1 kW, 15 μJ linearly polarized fiber laser operating at 977 nm

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ABSTRACT

A linearly-polarized, 977 nm pulsed laser capable of 1 kW, 15 μJ output has been demonstrated. The laser is based on Yb^{3+}-doped fiber technology, is core pumped and has a monolithic, all-fiber design. A 13 dB polarization extinction ratio was observed at the maximum measured output power. The output performance of the laser is pump-limited and shows no sign of non-linear effects at the demonstrated output powers. The laser emission is inherently near-diffraction limited due to the single-mode nature of the fibers used.

Keywords: optical fiber, linearly polarized laser

1. INTRODUCTION

Pulsed Yb^{3+} doped fiber lasers emitting multiple-kW peak powers and mJ-range pulse energies are attempting to address many demanding applications[1-3]. Such fiber-based devices have numerous advantages over other types of lasers; compactness, maintenance-free operation, robustness (all fiber design) and high efficiency.

Conventional high-power pulsed Yb^{3+}-doped fiber lasers have an operating wavelength range typically limited to 1040-1100 nm. There is a great interest, however, in high pulse-power devices operating in the wavelength range of 970 – 980 nm. This operating range, using Yb^{3+} doped fibers, presents challenges due to requirements of a large Yb^{3+}-ion inversion and a high threshold for signal amplification. To overcome these issues, high brightness pump sources and high-quality, compositionally-optimized, doped glass fibers are required.

Continuous wave randomly polarized Yb^{3+}-doped fiber laser capable of 4.3W power at 977nm has been demonstrated recently[4]. Also 1.2μJ pulse energy and 100W peak power have been achieved from randomly polarized pulsed fiber laser at 980nm[5]. However large variety of practical applications requires linearly polarized high peak power and pulse energy laser outputs.

This paper summarizes our recent progress in the design of a linearly-polarized, pulsed fiber laser operating at 977 nm that addresses the aforementioned challenges. This laser consists of linearly polarized 977 nm laser diode and a polarization maintaining (PM) fiber amplifier. The amplifier is based on PM specialty-fiber doped with Yb^{3+} that is core-pumped using single-mode 915nm pump diodes. The entire device has a compact, robust, all-fiber design. A peak power of 1kW and pulse energy of 15μJ has been achieved from this laser. To our knowledge, this result represents the highest pulse energy and peak power at 977nm achieved to date from Yb^{3+} fiber laser.

2. EXPERIMENTAL SETUP

Figure 1 illustrates the design of the laser. The laser consists of a linearly-polarized 500mW laser diode (977 nm operation) and PM fiber amplifier. This laser is monolithic, being all-fiber by design. The fiber amplifier portion consists of two stages. The first stage is based on PM large mode area (LMA) Yb^{3+} doped fiber with a 10μm core and 125μm cladding. The light from the 500mW 915nm pump diode and the 977 nm signal diode is coupled through a specially designed fiber coupler. This coupler is based on wavelength division multiplexing (WDM) technology that optimizes PM-signal light coupling and randomly-polarized pump coupling to the Yb^{3+} fiber. The second amplifier stage is also based on PM LMA Yb^{3+} doped fiber with a 10μm core and 125μm cladding. It also pumped with 500mW 915nm diode thru a similar WDM coupler as the first stage. A PM fiber isolator is installed between the 1st and 2nd amplifier stages. The 977 nm laser diode is operated in pulsed mode at a repetition rate of 7 kHz.

