OZ Optics
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LASER TO FIBER COUPLER WITH ADJUSTABLE FOCUS

USA PATENT #7431513

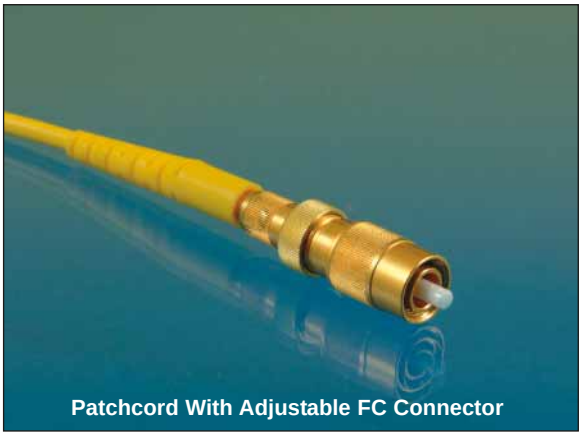
Features:

- Can handle powers up to 100 W CW
- Patented connector designs for precise coupling with focus adjustment
- Excellent coupling efficiency up to 90%
- Operating wavelengths 200nm - 2100nm
- Fiber end caps with ±25 micron thickness tolerance


Laser To Fiber Coupler With FC Adjustable Focus

Applications:

- Laser marking, cutting and welding
- Laser shows and entertainment
- Materials processing
- High power spectroscopy
- Non-linear optics
- Laser surgery (including cosmetic surgery, eye surgery, tattoo removal)
- Light detection and ranging (LIDAR)
- Interferometric sensors
- Laboratory applications
- Education and training
- Visual laser alignment for manufacturing
- Medical, pharmaceutical, and chemical sensors
- Fluorescence measurements
- OEM laser systems


Patchcord With Adjustable FC Connector

Specifications:

Coupling Efficiency:	Typically >70% for singlemode and polarization maintaining fibers >90% for multimode fibers
Backreflection Levels:	<-35dB for multimode fibers <-40dB for singlemode and polarization maintaining fibers <-60dB versions are also available
Polarization Extinction Ratios:	>20dB 25dB and 30dB versions are also available
Available Wavelengths:	200nm - 2100nm
Power Handling:	>5 Watts CW for achromats >10 Watts CW for aspheric lenses >100 Watts CW for fused silica or plano-convex and biconvex lenses (multimode fibers) >100 Watts CW for axial GRIN lenses (SM, PM, and LMA fibers)

Product Description:

Adjustable focus source couplers are ideal for situations where optical coupling efficiency is critical, such as in high power applications. A special connector allows the spacing between the fiber and lens to be precisely controlled without rotating the fiber. This is ideal in polarization maintaining applications, as the polarization axis does not change. The adjustments allow one to compensate for any change in wavelength or beam wave location, thus further optimizing the coupling efficiency. The minimized coupling efficiency lead to minimized heating of the fiber, especially important with high power.

Adjustable focus couplers are available with a variety of lens types and fiber types. Internal surfaces are angle polished and/or AR coated to minimize backreflection. Typical backreflection levels are -40dB. -60dB is available for certain options. OZ Optics also sells fiber patchcords with adjustable FC/PC connectors only. Please see our online catalog at http://shop.ozoptics.com for standard parts and specifications. Contact OZ Optics for further assistance.

