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Review of High Spectral Resolution Techniques for Measurements of the Aerosol Phase Function and Application in Extensive AirShower Detector Atmospheric Monitoring

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Abstract

We describe at first a review of the techniques used in the area of High Spectral Resolution Lidars (HSRL) for studying the aerosol phase function. We present results from the application of this technique in Extensive Air Showers telescopes atmospheric monitoring systems and our progress towards assembling such instrumentation. Using this, we are aiming to investigate the aerosol optical properties in the lower troposphere measuring the scattering cross section as a function of height.

Introduction

While the general atmospheric monitoring is presented in many references the issue of aerosol phase function measurement is usually treated by using as a detector the fluorescence telescopes themselves. Different geometries have been proposed for LIDAR atmospheric monitoring. The most popular is the one that the emitter and the receiver are in backscatter mode. This means that light is collected only at the angle of 180^0 as measured from the emitter. The light source is usually a pulsed Laser, so that the time interval determines the distance from the system. The backscattered light is usually collected by a mirror, filters reject the background light and finally photomultipliers, record the total amount of signal. In this way, a number of channels can be developed

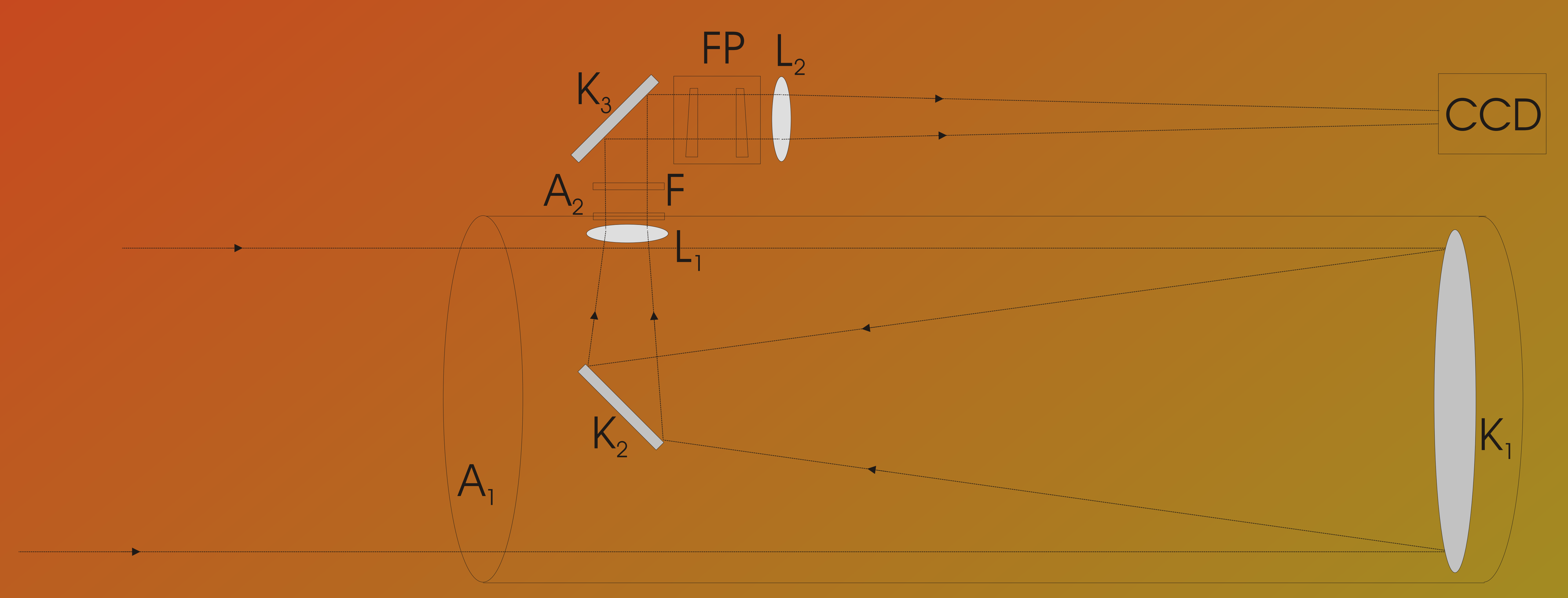

Fig. 1: A representative ray tracing diagram with the Newtonian telescope and one of the two Fabry-Perot channels fixed on it. A1, A2: telescope apertures, K1, K2, K3: Mirrors (the primary, the secondary and an inclined), L1, L2: Lenses, F: interference filter, FP: Fabry-Perot Interferometer

at a Lidar system, with different filters, measuring various atmospheric parameters, such as elastic scattering, Raman scattering etc. More sophisticated systems, like High Spectral Resolution Lidar (HSRL) use spectroscopic, inteferometric or other techniques in order to determine the exact components of the scattered light for high accuracy measurements. This light contains mainly two components. The one is due to Mie scattering from aerosols and the other to the Rayleigh scattering due to molecules. In order to distinguish these two components the Rayleigh night has to be used for the rejection of the signal due to molecules. The Rayleigh night is a night without aerosols. This method is based on the fact that the Rayleigh component has the same value for every other night. This assumption can be avoided if the Rayleigh component can be determined at the moment of the measurement. We present, therefore, another alternative approach, namely the use of dedicated detector in bi-static interferometric LIDAR. The most recent progress in the technology of HSRL is presented in [1]. Other techniques such as the Fizeau interferometer are used as high resolution attachment to a LIDAR for atmospheric monitoring.

