEFA									Ports A and S: FC/APC Ports B and R: FC/PC

a. Measured over the wavelength range from Port A to the core of Port S, as defined in the illustration on the *Overview* tab above. Performance from Port S to Port A will be similar.
b. Specified for light transfer from the inner cladding of Port S to Port B from 400 nm to 1750 nm, as described in the *Overview* tab. This specification excludes the water absorption region around 1383 nm.
c. All connectors are 2.0 mm narrow key. All unterminated fiber ends are scissor cut.

Part Number	Description	Price	Availability
DC1060LEB	**2x2 Double-Clad Fiber Coupler, 1060 nm, No Connectors**	**$1,182.10**	**Lead Time**
DC1060LEFA	**2x2 Double-Clad Fiber Coupler, 1060 nm, Connectors**	**$1,233.34**	**Today**

DC1060LEB - 2x2 Double-Clad Fiber Coupler, 1060 nm, No Connectors

Specs | Schematics | Transmission

Coupler Specifications	
Wavelength Range	960 - 1260 nm
Single Mode Core Insertion Loss[a]	≤0.5 dB
Multimode Inner Cladding Transfer[b]	≥60%
Max Power Level	100 mW
Port Configuration	2x2
Fiber Lead Length and Tolerance[c]	0.8 m +0.075 m / -0.0 m
Connectors[c]	Unterminated, Scissor Cut
Package Size	Ø0.12" x 3.15" (Ø3.2 mm x 80.0 mm)
Jacket	Ø900 µm Hytrel® Loose Tube
Pigtail Tensile Load	10 N
Operating Temperature Range	-40 to 85 °C
Storage Temperature Range	-40 to 85 °C

a. Measured over the wavelength range from Port A to the core of Port S. See the *Schematics* tab for an illustration with labeled coupler ports.
b. Specified for light transfer from the inner cladding of Port S to Port B from 400 nm to 1750 nm. This specification excludes the water absorption region around 1383 nm.
c. Additional lead lengths and connector options available upon request. Please contact techsupport@thorlabs.com with inquiries.

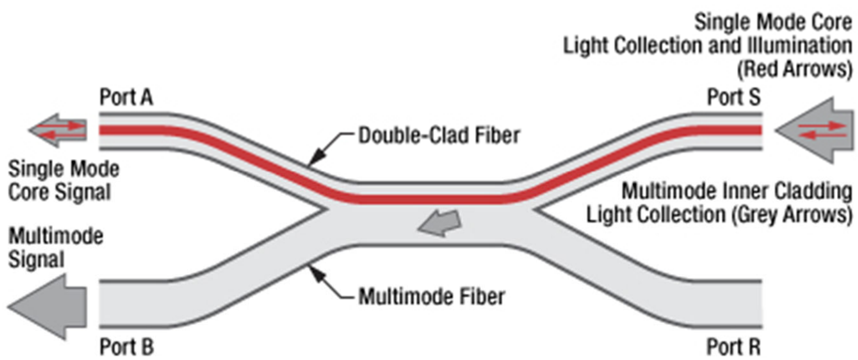
Fiber Specifications		
Fiber Type	Double-Clad Fiber	Multimode Fiber
Jacket Color	White	Orange
Core Diameter	4 µm (Typical)	200 µm
Core NA	0.19	0.26
Cut-Off Wavelength[a]	≤960 nm	-
Inner Cladding Diameter	102 µm	-
Inner Cladding NA	0.24	-
Outer Cladding Diameter	125 µm	220 µm

a. Single mode operation of the coupler is not guaranteed below the fiber cut-off wavelength. See the *Transmission* tab for details.

DC1060LEB - 2x2 Double-Clad Fiber Coupler, 1060 nm, No Connectors

Specs | **Schematics** | Transmission

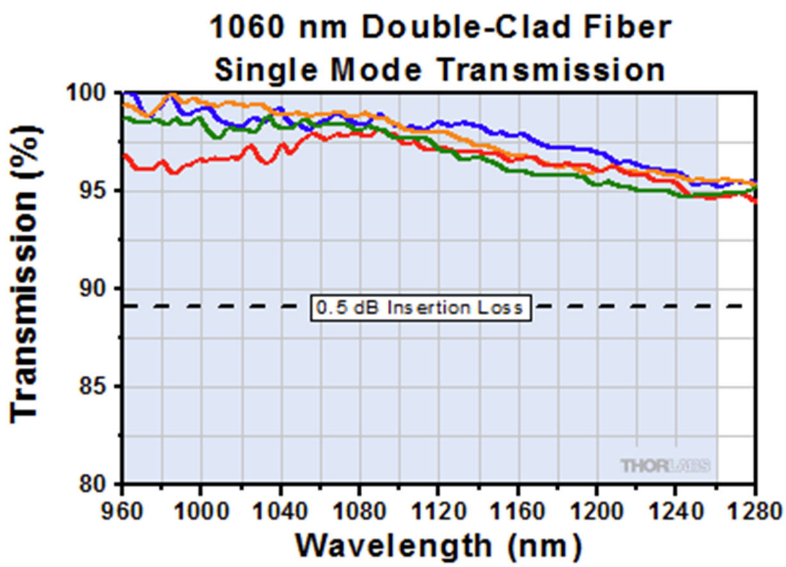
All Ports are Unterminated (Scissor Cut).



An Illustration of the Internal Structure of a Double-Clad Fiber Coupler

DC1060LEB - 2x2 Double-Clad Fiber Coupler, 1060 nm, No Connectors

Specs | Schematics | Transmission



This persistence plot shows the single mode transmission of four 1060 nm double-clad fiber couplers as an example of the typical variation in performance from coupler to coupler that can be expected. The blue-shaded region denotes the coupler's full operating wavelength range; performance outside of this region is not guaranteed. Multimode transfer from port B to port S (not shown) is flat and ≥60% from 400 nm to 1750 nm, except in the water absorption region at 1383 nm. An illustration showing the port configuration of the coupler is provided on the *Schematics* tab.