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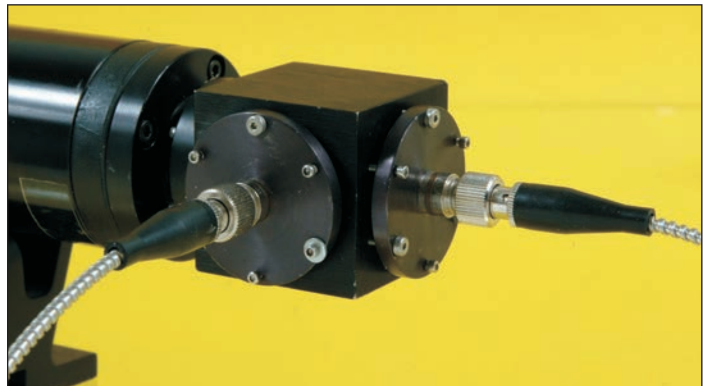
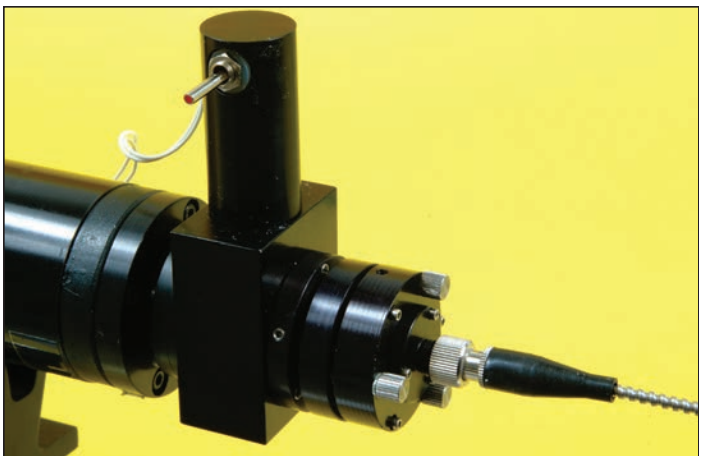
LASER TO FIBER SOURCE COUPLERS APPLICATION NOTES


Laser To Fiber Coupler With Adjustable Focus


Laser To Fiber Coupler With A Beam Splitter


Laser To Fiber Coupler With A Shutter


Laser To Fiber Coupler With Motor Driven Attenuator

Application Notes

OZ Optics offers a complete line of fiber optic source couplers, designed to couple light from a collimated source into either multimode, singlemode, or polarization maintaining fibers. Source couplers are available for wavelengths from 180 nm to over 2000 nm, and for input powers of up to 100 Watts CW. OZ Optics' offers couplers with a variety of lens types, such as Graded index (GRIN) lenses, aspheres, achromats, etc. to ensure optimum performance for your application. Source couplers can be used with singlemode, multimode and polarization maintaining fibers, and are ideal for use with gas lasers, such as HeNe and Ar-Ion lasers. They offer coupling efficiencies of 55% to 90% for singlemode fibers, and 75% to 95% for multimode fibers.

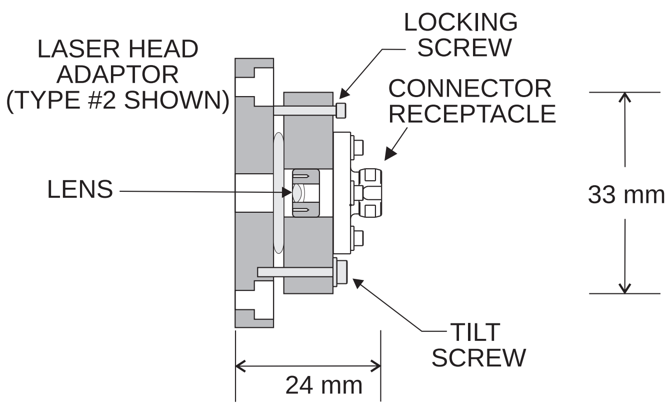
Using a combination of focusing lenses with a patented tilt adjustment technique, OZ Optics offers a device capable of submicron resolution, and coupling efficiencies close to the theoretical maximum. The package is rugged and stable, and does not require an optical bench for operation. Thus, it offers superior performance at a fraction of the cost of expensive micropositioner stages. All of these features make OZ Optics couplers worth purchasing. OZ Optics' source couplers use a lens to focus the light from the laser to a spot matching the size of the fiber core. The coupler is attached directly onto the laser. The coupling optics are precisely aligned with respect to the laser beam through the use of three fine tilt adjustment screws, together with an O-ring, that is used as a pivot. Once the coupler is aligned for maximum coupling efficiency, it is locked using three locking screws, forming a rigid, rugged coupling system. The design is flexible, allowing a wide variety of configurations.

