Millijoules high master-slave pulse ratio 532 nm picosecond laser

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Abstract: A high master-slave pulse ratio 532 nm picosecond laser with pulse energies of millijoules is reported in this paper. Mode-locking picosecond oscillator was used as seed source with 30.8 ps pulse width, spectral width 0.15 nm, 150 mW average power and 1064 nm center wavelengths at the repetition rate 88 MHz. With laser diode (LD) side-continuous-pumped Nd:YAG picosecond regenerative amplifier, average power of 2.5 W was achieved at 1 kHz, which corresponds to single pulse energy of 2.5 mJ. After LBO frequency doubling, 1.5 mJ and 26.6 ps output pulses at 532 nm are obtained with master-slave ratio higher than 200. The satellite laser ranging (SLR) accuracy is about 7 mm, which makes this laser an attractive device for satellite ranging

Key words: laser technology, picosecond pulse, high master-slave ratio, satellite laser ranging

1. INTRODUCTION

In recent years, diode-pumped-solid-state (DPSS) lasers have been rapidly developed for the advantages of high stability, good beam quality and smaller system size etc., which have been widely used in nonlinear frequency conversion, micro processing, medical treatment and scientific research. [1-4] Satellite laser ranging (SLR) is one of the main technical means to study geodynamics, geodesy, geophysics and astronomy. [5,6] Compared with microwave radar ranging, laser ranging has higher accuracy and do not affected by the space electromagnetic interference. High efficiency, high power and high energy picosecond laser has aroused wide concern in the laser and applications, especially kHz picosecond lasers with high master-slave pulse ratio is thought to be an important type of picosecond laser in the field of laser ranging. [7,8]

In this work, we demonstrate a high master-slave pulse ratio 532 nm picosecond laser with pulse energies of millijoules. Semiconductor saturable absorber (SESAM) mode-locked picosecond pulses are used as seed source, producing 88 MHz repetition rate and 150 mW average power in center wavelength of 1064 nm. With laser diode (LD) side-continuous-pumped Nd:YAG picosecond regenerative amplifier, average output power of 2.5 W is achieved at repetition rate of 1 kHz corresponding to single pulse energy of 2.5 mJ. By using LiB_3O_5 (LBO) nonlinear crystal frequency doubling, 1.5 mJ and 26.2 ps output pulses at 532 nm are obtained with high master-slave ratio. This laser system has high compact structure and high stability which is successfully applied for SLR at National Astronomical Observatory, Chinese Academy of Sciences. The SLR accuracy is up to 7 mm.

2. EXPERIMENTAL PRINCIPLE AND SETUP

Figure 1 shows the experimental setup of SESAM mode-locking. The Nd:YVO_4 crystal used in our experiment has an Nd^{3+} doping concentration of 0.3 at.% was pumped by fiber coupled laser diode at 808 nm. Both end faces of Nd:YVO_4 are coated with an anti-reflection coating for 808 nm and 1064 nm. The absorption ratio of the SESAM is 2% with modulation depth 0.5%. M_1, M_2, M_3 and M_4 are four 0 °mirrors with high-reflective (HR) coated at 1064 nm.

