

DEVELOPMENT OF A HIGH-ALTITUDE AIRBORNE DIAL SYSTEM--THE
LIDAR ATMOSPHERIC SENSING EXPERIMENT (LASE)

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The ability of a Differential Absorption Lidar (DIAL) system to measure vertical profiles of H₂O in the lower atmosphere has been demonstrated both in ground-based¹⁻³ and airborne^{4,5} experiments. In these experiments, tunable lasers were used that required real-time experimenter control to locate and lock onto the atmospheric H₂O absorption line for the DIAL measurements. The Lidar Atmospheric Sensing Experiment (LASE) is the first step in a long-range effort to develop and demonstrate an autonomous DIAL system for airborne and spaceborne flight experiments. The LASE instrument is being developed to measure H₂O, aerosol, and cloud profiles from a high-altitude ER-2 (extended range U-2) aircraft. This paper presents the science of the LASE program, describes the LASE system design, and discusses the expected measurement capability of the system.

The measurement of tropospheric H₂O profiles and column content with the LASE system can be used in various atmospheric investigations, including studies of air mass modification, latent heat flux, the water vapor component of the hydrological cycle, and atmospheric transport using H₂O as a tracer of atmospheric motions. The simultaneous measurement of aerosol and cloud distributions can provide important information on atmospheric structure and transport, and many meteorological parameters can also be inferred from these data. In addition, the impact of subvisible and visible aerosol/cloud layers on passive satellite measurements and radiation budgets can be assessed. The atmospheric science investigations that can be conducted with LASE are greatly enhanced because measurements of H₂O profiles and column content are made simultaneously with aerosol and cloud distributions. The LASE measurement objectives are given in Table 1. These objectives are consistent with the measurement requirements needed to conduct atmospheric investigations on the spatial scales indicated.

A block diagram of the LASE system is shown in Figure 1, and the LASE system parameters are given in Table 2. The transmitter consists of two Alexandrite lasers that are independently tunable over the wavelength range from 726.5 to 732.0 nm. With the assistance of a wavemeter, one of the Alexandrite lasers is tuned to the center of the selected H₂O absorption line, and the second laser is tuned off the absorption line but within 70 pm of the first laser. The laser

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pulses are sequentially transmitted with about 400 μ s separation. This permits the use of the same avalanche photodiodes (APD) for detecting the lidar returns. The use of low and high light level APD's are used to provide linear response to atmospheric and cloud/ground returns, respectively. Lidar returns are digitized and recorded at 5 Hz, and when possible, the data are telemetered to the LASE ground station for real-time processing and experiment control. Operation with either of two preselected H₂O lines can be made during the mission to optimize the measurement of H₂O in different altitude regions. A detailed description of the LASE system is presented in this paper.

Extensive simulations have been conducted to establish performance requirements for the various LASE subsystems. A simulation of the combined H₂O measurement errors for the LASE system is shown in Figure 2. The errors considered include those from systematic and random sources. With atmospheric modeling and analysis of the off-line lidar return for aerosol scattering distributions, the LASE measurement uncertainties can be reduced to less than 10 percent over about an 8 km altitude range. If the LASE system performance exceeds the minimum requirements, as expected, the measurement error can be further reduced. The capability of the LASE system to measure H₂O profiles and column content is discussed in this paper.

References

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Table 1. LASE Measurement Objectives

ATMOSPHERIC PARAMETER	INVESTIGATION REGION	ALTITUDE RANGE, km	SPATIAL RESOLUTION		MEASUREMENT UNCERTAINTY, %	
			HORIZONTAL, km	VERTICAL, m	NIGHT	DAY*
H ₂ O PROFILE	MESOSCALE	0-3	10	200	10	15
	CLOUD CLUSTER	0-3	100	200	8	12
		3-17	100	500	8(5**)	10
	LARGE SCALE	0-17	250	500	8(5**)	10
H ₂ O COLUMN CONTENT**	SUB-CUMULUS SCALE	---	200 m	---	8	10
ATMOSPHERIC BACKSCATTER	AEROSOL AND CLOUDS (SUB-CUMULUS CLOUDS)	0-17	40 m	50	3	5

