High Power Cladding Mode Stripper

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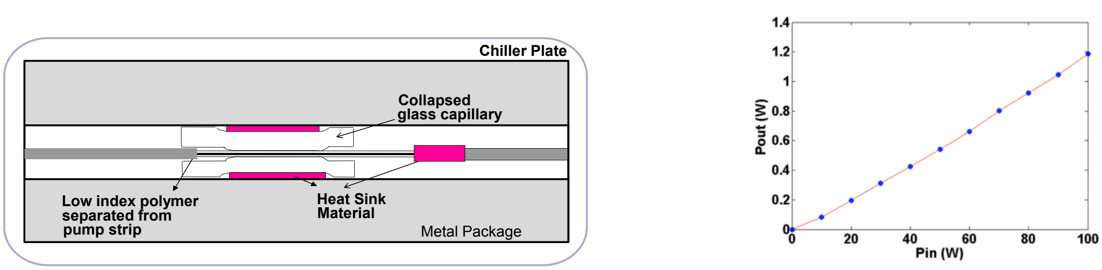
Abstract: Here we describe a novel approach for stripping cladding light from double clad fibers. This is achieved by index matching the cladding of the fiber with a glass capillary collapsed onto the fiber, allowing the cladding modes to expand in a larger volume of the capillary before they are dissipated through a high-index heat sink material into a metal package. We minimize the signal quality degradation by using a lower melting point capillary glass. We demonstrate a device with 100W cladding power removed with a 99% (20dB) extinction. Continuous operation for an hour without any power degradation is demonstrated

Despite significant advances in multi kW double-clad fiber lasers and amplifiers over the past decade [1], there still remain reliability and beam quality challenges, due to light in cladding modes [2]. Sources of cladding light include unabsorbed pump light, amplified spontaneous emission (ASE), and light scattered at splices and bends. Thermal issues arise in cladding mode strippers due to heat generation in the small surface area imposed by the fiber dimensions. A simple approach for stripping cladding light is to splice on a high index coated fiber [3]. This can have a very high power extraction ratio since the fiber can be made long. However the maximum extractable power is limited by the damage threshold of the high index polymer, and nonlinearities increase with longer fiber lengths. Another approach is to roughen the fiber by applying an etching material so that light is scattered out of the cladding. [4]. Here 20 dB of cladding light up with up to 500 W of power removed was demonstrated. However long-term reliability would be a concern, particularly in a manufacturing environment. . This is not only because the etching damages the glass surface, but the surface area available for heat dissipation is limited to the fiber's cladding diameter. Here we describe a novel approach for stripping cladding light from double clad fibers that overcomes these limitations.

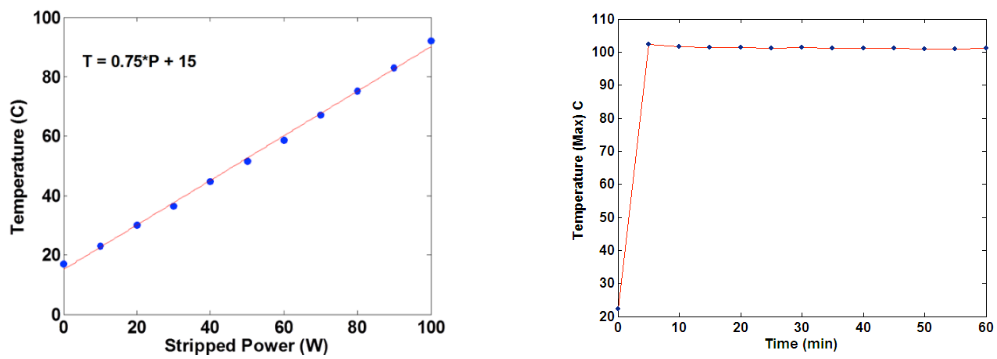
The mode stripper consists of a high-index borosilicate glass capillary tube collapsed on the inner cladding of a 200 μm cladding double clad fiber. Light guided in the fiber cladding refracts into the borosilicate capillary. A thin layer of higher-index heat-sink material is placed on the outer surface capillary tube so that cladding light is stripped and absorbed into a metallic package. The heat sinking material also assures a good thermal contact. Because the melting temperature of the borosilicate tube is lower than that of silica, fiber core distortion is avoided during the collapse of the capillary tube, preserving the integrity of the signal light even for large mode area cores. Fig1a shows the schematic of the device cross section. This approach is advantageous in that the delivery fiber of an amplifier can be used for stripping so that no additional fiber or splices are needed.



(a) **(b)**

Fig1. a) Schematic of the device cross section. , b) Cladding strippers output power as a function of input power.

The cladding mode stripper is tested up to 100W using 915nm pump diodes. The input consists of four 0.14 NA, 25 W diodes, spliced to a (18+1)x1 pump signal combiner with a 0.45 NA, 200μm diameter double clad output fiber. The pump dump device is spliced to the output fiber of the pump signal combiner. Fig1b shows the pump stripping efficiency of the device. For a device length of 5 cm the cladding light extraction is at the 20 dB level. The thermal slope measurement was performed using an IR thermal camera on the surface of the capillary and was measured to be 0.75 C/W as shown in Fig 2a. Including the splice to this device, The signal insertion loss was 0.13 dB with polarization extinction ratio 18dB. This shows the minimal influence of the process on the signal quality. The packaged device was tested for one hour for stable operation without degradation of performance or power, as shown in Fig 2b.



(a) **(b)**

Fig 2 a) Measured thermal slope of the device, b) Maximum temperate of the device as a function of time.

In summary, a novel method of stripping cladding light was demonstrated. It relied on over cladding the fiber with a capillary tube. This allows heat to be dissipated over a much larger surface area, allowing for a more reliable device. In the work reported here 100 W of cladding light was reduced by 20 dB at the output. This approach can be applied to any system without impacting the power or nonlinear system budget.

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