

2.5 MHz Line-Width High-energy, 2 μ m Coherent Wind Lidar Transmitter

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Abstract: The design of a diode pumped, injection seeded MOPA with a transform limited line width and diffraction limited beam quality is presented. This lidar transmitter produces over 300mJ energy at 10 Hz repetition rate.

OCIS codes: (140.3480) Lasers, diode-pumped; (140.3580) Lasers, solid-states

1. Introduction

2 μ m solid-state lasers are the primary choice for coherent Doppler wind detection. As wind lidars, they are used for wake vortex and clear air turbulence detection providing air transport safety. In addition, 2 μ m lasers are one of the candidates for CO₂ detection lidars. The rich CO₂ absorption line around 2 μ m, combined with the long upper state life of time, has made Ho based 2 μ m lasers a viable candidate for CO₂ sensing DIAL instrument.

The design and fabrication of a compact coherent laser radar transmitter for Troposphere wind sensing is under way. This system is hardened for ground as well as airborne applications. As a transmitter for a coherent wind lidar, this laser has stringent spectral line width and beam quality requirements. Although the absolute wavelength does not have to be fixed for wind detection, to maximize return signal, the output wavelength should avoid atmospheric CO₂ and H₂O absorption lines.

The base line laser material is Ho:Tm:LuLF which is an isomorph of Ho:Tm:YLF. LuLF produces 20% more output power than Ho:Tm:YLF. In these materials the Tm absorption cross-section, the Ho emission cross-section, the Tm to Ho energy transfer parameters and the Ho ⁵I₇ radiative life time are all identical [1]. However, the improved performance of the LuLF is attributed to the lower thermal population in the ⁵I₈ manifold. It also provides higher normal mode to Q-switch conversion than YLF at high pump energy indicating a lower up-conversion.

The laser architecture is composed of a seed laser, a ring oscillator, and a double pass amplifier. The seed laser is a single longitudinal mode with a line width of 13 KHz. The 100mJ class oscillator is stretched to 3 meters to accommodate the line-width requirement without compromising the range resolution of the instrument. The amplifier is double passed to produce greater than 300mJ energy.

2. Results and performance verifications

The schematic layout of the system is shown in Figure 1. To minimize the size of the system, both side of the optical bench is populated with optical components. Side one includes the seed laser, the isolation components and the receiver optics, while the oscillator and the amplifier are mounted on side two.

The seed lasers produce 50 mW; the line width of the seed lasers is measured by tuning two similar lasers within the bandwidth of a detector and beating them. The heterodyne signal is measured using spectrum analyzer to determine the line width. The seed laser output is routed through a single mode polarization preserving fiber into a fiber coupler to split the beam into various channels that are used for seeding, local oscillator, and for monitoring applications. The seed is routed through a collimator and an Acousto-optic modulator to produce an intermediate frequency which offsets the frequency by 105 MHz. The offset beam is seeded into the oscillator through the 75% reflective output coupler.

The seeding method used here is the ramp and fire method. This method is well suited for laser materials with a long upper state life time. Q-switch operation can be performed within 100 micro second after the end of the pump pulse without significantly affecting the output energy. During this time, one of the cavity mirrors is pushed with a peizo-electric element to obtain resonance signature from the seed laser circulating within the resonator. Once resonance is detected, the Q-switch is fired at the peak of the resonance to produce a seeded output. It has been shown that the pulse laser precisely replicates the seed wavelength [2]. Micro-controller and field programmable gate array based electronics are designed and implemented to accomplish the peak detection and synchronizing of the laser firing. The output of the oscillator is directed towards the amplifier where it extracts gain in double-pass mode. The output passes through the bench through a transmit/receive optics which is composed of a thin film

polarizer and a quarter wave plate. The return is directed into a fiber port and a dual balanced detector after it is mixed with the local oscillator.

The line width of the Q-switched laser is measured by heterodyning the temporal pulse with the seed laser. The offset frequency used for this test was 80 MHz. Once the heterodyne beat is obtained, it is examined in frequency domain. For a Gaussian beam the line width is determined by measuring the fft at the half power point. Figure 2 displays the result of the measurement.

