Flash-lamp-pumped picosecond Nd:YAG regenerative amplifier

Bingyuan Zhang (张丙元)[1,2], Gang Li (李 港)[1], Meng Chen (陈 檬)[1], Guoju Wang (王国菊)[2], Yonggang Wang (王勇刚)[3], and Xiaoyu Ma (马骁宇)[3]

[1]*College of Laser Engineering, Beijing University of Technology, Beijing 100022*

[2]*College of Physics Science and Information Engineering, Liaocheng University, Liaocheng 252059*

[3]*Institute of Semiconductors, Chinese Academy of Sciences, Beijing 100083*

Received July 4, 2005

A flash-lamp-pumped Nd:YAG regenerative amplifier has been developed at 1.06 μm, seeded with 10-ps pulses from a diode-end-pumped and mode-locked Nd:YAG oscillator with homemade semiconductor saturable absorber mirror (SESAM). The pulse energy was amplified to 2 mJ by the regenerative amplifier at 10-Hz repetition rate. In two-stages amplifier the regenerative amplified pulse energy was amplified to 100 mJ, and 35-mJ double frequency at 532 nm was obtained by extra-cavity double frequency with a KTP crystal.

OCIS codes: 140.3280, 140.4050, 140.3580.

Short-pulse, high-peak-power, solid-state lasers have numerous applications in variable fields. Compact, efficient, and robust laser transmitters are needed for altimetry and ranging, which require nanosecond and < 50-ps pulses, respectively. High–intensity physics is a fast–growing field that is strongly related to the rapid development of high-peak power lasers. Diode-pumped Nd:YAG, Nd:$GdVO_4$, and Nd:YVO_4 passively mode-locked lasers with semiconductor saturable absorber mirror (SESAM) in 1-μm region have been demonstrated with pulse widths down to several picoseconds and pulses energies in the nanojoule range[1−6]. These lasers are attractive seed sources for the regenerative because they are compact, long lived, efficient, and easy to use. Usually the pulse energy of the continuous wave (CW) mode-locked laser is too low. They need to be amplified to the required level of energy. Regenerative amplification is a good way to achieve amplification and is widely used for amplifying nanosecond or picosecond pulses at the present time[7−10]. High gain can be achieved because of the numbers of trips that the light pulse is amplified in the gain media, so regenerative amplification can deal with low-single pass gain media, making amplification possible in most materials. In this paper, a flash-lamp-pumped Nd:YAG regenerative amplifier has been developed at 1.06 μm, seeded with 10-ps pulses from a diode-end-pumped and mode-locked Nd:YAG oscillator with SESAM, the regenerative amplifier produces 2-mJ pulse energy at 10-Hz repetition rate. In two-stages amplifier the pulse energy was amplified to 100 mJ, and 35-mJ double frequency at 532 nm was obtained by the KTP crystal.

The seed pulses was generated by a diode-end-pumped mode-locked laser with a SESAM (see Fig. 1)[4−6]. It generates 100-MHz short pulse with 10-ps pulse duration and more than 100-mW average power, the mode-locking pulses train is shown in Fig. 2. In the experiment the stability of the mode-locking was observed by the oscilloscope, the fluctuation of the pulse intensity was less than 2%. With four hours continuous work, the laser maintains stable continuous mode-locking, and the waveform of the mode-locking pulse had no change. In the cavity a quarter wave plate was installed combining with the polarizer to insure the laser output from one side and to increase the output power. This laser employs a straight cavity, which has no astigmatism and is easy to ensure pure fundamental mode operation.

A schematic diagram of our regenerative amplifier is shown in Fig. 3. A half-wave plate was installed, in

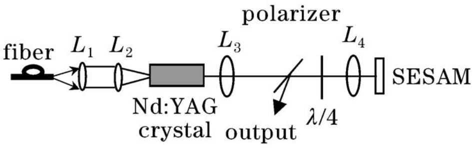

Fig. 1. Passively mode locked Nd:YAG laser oscillator with SESAM.

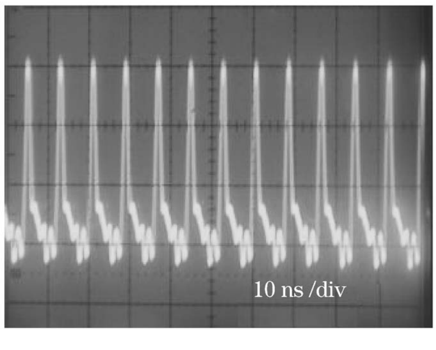

Fig. 2. Oscilloscope trace of CW mode-locking pulses.

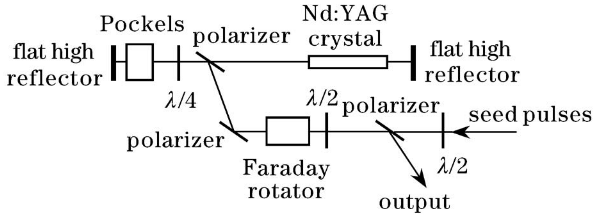

Fig. 3. Schematic diagram of flash-lamp-pumped picosecond Nd:YAG regenerative amplifier.

conjunction with polarizer to adjust the power of the seed pulse. The regenerative amplifier cavity was firstly optimized without intra-cavity components and with a 1% output mirror. Then the polarizer, quarter-wave plate and the Pockels cell were installed and adjusted for minimum insertion loss. The quarter-wave plate was rotated 45°, and the pockels cell was set for quarter-wave voltage, and adjusted to maximize the output power and minimize the buildup time of the Q-switched laser pulse. Without the seed pulse injection the system is a cavity-dumped Q-switched laser.

