A 4.3 W 977 nm ytterbium-doped jacketed-air-clad fiber amplifier

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A cladding pumped jacketed-air-clad ytterbium-doped fiber amplifier operating at 977 nm produced 4.3 W of single-mode output power with 300 mW of input power from a diode seed laser. The small-signal gain was 19 dB.

1. Introduction

High power sources ~at 980 nm such as laser diodes or fiber lasers can be used for pumping of erbium doped fiber devices. If frequency-doubled to 488 – 490 nm green-blue light, such sources can also replace bulky and highly inefficient argon ion lasers. Consequently, alternatives such as optically pumped, vertically emitting, semiconductor lasers as well as cladding-pumped ytterbium-doped fiber lasers (YDFLs) have been investigated for high-power 980 nm operation at the watt-level [1, 2] and more recently at the multi-watt level [3]. Q-switching has also been demonstrated [4]. Alternatively, it is possible to make a high-power 980 nm source using a high power amplifier in a master oscillator – power amplifier (MOPA) configuration. This can bring important advantages in terms of narrow line-width or even single-frequency operation, and improved temporal control for pulsed applications. Also tunability can be readily implemented. Here, we report what we believe is the first cladding-pumped ytterbium-doped fiber amplifier (YDFA) operating in the 980 nm wavelength range. An output power of 4.3 W was reached with a seed power of 300 mW from a grating-stabilized diode laser.

2. Amplifier Fiber Design and Experimental Setup

The YDFA is based on an ytterbium-doped jacketed-air clad (JAC) fiber [1] (inset Fig. 1). The air-clad structure of the fiber increases the numerical aperture of the inner cladding, allowing more pump power to be launched. The small size of the inner cladding (~25µm) enhances the pump absorption. Therefore a strong population inversion is achieved due to an efficient pump absorption. Furthermore, the ring doping technique has been used to ensure that the YDFL works as a two level system (emission at 980 nm) rather than as a quasi-four-level system (emission at 1030 nm) [5]. Ring-doping reduces the ground-state absorption by reducing the overlap of the signal mode with the Yb-doped gain medium. This promotes the two-level 980 nm emission relative to the quasi-four-level emission, which is less affected by ground-state absorption.

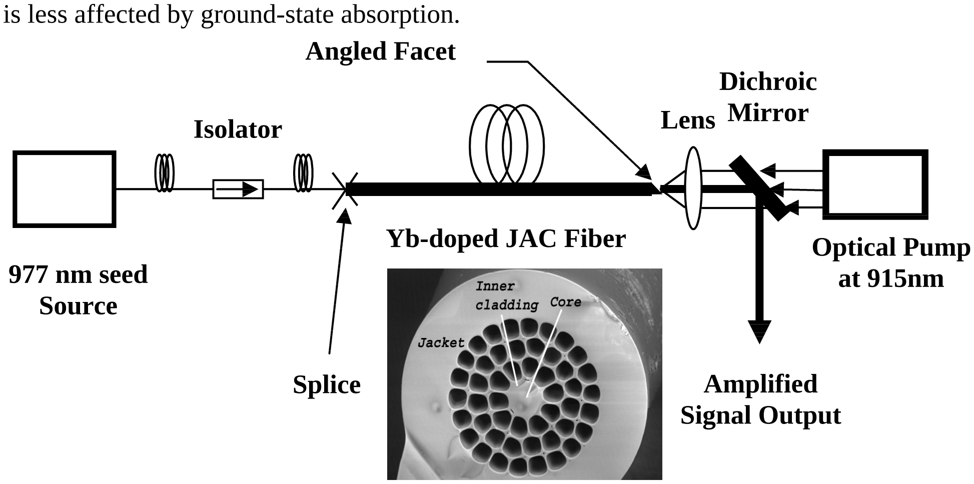


Fig. 1. 977 nm Yb-doped JAC fiber amplifier experimental setup

The YDFA experimental set-up is shown in Fig. 1. In the experiments, a 72 cm long JAC fiber was pumped at 915 nm by a multi-emitter broad-area laser diode source. The fiber length was optimized for efficient two-level operation. A dichroic mirror was placed between the fiber and the pump in order to extract the amplified signal. The pump was launched into the fiber through a 0.55 NA, 4.5 mm focal length collimating lens. The pump power launched into the inner cladding of the JAC fiber was measured to 11 W. The signal output end of the JAC fiber was angle cleaved (~7 deg) in order to suppress back-reflections. In the signal input end, the JAC fiber was spliced to an optical isolator for suppression of feedback and protection of the diode seed laser. Up to 300 mW of seed power could be launched into the JAC fiber.

