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DAYTIME RAMAN LIDAR PROFILING OF ATMOSPHERIC WATER VAPOR

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Detailed measurements of the distribution of water vapor in the atmosphere are needed for a variety of scientific inquiries, including global climate change and related issues in radiative processes (water vapor is the major greenhouse gas in the atmosphere), and studies of a variety of atmospheric processes such as cloud formation and atmospheric circulation. The Raman lidar is a leading candidate for an instrument capable of the detailed, time- and space-resolved measurements required by these and other studies.

Raman lidar operates by sending out a laser pulse and recording the atmospherically backscattered return signal as a function of time to provide range information. The return signal consists of an elastically scattered part which is useful for profiling cloud heights, aerosols, and the planetary boundary layer, and inelastically scattered parts that provide chemically specific profiles such as water vapor. The inelastic scattering utilized here is the result of the vibrational Raman effect that shifts the incident wavelength by a frequency characteristic of the molecule (3652 cm^{-1} for water vapor and 2331 cm^{-1} for molecular nitrogen). Simultaneous measurement and subsequent ratioing of the water vapor and nitrogen Raman signals provides a quantitative measurement of the water vapor mixing ratio (grams of water vapor per kilogram of dry air).[1,2] The capabilities of Raman lidar systems have steadily improved by taking advantage of technological advances, in laser systems and in interference filter technology in particular.[3-5]

While Raman lidar is used currently to perform meteorologically important, sustained, reliable nighttime profiling of water vapor, daytime measurements present added challenges because of the difficulties inherent in detecting Raman signals against solar backgrounds. In our studies[6] of two approaches for obtaining enhanced daytime operation, namely solar-blind operation and narrowband, narrow-field-of-view operation, computer models indicated that comparable daytime performance can be anticipated using the two approaches. Because the latter approach does not degrade the nighttime performance of the lidar system, we have chosen to base our system design on a narrowband, narrow-field-of-view channel. In order to provide both improved short-range measurements and extended dynamic range, the system also incorporates a channel with a wider field of view, and hence its description as a dual-field-of-view system.

The Sandia lidar system is housed in two mobile semitrailers, one trailer serving as a mobile laboratory and the other as a support vehicle providing a data acquisition/analysis area. The lidar uses an injection-seeded excimer laser to provide a beam with reduced divergence and spectral bandwidth, operated at 308 nm during both nighttime and daytime. Enhanced dynamic range, for daytime operation in particular, is provided by using photon counting in the narrow field-of-view channel, and analog to digital conversion in the wide field-of-view channel. We are currently completing two major modifications to the system that will provide greatly improved performance over that obtained previously. The addition of an XeCl amplifier will approximately double the output power of the laser transmitter, and the addition of a beam-expanding telescope to the transmitter will decrease the divergence of the output beam, making it possible to reduce the receiver field-of-view (and hence reduce the daytime background) without loss of signal. The overall system is shown schematically in Fig. 1.

