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Development of a Mie Scattering Lidar for Air Pollution Monitoring in Metro Manila, Philippines

Ma. Cecilia D. Galvez, Edgar A. Vallar,
Susana S. Dorado, and Minella C. Alarcon

Department of Physics, College of Arts and Sciences,
Ateneo de Manila University, Loyola Heights,
Quezon City, PHILIPPINES

Abstract: A Mie scattering lidar is developed at the Manila Observatory of Ateneo de Manila University, Metro Manila, Philippines. Its principal objective is to characterize air quality in the metropolis. The system employs an Nd:YAG laser emitting at its fundamental and second harmonic beams with output energy of 450 mJ and 250 mJ, respectively. This paper shows the Mie lidar system, its parameters, and signal simulation results.

I. Introduction

During the past years, there has been a growing concern on the continuous degradation of the environment of Metro Manila, Philippines. The increasing number of motor vehicles and industries, which are concentrated in the metropolis, has caused serious problem of excessive concentrations of suspended particulate matter. Existing atmospheric data have generally been unreliable because of a lack of uniformity in the frequency and method of collection and analysis. Effective environmental management requires accurate, consistent, and continuous measurement and observation of atmospheric properties and constituents. There is a need to introduce new technology to improve the environmental monitoring capability.

To achieve this goal, the Department of Science and Technology (DOST) has approved the development of a Mie Scattering Lidar at the Manila Observatory of Ateneo de Manila University. Its principal objective is to assess and characterize air quality in the metropolis. The purpose of this paper is to describe the Mie Scattering Lidar developed in Manila, Philippines.

II. The Mie Scattering Lidar System

The block diagram of the lidar system is shown in Fig. 1. The transmitter is Q-switched flashlamp pumped Nd:YAG laser operating simultaneously in the fundamental and second harmonic wavelengths with pulse energies of 450 mJ and 200 mJ, respectively. The output beam has a beam divergence of 0.6 mrad which is reduced to 0.2 mrad by a 3-time beam expander. The scattered radiation is collected by a 30 cm diameter Cassegrain-type telescope. A harmonic separator splits the received scattered radiation into the two wavelength channels. The specification of the lidar system is summarized in Table 1.

For the received power and SNR simulations, the scattering model used is found in ref. 4. This scattering model is shown in Fig. 2. Fig. 3 shows the total backscattering coefficients for 1064 nm and 532 nm laser wavelength. The calculated received power for this lidar system is shown in Fig. 4. The peak is from a cirrus layer which extends from about 5 to 10 km. The detection signal-to-noise ratio for two different average shots is shown in Fig.

5. This lidar system will be capable of measuring suspended particulate matters and clouds up to 12 km for 100 shot averaging, and 14 km for 1000 shot averaging.

Table 1. Specification of the Mie lidar System.

LASER:	Q-switched flashlamp pumped Nd:YAG (Surelite 1, Continuum)		**TELESCOPE:**	Schmidt Cassegrain
Wavelength	1064 nm	532 nm	Diameter	30 cm
Energy	450 mJ	200 mJ	Focal length	3048 mm
Pulsewidth	5-7 ns	4-6 ns	**TOTAL OPTICS EFFICIENCY:**	10%
Repetition Rate	10 Hz			
Beam Divergence	0.6 mrad (full angle)		**DATA ACQUISITION:**	
Beam Diameter	4 mm		Tektronix Model-Digital Storage Oscilloscope	
DETECTOR:	Si APD	PMT	Bandwidth:	500 MHz
Useful diameter	0.8 mm		Computer:	Macintosh
Efficiency	10%	17%		
Bandwidth	40 MHz	10 MHz		

III. Conclusion

The construction of the lidar system has started and initial measurements are expected next year. In its initial stage, only vertical measurement at the site is considered. Further improvements are necessary to make it an eyesafe and scanning lidar sytem for air pollution monitoring. Once operational, it will greatly enhance the environmental monitoring capability of the Philippines, especially in the area of air pollution monitoring.

