

Adaptation of the University of Wisconsin High Spectral Resolution Lidar for Polarization and Multiple Scattering Measurements

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Quantitative lidar measurements of aerosol scattering are hampered by the need for calibrations and the problem of correcting observed backscatter profiles for the effects of attenuation. The University of Wisconsin High Spectral Resolution Lidar(HSRL) addresses these problems by separating molecular scattering contributions from the aerosol scattering; the molecular scattering is then used as a calibration target which is available at each point in the observed profiles(Shiple et. al, Grund et al). This approach does not require knowledge of the backscatter/extinction ratio to correct for attenuation and thus avoids the uncertainties and numeric instabilities of schemes for inversion of single channel lidar profiles. Because the molecular backscatter cross section is approximately one thousand times larger than the Raman scattering cross section, the HSRL also holds a significant signal strength advantage over the use of Raman scattering approaches for measurement of aerosol backscatter cross sections.

While the HSRL approach has intrinsic advantages over competing techniques, realization of these advantages requires implementation of a technically demanding system which is potentially very sensitive to changes in temperature and mechanical alignments. This paper describes a new implementation of the HSRL in an instrument van which allows measurements during field experiments. The instrument has been modified to provide measurements of depolarization. In addition, both the signal amplitude and depolarization variations with receiver field of view are simultaneously measured. These modifications allow discrimination of ice clouds from water clouds and observation of multiple scattering contributions to the lidar return. In the past it has been very difficult to verify models of the multiply scattered lidar return. The ability to measure calibrated backscatter cross sections and optical depths while simultaneously measuring depolarization and field-of-view variations make the HSRL a unique instrument for these investigations.

Figure 1 provides a block diagram of the new HSRL transmitter and receiver. The depolarization measurement capability is implemented so as to provide extremely precise measurements. The transmitted polarization is rotated 90 degrees between alternate laser pulses by a Pockels cell. Calibrations show that with proper alignment the residual cross polarization in the transmitted beam can be reduced to approximately 0.1% of the parallel component. Separate depolarization measurements can be made in both the "molecular" and "aerosol" channels of the HSRL while simultaneously observing the depolarization in the wide field of view channel. Because both polarization components are observed with the same detector and receiver optics, no calibration is required to make accurate measurements of the depolarization ratio. Photon counting detection also provides linear detector response over a very large dynamic range. The small time separation between laser pulses (250 μ s) insures that the both polarization components are measured from the same ensemble of scattering particles.

