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High-Resolution Spectral Studies of Ho Lasers for LIDAR/DIAL Applications

Dennis K. Killinger, M. Vaidyanathan, Chuan He, and Thomas Taczak
Department of Physics
University of South Florida
Tampa, Florida 33620 USA
Phone (813) 974-3995 , Fax (813) 974-2635
E-Mail: killinge@chuma.cas.usf.edu

We have investigated the high-resolution spectral (wavelength) behavior of several different types of Ho lasers with an eye toward their use for atmospheric Lidar and DIAL applications. Our studies have included the development and study of (1) a high-power , pulsed (>300 mJ/pulse) Ho laser for atmospheric Lidar measurements, (2) a single-frequency CW Microchip Ho laser for injection seeding of a coherent Doppler Lidar system, and (3) a tunable, CW single-frequency (traditional cavity) Ho laser for atmospheric DIAL measurements of CO_2 and water vapor. Details are:

(1) High-Power Ho Laser/Lidar: Our studies of a high-power Ho laser involved the development of a large, flashlamp pumped Cr;Tm;Ho:YAG laser that appeared to produce a 300 mJ Q-switched pulse. However, initial atmospheric Lidar measurements showed that the laser actually operated on two closely spaced multiplets of lines (centered arround 2.090 and 2.097 µm). Under high pumping conditions, the laser spectral distribution within each of these multiplets would change as the flashlamp discharge/gain conditions varied over short and long term temporal scales. This variability could produce a spectral shift of the energy within the 2.090 µm line, which was in partial wavelength coincidence with an atmospheric water vapor absorption line. As an example, Fig. 1 shows the measured Ho Laser spectrum at two different operating temperatures superimposed with the calculated transmission spectrum of the atmosphere; as can be seen, there is a spectral overlap of a water vapor line and the Ho laser output near 2.090 µm. Under these conditions, Lidar returns were found to have variability due to this changing spectral overlap of the Ho laser output and the water vapor absorption lines. This problem was solved by use of two thin solid etalons (0.2 and 0.5 mm thick) in the Ho laser cavity, which reduced the laser spectrum to single line operation. The etalon controlled Q-switched laser parameters were: linewidth .15

cm-1, 75 mJ/pulse, pulse length 100 ns, and tunable from 2.088 to 2.098 μm. Using this etalon controlled Ho laser, Lidar returns were obtained from aerosols at ranges up to 4 km (horizontal and vertical paths) using a 30 cm diameter telescope and a red-shifted InGaAs photodetector.

(2) Dual-Polarization Single-Frequency Ho Microchip Laser: We have investigated the use of a diode-pumped microchip CW Ho;Tm:YAG laser for use in a Coherent Doppler Lidar. Initial Lidar tests revealed an unexpected heterodyne signal that was self-induced by the microchip laser itself. It was found that the supposedly single-frequency Ho microchip laser operated on a single longitudinal laser mode, but that two orthogonal modes were lasing simultaneously.[1] These dual-polarization modes were separated in frequency by about 12 to 15 MHz, and were sufficiently elliptical in polarization to produce a self-heterodyne beat signal without the use of a local oscillator. These dual-polarization modes were produced by mounting or manufacture induced stress within the YAG crystal, which turned the normally anisotropic YAG crystal weakly birefringent. The dual-polarization modes could be eliminated through use of an external polarizer which attenuated one of the modes. The absolute frequency of the single mode, however, was very sensitive to pump power changes, on the order of 140 MHz/mW.

(3) Tunable, Single-Frequency CW Ho,Tm:YLF laser: We have studied an Argon/Ti:Sapphire laser pumped CW Ho,Tm:YLF laser for use as a tunable source for atmospheric DIAL measurements of CO2 and water vapor. Using a conventional 10-cm long laser cavity and a 4 mm long Ho,Tm:YLF crystal, the output power of the laser was on the order of 50 to 100 mW with a pump input power of 300 mW at a wavelength of .792 μm. With the addition of two solid etalons in the cavity, the laser operated with 20 mW on a single frequency related to the multiplet of lines near 2.057 μm and the multiplet near 2.067 μm. The laser frequency was tunable over a spectral range of 47 cm^{-1} . Initial laboratory tunable spectroscopy measurements of CO2 and water vapor have been made.

