DEVELOPMENT OF SINGLE FREQUENCY ALL SOLID-STATE LASERS FOR LIDAR APPLICATION

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ABSTRTACT

Single frequency all solid state laser will be next generation laser sources for lidar system, especially in Doppler lidar and different absorption lidar (DIAL). In this proceeding, we will present several researches on single wavelength, all solid state lasers with either linear cavity or ring cavity. An injection seeding, frequency tripled, all solid-state Nd:YAG laser with MOPA configuration is demonstrated. A ring laser using technique of birefringence mode selection is used to get single frequency output. Both lasers are developed for Doppler lidar. Similar injection seeding technique is also used in an all solid-state Ti:Sapphire laser which it will be used in a DIAL system.

INTRODUCTION

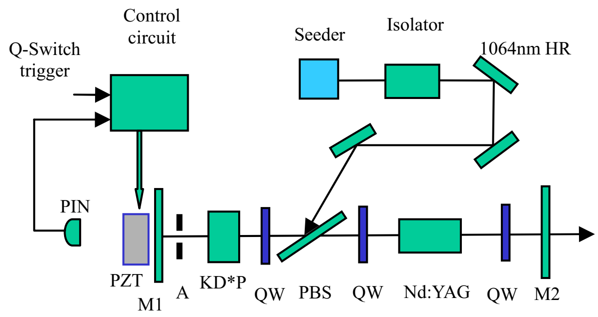
Remote sensing for aerosol, air pollution and wind speed using high resolution lidar, different absorption lidar (DIAL) and direct detection Doppler lidar has been widely used. These observations are very important for the study weather and climate. Global measurement of water vapor and wind speed are urgently required. These lidar systems require single frequency, good beam quality, high repetition rate, and high power laser transmitters. However, the current laser transmitters are not satisfied with all specifications and few reported [1]. The laser transmitter with all performance will be used in the next generation lidar[2,3].

Wind velocity measurement using direct detection Doppler techniques in a lidar system imposes special requirements on the frequency characteristics of the pulsed laser transmitter. The laser must be single frequency(~100MHz) on a single shot basis. For DIAL application, the laser must be match the absorption line of gas through the techniques of frequency-mixing or OPO. One standard technique to achieve this performance is to seed a high-power pulsed oscillator with a frequency-stable, cw seeder laser[4]. The salve cavity can be either a linear or ring cavity. For the DIAL application, the transmitter's frequency must be matched with absorption line of gas. Therefore, the tunable pulsed laser such as Ti: Sapphire with single frequency is a better candidate. The ring cavity with seeding injection is wide applied in Ti:Sapphire laser with wide spectrum gain[5,6]. In this paper, we present the laser activities of single frequency, pulsed laser with injection seeding on both linear and ring cavity in our lab.

INJECTION SEEDING MOPA

For the laser with pulse repetition rate above 100 Hz, the diode-pumped configuration is the best resolution. The 1 micrometer Nd:YAG with high energy is generally required. Other wavelengths can be generated through nonlinear processIn order to get good beam quality and high energy, the configuration of the mast oscillator power amplifier (MOPA) is implemented. . In this paper, the laser is water cooling rod crystal. The purpose is to demonstrate the performance of laser output. Future activities will be conductively cooling. It is also only roadmap for spaceborne application.

For the linear cavity of slave laser, 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. Two methods are examined in this paper. One adjustment is 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. Another method is called “ramp and fire”[7]: the pulsed salve laser cavity length is periodically tuned until a resonance with the seeder laser is detected, and Q-switch is opened to fire laser. The lasers can work well at high repetition rate by both approaches. Figure 1 is the schematic of the injection seeding Diode pumped Nd:YAG laser with build-up time reduction technique. The single frequency seeder laser for the injection seeding system is an Mephisto OEM200 cw NPRO Nd:YAG laser manufactured by the Innolight. The seeder laser has a linewidth of 1kHz and a power of 200mW . Both the M^2 of horizontal axis and vertical axis are less than 1.1. The OFR IOT-5-1064-HP isolator has an isolation of 60dB. The seeder laser is injected through the polarizer or rear mirror. The E-O Q-switched oscillator consists of a plane HR mirror, M1, and a convex mirror, M2, with radius of 3m and reflectivity of 30%. The optical length of the cavity is about 75cm. Two λ/4 wave plates are settled at both sides of laser rod to eliminate the space hole burning. The aperture A is used to limit the transversal mode. The laser rod is pumped by diode lasers from nine directions to achieve uniform pumping. In order to get the best injection-seeding , the temperature of the cooling water for rod is same as seeding laser with an accuracy of less than 1K. The feedback loop circuit is used to measure the build-up time and driver the piezoelectric actuator (PZT) to adjust the cavity length. The output pulses are recorded using a streak tube with ps rise time and sampled by a Tecktronix 3052B oscilloscope. The pulse shape with the injection seeding is shown in Fig 2 (a), and the interference pattern through a FPI is shown in Fig. 2(b). The output energy is 20 mJ at a repetition rate of 100 Hz. The M^2_x and M^2_y measured using Spiricon M^2-200 Beam Propagation Analyzer are 1.41 and 1.38 respectively.



