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ON THE MEASUREMENT OF ATMOSPHERIC DENSITY USING DIAL IN THE O_2 A-BAND (770 nm)*

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Differential absorption lidar measurements in the A-band of molecular oxygen have been suggested[1] as a means of profiling atmospheric density. This paper reports progress towards this capability.

Figure 1 illustrates the "troughs" in which optical absorption by O_2 is roughly temperature independent for near-ambient conditions. For measuring density (or pressure[2,3,4]) the "on-line" DIAL transmission is tuned to the appropriate trough, and the off-line laser is tuned to just outside the A-band. Identification of the "density troughs" is based on the far wing line absorption coefficient given by

$$K(\nu) = \frac{Ck^2\, b_c^o(T_o)}{\pi P_o\, (\nu-\nu_o)^2} \left(\frac{T_o}{T}\right)^n N^2 e^{-E/kT} \{1 - \text{h.o.}(3\%)\}$$

where N is particle density, $b_c^o(T_o)$ is the line profile HWHM at reference temperature T_o, pressure $P_o = Nk\,T_o$, and the exponent $n \sim 0.7$ for O_2.

We have carried out error analyses for this type of lidar and for related temperature- and pressure-measuring techniques that utilize the O_2 A-band. The parameters assumed are given in Table I. Figure 2 shows a representative example of the numerical simulations for a fixed altitude resolution of 150 meters; elevation angles of 90°, 60°, and 30° are used for time periods in the range 1-4 min. The accuracy of these O_2 density profile measurements is predicted to be 0.3% or better throughout most of the troposphere. Standard lidar instrumentation has been

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assumed. We have shown that tropospheric density can be profiled with accuracies of order 0.1-0.5%, with good altitude resolution, over a useful range of atmospheric conditions.

Density profiles in the atmosphere may also be measured _via_ Raman scattering by N_2, but require precise knowledge of the optical form factor for the lidar system. This requirement does not apply to the two-beam O_2 DIAL technique. However, DIAL does require careful monitoring of laser wavelength and linewidth, using spectrometer/wave-meter instrumentation.[5,6]

Generation of tunable, narrow band, pulsed laser output at 760-770 nm can be done with laser-pumped dye lasers or with a tunable crystal laser such as Alexandrite. As part of a program[7] described elsewhere at this meeting, we are investigating the alternative of "Raman shifting" in H_2 ($\Delta\nu \sim 4100$ cm^{-1}) starting with tunable dye laser output at 585 nm. Due to a special design, the radiation bandwidth can be as low as 0.02 cm^{-1}.

Detailed results on energy and narrow linewidth at 770 nm will be presented for both the straight dye laser and the Raman-shifted dye laser, including high resolution scans of the O_2 absorption spectrum for comparison with quantitative spectroscopic data.[8,9] This work is part of a general approach to develop a meteorological lidar system for measuring density, pressure, temperature, and humidity - all based on DIAL and the very near infrared absorption lines of H_2O and O_2 (700-1140 nm).

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Table I. Meteorological Lidar Parameters for O_2 A-band

Tunable laser: 100 mJ pulse energy, 10Hz PRF, λλ 760-770 nm
Rcvr. area 1.0 m^2; Optical efficiency 5% (night), 2.5% (day)
Transmitted beam divergence 0.3 mrad; Rcvr. FOV 0.5 mrad.