IV. References

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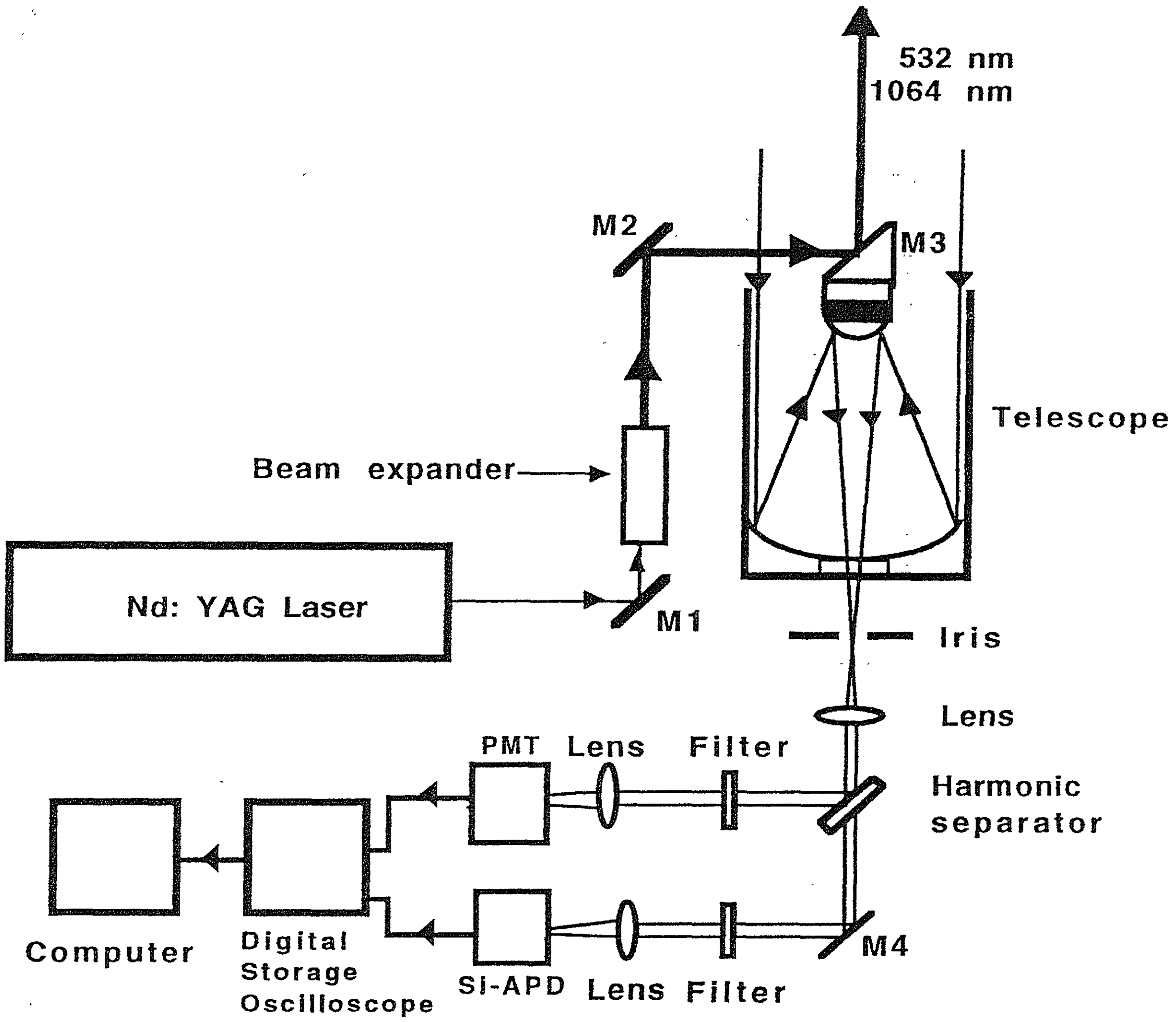

Fig. 1. Block diagram of the Mie lidar system.

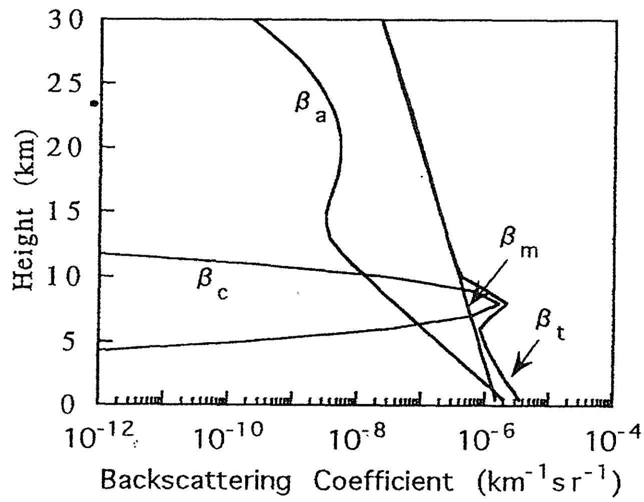

Fig. 2. The atmospheric model employed in signal simulations. β_m, β_a, and β_c are the backscattering coefficients of molecules, aerosols, and clouds respectively. β_t represents the total backscattering coefficient. Calculations were made for 532 nm laser wavelength.

