Broadband Yb:CaF2 regenerative amplifier for millijoule range ultrashort pulse amplification

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Abstract: We report a diode-pumped regenerative amplifier based on Yb:CaF_2 material delivering up to 1.8 mJ at 100 Hz. The pulses have a spectral bandwidth of 16nm, indicating a good potential for millijoule range sub 100 fs pulse duration.

OCIS codes: (140.3280) Laser amplifiers; (140.3480) Lasers, diode-pumped; (140.3615) Lasers, ytterbium

1. Introduction

Industrial diode-pumped ultrafast lasers offer high flexibility in energy and repetition rate. Ytterbium doped materials are popular since 10 years as active laser media because of their absorption spectrum which is suitable for direct diode-pumping and their large emission bandwidth permitting short pulse generation and amplification. For some specific applications, sub-100-fs energetic pulses are required. Intensive work was done on the generation of short pulse duration with diode-pumped oscillators based on Ytterbium materials, however for millijoule range energy, broadband amplifiers suffer from thermal effect, leading to lower average power [1] and efficient amplifiers suffer from gain narrowing, leading to longer pulse durations, typically >350 fs [2-3]. New materials are needed, with broad gain spectrum together with a high gain for good extraction efficiency.

A “new-old” laser material showed recently very promising results for short pulse generation in oscillators [4] as for short pulse high energy amplification up to the Terawatt level [5]. Yb:CaF_2 offers moreover a good thermal conductivity [6] and broadband continuous broadband laser wavelength tunability [7].

We report on a watt level regenerative amplifier based on Yb:CaF_2 laser material used at room temperature.

2. Experimental Set-up

Our approach to study the potential of Yb:CaF_2 for short pulse amplification was to use the crystal in a regenerative amplifier cavity with a Pockels cell for Q-switching and a thin film polarizer centred at 1040 nm used at Brewster angle. As depicted on the experimental set-up on figure 1, the crystal is a 5mm long crystal with 2.6 % doping concentration, used at Brewster angle, pumped through a dichroic mirror by a 10 W fiber coupled laserdiode with a central wavelength of 978 nm. The pump spot diameter is estimated to approach 200 µm in the middle of the crystal. The cavity is designed in order to obtain diffraction limited laser beam at the output, with a cavity length of about 1.5 m..

The Pockels cell is adjusted for quarter waveplate at 45° in static state, *i.e.* without high voltage, and no birefringent effect with high voltage. We extract the intracavity pulse when its energy is maximal after about 2 µs in the cavity depending on amplifier repetition rate.

Thin film polarizer (TFP) is used in combination with the Pockels cell to extract the output pulse. Moreover we exploit the spectrally-dependent losses of the TFP in order to tune the output pulse spectrum. Indeed, as the polarizer acts on gain cavity spectrum as a high-wavelength pass, adjusting its angle between 55° and 59° in order to allow the spectral tuning of the laser. We assume that other component coatings (on mirrors and on Pockels cell) are almost flat on all crystal gain spectrum (at typical inversion).

Yb:CaF_2 spectral gain depends on the inversion of the laser showing mainly a maximum gain around 1045 nm for low inversion and around 1035 nm for upper inversion. Our approach was to find spectral losses parameters necessary to use all materials gain spectrum to limit gain narrowing.

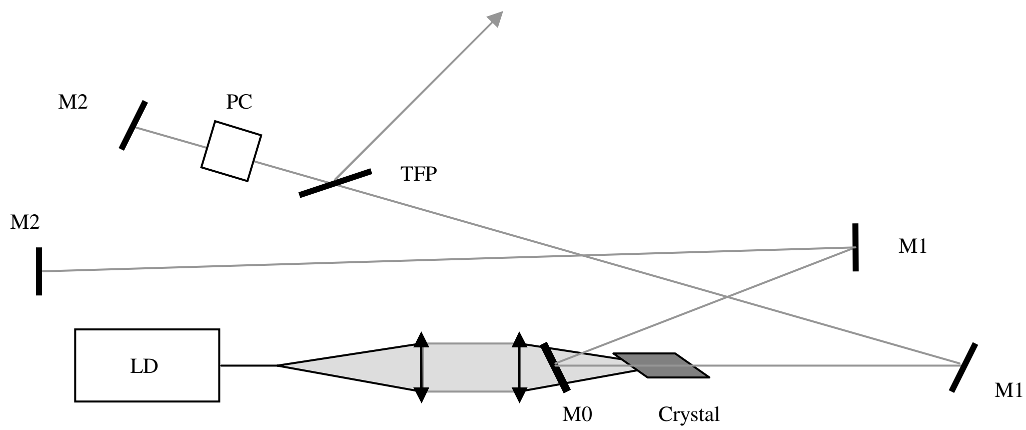

Fig. 1 Laser Set-up, M0: dichroic mirror, M1: curved mirror, M2: end-cavity flat mirror, TFP: thin film polarizer, PC: Pockels cell, LD: Laser diode

3. Results

We generated energy as high as 1.8 mJ at 100 Hz, and average power as high as 850 mW at higher repetition rate. The fluorescence lifetime of 2.4 ms of the crystal explains a decrease of the output energy for repetition rates higher than 300 Hz. However, the maximal average output power is reached at 800 Hz, due to a complex interplay between storage time and amplification time.

Figure 2 shows the dependence of the average power and energy versus the repetition rate.

