

## **Lensed Fibers & Tapered Ends Description:**

LaseOptics Corporation (“LaseOptics”) has been producing next generation optical lensed fibers. LaseOptics Lensed Optical Fibers technology is proprietary integrated laser fusion/thermal fusion /micro polishing/chemical etching enables, high-end lenses to be manufactured in volume at low costs. The laser quickly shapes the fiber tip into a precise geometry using an optimized numerical solution based on the targeted far-field profile. In-line far-field monitoring ensures repeatability and high coupling efficiency.

We have been creating custom end tips and different spot sizes, according to customers’ specifications. These fibers are highly useful for the fiber coupling of high power diode lasers (HPDLS), and also for single mode and multimode applications. They are bare fibers, such as SMF-28, Corning Flexcore, Pure Mode, Polarization Maintaining Fibers and other Multi mode fibers or any other custom bare fibers. Lensed fibers are rapidly becoming the method of choice for interfacing optical fiber to waveguide coupling and VCSEL’s.

LaseOptics main focus is in lensed/tapered fiber technology products line and is responsible of manufacturer of high quality lensed fibers, tapered fibers bio-medical cables, fiber bundles, defense fiber optics cables or patch cords. LaseOptics has been producing high quality telecommunication fibers in several designs like conical and ball lens and double wedge (screw driver) and 45 degree angle shaped etc.

Additionally, LaseOptics has been manufacturing two wavelengths mixing bio-medical fiber probes with connectorization of SMA, FC, ST, SC and LC for other dental and telecommunications purposes. LaseOptics lensed/tapered fibers are high performance components for collimating, focusing light and improve coupling between optical fiber and laser diode, active devices or photo diodes. The manufacturing processes allow the light can be transformed to improve mode matching and coupling efficiency with the waveguide device, laser diode chip or photo diode chip.

LaseOptics lensed fibers are manufactured by precisely drawing the fiber cladding as well as the core and then shaping the endface to create the optimal light output/input for specific applications. An alternative technique has incorporated with a specific radius and shaped angle, forming a lens by using laser fusion/micro polishing techniques, normally by shaping the fiber to form a chisel or double wedge or screw driver shape.

The characteristics of the fiber tapers depend greatly upon the application. For laser diode and waveguide coupling applications, beam quality is paramount. The focused spot characteristics must match the waveguide characteristics as closely as possible to ensure good coupling. In contrast, fiber to photodiode coupling does not require a high quality beam. Only one has to ensure that the focused spot size is smaller than the photodetector. Thus taper fibers for photodiode applications can be offered at a much lower cost. LaseOptics lensed fiber technology enables high-end lenses to be manufactured in volume at low costs.

## **Applications Notes:**

How do lensed/shaped fibers work? Shaped/Lensed fibers work by focusing the light to improve the mode matching between a waveguide and the fiber. Normally we try to get a lensed that produces a Gaussian beam. Ideally the Lensed fibers should be made to precisely match the laser diode or waveguide characteristics. Be prepared to supply as much information as possible to help develop the ideal taper.

**Applications:**

- Telecommunications
- Active Components Pigtailing
- Coupling to circular or Elliptical outputs
- Medical and Dental
- MEMS device connection
- Waveguide packaging



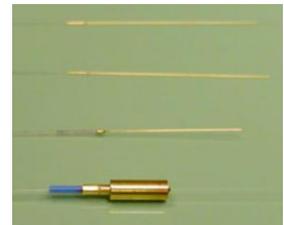
**Features:**

- Improved coupling to and from waveguides, laser diodes and photodiodes
- Single mode, PM Fibers or Multimode
- Metallized Lensed Fibers available
- AR coated Lensed Fibers available
- Other custom configurations available



**If you require any of the above products, we need this information:**

- Shaped-End Tips
- Fiber Size (Core, Clad, Buffer)
- What wavelengths are you using
- End Finish (Polish, Cleave, Lens)
- How long should be the Fiber
- Overall Assembly Size (Ferrule)
- Fiber Anchoring (Epoxy, Bare, or Other)
- Jacket, Buffer, and Strength Member Materials
- Numerical Aperture (NA) of Fiber
- Termination Type (SMA, FC, SC, LC or Other)



**Lensed Fibers Specifications:**

Fiber Type	SMF-28, 50/125, 62.5/125...or Multi Mode
Jacket, Protection Type	250µm Bare Fiber, 900µm Tube, 3mm Jacket
Connector Type	FC/PC, FC/APC, SC, ST, SMA, LC
Strip-off Length (mm)	7 ±1mm Typical; or otherwise specified
Operation Wavelength Range	400nm – 1700nm
Spot Size (µm)	1 - 12 (µm) Typical
Focal Length/Working Distance (µm)	5 - 500 (µm) Typical.
Tapering Angle (degree)	30- 170
Ferrule Accessories, V-Groove	Kovar Ferrule, Steel Ferrule or Silica V-Groove
Radius of Lensed Fiber-End Surface (µm)	5-50 (µm)
End Surface Coating	Option: AR or Mirror