Progress of HSRL Prototype

On the progress of the aerosol phase function measuring we present the technique of bi-static High Spectral Resolution LIDAR, which has not been up to now successfully implemented for atmospheric monitoring in EAS Fluorescence Telescopes. Our Prototype is based on the arrangement presented in Figure 1.

Receiver: The so called aerosol channel will be based on a Fabry - Perot (FP) etalon with a 50mm spacer and a liquid nitrogen cooled CCD, while the molecular channel will use FP etalon with 2.5 or 5 mm spacers, and a thermoelectrically cooled CCD.

Fig. 2: A very preliminary Fabry-Perot fringe pattern using the E2V 30-11 CCD cooled at -130^0 C.

Emitter: The corresponding emitter is a Single Longitudinal Mode 532 nm DPSS continuous wave laser at about 100-1500 m distance from the receiver place. We are going also to investigate the functionality of the System.

Improving S/N using LN_2 Cooled CCD

The aerosol channel has been modified to use a liquid nitrogen cooled ccd in order to increase the signal to noise ratio. The molecular channel is using a thermoelectrically cooled ccd. We use appropriate optics as seen in Fig.1. Some very preliminary results of the operation of the CCD at Liquid nitrogen temperature are seen in Fig. 2.

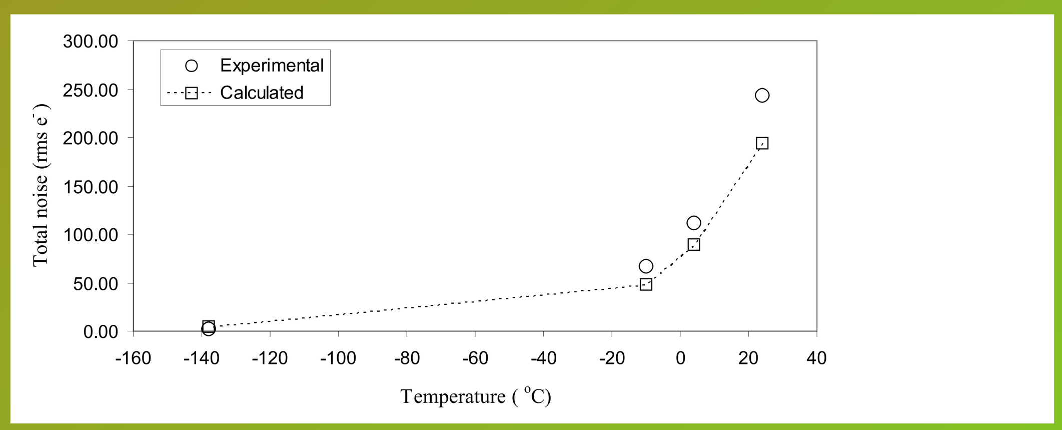

Fig. 3: The total noise of the E2V CCD as a function of temperature. The experimental values (circles) and the calculated by an appropriate empirical model (squares),appear to be consistent.

The sensitivity of the HSRL is discussed in [2]. The insertion of the narrowband optical filter is going to improve the signal to noise ratio considerably. Most of all, when operating the HSRL using as laser the emitter in CW mode, it is critical to use a low temperature CCD to improve the signal to noise ratio. For studying the ccd performance, we analyzed runs with the camera closed so that we can evaluate the overall CCD noise as a function of temperature. The results are seen in Fig. 3. The E2V based CCD was assembled in a dewar having fused silica window by XCAM Ltd, which provided the CCD sensor controller [3]. We plan to make further measurements to extend the exposure times to more than a few minutes. In this way, the signal to noise ratio will be improved.

Conclusion and Prospects

We are in the process of analyzing preliminary interferograms using the E2V camera at liquid nitrogen temperatures and also prepare to take such data under single longitudinal mode operation using low intensity laser source; the intensity of the latter will correspond to this expected from scattering by typical aerosol concentrations a various heights. In this way, we expect to determine the sensitivity of our HSRL system.

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REFERENCES

[1] Tan et al, The ADM-Aeolus wind retrieval algorithms,Submitted to Tellus, 60A, 2008 (Special Issue on ADM-Aeolus). Will be available at www.blackwell-synergy.com.
[2] E.Fokitis et al, Design of a High Spectral Resolution Lidar for Atmospheric Monitoring in EAS Detection Experiments, CRIS2008 Workshop, Malfa, Italy (Nucl. Physics B, Proc. Sup).
[3] XCAM Ltd, 1 Unit 8, Grove Farm Lane Moulton Northampton NN3 7TG.