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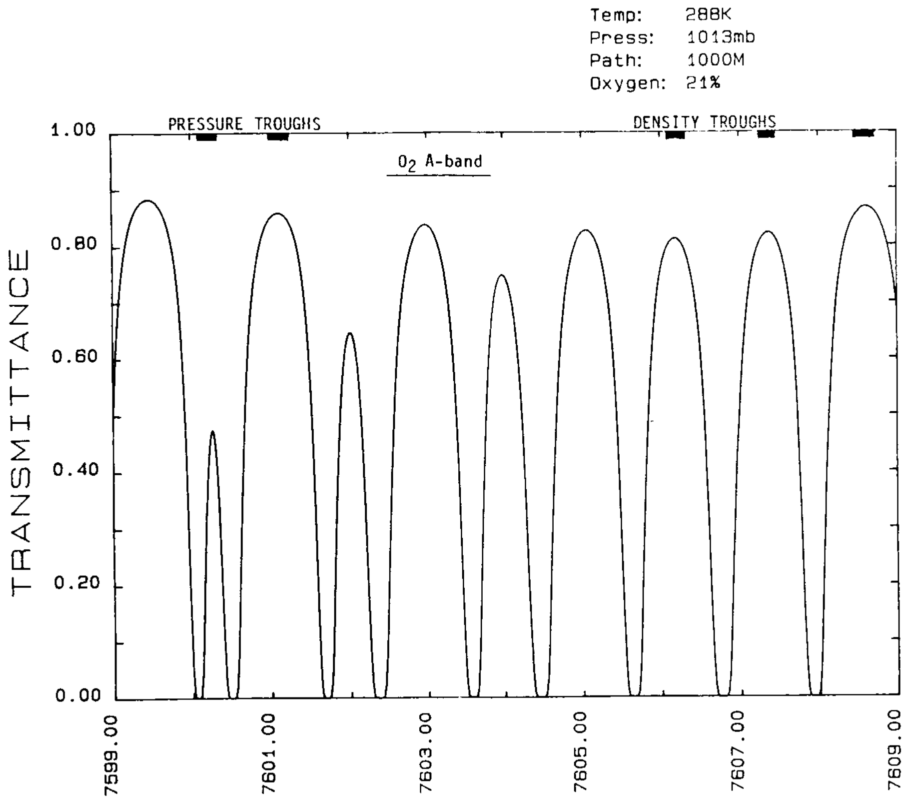

Figure 1.

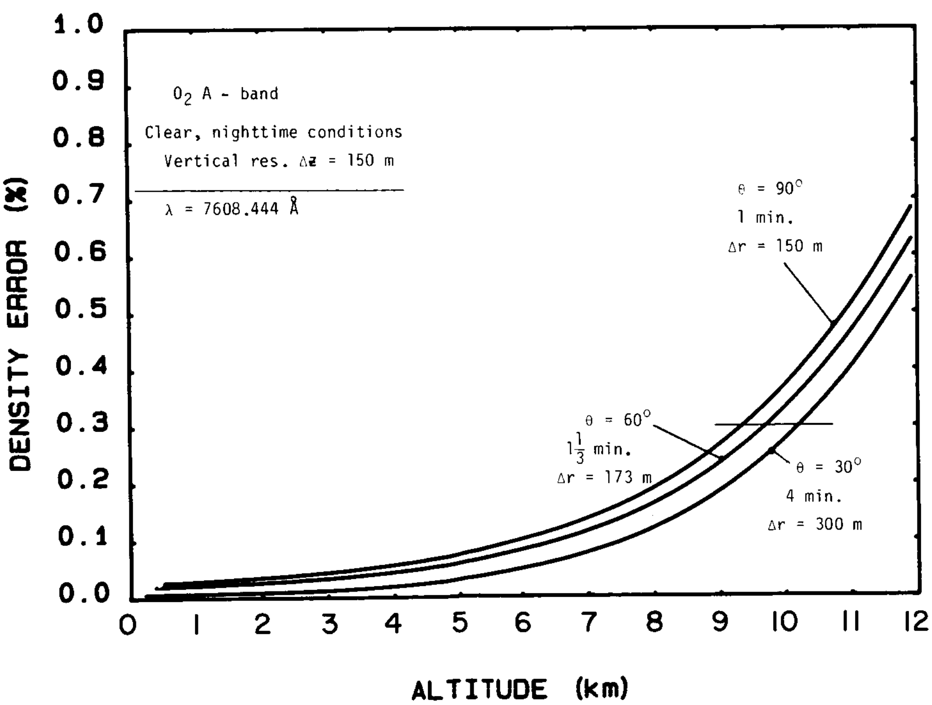

Figure 2.