References: Chuan He and D. K. Killinger, Optics Letters,19, 396(1994).
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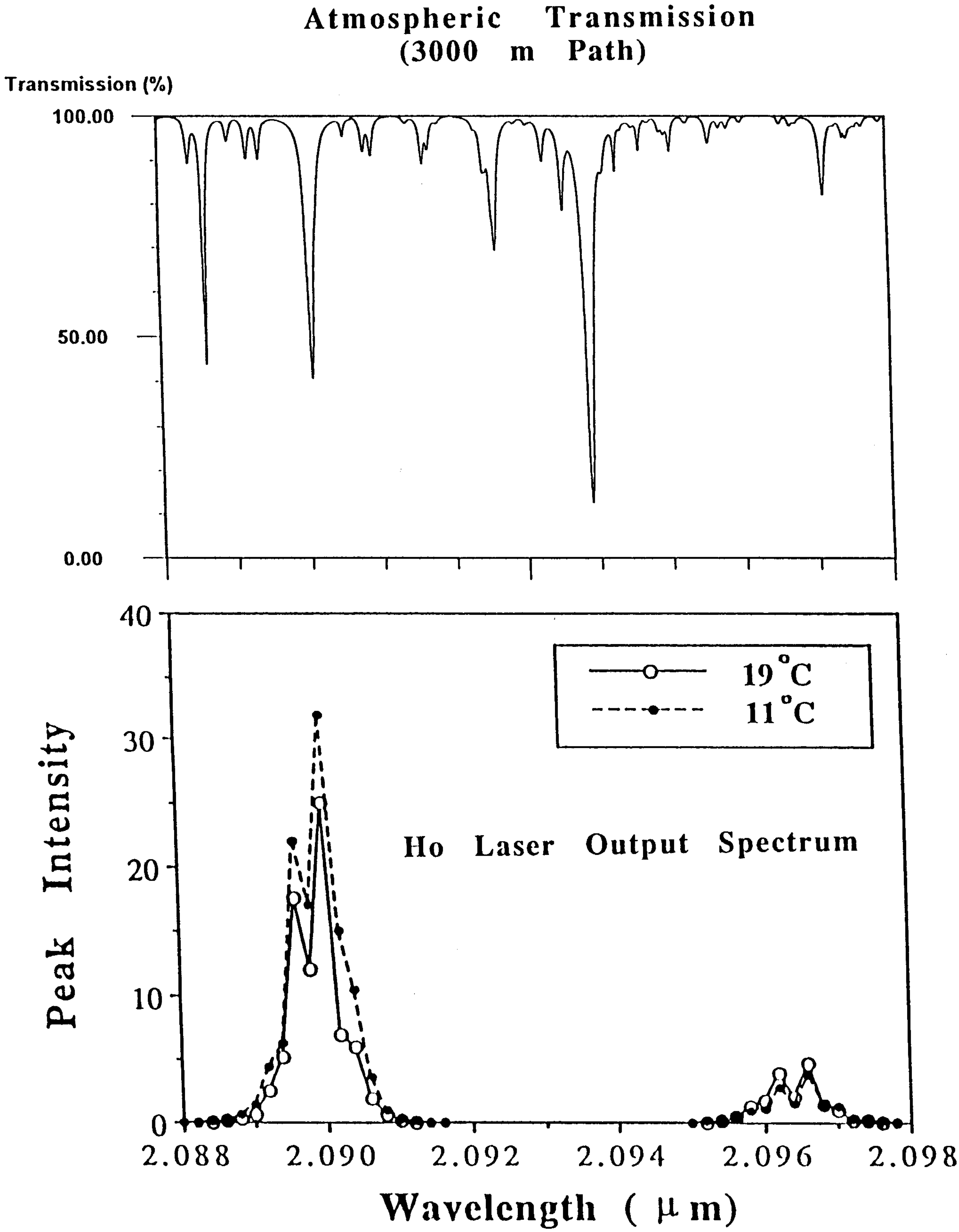

Atmospheric Transmission
(3000 m Path)
Transmission (%)
100.00
50.00
0.00
40
30
20
10
0
Peak Intensity
19 °C
11 °C
Ho Laser Output Spectrum
2.088
2.090
2.092
2.094
2.096
2.098
Wavelength (μ m)

Figure 1