DUAL POLARIZATION MICRO PULSE LIDAR FOR TROPICAL AEROSOL-CLOUD-CLIMATE INTERACTION STUDIES AT PUNE, INDIA

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ABSTRACT

A new portable, eye-safe Dual Polarization Micro Pulse Lidar (DPMPL) has been developed and installed at the Indian Institute of Tropical Meteorology (IITM), Pune (18°32'N, 73°52'E, 559 m AMSL), India. This system has been built to enlarge the scope of lidar monitoring of atmospheric aerosols and clouds that has been in progress over the experimental station for the past almost two decades. A DPSS Nd-YAG laser second harmonic, with either parallel polarization or alternate parallel and perpendicular polarization, is used as transmitter and a Schmidt-Cassegrain telescope with high speed detection and data acquisition/processing system as receiver. This on-line system in real-time mode provides backscatter intensity altitude profiles up to about 75 km at every minute in both parallel and perpendicular polarization channels corresponding to each polarization state of the transmitted laser radiation. Thus this versatile lidar system is expected to play a vital role not only in atmospheric aerosol and cloud physics research and environmental monitoring but also in weather and climate modeling studies aiming at impact of radiative forcing on hydrological cycle, Here, we report a detailed description of the lidar and some initial measurements made using this facility.

1. INTRODUCTION

Aerosols of both natural and anthropogenic origin perturb the atmospheric radiation field through direct and indirect interactions with solar radiation [1,2]. Monitoring of the impacts of natural aerosols can also help in understanding the evolution of past environments and predicting future climate. Moreover, atmospheric aerosol characteristics vary significantly in space and time over different environments. Hence accounting for the effects of aerosols in Earth-atmosphere radiation balance and environmental pollution/air quality assessment is very complex and a challenging exercise. Lidars play an important role in these studies because of their capability to make continuous measurements very precisely of different aerosol and cloud parameters [3]. Detailed knowledge of aerosols and clouds are peremptory mainly for obtaining better radiative forcing estimates — one of the major uncertainties in understanding the influence of aerosols and pre-cursor gases on weather, climate change and underlying processes, and for refining models for improving satellite data retrieval algorithms.

In view of the importance of aerosols in tropical atmospheric processes [4], the availability of data describing the main properties is rather poor, in particular, with respect to the vertical distributions. By considering these requirements, among others, a bi-static Argon ion lidar system has been developed and vertical profile measurements of aerosol number density have been made regularly at the Indian Institute of Tropical Meteorology (IITM), Pune, India since 1985. Utilizing more than 1500 vertical profiles of lidar-observed aerosol concentration profiles archived during October 1986-September 2000, tropospheric aerosol climatology has been established [5]. Using this multi-year lidar aerosol data, inter-annual, intra-seasonal and long-term trends in aerosol loading, aerosol-cloud-precipitation relationship and air quality over the experimental station have been investigated [6].

Although some considerable number of studies is available on direct radiative forcing due to aerosols on weather and climate, studies on aerosol semi-direct and indirect radiative forcing are very sparse [7]. Moreover, the most important component that is missing so far in the tropical aerosol research, particularly in India, is multi-dimensional mapping of aerosol properties and cloud structures during both day and night over different environments (associated with complex terrain and meteorological conditions). In this context, the Dual Polarization Micro Pulse Lidar (DPMPL) system at IITM, Pune would play a vital role in atmospheric aerosol and cloud (especially cirrus cloud characterization) physics research and environmental monitoring. This will also serve as very valuable input information to the weather, climate and air quality models [8-10], especially those aimed at accounting for the radiative forcing and its impact on hydrological cycle on different spatial and temporal scales.

2. INSTRUMENTAL DESCRIPTION

The system was built by following the uni-axial monostatic configuration. Since the objective was also to conduct field campaigns at multiple sites, the system was designed to be eye-safe and mobile. This was achieved using a low energy, high repetition rate Nd-YAG laser, with an expanded beam. The receiver is a compact Schmidt-Cassegrain telescope with focal ratio of f/10. Figure 1 shows the optical lay-out of the system. The entire system comprises of two basic parts- the first includes the transmitter, receiver, utility electrical plus electronics and mounted on a vibration isolated platform on castor wheels in Thermo-Electrically cooled and clean environment, and the second is a high reliability transportable control and data processing system. All the hardware sections of the system are controlled via software under Microsoft windows XP environment and majority of controls especially the high speed (~ 500 MHz) acquisition sequences are fully automated.

