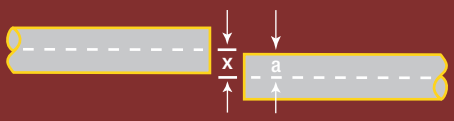
LOSSES DUE TO LATERAL MISALIGNMENT



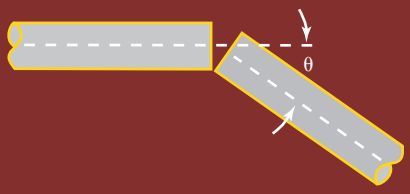
Multimode (Uniform MPD, Graded Index):

$$L_{lat} = -10 \log \left[1 - \frac{8x}{3\pi a}\right]$$

Single-Mode:

$$L_{lat} = -10 \log \left[e^{-u^2}\right], \text{ where } u = \frac{x}{w_0}$$

LOSSES DUE TO ANGULAR MISALIGNMENT



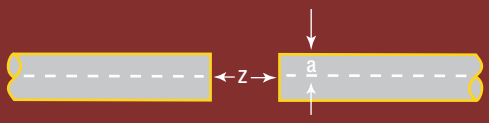
Multimode (Uniform MPD, Graded Index):

$$L_{ang} = -10 \log \left[1 - \frac{8\, n_0 \sin\theta}{3\pi\ NA}\right]$$

Single-Mode:

$$L_{ang} = -10 \log \left[e^{-T^2}\right], \text{ where } T = \frac{n_0 \pi w_0 \sin\theta}{\lambda}$$

LOSSES DUE TO LONGITUDINAL MISALIGNMENT



Multimode (Uniform MPD, Graded Index):

$$L_{long} = -10 \log \left[1 - \frac{zNA}{2a\, n_0}\right]$$

Single-Mode:

$$L_{long} = -10 \log \left[\frac{1}{Z^2 + 1}\right], \text{ where } Z = \frac{z\lambda}{2\pi n_0 w_0^2}$$

ACCEPTANCE ANGLE

where $n_0 = n_{air}$
$n_1 = n_{core}$
$n_2 = n_{cladding}$

Numerical Aperture $= n_0 \sin\theta_{max}$

$$= n_1 \sqrt{2\Delta}$$

where $\Delta = \dfrac{n_1^2 - n_2^2}{2n_1^2}$

therefore, $NA = \sqrt{n_1^2 - n_2^2}$

Single-Mode Cutoff Wavelength

$$\lambda_c = \left(\frac{2\pi a}{2.405}\right) \sqrt{n_1^2 - n_2^2}$$

F-Number $\quad F/\# = \dfrac{1}{2NA}$

CRITICAL ANGLE $\quad \sin\theta_{crit} = \dfrac{n_{clad}}{n_{core}}$

OPTICS FOR RESEARCH

OFR

FIBER-OPTIC PRODUCTS

DETERMINING THE NUMBER OF MODES

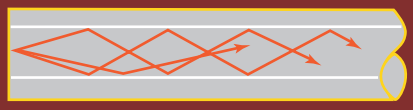
Normalized Frequency (V-number)

$$V = \frac{2\pi a}{\lambda} NA$$

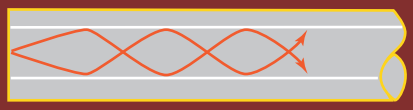
For each type of fiber, the approximate number of modes (N) in a multimode fiber is:

STEP INDEX: $N = V^2/2$

GRADED INDEX: $N = V^4/2$

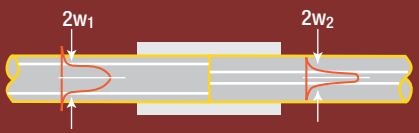


Step Index



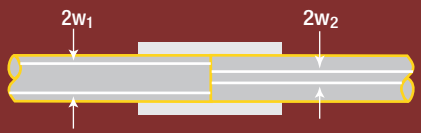
Graded Index

LOSSES DUE TO MODE FIELD RADIUS MISMATCH: SINGLE MODE FIBERS



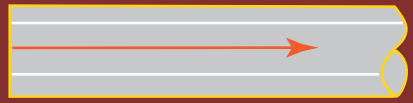
$$L_{mode} = -10 \log \left[\frac{4}{\left[\left(\frac{w_2}{w_1}\right) + \left(\frac{w_1}{w_2}\right)\right]^2}\right]$$

LOSSES DUE TO CORE RADIUS MISMATCH: MULTIMODE FIBERS (UNIFORMS MPD, GRADED INDEX)



$$L_{core} = -10 \log \left[\left(\frac{w_2}{w_1}\right)^2\right] \text{ where } a_1 \geq a_2$$

FUNDAMENTAL MODE RADIUS FOR STEP-INDEX SINGLE MODE FIBER



Single-Mode

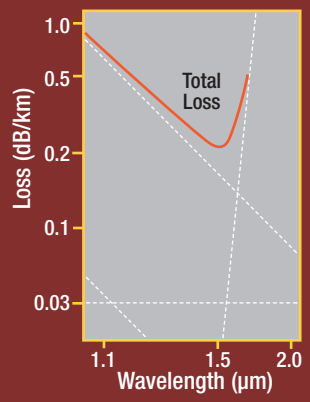
$$w_0 = a\left(0.65 + \frac{1.619}{V^{1.5}} + \frac{2.879}{V^6}\right)$$

where w_0 = beam radius at $1/e^2$ power density
a = core radius of single mode fiber

APPROXIMATE MODE FIELD DIAMETERS vs WAVELENGTH FOR SINGLE-MODE FIBERS

Wavelength (nm)	Mode field Diameter (μm)
1550	10.5
1300	9.3
1060	6.2
850	5.0
630	3.7

FIBER ATTENUATION NEAR 1.5 μm



FOCUS A LASER BEAM TO A MINUMUM SPOT

ASSUMPTIONS

a. light is collimated

b. single lens: OFR BestForm type

Minimum spot is the LARGER of the following:

$$\frac{Kd^3}{f^2} \quad \text{or} \quad \frac{2.85\lambda f}{d}$$

where K = 0.067 for n = 1.5

EFFECTS OF BENDING ON SINGLE MODE FIBERS

BIREFRINGENCE

$$\Delta n = k\,(r/R)^2$$

where k = 0.133 (constant)

R = radius of curvature of fiber

2r = cladding diameter

LINEAR RETARDATION PER UNIT LENGTH

$$\Delta\beta = \frac{2\pi\Delta n}{\lambda}$$

FARADAY ROTATOR

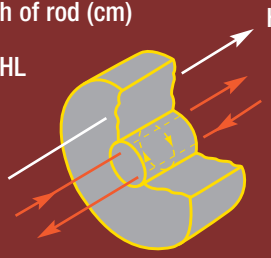
θ = Rotation (minutes of arc)

V = Verdet constant (min/Oersted-cm)

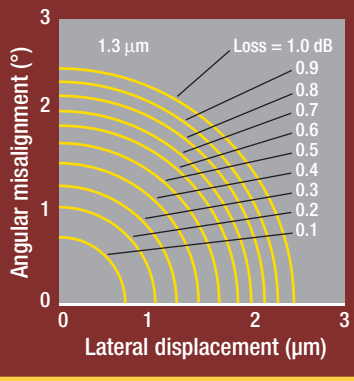
H = Magnetic field (Oersted)

L = Length of rod (cm)

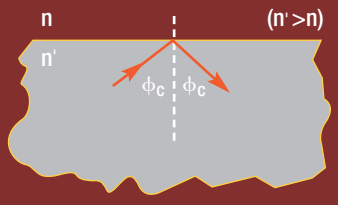
θ = VHL



CONSTANT-LOSS CURVE FOR ANGULAR AND LATERAL MISALIGNMENT BETWEEN TWO SINGLE-MODE FIBERS



CRITICAL ANGLE FOR TOTAL INTERNAL REFLECTION



$$\sin\phi_c = \frac{n}{n'}$$

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FAX: (973) 228-0915

www.ofr.com

Representatives Worldwide

OPTICAL dB UNITS

The relationship between DECIBELS and OPTICAL POWER is

$$dB = -10 \log \left(\frac{P_{out}}{P_{in}}\right)$$

$$dBm = 10 \log \left(\frac{P_{out}}{1mW}\right)$$

TRANSMISSION

$$T = 10^{\left(\frac{loss}{-10}\right)}$$

Where Loss is in dB

COUPLING LOSS RESULTING FROM A COMBINATION OF MISALIGNMENTS

Longitudinal misalignment z

Lateral misalignment x

Angular misalignment θ

Mismatch between mode field radii w_1 & w_2

The total coupling loss between two single-mode fibers can be expressed as:

$$\Phi_{tot} = -10 \log \eta_{tot} \qquad \eta_{tot} = \left(\frac{4D}{B}\right) e^{-AC/B}$$

where:

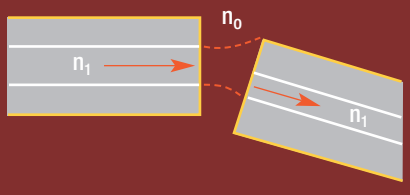
$$A = \frac{(kw_1)^2}{2} \qquad B = G^2 + (D+1)^2$$

$$C = (D+1)F^2 + 2DFG\sin\theta + D\,(G^2 + D + 1)\sin^2\theta$$

$$D = \left(\frac{w_2}{w_1}\right)^2 \qquad F = \frac{2x}{kw_1^2}$$

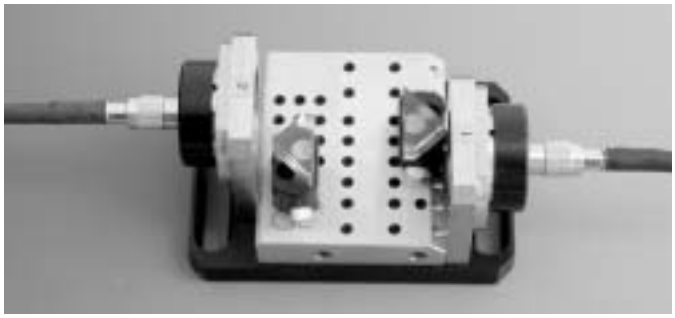
$$G = \frac{2z}{kw_1^2} \qquad k = \frac{2\pi n_o}{\lambda}$$

MULTIPLE SINGLE-MODE FIBER MISALIGNMENTS



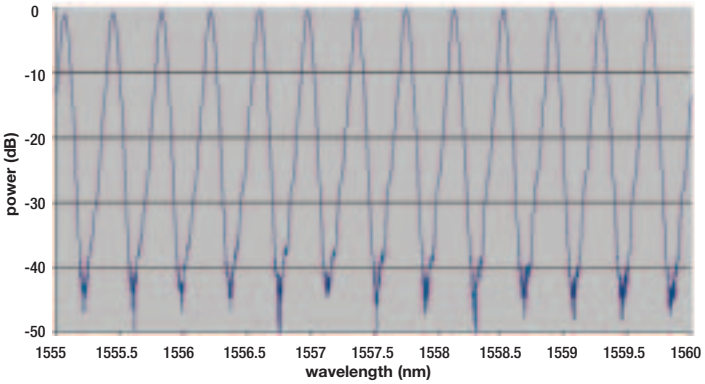
How can FiberBench Technology help you?

It starts with you. Use your imagination, then tell us what you would like to do. Here are a few ideas that turned into hardware.

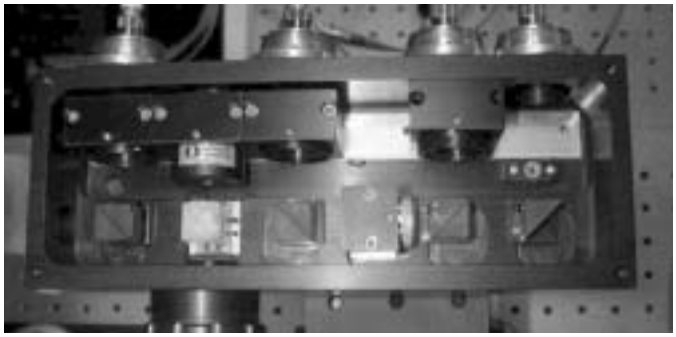


FiberBench DWDM C-Band Wavelength Comb Generator.
Interested? Contact OFR.

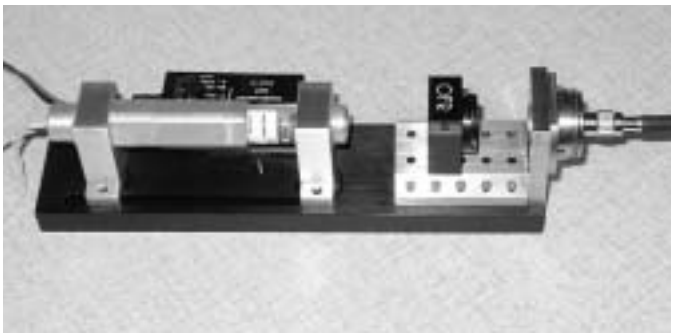
50-GHz etalon spectrum
triple-pass through OFR FiberBench™



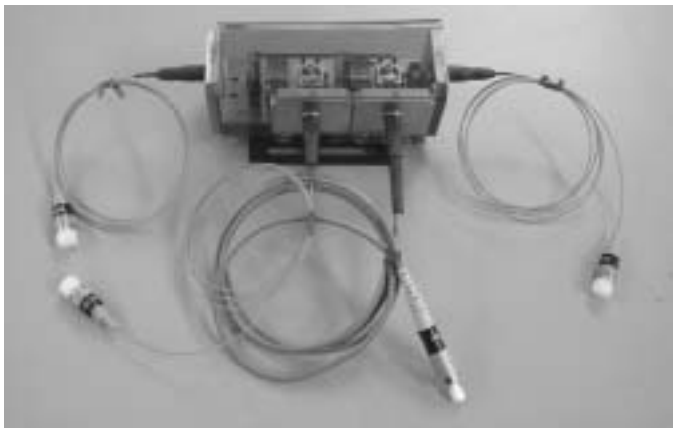
C-Band 50 GHz etalon spectrum with
35-45 dB peak-to-vally.



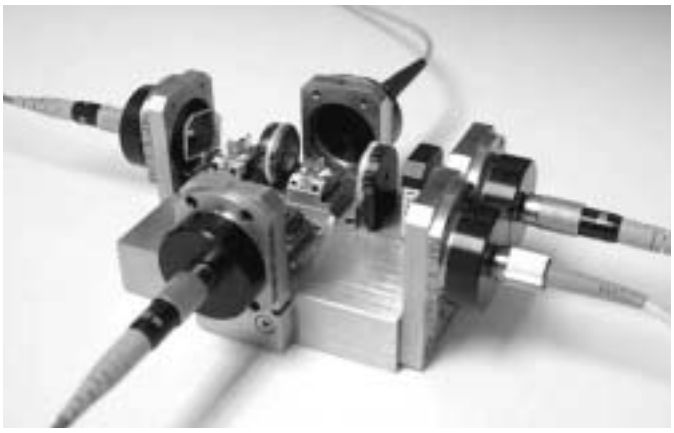
Fiber Interferometer using FiberPorts and
other OFR optics, 633 nm.



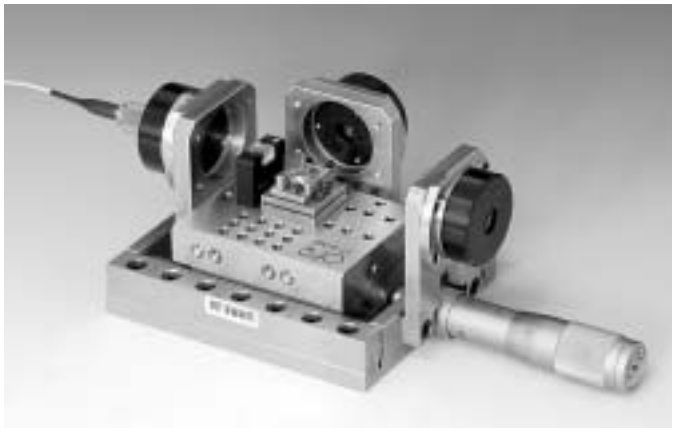
FiberBench Laser-to-Fiber Coupling, 532 nm



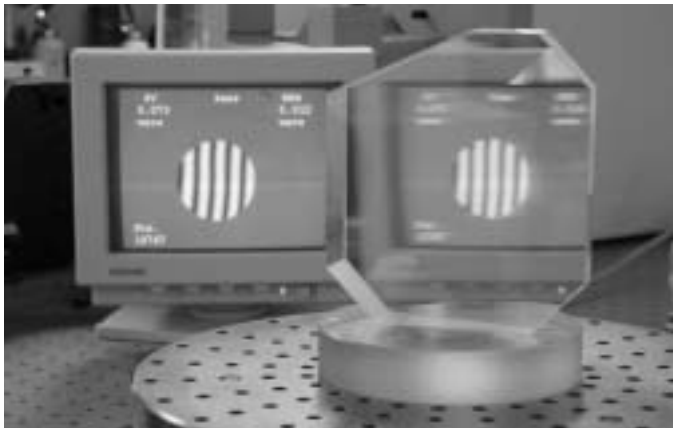
1x3 Polarization Splitter, 852 nm, page FO-23.



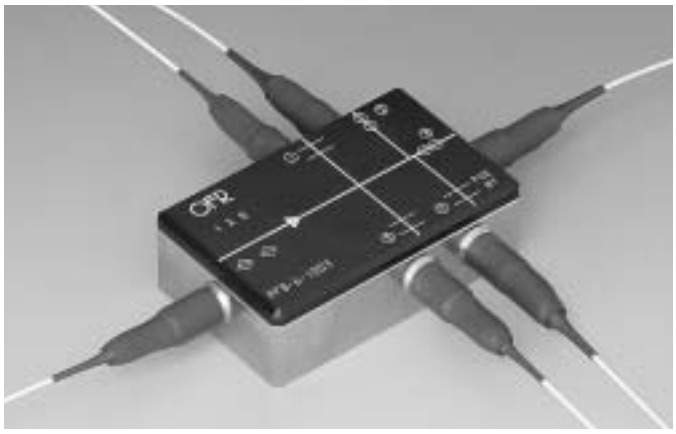
Phase Delay Analyzer, 980 + 1550 nm.



Variable Polarization Mode Disperser, page FO-24.



OFR custom optics production.



1x5 Splitter, finished product. Started life as a FiberBench Prototype

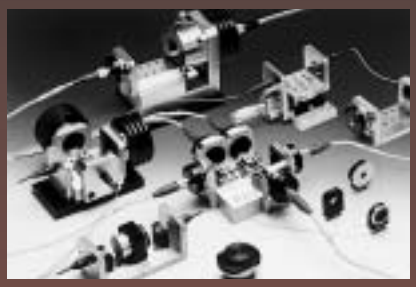
FIBER-OPTIC PRODUCTS

Part	Page No.	Part	Page No.	Part	Page No.	Part	Page No.
ACB	FO-11	FMBS	FO-25	IOB	FO-23	PCB	FO-14
CFC	FO-45,46	FS	FO-47	LPR	FO-28	PFC	FO-49
CFM	FO-47	FT	FO-4	LL	FO-16,41	PFP	FO-29
CFS	FO-47	FTBx	FO-20	LLO	FO-16,41	PFS	FO-49
CSMA	FO-46	HCB	FO-11	MFI	FO-54	PFSV	FO-23
FB	FO-4	HCF	FO-45,46	MFI-FMB	FO-25	POA	FO-6,16
FB-PAM	FO-34	HEF	FO-46	MS	FO-13	PSO	FO-29
FCB	FO-11	HW	FO-12	OC	FO-52	PSP	FO-13
FCM	FO-10,43	IO-F	FO-50	OCM	FO-52	PTE	FO-40
FCP	FO-9,42	IO-FFB	FO-21	OCT	FO-52	RCB	FO-11
FCS	FO-9,42	IO-FLB	FO-22	PAD	FO-34	RMAB	FO-15
FDB	FO-15	IO-G	FO-51	PAF	FO-6,37,38	RZB	FO-15
FFBx	FO-19	IO-H	FO-50	PAL	FO-7,40	SOP	FO-28,34
FLBx	FO-20	IO-J	FO-51	PBB	FO-14	VA	FO-26
FMB	FO-8	IO-PAF	FO-51	PC	FO-30	VDL	FO-24

CONTENTS

HIGH POWER

Basic FiberBench



HIGH POWER

Assembled FiberBench Systems

HIGH POWER

FiberBench Polarization Control & Measurement

HIGH POWER

Fiber-Optic Collimators

HIGH POWER

Packaged Devices

* *Look for* HIGH POWER *Products*

NOTE: Power damage is generally fiber-limited. Discuss with OFR.

Stability and Testing of FiberBench Systems

When we designed the original FiberBench, we recognized that long-term stability and coupling efficiency would be our most important design goals. We achieved those goals in the first unit off the workbench. Since then we have modified and fine-tuned, and today, with many more than a thousand units produced (or is it two thousand?) and hundreds of satisfied customers worldwide, the OFR FiberBench is simply the best engineered and most versatile fiber-optic coupling system available anywhere.

OFR design choice is stainless steel. We ruled out aluminum...it is just not thermally or mechanically stable enough for the kind of reliability we require of our FiberBenches. We thermally cycle our FiberBenches from -20°C to 70°C. We give them more severe vibration and shock than they would ever be subjected to in a normal laboratory or equipment installation. Result is <0.1 dB change in throughput.

Vibration & Shock
Frequency: 4 Hz
Amplitude: 30 mm
Shock: 4 G's
Thermal Cycling: -20° to 70°C

Stability originates in a sound engineering approach. The OFR FiberBench product line is designed by engineers for use by engineers.

High Power Capability

Look for... HIGH POWER

OFR FiberBench systems and components are capable of handling 2-10 Watts cw, as compared to typical fiber-optic components that are limited to a few hundred mW. Typical miniaturized components have very small (0.1-0.3 mm) optical beams, resulting in very high power density that can damage components.

OFR FiberBench technology, on the other hand, involves expanded beams, resulting in lower power densities, thus allowing much more total power before damage occurs.

In high power applications, there is only one choice, OFR FiberBench systems and components.

Power damage is generally fiber-limited. It is important to discuss with OFR.

FiberBench Kits

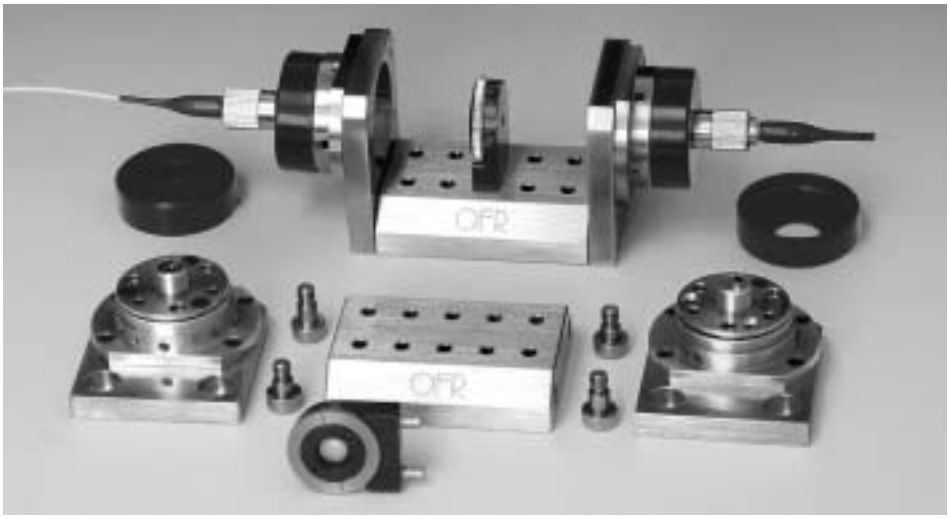
Build-it-Yourself Kits Available

Want to build your own FiberBench system? Discuss your application with an OFR engineer. He/she will help with your design, and will e-mail the complete list of part numbers to order. Your Kit will be delivered expeditiously along with assembly, alignment and test instructions.