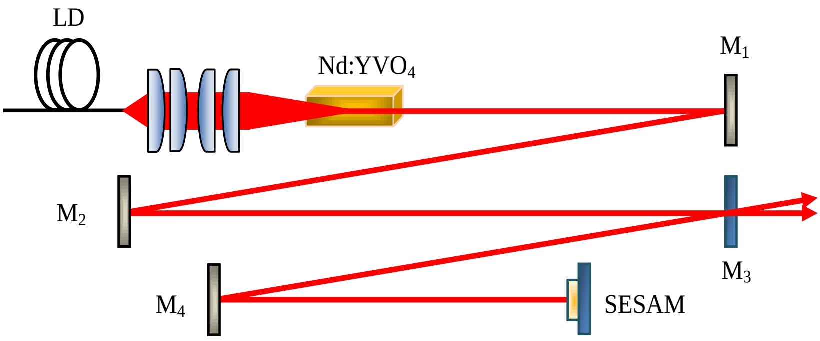


Figure 1. Schematic diagram of mode locking seed source

The experimental setup of the regenerative amplifier is shown in Figure 2. The picosecond pulses generated from SESAM mode-locking are injected into the regenerative amplifier. Inside the regenerative amplifier a Nd:YAG rod is LD-side-continuous-pumped. The size of the rod is Φ 4 mm × 15 mm with 0.5% Nd-doped. P_1, P_2 and P_3 are thin film polarizers that allowing the p-polarization beams pass through. MOI is a magneto optic isolator. PC is a β-BaB_2O_4 (BBO) crystal Electro-Optical (EO) Pockels Cell, which is used as pulse picker to reduce the repetition rate in the range of ~kHz. [9,10] M_5 and M_8 are a 0 ° mirrors with HR-coated at 1064 nm. M_6 is 45 °totally reflecting mirror at 1064 nm. M_7 is a 45 °short wave passed mirror coated with 808nm anti-reflection (AR) and 1064 nm HR.

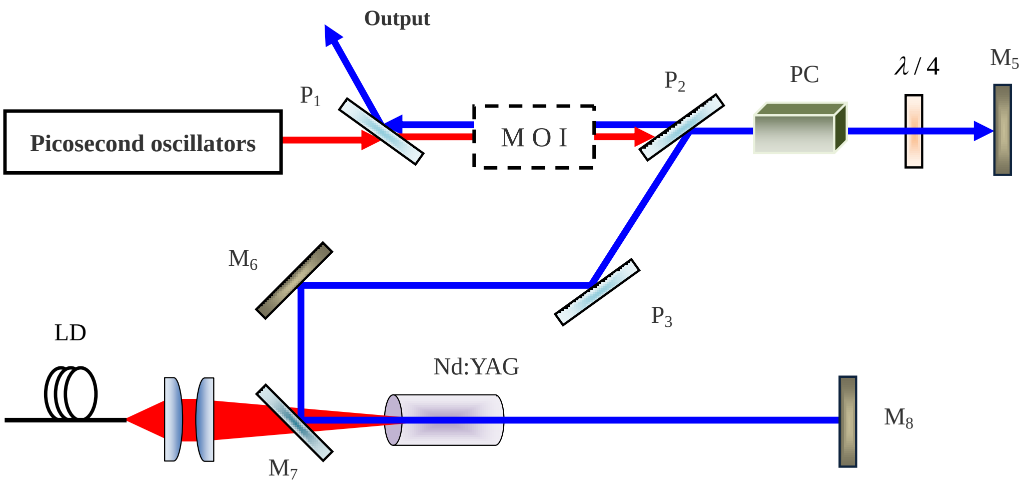


Figure 2. Schematic diagram of the regenerative amplifier

Picosecond pulses at 532 nm wavelength are generated by second-harmonic generation (SHG) in a LBO crystal. Figure 3 shows the schematic of frequency doubler. In our experiment, LBO crystal is optimized to obtain higher frequency-doubling efficiency with high damage threshold. [11,12] The LBO crystal is coated with 1064 nm AR coating on the incident surface and 532 & 1064 nm AR coated on the other surface. M_9 is a beam splitting lens that is AR-coated at 1064 and HR-coated at 532 nm. Garbage is used to absorb the rest of infrared light.