Coupler Types

There are three basic types of laser to fiber source couplers: 1) Non-contact receptacle style source couplers, 2) Pigtail style couplers, and 3) Adjustable focus source couplers. Non-contact style couplers connect the fiber to the coupler via commercially available connector receptacles, such as NTT-FC, AT&T-ST, SMA, etc. Pigtail style couplers have the output fiber permanently attached to the coupler. Adjustable focus couplers use a special connector to adjust the distance between the fiber and the lens. Each of the coupler types has its own advantages and disadvantages.

Receptacle Style Non-Contact Source Couplers (HPUC Model)

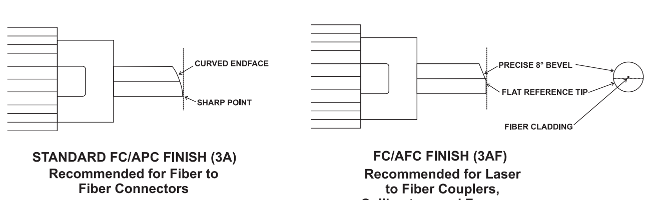
In non-contact style source couplers, an air gap exists between the fiber and the lens. This design is flexible, allowing a wide range of lens types and focal lengths to be used. The distance between the fiber and the lens can be adjusted to compensate for changes in the source wavelengths or to intentionally defocus the laser beam to prevent arcing in high power laser to multimode fiber applications. Couplers using GRIN lenses, achromats, aspheres, fused silica, plano-convex, and biconvex lenses have all been made utilizing this design.



Receptacle Style Source Coupler

Non-contact style couplers can handle input powers of up to 100W CW, and even higher energies from pulsed sources. They are best suited for applications where either the input energy is higher than 400mW, or when more than one wavelength is to be coupled into the fiber, or for input beams that have unusually large beam diameters or divergence angles. They also have superior polarization maintaining capabilities compared to physical contact style couplers. However because of the air gap between the fiber and the lens, the backreflection level for the endface of the fiber is about -14dB. This can be reduced to -40dB to -60dB by using angled polished connectors to deflect the backreflected signal.

One drawback with angled polished connectors is that there is a significant variation in the endface geometries of angled PC (APC) polished connectors. This affects the spacing between the endface of the fiber and the lens. To minimize this variation, OZ Optics offers an angled flat (AFC) polished connector. This connector features a beveled endface where the fiber itself is angled, but the ferrule tip is flat. This geometry provides optimum repeatability between connections.

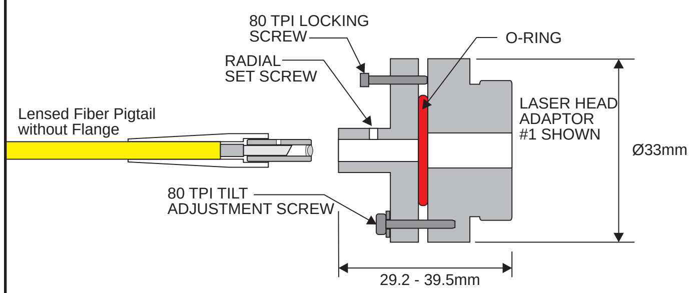


Connector Polish Styles

Pigtail Style Source Couplers (LPSC Model)

Pigtail style source couplers are recommended for permanent or semi-permanent situations, where optimum coupling efficiency, output stability, and minimum backreflection is desired. In these couplers the fibers are permanently glued to the focusing lens. The fiber-lens assembly is then inserted into the tilt adjustment flange, and held in place with two radial set screws. Because the fiber is permanently attached to the lens, the fiber cannot be replaced without also replacing the coupling lens.

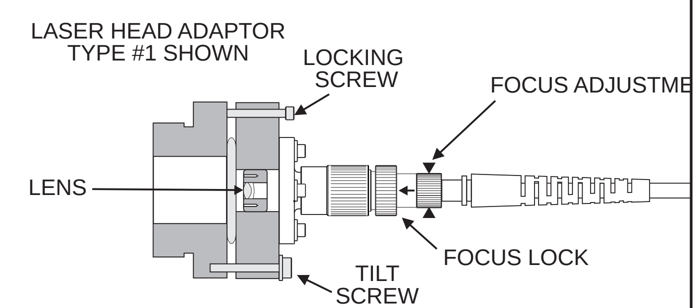
In pigtail style couplers the internal endface of the fiber is polished at an angle to reduce backreflection. Pigtailed couplers are available with up to -40dB or -60dB backreflection levels.



