Application Note Number M105
Uses of Tapered Optical Fibers

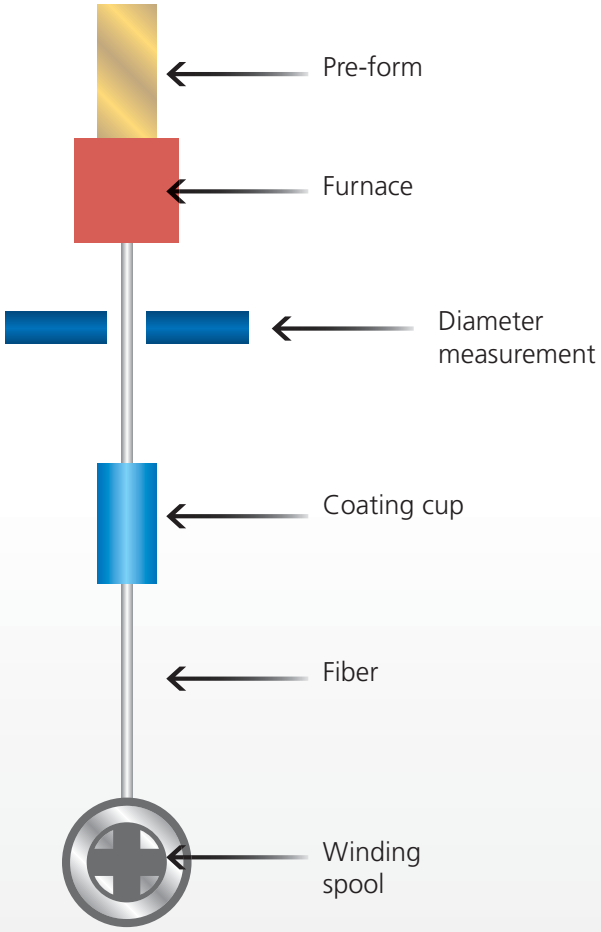
OXFORD ELECTRONICS
Manufacture and supply of specialised optical fibers

What are tapered optical fibers?

Regular silica/silica optical fibers are manufactured from a pre-form. A pre-form is a silica rod of a few centimetres diameter with a core of either pure or doped silica surrounded by a cladding layer of silica with a lower refractive index. The optical fiber is then drawn in a drawing tower by heating the preform in a furnace at the top of the tower and pulling the fiber in a controlled way to ensure a constant fiber diameter. The resulting fiber is coated in the tower and then wound on to a spool at the bottom of the tower. The drawing process for regular fibers is carefully controlled to ensure a constant fiber diameter.

Our tapered fibers begin as a pre-form in exactly the same way at a regular fiber and are also drawn on the drawing tower but in this case the drawing conditions are changed under computer control so the fiber diameter is changed in a linear manner. The tapered region of the fiber may vary in length from approximately 0.5 metres to 10 metres and can then be followed by a further length of fiber of the same diameter if required (pigtail).

Most of our regular silica-silica fibers can be made in tapered form. This includes two step index types (UVVIS and Near IR) and graded index and single mode types. Polarisation preserving types are also available.



Applications of Tapered Fibers

There are several applications for tapered fibers, the most common being for use with high-powered lasers. Many users of high-powered lasers would like the convenience of optical fiber power delivery but find that at high powers the laser is damaging the fiber. The threshold of damage for pure silica is usually stated as 1kW/mm2 (CW). However, some caution is advised when calculating damage thresholds. The quoted figures assume an ideal laser spot. This is rarely achieved in practice and most practical lasers suffer from one or more of the following defects.

Non circularity

Deviations from a circular spot are common. Many spots are elliptical or even irregular shape.

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Hot spots

Some laser spots contain small very high intensity regions or hot spots. The power per unit area in these hot spots can sometimes be as much as 100 or more times higher than the surrounding areas.

Variations in spot size

Some laser spots can vary dramatically in size as the power of the laser is changed. If the laser spot becomes too large, damage can occur to the connector or metal surrounding the fiber.

Problems associated with these defects in a laser spot can be eased by the use of a tapered fiber. If it is found that the input of a regular fiber is damaged, but the remainder of the fiber is undamaged, then a tapered fiber is likely to solve the problem. Suppose a 1.0 mm core diameter fiber is being damaged. By increasing the core diameter at the input of the tapered fiber to 2.0 mm the power per unit area is reduced by four times. The pigtail of the tapered fiber being 1.0 mm is still very flexible compared to a 2.0 mm diameter fiber.

Other applications

Tapered fibers can also be used to simplify the lateral alignment of lasers. If is desired to focus a laser spot of 50 µm on to a 50 µm fiber core but there is a variation in position of say ±25 µm due to optics or laser stability, then a tapered fiber with a 100 µm input core diameter and 50 µm will simplify x-y alignment.

Is there a downside?

One rarely gets something for nothing and with tapered fibers the conservation of brightness rule dictates that the 'effective N.A' of the tapered fiber will be reduced by the taper ratio. For example , the normal N.A for step index silica-silica fibers is 0.22. If the input core diameter is 2.0 mm and the output core diameter is 1.0 mm then the taper ratio is 2. The effective N.A of the tapered fiber then becomes 0.22/2 or 0.11. For most lasers this is not a problem as the N.A is usually sufficiently low that all the light can be coupled into the tapered fiber. This is not the case with most white light sources which are usually high N.A and with these sources light is lost by escaping from the tapered region of the fiber.

Practical considerations

Step Index tapered fibers are available with an input core diameter up to 4.2 mm. The maximum taper ratio is 5:1 so that for a 4.2 mm input core the output core cannot be less than 0.84 mm. The smallest output core diameter for step index fibers is 80 µm due to the fragility of smaller diameter fiber. Graded index and single mode tapered fibers are commonly used for laser alignment. In these cases the output core diameter is usually chosen to couple to a standard optical fiber. For graded index tapered fibers this is usually 50 or 62.5 µm. For single mode tapered fibers the output core diameter will normally correspond to the core diameter for that wavelength of single mode fiber. In the case of 1550 nm this will normally be 9 µm dropping to 4 µm for 400 nm fiber.

Packaging

Tapered fibers can be supplied with jackets for added strength and fitted with connectors or ferrules as required. We recommend SMA connectors for large core fibers up to 2.0 mm. For larger diameters we can fit suitable ferrules or make one to your drawing. Jackets can be Kevlar reinforced plastic or flexible stainless steel.

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