Cladding Shaping of Optical Fibre Preforms via CO_2 Laser Machining

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Double-clad silica fibres used in high power lasers typically comprise a core doped with a laser active ion, a silica inner-cladding pump guide and a low refractive index outer polymer coating for protection and low loss pump guidance. For efficient pump absorption in the active-ion doped core, the inner-cladding must be shaped in order to scramble the pump radiation to achieve a high spatial overlap with the core. This shaping is traditionally undertaken via diamond milling of the fibre preform into an octagon or hexagon, leaving a rough surface that is subsequently fire polished. We report on a new approach for shaping the inner-cladding using a CO_2 laser to machine the fibre preform. This process is shown to allow fabrication of novel cladding structures, which include concave and convex surfaces, as well as a significant increase in the processing speeds and avoids the need for fire polishing prior to fibre drawing.

The laser processing set-up (shown in Fig.1) employs a 100W 10.6μm pulsed CO_2 laser (Coherent G-100). The beam is passed through a periscope system before being directed vertically down through a focusing lens (f=100mm) onto the fibre preform surface. The preform itself is mounted within a rotation stage on an X-Y translation stage. The X stage translates the preform through the laser beam along its length at speeds of up to 300mm/s, with a slower Y stage utilised for repositioning for raster scanning along the surface. The laser is modulated at up to 3kHz repetition rates with varying pulse lengths from 140μs to 300μs used to control the depth of material removed per sweep. An extract system is employed to remove the ablated material from the system and beam path. Using computer generated raster scan profiles, machining of classical N-sided polygons onto preforms has been demonstrated at significantly reduced processing times (e.g. <1 hour to fully octagonalise a 100mm x12 mm diameter preform). Subsequent drawing to optical fibre has been undertaken without the necessity of further fire polishing after the milling, significantly reducing the processing time required to fabricate a double-clad fibre. Figure 2(a) shows an example fibre drawn from an octagonalised 12mm preform which was not fire polished prior to drawing.

In addition to the speed advantages, classical milling of a glass preform is limited to flat sides, whilst CO_2 machining of the preforms has been shown to allow significant capability to increase the complexity of the preform shaping as convex and concave surface features can also be realised. Previous theoretical work analysing cladding geometries with higher numbers of surfaces by J. J. Morehead suggested an optimised cladding that had 16 sides with a 3% depth modulation [1]. This profile has concave surfaces and provides pump scrambling whilst maintaining a smaller deviation from circular in order to improve splicing to circular fibres. Figure 2(b) shows the cross-section of a fibre preform that was machined using the developed CO_2 milling procedure to match this design. The prospects for further improvement in inner-cladding shape to increase pump absorption efficiency whilst maintaining integration capability will be discussed.

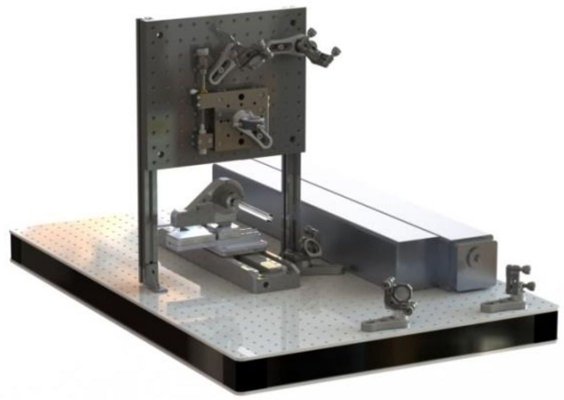

Fig. 1 Laser machining set-up showing the CO_2 laser delivery via a periscope onto a glass preform.

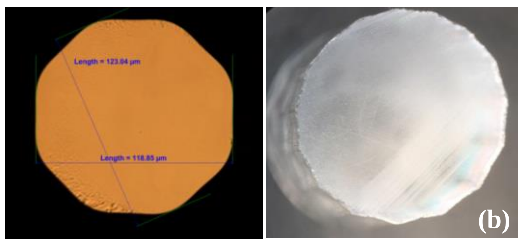

Fig. 2 (a) End face image of a fibre drawn from a glass preform that was machined to an octagon via CO_2 machining. (b) A slice from a 12 mm preform showing outer cladding shaping to specification defined by J. J. Morehead [1].

References

[1] J. J. Morehead and M. H. Muendel, “Nearly circular pump guides,” Proc. SPIE7914, Fiber Lasers VIII: Technology, Systems and Application, 79142Y (2011)