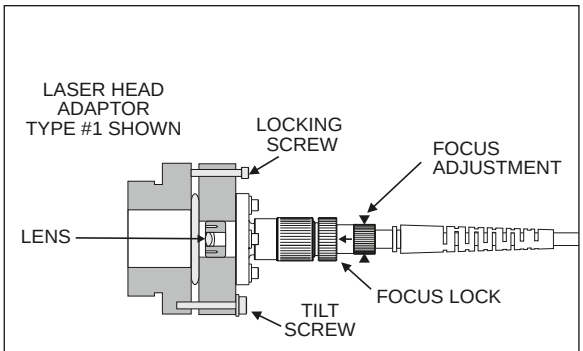
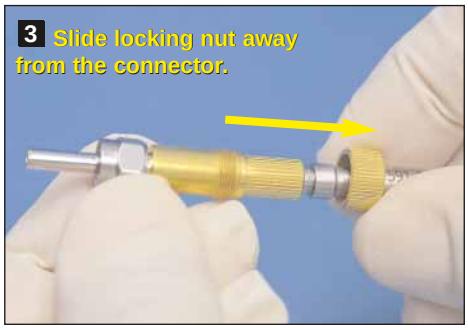
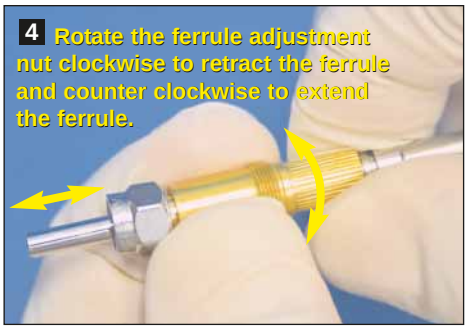


Figure 1: Operating Principle Of Adjustable Focus

Adjustable focus instructions





OZ Optics produces adjustable focus fiber optic patchcords specifically for high power applications. These patchcords feature special high power fibers, carefully prepared fiber endfaces, and specially designed fiber optic connectors to ensure maximum power handling for your application.

In standard connectors the fibers are glued into place, and the fiber is polished flush with the connector surface (See figure 4A). When used with high power lasers, heat generated at the tip of the fiber causes the surrounding epoxy to break down and give off gases. These gases, in turn, burn onto the tip of the fiber, causing catastrophic damage to the fiber and perhaps the entire system. In contrast, our high power connectors feature an air-gap design, where the fiber extends into free space by 1.1 mm to 1.5 mm, providing an epoxy-free region where thermal energy is safely dissipated without burning the surrounding material.

The fiber endface itself can be finished using several different techniques, depending on the maximum power requirements and cost restrictions. The simplest method is to polish the connector, as one does in standard connector termination (See figure 4B). While this provides a smooth finish, particles from the polishing material can embed themselves in the glass, forming absorption sites where the fiber can be burned. In addition, the fiber cladding has to exceed 200 microns to successfully polish the connector.

Power handling can be improved by mechanically cleaving the fiber instead, to give an optically smooth surface without polishing, thus preventing contamination (See figure 4C). Finally, the fiber can be laser treated to anneal the endface (See figure 4D). This technique gives the highest power handling possible. In all cases the fiber can be provided with either a flat or angled endface. PM fibers can also be angle cleaved and we can control the angle of the cleave with respect to the stress rods of the fiber.

Another way to improve power handling in certain applications is to fusion splice a short length of "coreless fiber" to the end of singlemode or polarization maintaining fiber (See figure 4E). This is also known as a fiber endcap. This endcap allows the light to expand to about half the diameter of the endcap before it emerges from the glass into air, reducing the power density at the glass/air interface. For standard fibers this is typically 350±25 microns long (OZ Optics can provide custom thickness endcaps). As it is this interface that is most sensitive to damage, expanding the beam increases the damage threshold. This method is only useful for fiber to free space applications, not fiber to fiber.

The end cap technique can also be used to terminate photonic crystal, or "holey" fibers. These fibers have a pattern of air holes in them, and these air holes constrain the light within the fiber. Potentially these holey fibers can give power handling that is several orders of magnitude better than conventional fibers. However, the air holes can trap dirt particles or other contaminates if left exposed on the fiber end. To prevent this, the end of the fiber can be capped with the coreless fiber, thus sealing the holes.