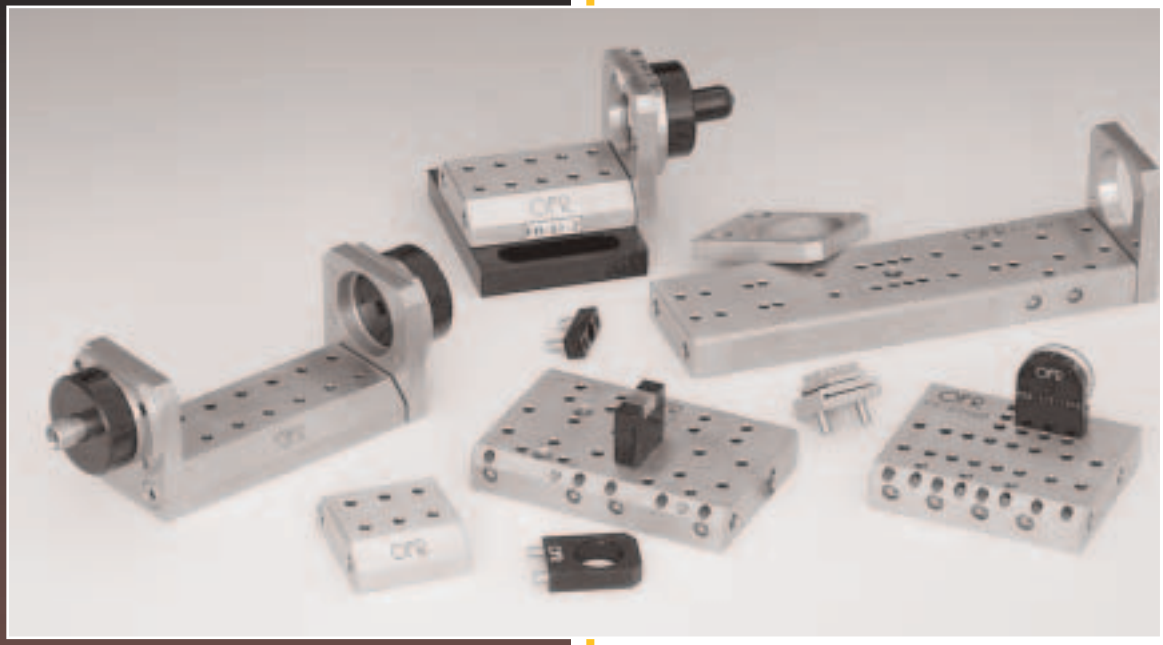
Look for ***KITS*** designation, especially in Assembled FiberBench Systems, page FO-17 and following. Note also that custom-designed FiberBench systems can be built from ***KITS***.

Consider this option when discussing your FiberBench requirement with OFR.

You will never be told to "Press 1 Now" when you call OFR!



KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***... see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer. See page FO-18 for an example of a FiberBench Kit.



Basic FiberBench

FiberBench mini-systems have been used to solve many fiber-optic system problems. Call us with yours.

Look for HIGH POWER ***Products***

NOTE: Power damage is generally fiber-limited. Discuss with OFR.

You will never be told to "Press 1 Now" when you call OFR!

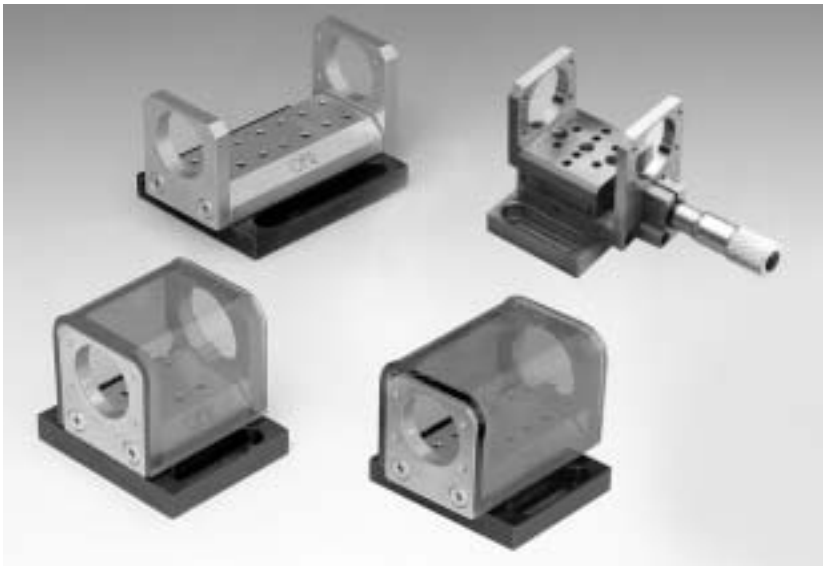
Empty FiberBenches & FiberTables

The FiberBench

The FiberBench is a 2-port "assembly bench" on which complex optical circuitry can be permanently assembled. FiberBenches are available in three sizes, Short, Medium and Long, that accommodate 3, 5 and 7 components respectively. Within the Component Stage area on the FiberBench Base is a series of precision holes. Stainless steel dowel pins on the base of the Component Modules lock into these holes.

Permanently mounted on all Fiber Benches are 2 Port Walls. It is onto these walls that the several types of Input/Output Ports are mounted.

Variable Delay Line FiberBenches are available (see FO-24). Precision z-axis translation is micrometer actuated, with no backlash or cross-talk between axis. Standard model has 0-13 mm travel. 25 mm optionally available. Please inquire.



FiberBenches are delivered with Mounting Base and Dust Cover.

Catalog Number	Component Stage Length	Description
FB-38	38 mm	Short FiberBench, holds 3 modules
FB-51	51 mm	Medium FiberBench, holds 5 modules
FB-76	76 mm	Long FiberBench, holds 7 modules
FB-VDL	38 mm	Variable Delay Line, holds 3 modules

The FiberTable

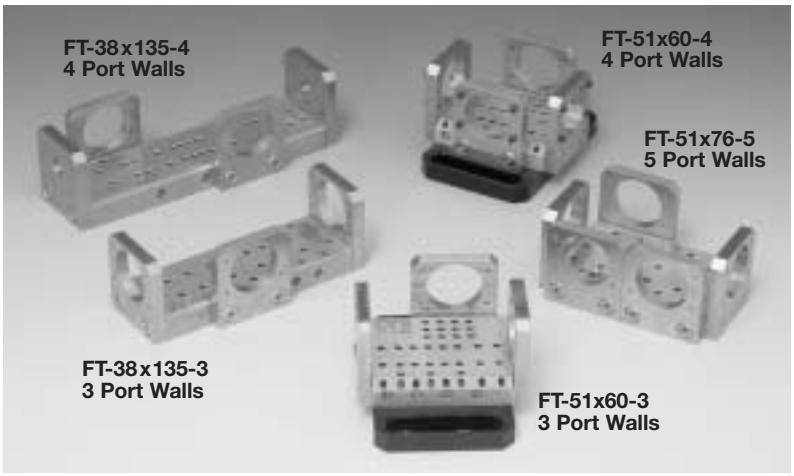
The FiberTables is a 3-or-more-port assembly bench much like the FiberBench. However, because its Ports can be moved to a number of locations, the FiberTable offers much flexibility. This is a miniature optical table with a regular criss-cross pattern of precision holes. It is into these holes that the Component Module dowel pins fit.

Each FiberTable is delivered with a Mounting Base that adapts the FiberTable for mounting onto a conventional optical table.

Custom FiberTables from 3 to any number of Ports are available on special order. OFR engineering will assist in the concept and design of the optimum layout for any application. Please inquire.

See **http://www.ofr.com/fibertables** for latest additions to our growing list of FiberTable design options.

You will never be told to "Press 1 Now" when you call OFR!



Empty FiberBenches. All FiberTables are delivered with Mounting Base.

Catalog Number	Dimensions	Description
FT-38x100-w*	38x100 mm	3 to 5 Ports Walls
FT 38x135-w*	38x135 mm	3 to 5 Ports Walls
FT-38x165-w*	38x165 mm	3 Ports Walls
FT-51x60-w*	51x60 mm	3 to 4 Ports Walls
FT-51x78-w*	51x78 mm	3 to 6 Ports Walls
FT-60x64-w*	60x64 mm	3 to 5 Ports Walls
FT-63x76-w*	63x76 mm	3 to 7 Ports Walls
FT-64x93-w*	64x93 mm	3 to 6 Ports Walls

Note: when ordering, specify number of Port Walls, for example, FT-38x100-5.

Coupling Ports

The OFR FiberPort (US Patent 5,638, 472) is an ultra-stable, miniature micropositioner, enabling active alignment of an AR-coated OFR aspheric lens for collimating or for free beam-to-fiber coupling. FiberPorts serve both input and output funtions, and are micro-positionable in six degrees of freedom:

3 linear (x, y, z)

2 angular (azimuth, elevation)

1 rotational (for PM fiber alignment)

While performing the same functions as large benchtop 5-axis positioners, the compact size of the Fiber-Port makes it ideally suited for incorporating into shipable OEM equipment, as well as for utility in the development laboratory.

A major application for the FiberPort among many laser manufacturers is as the laser interface to an output fiber pigtail. See page FO-39 for suggested means of mounting a FiberPort to a laser. Final alignment is done on site following simple instructions furnished by OFR. It is the FiberPort's rugged construction, stability and coupling efficiency that make it popular for this application.

The FiberPort is characterized by ultra-stability. Once aligned to maximum coupling efficiency, there is no drift, in spite of temperature changes, shock or vibration beyond that experienced in the normal laboratory. See page FO-2 for more information on **Stability and Testing.**

Tungsten carbide ensures extreme resistance to wear. The FC/APC connector ferrule inserts into a tungsten carbide ferrule holder contained in every OFR FiberPort. These tungsten carbide sleeves are extremely resistant to wear, thus assuring coupling repeatability after one or a hundred connections.

The micro-aspheric Lens in the FiberPort is AR coated. Specify wavelength when ordering. For a description of the micro-aspheric Lenses, see COUPLING LENSES, page FO-16.

Laser-To-Fiber Coupling...to couple a collimated free-beam into a fiber

❑ **FiberPorts** The OFR FiberPort (US Patent 5,638,472) is the most stable miniature micro-manipulator available. OFR's unique design allows input of large cross-section beams, as large as 4.9 mm in diameter.

Actual Beam Size	Accepts Beam Diameter	Single Mode Part Number	Multimode Part Number	Receptacle
·	0.5 mm	PAF-X-2		FC
•	1.0 mm	PAF-X-5		FC
•	1.6 mm	PAF-X-7		FC
•	2.0 mm		PAF-XM-5	FC
•	2.0 mm		PAF-SMA-5	SMA
•	2.4 mm	PAF-X-11		FC
•	3.4 mm	PAF-X-15	PAF-XM-7	FC
•	3.4 mm		PAF-SMA-7	SMA
•	4.9 mm		PAF-XM-11	FC
•	4.9 mm		PAF-SMA-11	SMA

Custom fiber-coupled solid-state laser (532nm)

IO-P-FLB-9CD-980-X, Laser-to-Fiber Isolators. (See page FO-22)

HIGH POWER

FiberPorts

The OFR FiberPort is an ultra-stable, miniature micropositioner, enabling active alignment of an OFR aspheric lens for collimating or free beam-to-fiber coupling. While performing the same functions as larger benchtop 5-axis positioners, the compact size of the FiberPort makes it ideally suited for incorporating into shipable, OEM equipment, as well as for utility in the development laboratory.

The micro-aspheric Lens in the Fiber-Port is AR coated. Specify wavelength when ordering. For a description of the micro-aspheric Lenses, see Coupling Lenses, page FO-16.

Connector-Interface Option
PAF-X Series Connector-Interface FiberPorts (FC/APC) are intended for applications in which it is desirable to connect/disconnect the FiberCable. OFR guarantees highly repeatable (± 0.1 dB)* coupling efficiency, only when PAF FiberPorts and OFR FiberCables are used as matched pairs.

* with single-mode systems

Permanent Pigtail Option
PAF-H Series Hard-Wired Permanent Pigtail FiberPorts are intended for applications not requiring connect/disconnect. When installed in any FiberBench assembly, system stability is guaranteed and transmission will not vary under normal laboratory usage.

Catalog Number	Fiber
PAF-X-λ	Matched FiberCable ordered separately, page FO-9
PAF-H-S-λ	1-Meter, single-mode Pigtail
PAF-H-P-λ	1-Meter, PM Pigtail

λ When ordering, specify wavelength in nm.

NOTES
- Insertion loss may vary depending upon fiber type and beam launch conditions.
- Return Loss typically -60 dB when used with FC/APC.
- PM FiberPorts, fast axis is vertical.

Tungsten carbide ensures extreme resistance to wear. The FC/APC connector ferrule inserts into a tungsten carbide ferrule holder contained in every OFR FiberPort. These tungsten carbide sleeves are extremely resistant to wear, thus assuring coupling repeatability after one or a hundred connections.

FiberPort with cover removed, face view, showing coupling adjust-and-lock screws

PAF-H Non-disconnectable

PAF-X Disconnectable (FC/APC)

Easy-Touch FiberPort, Beam Steering is Easy

The new Easy-Touch FiberPort, with easy-to-use fingertip adjusters, offers an alternative to the traditional FiberPort with its hexagonal Allen wrench adjustment.

Easy-Touch FiberPort, with ultra-fine-thread adjusting screws, allows fingertip fine control of steering adjustment.

It is intended for applications requiring realignment, such as fiber changes or lens changes. For permanent systems, OFR recommends standard FiberPorts.

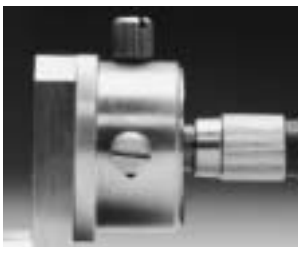
When used as a collimator, Easy-Touch FiberPort is an easy-to-use beam steerer. Whether used in collimating or coupling applications, Easy-Touch FiberPort is quickly and easily adjusted and readjusted.

Catalog Number	Fiber
PAFE-X-λ	Matched FiberCable order separately, see page FO-9

λ: when ordering specify wavelength.

Easy-Touch Fiberport... fine control of beam aiming is easy

Easy-Touch Fiberport has same coupling adjustment screws as traditional Fiberport



Easy-Touch Fiberport with optional FiberCable (See page FO-9)

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Cooled and Non-Cooled LaserPorts

T-E Cooled LaserPorts are available for 5.6 mm and 9.0 mm lasers. Included in the T-E LaserPort are:

- AR-coated micro-aspheric lens with 5 axes of adjustment
- Thermo-electric Peltier cooler, 100-900 mA typical
- Thermistor, 10 K Ohm for 25° C typical
- Heat sink and radiator
- OFR FiberBench FB-38-1W
- Alignment instructions
- Color-coded wiring instructions.

OFR does not supply the power supply. However, the LaserPort is pre-wired by OFR. Simply plug in your laser. Instructions for easy collimation alignment are included. Optionally available are AMP 10 pin or Cannon ITT mini 9 pin connectors.

Non-cooled LaserPort

TO3 LaserPorts are available for any customer-furnished TO3 laser. The LaserPort mounts onto a industry-standard heatsink with laser socket plate. Simply attach to your laser/radiator assembly and follow easy instructions for collimation alignment. See also page FO-20.

In all LaserPorts, the same ultra-fine FiberPort alignment mechanism houses the AR-coated aspheric Lens that produces a nominal 1x2 mm collimated beam. Having x-y-z and Φ-Θ fine controls, the LaserPort is precision aligned to maintain optimum collimation.

OFR will mount and align customer-furnished lasers when requested. However, OFR bears no responsibility for performance of customer-furnished lasers, nor for damage to same while in OFR possession. Please inquire.

You will never be told to "Press 1 Now" when you call OFR!

Catalog Number	Description
PAL-TE-5.6 or 9.0-λ	T-E Cooled LaserPort for 5.6 mm or 9.0 mm laser.
PAL-5.6 or 9.0-λ	Non Cooled LaserPort for 5.6 mm or 9.0 mm laser.
PAL-TO3-λ	LaserPort for TO3 Laser

NOTE: when ordering, specify wavelength.

PAL-TE-9.0-1550 with integral OFR-supplied T-E Cooler & calibrated thermistor. OFR does not supply the power supply.

PAL-TO3-830 mounted on customer's heatsink, with customer-furnished TO3 laser.

Interchangeable FiberPort Lenses (see FO-16)

HIGH POWER

It is often desirable to compare the performance of different Fiber-Port Lenses. The easiest and most economical way to do this is to use interchangeable Lenses, with one FiberPort that is never removed.

All FiberPort Lenses are mounted in a Cell that is compatible with all FiberPort models. The Cell positions the principal plane of the Lens at one focal length distance from the polished fiber endface, resulting in collimation. FiberPort Lens Cells are magnetic, and are easily installed and interchanged on site.

Bulkhead requirement. The Bulkhead, the threaded portion on which the Connector attaches, is different in length for the two groups of Lenses as listed below.

FiberPort Lenses LLO-PAF-2,5,7 can be interchanged using FCBH-S Bulkhead. Likewise, LLO-PAF-11,15 use the FCBH-LA. When interchanging Lenses from one group to another, it is not necessary to change FiberPort bodies. It is only necessary to inter-change Bulkheads.

In summary, interchanging Lenses and Bulkheads is simple, quick and economical.

Catalog Number	Effective Focal Length	Bulkhead
LLO-PAF-2-λ	2.0 mm	FCBH-S
LLO-PAF-5-λ	4.6 mm	FCBH-S
LLO-PAF-7-λ	7.5 mm	FCBH-S
LLO-PAF-11-λ	11.0 mm	FCBH-LA
LLO-PAF-15-λ	15.4 mm	FCBH-LA

λ: specify wavelength in nm.

Lenses are easily interchanged in FiberPort.

HIGH POWER

MirrorPorts
(Retrace Systems)

The MirrorPort contains a dielectric coated Mirror with >99% reflection. The same precision mechanism used in the FiberPorts and LaserPorts allows ultra fine adjustment of the MirrorPort to assure optimum reverse coupling of the laser beam back into the fiber.

Note that MirrorPorts are interchangeable, so that other wavelengths can be easily accommodated. OFR MirrorPorts can be assembled as an orthoconjugate retroreflector (Faraday Rotator Mirror). See page FO-25. Also see FO-53.

MirrorPort on Short FiberBench

Catalog Number	Max R Spectrum
FMB-VIS	450-700 nm
FMB-NIR	700-950 nm
FMB-YAG	950-1150 nm
FMB-IR1	1280-1340 nm
FMB-IR2	1530-1570 nm
FMB-AL	Aluminum
FMB-AU	Gold

DetectorPorts

An optional means of measuring intensities is the DetectorPort, which is mounted on a FiberBench or FiberTable. The DetectorPort contains an amplified silicon or InGaAs detector (for visible or infrared operation, respectively), whose output voltage is proportional to the average (cw) intensity of light. This voltage is measured using any voltmeter or oscilloscope.

Monitoring laser power in a system is easily done using a DetectorPort on the side of a FiberTable. A Tap Beamsplitter picks off a nominal 4% of the optical beam and directs it to the DetectorPort.

Clearly, it is necessary to have confidence that the tapped-off energy is a true indicator of the laser power. However, if the "tap beamsplitter" is a "standard beamsplitter", and if the State of Polarization (SOP) varies, then the tapped-off energy will vary according to changes in SOP. What is needed is a beamsplitter that is not sensitive to SOP. This is OFR's PSP (Polarization-State Preserving) Beamsplitter. See page FO-13

The Tap Beamsplitter is mounted on an ACB Base (see page FO-11), in turn mounted in the beam path on a FiberTable, page FO-4.

Specifications:

Detector area	0.8mm^2 (InGaAs)
Bandwidth	50 MHz
Wavelength	400-1100 nm (silicon) 800-1800 nm (InGaAs)
Input	110 VAC (power supply included)
Output	BNC connector

Catalog Number	Description
PAD-λ	DetectorPort
PSP-04/96-ACB-λ	Tap Beamsplitter on ACB Base

λ When ordering, specify wavelength in nm, for example, PAD-1550.

Tap Beamsplitter and DetectorPort on typical FiberBench

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Single Mode (SM) and Polarization-Maintaining (PM) FiberCables

FC-connectorized Single Mode and Polarization-Maintaining FiberCables are available with OFR standard APC or optional PC polish. FC-connectorized FiberCables connect to OFR X-Type FiberPorts (see page FO-6).

Single Mode FiberCables

FC/APC-connectorized SM FiberCables are available for wavelengths from 488 nm to 1550 nm. Also, OFR connectorizes customer-supplied, 125 µm cladded fiber.

FiberCables can be ordered with connector on one end and other end cleaved, or as a patchcord with both ends connectorized.

Polarization-Maintaining FiberCables

Polarization-Maintaining (PM) fibers employ a stress technique to stress the core of the fiber to create two propagation paths within the fiber core. Linearly polarized light aligned to either the slow or fast axis of the fiber will remain linearly polarized. This is analogous to an optical retarder.

OFR PM fibers are also available with FC/PC and FC/APC with the connector key aligned parallel to the slow axis of the fiber. The slow axis of PM fiber is parallel to the stress members or major diameter of Oval Inner-Clad PM fiber.

OFR stocks a variety of PM FiberCables, with emphasis on 1310nm & 1550nm.

Standard lengths are 1 meter and 2 meters. Minimum quantity of 2 each must be ordered for custom lengths.

Single Mode (SM) FiberCables with FC Connector

Catalog Number	Description
FCS-λ-*l*- FC/APC	FiberCable, FC/APC connector one end
FCS-λ-*l*- FC/APC/APC	Patchcord, FC/APC both ends
FCS-λ-*l*- FC/PC/APC	Patchcord, FC/PC one end, FC/APC other end
FCS-λ-*l*- FC/PC/PC	Patchcord, FC/PC both ends

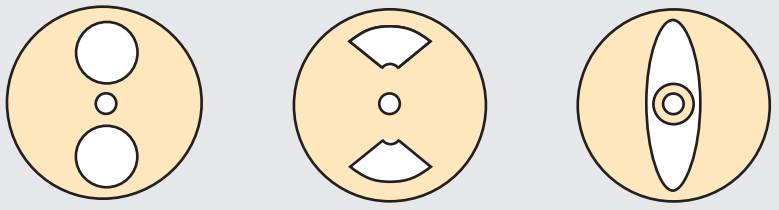
When ordering, specify λ wavelength in nm.
l: length, 1 meter or 2 meters or other. For example, for 3-meter length FCS-1550-3-FC/APC.