* OCEAN ALBEDO

** WITH EXPECTED SPECTRAL PURITY IMPROVEMENT

Table 2. LASE H₂O DIAL Parameters

<u>Transmitter</u>	
Energy per Pulse	150 mJ (on & off)
Linewidth	1.1 pm
Rep. Rate	5 Hz
Wavelength	726.5 - 732.0 nm
Beam Divergence	0.73 mr
Pulse Width	300 ns
Aircraft Altitude	16 - 21 km
Aircraft Velocity	200 m/s
<u>Receiver</u>	
Area (Effective)	0.11 m ²
Field of View	1.23 mr
Filter Bandwidth	0.3 nm (Day) 20 nm (Night)
Optical Transmittance (Total)	23% (Day) 70% (Night)
Detector Efficiency	80% APD (ξ)
Noise Eq. Power	7.5×10^{-15} W/Hz ^{1/2} (-20°C for Si APD)
Excess Noise Factor (APD)	1.5
Amplifier Noise (for APD)	710 Photoelectrons/ μ s

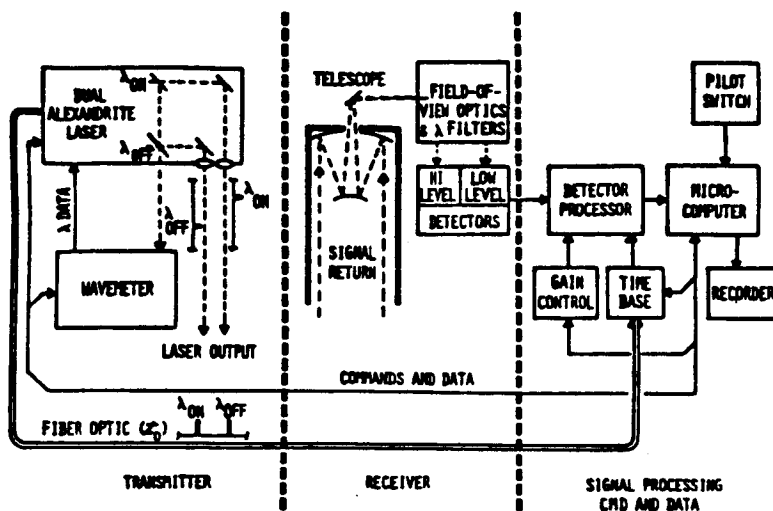


Figure 1. LASE system block diagram.

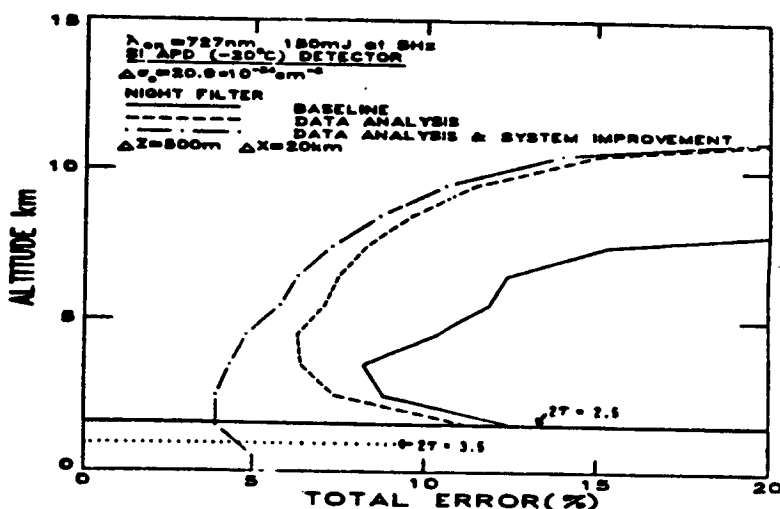


Figure 2. LASE H₂O DIAL combined measurement errors from all sources. Calculations assume aircraft altitude of 16 km and mid-latitude summer H₂O profile. Baseline curve assumes system performs to minimum requirements and no corrections made for systematic errors. Data Analysis line reflects correction for systematic errors, and System Improvements curve represents measurement improvement that would occur if the system performs beyond minimum requirements as expected.