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OLALA – Optical Lab for Lidar Applications

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Abstract: We are setting up a new scattering laboratory, the Optical Lab for Lidar Applications (OLALA) to measure the particle depolarization ratio of irregularly shaped mineral dust particles in the exact backscatter direction. For that, we will use size-segregated natural dust samples which will be observed at three wavelengths (355, 532 and 1064 nm) in order to assess the particle's size effect on the spectral slope of the depolarization ratio. The gained knowledge will be applied to a better understanding of particle's size in lidar field observations of mineral dust and to improve optical scattering models dealing with non-spherical particles at a scattering angle of 180°.

1. Introduction

Mineral dust is globally the most abundant aerosol type in terms of mass, influencing cloud formation and radiation even far away from its source regions. The irregular shape of mineral dust particles makes it easy to separate it from other spherical aerosol species such as anthropogenic pollution or (humid) sea salt, but it is a challenge for optical particle shape models. Especially, the scattering properties at exactly 180° scattering angle are hard to predict, but needed for height-resolving remote sensing observations with lidar. Discrepancies between the observed and modelled spectral slope of the depolarization ratio were reported [1]. Fig. 1 shows the differences in the spectral slope of the particle linear depolarization ratio observed with lidar and the retrieval of the AERONET sun photometer (adopted from [2]). Here, the advanced GRASP algorithm (Generalized Retrieval of Aerosol and Surface Properties) using 7 wavelengths as input was used [3,4], which leads to better results than the standard AERONET algorithm, but still could not completely describe the spectral slope of the observed depolarization ratio. The spectral slope of the depolarization ratio of mineral dust with a maximum in the visible and a decrease towards the UV and NIR was observed by several lidar studies [e.g., 5–7] and seems to be a typical feature for airborne mineral dust. However, a conclusive explanation for this spectral slope is still missing. Up to now, there is no comprehensive data set of the scattering properties of mineral dust at 180° scattering angle which could be used to explain the spectral slope from 355 to 532 and 1064 nm and in more general terms which can be used to test and improve the optical models at all relevant aerosol lidar wavelengths.

Therefore, a new scattering laboratory, the Optical Lab for Lidar Applications OLALA will be set up by a Leibniz Junior Research Group around the lead author at the Leibniz Institute for Tropospheric Research. The design and goals of this new laboratory will be outlined at the conference.

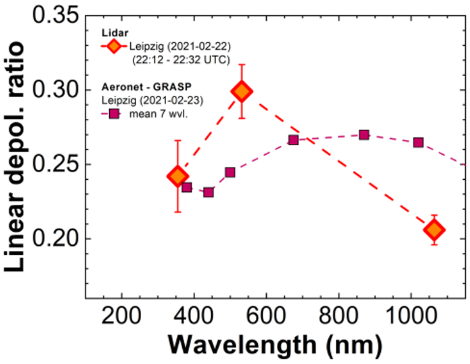

Figure 1 Spectral slope of the particle linear depolarization ratio of a mineral dust plume observed with lidar (nighttime) and an AERONET sun photometer on the next day (adopted from [2]). GRASP results are shown for 7 wavelengths (1640 nm is out of range) as mean of several photometer scans.

2. A new scattering laboratory

The overarching goal of OLALA is the fundamental understanding of the optical properties of mineral dust (regarding the backscatter) needed for global observations with active remote sensing from ground and space. A new laboratory will be constructed to measure the depolarization ratio of size-selected natural dust samples at 180° backscatter angle at the relevant aerosol lidar wavelengths of 355, 532 and 1064 nm. The depolarization ratio of mineral dust particles in the backscatter and near-backscatter direction was addressed previously by [8–11]. However, none of these studies could address the wavelength of 1064 nm, some studies have not reached the exact backscatter [8,9] or could apply a sophisticated size selection. The novel approach of using size-segregated dust samples (up to 5 µm in diameter) will allow us to study the influence of the particle size on the spectral depolarization ratio. Dust samples were collected in Central Asia, the Sahara, the Eastern Mediterranean and Australia. However, some first tests are planned to be done using ammonium sulphate and Arizona Test Dust. The laboratory investigations will provide information on the particle size, shape and refractive index from additional microscopic studies which are important input quantities in optical particle shape models.