Polarization Maintaining (PM) FiberCables with FC Connector

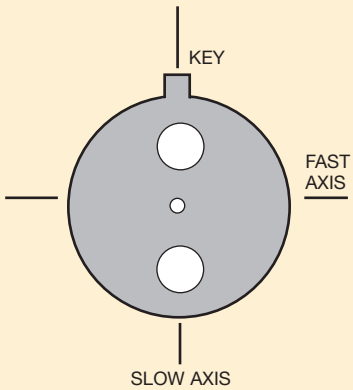
Catalog Number	Description
FCP*x*-λ-*l*- FC/APC	FiberCable, FC/APC connector on end
FCP*x*-λ-*l*- FC/APC/APC	Patchcord, FC/APC both ends
FCP*x*-λ-*l*- FC/PC/APC	Patchcord, FC/PC one end, FC/APC other end
FCP*x*-λ-*l*- FC/PC/PC	Patchcord, FC/PC both ends

When ordering, specify λ wavelength in nm.
l: length, 1 meter or 2 meters or other. For example, for 3-meter length FCPP-1550-3-FC/APC.

x: PANDA	FCPP-λ-3-FC/APC, etc.
x: Bowtie	FCPB-λ-3-FC/APC, etc.
x: Oval Inner Clad	FCPO-λ-3-FC/APC, etc.



PM Fiber Type	Order as	Most Common usage
PANDA (OFR Standard)	FCPP-	488-514, 633, 850, 1064, 1310, 1550 nm
Bowtie	FCPB-	1064 nm inquire
Oval Inner Clad	FCPO-	1064 nm inquire



FC Adapter, super high precision, monolithic stainless steel body

A simply better engineered product. One-piece stainless steel body. Ultra high dimensional tolerancing. Ceramic split-sleeve insert. These are some of the reasons that OFR's FC Adapters are absolutely repeatable, with no fiber end-face scratching. Extremely tight tolerance on keyway slot assures trouble-free performance, especially with PM fiber.

- Ultra high mechanical tolerancing
- One-piece stainless construction
- Ceramic split-sleeve insert
- 70% less keyway slop
- Absolute repeatability
- PM fiber repeatable connecting
- Reduced fiber-end scratching
- For PC and APC

Catalog Number	Description
FCA-N	FC Adapter with 2.00 mm key
FCA-W	FC Adapter with 2.14 mm key

Connector Types & End-Face Polish: FC/PC and FC/APC

The term "FC" comprises a mechanical definition of a specific type of connector, while "PC"and "APC" describe the kind of polish applied to that connector (thus, fiber) end face:

PC = physical contact, end face polished convex, OFR option.

APC = as above, but angle-polished at 8° angle, OFR standard.

Typically, FC/PC connectors have lowest insertion loss and low (-35 to -45 dB) return loss (back reflection), and are used for fiber-to-fiber connections.

FC/APC connectors are required for fiber-to-air applications requiring low return loss, such as Collimators, FiberPort couplers, and laser-to-fiber coupling.

Connector Losses

Insertion loss at each connector-pair varies according to type of connector polish and fiber core diameter (wavelength related).

		Typical Connector Loss (dB)			
Type	Description	633	850	1060	1310/1550
PC	Physical contact with convex radius	0.6	0.4	0.3	0.2
APC	As above, but end face tilted at 8°	0.8	0.6	0.5	0.3

Multimode FiberCables

Multimode FiberCables are available with FC or SMA connectors. Core diameters of 50 µm, 62.5 µm, 100 µm with 125 µm cladding are standard. 200 µm and 400 µm use SMA connector.

Standard lengths are 1 meter and 2 meters. Minimum quantity of 2 each must be ordered for custom lengths.

Multimode (MM) FiberCables with FC Connector

Catalog Number	Description
FCM-δ-*l*-λ- SMA	FiberCable, SMA connector one end
FCM-δ-*l*-λ- FC/PC	FiberCable, FC/PC connector one end

When ordering, specify δ core diameter 50, 63,100 µm.
l length, specify 1 meter or 2 meters or other.
λ wavelength in nm. For example, for 3-meter length FCM-50-2-830-SMA.

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Optical Components

OFR manufactures numerous, precision Optical Components that can be easily inserted into the optical path, simply by plugging the Component Module into the FiberBench or FiberTable. A Component Module consists of an Optical Component mounted onto an intermediate Stage Adapter. Precision, hardened steel dowel pins on the underside of the Stage Adapter fit into receiving holes on the FiberBench Base and FiberTable.

All Component Module Bases mount onto the FiberBench via hardened, precision pins, and are then locked for absolute stability.

Empty Component Bases

For applications using non-OFR or loose optical components, empty Component Bases are available. These are used on all standard OFR Optical Component Modules.

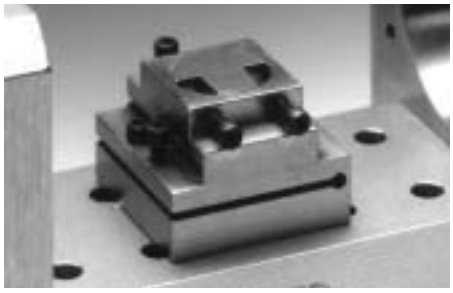
Catalog Number	Description
HCB	Fixed Base
RCB	Rotating Base
FCB	Fixed Component Base
ACB	3-Axis Aiming Base

Four Bases are available:

HCB Fixed Base for non-deviating components, such as parallel windows, filters, etc.

RCB Rotating Base for components requiring rotation, such as retarders, polarizers, etc.3° resolution.

FCB Fixed Component Base for half-inch components, such as Attenuating Filters (see page FO-15), and Aperture Plates (see page FO-12).



ACB 3-Axis Aiming Base for deviation compensation, featuring ultra-stable flexure joints. It is especially significant because it accommodates many different components.

See **http://www.ofr.com/fiberbench/emptycomponentbase.html** for diagrams showing the many options available.

You will never be told to "Press 1 Now" when you call OFR!

Tweakers

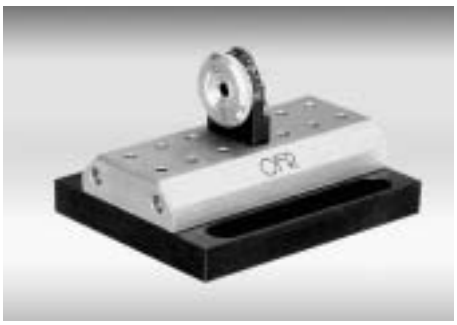
Normally, beam alignment in a FiberBench is effected by using the FiberPorts (see pages FO-6, 37). However, Tweakers offer an alternate means of x-y and F-Q control of beam alignment.

The X-Y Tweaker consists of a precision polished, AR coated plane-parallel plate mounted on a magnetic ball-and-socket. It is rotated and tilted in nearly any orientation. The beam is consequently displaced parallel to itself as much as ±250 µm with hyperfine precision. Tilting beyond 30° can affect insertion loss because of AR coating angular dependence.

The Φ-Θ Tweaker consists of two precision polished, AR coated weak wedges in a dual rotary mount that permits independent rotation of each wedge. Thus, the combined angular displacement of the pair can be controlled with hyperfine precision anywhere within a 0.5° cone.

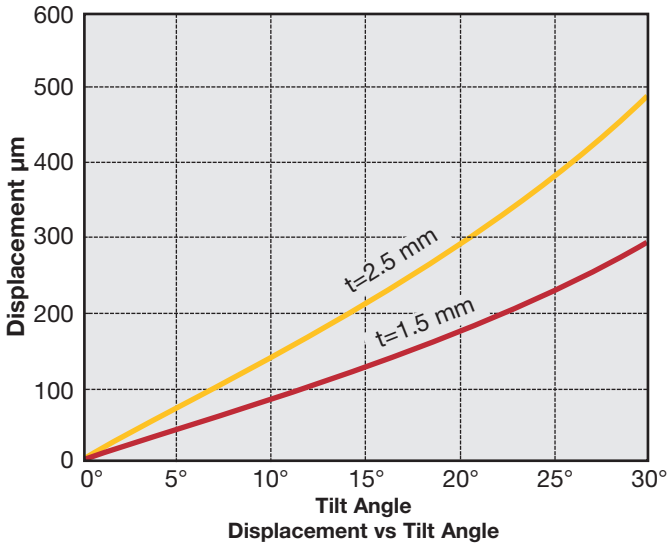
In addition to aligning a FiberBench or FiberTable, Tweakers are often used to steer a beam in free-space applications.

Catalog Number	Description	When ordering Specify Wavelength	
HW-XY-t-λ*	X-Y Tweaker*	-VIS	425-675 nm
HW-FT-λ	Φ-Θ Tweaker	-NIR	700-950 nm
*t: specify 1.5 mm or 2.5 mm thickness		-YAG	950-1150 nm
λ: specify wavelength, for example, HW-XY-1.5-IR		-IR	1300-1550 nm



Φ-Θ Tweaker

X-Y Tweaker



Displacement vs Tilt Angle

Aperture Plates

Fitting into the Fixed Component Base, page FO-11, are black-anodized Aperture Plates. These are used as an aid in alignment.

Catalog Number	Description
HW-1.5	Aperture Plate with 1.5 diameter aperture
HW-2.5	Aperture Plate with 2.5 diameter aperture

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50/50 Beamsplitters

An OFR Laser Beamsplitter Plate, mounted on a 3-Axis Aiming Base (see page 11), comprises the Beamsplitter Module.

These produce a 50/50 split with unpolarized light within the wavelength band specified. The beamsplitter coating is dielectric, and all air surfaces are AR coated. When ordering, specify wavelength of operation.

Beamsplitter Modules are intended for applications requiring access to two or more output beams. Split ratios other than 50/50 are available on special order.

For additional information on other beamsplitters, See PRECISION OPTICAL COMPONENTS, page OC-17.

Catalog Numbers		
50/50 Plates	**Polarizing Cubes**	**Wavelength**
MS-B-VIS	PSCL-B-VIS	450-675 nm
MS-B-VNIR	PSCL-B-VNIR	630-860 nm
MS-B-YAG	PSCL-B-YAG	950-1100 nm
MS-B-IR	PSCL-B-IR	1270-1600 nm

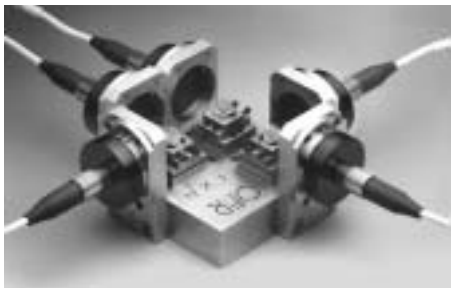
Polarizing Beamsplitters

An OFR Broadband Polarizing Beamsplitter prism cube, mounted on a 3-Axis Aiming Base (see page FO–11), comprises the Polarizing Beamsplitter Module. This splits the collimated laser beam into its S and P polarized components, with the S (vertical) component reflecting 90°, and the P (horizontal) component continuing undeviated.

Separation of polarization of the two components is > 1000:1 (30dB).

WDM Beamsplitters (dichroic) are available on a custom basis. Please inquire.

For additional information on other beamsplitters, See PRECISION OPTICAL COMPONENTS, page OC-17.



Custom 1x4 Splitter

Broadband PSP* Beamsplitters *Polarization-State-Preserving

HIGH POWER

In most fiber-optic applications it is necessary to maintain the State of Polarization (SOP) of light in the system. However, if an ordinary beamsplitter is used, the SOP will be changed. An “ordinary” beamsplitter is described as a plate of glass at 45° that reflects (S) and transmits (P) incident light, whether coated or uncoated. This is because this type of beamspitter affects the SOP of the S and P beams. See rear cover of PRECISION OPTICAL COMPONENTS brochure in this catalog for equations.

So-called “non-polarizing” beamsplitters might maintain the S and P amplitudes, but not the phase angle between them. In short, a non-polarizing beamsplitter does not maintain the SOP.

The OFR PSP Beamsplitter utilizes unique and proprietary technology. It is the only beamsplitter on the market that preserves the SOP of the input beam, and is characterized by wide bandwidths (50-100 nm) and wide fields-of-view (≥ 5°). The PSP Beamsplitter produces a 50/50 split within 3% for both output beams, and preserves the SOP and phase angle of the polarized components of the input.

Other split ratios are available on a custom basis. Please inquire.

A special PSP Beamsplitter with 4% reflection and 96% transmission is used to sample the optical beam for the purpose of mounting power. See page FO-8.

Catalog Number	R/T
PSP-B-50/50-λ	50/50

λ: when ordering, specify wavelength, for example PSP-B-50/50-IR2.

SPECIFICATIONS

- Rs = Ts = 50% ± 3%
- Rp = Tp = 50% ± 3%
- Bandwith: λc ± 50 -100 nm

Custom ratios available

Center (λc) Wavelength	Order as
500 nm	VIS
633 nm	VIR
800 nm	NIR1
980 nm	NIR2
1310 nm	IR1
1550 nm	IR2

NOTE: some wavelengths under development,

PSP Beamsplitter on empty FiberTable.

HIGH POWER

Polarizers

A Polarizer, mounted on a Component Base, comprises the OFR Polarizer Module. Transmittance is >98% (insertion loss <0.1 dB) within the wavelength range specified, and the extinction of a crossed pair is $>10^4$ (40 dB).

In addition to Polarizing Beamsplitters (see FO-13), two types of Polarizers are stocked:

Linear Polarizers, mounted in RCB Rotating Cell (see page FO-11). These are dichroic type linear Polarizers with both sides AR coated. Specify wavelength when ordering.

Walk-Off Polarizers, precision polished calcite blocks, are specifically designed for construction of polarization independent systems and other optical devices.

For complete separation of S and P, beam diameter cannot exceed Clear Aperture, otherwise overlap will occur.

The most common application of Walk-Off Polarizers is in a 1x2 splitter configuration. See photos below.

These Polarizers are capable of handling extremely high optical powers, and have extremely wide bandwith and the highest polarization ratio of all types of polarizers.

For additional information on other polarizers, see PRECISION OPTICAL COMPONENTS, pages OC-(22-25).

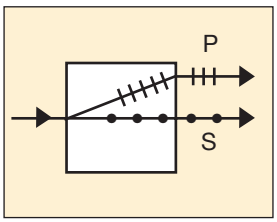
Catalog Number	Description	Extinction	Transmission	Clear Aperture
PCB-φ-λ	Linear Polarizer	>40 dB	>98%	1.5, 2.5, 4.0, 6.0 mm
PBB-φ-λ-R	Right Handed Walk-Off Polarizer	>50 dB	>98%	0.5,1.0 mm (and separation)
PBB-φ-λ-L	Left Handed Walk-Off Polarizer	>50 dB	>98%	0.5,1.0 mm (and separation)

φ: specify Aperture

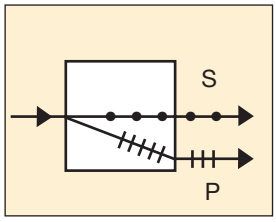
λ: specify Wavelength

*PBB, for complete S and P beam separation, beam diameter cannot exceed Clear Aperture.

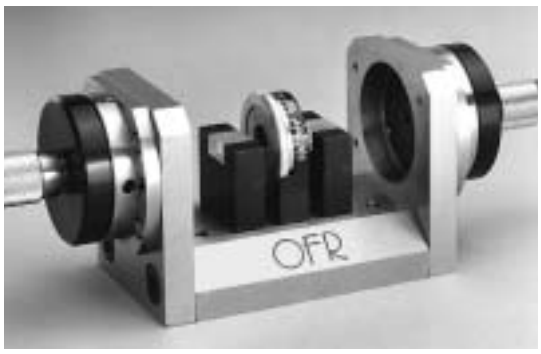
Optimized Wavelength	Catalog Numbers PCB	PBB
425-675 nm	n/a	PBB-VIS
600-900 nm	n/a	PBB-NIR
780-850 nm	PCB-NIR2	PBB-NIR2
900-1150 nm	PCB-YAG	PBB-YAG
1200-1400 nm	PCB-IR1	PBB-IR1
1400-1600 nm	PCB-IR2	PBB-IR2



Left Handed Walk-Off Polarizer



Right Handed Walk-Off Polarizer



Medium FiberBench with PBB Walk-Off Polarizers and PCB Linear Polarizer in RCB Rotating Cell.

Variable 1x2 Splitter, a Walk-Off Polarizer Application

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Retarders

An OFR Crystal Quartz Zero-Order or Achromatic Retarder in a Rotating Base comprises the Retarder Module. 1/4-Wave and 1/2-Wave Retarders are available for all standard laser wavelengths. These Zero-Order Retarders have the widest bandwidth (6 nm) and highest extinction potential (10^4-10^5) of all types of retarders.

In order to function in as many applications as possible, the Retarders are mounted in a Rotating Cell with engraved angle-index, page FO-11.

The 1/4-Wave Retarder produces circularly polarized light. It is used with a 1/2-Wave Retarder to construct a Polarization Controller. See page FO-27 for further details.

The 1/2-Wave Retarder is generally used to control rotation of the plane of polarization.

Catalog Number	Description	Insertion Loss	Aperture
RZB-1/4-λ	1/4-wave	<0.1 dB	4 mm
RZB-1/2-λ	1/2-wave	<0.1 dB	4 mm
RMAB-1/4-IR	1/4-wave, 1200-1600 nm	<0.1 dB	4 mm
RMAB-1/2-IR	1/2-wave, 1200-1600 nm	<0.1 dB	4 mm

λ: when ordering , specify wavelength, for example RZB-1/2-1310.

OFR Retarders are manufactured to the exact wavelength of intended use, and all surfaces are AR coated. Therefore, when ordering, specify wavelength of operation.

For additional information on these and other Retarders, see PRECISION OPTICAL COMPONENTS, page OC-26.

Axis alignment into PM fiber using Half-Wave Retarder (RZB-1/2)

Attenuators

An OFR Neutral Density Filter, mounted in Fixed Component Base (see page FO-11), comprises the dB Attenuator Module. These are available in dB attenuation steps of 3, 6, 10, 20, 30 and 40 dB.

Any of these can be added in series to achieve higher attenuation values. For example, 20 dB plus 30 dB yield a total of 50 dB. This is easily achieved by setting the Modules onto the Component Stage.

Components are tilted to prevent back reflection.

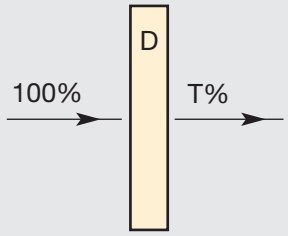
Both the FiberBench and FiberTable are designed to accept several Modules. See page FO-4.

Catalog Number	Attenuation Steps (dB)					
FDB-(dB)	3	6	10	20	30	40
Transmittance	0.50	0.2	10^{-1}	10^{-2}	10^{-3}	10^{-4}

Note: Order as FDB-20, for example.

Long FiberBench with FDB Attenuator Modules

Neutral Filters: Density vs Transmittance



$$D = \log_{10}\left(\frac{1}{T}\right)$$

$$T = (\log^{-1} D)^{-1} = (10^{D})^{-1}$$

HIGH POWER

Coupling Lenses

Coupling a laser output with maximum efficiency into a single-mode fiber requires a lens of extraordinary properties. Steep aspheric curves reduce back reflections, limiting feedback significantly in comparison to GRIN lenses. Optical performance must be diffraction limited. Insertion loss must be at an absolute minimum.

Such performance is typical of OFR Laser Lenses for Fiber-Optic and Laser Diode applications. These are micro double-aspheric Lenses, designed for diffraction limited performance. Both surfaces are multilayer anti-reflection coated. Transmittance exceeds 99% at the peak wavelength.

Mounted LLO series lenses are AR coated and mounted in a Microscope Objective Cell with industry standard RMS thread. Other mounting options available. Please inquire.

Unmounted LL series lenses as above but unmounted.

Interchangeable FiberPort Lenses, see page FO-7.

Threaded Adapter Rings

Two Adapter Rings are available for the FiberPort:

- RMS Thread Adapter for LLO Lenses
- C-Mount Adapter for miscellaneous, such as camera lenses.

These Adapter Plates bolt directly to the FiberPort Wallplate.

Mounted Double-Aspheric Lenses

Catalog Number	Focal Length	Working Distance	Numerical Aperture	Maximum Beam Dia.	Equivalent Magnification
LLO-4-18-λ*	18.4 mm	17.0 mm	0.13	4.4 mm	10X
LLO-6-11-λ	11.0 mm	9.1 mm	0.30	6.5 mm	16X
LLO-8-8-λ*	8.0 mm	5.5 mm	0.50	8.0 mm	20X
LLO-4-7-λ	7.5 mm	5.5 mm	0.30	4.5 mm	24X
LLO-4-4-λ	4.6 mm	2.4 mm	0.53	4.8 mm	40X
LLO-2-2-λ*	2.0 mm	0.9 mm	0.50	2.0 mm	90X

* not available for HoYAG.
NOTE: When ordering, specify wavelength, for example, LLO-4-4-NIR.

Unmounted Double-Aspheric Lenses

Catalog Number	Focal Length	Back Focal Length	Center Thickness	Numerical Aperture	Lens Diameter
LL-3-2-λ*	2.0 mm	0.9 mm	2.0 mm	0.50	3.0 mm
LL-4-7-λ	7.5 mm	5.8 mm	2.7 mm	0.27	4.0 mm
LL-4-11-λ	11.0 mm	9.6 mm	2.2 mm	0.18	4.0 mm
LL-6-5-λ	4.6 mm	2.9 mm	3.1 mm	0.53	6.0 mm

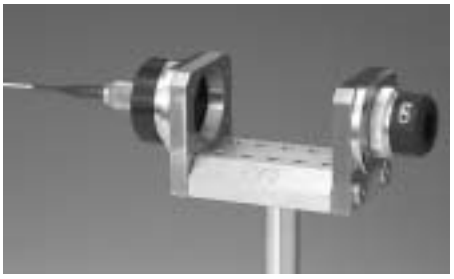
* not available for HoYAG.
NOTE: When ordering, specify wavelength, for example, LL-3-2-IR

Antireflection Coatings

Max T Spectrum	Order as
380 - 640 nm	- VIS
600 - 990 nm	- NIR
970 - 1100 nm	- YAG
1100-1550 nm	- IR
1.9 - 2.15 um	- HoYAG*

*LL-3-2, LLO-2-2 and LLO-8-8 not available for HoYAG.

LLO Aspheric Lenses in RMS Cells.