As an additional protective feature, the ends of mechanically cleaved fibers, laser treated fibers and fibers terminated with protective endcaps are recessed 15±5 microns with respect to the front face of the protective metal ring. This feature, shown in figure 1, prevents accidental damage to the fiber endface and also reduces the likelihood of contamination from accidental contact. The recessed fiber feature also makes fiber to fiber butt-coupling possible. Normally if the fiber was flush with the connector ring, butt coupling would damage the fiber endface and thus dramatically lower the optical power handling capability. As an added surface, OZ Optics can AR coat the ends of the fiber, thus reducing reflections to minimize connector losses.

The high power adjustable SMA and FC connector designs are shown in Figs. 2 and 3 respectively. Our engineers have extensive working knowledge with both continuous output (CW) and pulsed laser applications, and can help you select the best system for your application. Contact OZ Optics for further assistance.

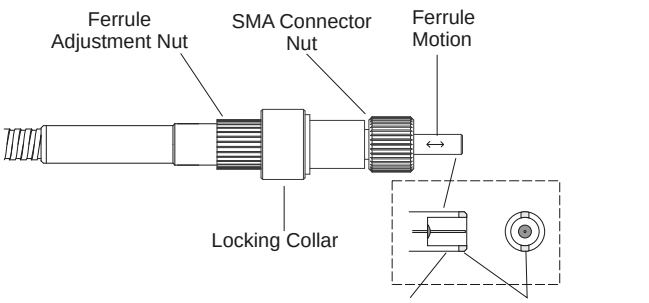


Figure 2: High Power Adjustable SMA Connector Design

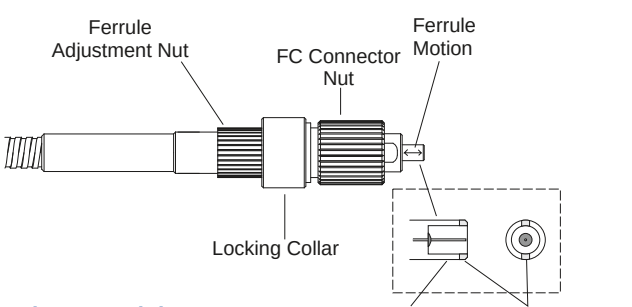
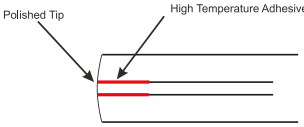
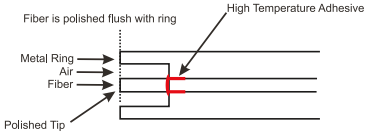
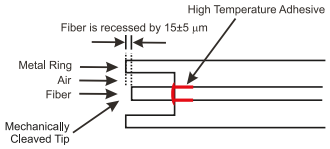
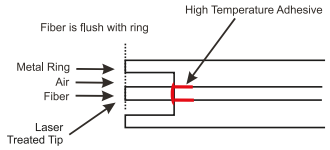
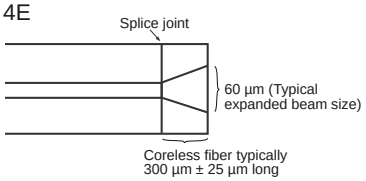