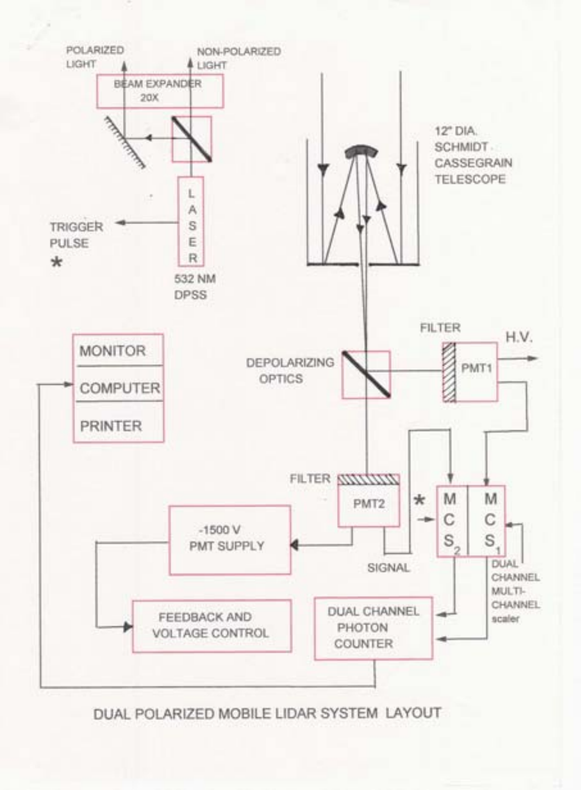


Fig. 1. Optical layout of the DPMPL

The software exhibits simple user friendly graphics interface that makes the system easy for operation. The transmitter-receiver axis alignment is achieved by means of octopus, which is a micro-controller-based remote terminal unit responsible for controlling the stepper motors of bore-sight mechanism to bring it into the path and retreat from transmitter's outgoing laser beam, controls x and y axis mirrors during alignment process. It also introduces Fabry Perot Etalon into receiver optics path for daytime and retreat from it for nighttime operation. It also generates external trigger laser pulses to control the laser and the polarization rotator. A photograph depicting the complete transmitter-receiver and interface for data acquisition system of the DPMPL is presented in Fig. 2.

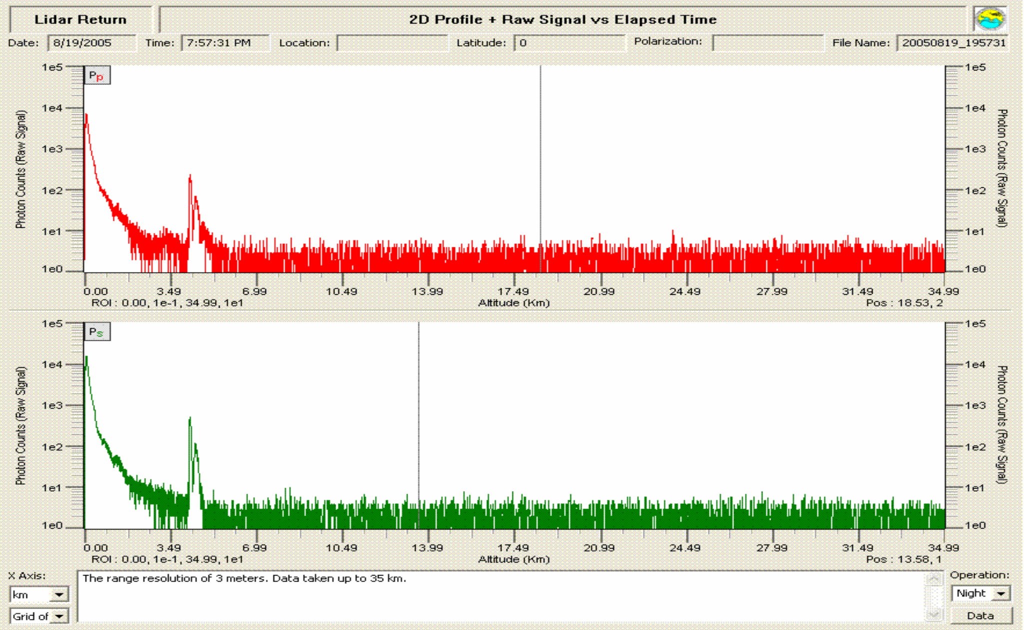
Fig.2. Outer view of the DPMPL

1. The rollers and the Thermo Electric Air Conditioner
2. Vibration isolation transmitter, receiver optics and the cool closed cabinet.
3. Laser controller and interface
4. ON/OFF an Emergency Panel
5. Alignment system
6. Beam expander telescope
7. Electrical and utility cabinet
8. 14" Diameter Telescope
9. System to power and computer interface
0. System tilt mechanism.