LLO Aspheric Lens Mounted on FiberBench

Catalog Number	Description
POA-RMS	RMS Threaded Adapter Ring for microscope objectives
POA-C	C-Mount Threaded Adapter Ring

Camera lens with C-Mount Adapter

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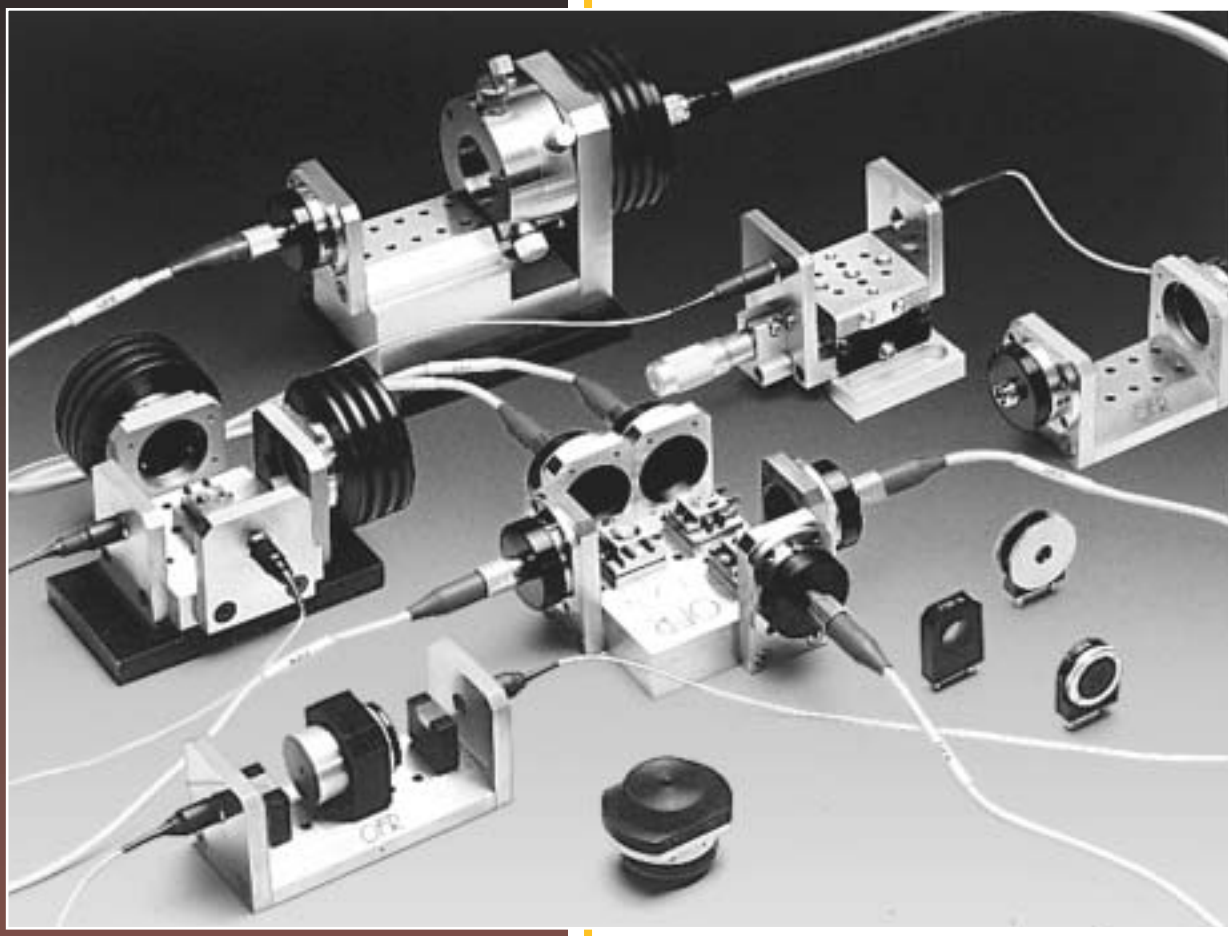


Assembled FiberBench Systems

We customize many of our standard FiberBench mini-systems. What's your requirement? Give us a call.

KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***...see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

Look for HIGH POWER ***Products***

NOTE: Power damage is generally fiber-limited. Discuss with OFR.

You will never be told to "Press 1 Now" when you call OFR!

Basic FiberBenches

One of the goals of the OFR FiberBench product line is to make possible the construction of specific fiber-optic mini systems that are not commercially available.

Stability is among the most important features of OFR's stainless steel FiberBench systems. The unique FiberPort (US patent) produces an expanded, collimated beam, and assures that a system remains aligned without loss of coupling efficiency.

Factory-assembled FiberBench Mini-Systems are pre-aligned for maximum coupling efficiency and throughput. Further, in order to assure alignment stability of FiberBench Mini-Systems, OFR has conducted shock, vibration and temperature testing on the three Basic Fiber-Benches. The result is that OFR FiberBench Mini-Systems retain alignment without degradation, in spite of environmental disturbances far beyond anything expected in most laboratory applications.

Normally, FiberBench Systems are permanently aligned with all components fixed in place, or they can be ordered without permanent affixing.

All OFR FiberBench Mini-Systems are tested, and a copy of test data is retained on file for every unit shipped.

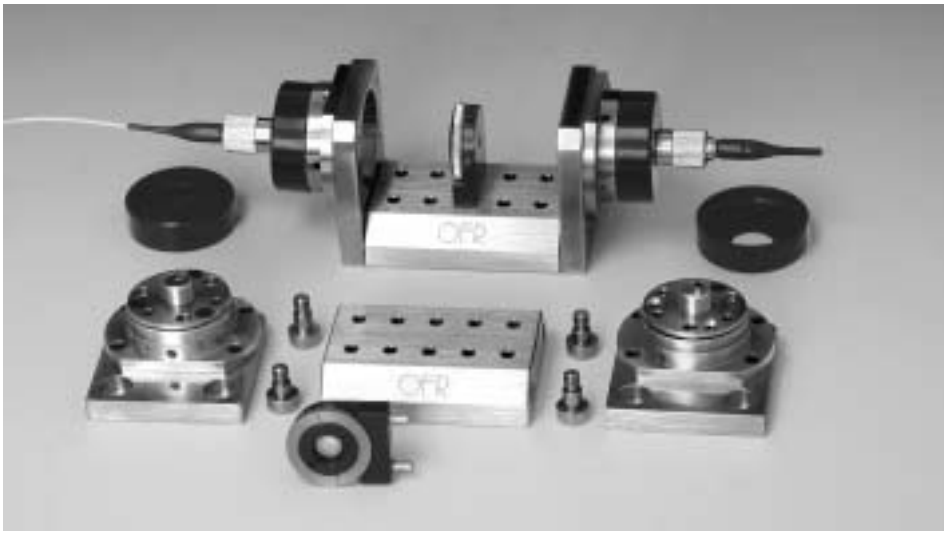
In addition to the OFR Factory Assembled FiberBench Systems described in the following pages, OFR will design and assemble custom configurations. Please call to discuss special requirements with OFR engineering sales department.

Build-it-Yourself Kits Available

Want to build your own FiberBench system? Discuss your application with an OFR engineer. He/she will help with your design, and will e-mail the complete list of part numbers to order. Your Kit will be delivered expeditiously along with assembly, alignment and test instructions.

Look for ***KITS*** designation, especially in Assembled FiberBench Systems, page FO-2 and following. Note also that custom-designed Fiber-Bench systems can be built from ***KITS***.

Consider this option when discussing your FiberBench requirement with OFR.



KIT... see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.
You will never be told to "Press 1 Now" when you call OFR!

Example

Build-It-Yourself *KITS* are available. Look for ***KITS*** throughout this catalog. See **www.ofr.com/fiberbench/kits** for schematic assembly diagrams and parts list as shown in the typical example below. See also page FO-2.

For **1x3 Variable Splitter, λ = 780 nm** (for example) ***KIT***, simply add "-KIT" on the part Number, for example, **PSFV-FFT-1x3-780-KIT**. The following parts, along with assembly, alignment and testing instructions, will be delivered.

Quantity	Part Number	Description	Page
1	FT-38x100	FiberTable	FO-4
4	PAF-X-λ	FiberPort	FO-6
2	PBB-10-780-L	Polarizer	FO-14
2	MY-B-780	45° Mirror	OC-16*
2	ACB	Aiming Base	FO-11
4	FCS-780-1-FC/APC	FiberCable	FO-9
2	RZB-1/2-780	Retarder	FO-15

*See PRECISION OPTICAL COMPONENTS catalog

HIGH POWER

Fiber-to-Fiber

The Fiber-to-Fiber Coupling System consists of the FiberBench Base with two FiberPorts and two (input & output) FiberCables (distal end is cleaved). The Fiber-to-Fiber Coupling System is "empty", containing no Optical Component Modules, and is used for coupling light from one fiber to another across an open air-gap.

In all FiberBench Coupling Systems using OFR PM FiberCables, both the slow axis and the FC receptacle keyway are vertical. Both the plane of polarization and the fiber stress rods are vertical.

A major feature of OFR FiberBench Coupling Systems is stability. Transmittance remains constant after temperature change, shock and vibration far greater than experienced in typical laboratory use.

STANDARD WAVELENGTHS (nm)

633	780	850	1310
670	810	980	1550
690	830	1064	

All OFR FiberBench Systems are available in two Hook-up Options:

- ❏ FC/APC Connector Interface (disconnectable). When ordering, terminate Part Number with-X.
- ❏ Permanent Pigtail, 1 meter. When ordering, terminate Part Number with-Y.

You will never be told to "Press 1 Now" when you call OFR!

Performance Specification of Typical FiberBenches

	S Base (1.5")	M Base (2.0")	L Base (3.0")
Fiber-to-Fiber Insertion Loss (dB)	0.4 ± 0.2	0.5 ± 0.2	0.7 ± 0.2
Return Loss at Input/Output (back reflection)	<50 dB		

Values shown are for single-mode fiber operating at 1310 nm or 1550 nm. Insertion loss can be higher with shorter wavelengths.
See pages 11 and 13 for descriptions of FiberBenches and FiberPorts, and page 15 for FiberCables.

Catalog Number	FiberBench Base	Input & Output FiberCable Type
KIT FFBS-S-λ-X or Y	Short Base, 1.5"	Standard Single-Mode
KIT FFBM-S-λ-X or Y	Medium Base, 2.0"	Standard Single-Mode
KIT FFBL-S-λ-X or Y	Long Base, 3.0"	Standard Single-Mode
KIT FFBS-P-λ-X or Y	Short Base, 1.5"	Polarization Maintaining
KIT FFBM-P-λ-X or Y	Medium Base, 2.0"	Polarization Maintaining
KIT FFBL-P-λ-X or Y	Long Base, 3.0"	Polarization Maintaining

When ordering, specify options as follows:
λ: Wavelength in nm
X: Connector Interface (FC/APC)
Y: Permanent Pigtail
For example FFBS-S-1310-X

KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***...
see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

FFBM-S-1310-X showing Connector Interface (FC/APC) FiberCables

FFBM-S-1310-Y showing Permanent Pigtail option

Laser-to-Fiber

The Laser-to-Fiber Coupling System consists of the FiberBench Base, a LaserPort and a FiberPort, with one output FiberCable with cleaved distal end . The Laser-to-Fiber Coupling System is "empty" (containing no Optical Component Modules), and is used for directly coupling a diode laser output into a fiber.

See page FO-7 for descriptions of LaserPorts that are available for the following laser types:

5.6 mm 9.0 mm TO3

OFR mounts and aligns customer furnished lasers. However, OFR bears no responsibility for performance of customer furnished laser, nor for damage to same while in OFR possession.

A customer-furnished TO3 laser mounts onto the OFR TO3 LaserPort.

In all FiberBench Coupling Systems using OFR PM FiberCables, both the slow axis and the FC receptacle keyway are vertical. Both the plane of polarization and the fiber stress rods are vertical.

A major feature of OFR FiberBench Coupling Systems is stability. Transmittance remains constant after temperature change, shock and vibration far greater than experienced in typical laboratory use.

STANDARD WAVELENGTHS (nm)

633	780	850	1310
670	810	980	1550
690	830	1064	

See pages FO-4 for descriptions of the FiberBench Base, FiberPort and LaserPort, and page FO-9 for FiberCables.

Laser-to-Fiber coupling Systems have disconnectable FC/APC output FiberCable.

Cooled and Non-Cooled Laser-to-Fiber Coupling Systems

A Non-Cooled Laser-to-Fiber Coupling System consists of a FiberBench with a Non-Cooled input LaserPort (page FO-7) and an output FiberPort (FO-6). A customer-furnished 5.6 mm or 9.0 mm laser is mounted on the LaserPort.

A Cooled Laser-to-Fiber Coupling System consists of a FiberBench with a T-E Cooled input LaserPort (page FO-7) and an output FiberPort (FO-6). A customer-furnished 5.6 mm or 9.0 mm laser is mounted on the cooled LaserPort. Included are the T-E cooling element and calibrated thermistor. OFR does not furnish the power supply.

A Cooled TO3 Laser-to-Fiber Coupling System consists of a FiberBench with an input LaserPort for TO3 laser (page FO-7) and an output FiberPort (FO-6). The customer-furnished TO3 laser and heatsink are mounted on the specially adapted LaserPort. OFR does not furnish the power supply.

Non-cooled Laser-to-Fiber Coupling System for customer-furnished 5.6 mm and 9.0 mm lasers.

T-E cooled Laser-to-Fiber Coupling System for customer-furnished 5.6 mm and 9.0 mm. OFR supplies T-E cooling element and calibrated thermistor, but not power supply

TO3 Laser-to-Fiber Coupling System, with customer-furnished TO3 laser and heatsink.

Catalog Number	FiberBench Base	Laser Type/Size (customer-furnished) "-*l*-"	Mini-System Type	Input & Output FiberCable
KIT FLBM-S-*l*-λ-X	Medium Base, 2.0"	5.6 mm, 9.0 mm,	Non-Cooled Coupling System	Standard Single-Mode
KIT FLBM-P-*l*-λ-X	Medium Base, 2.0"	5.6 mm, 9.0 mm,	Non-Cooled Coupling System	Panda PM
KIT FTBL-S-*l*-λ-X	Long Base, 2.0"	5.6 mm or 9.0 mm	T-E Cooled Coupling System	Standard Single-Mode
KIT FTBL-P-*l*-λ-X	Long Base, 2.0"	5.6 mm or 9.0 mm	T-E Cooled Coupling System	Panda PM
KIT FTBL-S-*l*-λ-X	Long Base, 2.0"	TO3	T-E Cooled Coupling System	Standard Single-Mode
KIT FTBL-P-*l*-λ-X	Long Base, 2.0"	TO3	T-E Cooled Coupling System	Panda PM

When ordering, specify options as follows:
l: Laser Type
λ: Wavelength in nm
X: Connector Interface (FC/APC)
For example FLBM-S-9.0-830-X.

KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***... see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

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HIGH POWER

Fiber-to-Fiber Isolators

The Fiber-to-Fiber Isolator consists of the FiberBench Base with two FiberPorts and two (input & output) FiberCables (distal end is cleaved). mounted on the FiberBench Base are the appropriate Isolator components.

OFR will assemble Isolators for the wavelengths listed below. These can include many non-standard wavelengths.

Both Polarization Dependent and Polarization Independent Isolators are available.

Flexibility in terms of wavelength fine-tuning, or pick-off of returned energy, for example, are possible with OFR FiberBench Isolators.

Available Wavelengths (nm)

633	780	850	1310
670	810	980	1550
690	830	1064	

All OFR FiberBench Systems are available in two Hook-Up Options:

- ❒ FC/APC Connector-Interface (disconnectable). When ordering, terminate Part Number with -X.
- ❒ Permanent Pigtail, 1-meter. When ordering, terminate Part Number with -Y.

See page FO-52 and following for smaller package, specific wavelength Isolators, both low and high power.

You will never be told to "Press 1 Now" when you call OFR!

Polarization Dependent

	Catalog Number	Fiber-In/Out
KIT	IO-G-FFB-λ-X or Y	PM

When ordering, specify Wavelength and Hook-Up Option:
λ: specify Wavelength in nm
X: specify Connector-Interface (FC/APC)
Y: specify Permanent Pigtail
For example IO-G-FFB-830-X

NOTE: that input plane of polarization must be parallel to slow axis of PM fiber (parallel to stress rods).
KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***...
see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

Performance Specifications	633 to 850 nm	980 nm	1064 nm	1310 & 1550 nm
Isolation at peak λ (dB)	33-38	30-36	36-40	36-40
Insertion Loss (dB)	1.3-1.8	1.5-2.0	1.5-2.0	1.0-1.7
Return Loss at Input/Output		>50 dB		
Bandwidth at 90% Peak Isolation		1-2% of Peak λ		

Polarization Independent

	Catalog Number	Fiber-In/Out
KIT	IO-F-FFB-λ-X or Y	Std. Single-Mode

When ordering, specify Wavelength and Hook-Up Option:
λ: specify Wavelength in nm
X: specify Connector-Interface (FC/APC)
Y: specify Permanent Pigtail
For example IO-F-FFB-830-X

NOTE: that input plane of polarization must be parallel to slow axis of PM fiber (parallel to stress rods).
KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***...
see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

Performance Specifications	633 to 850 nm	980 nm	1064 nm	1310 & 1550 nm
Isolation at peak λ (dB)	30-36	30-36	32-38	36-40
Insertion Loss (dB)	1.6-2.3	1.1-1.7	1.2-1.7	0.4-1.1
Polarization Dependent Loss		≤ 0.2 dB		
Polarization Mode Disperson		≤ 2.5 ps		
Return Loss at Input/Output		>50 dB		
Bandwidth at 90% Peak Isolation		1-2% of Peak λ		

IO-F-FFB-980-Y Isolator

IO-F-FFB-850-X Isolator

HIGH POWER

Laser-to-Fiber Isolators

A customer-furnished laser (5.6 or 9.0) is installed on an OFR Laser-to-Fiber Isolator. The Isolator is comprised of a T-E Cooled Laser-to-Fiber Coupling System (see page FO-20) on which are installed appropriate Isolator components.

OFR Laser-to-Fiber Isolators are available in all wavelengths listed below.

Output fiber is standard single-mode. Polarization maintaining (PM) or multimode (MM) fibers are available on special order. Please inquire.

A major feature of OFR FiberBench Coupling Systems is stability. Transmittance remains constant after temperature change, shock and vibration far greater than experienced in typical laboratory use.

Available Wavelengths (nm)

633*	780*	850*	1310
670*	810*	980*	1550
690*	830*	1064	

*also available for TO3

All OFR FiberBench Systems are available in two Hook-Up Options:

- ❒ FC/APC Connector-Interface (disconnectable). When ordering, terminate Part Number with -X.
- ❒ Permanent Pigtail, 1-meter. When ordering, terminate Part Number with -Y.

You will never be told to "Press 1 Now" when you call OFR!

IO-P-FTB-9-980-X, Laser-to-Fiber Isolator. Note that alignment of plane of polarization is achieved with a 1/2-wave retarder (RZB-1/2-980. page FO-15) mounted in RCB Rotation Base (page FO-11).

IO-P-FTB-TO3-780-X, TO3 Laser-to-Fiber Isolator

Catalog Number	"-*l*-" Laser Type (customer-furnished)	Fiber Out
KIT IO-P-FTB -*l*-λ-X or Y	5.6 mm, 9.0 mm, TO3	Std.Single-mode

When ordering, specify Wavelength and Hook-Up Option:
l: laser type 5.6, 9.0, TO3
λ: specify Wavelength in nm
X: specify Connector-Interface (FC/APC)
Y: specify Permanent Pigtail
For example IO-P-FTB-9.0-1310-X

KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***... see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

Performance Specifications	633 to 850 nm	980 nm	1064 nm	1310 & 1550 nm
Isolation at peak λ (dB)	33-38	30-36	36-40	40-44
Coupling (%)	>25	>30	>30	>30
Return Loss at Input/Output		>50 dB		
Bandwidth at 90% Peak Isolation		1-2% of Peak λ		

Isolator & Faraday Rotator Modules

HIGH POWER

Isolator Modules

An Isolator module is comprised of a Faraday Rotator with polarizers, mounted on a dowel-pinned base (see page FO-11) for mounting onto any FiberBench or FiberTable. Isolator Modules are aligned at OFR for the wavelength specified at time of order. The Isolator is polarization dependent. For a description of isolator function, see page IO-2.

Catalog Number	Select Wavelength	Isolation	Insertion Loss	Aperture	Body Type
IOB-3D-λ	760-840 mm	>30 dB	0.4-0.7 dB	3 mm	II (page IO-15)
IOB-2D-λ	960-1000 nm	>30 dB	0.4-0.6 dB	2 mm	II (page IO-15)
IOB-2D-λ	1040-1070 nm	>40 dB	0.3-0.5 dB	2 mm	III (page IO-15)
IOB-D-λ	1280-1340 nm	>40 dB	0.1-0.2 dB	1.7 mm	D (page IO-18)
IOB-D-λ	1450-1625 nm	>40 dB	0.1-0.2 dB	1.7 mm	D (page IO-18)

Note: specify wavelength when ordering

Faraday Rotator Modules (45°)

A primary application of a Faraday Rotator is in an Isolator or Circulator. Equally important is its use as a Faraday Rotator Mirror (see page FO-53) in an interferometer or sensor application. As with the Isolators above, the Faraday Rotator module is mounted on the dowel-pinned base for mounting onto any FiberBench of FiberTable. Faraday Rotators are aligned for 45° rotation at the wavelength specified at time of order.

Catalog Number	Select Wavelength	Isolation	Insertion Loss	Aperture	Body Type
IOB-3D-λ-I	630-860 nm	>30 dB	~0.1 dB	3 mm	II (page IO-15)
IOB-3D-λ-I	960-1000	>30 dB	0.2-0.4 dB	3 mm	II (page IO-15)
IOB-3D-λ-I	1047-1083 nm	>40 dB	~0.1 dB	3 mm	III (page IO-15)
IOB-D-λ-I	1280-1340 nm	>40 dB	~0.1 dB	1.7 mm	D (page IO-18)
IOB-D-λ-I	1480 or 1550 or 1625	>40 dB	~0.1 dB	1.7 mm	D (page IO-18)

Note: specify wavelength when ordering

Variable 1x2 & 1x3 Splitters

HIGH POWER

Variable 1x2 & 1x3 Splitters

A Variable Splitter consists of a Fiber Table with FiberPorts and appropriate optical components. The split ratio is varied by turning a 1/2- Wave Retarder mounted in a Rotating Base.

Catalog Number	Description	Variable Split Ratios
KIT PFSV-FFT-1x2 or 1x3-λ-X	FiberTable Variable Splitter	01/99 to 99/01

Note: specify wavelength in nm when ordering, and 1x2 or 1x3.

KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***... see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

Variable 1x2 Splitter with X-Ports.

Variable 1x3 Splitter with X-Port in, Y-Ports out.

FiberBench Variable Delay Lines

Variable Delay Lines

A Variable Delay Line is a modified FiberBench that is actually a stainless steel precision translation stage on which are mounted two FiberPorts.

Used in applications requiring a variable optical pathlength, the VDL Variable Delay Line has a precision z-axis translation slide with micrometer actuator. With the VDL it is possible to control with high resolution the air-path length of the collimated beam between the FiberPorts.

In order that the System retain the inherent stability of all FiberBenches, the OFR VDL Variable Delay Line is designed to eliminate backlash and cross-talk between axes, and to repeat within 1 µm (~3.3 f-s) anywhere over its travel range.

All OFR FiberBench Systems are available in two Hook-up Options:

- ❑ FC/APC Connector Interface (disconnectable). When ordering, terminate Part Number with -X.
- ❑ Permanent Pigtail, 1 meter. When ordering, terminate Part Number with -Y.

You will never be told to "Press 1 Now" when you call OFR!

Catalog Number	Air Gap Change (mm)	Total Delay (p-s)	Fiber In/Out	Insertion Loss
VDL-FFB-13-S-λ-X or X/Y	0-13 mm	0-43 p-s	SM	0.5-1.5 dB
VDL-FFB-13-P-λ-X or X/Y	0-13 mm	0-43 p-s	PM	0.5-1.5 dB
VDL-FFB-25-S-λ-X or X/Y	0-25 mm	0-83 p-s	SM	0.5-1.5 dB
VDL-FFB-25-P-λ-X or X/Y	0-25 mm	0-83 p-s	PM	0.5-1.5 dB

Note: 1 µm ≈3.3 p-s delay

When ordering, specify options as follows:

λ: Wavelength in nm

X: Connector Interface (FC/APC)

X/Y: Permanent Pigtail one end, connector other end

For example VDL-FFB-13-S-1550-X

KIT... see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

VDL-FFB-S-1310-X, Variable Delay Line

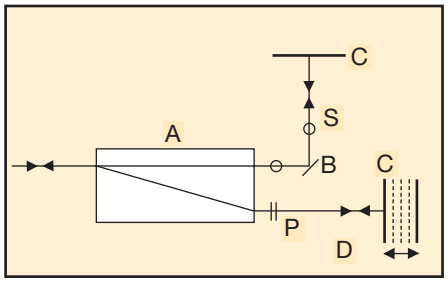
Variable Polarization Mode Disperser

A unique configuration of a combined 3-Port FiberTable, Variable Delay Line and 2 MirrorPorts, with appropriate optical components, allows a variable delay of one polarization mode with respect to the other of ±20 p-s (see photo).

