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## **Promising instrument, deserves a better presentation**

Anonymous Referee #2

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Referee comment on "Polarization lidar for detecting dust orientation: system design and calibration" by Alexandra Tsekeri et al., Atmos. Meas. Tech. Discuss.,  
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The article by Tsekeri et al describes an innovative lidar system (WALL-E), able to probe dust particle orientation by measuring the off-diagonal elements of the backscatter matrix. The lidar comprises two lasers and two telescopes, each featuring 2 channels. The full overlap between the emitted beam and the received field of view is achieved at a range of 400-600 m. One laser is linearly polarised whereas the second one is elliptically polarised, and both emit at the same wavelength (1064 nm). One telescope is equipped with a beam splitter permitting to measure two linearly polarised channels, whereas the other one permits measuring two circular polarisations. The article describes the system layout and provides photographs of its main components: the optical head, the positioner, and the electronic compartment. Moreover, the measurement strategy is illustrated and the equations governing the system are provided. Finally first measurements are shown, for the case of a dust event in Athens, where particle orientation was not observed.

I feel that the new system can become a game changer in the field of dust remote sensing, able to provide us with very interesting insights in the coming years, around the debated hypothesis of dust particle orientation, and for this reason the article merits publication. On the other hand, I believe that it needs major improvements, in terms of a presentation more oriented towards atmospheric scientists which are not necessarily experts in optical systems.

The main issue for me is that the largest part occupied by the development of the mathematical formulas. Whereas these equations are very important, in my opinion the article that explains them should mainly speak the language of the atmospheric sciences. I would suggest rewriting the text in such a way that the main principles governing the instrument are explained in words to the reader, with the equations relegated to one of the sections not taking up more than 20-30% of the paper. A scientist wishing to skip this section for brevity, should still be able to understand the article. I would also suggest: on one hand, to simplify the math where possible, and on the other hand to expand on the non-mathematical parts.

Note that due to the complexity of the math on one hand, and to the ambiguity of some of the quantities used (see e.g. below about angles) I am unable to check these mathematical equations. Moreover, as I have mainly dealt with simpler optical systems in the past, I suggest to the editor to find an expert on light polarisation to check them.

Papers by Daskalopoulou (2020) and Tsekeri (2021) is mentioned, however they have not been submitted yet. I suggest that the main learnings from these papers should be summarised here in the mean time, and/or that a preview should be provided for the reviewers and the colleagues taking part in the interactive discussion.

The introduction should place the research into context more. At present, the general presentation of the atmospheric science problem on dust orientation is discussed in the first 10 lines, and I believe that the topic deserves more, together with previous observations and to hypotheses on why it is believed to happen (e.g. dust electrification). See e.g. Nicoll et al (Env. Res. Lett 2010), Merrison et al (Plan. Sp. Sci. 2012), van der Does (Sci. Adv. 2018), Toth III (Atmos. Chem. Phys. 2020), Mallios et al (J. Aer. Sci. 2020, 2021). The topic of mineral dust in general could also be introduced before discussing the specific topic, citing a number of articles (easy to locate as there is plenty of literature), and mentioning the main points that need investigation (composition, particle size and shape, transport mechanisms, gaps in the observations, radiative effects, etc.) and the main methods used (in situ, remote sensing, modelling, etc.). The main applications of this research could also be mentioned.

There are some points which are unclear as well, and I suggest could be more explicitly be clarified, e.g. is the lidar a scanning one? It sounds like yes at the beginning, but later on there is a sentence about not using any moving parts. What is the preferred viewing geometry and why? Is the orientation controlled through a stepped motor, or is it manual?

Angles are expressed with respect to the horizon, but to the reader it is not fully clear what this means: it seems to make sense perhaps for a horizontal observation but not e.g. for a zenith geometry. I admit that I got lost with the different angles expressed in the article and that it should be made clearer every time what are the two planes between which an angle is measured.

The hardware set-up of the receiver could probably be better illustrated with a drawing than with Figure 3.

The function of some units of the hardware (LPC, precipitation sensor, UPS) is leaved implicit. I believe it should be explicit (e.g. "detection of precipitation causes shutdown of the lidar", "UPS can keep the system running for X hours in case of power failure", "the purpose of LPC is XXX", etc.). You also mention shutting down the lasers in case of emergency: what type of emergency and how is it detected?

In general the reasons behind the design choices could be given: why two telescopes and not e.g. a single telescope with a more complex optical system behind, allowing the same states of polarisation to be measured? Why does the second laser emit elliptically polarised light and not circular polarised, and how is the optimal polarisation ellipse chosen?

First measurements are shown very briefly and they show that the system works, but the case study chosen does not allow to highlight particle orientation (the main goal of this new instrument). I would support Anonymous Referee #1's suggestion that it would be useful to show an example where particle orientation is observed (not necessarily dust if an example has not yet been identified).

Finally, the 1-page long overview and future perspectives section is merely a summary of the article followed by a brief description of future plans. I believe that it would be useful to tie the research more widely to the wider field of research, going back to the main questions raised in the introduction and explaining how you are contributing to answer some of them. This section could be completely rewritten.

All in all, I feel that this paper is still immature for publication in the way that it is presently written, and that it is not yet ready for a detailed revision. I suggest a major rewriting along the above suggestions before I can seriously review it. As the new lidar system presented is very innovative and will certainly yield innovative results, I suggest that it is worth doing an additional effort into presenting it. I also suggest the editor to find an expert on light polarisation and Stokes vectors to review the equations.