Diode pumped injection seeded Nd:YAG laser

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Diode pumped, injection seeded single-longitudinal-mode (SLM) Nd:YAG laser is achieved through build-up time minimizing technique in Q-switching operation. Pulses with energy of 20 mJ are obtained at a repetition rate of 100 Hz. M_x^2 and M_y^2 are 1.41 and 1.38, respectively.

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Wind velocity measurement using direct detection Doppler techniques in a lidar system has special requirements for the frequency characteristics of the pulsed laser transmitter. The laser must be single frequency (~ 100 MHz) on a single shot basis. The standard technique to achieve this performance is to seed a high-power pulsed oscillator with a frequency-stable, continuous wave (CW) seeder laser[1−4]. Though lamp pumped injection seeded Nd:YAG is available in several venders, diode pumped injection seeded laser is attractive due to the compact and high repetition rate. Up to now, the single-longitudinal mode (SLM) all-solid-state lasers have either low energy or low repetition rate, and there is few report on both high repetition rate and high energy[5]. A critical point of the injection seeding system is to adjust the length of the pulsed oscillator to stay in resonance with the seeder laser. The adjustments are made by monitoring the build-up time of the Q-switched output pulse for each shot and then minimizing this build-up time by feedback loop controlled changes to the cavity length. The laser operates well at high repetition rate using this approach. In this letter, a detailed description of the diode pumped, injection seeded Nd:YAG laser is presented. This laser can be used in direct detection Doppler wind lidar.

Figure 1 is the schematic of the diode pumped injection seeded Nd:YAG laser. The single frequency seeder laser for the injection seeding system is a Mephisto OEM200 CW NPRO Nd:YAG laser manufactured by the Innolight. The seeder laser has a linewidth of 1 kHz and a power of 200 mW . Both M^2 of horizontal axis and vertical axis are less than 1.1. OFR IOT-5-1064-HP isolator has an isolation of 60 dB. The seeder laser is injected through the polarizer. The electro-optic (E-O) Q-switched oscillator is designed to decrease sensitivities of thermal and vibrational misalignment effects[6]. It consists of a plane high-reflection (HR) mirror M1 and a convex mirror M2 with radius of 3 m and transmission of 70%. The optical length of the cavity is about 75 cm. Two $\lambda/4$ wave plates are set at both sides of laser rod to eliminate the space hole burning[7]. KD*P and a $\lambda/4$ wave plate make up the E-O Q-switch. The aperture A is used to limit the transversal mode. The laser rod is pumped by diode lasers from three directions in a diffusive reflector cavity to achieve uniform pumping[8]. The laser diodes work at 100 Hz and the pump pulse width is 200 μs. The best injection seeding is achieved when the radiation spectra of the two laser crystals match each other. It requires that both laser crystals have the same temperature. So the temperature of the cooling water, which has a controlling accuracy of less than 1 K, is set as same as the temperature of the seeded laser crystal. The feedback loop circuit is used to measure the build-up time and drive the piezoelectric transition (PZT) to adjust the cavity length.

The effects of injection seeding are readily observable on the temporal pulse shape of the slave oscillator. The output pulses are recorded using a streak tube with ps rise time and sampled by a Tecktronix 3052B oscilloscope. The pulse shape without injection seeding is shown in Fig. 2(a). There are obvious jitters due to beat frequency between two or several longitudinal modes. After injection seeding, the pulse shape becomes smooth and free of jitters, as shown in Fig. 2(b). The sample rate of 5 G/s of the oscilloscope is enough to fully resolve the temporal structure (see Fig. 2). So it can be confirmed that there is only one longitudinal mode in the output laser.

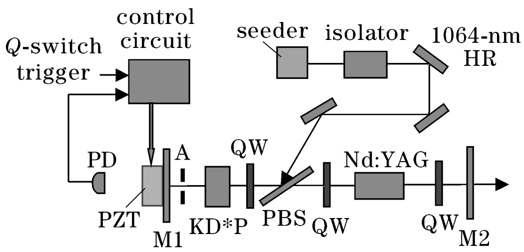

Fig. 1. Schematic of the injection seeding system. PD: photodiode; QW: $\lambda/4$ plate; PBS: polarization beam splitter.

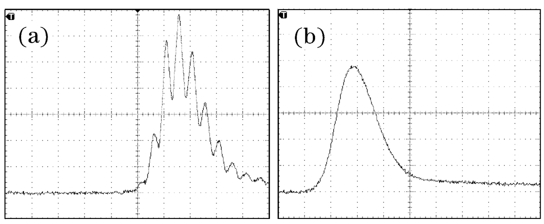

Fig. 2. Temporal pulse profiles before (a) and after injection (b).

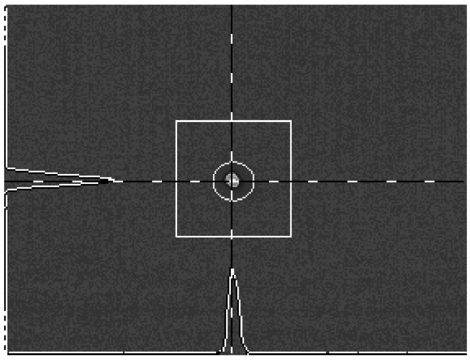

Fig. 3. Laser spot and intensity distribution.

For developing Doppler wind lidar, the output energy at 355 nm is aimed to be 50 mJ at a repetition rate of 100 Hz. The laser in this letter will be amplified and frequency tripled. Therefore, the beam quality is paid more attention. The energy of 20 mJ per shot, at the wavelength of 1064 nm, is obtained in TEM_{00} mode at 100 Hz. M_x^2 and M_y^2 measured using Spiricon M^2-200 beam propagation analyzer are 1.41 and 1.38, respectively. The laser spot and transversal intensity distribution are shown in Fig. 3.

The laser is running continually for more than 2 hours without any adjustment. The probability of output pulse with SLM is over 99% during the observation duration. There are still 1% pulses out of SLM due to the enviremental noise. It cannot be completely avoided for the build-up time techniques. The repetition rate is limited by the diode laser and cooling system, it will be enhanced by using diode laser with higher repetition rate.

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