## **Lensed Fibers Part Numbers and Description:**

**1). Part#: LF-SM-SC-01: (Sharp conical tip):** SMF-28 or any single mode fiber one end is prepared to make lens into a sharp conical tip would be 1-2 $\mu$ m diameter spot size, the tolerance is  $\pm 0.5\mu$ m, and the length of the fiber is up to the customer requirement. Other end of the fiber would be striped and cleaved of 5mm or any length. This is bare fiber and having salient feature of high quality lens that is achieved on state-of-the-art equipment. Useful for coupling of transmission lasers (1310 nm and 1550 nm) and pump lasers (980 nm single mode). Please see the pictures.

**2). Part#: LF-SM-MC-02: (Medium conical tips):** SMF-28 or any Single Mode Fiber one end is prepared to make the lens into a medium conical tip would be 3-6 $\mu$ m diameter spot size, the tolerance is  $\pm 0.5\mu$ m, and the length of the fiber is up to the customer requirement. Other end of the fiber would be striped and plane cleaved 5mm or any length. This is bare fiber and having salient feature a high quality lens that is achieved on state-of-the-art equipment. Useful for coupling of transmission lasers (1310 nm and 1550 nm) and pump lasers (980 nm single mode), coupling of MEMS devices.

**3). Part#: LF-SM-LC-03: (Large Conical tip):** SMF-28 or any Single Mode Fiber one end is prepared to make the lens into a large conical tip would be 7-10 $\mu$ m diameter spot size, the tolerance is  $\pm 0.5\mu$ m, and the length of the fiber is up to the customer requirement. Other end of the fiber would be striped and plane cleaved 5mm or any length. This is bare fiber and having salient feature a high quality lens that is achieved on state-of-the-art equipment. Useful for coupling of transmission lasers (1310 nm and 1550 nm) and pump lasers (980 nm single mode), coupling of MEMS devices.

**4). Part#: LF-SM-AC-04: (Conical tips):** SMF-28 or any Single Mode Fiber one end is prepared to make the lens into any conical tip diameter would be 11 $\mu$ m and above, the tolerance is  $\pm 0.5\mu$ m, and the length of the fiber is up to the customer requirement. Other end of the fiber would be striped and plane cleaved 5mm or any length. This is bare fiber and having salient feature a high quality lens that is achieved on state-of-the-art equipment. Useful for coupling of transmission lasers (1310 nm and 1550 nm) and pump lasers (980 nm single mode), coupling of MEMS devices.

**5). Part#: LF-SM-BL-05: (Ball Lens):** SMF-28 or Single Mode Fiber one end is prepared to make the lens into a ball lens would be 200 $\mu$ m - 300 $\mu$ m diameter up to the customer requirement the tolerance is  $\pm 1\mu$ m, and the length of the fiber is up to the customer requirement. Other end of the fiber would be striped and plane cleaved 5mm or any length. This is bare fiber and having salient feature a high quality lens, that is achieved on state-of-the-art equipment. Useful for coupling of transmission lasers (1310 nm and 1550 nm) and pump lasers (980 nm single mode), coupling of photo diodes, please see figure 1.

**6). Part#: LF-MM-BL-06: (Ball Lens):** Multi Mode Fiber of geometry 62.5/125/250, 100/125/250, 100/110/140, 150/165/190, 200/220/240 and 400/430/530 parameter of core/cladding/coating respectively, one end is prepared to make the lens into a ball lens and ball diameter would depend on the core diameter of the fiber and between 200 $\mu$ m - 600 $\mu$ m up to the customer requirement the tolerance is  $\pm 1\mu$ m, and the length of the fiber is up to the

customer requirement. Other end of the fiber is striped and plane cleaved 5mm or any length. This is bare fiber and having salient feature a high quality lensed which is achieved on state-of-the-art equipment. Useful for coupling of 808nm/850nm laser diodes, other multimode lasers and other medical applications.

**7). Part#: LF-SM-DW-07: (Double wedge or Screw driver):** SMF-28 or any Single Mode Fiber one end is prepared to make the lens into double wedge tip angle is 50-55 ° each side and the tolerance is  $\pm 1^\circ$  and the length of the fiber is up to the customer requirement. Lensed side end is stripped 12mm. Other end of the fiber is striped and plane cleaved 4mm or any length. This is bare fiber and having salient feature a high quality shaped which is achieved on state-of-the-art equipment. Useful for coupling of transmission lasers (1310 nm and 1550 nm) and pump lasers (980 nm single mode). Please see the figure 1.