Currently, we are setting up the laboratory by constructing the optical setup and transforming the aerosol generation unit from the Leipzig Aerosol Cloud Interaction Simulator (LACIS) [12] to the new needs of OLALA. A sketch of the aimed setup is shown in Fig. 2. Therefore, only a concept can be presented at the conference.

At first, we want to test at a single wavelength (532 nm) two approaches to get the 180° backscatter: a 50:50 beam splitter and a Faraday rotator. Then, we will extend the setup to use three wavelengths. More technical details and first tests are reported in Esha Sewmal's ILRC contribution [13].

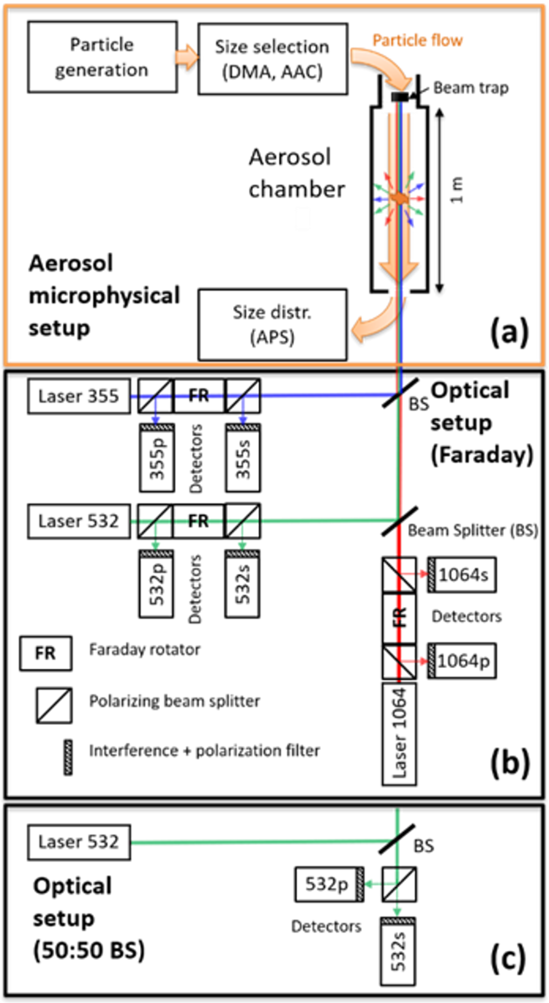

Figure 2 Sketch of the planned laboratory setup including the particle generation unit and measurement path (a) and the optical setup (b,c). The optical setup with the Faraday rotators is shown in (b) for all three wavelengths. (c) depicts the optical setup with the 50:50 beam splitter (BS) for a single wavelength. The scattering at a dust particle is visualized in the center of the aerosol chamber. DMA – Differential Mobility Analyzer, AAC – Aerodynamic Aerosol Classifier, APS – Aerodynamic Particle Sizer.

3. Benefits for lidar applications

The laboratory is strongly linked to lidar field observations by PollyNET [14], e.g., the new Polly^{XT} lidar on Cabo Verde with the capability to observe the backscatter and extinction coefficient and the depolarization ratio at 355, 532 and 1064 nm (3+3+3 data set, [15]). The knowledge about the effect of particle size, shape and refractive index on the spectral slope of the particle linear depolarization ratio gained in the laboratory will be applied to the field observations. A better understanding of the irregular shape of mineral dust particles will improve retrievals of size and particle number concentration from global lidar observations from ground and space, especially for multiwavelength polarization observations which become more frequent in recent times. Furthermore, the laboratory results will help to harmonize long-term observations of mineral dust at different wavelengths from CALIPSO (532 nm, linear depolarization ratio), Aeolus

(355 nm, circular) and EarthCARE (355 nm, linear).

4. Improvements of optical models

The OLALA project will substantially support the dust optical modelling by developing realistic size/shape parameterizations. The realistic shape parameterizations for mineral dust which will be developed within the project from the laboratory efforts will lead to more representative particle size distributions estimates (e.g., fine and coarse mode distribution), mass concentrations and aerosol typing from active remote sensing with lidar.

There are numerous optical models available [16–20]. We plan to match our observations with the widely-used spheroids [16], the irregularly shaped particles by Gasteiger et al. (2011) [17] which were already successful in explaining field observations and the newly proposed hexahedra by Saito et al. (2021) [18] which allow the treatment of large dust particles. However, we are open to apply further particle shape compositions that might fit better both the optical and physical parameter of real dust particles.

5. Acknowledgments

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6. References

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