Figure 3: High Power Adjustable FC Connector Design

Table 1: Summary of Key Features of High Power Connectors

Item No.	Type of Connector Finish	Relevant Diagram	Key Feature(s)	Applicable Fiber Sizes	Connector Types Available (1)	Fiber Recess
1	Standard Finish	Fig 4A  **A) Standard Connector Finish Fiber is flush with connector ring**	High Temp. Adhesive	All fiber sizes	FC, Adjustable FC, SMA 905 and Adjustable SMA 905	Fiber is polished flush with the metal ring
2	HP: High Power Polish	Fig 4B  **B) High Power Polished Air Gap Connector Finish**	High Temp. Adhesive + Air Gap Connector Design	From 200/240 µm to 940/1000 µm sized fibers, except Polymer clad fibers	FC, Adjustable FC, SMA 905 and Adjustable SMA 905	Fiber is polished flush with the metal ring
3	HPM: High Power Mechanical Cleave	Fig 4C  **C) High Power Mechanically Cleaved Air Gap Connector Finish**	Mechanical Cleave + High Temp. Adhesive + Air Gap Connector Design	All fiber sizes and types except Polymer clad fibers	FC, Adjustable FC, SMA 905 and Adjustable SMA 905	Fiber is recessed by 15±5 microns from the metal ring edge
4	HPL: High Power Laser Treated	Fig 4D  **D) High Power Laser Treated Air Gap Connector Finish**	Laser Treated + High Temp. Adhesive + Air Gap Connector Design	For up to 200 µm core sized fibers (Laser Treated)	FC, Adjustable FC, SMA 905 and Adjustable SMA 905	Fiber is polished flush with the metal ring
5	HPC: High Power Coreless Fiber Endcap	Fig 4E 	Mechanical Cleave + Coreless fiber fusion splice + High Temp. Adhesive + Air Gap Connector Design	All 125 µm cladding fibers	Adjustable FC, and Adjustable SMA 905 only	Fiber is recessed by 15±5 microns from the metal ring edge

Notes:
(1): For more details see Table 2 on high power connector finishes available.

Ordering Information For Standard Parts:

Laser To Fiber Source Couplers with Adjustable Focus

Bar Code	Part Number	Description
8657	HPUC-2A3A-400/700-S-3.5AC-1	Non-Contact style laser to SM fiber coupler for 400-700nm, with an adjustable angle FC compatible receptacle, f=3.5mm achromatic lens and 1"-32 TPI male threaded adapter.
16254	HPUC-2A3A-400/700-S-3.5AC-11	Non-Contact style laser to SM fiber coupler for 400-700nm, with an adjustable angle FC compatible receptacle, f=3.5mm achromatic lens and post mount adapter.
16811	HPUC-2A3A-400/700-P-3.5AC-1	Non-Contact style laser to PM fiber coupler for 400-700nm, with an adjustable angle FC compatible receptacle, f=3.5mm achromatic lens and 1"-32 TPI male threaded adapter.
11623	HPUC-2A3A-400/700-S-6AC-1	Non-Contact style laser to SM fiber coupler for 400-700nm, with an adjustable angle FC compatible receptacle, f=6mm achromatic lens and 1"-32 TPI male threaded adapter.
14160	HPUC-2A3A-400/700-S-6AC-11	Non-Contact style laser to SM fiber coupler for 400-700nm, with an adjustable angle FC compatible receptacle, f=6mm achromatic lens and post mount adapter
12070	HPUC-2A3A-400/700-P-6AC-11	Non-Contact style laser to PM fiber coupler for 400-700nm, with an adjustable angle FC compatible receptacle, f=6mm achromatic lens and post mount adapter