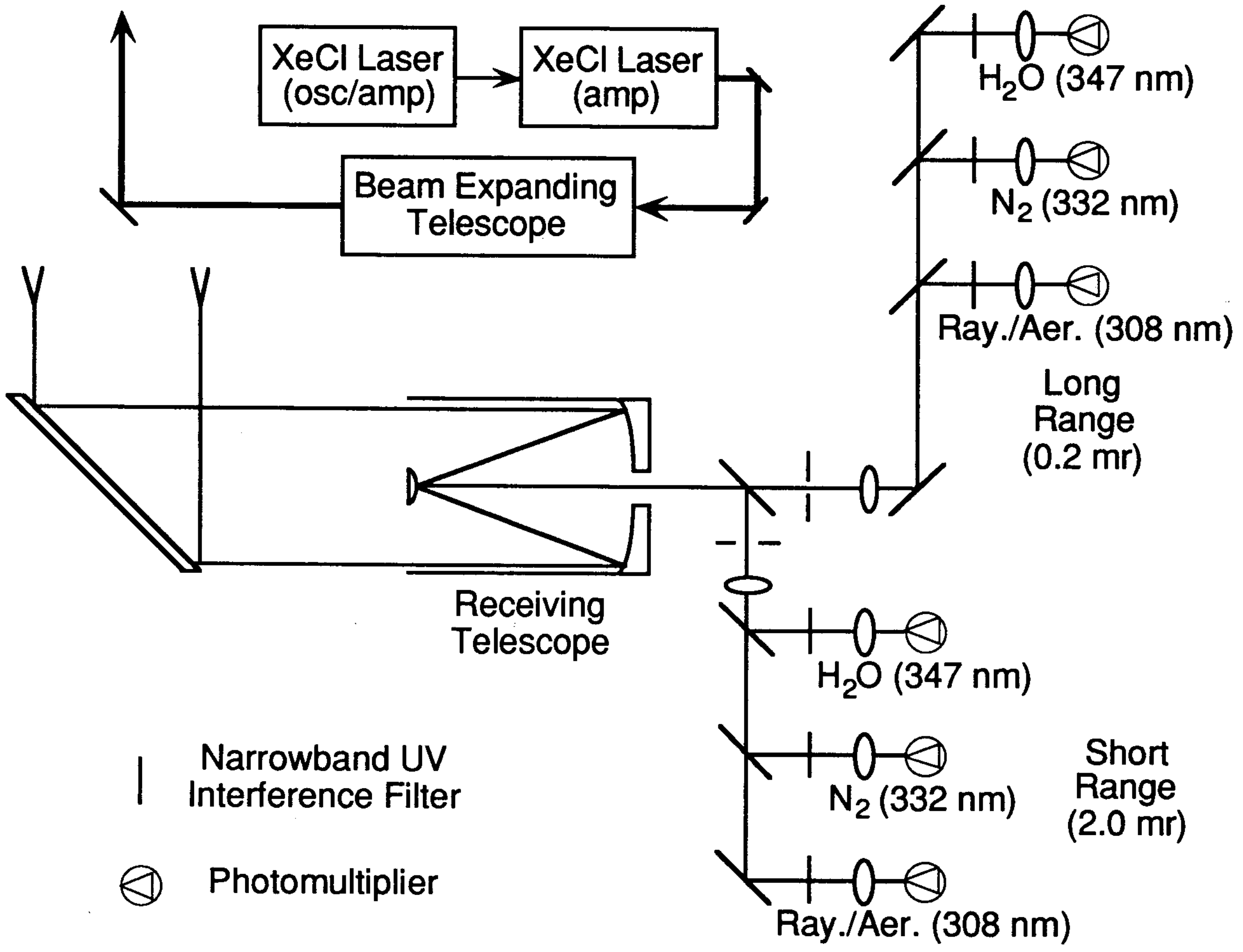

Figure 1. Schematic of the narrowband, dual field-of-view Raman lidar system.

The lidar transmitter consists of two laser "heads." The first is a Lambda Physik LPX 150T injection-locked, tunable XeCl laser. We are currently adding a single-pass amplifier using a Lambda Physik LPX 220i system located after a periscope system that rotates the rectangular beam profile to account for the different electrode configurations of the two systems. The 5× beam-expanding telescope shown in the figure is also being added at this time. After the receiving telescope, a 5% beamsplitter directs the collected backscattered radiation through two independent field stops whose apertures define the wide (short range) and narrow (long range) fields of view of the system. For each field of view, the radiation is subsequently split into three wavelength channels for monitoring Raman backscatter from nitrogen and water vapor and the combined Rayleigh and aerosol backscatter at the laser wavelength. The high transmission, narrowband interference filters used in each wavelength channel are key to obtaining good daytime performance from the system. The lidar characteristics are given in more detail in Table 1.

Datytime studies performed using the previous version of this system provided measurements to a range of ~3 km.[7] With the enhancements described here, we will be able to obtain significantly greater range not only during the daytime, but during nighttime as well. The enhanced system is being deployed at the Remote Cloud Sensing Intensive Operational Period being conducted during April 1994 at the Department of Energy climate-study site in the U.S. southern great plains area. Daytime and nighttime measurements performed during this campaign will be presented at the conference.

Table 1. Lidar Characteristics

Transmitter	
Laser	XeCl Excimer
Wavelength	308 nm
Energy/pulse	300 mJ
Repetition rate	200 Hz
Bandwidth	3 pm
Divergence	0.1 mr
Receiver	
Configuration	Dall-Kirkham
Diameter	0.76 m
f number	4.5
Channel bandpass	0.4 nm
Filter transmission	30-35%
Field of view	Dual, adjustable (typically 0.2 mr, 2 mr)
Ranges	2 (narrow, wide fov)
Channels	3
Species	Rayleigh/aerosol (308 nm) Water vapor (347 nm) Nitrogen (332 nm)
Electronics	
Short range	Analog to Digital Conv.
Long range	Photon counting
Range resolution	75 m (0.5 μsec)

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