For further information on this application, contact OFR. For use of the Variable PM Disperser in a **PMD Compensator** application, see page FO-30

Variable Polarization Mode Disperser

(A) Walk-Off Polarizer	FO-14
(B) PSP Beamsplitter	FO-13
(C) MirrorPort (2)	FO-8
(D) Variable Delay Bench	FO-24



Pathlength of p-mode is varied with respect to s-mode

HIGH POWER

FiberBench Retrace Systems

The Fiber-to-Mirror Coupling (Retrace) System consists of the FiberBench Base and one MirrorPort, with one FiberPort and one FiberCable (distal end is cleaved) serving both input/output functions. The Fiber-to-Mirror Coupling System is "empty," containing no Optical Component Modules, and is used for fiber path retrace applications.

The total (2-way) insertion loss of the FBM Retrace System is 0.5-1.0 dB.

Two applications for the Retrace Systems are:

- Faraday Rotator Mirrors, see below.
- Magnetic Field & Electrical Current Sensors, inquire.

See page FO-4 for descriptions of the FiberBench Base and FiberPort (FO-6), and page FO-8 for the MirrorPort.

Catalog Number	FiberBench Base	Input & Output FiberCable Type
KIT FMBS-S-λ-X or Y	Short Base, 1.5"	Standard Single-Mode

When ordering, specify options as follows:
λ: Wavelength in nm
X: Connector Interface (FC/APC)
Y: Permanent Pigtail
For example FMBS-S-830-X.

KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***... see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

STANDARD WAVELENGTHS (nm)

633	780	850	1310
670	810	980	1550
690	830	1064	

All OFR FiberBench Systems are available in two Hook-up Options:

❑ FC/APC Connector Interface (disconnectable). When ordering, terminate Part Number with -X.

❑ Permanent Pigtail, 1 meter. When ordering, terminate Part Number with -Y.

You will never be told to "Press 1 Now" when you call OFR!

FMBS-S-1550-X, Retrace System

HIGH POWER

Faraday Rotator Mirrors
(Orthoconjugate Retroreflector)

The Faraday Rotator Mirror consists of the Fiber-to-Mirror Coupling System plus a Faraday Rotator Module See page FO-53.

Two basic applications are possible:

- minimizing effects of polarization state changes in single-mode retrace applications, e.g., Michelson Interferometer. Request separate literature from OFR.
- as polarization-state 90° rotator in retrace circuits in fiber-optic lasers and fiber-optic amplifiers.

A major feature of OFR FiberBench Coupling Systems is stability. Transmittance remains constant after temperature change, shock and vibration far greater than experienced in typical laboratory use.

STANDARD WAVELENGTHS (nm)

633	780	850	1310*
670	810	980	1550*
690	830	1064	

Catalog Number	Fiber
KIT MFI-FMB-λ-X or Y	Std. Single-Mode

When ordering, specify options as follows:
λ: Wavelength in nm
X: Connector interface (FC/APC)
Y: Permanent Pigtail
For example, MFI-FMB-1310-X.

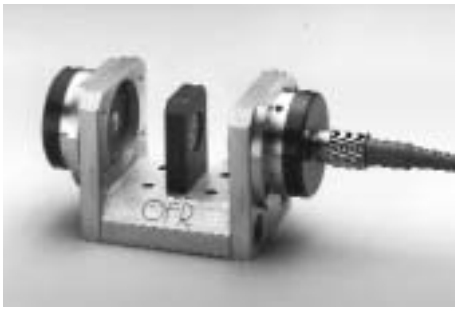
KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***... see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

All OFR FiberBench Systems are available in two Hook-up Options:

❑ FC/APC Connector Interface (disconnectable) When ordering, terminate Part Number with -X.

❑ Permanent Pigtail, 1 meter. When ordering, terminate Part Number with - Y.

You will never be told to "Press 1 Now" when you call OFR!



MFI-FMB-1550-X, Faraday Rotator Mirror

Variable Attenuators

The OFR Variable Attenuator consists of the Fiber-to-Fiber Coupling System plus appropriate Polarizer and Retarder Modules. See pages FO-13,14 for descriptions.

Both Polarization Dependent and Independent Variable Attenuators are possible.

In all FiberBench Coupling Systems using OFR PM FiberCables, both the fast axis and the FC receptacle key-way are vertical. Both the plane of polarization and the fiber stress rods are horizontal.

A major feature of OFR FiberBench Coupling Systems is stability. Transmittance remains constant after temperature change, shock and vibration far greater than experienced in typical laboratory use.

STANDARD WAVELENGTHS (nm)

633	780	850	1310
670	810	980	1550
690	830	1064	

All OFR FiberBench Systems are available in two Hook-up Options:

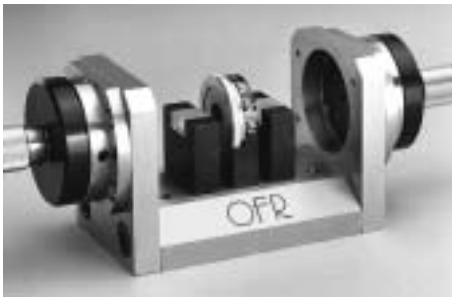
- ❑ FC/APC Connector Interface (disconnectable). When ordering, terminate Part Number with -X.
- ❑ Permanent Pigtail, 1 meter. When ordering, terminate Part Number with -Y.

You will never be told to "Press 1 Now" when you call OFR!

Catalog Number	Polarization Type	Attenuation Range	Fiber
KIT VA-FFB-S-λ-X or Y	Independent	(1-40) dB)	Std. Single-Mode
KIT VA-FFB-P-λ-X or Y	Dependent	(1-40) dB)	PM

When ordering, specify options as follows:
λ: Wavelength in nm
X: Connector Interface (FC/APC)
Y: Permanent Pigtail
For example VA-FFB-S-1310-X

KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***...
see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.



VA-FFB-S-980-X, Variable Attenuator

FiberBench Polarization Control & Measurement

Our customers tell us that polarization is their most important problem. Here are some of our solutions.

KIT... see **www.ofr.com/fiberbench/kits,** or call OFR and speak to an engineer.

Look for HIGH POWER ***Products***

NOTE: Power damage is generally fiber-limited. Discuss with OFR.

You will never be told to "Press 1 Now" when you call OFR!

Polarization Reference Standards

SOP* Reference (Patent 6,061,190)

***State of Polarization**

Please see page FO-31 for a description of the SOP Module. This, mounted on a FiberBench, is used to generate 4 states of polarization.

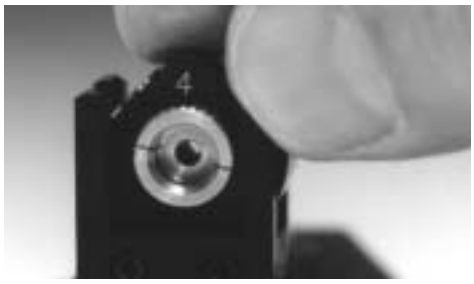
The heart of the SOP Module is an assembly containing a PCB Linear Polarizer and an RZB-1/4 Retarder. The Module is set in the appropriate positions to generate the States of Polarization.

State	Position
Linear Horizontal (0°)	No. 1 is up
Linear Vertical (90°)	No. 2 is up
Linear (45°)	No. 3 is up
Circular, right	No. 4 is up, rotated

These are wavelength specific. Therefore, specify wavelength when ordering

Catalog Number	Description	Aperture
SOP-λ	SOP Reference*	2 mm

λ: when ordering, specify wavelength.
* FiberBench must be ordered separately



Module is manually set in various positions.

Linear Polarization Reference (0°, 45°, 90°, 135°)

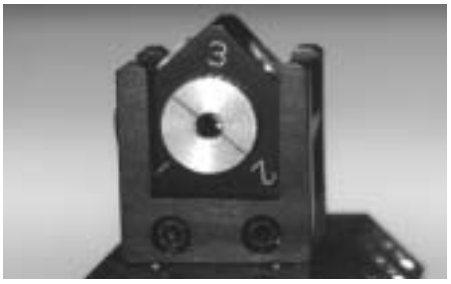
The Linear Polarization Reference establishes a reference plane, starting at 0°, and then at every 45°. The LP Reference consists of a PCB Linear Polarizer in an SOP Module, held in a Capture Cage.

Plane	Position
0° (Horizontal)	No. 1 is up
90° (Vertical)	No. 2 is up
45°	No. 3 is up
135°	No. 4 is up, rotated

These are wavelength specific. Therefore, specify wavelength when ordering

Catalog Number	Description	Aperture
LPR-λ	LP Reference*	2 mm

λ: when ordering, specify wavelength.
* FiberBench must be ordered separately



LP Reference is based on SOP Module (US Patent 6,061,190)

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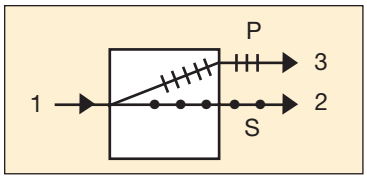
In-Line Polarizer with SOP* Monitor Output

***State of Polarization**

Based on the OFR Polarization Splitter design (see page FO-49), the In-Line Polarizer contains a crystal polarizer (see page FO-14) that separates light into its S and P components by >55 dB. Assuming the input is predominately S-polarized, with some P-polarized component included, the In-Line Polarizer passes pure S-pol straight through and out from Port 2. Any P-pol content is split off and outputs from Port 3.



Applications

- ❒ Fiber extinction measurement
- ❒ Clean-up polarizer
- ❒ System monitoring of linear polarized light
- ❒ Feedback source for active polarization control
- ❒ Polarization analysis

Clean-Up Polarizer

The slow axis of the input PM fiber at Port 1 is aligned to the polarizing axis of the crystal so that only correctly aligned S-pol can pass through to output Port 2. Any P-pol component is split off and directed to Port 3, the monitor output.

Thus, the In-Line Polarizer "cleans up" degraded extinction ratio in a PM fiber by removing the P-pol component and passing only the S-pol.

SOP Monitor, Port 3

Because any P-polarized component in the input is split off and is output from Port 3, that output can be used to monitor any change in SOP of the input PM fiber. For information on polarization analysis, see page FO-31.

Definitions

Port 3 Signal (total P-pol component in the input) = **Port 3 Output - Polarization Noise** (inherent leakage of S-pol into Port 3 Output).

Thus, Polarization Noise limits the minimum detectable departure of the input from "perfect" SOP.

Extinction Ratio Resolution is the ratio of **Port 3 Signal ÷ Port 2 Signal**, where Port 2 Signal is the S-pol content in the input. This indicates the minimum detectable "undesirable" polarization.

Specifications	(1→2)	(1→3)
Insertion Loss	0.4-0.9 dB	0.5-1.1 dB
Extinction (output from PM fiber at Port 2)	>27-34 dB	
Polarization Noise*	<26-32 dB	
Extinction Ratio Resolution	>30-36 dB	
Return Loss (back reflection)	>50-65 dB	
PM Fiber	PANDA	

* Polarization Noise results from alignment error between fiber axis and polarizer axis, and extinction of input PM fiber (normalized value provided on data sheet).

Catalog Number	Description
PFP-λ-P/P/P	In-Line Polarizer with Monitor Output, PM at Port 3
PFP-λ-P/P/S	In-Line Polarizer with Monitor Output, SM at Port 3

NOTE: specify wavelength in nm, for example, PFP-1550-PPS.

Add-On Polarizers

Stainless Steel Add-On Polarizers are designed to slip onto a Snap-On Collimator (page FO-45), to polarize the collimated beam output.

❒ **Linear Polarizer**
AR coated, dichroic thin-plate Polarizer, ≥ 45 dB (3 x 10^{-4}), > 98% transmittance, in Rotating Mount.

Wavelength Range	Order as	Transmittance
630-860 nm	VIR	85-95%
960-1100 nm	YAG	96-98%
1275-1350 nm	IR1	98%
1480-1600 nm	IR2	98%

Catalog Number	Catalog Order as
PSO-L-λ	Linear Polarizer

λ: When ordering, specify wavelength. For example, PSO-L-IR2.

Applications:
- clean-up polarizer
- measuring extinction of PM fiber

Extinction measurement of PM fiber could not be easier. First, turn the Add-On Polarizer to maximum output from the PM FiberCable and measure that value. Then, turn the Polarizer to minimum output and measure that. The ratio is the extinction.

The Add-On Polarizer slips onto the Snap-On Collimator, and locks in place after the desired plane-of-polarization orientation has been set. A unique magnetic coupling enables this adjustment without danger of drifting.

Add-On Polarizer (Standing at the rear) slips onto any Snap-On-Collimator, page FO-45.

FiberBench Polarization Controller

The OFR Polarization Controller replaces conventional looped fiber types, yet performs the same functions. It consists of the Fiber-to-Fiber Coupling System with appropriate Retarder Component Modules. See page FO-15 for description of Retarder Modules.

Control of polarization is achieved through the use of 1/4-Wave and 1/2-Wave Retarders whose parameters are not affected by environmental changes on the fiber. This accounts for the stability of the OFR Polarization Controller.

A Linear Polarizer (page FO-14) is the third Module in the PC-FFB. It precedes or follows the 1/4-Wave and 1/2-Wave Retarders (in that order) according to the application. See **www.ofr.com/fiberbenches/polarizationcontroller**.

In contrast, looped fiber controllers are sensitive to environmental changes, and therefore must be frequently adjusted.

In all FiberBench Coupling Systems using OFR PM FiberCables, both the fast axis and the FC receptacle key-way are vertical. Both the plane of polarization and the fiber stress rods are horizontal.

A major feature of OFR FiberBench Coupling Systems is stability. Transmittance remains constant after temperature change, shock and vibration far greater than experienced in typical laboratory use.

You will never be told to "Press 1 Now" when you call OFR!

Questions	OFR Polarization Controllers	Looped Fiber Polarization Controllers
Is PM output fiber available as standard?	Yes	No. PM fiber must be Spliced to output SM fiber
What about time, temperature and motion stability?	Extremely stable. Insensitive to physical disturbances.	Sensitive to physical disturbances. Drifting is common.

Typical insertion loss is ≤1 dB (fiber-to-fiber). Return loss < 50 dB input/output.

Catalog Number	Fiber
KIT PC-FFB-S/S-λ-X or Y	Std. Single-Mode
KIT PC-FFB-S/P-λ-X or Y	SM/in, PM/out

When ordering, specify options as follows:
λ: Wavelength in nm
X: Connector Interface (FC/PC)
Y: Permanent Pigtail
For example, PC-FFB-S/S-1550-Y.

KIT...FiberBench Systems are also available as Build-it-Yourself ***KITs***...
see **www.ofr.com/fiberbench/kits**, or call OFR and speak to an engineer.

PC-FFB-S/P-1550-X

PC-FFB-S/S-1310-Y

OFR Polarization Controllers include RZB-1/4, RZB-1/2 and PCB. See pages FO-14 and FO-15.

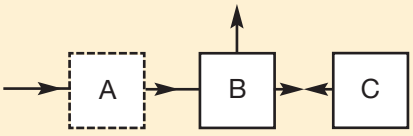
PMD Compensation/Manipulation

The Variable PM Disperser (see page FO-24), in combination with a Polarization Controller and Circulator, can be used to control PMD ±20 ps.

Please contact OFR for more information on this new application.

Variable Polarization Mode Disperser

	Page
(A) Polarization Controller (optional)	FO-29
(B) Circulator	FO-53
(C) PM Disperser	FO-24



Suggested FiberBench configuration for control of PMD

FiberBench Polarization Analyzer

Introduction

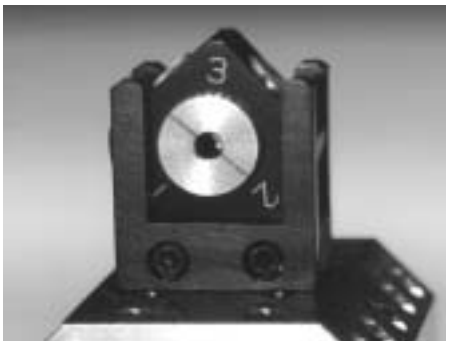
FB-PAM, the OFR FiberBench Polarization Analyzer, is a highly accurate, intuitive, and easy-to-use manual polarimeter. The System completely describes the State of Polarization (SOP) of light, whether from an optical fiber, or from a free-space beam.

The FB-PAM consists of a Fiber Bench Collimator System on which is mounted a Module Capture Cage with State of Polarization (SOP) Module. Included are analysis software, applications notes and operations manual.

Description

The FB-PAM uses time-sequential polarimetry, the most fundamental method of polarization measurement. Here, four required intensities are measured in sequence.

The heart of the FB-PAM is the SOP Module, a triangular block in which are mounted a Polarizer and a 1/4-Wave Retarder. The Module is set into its Capture Cage which is mounted on the FiberBench base plate. The Module is inserted into the beam path, and the four intensity values are measured. These numeric values are entered into the supplied analysis software, which calculates and displays complete polarimetric information in graphical and tabular form.



SOP Module in Capture Cage (US patent 6,061,190), 2 mm aperture

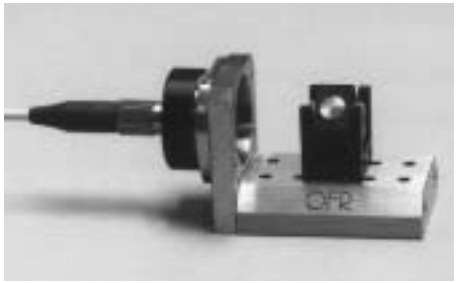
The accuracy of the FB-PAM is ensured by the tight manufacturing tolerances of the SOP Module. It is a precision machined 45°-45°-90° triangle, the simplest of geometric shapes. Measurements are made with the Module in each of three positions, corresponding to the three faces of the triangle. The design eliminates human error.

An added safety feature of the Module Capture Cage is that it does not allow the SOP Module to tilt during installation/removal, thus eliminating any chance of stray reflections from optical surfaces.

Finally, all optical surfaces are deeply recessed in the Module, thus preventing inadvertent fingerprints on optical apertures.

Operation

In order to analyze the SOP of light, the FB-PAM requires a collimated beam. Normally, the light-under-test is from an optical fiber. This fiber is connected to the FiberPort Collimator. From this, a collimated beam transmits through the optical components in the SOP Module and directly to a detector or power meter.



FB-PAM, FiberBench Polarization Analyzer

The FB-PAM can be bolted directly to the optical table, or it can be post-mounted to simplify alignment. Any detector or power meter can be used to measure the transmitted intensity.

A high strength magnet is imbedded in the Cage Base, and a magnetic disc is imbedded in each of the three facets of the SOP Module. When the Module is set in any of its three positions, the Cage Base magnet grabs against the corresponding magnetic disc in the SOP Module. This force of attraction, in combination with tight-tolerance machining, assures absolutely repeatable positioning, time-after-time, as the Module is set in sequence in the Cage.

SOP Module is manually set in 4 positions.

The Sequence of Measurements is as follows.

Measurement #1: the SOP Module is reset in the Cage so that the engraved '1' is at the top position, facing the beam. In this position, the horizontal, linearly polarized portion of the light-under-test is measured. The value on the power meter is entered into the appropriate box in the software.

SOP Module sets into Module Capture Cage, in Positions 1 thru 3.

Measurement #2: the SOP Module is reset in the Cage with the engraved '2' at the top position. The vertical, linearly polarized portion of the light-under-test is measured. The value is entered.

Measurement #3: the SOP Module is reset with the engraved '3' at the top position. The 45°, linearly polarized portion of the light-under-test is measured. The value on the power meter is entered.

FiberBench Polarization Analyzer

Measurement #4: during the previous three measurements, the engraved #4 has faced away from the input beam. Now, it is necessary to turn the SOP Module "backwards" so that the #4 faces forward, and is at the top. In this position, the right-circularly polarized portion of the light-under-test is measured. The value is entered.

Position 4 is on the reverse side of Module, behind position 3.

File Edit View Insert Format Tools Data Window Help

OFR FiberBench Polarization Analyzer

USER INPUTS

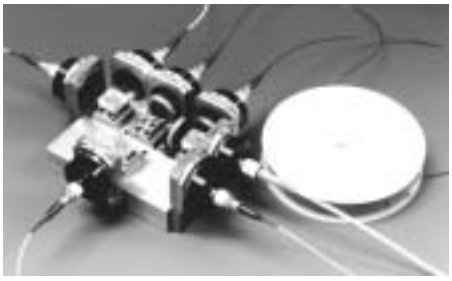
power 1 (horizontal polarizer)	95.2
power 2 (vertical polarizer)	45.6
power 3 (45° polarizer)	122.5
power 4 (circular polarizer)	30.05

Data analysis

These four intensity measurements are all that is required to calculate all of the polarimetric information about the light-under-test. The software processes the data via matrix multiplication (the exact details of which depend on the Calibration Option selected by the user).

The following quantities are calculated and displayed in the software:

- Stokes Parameters
- Jones Vector
- Degree of Polarization
- Degree of Linear Polarization
- Linear Polarization Extinction
- Azimuth Angle
- Degree of Circular Polarization, Ellipticity, Helicity (handedness)

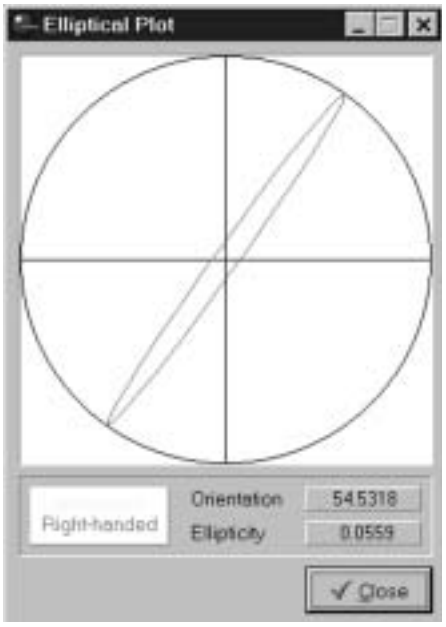


Custom Polarization Analyzer with 100 meter-phase delay line.

Stokes parameters		**Jones Vector**	
SO	1.000	Ex	0.8223
S1	0.3523	Ey	0.5692
S2	-0.7401	d (degrees)	142.2432
S3	0.5732	d (waves)	0.3954
		Polarimetric Data	
Degree of Polarization	100.0%	orientation angle	32.273
Degree of Linear Polarization	82.0%	ellipticity (E-field	0.315
Degree of Circular Polarization	57.3%	helicity	right handed
Linear Extinction (dB)	-10		

Sample data box generated by analysis spreadsheet

Plots of the Degree of Polarization, Stokes Parameters, and Polarization Ellipse are generated, and can be printed or exported to other applications.