(a)

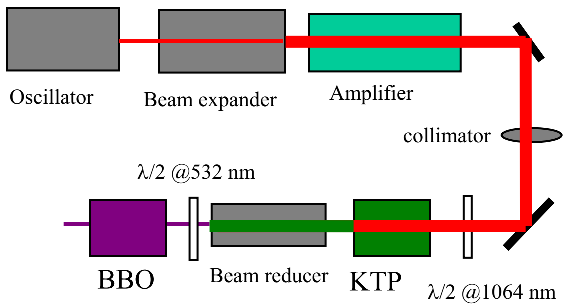
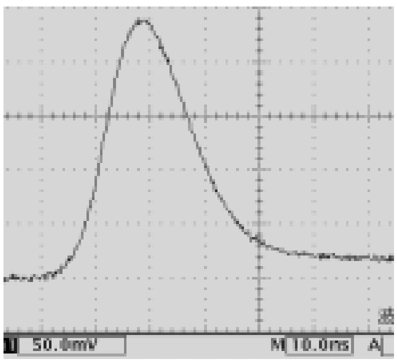
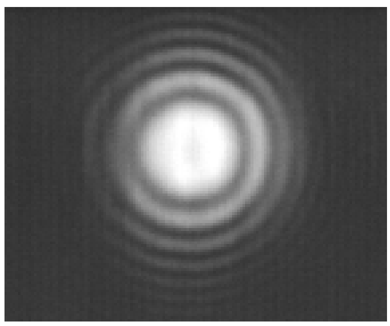


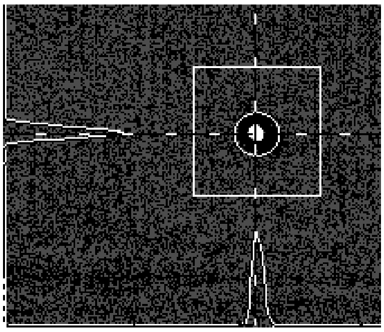
Fig.1. Schematic of the injection seeding, diode-pumped Nd:YAG oscillator (a) and its amplifier, nolinear output.



(a)



(b)



(c)

Fig. 2 Output pulse (a), pattern through FPI(b), and beam shape obtained from single frequency, diode-pumped Nd:YAG at100 Hz.

The oscillator was amplified to be 100 mJ/pulse at 100 Hz. The amplifier consists of a crystal rod with a diameter of 5 mm and a length of 70 mm side pumped by 45 bars with peak power of 100 W from nine direction. The output from amplifier is frequency doubled by KTP on type II, and frequency mixed by BBO on type I. The overall efficiency of frequency-triple is about 25%. The output energy at 355 nm is larger than 25 mJ at 355 nm. It will be used in a mobile direction detection Doppler lidar. The prototype of laser is shown in Fig. 3