Pigtail Style Source Coupler

Laser To Fiber Couplers With Adjustable Focus

Adjustable focus couplers are ideal for situations where optimum coupling efficiency is critical. A special connector allows the spacing between the fiber and the lens to be precisely controlled without rotating the fiber. This allows one to compensate for any changes in the wavelength or the beam waist location, thus further optimizing the coupling efficiency. Adjustable focus couplers feature the same wide range of lens types as non-contact style couplers with receptacles. Internal surfaces are angled polished and/or AR coated to minimize backreflection. Fiber patchcords with adjustable connectors are available separately. Contact OZ for more information.

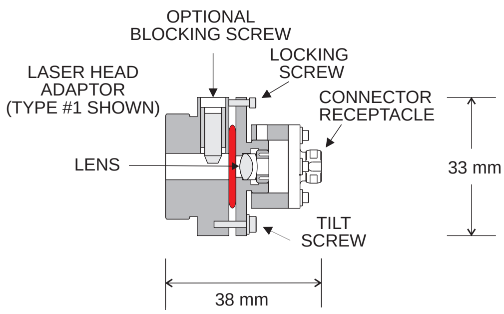


Receptacle Style Source Coupler with Adjustable Focus

Options

OZ Optics couplers are available in a wide variety of configurations. The following section outlines some of the possible variations.

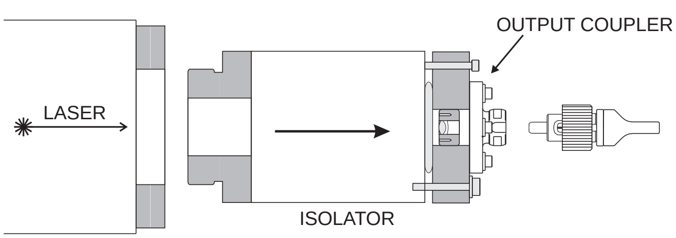
Built in attenuators and shutters: Often one wants to control the amount of light coupled into a fiber in a precise manner. One technique to do this is using a blocking style attenuator. A precision blocking screw intercepts part of the beam before it enters the coupler. By turning the screw, one controls how much light reaches the coupler, and thus the output power.



Receptacle Style Source Coupler with manual blocking attenuator

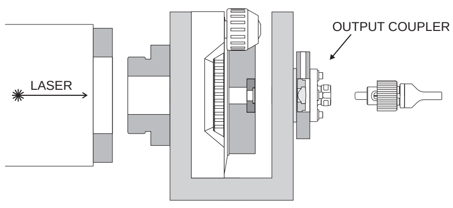
Source couplers are available with both manual and electrically controllable attenuators. Electrically controlled attenuators can be calibrated, to give exact power control. Shutters provide a simple way to block or transmit light through a fiber. They are commonly used in safety interlocks, or as on/off switches.

Isolators: Some lasers are sensitive to any feedback from reflected light returning to the laser cavity. To stop reflected light from entering the cavity an optical isolator can be added. The isolator transmits light in one direction while blocking light in the reverse direction.



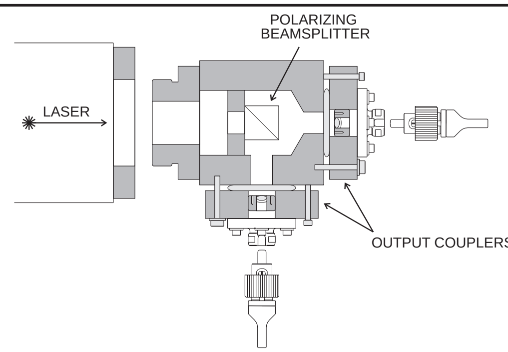
Receptacle Style Source Coupler with Isolator

Built-in polarization rotation stages: When coupling light into polarization maintaining fiber, it is important to align the polarization of the laser with the polarization axis of the fiber. Polarization rotation stages provide a convenient means of doing this. A half-wave plate on a rotary platform is mounted between the laser and the coupling optics. Rotating the halfwave plate rotates the angle of polarization of light being launched into the fiber. The orientation of the wave plate can be read directly on the rotary stage. This technique can also be used to study the behaviour of fiber optic devices with respect to polarization.



Receptacle Style Source Coupler with Polarization Rotator

Source to fiber optic beamsplitters: Source to fiber optic beam splitters divide the light before coupling it into fibers. This is useful whenever we need more than one output from the same source. For instance the system can be used to form fiber optic interferometers. Another application is to use one port to monitor the output power from the laser.



Collimated Source To Fiber Splitter

This list of options presented here is by no means complete. Additional information is readily available. Just contact an OZ Optics technical salesperson for more details.

Operating Principle

OZ Optics' couplers consist of two baseplates, separated by a resilient O-ring. One plate, the laser head adapter, is designed to attach directly onto the laser. The other plate contains the focusing optics and the connector for the input fiber. A focusing lens is used to focus the light from the source to a spot matching the core size of the fiber. The connector has a stop inside to stop the fiber precisely at the focal plane of the lens being used. This eliminates the need to do any time consuming Z-axis adjustment of the fiber position, saving time and money.