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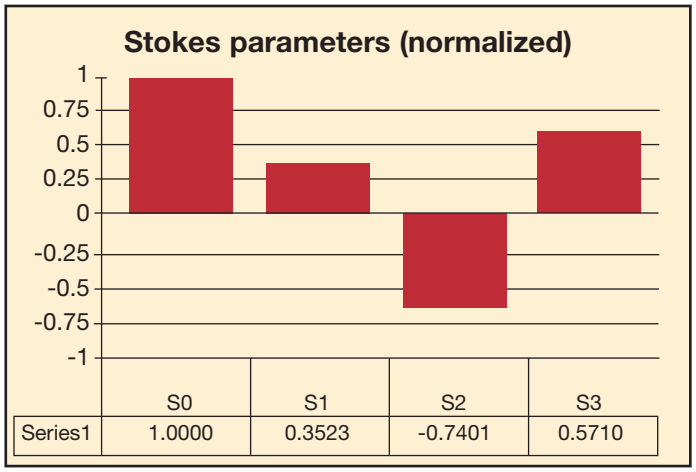
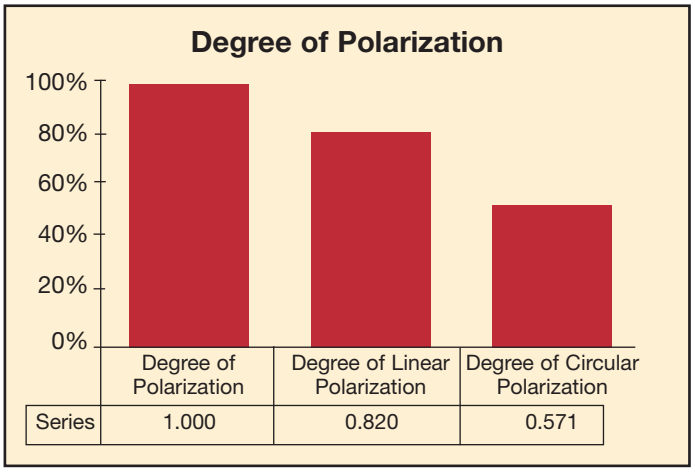
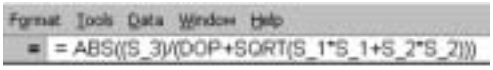
FiberBench Polarization Analyzer





In addition, the Excel™ platform allows the user to customize the program and to add calculations, plots, and graphs.



Sample formula (calculates degree of polarization). Formulas can be added or modified to suit specific needs or applications.

Applications

In addition to measuring the SOP of light-under-test, the FB-PAM can also characterize fiber-pigtailed devices and bulk optics. For example, the FB-PAM can answer the following questions:

- ❒ What is the SOP of a signal (free-beam or fiber-optic)?
- ❒ What is the Polarization-Dependent Loss/Gain of a fiber device?
- ❒ What is the extinction ratio after propagating through PM or PZ fiber?
- ❒ What is the retardance of a retarder?
- ❒ Has a signal been depolarized after propagating through a long single mode fiber? Through a multimode fiber?
- ❒ Is the SOP changed after propa gating through short lengths of singlemode fiber?
- ❒ What are the effects of multilayer coatings on the SOP?
- ❒ What are the polarizing effects of a beamsplitter?
- ❒ Does a beamsplitter change the phase of the polarization?
- ❒ How effective is a depolarizer at reducing degree of polarization?

Theory

The State of Polarization (SOP) of light describes the orientation and oscillation of its electric field. It is uniquely specified by four quantities known as the *Stokes Parameters*. These Parameters, designated as S_0, S_1, S_2 and S_3, are defined as:

$S_0 = I_{0°} + I_{90°}$	(horizontal + vertical)
$S_1 = I_{0°} - I_{90°}$	(horizontal - vertical)
$S_2 = I_{45°} - I_{135°}$	(45° - 135°)
$S_3 = I_{RCP} - I_{LCP}$	(right circular - left circular)

Where:

- ❒ $I_{x°}$ refers to the intensity of the light that transmits through a Linear Polarizer oriented at x°.
- ❒ I_{RCP} and I_{LCP} are the intensities transmitted through a right-hand and left-hand circular polarizer, respectively.
- ❒ S_0 is the total intensity of the light.
- ❒ S_1 represents the dominance of horizontally polarized light vs. vertically-polarized light.
- ❒ S_2 represents the dominance of 45° polarized light vs. 135° polarized light.
- ❒ S_3 represents the dominance of right-circular polarization vs. left-circular polarization.

Although six intensity values are required to define the Stokes Parameters, a fundamental relationship allows the four measurements: $I_{0°} + I_{90°} = I_{45°} + I_{135°} = I_{RCP} + I_{LCP}$.

When the Stokes Parameters are known, the SOP can be completely described. It is a remarkable result that the electric field can be determined solely by these intensity values.

Polarization State	S_0	S_1	S_2	S_3
Linear, Horizontal	1	1	0	0
Linear, 135°	1	0	-1	0
Linear, 30°	1	0.5	0.866	0
Circular, right handed	1	0	0	1
Unpolarized	1	0	0	0
50% unpolarized, 50% elliptical	1	0.235	-0.120	-0.424

FiberBench Polarization Analyzer

Calibration

Conversion of intensity measurements to Stokes Parameters is achieved by multiplying the data by an "instrument matrix", which uniquely characterizes the Polarization Analyzer. This instrument matrix is a function of the operating wavelength, because the optics will be wavelength dependent. However, the FB-PAM is designed to have low wavelength dependence.

In order to determine the instrument matrix, the entire System must be calibrated. Two Calibration Modes are available with the FB-PAM:

Built-in Data Tables are used for compensation when operating at wavelengths other than the design wavelength.

Matrix Calibration makes no assumptions about the system components. Therefore, a more rigorous calibration procedure is used to describe system characteristics at any wavelength.

Specifications:

The FB-PAM FiberBench Polarization Analyzer includes:

- State of Polarization Module
- Module Capture Cage
- FiberBench with Input FiberPort
- Analysis Software

For free-space applications, the Input FiberPort is easily removed from the FiberBench. The FB-PAM can be post-mounted or table-mounted.

Standard Wavelengths	633-1600 nm (specify λ)
Spectral Bandwidth	±10% of the design wavelength
Operating power range	< 200 mW (higher with optional attenuator)
Degree of Polarization uncertainty	1% calibrated
Orientation Angle uncertainty	0.5% for linear polarization (15 minutes)
Software	2 versions included: Windows-based graphical software (PC only), and Excel™ spreadsheet files (PC or Mac™)
System Requirements	Detector or Power Meter, computer (PC or Mac™)

DetectorPorts

An optional means of measuring intensities is the DetectorPort, which is mounted on a FiberBench or FiberTable. The DetectorPort contains an amplified silicon or InGaAs detector (for visible or infrared operation, respectively), whose output voltage is proportional to the average (cw) intensity of light. This voltage is measured using any voltmeter or oscilloscope.

DetectorPort on FB-PAM, Polarization Analyzer

Specifications:

Detector area	0.8mm² (InGaAs)
Bandwidth	50 MHz
Wavelength	400-1100 nm (silicon) 800-1800 nm (InGaAs)
Input	110 VAC (power supply included)
Output	BNC connector

Catalog Number	Description
FB-PAM-λ	FiberBench™ Polarization Analyzer System, including FiberBench, FiberPort, SOP Module with Module Capture Cage, and Analysis Software.
SOP-λ	State-of-Polarization (SOP) Module, for other wavelengths.
PAD-λ	DetectorPort

λ When ordering, specify wavelength in nm, for example, FB-PAM-1550.

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Fiber-Optic Collimators

FiberPorts are among our hottest products. And these neat little attachments are the coolest!

Look for HIGH POWER *Products*

NOTE: Power damage is generally fiber-limited. Discuss with OFR.

You will never be told to "Press 1 Now" when you call OFR!

HIGH POWER

FiberPort Collimators

OFR FiberPorts serve both input and output collimating. Please see page FO-6 for details and specifications on FiberPorts.

For input coupling details, see page FO-5

Collimators...to produce a collimated output beam from a fiber

- ❏ VariFocus, for FC or SMA Snap-On Collimators (pages, FO-45, 46)
- ❏ Fixed collimation Pigtailed Collimators (page FO-47)
- ❏ VariFocus, beam steering FiberPorts (pages FO-37, 38)

OFR Snap-On and Pigtailed Collimators and FiberPorts are designed to produce an expanded beam.

Actual Beam Size	Collimated Beam Diameter	Single Mode Part Number	Multimode Part Number	Collimator Type
·	0.5 mm	CFC-2		Snap-On
·	0.5 mm	CFS-T		Pigtailed
·	0.5 mm	PAF-X-2		FiberPort
•	1.0 mm	CFS-T-5		Pigtailed
•	1.0 mm	CFC-5		Snap-On
•	1.0 mm	PAF-X-5		FiberPort
•	1.6 mm	CFC-8		Snap-On
•	1.6 mm	PAF-X-7		FiberPort
•	2.0 mm		CSMA-5	Snap-On
•	2.0 mm		CFC-5	Snap-On
•	2.0 mm		CFM-T-5	Pigtailed
•	2.0 mm		PAF-XM-5	FiberPort
•	2.0 mm		PAF-SMA-5	FiberPort
•	2.4 mm	CFS-T-11		Pigtailed
•	2.4 mm	PAF-X-11		FiberPort
•	3.4 mm		CSMA-8	Snap-On
•	3.4 mm		CFC-8	Snap-On
•	3.4 mm	PAF-X-15	PAF-XM-7	FiberPort
•	3.4 mm		PAF-SMA-7	FiberPort
•	4.0 mm	CFS-T-18		Pigtailed
•	4.9 mm		CFM-T-11	Pigtailed
•	4.9 mm		PAF-XM-11	FiberPort
•	4.9 mm		PAF-SMA-11	FiberPort

FiberPorts

The OFR FiberPort is an ultra-stable, miniature micropositioner, enabling active alignment of an OFR aspheric lens for collimating or free beam-to-fiber coupling. While performing the same functions as larger benchtop 5-axis positioners, the compact size of the FiberPort makes it ideally suited for incorporating into shipable, OEM equipment, as well as for utility in the development laboratory.

Applications for FiberPorts are:

- ❒ Input launching of a collimated beam into a fiber.
- ❒ Output collimating from a fiber.
- ❒ Beam Steering of collimated beam.

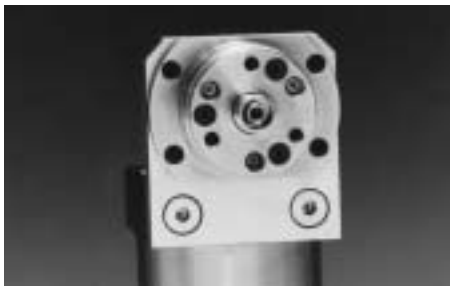
Which fiber? How is it connected?

Fiber Type	FiberPort	FiberPort Receptacle	Description
SM or PM	X-Version	FC	For FC connectorized fiber
SM or PM	H-Version	none	Non-detachable pigtail
MM	XM-Version	FC	For FC connectorized fiber 50 µm, 62.5 µm, 100 µm core
MM	SMA-Version	SMA	For SMA connectorized fiber 50-600 µm core

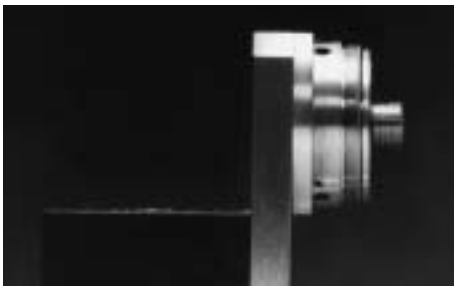
FiberPorts are available for single-mode (SM), polarization-maintaining (PM) and multimode (MM) fibers. FiberPorts, which mate to detachable, connectorized fibers, are available with FC receptacle (X-Type and XM-Type) or SMA receptacle (SMA-Type).

The micro-aspheric Lens in the Fiber-Port is AR coated. Specify wavelength when ordering. For a description of the micro-aspheric Lenses, see **Coupling Lenses**, page FO-15.

H-Type FiberPort with non-detachable PM pigtails, on custom 4-Port, Polarization-Dependent Circulator for 1550nm.



FiberPort with cover removed, face view, showing coupling adjust-and-lock screws



FiberPort with cover removed, side view, showing access to beam steering adjusting screws (x-y plane lens adjustment).

FiberPort for Single-Mode & Polarization-Maintaining Fibers

OFR X-Type FiberPorts use an FC receptacle for FC-connectorized fibers. For applications requiring non-detachable fiber pigtail, H-Type FiberPorts are also available.

The fiber connecting to a FiberPort terminates in air. To minimize the effects of the resultant back reflection, an FC/APC angle-polished connector is used. On the other hand, with an FC/PC connector or a straight polished connector, there is a -14 dB return loss. OFR FiberCables are available in standard FC/APC or optional FC/PC.

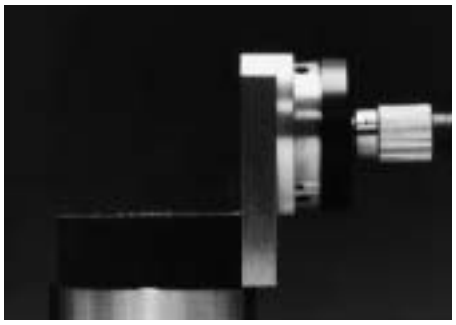
LAUNCHING A FREE-BEAM INTO PM FIBER. It is critical that fiber and laser polarization axes be aligned when launching into a PM fiber. This task is made much easier if a 1/2-Wave Retarder is inserted into the beam.

A FiberBench solution is recommended, with rotatable zero-order 1/2-Wave Retarder for rotation of polarization plane, mounted onto the FiberBench base. Alignment is then a straightforward procedure.

Single-Mode FiberPorts* for SM & PM Fiber with FC Connector

Catalog Number	Effective Focal Length	(Coupling) Input Beam Diameter	Collimated Output Beam Diameter	Best Collimation Distance at
PAF-X-2-λ	2.0 mm	0.3-0.8 mm	0.5 mm	1-20 cm
PAF-X-5-λ	4.6 mm	0.8-1.4 mm	1.0 mm	10 cm & beyond
PAF-X-7-λ	7.5 mm	1.2-2.0 mm	1.6 mm	20 cm & beyond
PAF-X-11-λ	11.0 mm	1.9-3.0 mm	2.4 mm	20 cm & beyond
PAF-X-15-λ	15.4 mm	2.8-4.0 mm	3.4 mm	30 cm & beyond

λ: Specify wavelength in nm.
*Optional FiberCables, with FC connector, are ordered separately See page 10.
NOTE: For coupling into PM fiber, a FiberBench solution is recommended. See above.



FiberPort (US Patent 5,638,472) on HCP Bracket

FiberPorts with SM or PM Pigtail (non-disconnectable)

Catalog Number	Coupling Input Beam Diameter	Collimated Output Beam Diameter	Best Collimation Distance at
PAF-H-(S or P)-2-λ	0.3-0.8 mm	0.5 mm	1-20cm
PAF-H-(S or P)-5-λ	0.8-1.4 mm	1.0 mm	15 cm & beyond
PAF-H-(S or P)-7-λ	1.2-2.0 mm	1.6 mm	20 cm & beyond
PAF-H-(S or P)-11-λ	1.9-3.0 mm	2.4 mm	50 cm & beyond

λ: Specify wavelength in nm.
S or P: When ordering, specify Single-mode (S) or Polarization Maintaining (P) pigtail (1 meter long)
NOTE: For coupling into PM fiber, a FiberBench solution is recommended. See previous page.

FiberPort for Multimode Fibers

HIGH POWER

OFR XM-Type FiberPorts use an FC receptacle for FC-connectorized MM fibers. SMA-Type FiberPorts are for SMA connectorized fibers.

FiberPorts are available for 50 µm, 63 µm and 100µm core diameter, FC-connectorized fibers, and for SMA-connectorized fibers with 50 µm, 63 µm and 100-600 µm core diameter.

For complete description of all OFR FiberCables, see FiberCables, page FO-9.

Multimode FiberPorts for MM Fiber with FC or SMA Connector

Catalog Number	Receptacle	Effective Focal Length	FiberPort N.A.	Collimation Output Beam Diameter
PAF-XM-5-λ	FC*	4.6 mm	0.40 mm	2.0 mm
PAF-XM-7-λ	FC*	7.5 mm	0.33 mm	3.4 mm
PAF-XM-11-λ	FC*	11.0 mm	0.24 mm	4.9 mm
PAF-SMA-5-λ	SMA**	4.6 mm	0.40 mm	2.0 mm
PAF-SMA-7-λ	SMA**	7.5 mm	0.33 mm	3.4 mm
PAF-SMA-11-λ	SMA**	11.0 mm	0.24 mm	4.9 mm

λ: Specify wavelength in nm.
*Optional FiberCables, with FC connector, are ordered separately for 50, 63, 100 µm core diameter.
**Optional FiberCables, with SMA connector, are ordered separately for 50, 63, 100-600 µm core diameter. See page FO-10.

FiberPort on HCC C-Mount (1-inch x 32 thd/in). PAF-X-5-633 is shown.

FiberPort on HCL Mounting Adaptor. Shown with Beam Delivery System.

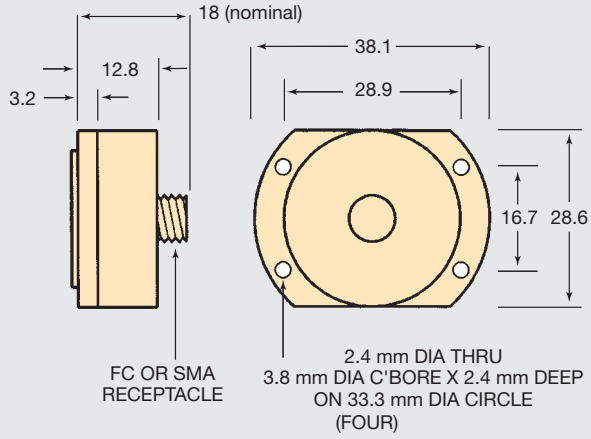
STABILITY OF FiberPorts is equally as important as coupling efficiency. See page FO-2 for a discussion on the testing and reliability of FiberBench systems.

It is necessary that absolute spatial stability exist between the laser and the FiberPort. This is best accomplished if the laser and the FiberPort are firmly mounted on a common base, or if the FiberPort is mounted directly onto the laser. The FiberPort is then micro-aligned, following the alignment procedure. Once aligned and locked, a FiberPort will not drift, and maximum coupling is maintained, in spite of connect/disconnect sequences.

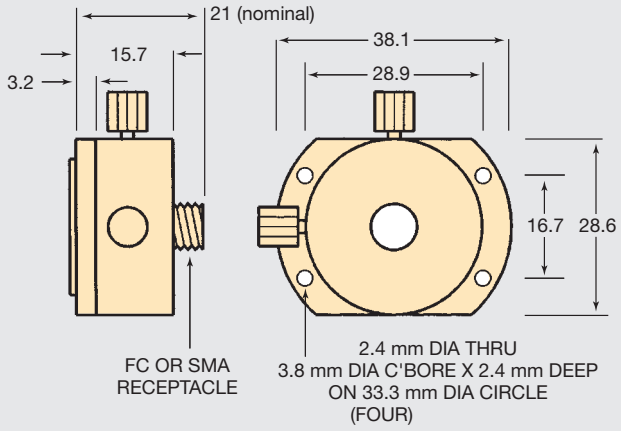
The FiberPort is aligned on site for maximum coupling efficiency. Good mechanical design and stainless steel construction assure very high stability, so that realignment is simply not necessary in spite of temperature changes and mild shock and vibration.

Mounting the FiberPort

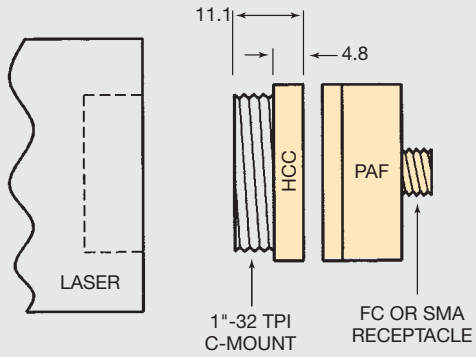
FIBERPORT



EASY TOUCH FIBERPORT

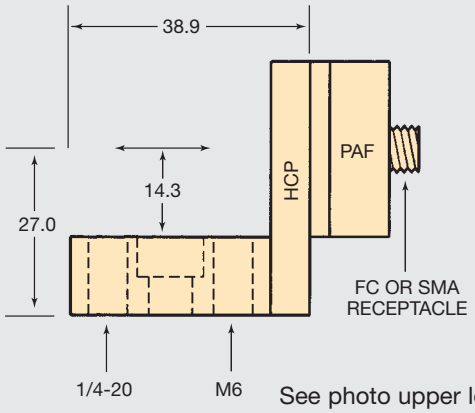


PAF MOUNTED TO HCC ADAPTOR



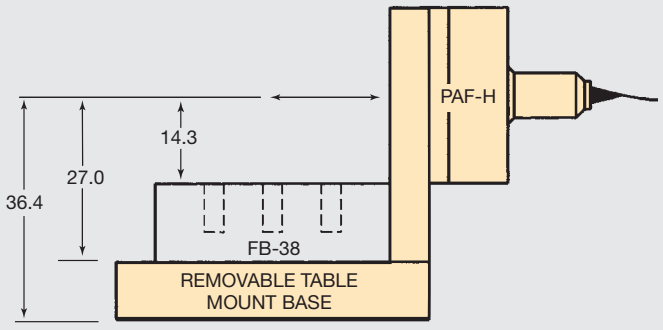
See photo lower left, FO-38.

PAF MOUNTED ON HCP

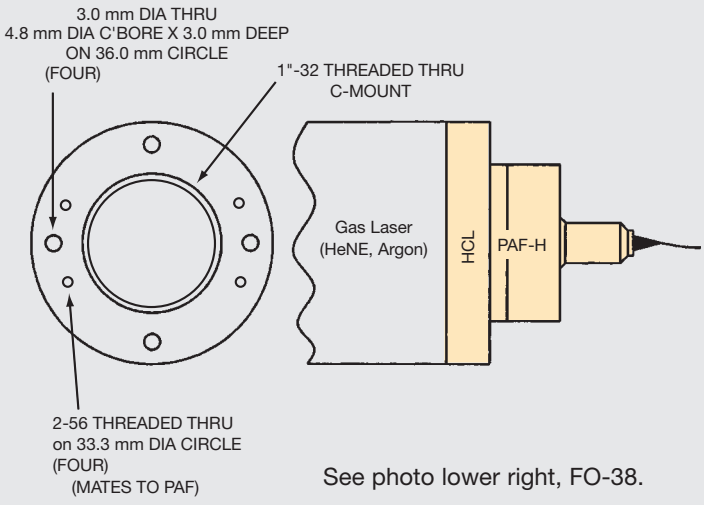


See photo upper left, FO-38.

FIBERPORT MOUNTED TO FIBERBENCH



PAF MOUNTED TO HCL ADAPTOR



See photo lower right, FO-38.

Cooled and Non-Cooled LaserPorts

T-E Cooled LaserPorts are available for 5.6 mm and 9.0 mm lasers. Included in the T-E LaserPort are:

- AR-coated micro-aspheric lens with 5 axes of adjustment
- Thermo-electric Peltier cooler, 100-900 mA typical
- Thermistor, 10 K Ohm for 25° C typical
- Heat sink and radiator
- OFR FiberBench FB-38-1W
- Alignment instructions
- Color-coded wiring instructions.

OFR does not supply the power supply. However, the LaserPort is pre-wired by OFR. Simply plug in your laser. Instructions for easy collimation alignment are included. Optionally available are AMP 10 pin or Cannon ITT mini 9 pin connectors.