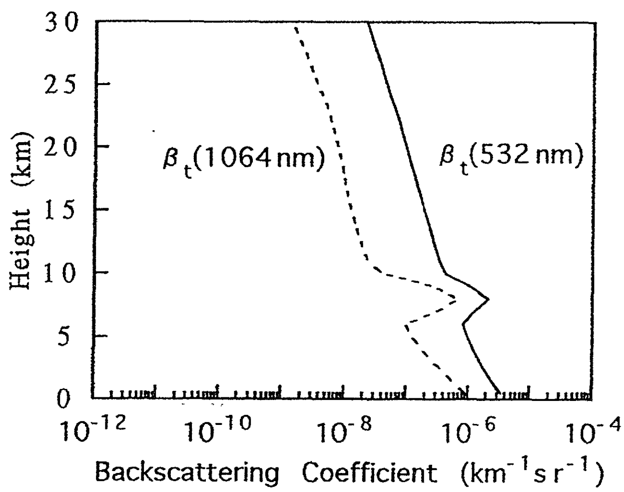

Fig. 3. The total backscattering coefficients for 1064 nm and 532 nm laser wavelength.

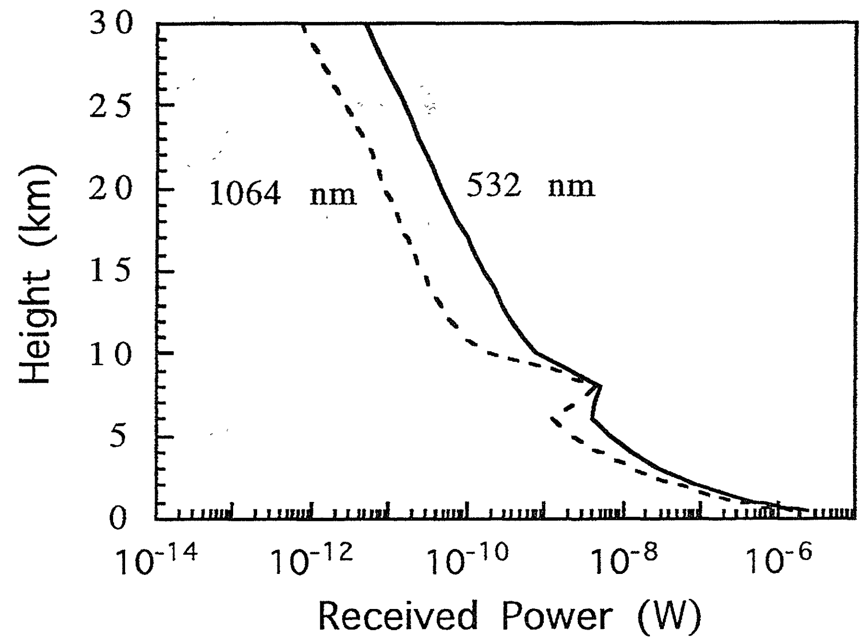

Fig. 4. The calculated received signal for both wavelengths based on the model atmosphere and the system parameters given in Table 1.

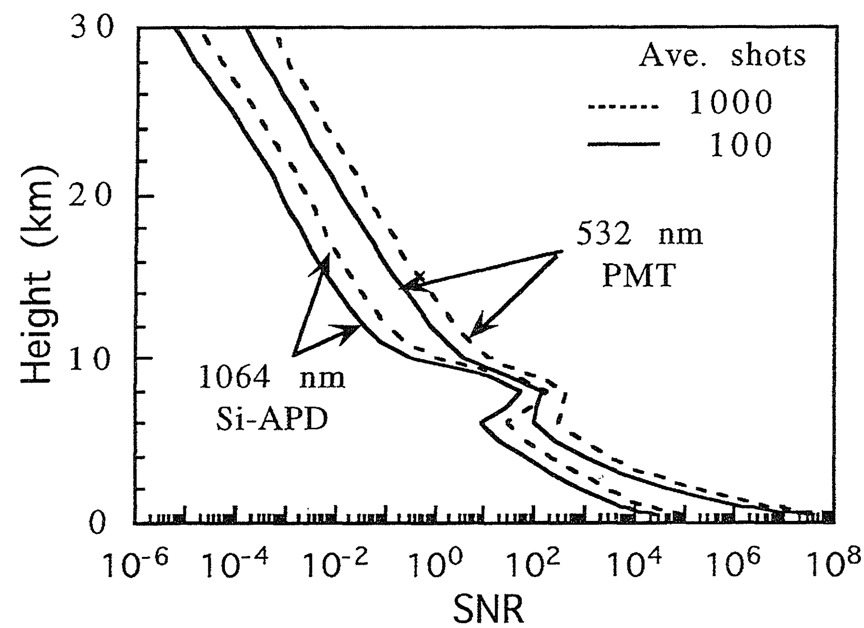

Fig. 5. The range dependence of signal-to-noise ratio for both wavelengths. The SiAPD is assumed to have an avalanche gain of 100 and quantum efficiency of 10%. The NEP is $8 \times 10^{-14} W Hz^{-1/2}$. The PMT has a current amplification gain of 1×10^{7}. The dark current is 3 nA, sensitivity is 74 mA/W and quantum efficiency is 10%. Calculations are also based on night time operation.