Semiautomatic Twilight Photometer, Design and Working

Pratibha B. Mane, A. Venkateswara Rao

Abstract

Aerosol measurements have been carried out at Kolhapur (16.41°N 74.13°E) by using newly designed Semiautomatic Twilight Photometer. Some noticeable features of the semiautomatic twilight photometer are improvement in efficiency of the system, growth in signal to noise ratio, augmentation in height resolution, lot of upgrading in the sensitivity of the system, expansion in duration of operation of the system, rise in rate of sampling, better accuracy in storing the data etc. The twilight scattering method yields a reasonable qualitative picture of the vertical distribution of the aerosols from about 6 km to a maximum of 350 km.

Keywords: Semiautomatic Twilight Photometer, aerosol measurements, passive remote sensing technique

1. INTRODUCTION

The instrument, **semiautomatic** twilight photometer, has been newly designed, developed and tested at IITM, Pune, India. The system is a ground based passive remote sensing technique used to monitor the vertical distribution of the atmospheric aerosols. It is a simple and inexpensive technique and hence can be operated continuously for monitoring the day-to-day variability of the aerosols, at any place. The semiautomatic twilight photometer consists of a simple experimental set up. The twilight photometer setup operated manually is used by earlier workers (Patil et al., 2003, Shah (1969, 1970), Jadhav and Londhe (1992), Nigut et.al. (1999), Padma Kumari et al. (2002, 2004, 2006, and 2008)). However, during the course of this study the system is suitably modified to improve the sensitivity of the system. A brief description of the instrument, **semiautomatic** twilight photometer, details of the experimental set up and its details of used optical, mechanical and electronic components are given in this paper.

2. INSTRUMENTAL SETUP

The semiautomatic twilight photometer consists of a simple experimental set up. A block diagram of it is shown in the figure-1; also photograph is shown in the figure-2. The various components of **Semiautomatic** Twilight Photometer are described as below.

2.1. Telescopic lens:

The photometer consists of a convex lens of diameter 15cm having a focal length of 35cm. It is used as telescopic lens for gathering the scattered zenith sky light intensity. Lens fixed on lid of the cylindrical box using 'z' angles and screws, such as the sky light from different zenith angles fall on it. The cylindrical box having length 35cm is fixed on a rectangular box such that the center of the lens and the center of the PMT are perfectly matched.

2.2. Filter:

A red glass filter peaking at 670nm with half bandwidth of about 50 nm is used. The filter transmission is about 65%. The longest wavelength has been selected in order to reduce the Rayleigh scattering contribution. The red filter of 2cm diameter and an aperture of 0.6 cm diameter are placed at the focal length of convex lens, provides approximately 1^0 field of view [(Aperture diameter/Focal length of lens) X57= (0.6cm/35cm) X 7=0.9771 degree]. The filter used has a wavelength cut-off at about 620 nm and therefore most of the chapeaus band with maximum ozone absorption at 610 nm would remain in the cut-off region of the filter. At this wavelength no other gas with maximum absorption is present. Therefore the information that is obtained at this wavelength is predominantly due to the aerosols. The filter is fixed on 0.6cm aperture on the center of the PMT.

2.3. Shutter:

The small shutter is fixed above the filter. When this shutter is closed, no skylight will fall on PMT. This shutter is controlled by solenoid valve, which works on 12Volts dc @ 1amp power supply. The dc power supply gives 12V to the solenoid valve, which then used to open the shutter and allows the light intensity to fall on the detector (PMT) through the red filter.

2.4. Detector:

The detector used is photomultiplier tube (PMT), 9658B. The 9658B is a 51mm (2") diameter end window photomultiplier with a prismatic window for enhanced cathode sensitivity, S20 infra-red sensitive photocathode, and 11 high gain, high stability, SbCs dynodes of the long-established Venetian blind design providing a low after pulse rate. Photo multipliers are extremely sensitive light detectors providing a current output proportional to incident light intensity. By using a variable high voltage supply the PMT output signal can be varied over a wide range.