Non-cooled LaserPort

TO3 LaserPorts are available for any customer-furnished TO3 laser. The LaserPort mounts onto a industry-standard heatsink with laser socket plate. Simply attach to your laser/radiator assembly and follow easy instructions for collimation alignment. See also page FO-20.

In all LaserPorts, the same ultra-fine FiberPort alignment mechanism houses the AR-coated aspheric Lens that produces a nominal 1x2 mm collimated beam. Having x-y-z and Φ-Θ fine controls, the LaserPort is precision aligned to maintain optimum collimation.

OFR will mount and align customer-furnished lasers when requested. However, OFR bears no responsibility for performance of customer-furnished lasers, nor for damage to same while in OFR possession. Please inquire.

You will never be told to "Press 1 Now" when you call OFR!

Catalog Number	Description
PAL-TE-5 6 or 9.0-λ	T-E Cooled LaserPort for 5.6 mm or 9.0 mm laser.
PAL-5.6 or 9.0-λ	Non-Cooled LaserPort for 5.6 mm or 9.0 mm laser.
PAL-TO3-λ	LaserPort for TO3 laser

NOTE: when ordering, specify wavelength.

PAL-TE-9.0-1550 with integral OFR-supplied T-E Cooler & calibrated thermistor.

PAL-TO3-830 mounted on customer's heatsink.

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Coupling Lenses

Coupling a laser output with maximum efficiency into a single-mode fiber requires a lens of extraordinary properties. Steep aspheric curves reduce back reflections, limiting feedback significantly in comparison to GRIN lenses. Optical performance must be diffraction limited. Insertion loss must be at an absolute minimum.

Such performance is typical of OFR Laser Lenses for Fiber-Optic and Laser Diode applications. These are micro double-aspheric Lenses, designed for diffraction limited performance. Both surfaces are multilayer anti-reflection coated. Transmittance exceeds 99% at the peak wavelength.

Mounted LLO series lenses are AR coated and mounted in a Microscope Objective Cell with industry standard RMS thread. Also available in a 1" dia. x .250" thick postmountable cell with 8-32 tapped hole. Other mounting options available. Please inquire.

Unmounted LL series lenses as above but unmounted.

Interchangeable FiberPort Lenses, see page FO-7.

Mounted Double-Aspheric Lenses

Catalog Number	Focal Length	Working Distance	Numerical Aperture	Maximum Beam Dia.	Equivalent Magnification
LLO-4-18-λ*	18.4 mm	17.0 mm	0.13	4.4 mm	10X
LLO-6-11-λ	11.0 mm	9.1 mm	0.30	6.5 mm	16X
LLO-8-8-λ*	8.0 mm	5.5 mm	0.50	8.0 mm	20X
LLO-4-7-λ	7.5 mm	5.5 mm	0.30	4.5 mm	24X
LLO-4-4-λ	4.6 mm	2.4 mm	0.53	4.8 mm	40X
LLO-2-2-λ*	2.0 mm	0.9 mm	0.50	2.0 mm	90X

* not available for HoYAG.
NOTE: When ordering, specify wavelength, for example, LLO-4-4-NIR.

Unmounted Double-Aspheric Lenses

Catalog Number	Focal Length	Back Focal Length	Center Thickness	Numerical Aperture	Lens Diameter
LL-3-2-λ*	2.0 mm	0.9 mm	2.0 mm	0.50	3.0 mm
LL-4-7-λ	7.5 mm	5.8 mm	2.7 mm	0.27	4.0 mm
LL-4-11-λ	11.0 mm	9.6 mm	2.2 mm	0.18	4.0 mm
LL-6-5-λ	4.6 mm	2.9 mm	3.1 mm	0.53	6.0 mm

* not available for HoYAG.
NOTE: When ordering, specify wavelength, for example, LL-3-2-IR.

Antireflection Coatings

Max T Spectrum	Order as
380 - 640 nm	- VIS
600 - 990 nm	- NIR
970 - 1100 nm	- YAG
1100-1550 nm	- IR
1.9 - 2.15 um	- HoYAG*

*LL-3-2, LLO-2-2 and LLO-8-8 not available for HoYAG.

LLO Aspheric Lenses in RMS Cells.

Interchangeable FiberPort Lenses (see FO-16)

HIGH POWER

Normally, the only difference between FiberPorts used in different applications is the lens focal length, usually determined by the application. All FiberPort Lenses are mounted in a Cell that is compatible with all FiberPort models. The Cell positions the principal plane of the Lens at one focal length distance from the polished fiber endface, resulting in collimation. FiberPort Lens Cells are magnetic, and are easily installed and interchanged on site.

Thus, for experimentation purposes, rather than interchanging FiberPorts (containing different focal length lenses), it is more economical to interchange Lenses, mounted in their magnetic Cell, using a single FiberPort.

For Lens characteristics, see tables above.

Bulkhead requirement.
The Bulkhead, the threaded portion on which the Connector attaches, is different in length for the two groups of Lenses as listed below.

FiberPort Lenses LLO-PAF-2,5,7 can be interchanged using FCBH-S Bulkhead. Likewise, LLO-PAF-11,15 use the FCBH-LA. When interchanging Lenses from one group to another, it is not necessary to change FiberPort bodies. It is only necessary to interchange Bulkheads.

In summary, interchanging Lenses and Bulkheads is simple, quick and economical.

Catalog Number	Effective Focal Length	Bulkhead	Use with
LLO-PAF-2-λ	2.0 mm	FCBH-S	PC, APC
LLO-PAF-5-λ	4.6 mm	FCBH-S	PC, APC
LLO-PAF-7-λ	7.5 mm	FCBH-S	PC, APC
LLO-PAF-11-λ	11.0 mm	FCBH-LA	APC
LLO-PAF-15-λ	15.4 mm	FCBH-LA	APC

λ: specify wavelength in nm.

Lenses are easily interchanged in FiberPort.

Single Mode (SM) and Polarization-Maintaining (PM) FiberCables

FC-connectorized Single Mode and Polarization-Maintaining FiberCables are available with OFR standard APC or optional PC polish. See further descriptions below of these three types of connectors. FC-connectorized FiberCables connect to OFR X-Type FiberPorts (see page FO-6).

Single Mode FiberCables

FC/APC-connectorized SM FiberCables are available for wavelengths from 488 nm to 1550 nm. Also, OFR connectorizes customer-supplied, 125 µm cladded fiber.

FiberCables can be ordered with connector on one end and other end cleaved, or as a patchcord with both ends connectorized.

Polarization-Maintaining FiberCables

Polarization-Maintaining (PM) fibers employ a stress technique to stress the core of the fiber to create two propagation paths within the fiber core. Linearly polarized light aligned to either the slow or fast axis of the fiber will remain linearly polarized. This is analogous to an optical retarder.

OFR PM fibers are also available with FC/PC, FC/SPC, FC/APC with the connector key aligned parallel to the slow axis of the fiber. The slow axis of PM fiber is parallel to the stress members or major diameter of Oval Inner-Clad PM fiber,

OFR stocks a variety of PM Fiber-Cables, with emphasis on 1310nm & 1550nm.

Standard lengths are 1 meter and 2 meters. Minimum quantity of 2 each must be ordered for custom lengths.

Single Mode (SM) FiberCables with FC Connector

Catalog Number	Description
FCS-λ-*l*- FC/APC	FiberCable, FC/APC connector one end
FCS-λ-*l*- FC/APC/APC	Patchcord, FC/APC both ends
FCS-λ-*l*- FC/PC/APC	Patchcord, FC/PC one end, FC/APC other end
FCS-λ-*l*- FC/PC/PC	Patchcord, FC/PC both ends

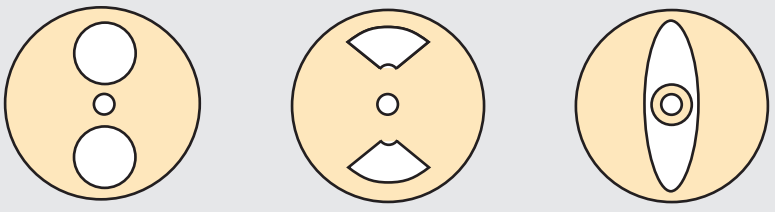
When ordering, specify λ wavelength in nm.
l: length, 1 meter or 2 meters or other. For example, for 3-meter length FCS-1550-3-FC/APC.

Polarization Maintaining (PM) FiberCables with FC Connector

Catalog Number	Description
FCP*x*-λ-*l*- FC/APC	FiberCable, FC/APC connector on end
FCP*x*-λ-*l*- FC/APC/APC	Patchcord, FC/APC both ends
FCP*x*-λ-*l*- FC/PC/APC	Patchcord, FC/PC one end, FC/APC other end
FCP*x*-λ-*l*- FC/PC/PC	Patchcord, FC/PC both ends

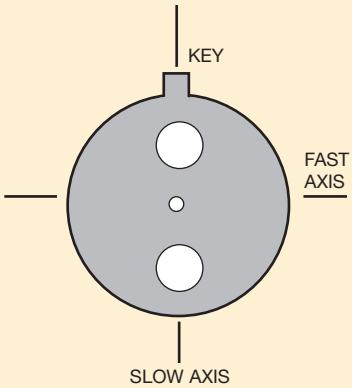
When ordering, specify λ wavelength in nm.
l: length, 1 meter or 2 meters or other. For example, for 3-meter length FCPP-1550-3-FC/APC.

x: PANDA	FCPP-λ-3-FC/APC, etc.
x: Bowtie	FCPB-λ-3-FC/APC, etc.
x: Oval Inner Clad	FCPO-λ-3-FC/APC, etc.



PANDA BOWTIE OVAL INNER CLAD

PM Fiber Type	Order as	Most Common usage
PANDA (OFR Standard)	FCPP-	488-514, 633, 850, 1064, 1310, 1550 nm
Bowtie	FCPB-	1064 nm inquire
Oval Inner Clad	FCPO-	1064 nm inquire



FC Adapter, super high precision, monolithic stainless steel body

A simply better engineered product. One-piece stainless steel body. Ultra high dimensional tolerancing. Ceramic split-sleeve insert. These are some of the reasons that OFR's FC Adapters are absolutely repeatable, with no fiber end-face scratching. Extremely tight tolerance on keyway slot assures trouble-free performance, especially with PM fiber.

- Ultra high mechanical tolerancing
- One-piece stainless construction
- Ceramic split-sleeve insert
- 70% less keyway slop
- Absolute repeatability
- PM fiber no-loss connecting
- No fiber-end scratching
- For PC and APC

Catalog Number	Description
FCA-N	FC Adapter with 2.00 mm key
FCA-W	FC Adapter with 2.14 mm key

Connector Types & End-Face Polish: FC/PC and FC/APC

The term "FC" comprises a mechanical definition of a specific type of connector, while "PC"and "APC" describe the kind of polish applied to that connector (thus, fiber) end face:

PC = physical contact, end face polished convex, OFR option.

APC = as above, but angle-polished at 8° angle, OFR standard.

Typically, FC/PC connectors have lowest insertion loss and low (-35 to -45 dB) return loss (back reflection), and are used for fiber-to-fiber connections.

FC/APC connectors are required for fiber-to-air applications requiring low return loss, such as Collimators, FiberPort couplers, and laser-to-fiber coupling.

Connector Losses

Insertion loss at each connector-pair varies according to type of connector polish and fiber core diameter (wavelength related).

Type	Description	Typical Connector Loss (dB) 633	850	1060	1310/1550
PC	Physical contact with convex radius	0.6	0.4	0.3	0.2
APC	As above, but end face tilted at 8°	0.8	0.6	0.5	0.3

Multimode FiberCables

Multimode FiberCables are available with FC or SMA connectors. Core diameters of 50 µm, 62.5 µm, 100 µm with 125 µm cladding are standard. 200 µm and 400 µm use SMA connector.

Standard lengths are 1 meter and 2 meters. Minimum quantity of 2 each must be ordered for custom lengths.

Multimode (MM) FiberCables with FC Connector

Catalog Number	Description
FCM-δ-*l*-λ- SMA	FiberCable, SMA connector one end
FCM-δ-*l*-λ- FC/PC	FiberCable, FC/PC connector one end

When ordering, specify δ core diameter 50, 63,100 µm.
l length, specify 1 meter or 2 meters or other.
λ wavelength in nm. For example, for 3-meter length FCM-50-2-830-SMA.

Optical Power Delivery Cables

HIGH POWER

Stability, high efficiency and ease of attachment and alignment describe OFR's Fiber Delivery Systems. A Delivery System consists of three component sections:

Input Couplers, Page FO-5. To provide stable and efficient coupling of collimated free beam laser energy of any wavelength, into the...

Delivery Cables, Page FO-9. Single-mode, polarization-maintaining or multimode, 3 mm kevlar reinforced or optionally protected by armored shielding, of any length, to deliver optical power to the...

Output Collimators, Page FO-45 and following.To produce a collimated output beam in a wide choice of diameters.

OFR Optical Delivery Systems are assembled from FiberBench components, such as:

FiberPorts for input, **FiberCables** for delivery, and **Snap-On Collimators** for collimated output; focus option is also available (FO-45).

Flexibility in design of the Delivery System is possible by combining the many options available using existing components.

Custom 3-output assembly.

FiberPort on HCC C-Mount (1-inch x 32 thd/in). PAF-X-5-633 is shown.

FiberPort on HCL Mounting Adaptor. Shown with Beam Delivery System.

Hi-power armored cable.

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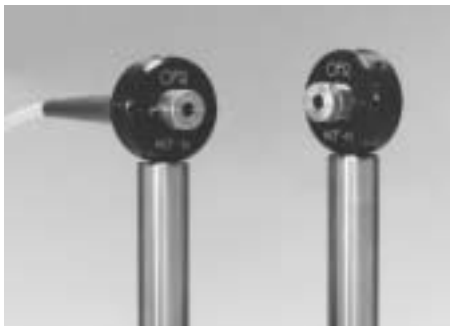
HIGH POWER

Snap-On Collimators

Stainless Steel Snap-On Collimators are designed to "snap" onto an FC or SMA connectorized fiber to produce a collimated beam. Snap-On Collimators contain a micro, double-aspheric lens, which is designed for diffraction-limited performance. Both surfaces are multilayer anti-reflection coated, with ≥ 98% transmission at the peak wavelength.



Snap-On Collimator in HCF-N Holder

Snap-On Collimators with VariFocus
An OFR LLO-Series Aspheric Coupling Lens (see FO-16) is mounted in the fine-threaded, spring-loaded adjustment barrel, which is rotated to achieve optimum collimation.
OFR VariFocus "focusability" feature allows simple recollimation of the beam when using different wavelengths. Turning the knurled ring a mere fraction of a turn will recollimate the beam over the full transmission range of the Lens.

All Snap-On Collimators have VariFocus features

Snap-On Collimators are available with a choice of different focal length Lenses as follow:

Connector	Focal Length	Fiber Type	Best Collimation Distance at
FC	2 mm	SM only	2 cm-50 cm
FC	5 & 8 mm	SM & MM	5 cm-10 m
SMA	5 & 8 mm	MM only	1 cm-2 m

Divergence of the collimated output beam is dependent upon laser wavelength and fiber core diameter.

Snap-On Collimators can be used "as is", or mounted in the optional HCF-N COLLIMATOR HOLDER, which secures the Snap-On Collimator for post mounting (8-32 and M4), or in 1-inch mount.

All optics in all OFR Fiber-Optic Collimators and accessories are AR coated according to wavelength. Therefore, when ordering, specify wavelength as follows.

Wavelength Range	Order as
475-675 nm	VIS
630-860 nm	VIR
960-1100 nm	YAG
1275-1350 nm	IR1
1480-1600 nm	IR2

SINGLE-MODE

Snap-On Collimators for Single-Mode Fiber, FC Connector

Catalog Number	Collimated Output Characteristics: Beam Diameter	Clear Aperture	Numerical Aperture	Beam Divergence	Body Diameter	Body Length
CFC-2-λ	0.5 mm	1.5 mm	0.30	<1 m-rad	9.5 mm	22-24 mm
CFC-5-λ	1.0 mm	2.3 mm	0.25	<1 m-rad	9.5 mm	22-24 mm
CFC-8-λ	1.6 mm	3.3 mm	0.22	<1 m-rad	9.5 mm	22-24 mm
CFC-SET-λ	Set of 3 of above					
HCF-N	Collimator Holder (see photo at left). Also can fit into 1" mount.					

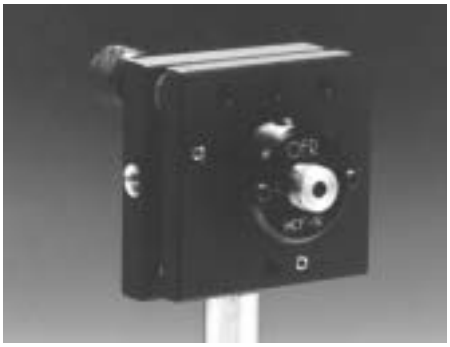
NOTE: Output beam diameter and divergence may vary.

Divergence of the Collimated Output from multimode fiber varies with the core diameter of the fiber. The following table lists the expected divergence of the output beam from the Snap-On Collimator according to the core diameter of the multimode fiber.

MULTIMODE
Snap-On Collimators for Multimode Fiber

Catalog Number	Collimated Output Characteristics: Beam Diameter	Clear Aperture	Numerical Aperture	Body Diameter	Body Length
CFC-5-λ	1.7-2.3 mm	2.3 mm	0.25	9.5 mm	22-24 mm
CSMA-5-λ	1.7-2.3 mm	2.3 mm	0.25	9.5 mm	22-24 mm
CFC-8-λ	2.7-3.3 mm	3.3 mm	0.22	9.5 mm	22-24 mm
CSMA-8-λ	2.7-3.3 mm	3.3 mm	0.22	9.5 mm	22-24 mm
HCF-N	Collimator Holder (see photo, page FO-45)				
HEF	Steering Mount. Includes HCF-N (see photo below)				

NOTE: Output beam diameter and divergence may vary.
λ: Specify wavelength in nm.



Snap-On Collimator in HCF -N Holder (see photos FO-45) mounted in HEF Tilt Mount, used for beam steering.

Core Diameter	Typical Divergence CSMA-5-λ	Typical Divergence CSMA-8-λ
50 µm	3 m-rad	2 m-rad
62 µm	5 m-rad	4 m-rad
100 µm	6 m-rad	4 m-rad
200 µm	17 m-rad	10 m-rad
400 µm	45 m-rad	30 m-rad

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Pigtailed Collimators

Pigtailed Collimators

CFS-T Pigtailed Collimators are designed for OEM applications. These are supplied with a 1-meter fiber pigtail.The input end of the fiber is normally cleaved.

The fiber and an AR-coated, aspheric microlens are rigidly potted inside the stainless steel Collimator body. In order to ensure optimum collimation, it is essential that the wavelength be specified when ordering.

Custom modifications for non-collimated applications or larger-than-standard beam diameters are possible. Please inquire.

Insertion loss is < 0.2 dB. Back reflection (return loss) is > -55 dB on all SM models.

Pigtailed Collimators have a 1-meter fiber pigtail. For other lengths, order as dash-number. For example, for a 3-meter pigtail, order as CFS-T-5-1550-3.

Collimators with Single-Mode Fiber Pigtail

Catalog Number	Core Diameter	Beam Diameter at Output	Nominal Divergence	Body Diameter	Body Length
CFS-T-λ	4-10 µm	≈0.5mm*	1–3 m-rad*	4.0 mm	11 mm
CFS-T-5-λ	4-10 µm	≈1.0mm*	0.5–2 m-rad*	5.7 mm	17 mm
CFS-T-11-λ	4-10 µm	≈2.4mm*	< 1 m-rad*	7.9 mm	21 mm
CFS-T-18-λ	4-10 µm	≈4.0mm*	< 1 m-rad*	7.9 mm	28 mm

λ: Specify wavelength in nm.
*Output beam diameter and divergence may vary.

Collimators with Multimode Fiber Pigtail

Catalog Number	Core Diameter	Beam Diameter at Output	Nominal Divergence	Body Diameter	Body Length
CFM-T-5-λ	50 µm*	≈2mm**	3-4 m-rad*	5.7 mm	17 mm
CFM-T-11-λ	50 µm*	≈5mm**	<2 m-rad*	7.9 mm	21 mm

λ: Specify wavelength in nm.
*NOTE: 50 µm core MM fiber, unless otherwise specified. 62 µm and 100 µm.available Please inquire.

FOCUSERS

Pigtailed Focusers

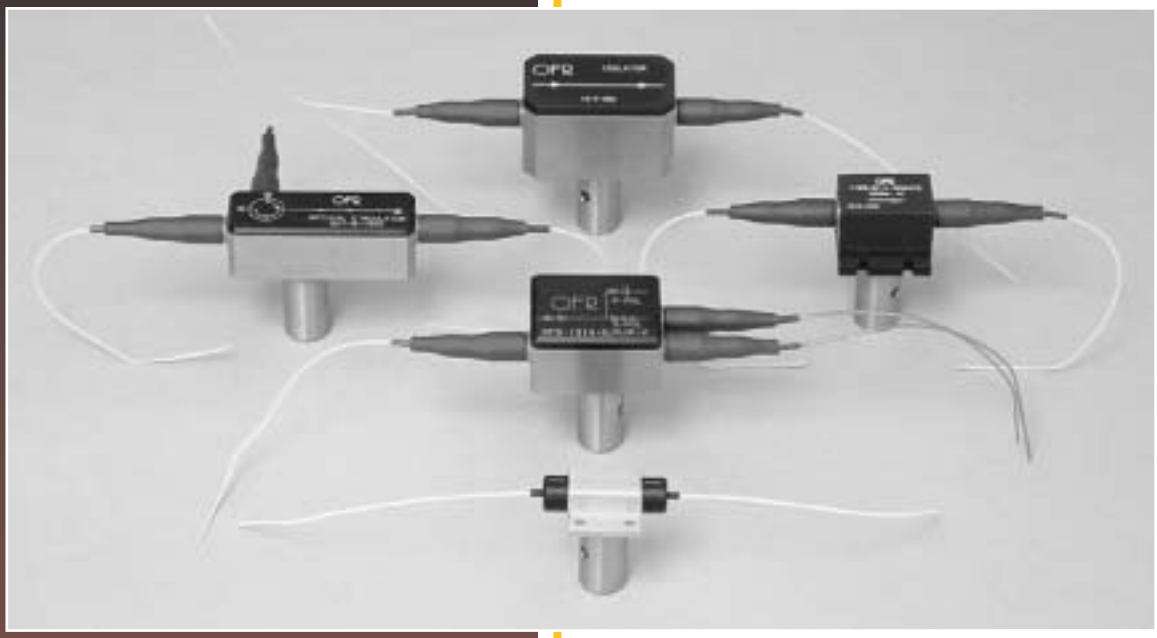
Pigtailed Focusers terminate a 1-meter single-mode or multimode fiber pigtail. Like Snap-On Focusers, Pigtailed Focusers focus at a fixed distance.

Two OFR LLO-Series Aspheric Coupling Lenses (one collimator, the other focuser) focus the output to a predictable Airy's Disc (see Coupling Lenses page FO-16). Each micro double-aspheric lens is multilayer anti-refraction coated, with >98% transmission at the peak wavelength.

Pigtailed Focusers For Single-Mode Fiber

Catalog Number	Working Distance	Focal Spot*	Body Diameter	Body Length
FS-T-5/5-λ	2.3 mm	17 µm*	5.7 mm	15 mm
FS-T-11/5-λ	2.3 mm	6-8 µm*	7.9 mm	21 mm
FS-T-11/11-λ	9.0 mm	17 µm*	7.9 mm	25 mm

λ: Specify wavelength in nm. *1550nm



Packaged Devices

All of these started out life as a FiberBench prototype. So did many of our customers' products. Any ideas? Call us!