3. Results

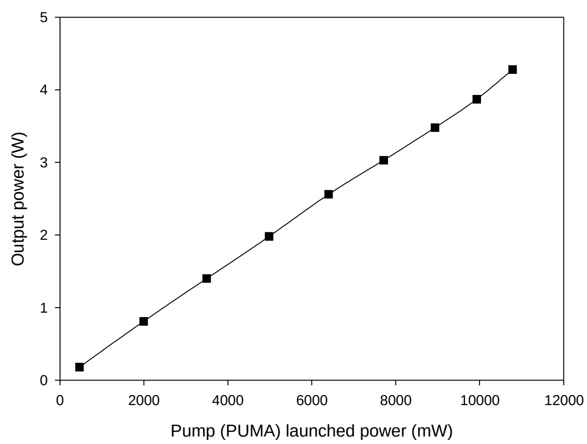
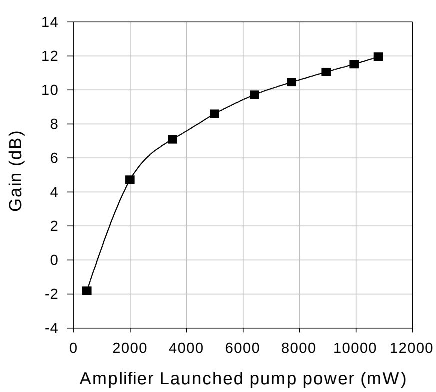
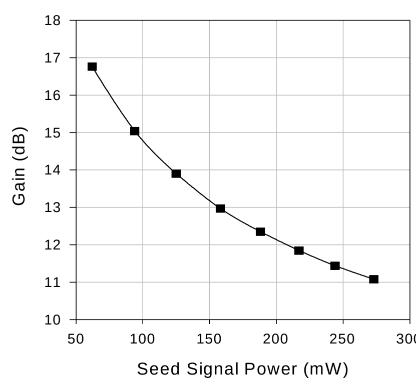


Fig. 2. JAC YDFA output power with respect to launched pump power

Fig. 2 shows the amplified signal output power versus launched 915 nm pump power. With 11 W of launched pump power, the output power of the amplifier reached 4.3 W at 977 nm for 300 mW input signal. The gain of the amplifier was then 11.6 dB. The input signal wavelength was 977 nm. Figure 3 shows the amplifier gain with (a) the input signal power fixed at 275 mW, and (b) the pump power fixed at 9 W. The small signal gain was measured to be 19 dB with 0 dBm seed source.



(a)



(b)

Fig. 3 JAC YDFA gain characteristics for (a) seed signal power fixed at 275 mW, (b) launched pump power fixed at 9 W.

Fig. 4 shows the typical output spectrum of the JAC YDFA. The linewidth of 977 nm amplified signal was measured to be 0.2 nm, which was identical to that of the seed source. The output beam quality was measured and an M^2 value of 1.14 was found.

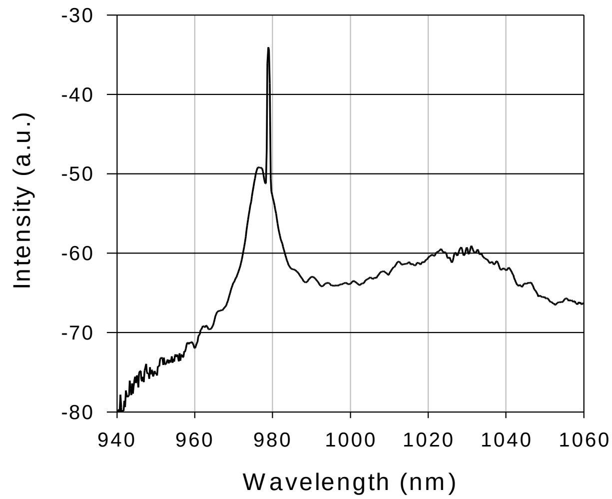


Fig. 4. JAC YDF amplifier output spectrum with 100 mW 977 nm seed signal (OSA resolution 0.5 nm)

4. Conclusion

We have presented a cladding-pumped 977 nm YDFA based on a ring-doped JAC fiber. The YDFA produced 4.3 W of single mode output power in a MOPA configuration, when seeded by 300 mW of power from a laser diode. The system was spliced together so that the signal remained in fiber or fiber-pigtailed components all the way to the output of the JAC YDF. A MOPA with a diode laser and fiber amplifier is a very versatile concept that allows for precise spectral and temporal control.

5. References

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