1.75W 3μm Pulsed Er:YLF Laser Diode End Pumped with Side Pumped MOPA.

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Abstract

We demonstrate a high pulsed output in the 3-μm wavelength range from a solid state laser. The main resonator is pumped by an opto power fiber coupled diode array with a collimating telescope that delivers 21,5W peak power at 975nm. As an active medium we used a Brewster-cut, 15% Er:YLF crystal, 4mm length, which was end-pumped by the fiber coupled diode laser bar. In our experiments, we used a hemispherical resonator based on one concave mirror with 10cm radius of curvature, HR coated at 2,8μm and HT coated at 973nm, and one flat mirror with 1,4% transmission at 2,8μm . For the amplifier we chose to work with a side-pumping geometry because this way we can use very high pump power diodes. As an active medium we used a Brewster-cut, 15% Er:YLF crystal 4mm length side-pumped by a SLI 100W peak power at 970nm diode array collimated with a cylindrical 2,54cm radius lens. With this configuration we were able to achieve 1,75W peak power pulse with 200μs duration. We obtained (11,6±1,0)% of slope efficiency and perform a Findlay-Clay analysis to obtain the loss of the resonator (3,9±1,4)% and the small signal single pass gain 0,324 (77) cm^{-1}. The main resonator is setup to provide a 450μs pump pulse duration that generates a 200μs Er:YLF laser pulse. Due to the small pump pulse time we are operating the device in a region strongly modulated by oscillation relaxations. As the result of that, the average power of the first 200 μs of the output pulse is a factor 2.5 higher than for a 3 ms long pulse. Using one 100W qcw diode and one Brewster-cut, 15% Er:YLF for external side-pumping amplification we achieved a gain of 4.5% per pass.

Introduction

The main objective of this work is to achieve high pulsed output in the 3-μm wavelength range from a solid state laser. As it was shown in previously published papers [[1], [2], [3]], Er:YLF is an efficient 3-μm material suitable for laser diode pumping

Diode pumped solid state laser are developing at a very fast rate mainly because of decreasing cost of diode lasers and increasing power, narrower spectral emission and better beam quality of the diodes.

The end-pumping geometry limits the total power that can be delivered to the crystal because of pump face fracture but it provides a much better beam quality and overlap between the pump and the Erbium laser than a side-pumping geometry. To use a high power diode with an YLF matrix it is recommended to use it in a side-pumping geometry but this will decrease the quality of the beam.

In the present work we developed a compact main oscillator in end-pumping geometry with a high beam quality associated with a high power diode used in side-pumping geometry as an amplifier

Experimental Setup

The main resonator is pumped by an *opto power* fiber coupled diode array with a collimating telescope that delivers 21,5W peak power at 975nm (the absorbed power is measured to be of 21,4W). The collimating telescope provides a high intensity circular beam (232μm radius, M^2=159). A schematic sketch of the laser set-up is shown in figure 1

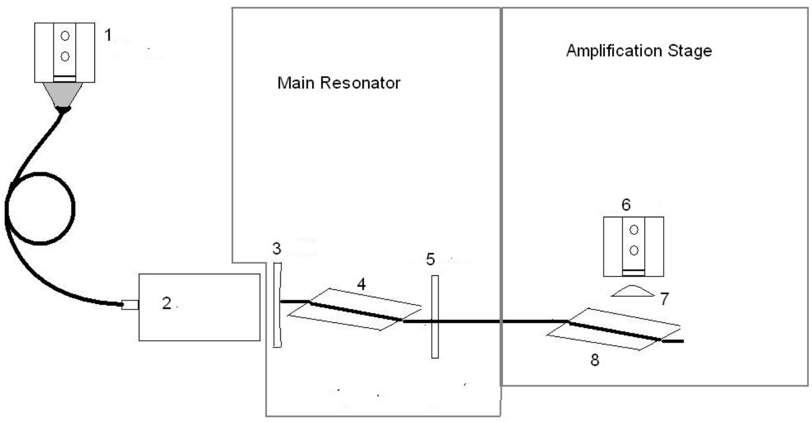

Figure 1: Schematic layout of end-pumped Er:YLF main resonator with amplifier stage 1. Fiber couples diode; 2. collimating telescope; 3. input HR mirror; 4. main oscillator Er:YLF crystal; 5. output 1.4% transmission mirror; 6. High power amplifier diode; 7. Cylindrical lens; 8. Amplifier crystal.

As an active medium we used a Brewster-cut, 15% Er:YLF crystal, 4mm length, which was end-pumped by the fiber coupled diode laser bar. In our experiments, we used a hemispherical resonator based on one concave mirror made of BK7 with 10cm radius of curvature, HR coated at 2,8μm and HT coated at 973nm, and one flat mirror made of CaF_2 with 1,4% transmission at 2,8μm . With this configuration we were able to achieve 1,75W peak power pulse with 200μs duration.

For the amplifier we chose to work with a side-pumping geometry because this way we can use very high pump power diodes. As an active medium we used a Brewster-cut, 15% Er:YLF crystal 4mm length side-pumped by a *SLI* 100W peak power at 970nm diode array. The width of the diode array is about 10mm, which is much bigger than our crystal, for which reason we collimated the diode laser with a cylindrical 2,54cm radius lens.

Results and Discussions

A typical input/output curve of the laser is shown in figure 2. To obtain the slope efficiency [[4]] and to estimate the error of the data we used the minimum square method. Output couplers with transmission ranging from 0,4% to 3,8% at 2.81µm were tried.