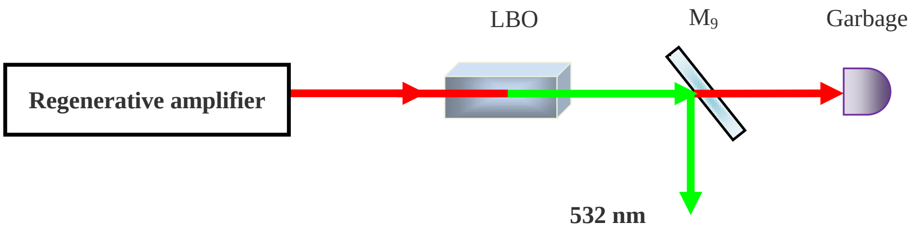
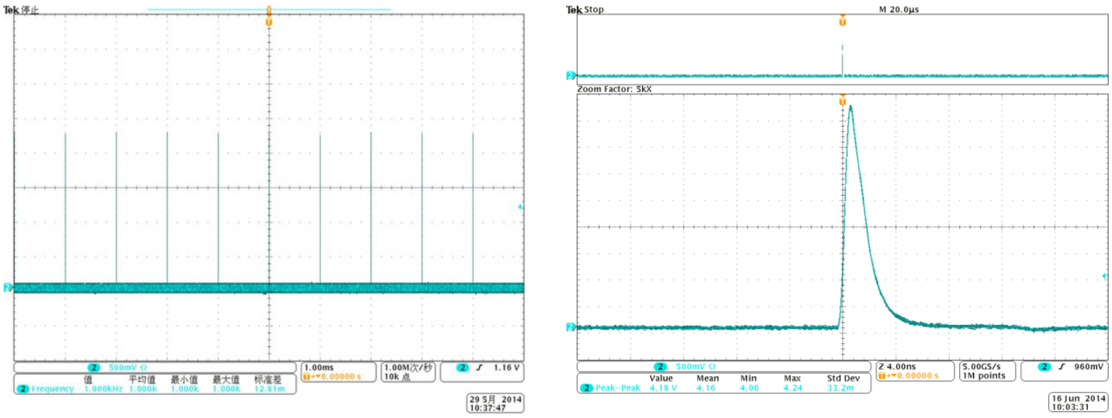


Figure 3. Schematic diagram of frequency doubler

3. RESULTS AND DISCUSSIONS

The regenerative amplified waveform of the pulse sequence at 1 kHz and single is shown in Figure 4. The output pulse has high stability with no Q-switch phenomenon.



(a) Regenerative pulse sequence at 1 kHz (b) single pulse

Figure 4. Waveform of the regenerative amplified pulse

Figure 5 shows the spot intensity distribution in near field. The prototype delivers near Gaussian intensity profiles. The diameter of beam spot is 1.2 mm. The autocorrelation curve of output pulse is shown in Figure 6.

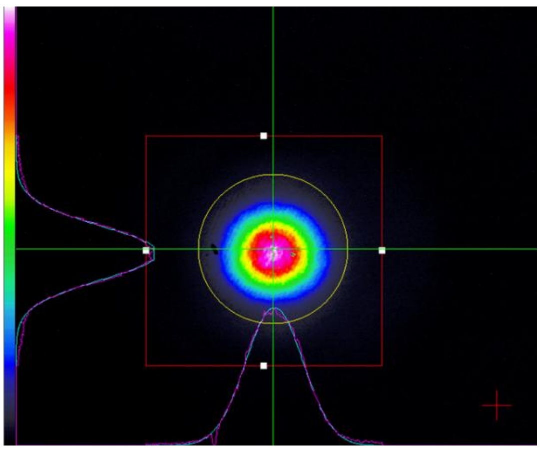


Figure 5. Spot intensity distribution

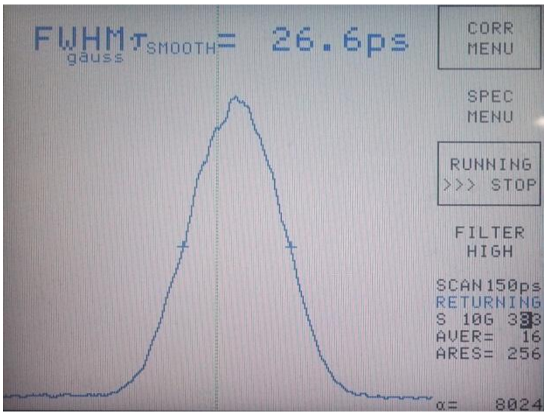


Figure 6. Autocorrelation curve of the output pulse

As Figure 7 shows, 22.4 hours' power stability of the output pulse is very high (dates were collected every 6 seconds). The system has been in long term operation without failure.