**8). Part#: LF-SM-A8-08: (8° Angle):** SMF-28 or any Single Mode Fiber one end is prepared to make the lens into 8 ° tip angle and the tolerance is  $\pm 0.5^\circ$  and the length of the fiber is up to the customer requirement. Lensed side end is stripped 12mm. Other end of the fiber is striped and plane cleaved 5mm or any length. This is bare fiber and having salient feature a high quality lens that is achieved on state-of-the-art equipment. Mostly these fibers are use full to couple light and eliminate the back reflection of light.

**9). Part#: LF-SM-A45-09: (45° Angle):** SMF-28 or any Single Mode Fiber one end is prepared to make the lens into 45 ° tip angle and the tolerance is  $\pm 1^\circ$  and the length of the fiber is up to the customer requirement. Lensed side end is stripped 12mm. Other end of the fiber is striped and plane cleaved 5mm or any length. This is bare fiber and having salient feature a high quality lens, that is achieved on state-of-the-art equipment. Mostly these fibers are use full to side firing fibers.

**10). Part#: LF-SM-FC-10: (Conical Lensed Fiber with FC/any connector on other end):** SMF-28 or any Single Mode Fiber one end is prepared to make the lens into a different conical tips between 1 $\mu$ m - 12 $\mu$ m diameter spot size, up to the customer requirement the tolerance is  $\pm 0.5\mu$ m, and the length of the fiber is up to the customer requirement. Other end of the fiber is FC/PC, FC/APC, ST, SC, LC, & SMA connectorized and polished. This fiber having jacket option of 900  $\mu$ m hytrel tube or 2.5 mm jacket cable.

**11). Part#: LF-SM-FC-11 (Ball Lensed Fiber with FC/any connector on other end):** SMF-28 or Single Mode Fiber one end is prepared to make the lens into a ball lens would be 200 $\mu$ m - 300 $\mu$ m diameter up to the customer requirement the tolerance is  $\pm 1\mu$ m, and the length of the fiber is up to the customer requirement. Other end of the fiber is FC/PC, FC/APC, ST, SC, LC, & SMA connectorized and polished. This fiber having jacket option of 900  $\mu$ m hytrel tube or 2.5 mm jacket cable. Please see the Figure-2

**12). Part#: LF-PM-AC-12 (Lensed Fiber with Polarization Maintaining Fiber):** PM Single mode fiber or any custom PM fiber one end would prepared to make lens into a different conical tips between 1-10 $\mu$ m diameter spot size, the tolerance is  $\pm 0.5\mu$ m, with slow axis alignment and the length of the fiber is up to the customer requirement. Other end of the fiber would be striped and plane cleaved 5mm or any length. This is bare fiber and having salient

feature a high quality lens, that is achieved on state-of-the-art equipment. Useful for coupling of 14XX, 1480nm, 1550nm laser diodes.

**13). Part#: LF-PM-FC-13: (Lensed Fiber with Polarization Maintaining Fiber with FC connector on other end):** PM Single mode fiber or any custom PM fiber one end is prepared to make the shape into a sharp conical shape and tip diameter is 12 $\mu$ m - 20 $\mu$ m, up to the customer requirement the tolerance is  $\pm$  1 $\mu$ m, with Slow axis alignment and the length of the fiber is up to the customer requirement. Other end of the fiber is FC/PC, FC/APC ST, LC, & SC, connectorized and polished. This fiber having jacket option of 900  $\mu$ m loose tube or 2.5 mm regular cable.

**14). Part#: SM-PC-14: (Single Mode Fiber Patch Cable):** SMF-28 or Any Single Mode we will make FC/PC, FC/APC, ST, SC, LC, & SMA connectorized and polished. This fiber having jacket option of 900  $\mu$ m hytel loose tube or 3 mm jacket cable, or customers spec's.

**15). Part#: MM-PC-15: (Multi Mode Fiber Patch Cable):** Multi Mode Fiber of geometry 62.5/125/250 or 100/125/250 or 100/110/140 or 150/165/190 or 200/220/240 parameter of core/cladding/coating respectively with FC/PC, FC/APC, ST, SC, LC, & SMA connectorized and polished. We can make two wavelengths mixing (Y-guide cables) in one cable for medical fibers with end connectors This fiber having jacket option of 900 $\mu$ m hytel loose tube or 3 mm jacket cable, or customers spec's.