First, the focusing lens is centered with respect to the incident laser beam. This is done by laterally sliding the baseplate containing the focusing optics with respect to the fixed laser head adapter. The coupler allows about 1mm of lateral (x-y) travel to center the optics. If this range is insufficient, then the coupler may be attached to an x-y positioning stage. One advantage of OZ couplers is that only coarse centering of the optics is required. Fine adjustment of the focused beam is achieved using three tilt adjustment screws.

The two halves of the coupler are connected by three fine thread screws. These screws are adjusted with a screwdriver, provided with the coupler. By adjusting these screws, one can adjust the tilt angle between the focusing optics and the incident laser beam. This in turn moves the point at which the focused beam strikes the fiber. Thus by adjusting the tilt angle, one can align the focused rays to strike the fiber core.

Figure 1 shows the effect of adjusting the tilt angle between the focusing optics and the source beam by an angle θ. The focused beam is displaced by a distance $z = f \tan\theta$, with respect to the fiber where f is the focal length of the lens being used. For small tilt angles, the resolution of the coupler (Δz) is determined by $\Delta z = f\Delta x/L$, where Δx is the resolution of the screws and L is the length of the lever arm. For 80 TPI screws, a 1 mm focal length lens, and a 20 mm lever arm, Δz = 1 mm · 2 µm/20 mm = 0.1 µm.

To obtain good coupling efficiency one must focus the light from the source precisely onto the core of the fiber. In addition the focused laser beam must match the parameters of the fiber for optimum coupling efficiency. In particular, two conditions should be met for maximum coupling efficiency:

(i) The focused spot diameter **(SD)** of the laser beam should be less than or equal to the mode field diameter of the fiber being used (**a**).

(ii) The numerical aperture of the focused laser rays (**NA_{rays}**) should not exceed the NA of the fiber being used (**NA_{fibers}**).

To match these two conditions, one must know two basic properties of the laser beam - the laser beam diameter (**BD**) and the laser beam full divergence angle (**DA**). Given these two values and the focal length (**f**) of the lens being used to focus the laser rays, one can calculate the focused spot properties. To do so use the following formulas:

$$SD\ (\mu m) = f\ (mm) \times DA\ (mrad) \leq a$$

$$NA_{rays} = BD\ (mm)/2f\ (mm) \leq Na_{fiber}$$

For multimode fibers, a range of focal length lenses can be found that can meet the conditions listed above. If possible, try to select optics that can achieve values for SD and Na_{rays} less than or equal to 70% of the maximum allowable values. At the same time, do not focus the spot to a size less than 30% of the fiber core size. In high power applications, this may cause the fiber endface to be burnt.

For singlemode fibers, the choice of lens focal length is more critical. Only one focal length can be found that can meet both requirements for spot size and numerical aperture. Furthermore, the numerical aperture for singlemode and polarization maintaining fibers is not well defined. For reference, we have produced a data sheet titled *Standard Tables For Fibers, Connectors, and Lenses* that lists what we have defined as the Effective Numerical Aperture for these fibers.

Since it is impractical to custom manufacture lens to exactly match each customer's laser, a set of standard focal length lenses are offered. By using the lens that comes closest to the ideal focal length, one can achieve reasonable coupling efficiency (>55%).

The equations given so far assume that the focusing optics are at or near the beam waist. As mentioned earlier, all beams diverge, so the question becomes how far away from the beam waist are the given equations valid? Again, as a rule of thumb, excess losses do not become significant until the beam diameter at the lens is more than 40% larger than the beam diameter at the waist. Outside of this range a more detailed analysis of the optical system must be performed to devise an arrangement to minimize losses. Adjustable focus couplers are ideal for these situations.

In addition, the quality of the focused spot depends greatly on the quality of both the collimated beam and the focusing optics. The equations given so far give only the theoretical limit on the minimum spot size, numerical aperture, etc. The actual measured values may be significantly larger, depending on the optics used. Care should be given on this point.