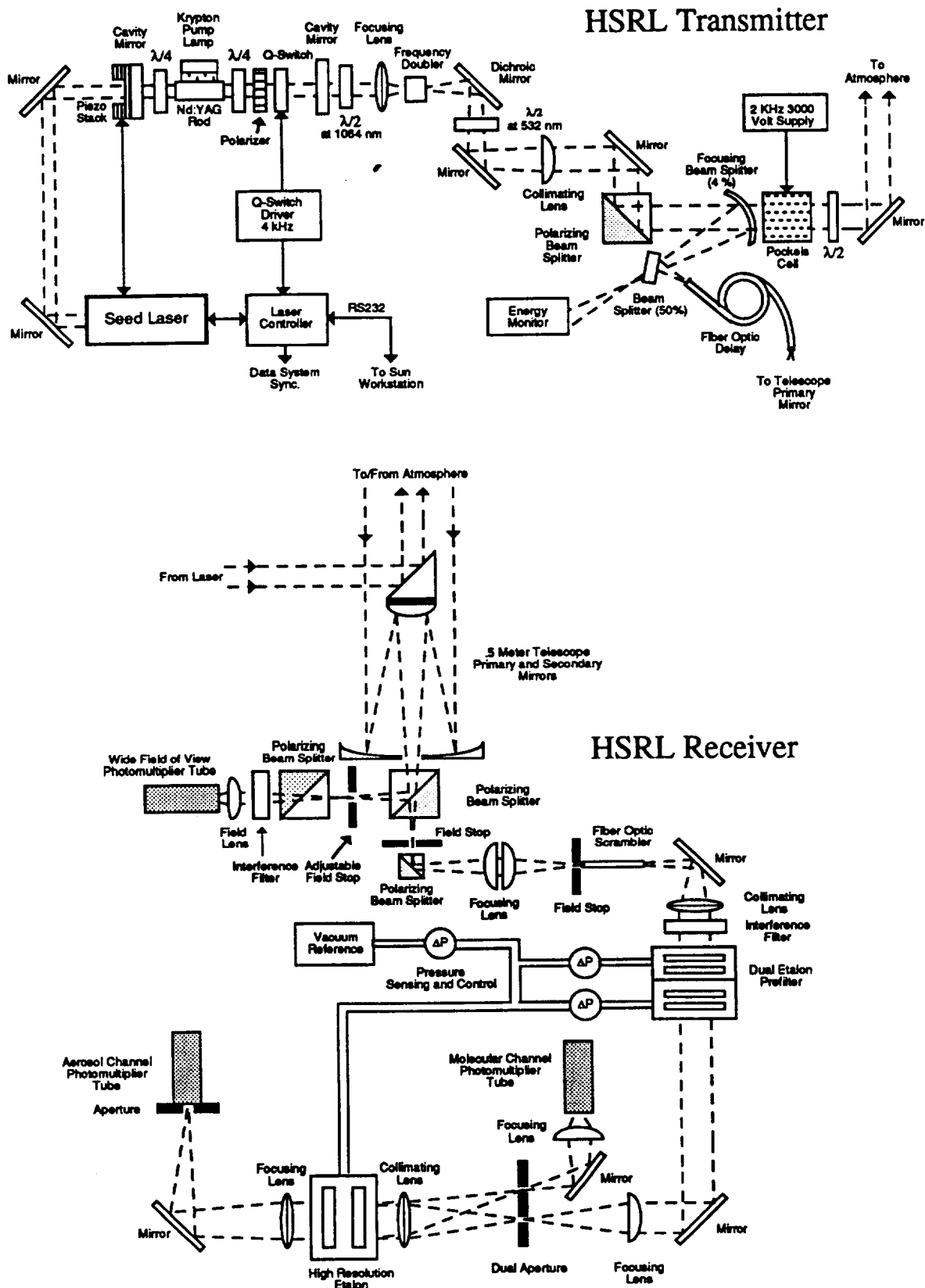
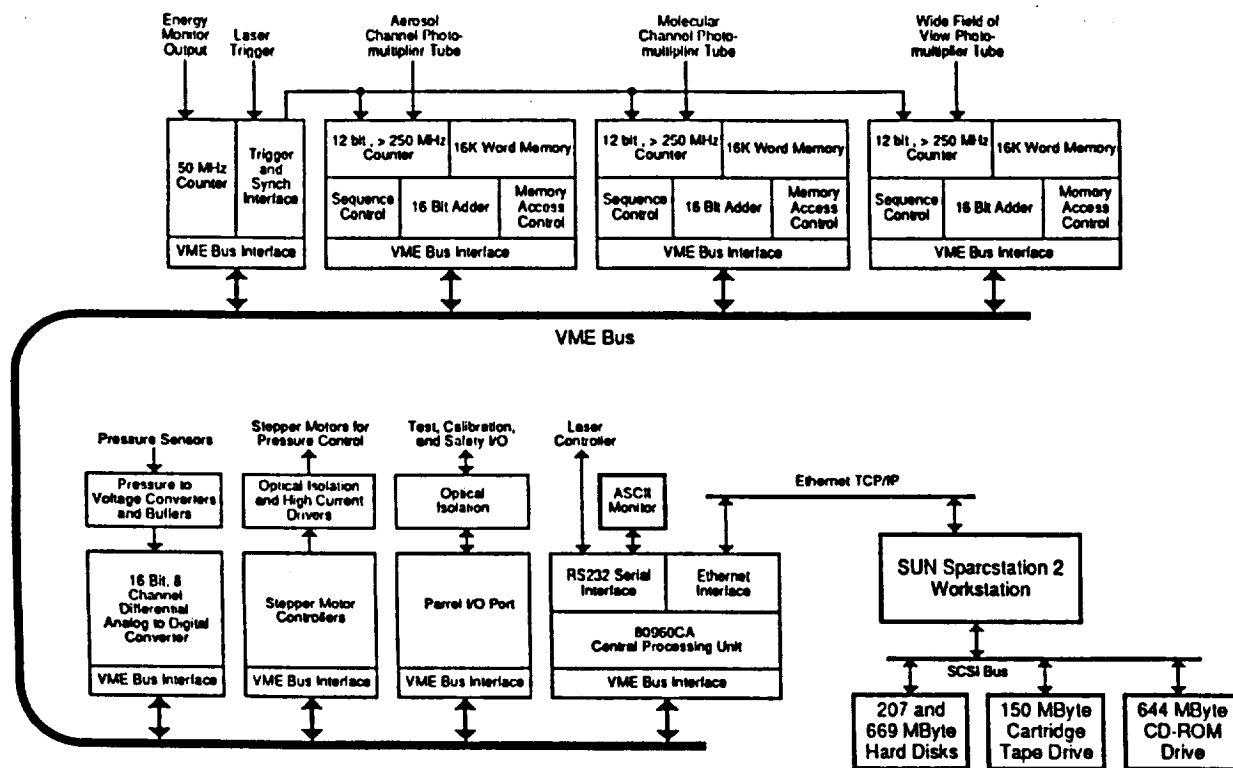


Figure 1.

