High power linearly polarized fiber laser

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Abstract. We report on a linearly polarized (extinction ratio ~17 dB) large-mode-area fiber laser with an output power above 300 W and diffraction-limited beam quality. The PANDA-design is applied to induce the birefringence in the fiber.

OCIS codes: (140.3510) Lasers, fiber; (060.2280) Fiber design and fabrication

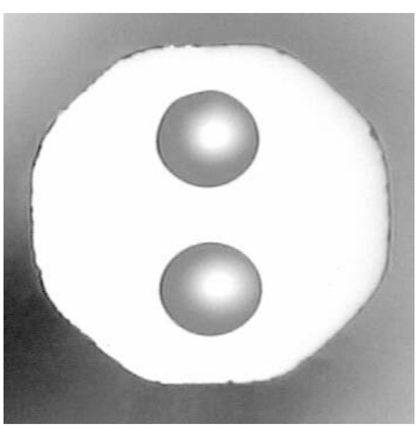
1. Introduction

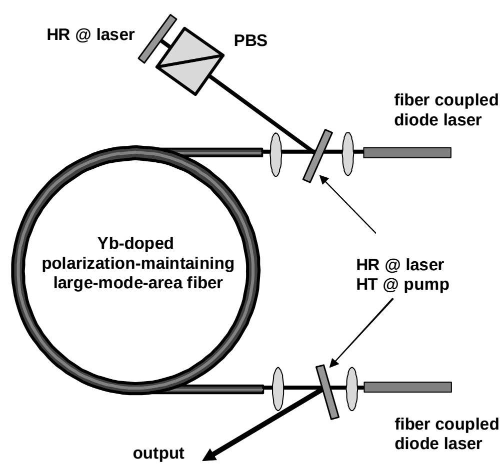
Rare-earth-doped fibers have established themselves as a very attractive and power scalable solid-state laser concept. This fact is due to their inherent properties such as high optical-to-optical efficiency and outstanding thermo-optical behaviour, but also due to compactness, robustness and simplicity of operation. In continuous-wave operation output powers approaching the kW-regime with diffraction-limited beam quality are demonstrated [1,2,3]. This power level is reached by applying so-called large-mode-area fibers which feature a reduced nonlinearity, what usually constitutes the main performance limitation of fiber laser systems. However, the polarization of these high power fiber lasers is in general random. Because the technological implementation of well-known (for singlemode fibers) designs of polarization maintaining fibers, such as "PANDA" or "bow-tie" structures, was so far not possible. This is mainly due to the significantly large core area, where the stress has to be induced.

In this contribution, we report on a 310 W cw output power linearly polarized fiber laser with diffraction-limited beam quality. The degree of polarization is as high as 96% (extinction ratio ~17 dB) at the highest power level.

2. Experiment and results

The fiber used in this experiment bases on a Panda design, the fiber cross-section is shown in figure 1.a. The fiber has a core diameter of 20 µm (NA = 0.065) and is ytterbium-doped. The core is surrounded by two borosilicate stress rods to induce birefringence. The birefringence of this structure is as high as $3 \cdot 10^{-4}$. The fiber has an octagonal inner cladding with a diameter of 400 µm (NA = 0.46). The fiber has a pump-light absorption of ~ 2dB/m at 976 nm.


(a)



(b)

Fig. 1. Microscope image of fiber cross-section (a) and experimental setup (b)

The experimental setup of the high power linearly polarized fiber laser is shown in figure 1.b. A length of 45 m of the above described PM fiber is employed. The fiber is pumped from both sides with wavelength multiplexed laser diodes (976nm + 940 nm). On the high-reflecting side of the cavity a high power polarizing beam splitter is applied

to selected the orientation of the polarization and adjust is to one of the two axes of the PM fiber. For comparison, a fiber with identical parameters and length but without the stress rods (non-polarization maintaining) is investigated.
Figure 2 shows the output power characteristics of the polarized fiber laser. At a launched pump power of 400 W we were able to extract 310 W of output power with a slope efficiency of 76%. The efficiency is just slightly lower than the efficiency of the non-PM fiber laser. The beam quality of the output is diffraction-limited (M^2 = 1.1±0.1). The large-mode-area fiber design avoids the onset of stimulated Raman scattering at this power level.
The degree of polarization is analyzed with a polarizing beam splitter at the output and is defined as

$$\mathbf{deg.}\,\text{of pol.} = \frac{P_{\mathbf{max}} - P_{\mathbf{min}}}{P_{\mathbf{max}} + P_{\mathbf{min}}} \quad (1).$$

Figure 3 shows the degree of polarization of the PM and non-PM fiber lasers as a function of output power. In the case of the PM fiber the degree of polarization decreases just slightly from 99% to 95% at the highest power level and the orientation of the polarization is fixed. In comparison, the polarization of the non-PM fiber is in the range of 10%-15% and furthermore the axis of polarization is changing with output power. This significant difference illustrates the advantage of the PM fiber design.

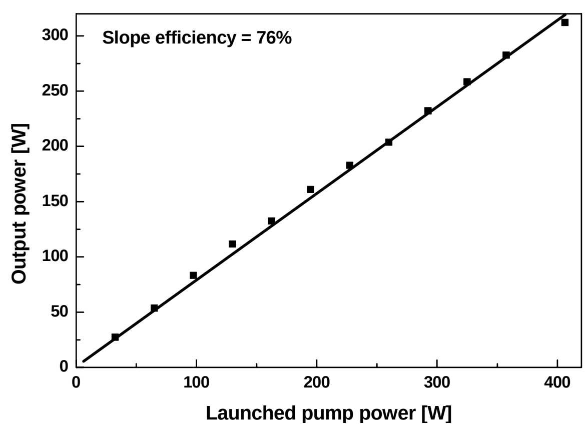


Fig. 2. Output characteristics of the linearly polarized fiber laser

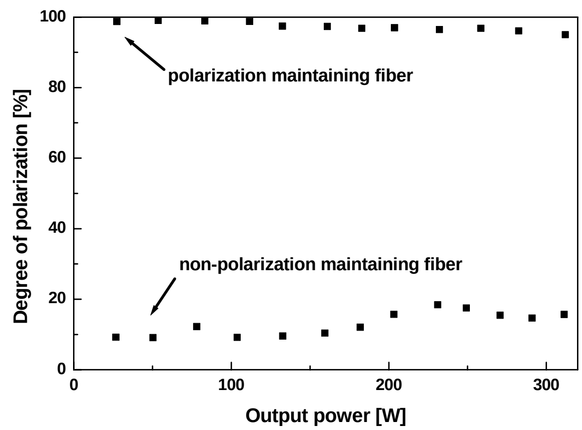


Fig.3. Degree of polarization versus output power of the PM fiber laser in comparison to the non-PM fiber laser

In conclusion we have demonstrated a 300 W linearly polarized fiber laser with diffraction limited beam quality. This reached power level opens a lot of new applications of fiber lasers and is of high interest for pulsed amplification which is followed by any polarization selective element (grating compressor, frequency conversion).

References

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