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HIGH-ENERGY, 2µM LASER TRANSMITTER FOR COHERENT WIND LIDAR

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ABSTRACT

A coherent Doppler lidar at 2µm wavelength has been built with higher output energy (300 mJ) than previously available. The laser transmitter is based on the solid-state Ho:Tm:LuLiF, a NASA Langley Research Center invented laser material for higher extraction efficiency. This diode pumped injection seeded MOPA has a transform limited line width and diffraction limited beam quality. NASA Langley Research Center is developing coherent wind lidar transmitter technology at eye-safe wavelength for satellite-based observation of wind on a global scale. The ability to profile wind is a key measurement for understanding and predicting atmospheric dynamics and is a critical measurement for improving weather forecasting and climate modeling. We would describe the development and performance of an engineering hardened 2µm laser transmitter for coherent Doppler wind measurement from ground/aircraft/space platform.

INTRODUCTION

2µm 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, 2µm lasers are one of the candidates for CO_2 detection lidars. The rich CO_2 absorption line around 2µm, combined with the long upper state life of time, has made Ho based 2µm lasers a viable candidate for CO_2 sensing DIAL instrument. As a transmitter for a coherent wind lidar, this laser has stringent spectral line width and beam quality requirements. Among the rare-earth ions lasers operating at 2µm region, Ho doped crystals show high enough gain cross-sections for effective high energy amplification. To accommodate the efficient diode laser pumping, Tm ions were added to absorb the conventional diode laser pump energy at 780-795nm.

The operating principles of Tm:Ho lasers are well known and has been the subject of intense research in the last two decades. Basically, a 792nm quasi CW laser diode array provides the pump radiation which is absorbed by Tm ions. Consequently, Tm ions are excited from the $^3H_6$ ground-state up to the $^3H_4$ manifold. Tm ions in the $^3H_4$ manifold then interact with Tm ions in the ground-state. This energy transfer usually referred as “self-quenching”, converts one ions at $^3H_4$ excited-state into two ions at $^3F_4$ states. Subsequently, energy transfer from the Tm $^3F_4$ to the Ho $^5I_7$ manifolds occurs and finally 2 micron laser radiation occurs on the Ho $^5I_7 \rightarrow {}^5I_8$ transition.

SUMMARY AND RESULTS

An engineering packaged 2-micron laser transmitter for the wind lidar is being developed. This compact laser is configured as a master oscillator and power amplifier system. It is injection seeded with a highly stabilized seed laser operating at 2.053 µm which is very close to the oscillator operating wavelength. The line width measurement of the seed laser is done by beating two similar lasers, the result showed a line width better than 13 KHz. The oscillator output is amplified with a double pass amplifier. The target output energy is 250mJ at 10Hz pulse repetition rate.

The overall dimension of the laser is 67cm X 16.5cm X 26cm. The optical bench is populated on both sides. The seed laser and the associated fiber optics couplers and the Faraday isolators are on the back side of the bench while the oscillator and the amplifier are mounted on the front. All the optical mounts are designed to be adjustable and lockable and hardened to withstand vibrations that can occur in ground or airborne operation.

The performance of the oscillator has been evaluated at different repetition rates and at different rod coolant temperatures. The maximum Q-switched output obtained ranges from 118mJ at 10Hz to 150mJ at 2Hz. Since the laser material is not a 4-level laser, it is sensitive to heat load; and hence the output drop at higher repetition rate is not totally unexpected. Using 100mJ as a probe beam from the oscillator, the double pass amplifier produced over 300 mJ. At of 5°C with a double pass gain is slightly over 3. At a higher rod temperature of 8°C, the output energy was 275mJ. This was partially due to the reduction of the probe beam energy to 95 mJ, but the main reason is the thermal populating of the lower laser level. This shows the importance of depopulating the lower laser level for efficient operation.

The output of the amplifier is directed into the atmosphere through a large telescope after passing through a thin-film polarizer and a quarter wave plate. Since the return signal has orthogonal polarization to the output beam, the polarizer directs it into the receiver where it is mixed with the local oscillator signal.

In summary, a hardened 2µm laser, capable of producing over 300 mJ has been designed, and the performance has been verified. This diode pumped injection seeded MOPA has a transform limited line width and diffraction limited beam quality. Although it is primarily designed as a wind Doppler lidar [1], with minimal modification it can be used as a Differential Absorption Lidar (DIAL) instrument for CO_2 sensing. In addition to being used as a field instrument, the laser will also be used as an engineering design tool for evaluating essential wind lidar parameters for a long term flight instrument.

REFERENCES

[1] Koch, G. J., Beyon, J. Y., Barnes, B. W., Petros, M., Yu, J., Amzajerdian, F., Kavaya, M. J., and Singh, U. N., 2007: High Energy Doppler 2µm Doppler Lidar for Wind Measurements, *Optical Engineering*, **46 (11)**, pp. 116201-116214.