

242W single -mode CW fiber laser operating at 1030nm lasing wavelength and with 0.35nm spectral width

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Abstract: Conventional high-power, single-mode CW fiber lasers typically have operating ranges limited to 1060-1110nm. Here we demonstrate a fiber laser with 242W output power, operating at 1030nm with a narrow, stabilized 0.35nm spectral width and diffraction limited beam $M^2=1.05$.

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1. Introduction

Advances in large mode area (LMA) Yb-doped fiber designs, coupled with the development of high power multi-kW pump diodes, have enabled the realization of high-power fiber lasers with single transverse mode output. Single-fiber CW lasers exhibiting output powers exceeding 1 kW, with M^2 values less than 1.5, have been demonstrated recently [1-3]. As the number of high power results reported increases, it is clear that fiber lasers currently represent one of the most promising solid-state laser technologies, combining unprecedented output powers and excellent beam quality.

Typically, the conventional high-power single-mode Yb fiber lasers have a limited spectral operating range (1060-1110nm). For a number of emerging applications, there is great interest in extending this operating range. Here we demonstrate a fiber laser operating at 1030 nm, approximately 30 nm shorter than the typical laser. The laser presented here exhibited 242W of output power, as well as a narrow stabilized 0.35nm spectral width diffraction limited beam ($M^2=1.05$) and excellent efficiency (73%). The laser is based on Yb-doped LMA double clad fiber and has a monolithic, all-fiber design.

2. Laser design

A double-clad LMA Yb-doped fiber (YDF) has been specifically designed for efficient lasing at shorter wavelengths (<1060 nm). The fiber has a 20 micron diameter, ytterbium-doped core (NA=0.06) and a 400 micron octagonally shaped inner cladding (NA=0.46). Although the fiber core is slightly multimode (it supports two modes, $V \# \sim 3.5$) proper coiling of the fiber enables single mode operation [4]. Coiling induces a bend loss for the higher order mode (LP_{11}), but allows fundamental mode propagation with no substantial loss (<0.01dB/m). The fiber design and coiling technique are schematically demonstrated in Figure 1.

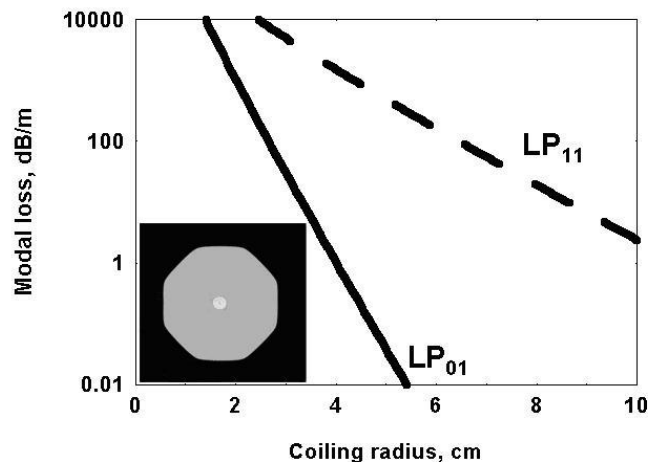


Fig. 1. Fiber design and coiling technique principal.

Figure 2 illustrates the design of the laser. The laser cavity includes 10 meters of the aforementioned rare-earth doped LMA fiber and fiber Bragg grating (FBG) reflectors spliced on both ends of the active fiber. These grating-based mirrors have >99% reflectivity on one end and a~10% on the other end. The photosensitive fiber used to make the Bragg gratings was specially designed to have a similar configuration as the Yb-doped fiber. Such a fiber transmits both pump and lasing signals with minimal loss. The YDF was coiled around an aluminum mandrel to eliminate the undesired higher-order modes. The laser was pumped from both ends by 976nm diode bars. Free-space coupling was used for the experiment.

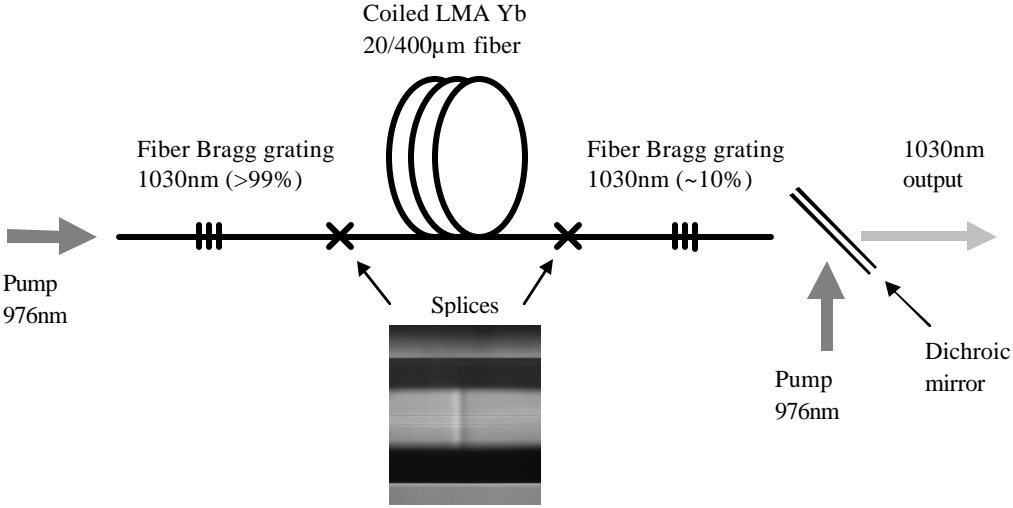


Fig. 2 - Fiber laser design

3. Experimental results

Figure 3 shows the 1030nm laser output vs. coupled pump power. 242W of output signal was achieved from the 333W of total pump power coupled into the fiber laser. One will observe the output power grows linearly and does not roll off. The laser demonstrated excellent slope efficiency 79% and overall efficiency 73%. It is also noted that the output power result achieved was limited only by the available pump power.