The bore-sight mechanism of the system provides adjustment in two axes and maintains co-linearity between transmitter's outgoing laser beam and the telescope that is used to collect the return energy. The complete system can be tilted by a few degrees for the vertical before acquiring the data to avoid specular reflection which might occur from horizontally oriented ice crystals during high-altitude cloud studies. The system has built-in provision to apply corrections to the observed data due to background and dark count. In real-time (un-attended) mode of operation, the system continuously acquires the raw backscattered intensity (photon count) profiles for every minute as per the prescribed altitude range and resolution settings. There

Table 1 : Main specifications of DPMPL

Transmitter	Receiver	Data Acquisition
Laser type : DPSS Nd YAG Laser wavelength : 532 nm	Optical design : Telescope (Schmidt Cassegrain) Clear aperture : 355.6 mm	Method : Photon Counting Interface type : Dual Channel MCS
Laser Repetition Rate : 2 KHz (for 75 km) max. 50 KHz	Focal length : 3556 mm	Time bin resolution (chosen in power of 2): 2 ns to 8 ms
Pulse energy @ 10 KHz : 21μJ/pulse	Focal ratio : f/10	Range resolution : 0.3 m
Pulse width @ 2KHz PRR : 18.3 ns	Transmitter-receiver coupling : Direct	Dynamic range : 35 bits @ 2 ns
Beam profile : Tem00	Filter bandwidth : 0.6 mm	Dead time @ end of sweep : < 200 ns
Polarization ratio/direction : 100:1/Vertical	Fabry Perot port : Available	Dead time between time bins: None
Beam expansion (external Expander) : > 20	Fabry Perot driver : Stepper Motor Available	
Polarization flipper : Alternate parallel and perpendicular	Fabry Perot control : Octopus	
Polarization switching : 1 KHz @ 2 KHz Laser PRR		
Detectors	**Energy Monitor**	**Alignment**
Type: Metal package PMTs	Integrated with the system	Mechanism: Bore-sight
Sensitivity : 1e6 @ 8 V (approx)	Interface : USB	Position sensing:4 Quadrant PSD
Set point and monitor : Octopus	Software : Standalone	Alignment axis : x-y (stepper motors)
Control by computer		Mechanism control : Octopus
Data Processing Computer	**Utilities**	
Pentium 42.8 GHz	Vibration isolation : 8x isolation columns	
Memory : 1GB	Cooling (Optics + Laser Detectors) : By Solid State Thermo Electric Cooling System (TEC)	
Hard disk : 110 GB		
Graphic card : NVIDIA GeForce 4 MX 4000		
Monitor : LCD 17”		
Environment : Windows XP Professional SP2		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Pos : 18.53, 2
ROI : 0.00, 1e-1, 34.99, 1e1
Pos : 13.58, 1
X Axis: km
Operation: Night
The range resolution of 3 meters. Data taken up to 35 km.

Fig. 3. Sample profile of lidar backscatter intensity at 3m range resolution.

is also provision available to select any altitude range of interest from the total vertical profile for detailed analysis. The finest range resolution that can be achieved with the system is 0.3m (30 cm). Further, once any range resolution is set (depending upon the experimental requirement), same resolution is achieved throughout the set-altitude range. Thus the data flow would be very high during the high resolution data recording periods. A sample profile of the lidar backscatter intensity acquired at a range resolution of 3m from surface to ~ 35 km altitude range is depicted in Fig. 3. In addition to the exponential decay in the lidar return intensity in the lower altitude region, a strong echo from low-level cloud around 4.5 km can be clearly seen in both p (parallel polarization) and s (perpendicular polarization) channels from the figure.

After acquiring the data and performing the relevant corrections, the data is finally range corrected. These data sets are finally subjected to the extinction coefficient (employing Klett's far end solution[11]) and linear depolarization ratio (following the methodology reported by Sassen[12]) analyses. Rayleigh scattering is included with values taken from the standard atmosphere. Whenever available, the column optical thickness obtained from the collocated sun photometer is used. Also, by utilizing the unique facility (alternate switching of state of polarization of laser pulse energy between parallel and perpendicular) available with the system, data sets are being collected to undertake detailed analysis of cloud composition such as water, ice and mixed phase besides the influence of laser beam polarization on non-sphericity of droplets, and extinction profiles recorded with both co- and cross-polarization characteristics of the laser beam.

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