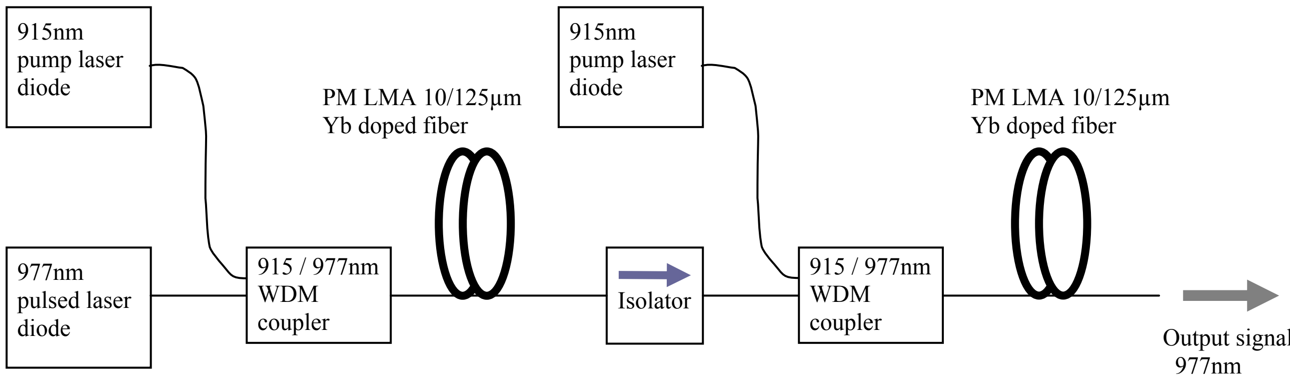

Figure 1 – 977 nm laser design

The PM LMA 10/125 fiber has been specifically developed for efficient amplification of 977 nm signals. Figure 2 shows fiber image taken with the microscope. It is a PANDA-type fiber. The 10µm-diameter fiber core has a 0.07 numerical aperture and supports only the fundamental transversal mode at 977 nm.

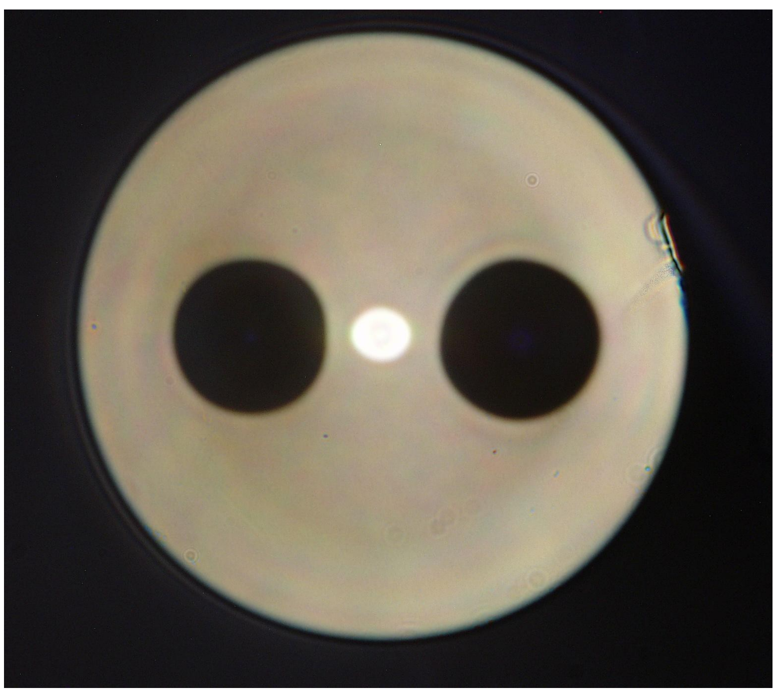

Figure 2 – PM LMA 10/125 fiber image

Small signal gain has been measured from the PM LMA 10/125 fiber in CW mode (Figure 3). A broadband LED source operating at 980nm was used as the seed source for this measurement. Figure 3 clearly shows the 10/125 PM fiber provides efficient gain amplification in the 977 nm wavelength range.