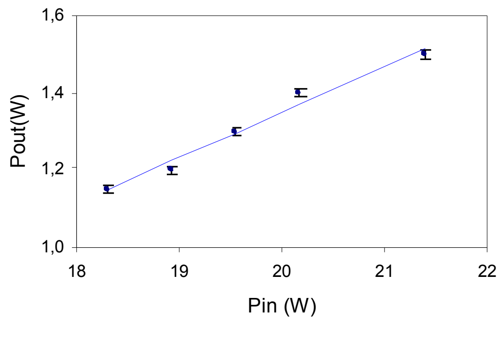

Figure 2: Output/impute curve for a 1,4% transmission output mirror. Slope efficiency (11,9±1,0)%

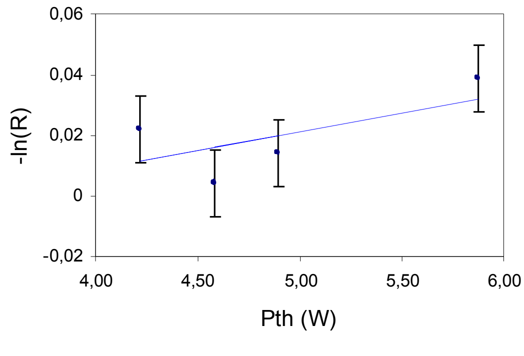

Figure 3: Findlay-Clay analysis of the main resonator. Loss (3,9±1,4)%

The output coupler with transmission 0,4% has show a very high stability but a low output power. The output mirrors with transmission ranging from 2,2% to 3,8% showed a small gain in the output power but the behavior was very unstable. With these data we were able to perform a Findlay-Clay analysis and obtain the loss of the resonator and the small signal single pass gain. This analysis can be seen in figure 3. At the peak power, the small signal single pass gain obtained is 0,324 (77) cm^{-1}.

The main resonator is setup to provide a 450μs pump pulse duration that generates a 200μs Er:YLF laser pulse. Due to the small pump pulse time we are operating the device in a region strongly modulated by oscillation relaxations as shown in figure 4.b. Modulation depth and, therefore, peak power increases for higher output mirror transmissions without loss of pulse energy.

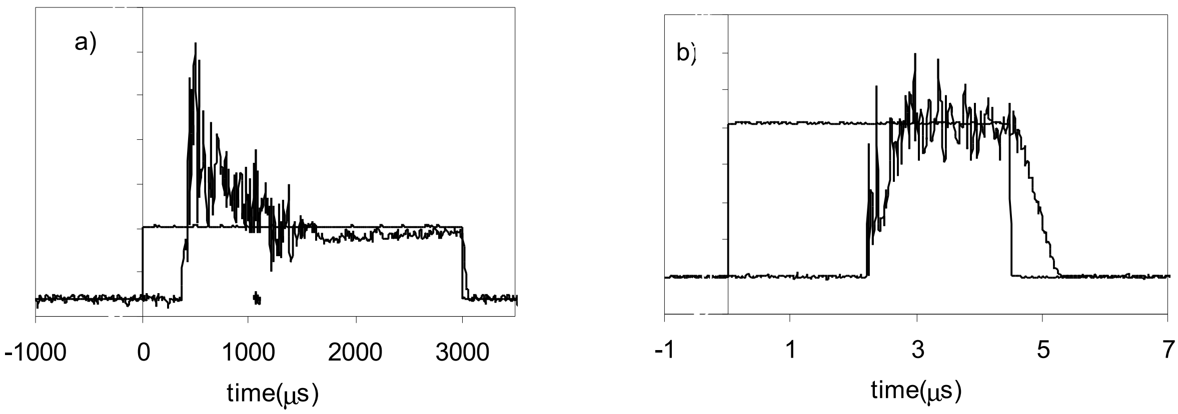

Figure 4: Pump laser (square pulse) and Er:YLF laser for :a) 3ms pump pulse and b) 450μs pump pulse.

The average power of the first 200 μs of the output pulse is a factor 2.5 higher than for a 3 ms long pulse.

All the diodes available for our amplifier stage had a very large spectral distribution (around 10nm) and due to excessive diode failure we had to down rate the diodes which caused peak emission at 967nm and not 973 nm as desired (figure 5), decreasing significantly the absorption of the diode and, consequently, signal amplification. Using one qcw diode for external amplification of crystal 8 we achieved a gain of 4.5% per pass.

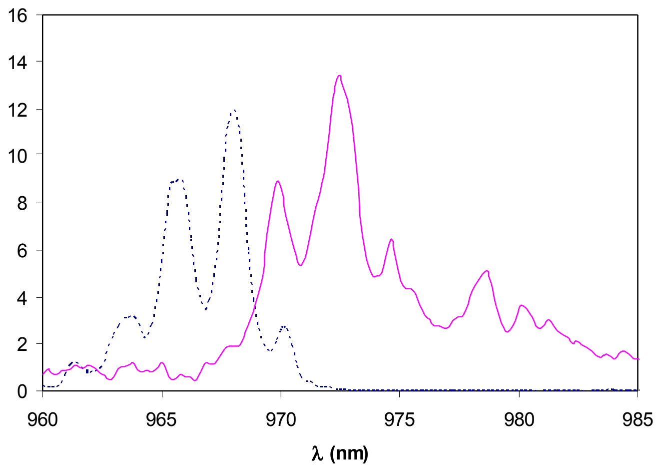

Figure 5: Amplifier pump diode spectrum (dot line) and Er:YLF absorption spectrum (solid line).

Conclusions

We conclude that the best way to achieve a high power, high beam quality Er:YLF diode-pumping is using an end-pumping geometry with a medium power pumping device and a high power diode side-pumping as an amplifier. We also found that it is possible to operate the Er:YLF in the region of the relaxation oscillations to achieve a higher peak power

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1 References

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