Acousto-Optical Tunable Filter Atmospheric Imager for Determination of Aerosol Extinction

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1 Introduction

The Atmospheric Limb Imager (ALI) is a prototype atmospheric instrument developed at the University of Saskatchewan with the eventual plan for a satellite instrumentation in the future with the purpose to gather high resolution horizontal and vertical aerosol extinction profiles. The purpose of the ALI prototype is to test and verify the use of an Acousto-Optical Tunable Filter (AOTF), the fundamental technology behind ALI, in a space environment and to be gather atmospheric sulfate aerosol profiles with high spacial resolution. ALI will measure light from the atmosphere through the limb geometry which measures the radiance from scattered sunlight from the sunlit atmosphere. ALI is a single channel instrument measuring radiance from the visible to the near infrared wavelengths (650-950 nm) and through successive images build spectral information. The system uses a telescoptic front end to pass collimated light through through the AOTF which is then focused onto the the detector. The AOTF has the unique property of separating the incoming radiance into each of its polarized components selecting one and rotating it polarization through 90 ° allowing on to recover some polarization information of the incoming radiance. The ALI prototype was complete in August of 2014 with a stratospheric balloon test flight from the Canadian Space Agency balloon launch facility in Timmins Ontario onboard the CNES gondola platform on September 20, 2014.

The atmosphere has been monitored in several geometries throughout the history. Occultation was one of the first methods used on satellite instrumentation to measure atmospheric quantities including ozone which included SAM II (*McCormick et al.*, 1979), SAGE II (*McCormick*, 1987), and SAGE III (*Thomason and Taha*, 2003). Different instrumentation using other geometries were also put into space to acquire atmospheric data for different species with altering resolutions and the quantity of data that could be acquired in a single day. One such geometries is the limb geometry which measures radiance from the sun light atmosphere as it scatters and interacts with molecules in the atmosphere. However, the limb scatter geometry has a complexity that requires a foreword model to be able to model the scattering interaction, both single and multiple, between different consituents in order to be able to acquire any useful atmospheric information form the recorded data. Two instruments from the previous generation of space remote sensing instruments use have sucessfully used limb scatter to determine atmospheric parameters, Optical Spectrograph and InfraRed Imaging System (OSIRIS) an Canadian instrument onboard the Odin satellite (*Llewellyn et al.*, 2004) and SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) onboard the ENVISAT (*Bovensmann et al.*, 1999) which are grating spectrometers that can only acquire data at a single altitude at a time so a series of exposures is required to create a vertical profile. The new proposed method with ALI allows for a two dimensional spacial images of a single wavelength polarized light to be acquired giving both vertical and horizontal resolution of the environment through the use of the innovative AOTF technology.

Current generation instrumentation does not have the necessary resolution needed for current scientific needs. The pervious generation instruments (Talk about aerosol here)

In this paper the first section will outline the technology behind the AOTF used within the ALI system and then describe the optical design behind ALI and an ulterior optical presentation including and comparison with the Belgium instrument ALTIUS. Followed by ALI's maiden flight onboard the CNES CARMEN gondola from the CSA balloon launch facility in Timmins, Ontario including the conditions and trajectory of the flight day, and the measurement taken during the campaign including an analysis of the converion from raw measurement into calibrated data. Lastly, an retrieval algorithm for aerosol extinction and particle size parameters will be outlined and then preformed on the from the data for the campaign.

2 Instrument Design

2.1 Acouto-Optical Tunable Filter

Start with background of AOTF theory (momentum matching etc) then Cover the rational for picking the wavelength range that was used for the AOTF as well the the significance of the testing results.

2.2 Optical Design and Performances

Outline optical layout and rational for picking it with regard to aerosol concentrations optical characteristics. Final results and expected resolutions and wavelength

3 Stratospheric Balloon Flight

3.1 Flight Day Conditions and Flight Path

As the title says

3.2 Measurements

How measurements are made. Processing from level 0 -¿ level 1

3.3 Retrievals

The method on how the retrievals are transferred from level 1 data to aerosol profiles (level 2). (MART method with OMPS algorithm for particle size)

3.4 results

What the final measurements showed and how they compare to SOLAMON and OSIRIS

4 Conclusions and Future Prospects

Self explanatory.

Figures for Measurement and retrieval section not completed yet.

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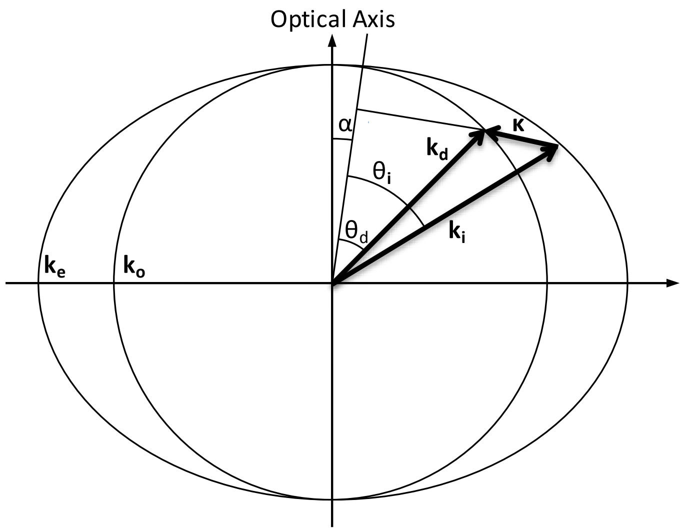

Figure 1: The wave vectors generated by the AOTF experiment set up in **??**. From the above figure k_e and k_o are the wave vectors of the extraordinary and ordinary axis of the AOTF crystal and can be represented as $2\pi n_e/\lambda$ and $2\pi n_o/\lambda$ respectively. The cut angel, α, is the cut angle form the optional axis to the piezoelectric transducer.