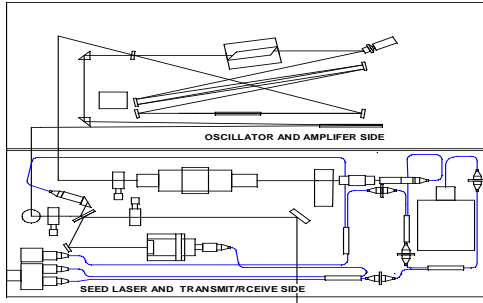


Fig. 1. Simplified system layout

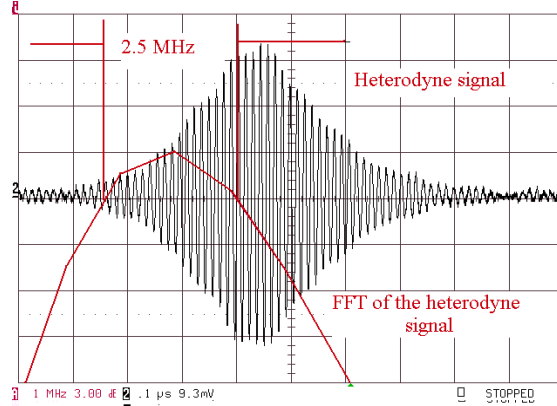


Fig. 2. Line width of the pulsed laser

The performance of the oscillator and the amplifier are shown in figures 3a and 3b. The oscillator produces over 250mJ in Normal mode and 100 mJ in Q-switch mode for an input pump energy of 3.1 Joules the slope efficiency of the Q-switched output is 8.4%. The amplifier head has pump capability of 7.2 Joules and the laser gain medium is 40mm which is twice as long as the oscillator. It provides a gain of 3 in a double pass operation.

The result of the beam quality measurement showed that M^2 value for the double pass amplifier is 1.19 and 1.17 for x and y, respectively.

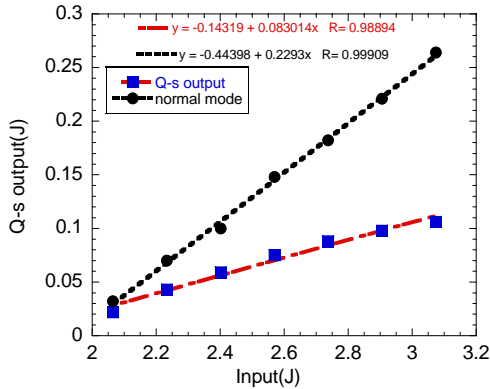


Fig. 3a Oscillator performance

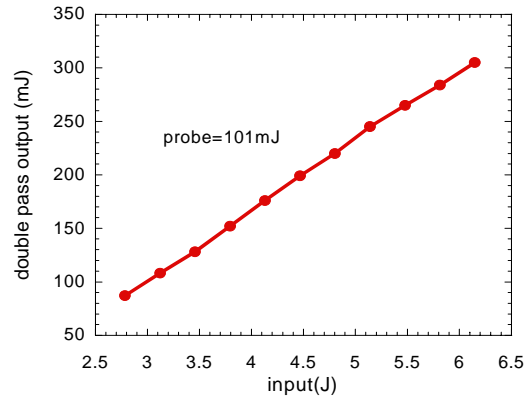


Fig. 3b Double-pass Amplifier performance

3. References

[1] Brian M. Walsh, Norman Barnes, Mulugeta Petros, Jirong Yu, Upendra N. Singh, Spectroscopy and modeling of solid state lanthanide lasers: Application to trivalent Tm³⁺ and Ho³⁺ in YLiF₄ and LuLiF₄” Journal of Applied Physics, Vol. 95, No. 7, 1 April 2004, pp 3255-3271.

[2]Grady J. Koch, Mulugeta Petros, Jirong Yu, Upendra N. Singh, “Precise wavelength control of a single-frequency pulsed Ho:Tm:YLF laser” APPLIED OPTICS, Vol.41, No. 9 , 20 March 2002, pp1718-1721.