An efficient single frequency Ho:YLF laser for IPDA lidar applications

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A highly efficient, versatile, single frequency 2-micron pulsed laser can be used in a pulsed Differential Absorption Lidar (DIAL) / Integrated Path Differential Absorption (IPDA) instrument to make precise, high-resolution measurements to investigate sources and sinks of CO_2. For a direct detection IPDA lidar, the desired 2 µm Ho:YLF laser should generate 30-40 mJ pulses at the repetition rate of 100 to 200 Hz, with short pulse length (<100 ns) and better than 2% wall plug efficiency. A Tm fiber laser in-band pumped Ho:YLF laser has been developed to meet this technical challenge.

This Ho:YLF laser is designed in a four mirror ring resonator with bow tie configuration, which helps to obtain high beam quality. It is end-pumped by a 40 W linearly polarized Tm fiber laser at 1.94µm. The resonator length is 1.10 meters with output coupler reflectivity at 45%. The laser crystal size is 3 x 3 x 60 mm (w, h, l) with a doping concentration of 0.5% Holmium. The laser beam and pump beam are mode-matched in the active medium. Thus, the pump and laser beams have the same confocal parameters. Mode-matching is also helpful for operating the laser in a single transverse mode. The laser beam waist is slightly less than 0.5 mm at the center of the laser crystal. Based on quasi-four level modeling, pump absorption and saturation depend on laser intensity. Laser amplification and saturation also depend on the pump intensity in the crystal. The laser is injection seeded to obtain the single frequency required by an IPDA lidar measurement. The seed beam is entered into the resonator through an output coupler. The laser is mounted on a water cooled optical bench for stable and reliable operation. The size of the optical bench is 22.16 x 9.20 x 1.25 inches. It is stiffened so that the laser can be operated in any orientation of the optical bench. This packaged Ho:YLF laser is designed for either mobile trailer or airborne platform operation.

The engineering prototype Ho:YLF laser has been fully characterized to demonstrate laser performance. Figure 1 shows the laser output power as a function of pump power at different pulse repetition rates from 100 Hz to 333 Hz. The threshold of the laser is less than 14 W. The slope efficiencies are 28%, 40%, 41% and 43% for pulse repetition rates of 100, 200, 250 and 333 Hz, respectively. Maximum power increases with the pulse repetition rate. Output power of 4.2 W, 6 W, 6.7 W, and 7.7 W is achieved for pulse repetition rates of 100, 200, 250 and 333Hz, respectively. This represents the optical conversion efficiency of 16.7%, 22.4%, 23.7%, and 26.5% at these various pulse repletion rates. It is the most efficient and compact Ho:YLF laser demonstrated in the high pulse energy (>20mJ) and moderate pulse repetition rate (100's Hz) operation range. As shown in Figure 1, the maximum pulse energy at 100 Hz is 42 mJ. This is limited due to optical damage. The laser stability is characterized and found to be very stable. A relative pulse energy standard deviation of 2% was measured. The beam quality of the Ho:YLF was measured by a Spiricon infrared laser beam camera. Figure 2 shows the beam profile image of the laser. Both the X-profile of the beam (horizontal direction) and the Y-profile of the beam (vertical direction) are well fitted by a Gaussian profile. The qualitative beam quality measurement shows excellent beam quality in both axis. The M-square value for the laser beam is measured at 1.06 and 1.09 for the x and y axis respectively.

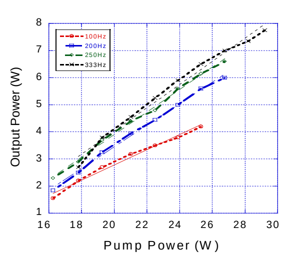

Figure 1. Laser output power performance

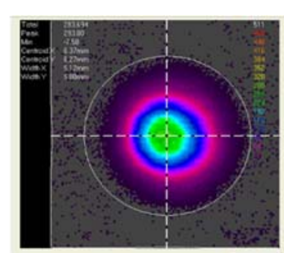

Figure 2. Laser beam image shown with Spiricon infrared laser beam camera

The key characteristics of this laser, which are energy, pulse repetition rate, pulse width, efficiency, frequency accuracy and stability, meet the pulsed CO_2 IPDA instrument requirements. Another important and potential application of this laser is its usage as a wind lidar transmitter. Higher pulse repletion rate lidar increases the lidar special resolution and has a high probability to transit through cloud holes to measure surface winds.