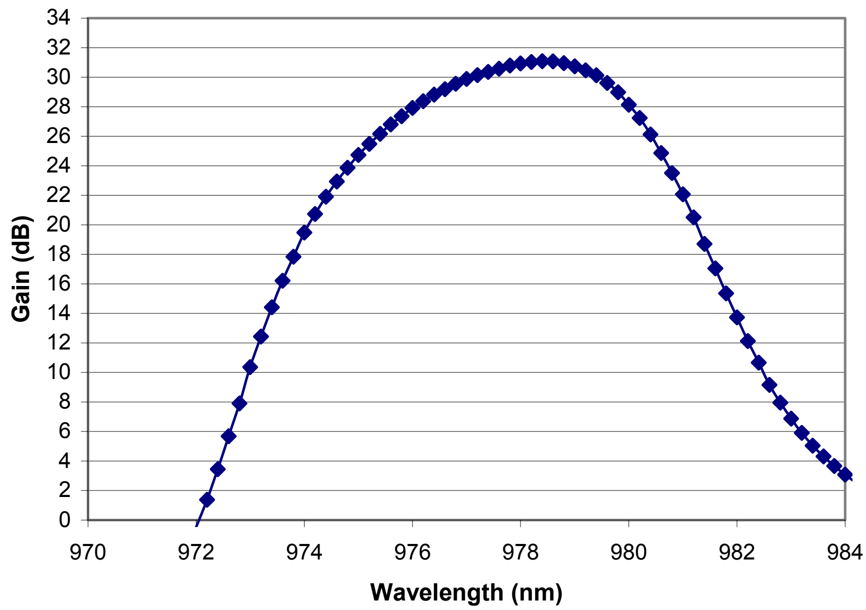

Figure 3 – PLMA 10/125 fiber small-signal gain in the 977 nm wavelength range

3. EXPERIMENTAL RESULTS

Figure 4 shows the average 977nm laser output power versus the coupled 915 nm pump power. The pulse repetition rate used was 7 kHz. The laser demonstrated slope efficiency of 25.3%. The maximum laser average output power was 110mW. 15µJ pulse energy and 1kW peak power was measured at the highest point. A Polarization Extinction Ration (PER) of 13dB was measured at the largest output power condition.

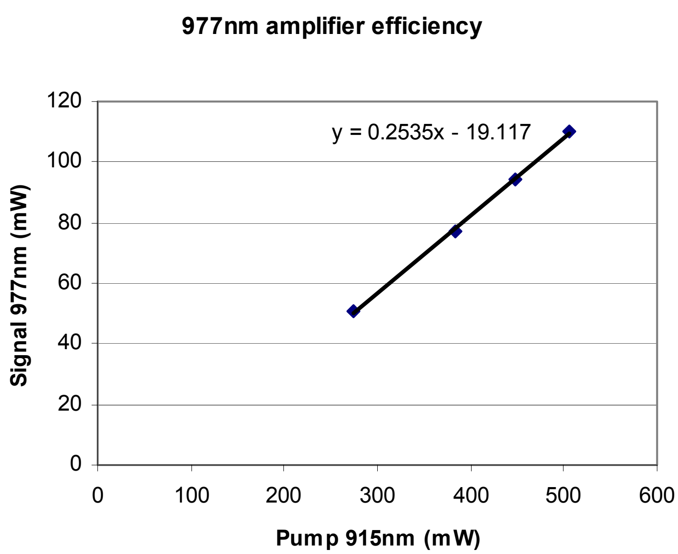

Figure 4 - Laser slope efficiency

The output beam of this laser is near diffraction limited since the PM LMA 10/125 fiber is single-mode by nature and only supports the fundamental mode.

Figure 5 shows the measured laser spectrum and line-width. It shows clean 977 nm lasing with low amplified spontaneous emission (ASE) at other wavelengths (peak-to-peak difference is >25dB). The laser had a relatively narrow line-width (1.06 nm) centered at 976.6 nm.

Figure 6 shows the pulse shape of the laser output signal. The pulse duration is approximately 6-7 ns. The slight pulse distortion is an artifact from the pulsed laser diode driver used. It can be removed by improving the high-frequency matching between the laser diode and diode driver.

One will observe from Figure 4 the output power of the laser increases linearly with coupled pump power. The maximum laser output power measured is therefore limited only by the available pump power used for this test – higher outputs are achievable. No sign of detrimental nonlinear effects, such as Brillouin or Raman scattering (typically seen in small-core fibers), was observed.

