# 35 Core Polarization-Maintaining Multi-core Fiber for High Power Operation

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**Abstract**: This work presents a novel rod-type 35 core multi-core fiber design that is capable of overcoming the inherent lack of polarization maintenance in such structures. A polarization extinction ratio of 10.5dB is achieved.

Optical fibers in lasers development exhibit an excellent performance in terms of their high heat-dissipation, beam quality and small signal gain. Furthermore, fiber lasers have been utilized for average and peak power scaling. However, their scalability is hindered by the appearance onset of non-linear and thermal effects at high powers [1].

Such effects can be mitigated by exploiting parallelization. This implies that, ideally, the onset of the threshold of the limiting effects increases linearly with the number of channels. One possible implementation of this approach is by utilizing multiple fiber lasers (or channels) in parallel and combining their output [2].

Scaling the number of channels to tens or hundreds of channels is not straight-forward since it leads to a linear increase of the component count, cost, footprint and complexity of the system. A way to break the linear dependency of these parameters on the channel count is channel integration in a multicore fiber (MCF). Such an approach has been shown to scale the modal instability threshold (the current most significant limit for fiber lasers) by the number of cores (channels)[3].

The structure of MCFs entails the close proximity of cores to one another, which has been shown to induce stress. Such stress implies that each core has its own level of birefringence and that the orientation of the main polarization axes changes from core to core [4]. Many high-power applications are polarization-dependent (e.g., coherent beam combination and frequency conversion). Currently, the lack of polarization maintenance is pre-compensated. In this work we report on the development of an in-house rod-type 5x7 polarization-maintaining MCF (PM-MCF) for high-power operation that overcomes such an inherent limitation.

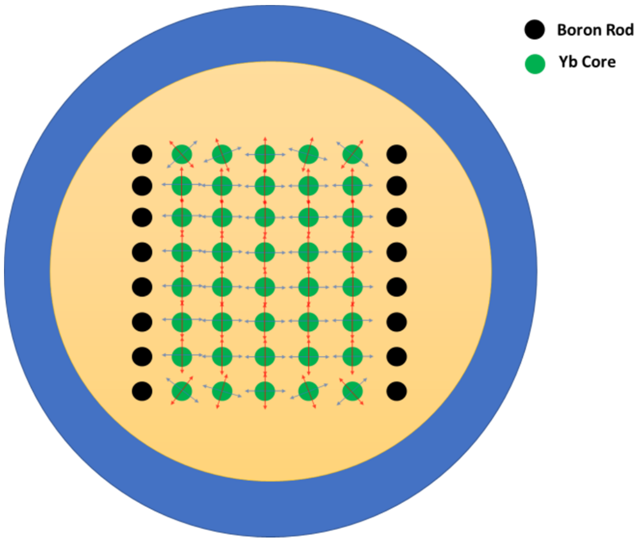
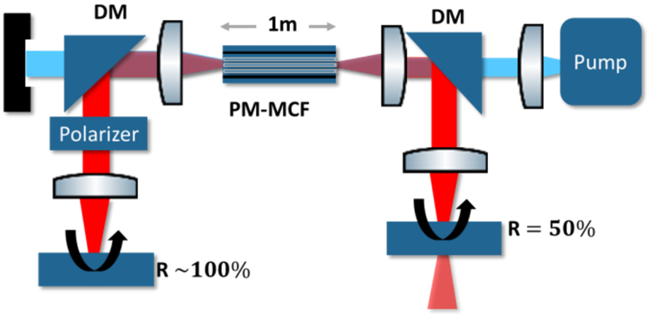


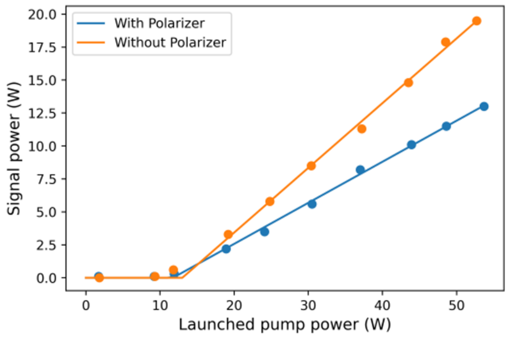

**Fig. 1.** Sketch of the 5x7 PM-MCF cross-section with simulated polarization axes of the various cores. The length of the arrows represents the strength of the birefringence (blue: slow axis; red: fast axis).

The ytterbium-doped PM-MCF has a step index of approximately 6x10$^{-4}$. The stress-inducing boron-doped glass rods (~16%) are on the outermost columns of a 7x7 matrix, thus resulting in a 5x7 PM MCF. Such a design, where the boron rods are on the outermost columns, means that the penalty on pump absorption is minimized (ratio of boron rods to pump cladding area ~1%).

The PM-MCF has been placed in an oscillator setup, as shown in Fig. 2(a). Here, in order to obtain a linearly polarized output, a polarizer is placed in front of the high reflectivity mirror. However, the use of the polarizer introduces a penalty on the slope efficiency, as shown in Fig. 2(b). Nevertheless, more than 10W of output average power could be demonstrated. It was not possible to significantly increase the output power of this system since the fiber was only passively air-cooled. We are currently preparing the water-cooling module for this fiber and expect to be able to scale the output power towards 100W.



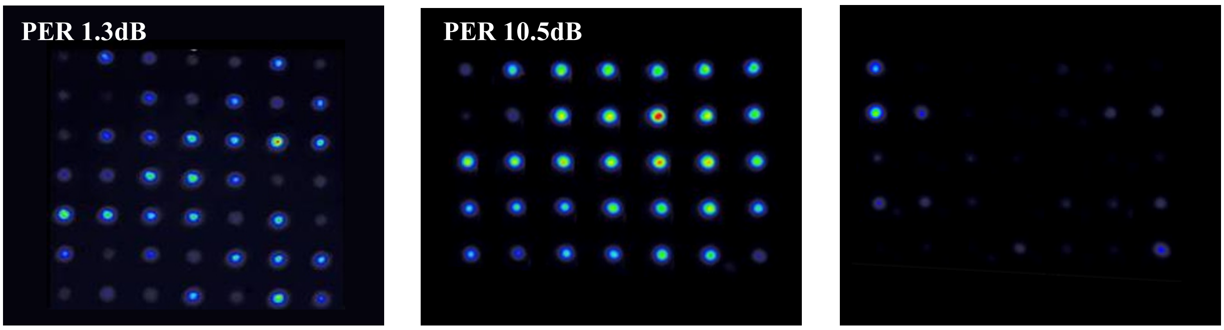

(a)




(b)

**Fig. 2.** (a) Experimental setup of the oscillator (DM: Dichroic mirror). (b) Output signal power with respect to the launched pump power depending on the use of a polarizer intra-cavity. The slope efficiency of the laser without polarizer is 49% and 31% with.

A non-PM 7x7 MCF was initially tested, as shown in Fig. 3(a). It was shown that a polarization extinction ratio (PER) of only 1.3dB could be achieved. The PM-MCF, on the other hand, has demonstrated a PER of 10.5 dB, as shown in Fig. 3(b-c) [5].




(a) (b) (c)

**Fig. 3.** (a) Output of a non-PM 7x7 MCF seeded with a linearly polarized input beam array, after a polarization analyzer. 5x7 PM-MCF output after polarization analyzer oriented for (b) maximum (c) and minimum transmission.

The presented PM-MCF provides a pathway for polarization-dependent applications while not incurring a significant penalty on pump absorption. At the conference we would like to present the high-power operation of this novel PM-MCF and discuss ways to improve its performance even further.

## References

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