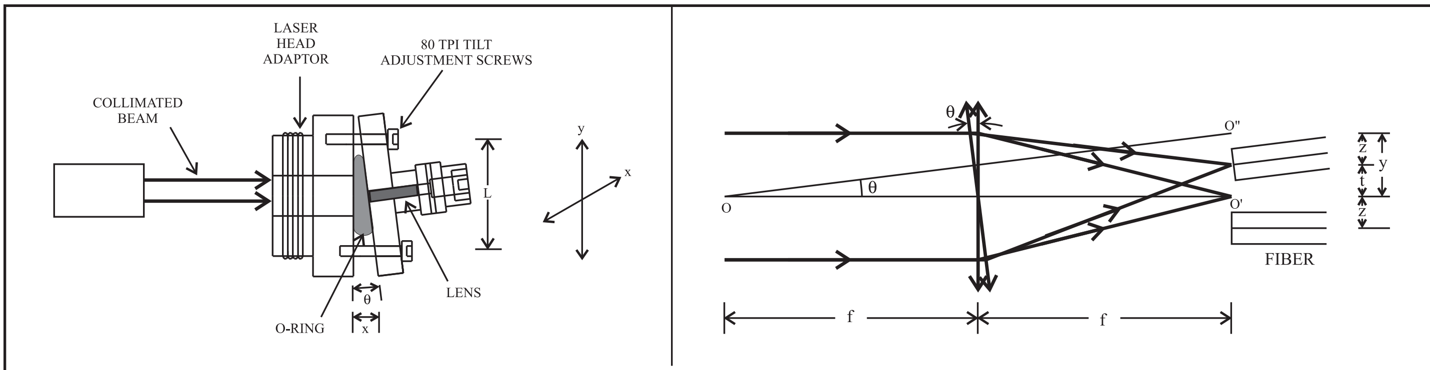


Figure 1: Tilt Adjustment Operating Principle

Coupling Considerations

Backreflection: In some lasers, back-reflection can often cause the laser intensity to fluctuate as well as change the laser frequency. We recommend pigtail style couplers for minimum backreflection (-40dB or lower). You could also use physical contact style couplers with index matching gel to reduce backreflection to 25dB. Index matching gel is not recommended for high power lasers (>100mW), or low power lasers with less than 550 nm wavelengths. The index matching gel may burn if used in such cases.

If you have to have receptacle style couplers, and backreflection is a concern, then we recommend using noncontact style couplers with angled polished (APC) connectors. The problem with angled connectors is that the coupling efficiency into the fiber will change if you use the same coupler with a different APC connector. This is because the position of the fiber with respect to the lens changes due to tolerances on the angle tip of the connector. For this reason, we recommend using fibers with angled flat (AFC) connectors.

Receptacle style couplers are generally recommended for systems that are not sensitive to backreflection and where different fibers are often used. They are also recommended for high power applications where fiber ends could be burnt, in which case connectors could easily be repolished or reterminated. To minimize the backreflection, both ends of the fiber should be angle polished and/or AR (antireflection) coated.

Power Handling: For most applications, power handling is not a concern. All coupler types can handle up to 400mW of optical power without having problems. Recall however, that index matching gel should not be used with physical contact couplers if the output power is greater than 100mW, or if the laser wavelength is shorter than 550 nm.

At optical powers above 400mW, damage can occur in physical contact couplers. Thus only non-contact receptacle style, pigtail style, and adjustable focus couplers are recommended for these power levels. Furthermore, one must be careful during the alignment stage when operating at these power levels. One should do the initial alignment with the laser running at a low output level (< 250mW), then slowly increase the power until the operating level is reached. The total amount of power that can be coupled into a fiber is eventually limited by the fiber itself. If the power density within the fiber is too high, then the fiber core itself can be burned. The limiting factor for this is the fiber core size. A 4/125 fiber can handle 1 to 3 Watts, 9/125 fiber can handle 3 to 5 Watts, 25/125 fiber can handle 5 to 10 Watts, and 50/125 fiber can handle 10 to 20 Watts. Thus someone who wants to couple light from a 15Watt laser will have to use a 50/125 multimode fiber or larger.

OZ Optics carries a complete line for fibers with pure fused silica cores, designed for high power applications. Singlemode fibers for 325 nm, 440 nm, and 488-514 nm wavelengths are available. Fused silica core fibers with 10/125, 25/125, and 50/125 core/cladding sizes, and with 0.11NA are also available.

Lens Types

A wide variety of lenses are available for laser to fiber couplers. Each type has its own advantages and disadvantages. The main types of lenses used are as follows: Graded index lenses, Aspheric lenses, achromat lenses, plano-convex lenses, and biconvex lenses.

Graded index (GR) lenses: Graded index (GRIN) lenses are the most economical lens choice for most collimation applications. They are available in focal lengths from 1.8 to over 6 mm, and provide good coupling with low back reflection. They should be your first consideration for source couplers. They maintain polarization to better than 20dB, while limiting backreflection to as low as -40 dB. They are able to handle up to 1Watt CW of incident light, making them suitable for most low and medium power applications.

Chromatic aberration is negligible at wavelengths beyond 1000 nm. Thus, the same collimator can be used for both 1300 nm and 1550 nm wavelengths. At shorter wavelengths, chromatic aberration does appear. As a result, a collimator using a GRIN lens optimized for 633 nm will not collimate properly at 488 nm. GRIN lenses are also more sensitive to high radiation, and should not be used in radioactive environments.