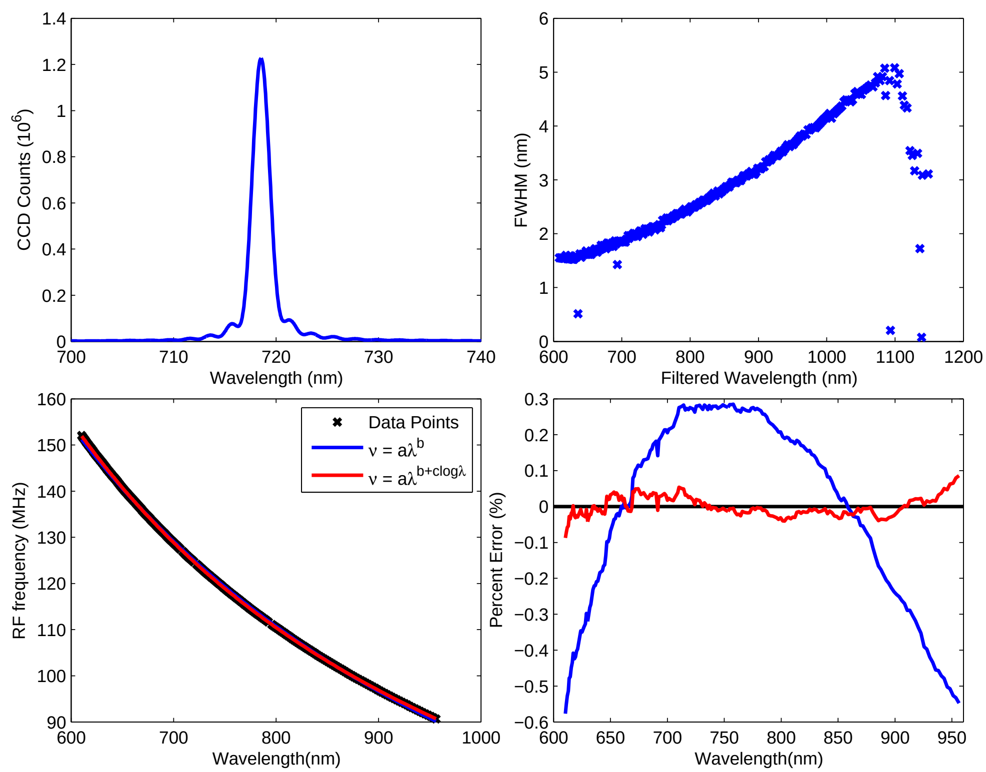

Figure 2: Top Left: A standard image taken from the AOTF calibration experiment when the tuning frequency of the AOTF was at 124.96 MHz. Top Right: The FWHM for each of the determined wavelengths for the AOTF. It should be noted that the FWHM at 600 nm is 1.5 and as the wavelengths get longer the FWHM increases to 4.9 at 1080 nm. Bottom Left: The calibration curves for the AOTF RF versus the diffracted wavelength which contains the data points recorded and two best fit curves. Bottom Right: The percent error with respect to the measured frequency for the two best fit curves in the previous panel. It can be noted the modified power function approximates the AOTF wavelength dependance to within 0.1%.

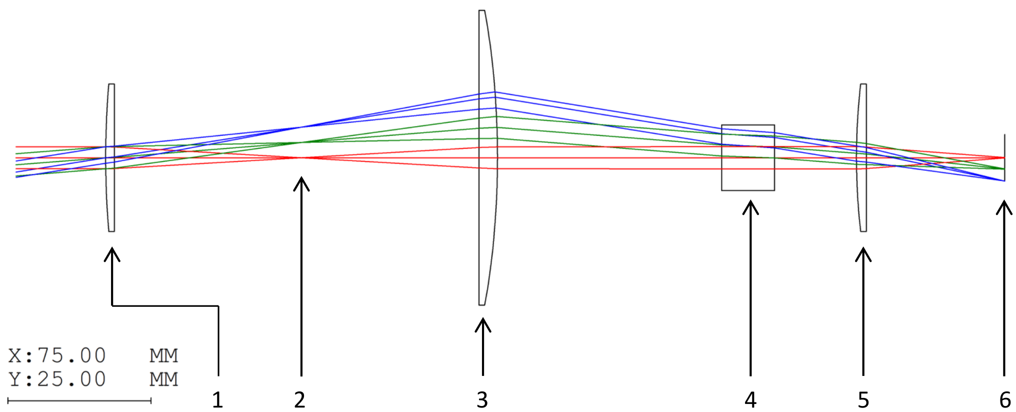

Figure 3: Ray Tracing diagram of the telescopic lens system simulated by Code V. The elements in the system are the following: (1) 100 mm focal length plano-convex lens. (2) Location where shutter will be located to limit stray light (3) 100 mm focal length plano-convex lens. (4) Brimrose AOTF characterized in **??**. (5) 75.6 mm focal length plano-convex lens. (6) Imaging plane. It should be noted that the x and y scales are not the same in this image. Also, in the lab a polarizer is added in front and behind the AOTF as well as prisms behind the AOTF.