Adjustable Patchcords

Bar Code	Part Number	Description
12538	QSMJ-A3A,3S-488-3.5/125-3-2	2 meter long, 3mm OD PVC jacketed 3.5/125µm 488nm high power SM fiber patchcord, terminated with an adjustable angled FC/APC connector on one end, and a Super FC/PC connector on the other end.
17546	QSMJ-A3A,3A-488-3.5/125-3A-2	2 meters long, 3mm OD armor cabled, 3.5/125µm 488nm high powered SM fiber patchcord, terminated with an adjustable angled FC/PC connector on one end and an angle FC/PC connector on the other end.
10152	SMJ-A3A,3A-633-4/125-3-1	1 meter long, 3mm OD PVC jacketed, 633nm 4/125 SM fiber patchcord, terminated with an adjustable angled FC/PC connector on one end, and an angled FC/PC connector on the other end.
10822	SMJ-A3A,3A-800-5/125-3-2	2 meter long, 3mm OD PVC jacketed, 800nm 5/125 SM fiber patchcord, terminated with an adjustable angled connector FC/PC on one end, and an angled FC/PC connector on the other end.
13091	SMJ-A3A,3S-1300/1550-9/125-3-2	2 meter long, 3mm OD PVC jacketed, 1300/1550nm 9/125 SM fiber patchcord, terminated with an adjustable angled connector FC/PC on one end, and a Super FC/PC connector on the other end.
16648	SMJ-A3A,3A-1300/1550-9/125-3-1	1 meter long, 3mm OD PVC jacketed, 1300/1550nm 9/125 SM fiber patchcord, terminated with an adjustable angled connector FC/PC on one end, and an angled FC/PC connector on the other end.
16898	QPMJ-A3A,3S-488-3.5/125-3AS-2-1	2 meter long, 3mm OD stainless steel armored 3.5/125µm 488nm high power polarization maintaining fiber patchcord, terminated with an adjustable angled FC/PC connector on one end, and a Super FC/PC connector on the other end. Both ends have the fiber slow axis pre-aligned and locked in line with the connector key.
15324	QPMJ-A3A,3A-488-3.5/125-3AS-2-1	2 meter long, 3mm OD stainless steel armored 3.5/125µm 488nm high power polarization maintaining fiber patchcord, terminated with an adjustable FC/PC connector on one end, and an Angled FC/PC connector on the other end. Both ends have the fiber slow axis pre-aligned and locked in line with the connector key.
9697	PMJ-A3A,3A-633-4/125-3A-3-1	3 meter long, 3mm OD armor cabled, 633nm 4/125µm polarization maintaining fiber patchcord terminated with an adjustable angled FC connector on one end and an angle FC/PC connector on the other end. Both ends have the fiber slow axis pre-aligned and locked in line with the connector key.
17409	PMJ-A3A,3A-800-5/125-3-1-1	1 meter long, 3mm OD PVC jacketed, 800nm 5/125µm polarization maintaining fiber patchcord, terminated with an adjustable angle FC/PC connector on one end and an angle FC/PC connector on the other end. Both ends have the fiber slow axis pre-aligned and locked in line with the connector key.

Alignment Kits

Bar Code	Part Number	Description
30635	START-0A3A-USB-IRVIS	Alignment kit for laser to fiber couplers with adjustable angle FC/APC compatible receptacles. The kit includes a MM patchcord and a instructional video on a USB drive. For 400–1600nm applications.
31190	START-0A3A-USB-UVVIS	Alignment kit for laser to fiber couplers with adjustable angle FC/APC compatible receptacles. The kit includes a MM patchcord and a instructional video on a USB drive. For 180–700nm applications.

Ordering Information For Custom Parts:

OZ Optics welcomes the opportunity to provide custom designed products to meet your application needs. Customized products do take additional effort, so please expect some differences in the pricing compared to our standard parts list. In particular, we will need additional time to prepare a comprehensive quotation, and lead times will be longer than for standard products. These points will be carefully explained in your quotation, so your decision will be as well-informed as possible.

Questionnaire For Custom Parts:

1. What wavelength of light will you be transmitting through the fiber?
2. Are you working with a pulsed or continuous source?
3. If continuous, what is the output power from your source, in watts?
4. If pulsed, what are the pulse energies (in mJ), pulse duration (in nsec), and repetition rate?
5. Do you need multimode, singlemode, or polarization maintaining fiber?
6. If multimode, do you need graded index or step index fiber?
7. What fiber core/cladding size do you prefer?
8. What should the numerical aperture of the fiber be?
9. How long should the patchcord be, in meters?
10. What type of connectors do you need on each end?
11. What type of cabling do you need?