Aspheric (AS) lenses: Aspheric lenses are an excellent choice for applications requiring extremely low backreflection (<-60 dB), and/or excellent polarization maintenance (30dB). Because they are a molded single element lens with a constant refractive index, they have very low internal stress, thus minimizing birefringence. Their curved surfaces ensure than any reflected light from the lens surfaces is spread out rather than reflected straight back along the optical path. They can withstand over 10W CW of incident light, making them also suitable for high power laser applications. They also exhibit less chromatic aberration compared to GRIN lenses, although it is still present. Focal lengths from 2 mm to over 11 mm are available.

Achromat (AC) lenses: Achromat lenses are the lenses of choice when coupling light of different wavelengths into the same fiber. By using two lens elements, made out of different materials, chromatic aberration is effectively eliminated. Cemented achromats can typically couple up to five to ten Watts of optical power without system failure. Air spaced achromats are also available for higher power applications. Achromats with focal lengths ranging from 3.5 mm to over 20 mm are readily available. They are normally coated with a broadband MgF_2 antireflection coating. High power multiplayer AR coatings are also available. Achromatic doublet lenses for near infrared wavelengths are also available. These lenses are coated for infrared wavelengths. Contact OZ Optics for further details.

Plano-convex (PX, PQ) and Biconvex (BX, BQ) Lenses: Plano-convex and biconvex lenses are best suited for very high power coupler applications, using multimode fiber. Because they are simple lenses, they do exhibit spherical and chromatic aberration, which limits the quality of the focused spot. However, they can handle tens of Watts of optical power without trouble, making them efficient gatherers and deliverers of high intensity light. Standard plano-convex (**PX**) and biconvex (**BX**) lenses are made from BK7 glass. Fused silica plano-convex (**PQ**) and biconvex (**BQ**) lenses are available as well. These lenses are transparent at wavelengths as low as 180 nm, making them ideal for near ultraviolet (**UV**) applications.

Lens Type	Grin Lens	Aspheric Lens	Achromat Lens	Plano And Biconvex Lenses
Multimode Fiber Coupling	Excellent	Excellent	Excellent	Excellent
Singlemode Fiber Coupling	Very Good	Excellent	Very Good	Poor
Polarization Maintaining Fiber Coupling	Good	Excellent	Good	Poor
High Power Handling	Fair	Very Good	Good	Excellent
Coupling Multiple Wavelengths	Telecom Wavelengths Only	Telecom Wavelengths Only	Ideal for Visible	Poor

Frequently Asked Questions (FAQs)

Q: What is the difference between the outputs from multimode, singlemode, and polarization maintaining fibers when they are used with laser sources?

A: The output from a multimode fiber will not emit a uniform, Gaussian output. Instead, it will exhibit a speckle pattern. These speckles are caused by interference between many different modes traveling within the fiber. The larger the fiber core size is, the more modes there are appearing in the fiber output. This pattern of speckles will change with changes in temperature, movement, vibration, and other external factors. If the fiber is only being used as a means of delivering the light energy, then the speckle patterns should not be important.

The output from a singlemode fiber is an almost ideal Gaussian output. Singlemode fibers have much smaller core sizes, so they only propagate one mode. The output beam quality is excellent, with as low as l/15 distortion. However they will not preserve information about the polarization from a fiber. As the fiber is bent, the output polarization changes.

Polarization preserving fiber will preserve the output polarization, provided that the input polarization is both linearly polarized, and that the polarization axis of the light is aligned with the one of the two perpendicular polarization axes of the fiber. If not, the output polarization can also change when it is bent. The output beam quality from a PM fiber is also a near ideal Gaussian.

Q: Will a coupler designed for singlemode fibers work with multimode fibers? Will a coupler designed for polarization maintaining fibers work with singlemode or multimode fibers?

A: Yes it will. The only difference between the couplers is in the quality of the lenses used, and the tolerance of the receptacle. Singlemode source couplers use high quality, AR coated, diffraction limited lenses, and precision tolerance receptacles. PM source couplers use special stress free lenses, and a receptacle with a tight tolerance keyway for better angular alignment. Consequently, either will give good coupling into singlemode or multimode fiber. In general, if you are working with more than one type of fiber, order the coupler designed for the best fiber.

Q: Can I use a coupler with a regular FC receptacle with a fiber with an Ultra PC finish?

A: Yes you can. Flat, Super PC finish, and Ultra PC finish connectors can be used interchangeably in the same receptacle style coupler, with no discernable difference in performance. For that reason we do not distinguish between receptacles for flat, Super PC and Ultra PC finishes.

Q: My fiber has an Ultra PC polished connector. Will I get -50dB return losses?

