10 mJ-level Picosecond OPCPA Pump Laser Based on Room Temperature Hybrid Yb:YAG Amplifier System

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High energy, high average power picosecond laser systems are applicable in a variety of scientific and industrial fields such as attosecond science, EUV or THz radiation generation, single shot laser marking, high speed and large area processing and many more. These lasers are also commonly used as pump sources in high intensity optical parametric chirped pulse amplification (OPCPA) systems with sub-ps or ps pulse durations being favorable due to lower amplified parametric fluorescence background in the ps to ns temporal window. End pumped Yb:YAG amplifiers feature extremely good parameters for high energy and average power laser development with major problems being nonlinear temporal and thermally induced spatial distortions. Several state of the art laser technologies have been proposed to overcome these limitations, such as thin disc [1], slab [2] and coherent beam combining [3]. However, these technologies rely on highly complex and expensive optical arrangements, which are not always necessary to avoid beam distortions.

Our aim is to create a compact and cost effective 100W-class, high energy laser system based on hybrid laser approach comprising fiber laser technology and free-space amplification combined with our patented thermal aberration management techniques [4]. During the first development stage we chose laser operation regime that allowed us to avoid polarization and beam distortions due to thermal effects and investigate amplification and nonlinear temporal pulse characteristics of the resulting laser radiation. In this work we demonstrate 1 ps laser system capable of delivering > 13 mJ energy laser radiation at 20 Hz.

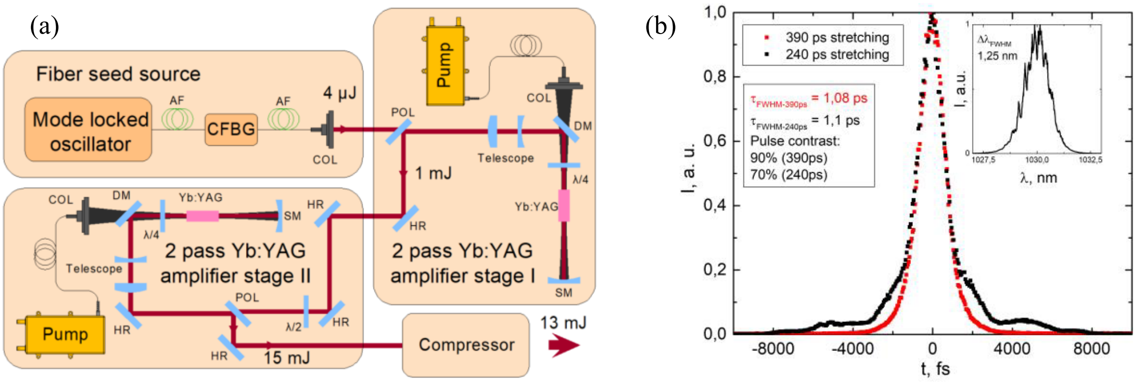

Fig. 1. (a) Schematic representation of 10 mJ, 20 Hz laser system. AF – fiber amplifier, CFBG – chirped fiber Bragg grating, λ/4, λ/2 – quarter-wave and half-wave plates, COL – beam collimator, POL – thin film polarizer, DM – dichroic mirror, SM – spherical mirror, HR – high reflectivity mirror. (b) Intensity autocorrelation of the output pulse at different pulse stretching ratios and pulse spectrum (inset).

The laser system is shown in Fig. 1. Ultrashort picosecond pulses were generated in a SESAM mode-locked fiber oscillator, stretched in a chirped fiber Bragg grating (CFBG) and amplified in several single mode fiber amplifiers resulting in 4 μJ energy pulses. Pulse energy was further increased to 1 mJ and 15 mJ in the 1st and 2nd free space Yb:YAG amplifiers. The output pulse spectrum width was ≈1.25 nm and corresponded to 1 ps Fourier transform-limited pulse duration. Pulse compression experiment showed that stretching up to 390 ps in the fiber laser was necessary to achieve 1,08 ps pulses with reasonable 90% pulse contrast (Fig. 1. b). Finally, beam quality proved to be close to diffraction limited ($M^2 \leq 1.08$) whereas the second harmonic generation experiment resulted in maximum 82% conversion efficiency indicating negligible output pulse phase distortion. These results proved that such optical arrangement is suitable to achieve high energy output pulses with desired spectral and temporal characteristics and allows us to move forward with 100W system development.

References

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