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Highly efficient side-fused signal pump combiners based on CO_2-laser restructured optical fibers

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Fiber-based laser and amplifier systems have great potential to provide high output power in combination with high beam quality [1,2] required for a variety of applications ranging from sensor technology and material processing to telecommunications. Such systems achieve high reliability and long-term stability when fiber-based components are used and free-space optics are mostly avoided. Hence, a key fiber component is the signal pump combiner (SPC), which couples the required pump power to the active fiber. The fiber-based side-fused SPC design introduced by Theeg. et al. allows for high pump-power coupling efficiencies while minimizing signal power loss, preserves beam quality, and polarization properties, which enables the amplifier systems to achieve excellent beam properties [3]. It uses tapered coreless intermediate fibers (IFs) to enable efficient coupling of pump power into the target gain fiber. With this design, when using a 25/400-µm LMA-fiber and 200/220-µm pump fibers (PFs), usual pump power to signal fiber cladding coupling efficiency around 90% is experimentally recorded while ray-tracing simulations show a theoretical maximum of 97.8%. As current research focuses on signal output power scaling towards multiple hundreds of watt (which requires multiple hundreds of watt of pump power), even small improvements in coupling efficiency present a significant gain for the overall system performance as well as thermal stability of the fiber components. One significant loss mechanism is the diameter mismatch of the coreless IFs and the core diameter of the PFs. As the pump power from the high-power multimode diodes is delivered by the 200/220-µm PFs, they need to be connected ("spliced") to the IFs to allow for efficient coupling. Because of fiber manufacturing tolerances of the PF and IF diameter, the IF is usually larger compared to the PF core. When simulating a diameter mismatch of 1% the maximum achievable coupling efficiency is reduced by approximately 3%.

In this work, we present the CO_2-laser machining of 200/220-µm pump fibers, where the cladding structure is symmetrically removed over a distance relevant for SPC production. This cladding removal enables the manufacturing of an SPC without splicing the IF and avoiding the fiber diameter mismatch to increase the coupling efficiency. As presented in Fig. 1 a), a coupling efficiency of 92% was experimentally achieved in this

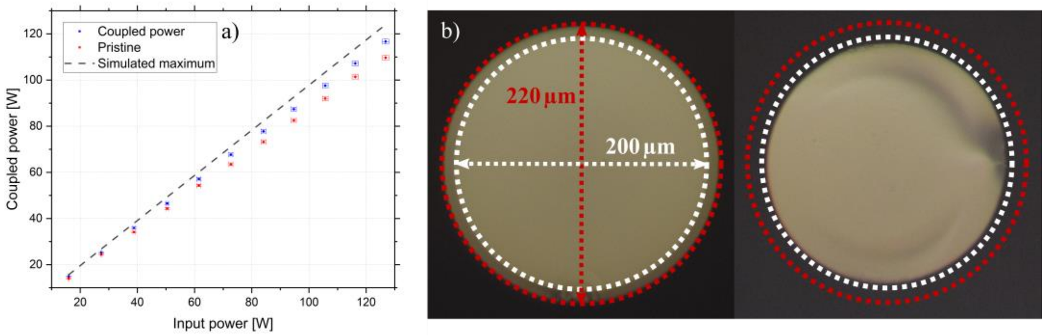

Fig. 1 a) Coupling efficiency over different input powers of an SPC with two pristine pump fibers and an SPC with CO_2-laser machined pump fibers compared to the simulated maximum. b) End facet view of a pristine 200/220-µm pump fiber compared to a CO_2-laser machined sample.

configuration. This presents an increase in coupling efficiency of 4% compared to an SPC manufactured with identical production parameters but a pristine pump fiber. The observed difference to the theoretical maximum is related to manufacturing practical limitations of fiber tapering and fusing. Fig. 1 b) shows the end facets of a pristine pump fiber and a restructured fiber where the entire outer cladding was symmetrically ablated. This work presents an important step towards further power scaling in fiber-based amplifier systems by improving efficiency and high-power reliability. The process could also be transferred to different fiber diameters and other fiber types.

References

[1] S. Hochheim, A. Büttner, P. Weßels, E. Brockmüller, W. Fittkau, J. Neumann, D. Kracht, "100W optical amplifier for 10 channel laser communication system with enhanced wall-plug efficiency in the 1µm wavelength range," Proc. SPIE 11993, 106–111 (2022).

[2] F. Wellmann, M. Steinke, F. Meylahn, N. Bode, B. Willke, L. Overmeyer, J. Neumann, and D. Kracht, "High power, single-frequency, monolithic fiber amplifier for the next generation of gravitational wave detectors," Opt. Express 27, 28523–28533 (2019).

[3] T. Theeg, H. Sayinc, J. Neumann, L. Overmeyer, and D. Kracht, "Pump and signal combiner for bi-directional pumping of all-fiber lasers and amplifiers," Opt. Express 20, 28125–41 (2012).

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