Ordering Information: Coupler With Adjustable Focus:

HPUC-*2X*-*W*-*F*-*f*-*LH*

Receptacle Code:
A3 for adjustable FC
A3A for adjustable FC/APC
A5 for adjustable SMA

Wavelength: Specify in nanometers
(Example: 1550 for 1550nm)
For achromats for wavelengths specify 400/700

Fiber Type: M for Multimode
S for Singlemode
P for Polarization Maintaining

Laser Head Adapter
1 for 1"-32TPI Male Threaded Adapter
2 for Disk Adapter with 4 holes on 1" square
11 for Post Mount Adapter

See Table 8 of the *Standard Tables* for other adapters
http://www.ozoptics.com/ALLNEW_PDF/DTS0079.pdf

Lens ID: See Lens Selection Guide 2 for Non - Contact couplers with receptacles in the *Laser to Fiber Coupler Application Notes.*
http://www.ozoptics.com/ALLNEW_PDF/APN0004.pdf

Adjustable Patchcords:

F*MJ-*X,Y*-*W*-*a/b*-*JD*-*L*(-*A*)-*(OPT)

Fiber Type: M for Multimode
S for Singlemode
P for Polarization Maintaining
QM for High Power Multimode
QS for High Power Singlemode
QP for High Power PM

Connector Code:
A5 = Adjustable SMA
A5HP = Adjustable high power polished airgap SMA90S connector
A5HPM = Adjustable high power mechanically cleaved airgap SMA905 connector
A5HPL = Adjustable high power laser treated airgap SMA905 connector
A3 = Adjustable Flat NTT-FC
A3S = Adjustable Super NTT-FC/PC
A3U = Adjustable Ultra NTT-FC/PC
A3A = Adjustable Angled NTT-FC/PC
X = Unterminated End
A3HP = Adjustable high power polished airgap FC connector
A3HPM = Adjustable high power mechanically cleaved airgap FC connector
A3HPL = Adjustable high power laser treated airgap FC connector
A3AHP = Adjustable high power angle polished airgap FC connector
A3AHPM = Adjustable high power mechanically angle cleaved airgap FC connector
A3AHPL = Adjustable high power laser treated angled airgap FC connector

See table 6 of the *Standard Tables* for other connectors.
http://www.ozoptics.com/ALLNEW_PDF/DTS0079.pdf

OPT = Options
-CF1 for cooling fins on the first end only
-CF2 for cooling fins on both ends
-CM1 for cladding mode stripping and cooling fins on the first end only
-CM2 for cladding mode stripping and cooling fins on both ends

A = Alignment (Polarization maintaining patchcords only)
0 = unaligned and rotatable
1 = slow axis of the fiber aligned with respect to the key and locked

Fiber Length in meters

Fiber Jacket Type: 1 = 900 micron OD hytrel jacket
3 = 3mm OD Kevlar reinforced PVC cable

See Table 7 of the *Standard Tables* for other jacket sizes.
http://www.ozoptics.com/ALLNEW_PDF/DTS0079.pdf

Fiber Core/Cladding Sizes in Microns:
9/125 for 1300/1550nm SM fiber

See Tables 1 to 5 of the *Standard Tables* for other standard fiber sizes.
http://www.ozoptics.com/ALLNEW_PDF/DTS0079.pdf

Wavelength: Specify in nanometers
(Example: 633 for 633nm)

For Multimode fibers specify either UVVIS for ultraviolet/visible wavelengths or IRVIS for visible/infrared wavelengths.

NOTE: To determine the best laser to fiber source coupler for your application please complete a *Laser to Fiber Delivery System Questionnaire* http://www.ozoptics.com/ALLNEW_PDF/QTR0002.pdf. OZ Optics will then recommend a coupler system based on your response.

Lens Selection Guide for Laser to Fiber Couplers can be found: http://www.ozoptics.com/ALLNEW_PDF/DTS0108.pdf
Laser Head Adapter Drawings can be found: http://www.ozoptics.com/ALLNEW_PDF/DWG0001.pdf
Standard Tables can be found: http://www.ozoptics.com/ALLNEW_PDF/DTS0079.pdf
Laser to Fiber Source Couplers - Application Note can be found: http://www.ozoptics.com/ALLNEW_PDF/APN0004.pdf

Frequently Asked Questions (FAQs):

Q: What are the maximum power handling levels for singlemode and polarization maintaining fibers?
A: It depends on the size of the fiber core and the operating wavelength. For instance singlemode fiber for 488nm can typically withstand a maximum of 1 to 3 W of continuous input power. In comparison 9/125 fiber can transmit 3 to 5 W of power. For fiber and wave lengths between these two examples the maximum power level will be somewhere between these two levels.