## Frequently asked questions (FAQ's):

**Q:** I saw shaped fibers specified by lensed angle and radius of curvature. Why aren't yours?

**A:** In order to simplify the specification and ensure that the customers understand exactly what they will be receiving, we have specified the actual output that the tapered fiber will provide as opposed to the physical geometry which takes several complicated formulas to determine the actual output. The method used to manufacture the LaseOptics Lensed fibers create a structure difficult to physically measure but does provide the required spot size/output characteristics and we consider as tip diameter/spot size.

**Q:** What does adding an AR coating improve, and by how much?

**A:** An AR coating is an antireflection coating, which typically reduces the effects of light reflecting back into the fiber from the fiber endface (Back reflection). In the case of the lensed/tapered fibers an AR coating has the potential of increasing the coupling ability by up to 10%. The power will be better transmitted through the end of the fiber instead of reflecting.

**Q:** Can I get Multimode Lensed Fibers?

**A:** Yes, although the tapered fiber behavior is mode dependent, in the opposite direction. This will reduce the etalon effects, which will reduce laser feedback and improve the laser diode stability. We have been making different lens and ball lenses on large diameter multi mode fibers 400/430; 600/660.

**Q:** I have seen advertised shaped multimode fibers. Are these the same?

**A:** No, Shaped multimode fibers take a long section of fiber and gradually taper the full length to convert it from a larger core diameter on one end to a smaller core diameter on the

other end. These are typically used with connectors on both ends and are used for a completely different application mostly in medical application.

**Q:** What are your standard spot sizes?

**A:** 1  $\mu\text{m}$  to 10  $\mu\text{m}$  is the standard spot sizes of conical tip. However others can be manufactured.

**Q:** I have seen from other manufacturer's specifications for polished tapered fibers. Is your product polished?

**A:** No, for Conical tips and Ball Lens, LaseOptics uses laser fusion/thermally create the actual tips and some times we integrate. Whereas double wedge and other angled fibers are micro polished.

**Q:** Can the same lensed fibers be used for 980 nm pumps as well as 1550nm?

**A:** Yes, but the different geometry of fiber core due to the difference in the mode field diameter for the different wavelengths, expect the spot sizes to be between 10% and 15% smaller, with slight changes in the working distance.

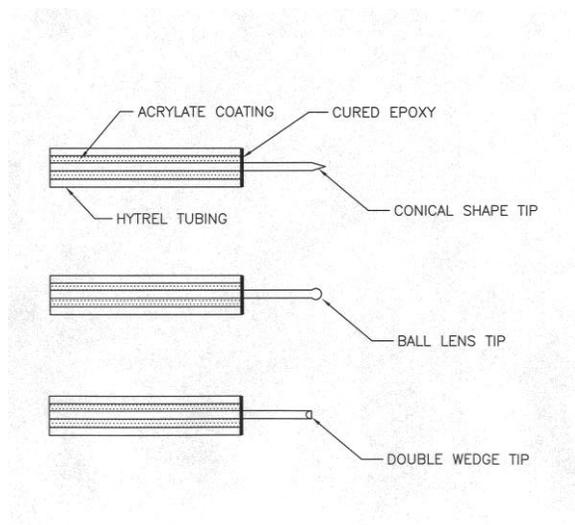


Figure. 1

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|--------------------|------------------|
| LF= Lensed Fibers  | BL= Ball Lens    |
| SM= Single Mode    | AC= Any Conical  |
| MM= Multi Mode     | DW= Double Wedge |
| SC= Sharp Conical  | A8= 8° Angle     |
| MC= Medium Conical | A45= 45° Angle   |
| LC= Large Conical  | PC= Patch Cord   |

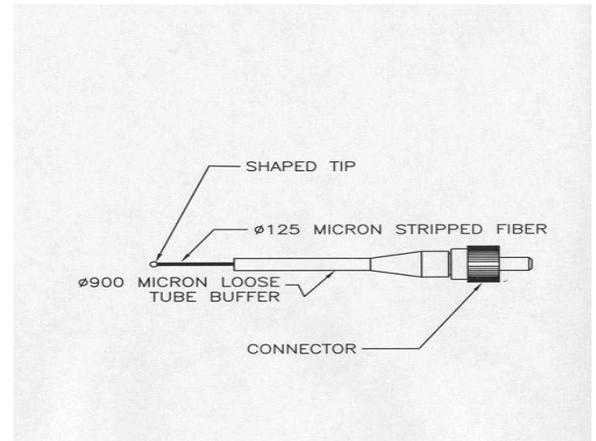
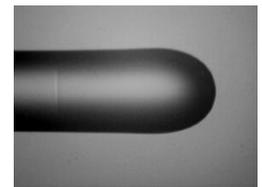


Figure. 2



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