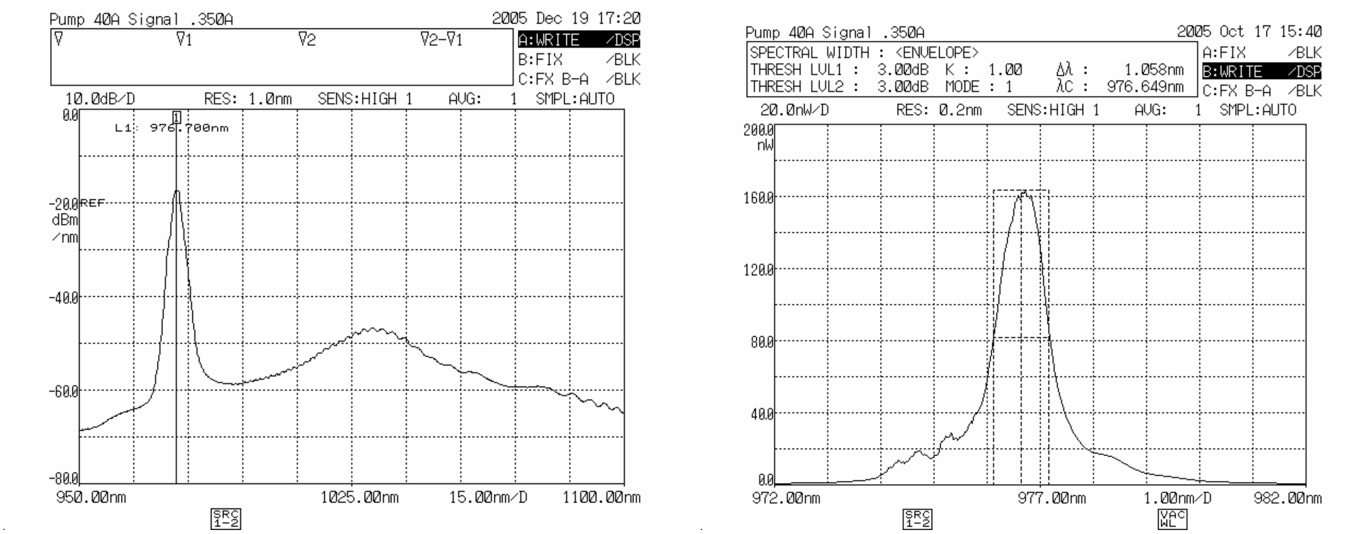

Figure 5 - Output laser spectrum and line-width

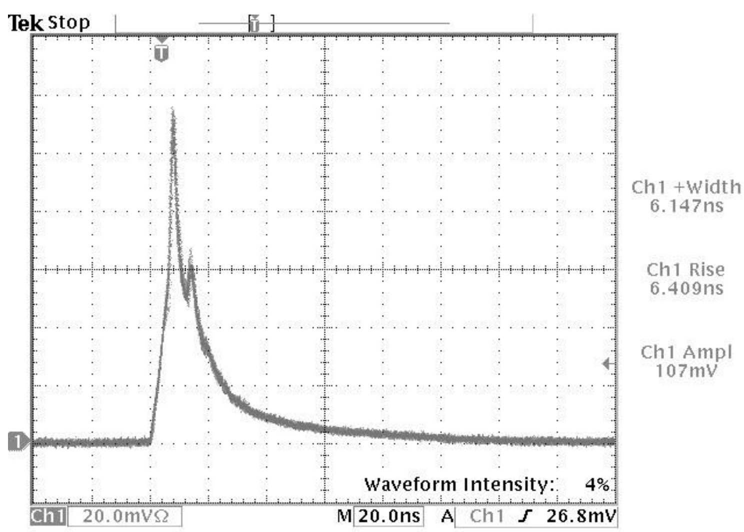

Figure 6 – Output pulse shape

4. CONCLUSIONS

In conclusion, we have demonstrated a linearly-polarized pulsed fiber laser with 1 kW peak power and 15 μJ pulse energy, operating at 977 nm. The laser output power was limited by available pump power and is scalable based on the pump power. This laser has a monolithic, all-fiber design and is robust in nature. This novel fiber laser is an attractive source for blue-light generation, laser radars and other applications.

References

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