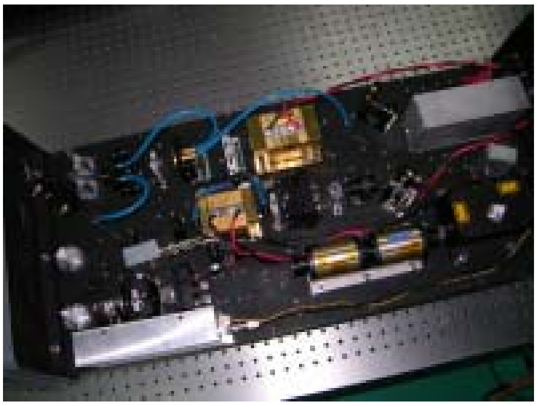


Fig. 3 Photography of the prototype of single frequency all solid-state UV laser

RING CAVITY LASER

The technique using build-up reduction to injection seeding can not keep good performance under high vibration environment. We also tested the method of "ramp and fire" technique to seeding the salve laser. The higher laser energy fluctuation was observed due to the time-difference of Q-switch between pulse and pulse. The fluctuation can be minimized through increasing the responding time of PZT, or through saturated amplifier. and will be upgraded in near future. Therefore, a ring cavity oscillator was also investigated. Figure 4 is the schematic of the all solid-state ring oscillator. The unidirectional ring cavity, consisting of two mirrors M1, M2, and a roof prism, was used to eliminate the spatial hole burning. The optical length of the resonator is about 60 cm. The Faraday rotator and half-wave plate (HW) forces light running in the cavity unidirectionally. A $\phi 3.5\times 50$-mm Nd:YAG rod was side pumped uniformly by 24 laser diodes with a peak power of 60 W per diode from five directions. An aperture with a diameter of 2 mm is inserted in cavity to improve the transversal mode. A partial laser reflected by TFP is detected by a photodiode. Once the peak hold circuit is to detect the maximum pulse of free running laser, and a $LiNBO_3$ Q-switch is triggered immediately. High stability of output energy can be obtained by this technique. The principle of the laser operation was described in Ref. 8.

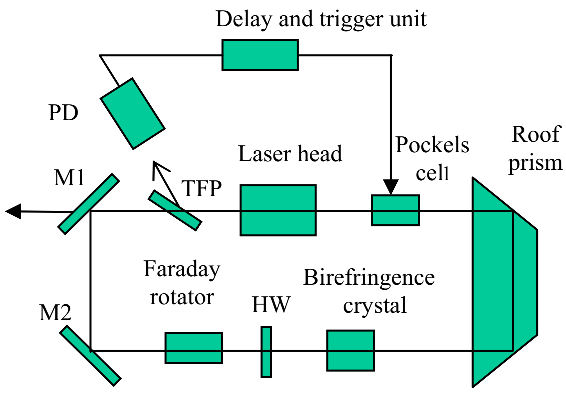


Fig.4 Schematic of ring resonator single-longitudinal mode all solid-state laser

The laser is implemented at 100 Hz. The pulse energy is more than 1 mJ with the pulse width of 30 ns. The output energy of laser pulse is stable and less than 3% (RMS). Through controlling the high voltage of Q switch, the pulse width can be adjusted between 30 ~ 300 ns, and the single longitudinal mode is kept. The temporal profiles for various pulse widths as shown in

Fig.4. The laser is running continually for more than 4 hours, SLM is maintained without mode hope through monitoring the pulse width shape and the interference patterns. The probability of output pulse with SLM is almost 100% during the observation duration, which it is very important in Doppler lidar. This oscillator will be first amplified to be 20 mJ/pulse by a pre-amplifier. Thus it can replace the oscillator in above section. The M2 of laser is measured to be less than 1.5 on both diection.

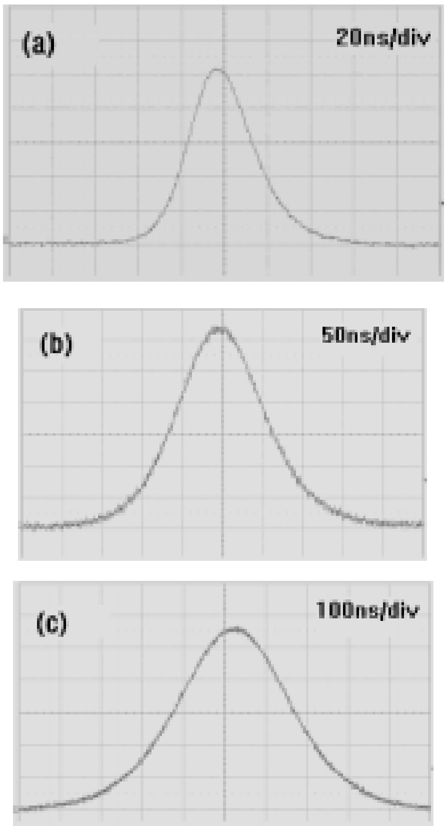


Fig.4. Output pulses with different pulse widths from the ring cavity all solid-state oscillator

SUMMARY

The diode-pumped, frequency-doubled Nd:YAG pumped ring Ti:Sapphire laser with injection seeding is also developed. The laser is a three-mirror ring cavity, the seeder laser is an external cavity diode laser. Because of the wide gain spectrum, the ring cavity become necessary to get single frequency output. The output energy at 774 nm is about 40 mJ at 50 Hz. The output laser will be mixed with fundamental wavelength of pumping laser(1064 nm) to generate 448 nm of NO2, and be taken as the transmitter of a DIAL system.

In summary, we present three single-frequency, all solid-state lasers with good beam quality and high pulse repetition rate. Either linear or ring cavity can be get single frequency output. The high energy can be obtained by MOPA. This kind of laser has a great potential in lidar application.

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