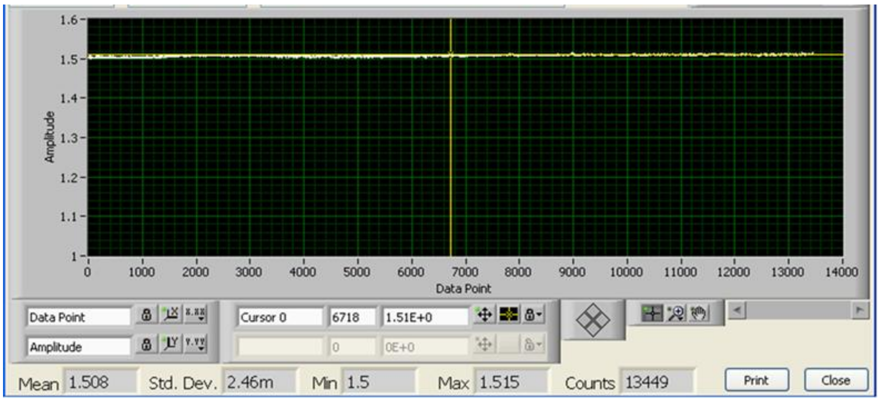


Figure 7. Power stability measured in long term operation (22.4 hours)

The working state of the SLR system is shown in Figure 8. The accuracy of ground target measured is 7.6mm. By using this laser system, we successfully tracked the cooperative satellite Lageos in the day time. The precision measured is as high as 10 mm. The laser returns from the satellite is shown in figure 9. The central points in the line are the laser returns, the other points are noise from the detector and the background.


Figure 8. Working state of system in SLR

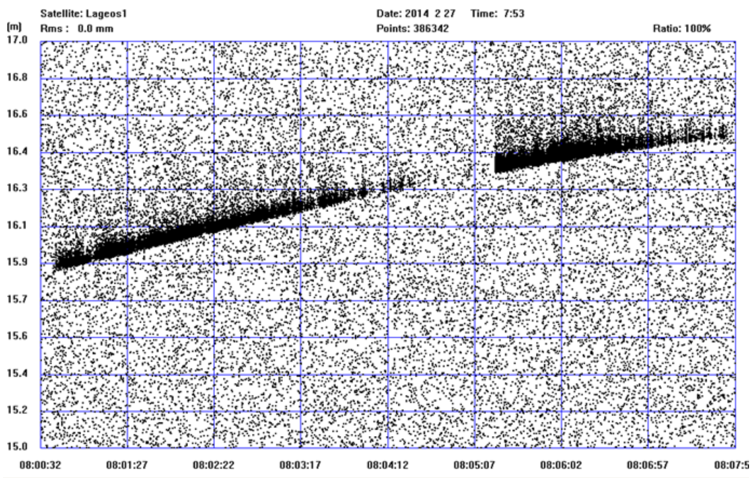


Figure 9. Laser returns from the satellite

4. CONCLUSIONS

In conclusion, we have developed a high master-slave pulse ratio 532 nm picosecond laser on the magnitude of millijoules. The system combines the techniques of SESAM passively mode-locking, regenerative amplifier, and LBO crystal frequency doubling. In this way, pulses energy of 1.5 mJ and 26.6 ps output at 532 nm are obtained with master-slave ratio higher than 200. The output pulses of the system have good beam quality and high stability that in continuous operation for more than 22.4 hours without failure. Finally, through the actual ranging, we draw the conclusion that this system is capable to be applied in SLR.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge financial support by the This work is supported by funding from the National key foundation for exploring scientific instrument (No. 2011YQ120024) .

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