A: Not with a receptacle style laser to fiber coupler. These connectors only give -50dB return losses when connected to another connector with an Ultra PC finish. In receptacle style couplers the fiber is not touching another fiber, so the reflection levels are much higher, as much as -14dB. If it is important to get low return losses, then we recommend either using a pigtail style laser to fiber coupler with a matching connector on the output, or using fibers with angled finishes.

Q: Can I use a coupler with a regular FC receptacle with a fiber with an Angled PC (APC) finish?

A: Not without experiencing a large decrease in coupling efficiency. The coupler uses an internal stop to ensure that the fiber stops at the point where the light is focused. If you use a fiber with an APC connector inside a coupler designed for non-angled finishes, the fiber core will not lie at the focal plane so coupling efficiency will be lower.

Q: I'm using a coupler for angled PC (APC) connectors with a fiber with an APC connector, but I still don't see good efficiency. What's wrong?

A: Assuming that you have done the alignment correctly, the issue may be the design of the connector endface. They are not all the same. Some are polished at different angles, or with different radius of curvatures. Some have a very strong taper on the end of the ferrule. This the fiber core may or may not lie at the focal point, depending on how the connector is finished.

To produce more uniform results, OZ Optics recommends using its own Angled Flat Connector (AFC). This connector gives the low return losses of the APC connector, but has a flat surface over a large portion of the ferrule, to provide uniformly high coupling efficiencies in matching couplers.

Q: How much power can I couple into a fiber using an OZ Optics source coupler?

A: OZ Optics source couplers are available using quartz or sapphire lenses with special AR coatings to focus over 1000 Watts of light into a fiber. The limiting factor is usually the fiber itself. The larger the fiber core size is, the more power it can withstand without failing. Fused silica fibers, and occasionally sapphire fibers, are used for maximum power handling ability. Polarization maintaining fibers with fused silica cores are also available for high power applications.

Q: Is there a danger of burning the fiber?

A: For laser powers higher than 100mW, or for wavelengths less than 550 nm, there is always a risk of burning the tip of the fiber. However, by following a few simple precautions, one can expect to use OZ Optics couplers without incidence.

First, always ensure that all connectors and receptacles are as clean as possible. There should be no visible signs of contamination on the fibers. Do not use high power fiber optics in the presence of chemical fumes or oils. Do not attempt to clean a fiber while the laser is on.

Second, when initially attaching the fiber to the laser, operate at powers less than 250mW. Once you have confirmed that the light is being coupled correctly, you can then increase the laser power to the proper level.

Q: Can the same source coupler be used with different lasers?

A: It depends. Normal source couplers use lenses that are wavelength dependent, especially at visible wavelengths. At wavelengths less than 550 nm, the couplers should be used for the design wavelength only. For wavelengths between 633 and 1060 nm, singlemode couplers can be used over a wavelength range of ±50 nm without seriously affecting the coupling efficiency. For multimode fibers, the coupling efficiency will be affected much less by changes in the wavelength. Non-contact style laser to fiber couplers that use achromat lenses are also available. They are recommended for multiple wavelength applications in the visible range.

With non-contact style couplers one can also adjust the distance between the fiber and the lens to compensate for changes in the source wavelengths or to intentionally defocus the laser beam to prevent arcing in high power laser to multimode fiber applications. For the far infrared wavelengths (greater than 1250 nm), the focal length hardly varies. At these wavelengths the coupling efficiency will not change by more than a few tenths of a dB.

A more important factor is the laser beam characteristics (the beam diameter and divergence angle). Focusing lenses are selected for optimum coupling efficiency for particular beam characteristics. If these beam characteristics are very different for each laser, then the coupling efficiency will be reduced. Again, for multimode fibers the results will be much smaller, often negligible.

Finally, do not use a source coupler at higher power levels than it is designed for. A source coupler designed for high power applications can be safely used at lower powers. However couplers designed for low power applications can be damaged if used with high power lasers. Refer to the source coupler specifications for information on power handling capabilities.

Q: The output from my fiber keeps fluctuating. What's going on?

A: There are three main possible causes of fluctuations in the output power from a fiber. They are:

a) The laser beam alignment drifts angularly with time and temperature. This changes the angle of incidence at which the light strikes the coupler. This in turn causes the focused spot to move with respect to the fiber core,causing the coupling efficiency to change.

b) The output intensity from the laser changes with time. This is especially common with older gas tube lasers, where the tube needs time to warm up.

c) The laser cavity is sensitive to backreflection. Reflections from either the input or output fiber end cause feedback within the laser cavity, causing the laser output to change in both intensity and frequency.

The first two causes of output fluctuations are laser dependent. By using a better laser, the effects can be eliminated. Backreflection problems can be reduced in one of three ways. First, an isolator can be added between the laser and the coupler. Unfortunately this method is often very expensive. Another option is to use a low backreflection fiber source coupler. For these couplers, the input and output ends of the fiber are angled polished. In addition, AR coated lenses that have no flat surfaces are used. For the very lowest backreflection levels, output stability, and maximum coupling efficiency use pigtail style couplers.