In order to isolate the output of amplifier from the oscillator, the seed pulse was sent through the Faraday isolator and injected into the amplifier cavity. The seed pulse is amplified in regenerative amplifier as follows. Firstly, the pulse passes through the Pockels cell, which initially has no applied voltage. The seed pulse doubly passes through the laser crystal with the static quarter-wave plate providing a half-wave retardation per double pass. Secondly, when the quarter-wave voltage is applied to the Pockels cell, the pulse circling in the cavity is trapped, and the seed pulse train experiences a full-wave retardation from the combination of the quarter-wave plate and the Pockels cell. This insures that only one pulse is trapped, circling in the cavity, and amplified in the crystal. Lastly, when the pulse energy reaches saturation, the voltage on the Pockels cell switch to the zero, and the amplified pulse is cavity dumped. In normal operation the pulse was switched out at the point of maximum energy. The pulse made 30 round trips in the amplifier before the gain was saturated and the pulse was switched out. The pulse evolution in the amplifier and the ejected pulse were observed by a 5-ns rise-time photodiode at the end mirror and the pulses were monitored with a Tektronix oscilloscope with a 100-MHz band width (see Figs. 4 and 5). The seed pulse injected into the regenerative amplifier was amplified to 2 mJ from 1 nJ at 10-Hz repetition rate, which was detected by the energy meter.

In order to obtain higher single pulse energy, the pulse ejected from the regenerative amplifier was amplified in two-stages amplifiers. The schematic diagram of the two-stages amplifiers and the extra-cavity double frequency are shown in Fig. 6. In two amplifiers the Nd:YAG crystals were employed as the gain medium. In order to increase the efficiency of the amplifiers and the damage threshold of the crystals , we set a reverse telescope to enlarge the laser beam before each crystal. In the experiment we adjust the telescopes to obtain better state. After two amplifier the pulse energies at 1.06 μm are about 17 and 100 mJ, respectively, and after the crystal KTP 35-mJ pulse energy at 532 nm was obtained.

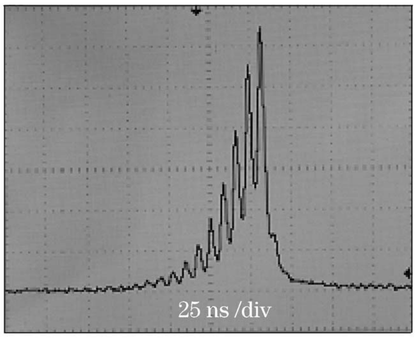

Fig. 4. Evolution of the pulse in the cavity during the amplification.

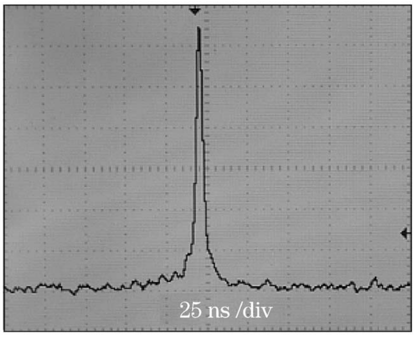

Fig. 5. The pulse ejected from the regenerative amplifier.

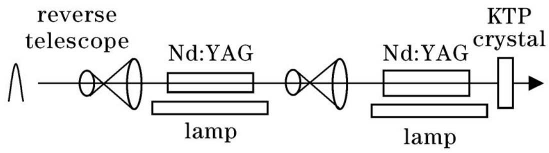

Fig. 6. Schematic diagram of the two-stages amplifiers and the extra-cavity double frequency.

In conclusion, a flash-lamp-pumped Nd:YAG regenerative amplifier has been developed at 1.06 μm, seeded with about 10-ps pulses from a diode-end-pumped mode-locked Nd:YAG oscillator with homemade SESAM. The regenerative amplified pulse energy was 2 mJ at 10-Hz repetition rate, in two-stages amplifier the regenerative amplified pulse energy was amplified to 100 mJ, and 35-mJ double frequency at 532 nm was obtained by extra-cavity double frequency with the KTP crystal.

This work was supported by Ministry of Science and Technology of China (No. JG-2000-05), the Natural Science Foundation of Beijing (No. 3021001), and the foundation of Liaocheng University. B. Zhang's e-mail address is byzhang2008@163.com.

References

1. U. Keller, Appl. Phys. B **58,** 347 (1994).
2. U. Keller, D. A. B. Miller, G. D. Boyd, T. H. Chiu, J. F. Ferguson, and M. T. Asom, Opt. Lett. **17,** 505 (1992).
3. Th. Graf, A. I. Ferguson, E. Bente, D. Burns, and M. D. Dawson, Opt. Commun. **159,** 84 (1999).
4. B. Zhang, G. Li, M. Chen, Y. Wang, and Z. Zhang, Opt. Lett. **28,** 1829 (2003).
5. B. Zhang, G. Li, M. Chen, H. Yu, Y. Wang, and X. Ma, Opt. Commun. **244,** 311 (2005).
6. B. Zhang, G. Li, M. Chen, Y. Wang, and Z. Zhang, Chin. Opt. Lett. **1,** 477 (2003).
7. M. D. Dawson, W. A. Schroeder, D. P. Norwood, A. L. Smirl, J. Weston, R. N. Etterlbrick, and R. Aubert, Opt. Lett. **13,** 990 (1988).
8. L. Turi and T. Juhasz, Opt. Lett. **20,** 154 (1995).
9. M. Gifford and K. J. Weingarten, Opt. Lett. **17,** 1788 (1992).
10. F. Balembois, P. Georges, F. Salin, and A. Brun, Opt. Lett. **18,** 1250 (1993).