In order to increase the dynamic range of the HSRL we have designed new photon counting electronics to enable count rates near 1 GHz while accumulating counts in up to 8,192 range bins of 100 ns each. These counters have thus far been tested to count rates of over 250 MHz. Full utilization of these counters awaits the installation of phototubes providing shorter single photon pulses than the EMI model 9860 currently employed. A schematic of the HSRL data system is shown in figure 2.



HSRL Data Acquisition System

Figure 2.

Figure 3 shows HSRL returns from a super-cooled water cloud (at an altitude of 5 km) and from ice crystal precipitation falling from this cloud (between altitudes of 3.3 and 4.8 km). The received signals polarized parallel and perpendicular to the transmitted polarization are shown along with the depolarization ratio. Notice that the depolarization observed in the clear air below the cloud is approximately 1% and thus very near the depolarization expected for molecular depolarization of the Cabannes line. Also note that the water cloud depolarization is approximately 2% indicating that for this cloud the 200 microradian field-of-view of the HSRL effectively suppresses depolarization caused by multiple scattering.

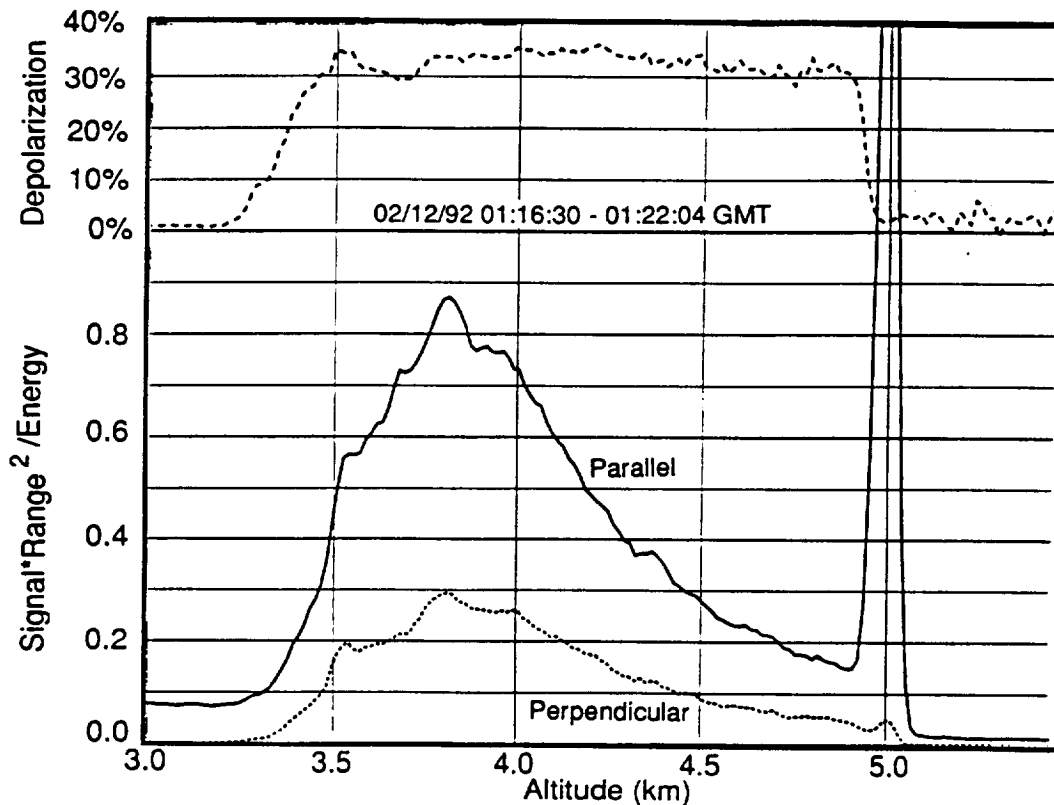


Figure 3.

Acknowledgements

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References

Shipley, S.T., D.H. Tracy, E.W. Eloranta, J.T. Sörga, F.L. Roeseler, and J.W. Weinman, "High spectral resolution lidar to measure optical scattering properties of atmospheric aerosols. 1: theory and instrumentation," *App. Optics*, 22, 1983, p3716-3724.

Grund, C.J. and E.W. Eloranta, "University of Wisconsin high spectral resolution lidar", *Optical Engineering*, Vol 30, #1, p6-12, Jan 1991.