2.5. DC-to-DC converter:

During morning and evening observation period light intensities are changing hence it is necessary to compensate for changes in light. For this compensation the gain of PMT i.e. supply voltage is adjusted. A DC-to-DC converter is a device that accepts DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converter is used to provide noise isolation, power bus regulation etc. The DC-to-DC converter used is 'Powertex-061081001, High volt unit' with high output voltage as a power supply. This modular supply has 12V input with fully adjustable output from 50V to 1000V. In this study, for throughout the experiment the PMT supply voltage is kept constant at 700Volts.

2.6. Fast Pre Amplifier:

The output signal (current) of the PMT, used for detecting the light intensity during the twilight period, is very low. It is of the order of nano to microamperes. The amplitude or strength of this low signal is amplified by using newly designed fast pre-amplifier during this study. The amplification is so high that the amplified signal can be easily recorded with a digital multlimeter. There presents internal noise which is called as 'white noise', with the output signal of the PMT. In case of single-IC amplifier this internal noise of the system also gets amplified along with the signal. Hence to keep the noise at a minimum level and to improve the Signal/Noise ratio, multi-IC configuration is used in this amplifier. In this system the noise at the output signal of each amplifier not being in phase with the other amplifier signal, a random noise is generated. Therefore total sum of internal noise of produced by all IC's approaches nearer to zero. Thus keeping noise at minimum level (near about zero) we get amplified signal.

The Signal/Noise ratio is increased by ten times of that obtained with a single IC amplifier. The amplifier output recorded varies from 1V to 10V depending upon the twilight intensity.

2.7. Recorder:

The output of the amplifier is given to the digital multimeter, Rishcom-100 for measurement and recording the row data, which is used for analysis. The Rishcom-100 has an adapter. It stores the data automatically for every 10secs in the form of date, time and intensity in Volts.

2.8. Disk with various apertures

The semiautomatic twilight photometer is operated during evening and morning twilight periods. During evening twilight, it is operated for a time spell of ~90 minutes after the local sunset and during morning twilight it is operated ~90minutes before sunrise. Throughout the experiment the PMT supply voltage (700V) is kept constant. The light exposure area of the telescopic lens is increased / decreased by using proper apertures over the telescopic lens. For the measurement of twilight zenith sky intensive, a disk with various apertures is mounted over the telescopic lens. One aperture at a time is used for the measurement. In this configuration the solid angle of photometer remains the same but light gathering power of the system is controlled. The PMT supply voltage is kept constant throughout the observation period. The area of apertures is selected in such a way that the ratio of the larger area aperture to next lower area aperture is 6.8. During morning twilight zenith sky intensity at the beginning of the experiment is less, hence larger aperture is used first to get maximum light exposure and then light exposure is reduced by placing the next smaller aperture so as to keep the output signal of the photometer within the required range. Five apertures are used to accommodate the four order of magnitude change of twilight intensity.

During evening twilight, initially the twilight intensity is more and hence very small area of the lens is exposed. The scattered light intensity decreases with time and hence the area of exposure is slowly increased. In the morning twilight the intensity of the light is less and increase with time. Hence, at the beginning the maximum area of the lens is exposed to light and then it decreased with increased intensity. The system output signal is measured with data logger automatically for every 10 sec interval. The output signal in the range of 1-10V is measured. The measured voltage varied linearly with the incident illumination. Hence the measured quantity hereafter called twilight intensity or the scattered light intensity (I) is expressed in Volts. Dark current of the system without light exposure is noted before starting and at the end of the experiment by closing the photometer. It is in mili volt range and averaged value is subtracted from the output signal. Thus the internal noise in the signal is eliminated. The instrument looks only at the zenith and hence the zenith sky light intensity is measured. The measured scattered light intensity and the corresponding time constitute the raw data. These measured quantities are analyzed for retrieving the aerosol vertical profile.

3. RESULTS AND DISCUSSION

All the earlier workers reported the vertical distribution of aerosols from about 6 km to a maximum of 120 km. In the present work, newly designed Semiautomatic twilight photometer, is used for aerosol measurements over Kolhapur (16.41°N 74.13°E). The efficiency of the system is increased by adopting multiple pre-amplifier configuration which improves signal to noise ratio by factor of 10 and this fact is responsible for measuring low level intensity by photometer. Therefore the duration of operation of the system has been increased to 90 min as compared to 45 min obtained by earlier system. As a result the system now can yield a reasonable qualitative picture of the vertical distribution of aerosols from about 6 km to a maximum of 350 km. This gives an opportunity to monitor the aerosols not only up to stratospheric levels (as by the earlier workers) but also at the mesospheric and thermospheric levels. Thus the sensitivity of the system is improved a lot.