A final option for contact style source couplers is to use index matching gel between the lens and the fiber. This eliminates any reflections from any small air gap between the lens and the fiber. However, gel absorbs light at wavelengths less than 550 nm. Do not use gel for these wavelengths, or with lasers with output powers greater than 100mW. Do not use gel with noncontact style couplers. They are not designed to work with gel.

Q: I am using a coupler and fiber with an angled connector on the input side, but I still see a strong reflected signal. Why?

A: Did you use angled connectors for your output end as well? If the far end of the fiber has a non-angled connector, then the reflection for that end of the fiber may also be reflected back into the source. It is essential to consider all possible points of reflection in a system.

Q: I don't want to attach the source coupler directly onto the laser. How can I couple a beam in free space into a fiber?

A: In many applications, the laser is positioned on an optical bench. The laser beam then has to pass through several optical devices, such as polarizers, modulators, mirrors, etceteras. OZ Optics source couplers can be mounted on X-Y translational stages, U-brackets, post mounts, etc. A variety of these devices are already provided by OZ Optics. Table 2 of this brochure lists the different adapters available. For information on U-brackets, refer to the separate data sheet available.

In essence, the OZ Optics coupler consists only of a fixed mount of some sort, and the tilt adjustable coupling optics, separated only by an O-ring. The fixed mount serves as the reference against which the tilt of the coupling optics is adjusted, to achieve optimum efficiency. If you can provide some sort of mounting surface, you can use an OZ Optics source coupler.

Q: My laser does not have any mounting holes. How can I use a source coupler?

A: OZ Optics manufactures many laser head adapters that simply slide over cylindrical laser tubes. Set screws on the adapter are tightened against the tube to secure the coupler. See table 2 of the brochure for a list of different adapters. If you cannot find an adapter that fits your laser, then contact OZ Optics. A laser head adapter can be custom made to fit your laser.

Q: How stable is the laser to fiber source coupler with respect to vibration and temperature?

A: OZ Optics source couplers are designed to operate over a temperature range of -35 °C to +65 °C. They have also been used in heavy vibration environments, such as helicopters. To achieve optimum coupling and stability, it is very important that the tilt alignment be securely locked using the locking screws on the coupler. Pigtail style couplers are recommended for the very best stability and ruggedness.

Q: Can I use a source coupler with a source that does not have a collimated output?

A: If the source is a laser diode or SLED, a lens can be attached to the source to collimate the output before coupling it into the fiber. If the source has a beam output that cannot be collimated, then one can use a non-contact style coupler where the distance between the fiber and the lens can be adjusted until the image of the source is focused on the endface of the fiber. This will produce the optimum coupling efficiency.

Q: What if my laser beam is not centered exactly with respect to the outer housing?

A: If the offset is less than 1 mm, it can easily be compensated for by laterally adjusting the coupling optics with respect to the laser head adapter. This ability is built into the source coupler design. If the offset is more than 1 mm, then an adapter must be constructed with tapped holes positioned to compensate for the offset. OZ Optics can also offer couplers with a built in XY positioning stage to compensate for large offsets.

Q: I seem to be only able to get about a few percent of my laser light launched into my fiber. What should I do?

A: The most likely reason for the low coupling is that you have not aligned the coupler to the main beam, but instead to either a weak internal reflection of the beam, or to a local maximum within the structure of the focused spot. These are usually caused by a diffraction ring, or Airy Disk, surrounding the focused spot.

Typically the problem can be solved by just adjusting each tilt screw first one way, then the other, by at least a full turn. If necessary, recheck the centering of the optics. Watch the output signal as you do this and you will find at some point that the output power will increase dramatically.

Q: What else can limit the coupling efficiency of my system?

A: There are several possible causes. These include:

1. Your laser beam output is not well collimated. You should consider using a coupler with an adjustable focus instead.
2. Your laser might not be a true TEM00 laser beam. Laser beams need to provide good Gaussian outputs to obtain good coupling efficiency into singlemode or polarization maintaining fibers.
3. Your laser beam output is elliptical instead of round. This is especially common for collimated laser diode assemblies.
4. You have mounted the coupler far away from the laser. This is often done on optical bench assemblies. If the coupler is too far away from the beam waist then the light will diverge too much before it reaches the coupler. Again consider a laser to fiber coupler with adjustable focus.

Q: I have a problem with the pointing stability of my laser. The angle of the laser tube with respect to the laser chassis changes with time and temperature. What can I do?

A: Instead of attaching the coupler onto the outer chassis, attach the source coupler to the laser tube itself. This will solve the stability problem.