Q: I have a pulsed laser source. How do I select the correct fiber core size?
A: Pulsed lasers are more difficult to work with, because factors such as pulse energy duration and repetition rate must be factored into the calculation. We recommend contacting one of our sales representatives, who can determine the optimum fiber for your application.

Q: Can I connect together two fibers that are terminated with your high power connectors?
A: Our patented adjustable connector design allows one to safely connect two fibers together without damaging the fiber ends. A gap of between 20 microns and 100 micron in width will be present between the two fibers.

Q: What is the difference between a multimode fiber and a fiber bundle?
A: A multimode fiber is a single fiber, whose core is large enough to allow different paths, or modes, for the light to travel within the fiber core. In contrast a fiber bundle consists of several fibers glued together to form a bundle. Each fiber carries light independently. OZ Optics normally offers multimode fibers, not fiber bundles.

Q: Are there any special handling precautions when working with high power connectors and patchcords?
A: Yes. Two factors must be kept in mind at all times. First, the fibers must be aligned and tested at low powers and only once good coupling from the laser into the fiber is achieved can the input power be increased. Second, the fiber ends must be kept completely clean, as any contamination can cause burning of the fiber. See the application notes for further details.

Q: What sort of warranty do you provide?
A: OZ Optics products are warranted against defects in materials and workmanship for a period of 1 year, unless otherwise stated, from the date of delivery to the initial end-user of the product. However if a patchcord end gets burned during installation or operation at high powers, the failure is usually due to factors outside of our control, such as misalignment or contamination. As a result failures of this nature are usually not covered under warranty.

Application Notes:

Safe installation of high power patchcords in laser to fiber delivery systems:

Important: Before using OZ Optics' fibers with your equipment, make sure that you are familiar with all operating and safety instructions provided with your source. **OZ Optics is not liable for any damage or harm caused by misuse of either the laser or of OZ Optics devices.**

1. Before attaching the provided fibers to your system, inspect both the input and output connector ends. The endfaces should be clean, shiny, and as free from contamination as possible. If not, clean the ends as outlined in the section titled Maintenance. Check the fiber ends both before connecting the fiber and also after disconnecting the fiber. It is very easy for contaminants to be transferred from one connector to another if one is not careful.
2. To avoid damage to the fibers being used, turn the source off, or reduce the power level to less than 50mW before attaching the fiber. If any optics have to be aligned, then perform the initial alignment at low power (<50mW). Only after the optics are fully aligned and locked should the laser power be increased.
3. It is recommended that the laser power be increased by only 0.25 watts every few minutes, and that the output power from the fiber should be monitored, to ensure that the coupling efficiency is not changing with power.
4. Do not use any index matching gel, thread locking fluid, or any lubricants with the connector. Do not use in the presence of chemical fumes or oils.

MAINTENANCE

When not in use, the ends of the fiber and the connector receptacles should be covered with the supplied metal caps. This will protect the connectors from dirt and contamination. DO NOT USE PLASTIC CAPS. Plastic caps often are contaminated with mold release agents, which can get onto the fiber ends. This contamination is extremely difficult to see, and resists cleaning.

Air gap connectors are best cleaned by immersing them in an ultrasonic bath containing either methanol (preferred) or isopropanol (acceptable). This thoroughly cleans the connectors without physically touching the fiber ends. Please read all safety instructions for both the cleaner and the solvents before using them. Use filtered compressed air to blow any dust or dirt off the ferrule when finished. Carefully inspect the tip of the fiber under reflected light. The tip should be clean and shiny.