One of the main advantages of the semiautomatic twilight photometer is improvement in height resolution. This is achieved due to high rate of sampling, as data is stored for every 10secs, as compared to 30secs in earlier system. The height resolution is .03Km, 0.15Km, 0.29, 0.51Km, 0.76Km, and 0.91 Km for 6Km, 10Km, 20Km, 50Km, 100KLm, 150Km respectively. Due to this improvement in height resolution, the small fine-scale features, which are not visible in the profiles derived by earlier workers, are visible in the profiles derived in the present study.

In this system it is possible to avoid the manual errors viz., error in time and oversight in noting down the readings from the digital multimeter, because as stated above Rishcom-100 has an adapter which stores the data automatically for every 10secs. Thus accuracy in measurement and recording the data is increased in this system.

4. SUMMARY AND CONCLUSIONS

Some noticeable features of the Fast Pre-amplifier are,

I. Augmented efficiency of the system
II. Improvement in height resolution
III. Increased duration of operation of the system
IV. Visibility of the small fine-scale features in the profiles derived by this system
V. A lot of upgrading in the sensitivity of the system
VI. Amplified Signal to noise ratio
VII. Drastically reduction in the white noise of the system
VIII. Better accuracy in measurement and recording the data

Acknowledgements: One of the authors (Sou. Pratibha B. Mane) is grateful to the Shivaji University authorities, Kolhapur, for the encouragement during the course of this work.

REFERENCES

1. B. Padma Kumari, , A. L. Londhe, H. K. Trimbake, D. B. Jadhav comparison of aerosol vertical profiles derived by passive and active remote sensing techniques-a case study, Atmospheric Environment, December 2004, Vol. 38, Issue 39 : pp. 6679-6685.
2. B. Padma Kumari, A. L. Londhe, D. B. Jadhav, and H. K. Trimbake, Seasonal variability in the stratospheric aerosol layer in the current volcanically-quiescent period over two tropical stations in India using the twilight sounding method, Geophys. Res. Lett., 33, 2006, L12807, doi: 10.1029/ 2006GL026087.
3. B. Padma Kumari, A. L. Londhe, H. K. Trimbake & D. B. Jadhav, Study of vertical aerosol distribution from twilight photometry, Bulletin of Indian Aerosol Science & Technology Association, 14, 2002, 31-33.
4. B. Padma Kumari, S. H. Kulkarni, D. B. Jadhav, A. L. Londhe, H. K. Trimbake, Exploring Atmospheric Aerosols by Twilight Photometry, Journal of Atmospheric and Oceanic Technology, September 2008, Vol. 25, No. 9 : pp. 1600-1607.

ISSN 2229-5518

5. Jadhav, D. B. & A. L. Londhe, 1992: Study of atmospheric aerosol loading using the twilight method, J. Aerosol Sci., 23, 623-630.
6. Nighut, D. N., A. L. Londhe, D. B. Jadhav, 1999: Derivation of vertical profile in lower stratosphere & upper troposphere using twilight photometry, Indian J. Radio & Space Phys., 28, 75-83.
7. P.R. Patil, D.B. Jadhav, D.R. Jadhav, B. Padma Kumari, H. K. Trimbake, 2003:Automatic twilight photometer for monitoring meteor showers and vertical profiles of aerosols, New Instruments and Technology, Advances in Remote Sensing,IUGG, TIME [1700] [MI09/08P/B22-008].
8. Shah, G. M., 1970: Study of aerosol in the atmosphere by twilight scattering, Tellus, 22, 82-93.