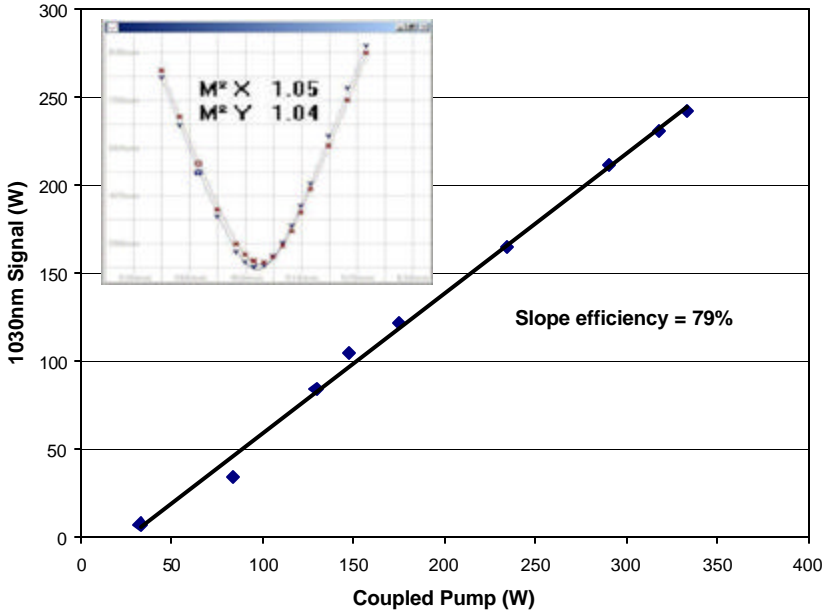


Fig. 3 - Fiber laser efficiency and beam quality measurement.

Beam quality measurement is also shown in Figure 3. It was obtained with a Spiricon M2-200 beam analyzer. The beam is very close to being diffraction limited, as indicated by the measurement of $M^2 = 1.05$.

Figure 4 shows the measured fiber laser output spectrum and spectral line-width. The output spectrum shows clean 1030nm lasing with low spontaneous emission in 1040-1100nm region (peak to peak difference of ~ 45 dB). The laser has narrow line-width 0.35nm, stabilized by the FBGs. Note that the spectral width was limited by the width of the FBGs. We believe even narrower spectral line-widths are achievable at this power level. In addition to the narrow line-width and low spontaneous emission level, no sign of detrimental nonlinear effects, such as Brillouin or Raman scattering, was observed.

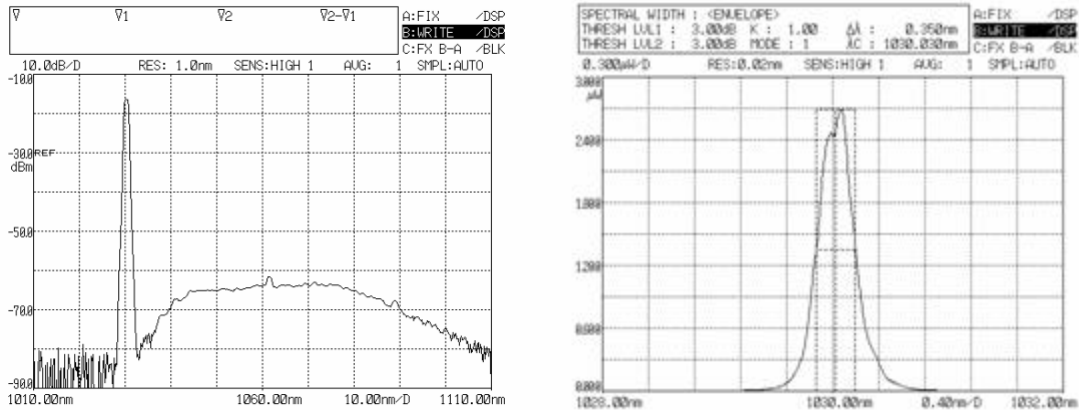


Fig.4 - Fiber laser output spectrum and spectral width.

The power density in the fiber core was $\sim 0.6\text{W}/\mu\text{m}^2$ at highest output power. Compared to the theoretical glass damage threshold of $>5\text{W}/\mu\text{m}^2$, this fiber is fully capable of handling larger output powers. Although the maximum power output at 1030 nm of the system is unknown at present, numerical modeling presented elsewhere [5] indicates the output power using this fiber and laser design is scalable up to 2kW CW and higher.

4. Conclusion

A 242W fiber laser operating at 1030nm, with a stabilized 0.35nm spectral width and diffraction limited beam of $M^2=1.05$, has been demonstrated. It is believed this output power to be the largest reported thus far at 1030 nm for a fiber-laser. The observed laser efficiency is 73%. This laser has a very practical design: a monolithic all-fiber laser cavity consisting of Yb-doped large mode area fiber with high/low fiber Bragg grating reflectors spliced to both ends of the active fiber. The output power demonstrated is only limited by available pump power and the fiber design itself may be capable of $>2\text{kW}$ output. This result shows that the operating wavelength range for high-power single-mode fiber lasers can be extended to 1030-1110nm and can open up new applications for fiber lasers, such as achieving extremely high power $>10\text{kW}$ single-mode outputs through spectral combing and other wavelength-specific applications such as pumping lasers based on Yb:YAG crystals, Pr-doped materials.

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