Hollow Silica Waveguide
Usage Guide and Test Process Overview

Introduction

The Hollow Silica Waveguide (HSW) built and marketed by Polymicro Technologies is designed to deliver infrared power in a flexible and rugged package from below 2.9 microns up to 20 microns, a region where silica fibers are far too glossy for practical operation. The waveguides consist of a fused silica capillary tube with an optically reflective internal silver halide coating. For protection, the capillary tube is coated with an external jacket of acrylate, which improves the strength and flexibility of the waveguide.

Because typical silica-based fibers heavily absorb light with wavelengths above 1.9 microns, a different technology is required. The Hollow Silica Waveguide is a good solution for mid to far infrared applications, such as power delivery for CO2 and Erbium YAG lasers, and spectroscopy making use of the unique hollow structure.

Polymicro Technologies' waveguides have been optimized for low optical power loss operation at either CO2 (10.6 µm) or Er:YAG (2.94 µm) wavelengths, although relatively low loss operation is possible in the intervening wavelength band. These waveguides are available with internal bore sizes of 300, 500, 750, and 1000 microns. They can also be built into custom assemblies with protective outer jackets and connectors.

While these waveguides have similarities with normal optical fibers, significant differences exist which require different handling and operation techniques. This note has been written to discuss the processes needed to work with these waveguides, with an additional section outlining the methods and conditions used to test their optical performance prior to shipment here at Polymicro.

Handling

Because of the hollow structure, the waveguides should be handled with reasonable care. The outer acrylate jacket will protect the capillary tube from normal handling, but can only do so much with stress from tight bends or compression on the sides of the device. Because of the stiffness of the larger diameter HSWs, one should not subject them to bend diameters less than 30 cm. Tighter bends have a potential for breaking the glass and destroying the waveguide.

Cleaving

Polymicro supplies Hollow Silica Waveguides in two basic forms, basic waveguide or built into a custom assembly with permanent connectors. Our sales representatives can help you with defining the best configuration for your application.

If required, a non-connectorized waveguide can be cleaved at the customer, and does not have to be sent back to Polymicro. A clean flat cleave of the end face is very important. The cleaving process is accomplished by cutting through the outer acrylate coating and lightly scribing the glass tubing underneath. This is done using a diamond scribe tool. We typically suggest the following tool (actually two separate parts) or an equivalent be used for the task.

Handle:
Newport Corp
(800)222-6440
Carbide Scribe
P/N: F-CL1
Cost: ~$80
Comes with a carbide blade which should be replaced with the following item

Blade:
Harris Diamond Corp.
(973)770-1420
Diamond Blade
P/N: 5000293 TA-88
Cost: ~$75

With this tool one can cut directly through the acrylate until the blade contacts the glass, then pull the waveguide off straight (without bending). It is important that no particles fall into the waveguide that could cause scattering and potential damage. Any jacket or silica tubing material left in the bore of the waveguide will affect light propagation, and at higher laser powers will likely cause catastrophic damage to the device.

Connectorization

To avoid unstable launch conditions and potential damage due to beam wander, the waveguide should be securely fixtured during launch. This can be accomplished in several ways, including permanent fiber connectors. One alternative handy solution is the PolylokTM connector available from Polymicro Technologies. This reusable connector fitting is ideal for prototyping and testing the waveguides, and is available in SMA, STII and FC configurations.

Launching Light

The process for launching light into a Hollow Silica Waveguide in general is very similar to launching into a standard optical fiber, with a few differences that the user needs to keep in mind.

- Fill Factor. To minimize the optical loss, the focused input beam should have a beam diameter at the entry to the waveguide at around 65% to 70% of the waveguide bore size. When reasonably well centered, this leads to the best transmission characteristics. Also, this avoids the beam hitting the front edge of the waveguide, a situation that easily causes damage.
- Minimize Entry Angle/NA. In order to minimize the loss at the launch through the waveguide, the numerical aperture of the focused laser beam needs to me kept very low. Higher input angles are less likely to propagate down the HSW, being absorbed and causing localized heating, often burning up the waveguide. So, the lowest beam input NA which correctly fills the waveguide bore is desired. Below is a summary of suggested lenses based on waveguide bore size. Also, a list of potential lens suppliers is listed later in this paper.

Lens FL versus Waveguide Bore Diameter
(Assumes ~ 4 mm beam diameter into lens)

HSW Bore Diameter	Input Lens E.F.L
1000 µm	6” (150 mm)
750 µm	4.5” (115 mm)
500 µm	3” (75 mm)
300 µm	2” (50 mm)

- Exit Divergence. Theoretically, the divergence angle of the beam out of the waveguide will match that of the input. In reality, there will be some broadening caused by mode mixing when the waveguide is bent, along with some small broadening caused by microscopic roughness or non-uniformities in the silver halide coating on the inside of the waveguide.
- Lens Materials. For the infrared wavelengths used with the waveguides, the correct material must be chosen for the lens. For our CO2 laser systems, we use Zinc Selenide for the lenses. If another material is chosen, the user needs to verify that absorption will not be a problem.
- Lens Type. The standard lens configuration used for launching into the waveguides is a positive meniscus lens, with the convex side towards the laser. These are available from several commercial suppliers, a few of which are listed below.

Possible Lens Suppliers

Rocky Mountain Instrument Company
(303)664-5000
106 Laser Drive
Lafayette, CO 80026
http://www.rmico.com/

II-VI
(724)352-1504
375 Saxonburg Blvd.
Saxonburg, PA 16056
http://www.ii-vi.com/

Laser Research Optics
(888) 239-5545
120 Corliss Street
Providence, RI 02904
http://www.optics-r-us.com/

Hollow Silica Waveguide Testing

HSWs are fabricated in 3 meter lengths and sent through a series of optical performance tests to verify their meeting specifications prior to shipment. At this time we are looking at the possibility of fabricating and testing the waveguides in longer lengths. The tests are outlined below:

- Straight Insertion Loss. Light from a CO_2 laser is coupled into each waveguide set out straight on an optical bench. The output from the waveguide is measured using an infrared optical power meter. The waveguide is then cleaved, leaving a short, approximately 100 mm, section at the proximal end. The output of this cut-back section is then measured and compared to the initial measurement. The waveguide loss is then calculated at 10.6µm wavelength and normalized in terms of the length as shown below:

$$\text{Straight Loss(at 10.6µm)} = (10*\text{Log10(Power(Long)/Power(Cutback))})/\text{Length}$$

See the Spectral Loss section below for losses at 2.94µm erbium YAG wavelength.

- Bend Loss. The bend loss is calculated by measuring the optical power out of a straight waveguide, then putting a single controlled 360° bend into the center of the waveguide using a specially built bend fixture which controls the 40cm bend in a single axis. The output is again measured and the added loss can be easily calculated:

$$\text{Bend Loss} = 10*\text{Log10(Power(Bend)/Power(Straight))}$$

- Spectral Loss. Each of the waveguides is also tested using a FTIR spectrometer, which allows a relative measurement of loss across the wavelength band of 2.5 to 12µm. The spectral loss for a straight waveguide versus a cut-back piece is measured, along with the spectral loss for a waveguide with the controlled 40cm bend versus straight. Using these measurements, we can compare the relative loss between the known straight and bend losses at 10.6µ from the tests above, and calculate a loss at the wavelength desired. It is most commonly used for erbium YAG waveguides.

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