Figure Captions

Figure 1:Block diagram of the semiautomatic twilight Photometer

Figure 2: Photograph of the semiautomatic twilight photometer

Department of Physics, Shivaji University,
Kolhapur-416 004, Maharashtra state, India.
Corresponding author
Email: pratibhabm263@gmail.com

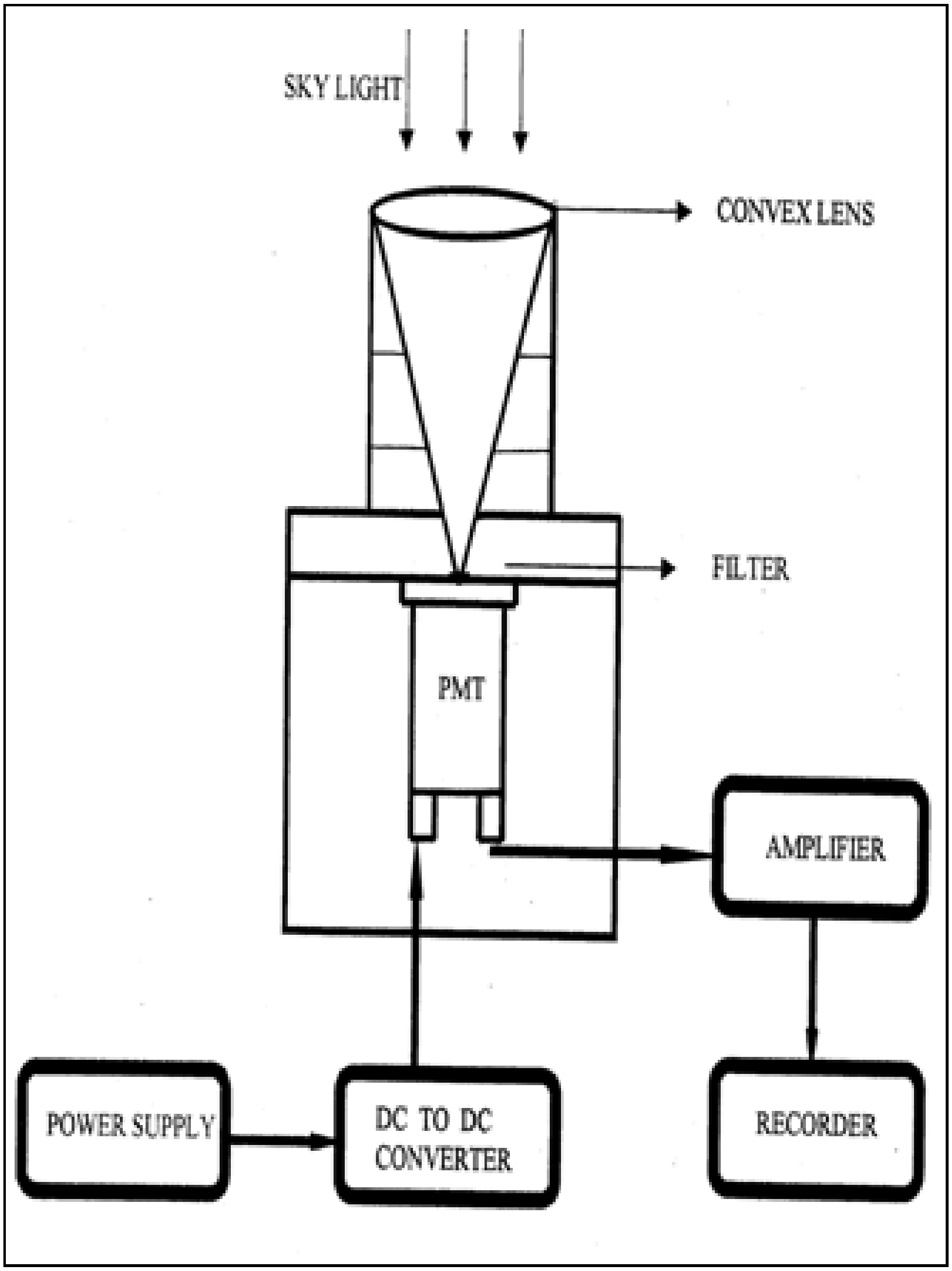
SKY LIGHT
CONVEX LENS
FILTER
PMT
AMPLIFIER
POWER SUPPLY
DC TO DC
CONVERTER
RECORDER

Figure-1

Figure-2