Look for HIGH POWER Products

NOTE: Power damage is generally fiber-limited. Discuss with OFR.

You will never be told to "Press 1 Now" when you call OFR!

Polarization Splitters / Combiners

HIGH POWER

OFR Polarization Splitters divide the input (Port 1) into two oppositely polarized outputs (Ports 2 and 3).

The standard P/P/P model equally splits the input energy into the two outputs.

OFR Polarization Combiners do the reverse of the Splitters. Two oppositely polarized inputs (Port 2 and 3) are combined into a single output (Port 1). In the P/P/P model, the combined energies are coupled into both slow and fast axes of the output fiber (Port 1).

OFR Walk-OFF Polarizers (see page FO-14) in OFR Splitters separate the two polarization modes better than 55 dB. Because of near-zero absorption and absence of any optical cement, Walk-Off Polarizers are capable of handling very high powers, far beyond those in a fiber-optic system. Walk-Off Polarizers are inherently extremely broadband. AR coated, specify λ.

The PM Fibers (PANDA) on all models are aligned so that the plane of polarization is parallel to the slow axis in the fiber.

1-Meter Fiber pigtails on all models can be ordered as single-mode (SM) or polarization-maintaining (PM), as designated in the Part Number. Distal end is cleaved or optionally connectorized.

Polarization Splitters

Input on Port 1, and oppositely polarized outputs on Ports 2 and 3. Pigtails can be ordered as Single-mode (S) or Polarization Maintaining (P) on all Ports.

Catalog Number PORTS 1 2 3	Description	Comments
PFS-λ-S/P/P	Standard Splitter	Cement-free
PFS-λ-S/S/S	Standard Splitter	Cement-free
PFS-λ-P/P/P	Standard Splitter	Cement-free

NOTE: when ordering, specify λ in nm.

Polarization Combiners

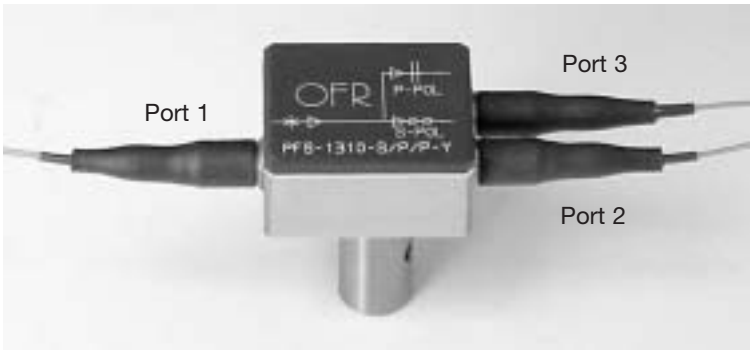
Oppositely polarized inputs on Ports 2 and 3. Output on Port 1. Pigtails can be ordered as Single-mode (S) or Polarization Maintaining (P) on Port 1. Polarization Maintaining (P) only on Ports 2 and 3.

Catalog Number PORTS 1 2 3	Description	Comments
PFC-λ-S/P/P	Combiner, Y Model	Cement-free
PFC-λ-P/P/P	Combiner, Y Model	Cement-free

NOTE: when ordering, specify λ in nm.

Specifications

Total Insertion Loss	0.5-1.2 dB
Extinction Ratio (on PM output)	25-32 dB
Return Loss (back reflection)	50-65 dB
PM Fiber	Panda PM
Operating Temperature	0°C to 40°C
Storage Temperature	-20°C to 60°C

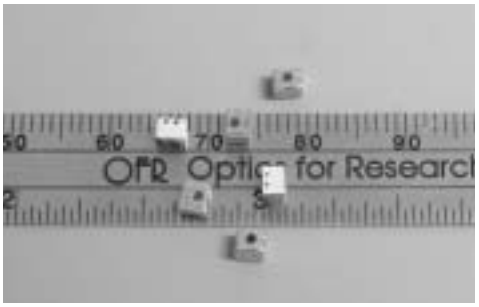


Polarization Independent Isolators

OFR Polarization Independent Isolators are pigtailed with 1 meter of single-mode fiber. Fiber ends are cleaved or can be optionally FC connectorized.

Isolators for non-standard λ's are available. See page FO-21.

IO-H-1550



Custom isolators for high quantity production

Low Power Models, to 300 mW

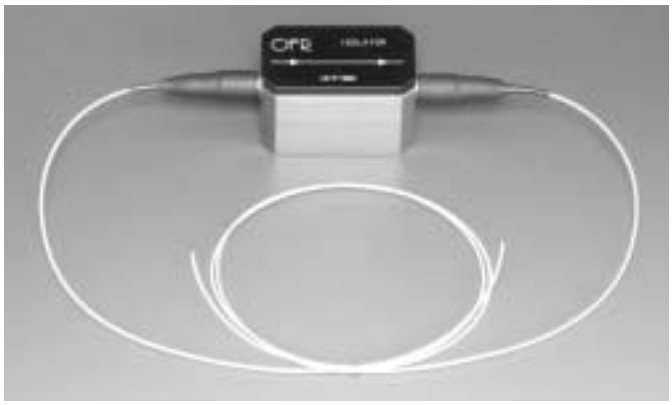
Catalog Number	Isolation	Bandwidth*	Insertion Loss	PDL	PMD	Return Loss	Power Handling
IO-H-1310	36-40 dB	13-26 nm	0.3-0.6 dB	≤0.1 dB	≤0.2 ps	>55 dB	300 mW
IO-H-1550	38-44 dB	15-30 nm	0.3-0.6 dB	≤0.1 dB	≤0.2 ps	>55 dB	300 mW

*Measured at 90% of peak λ.
NOTE: Inquire about economically priced "B Models" with sligthly downgraded spec's.

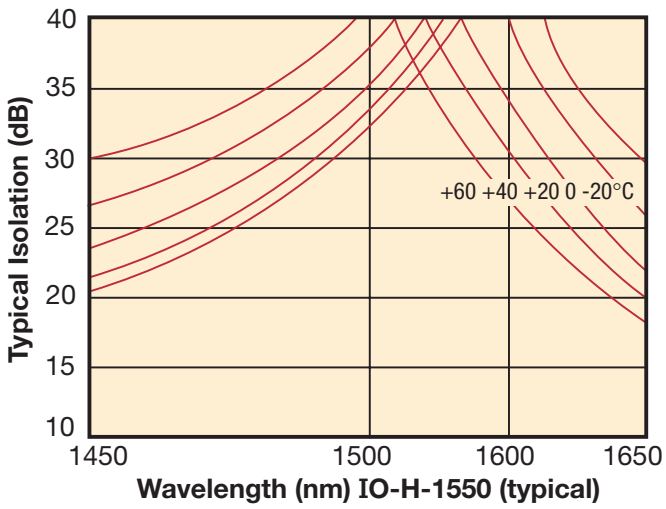
High Power Models, to 2-5 W cw

Catalog Number	Isolation	Bandwidth*	Insertion Loss	PDL	PMD	Return Loss	Power Handling**
IO-F-780/860	30-38 dB	8-16 nm	1.0-1.8 dB	≤0.25 dB	≤0.2 ps	>50 dB	2-5 W cw
IO-F-980	30-38 dB	10-20 nm	0.8-1.6 dB	≤0.25 dB	≤0.2 ps	>50 dB	2-5 W cw
IO-F-1064	30-38 dB	10-20 nm	0.8-1.6 dB	≤0.25 dB	≤0.2 ps	>50 dB	2-5 W cw
IO-F-1319	30-38 dB	13-26 nm	0.5-1.2 dB	≤0.20 dB	≤0.2 ps	>55 dB	3-5 W cw
IO-F-1550	36-40 dB	15-30 nm	0.5-1.2 dB	≤0.20 dB	≤0.2 ps	>55 dB	3-5 W cw
IOT-F-1550	>60 dB	30 nm	0.6-1.1 dB	≤0.20 dB	≤0.2 ps	>55 dB	3-5 W cw

*Measured at 90% of peak λ.
*Power is limited by fiber. Isolator itself is capable>20 W.



IO-F-980 Polarization-Independent Isolator



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Polarization Dependent Isolators

OFR Polarization dependent Isolators are pigtailed with 1 meter of PM fiber. Fiber ends are cleaved, or can be optionally FC connectorized.

Isolators for non-standard λ's are available. See page FO-21.

Inquire about isolator development and special packaging

Custom, mini and micro Isolators.

Low Power Models, to 300 mW

Catalog Number	Isolation	Bandwidth*	Insertion Loss	Return Loss	Power Handling
IO-G-980	30-38 dB	± 1.5%	0.7-1.5 dB	>50 dB	300 mW
IO-G-1064	30-38 dB	± 1.5%	0.7-1.5 dB	>50 dB	300 mW
IO-G-1310	39-42 dB	± 1.5%	0.7-1.2 dB	>55 dB	300 mW
IO-G-1480	39-42 dB	± 1.5%	0.7-1.2 dB	>55 dB	300 mW
IO-G-1550	39-42 dB	± 1.5%	0.7-1.2 dB	>55 dB	300 mW

*Measured at 90% of peak isolation.

High Power Models, to 2-5 W cw

Catalog Number	Isolation	Bandwidth*	Insertion Loss	Return Loss	Power Handling**
IO-J-980	30-38 dB	± 1.5%	0.8-1.6 dB	>50 dB	2-5 W cw
IO-J-1064	30-38 dB	± 1.5%	0.8-1.6 dB	>50 dB	2-5 W cw
IO-J-1310	36-42 dB	± 1.5%	0.5-1.2 dB	>55 dB	2-5 W cw
IO-J-1550	36-42 dB	± 1.5%	0.5-1.2 dB	>55 dB	2-5 W cw

*Measured at 90% of peak isolation.

**Power is limited by fiber. Isolator itself is capable >20 W.

Laser-Interface Isolators

The OFR Laser-Interface Isolator permits coupling of a free-space laser beam into the FiberPort, at the same time isolating the laser. IO-PAF Isolated FiberPorts contain an OFR IO-D "Aspirin Tablet" Isolator (page OC-00), with insertion loss <0.2 dB and isolation 40-45 dB. Standard wavelengths are 1310 nm and 1550 nm, and others are available.

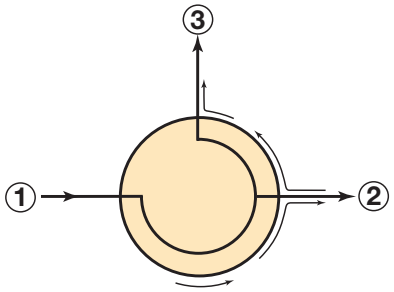
When ordering, specify vertical or horizontal input polarization. FiberCable is ordered separately.

Catalog Number	Fiber Type	Input Beam Diameter
IO-PAF-X-5-λ	SM or PM	0.8-1.3 mm
IO-PAF-X-7-λ	SM or PM	1.6-2.0 mm

λ: specify wavelength 980,1310 or 1550 nm, for example, IO-PAF-X-11-1550.

IO-PAX-X-7-980

High Power Circulators 2-5 Watts cw (US Patent 5,212,586)



3-Port Design

Description

The OFR polarization-independent 3-Port-High-Power Circulator, in stainless steel body, is intended for high-power laser applications, as much as 2-5 Watts cw. This compares to around 300 mW for most circulators on the market.

Standard pigtails are 1 meter long, 900 µm, 9/125 SMF 28 fiber. Distal ends are cleaved or optionally terminated with FC/PC connector. Thermal drift of isolation is <0.2 dB/° C.

Custom Circulators are possible for special wavelengths and for 4 or more ports.

Very high isolation (60 dB) is unique to OFR High Power Circulators. These are the OCT Series, with dual isolator stages, that produce 60 dB between Ports 3 to 2 and Ports 2 to 1.

New OCM high-production model
For telecom applications, the new OCM is available in production quantities. The OCM meets international telecom standards. It is limited to 300 mW.

Custom Wavelengths
OC-3 and OCT-3 High-Power Circulators are available at 1310 nm or 1550 nm. Circulators at other wavelengths are built on a custom basis. Please inquire.

High Power Models, to 2-5 W cw

Catalog Number	Comments	Insertion Loss 1→2, 2→3	Isolation 3→2, 2→1	Cross Talk 1→3	Return Loss all Ports	PDL	PMD
OC-3-λ	High Power	0.5-1.1 dB	<35 dB	>40 dB	>58 dB	<0.1 dB	<0.1 ps
OCT-3-λ	High Power	0.7-1.2 dB	<60 dB	>50 dB	>58 dB	<0.1 dB	<0.1 ps
OC-3-λ-PM	High Power	0.5-1.1 dB	<35 dB	>50 dB	>55 dB	------	------
OCT-3-λ-PM	High Power	0.5-1.1 dB	<60 dB	>50 dB	>55 dB	------	------
OCM-λ	Low Power, Production quantities	0.5-0.8 dB	<45 dB	>50 dB	>55 dB	<0.1 dB	<0.1 ps

λ: specify wavelength when ordering, 1310 or 1550 nm. Other wavelengths available.


Custom High-Power 4-Port Circulator


OC-3 High-Power Circulator


OCM-1550, for production quantities


Custom Polarization-Dependent Bi-Directional Circulator (Double-Pass Fiber Amplifier)

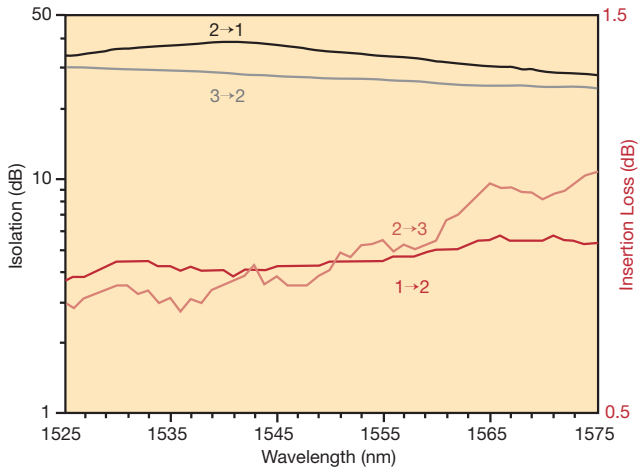


FIGURE 6 Typical performance data, OC-3-IR2 (1550nm)

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Faraday Rotator Mirrors *(very low loss)*

HIGH POWER

Faraday Rotator Mirror

Thermal and mechanical perturbations introduced to a standard, single-mode fiber often cause variations in the state of polarization (SOP) of the guided light. These changes can adversely effect the performance of many different types of systems. Retaining the SOP using polarization-maintaining (PM) fiber can reduce or eliminate these negative effects, but PM fiber is costly and often difficult to incorporate effectively.

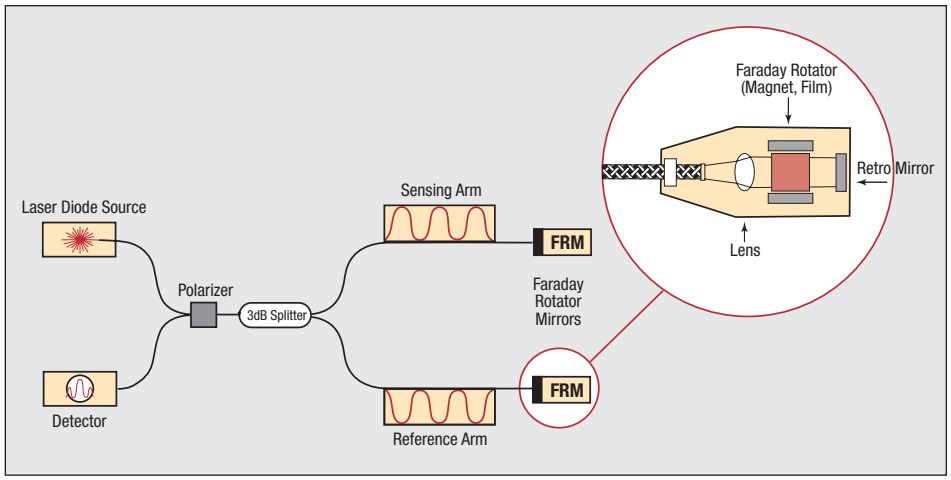
The Faraday Rotator Mirror is a low-cost, passive device that correctly compensates for such SOP variations. This simple, easily installed component works to neutralize the effects caused by changes in the SOP, allowing engineers greater control over the design of systems such as fiber sensors, erbium-doped fiber amplifiers, tunable fiber lasers, etc.

Principle

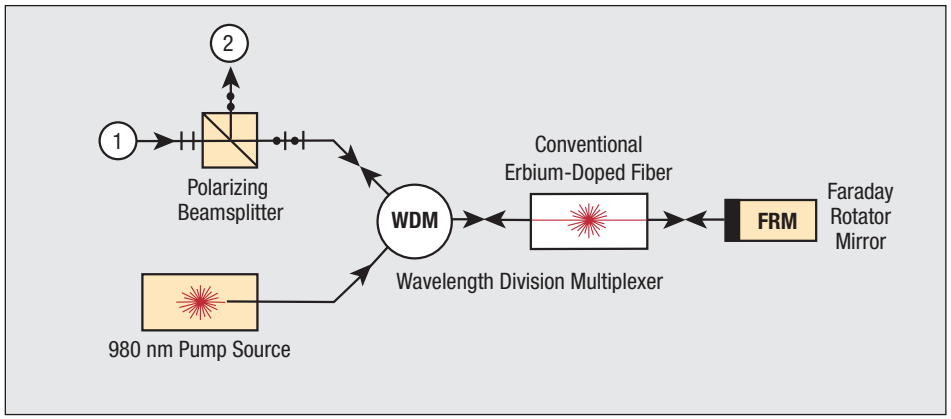
The Faraday Effect describes the non-reciprocal rotation of a signal's polarization as it passes through an optical medium within a magnetic field. Situated at the end of an optical fiber, the Faraday Rotator Mirror is designed to rotate a signal's SOP by 45°, twice –once when the light enters, and again when the light is reflected back into the fiber. Since the Faraday Effect is non-reciprocal, the resultant SOP is rotated by 90° with respect to the original signal.

A Faraday rotator is situated in front of the mirror. It is this element that provides the non-reciprocal 45° rotation of the state of polarization each time the light passes through it. These rotations, applied in combination with a reversal of the polarization state's handedness upon reflection at the mirror interface, yield a state that is perpendicular to the original signal.

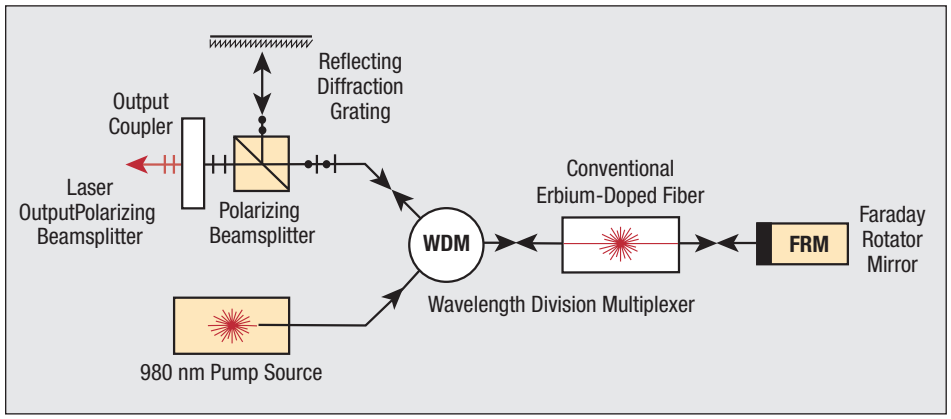
In this way, any SOP fluctuations that occur anywhere along the fiber are exactly compensated and their unwanted effects neutralized.



Interferometric Fiber Sensor using Faraday Rotator Mirrors



Single Polarization Fiber Amplifier, using conventional erbium-doped fiber and a Faraday Rotator Mirror for double signal pass operation.



Polarized Tunable Fiber Laser, narrow linewidth and amplification that is stable in time using a Faraday Rotator Mirror

Faraday Rotator Mirrors

Design

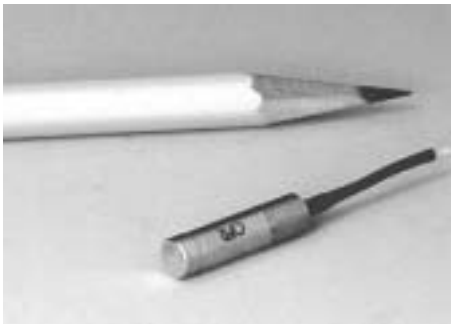
Using a micro aspheric glass lens, light exiting the fiber is properly collimated through a Bismuth Iron Garnet (BIG) Faraday rotating element that is accurately positioned in the field of a permanent magnet. The beam, reflected at normal incidence by a dielectric coated mirror, retraces its original path and re-enters the fiber.

OFR's Faraday Rotator Mirrors are available off-the-shelf pigtailed with standard single mode fiber, Corning SMF 28 or equivalent. The fiber is mounted in a standard 900 mm tight tube buffer with proper strain relief.

Custom models are available upon special request.

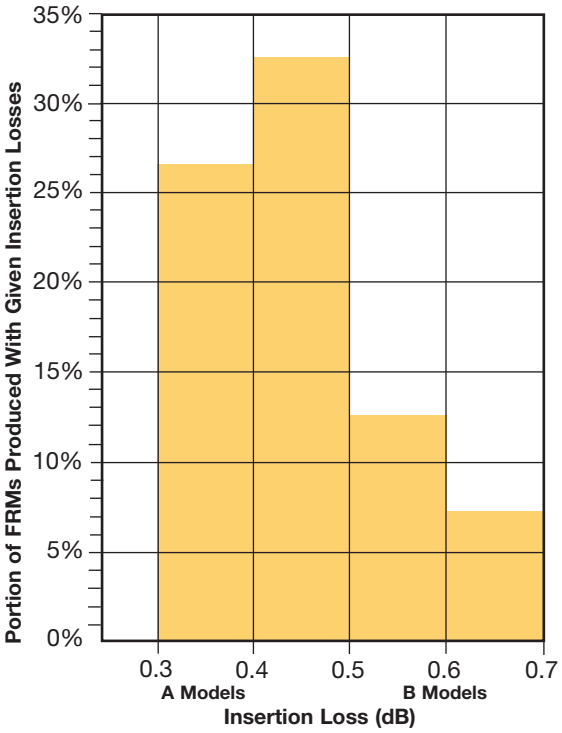
Low-loss Models, unique to OFR, are selected for Insertion Loss less than 0.5 dB. Standard loss models are available at less than 0.8 dB. Also unique to OFR's FRMs is high power capability...2-3 W.

No other FRMs on the market can claim to match OFR's specifications.



Faraday Rotator Mirror, stainless steel body, 5.5 mm dia x 22 mm long.

Catalog Number	Model	Wavelength	Bandwidth	Isertion Loss	Return Loss	Faraday Rotation
MFI-1310-A	Low loss	1310 nm	13 nm	≤0.5 dB	>55 dB	45°
MFI-1550-A	Standard	1550 nm	13 nm	≤0.5 dB	>55 dB	45°
MFI-1310-B	Low loss	1310 nm	15 nm	≤0.8 dB	>55 dB	45°
MFI-1550-B	Standard	1550 nm	15 nm	≤0.8 dB	>55 dB	45°



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