Innovative Patent-Pending End Cap for High Power Laser-Fiber Coupling

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Introduction
Launching high power laser light into a pure silica core optical fiber can sometimes damage the input face of the fiber, causing failure in fiber coupling. The coupling failure occurs more commonly when using pulsed lasers with high peak power. To avoid this damage, careful consideration must be given to characteristics of the laser and fiber. These characteristics include fiber end-face cleanliness, matched numerical apertures (NA) of the fiber and laser, and power handling capability of the fiber material.

As fibers are prone to laser damage at the input air-silica interface, one solution is to reduce the laser power density to a level below the damage threshold through modification at the fiber end. This can be accomplished by integrating a silica disk or end-cap to the fiber. As laser light focuses through an end-cap into the fiber, the air-silica interface sees an enlarged light spot with a decreased power density compared with a fiber without an end-cap. As a result the end-capped fiber is capable of handling more optical power. This is illustrated in Figure 1 below.

Fig. 1 Laser coupled into optical fiber without and with the end-capping process.

Patent-Pending Coreless End-capping
Polymicro Technologies has developed an innovative approach to laser fuse a coreless end-cap as an integral part of the fiber. The end cap is formed from a section of precision silica tubing that surrounds the fiber. The end-cap matches the refractive index of the fiber core, eliminating potential Fresnel reflections at the fusing interface. Depending on optical intensity and application, the end-cap can be produced in a variety of thicknesses. With a thicker end-cap, the power density at the air-silica interface is reduced, and the power handling capability of the fiber is improved.

It is critical to center the end-cap to the core of optical fiber. If it is not centered prior to the fusion process, the termination results in poor coupling alignment in later use. Careful alignment of the end-cap to the side of the fiber during the fusion process is also crucial if a connector will be installed. Use of precision tubing improves the end-cap centering and alignment in relation to the fiber.

The precision tubing structure used in the end capping process offers a more durable fiber pigtail. Due to the potential for induced stress and handling sensitivity during the fusion process, a mechanical strain relief is placed between the fiber and tubing. This provides additional mechanical strength and ensures the integrity of the optical fiber assembly during connector termination and improves the durability in use.

Observed Results
Test results for the coreless end-capped fiber assemblies have shown significant improvements in power handling capability compared to uncapped fibers. In one case, the laser power transmission increased by more than 60% for a 300um core fiber, using a 2mm thick end-cap. The capped fiber assembly did not exhibit premature failure, which is a common failure mode for bare fiber assemblies using the same input laser power parameters.
Summary
Polymicro has developed a laser fusion process to integrate a coreless end-cap to the input end face of optical fibers, using precision silica tubing. The patent-pending technology eliminates Fresnel reflection at the fusion interface, while offering ease of connector termination and improved durability. The end-capped fiber has shown great improvement in power handling capability and elimination of premature failure of assemblies in field tests.