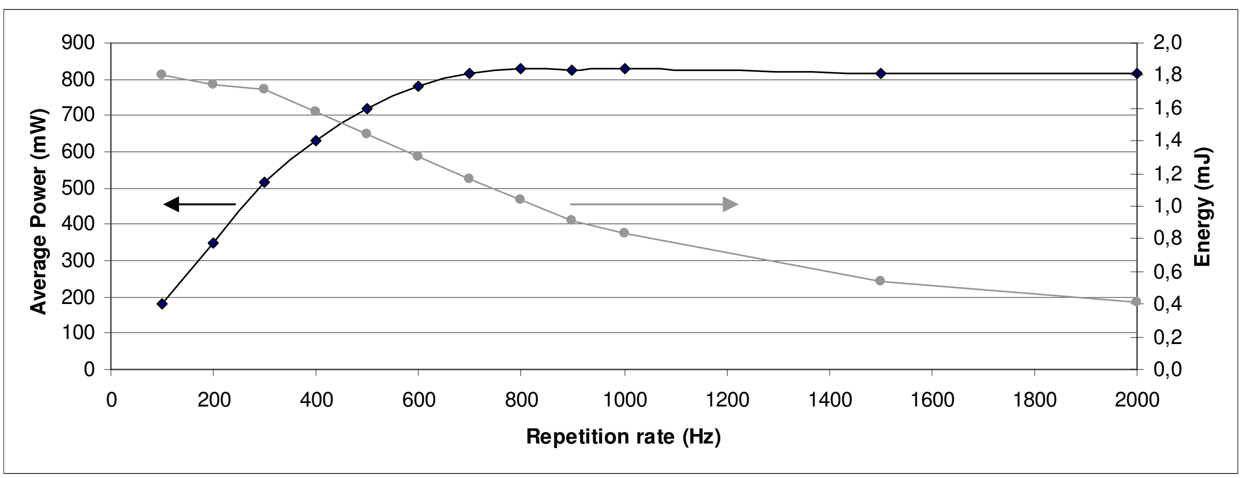

Fig. 2 Evolution of average power and output pulse energy versus repetition rate

We observed a significant influence of the polarizer alignment on the amplified spectrum, which allowed to tune and optimize the spectral shape for broadband amplification, necessary to achieve short pulses after compression in a chirped-pulse amplification architecture..

Figure 3 shows the spectrum obtained at a 500 Hz repetition rate and 1.5 mJ output pulse energy. The spectrum is centered at 1040 nm with a bandwidth of 16 nm FWHM, with a "camel" shape transcribing the valley at 1040 nm observable in the spectral gain profile.

This result clearly indicates a strong potential for sub 100 fs pulse duration in the millijoule range. Work is ongoing to seed this laser cavity with stretched pulses from an oscillator, and compress the extracted pulses in a broadband grating compressor. This system constitutes an excellent solution for seeding laser amplifiers for high energy diode-pumped ytterbium lasers.

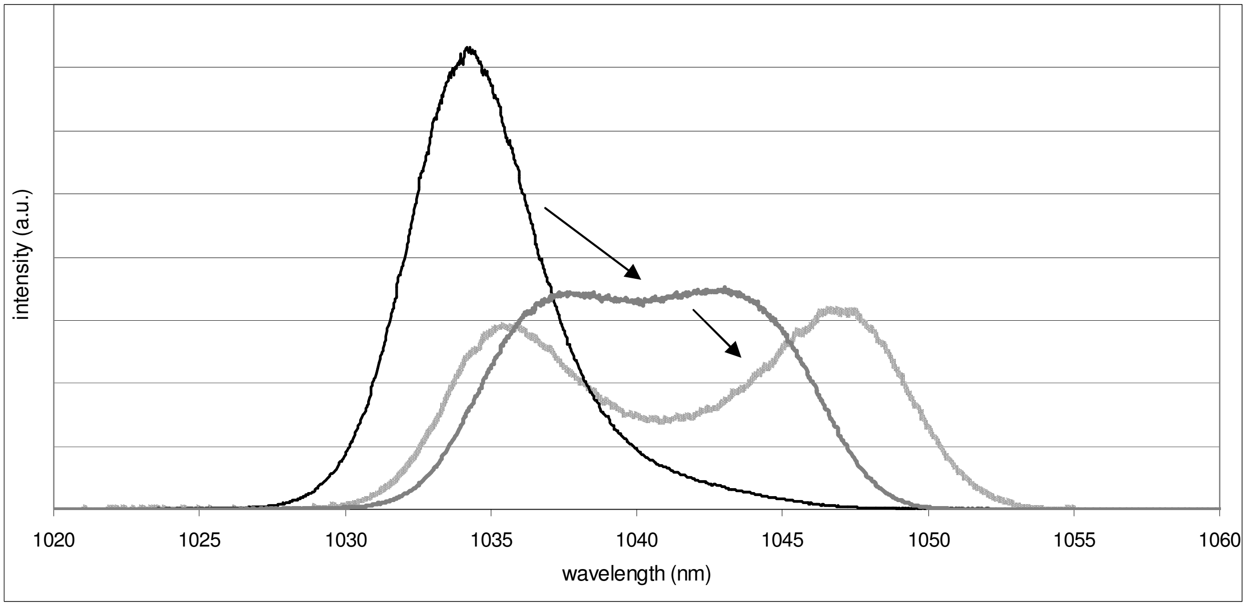

Fig. 3 Output pulse spectrum at 500Hz (1.5mJ), and dependence of the polarizer angle of incidence

4. Conclusion

We demonstrated broadband, high energy regenerative amplifier. We obtained maximal output energy of 1.8 mJ, maximal output power of 850 mW and maximal spectral bandwidth of about 16 nm centered at 1040nm. Our solution using Yb:CaF_2 as active amplification medium together with passive spectral shaping indicates a good potential for sub-100-fs pulses amplification. New results on the seeding of this cavity will be presented at the conference.

5. References

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