Review report for manuscript amt-2020-487

A new lidar design for operational atmospheric wind and cloud/aerosol survey from space

Didier Bruneau and Jacques Pelon

General comments:

The manuscript by Bruneau and Pelon reports a novel spaceborne wind lidar scheme for potential Aeolus follow-on missions. The proposed wind measurement principle relies on a single Quadri-channel Mach-Zehnder (QMZ) interferometer which allows for relaxed operational constraints and reduced measurement bias compared to the receiver concept based on Fizeau and Fabry-Perot interferometers that is currently implemented in the Aeolus instrument. In addition, the new design offers the capability to retrieve cloud and aerosol properties. The article discusses the optimization of the key system parameters of the QMZ and provides a simulation of the systematic and random errors, demonstrating that they are compliant with the Aeolus mission requirements.

The direct-detection wind lidar technique based on a QMZ interferometer was already described in several previous publications, primarily by the two co-authors and colleagues. In the present manuscript the concept is revisited in the context of Aeolus and its mission requirements. In this respect, the study contains novel aspects and is certainly of interest to many readers in the space-based remote sensing and Earth observation communities, particularly given the current discussions about potential Aeolus follow-on missions. The results of the simulations that were carried out to estimate the performance of horizontal wind speed and particle backscatter and extinction measurements under different atmospheric conditions are conclusive. However, a further substantiation of the performance estimations based on atmospheric measurements from the airborne LNG instrument which also relies on the proposed design is only briefly indicated and should be elaborated in more detail (see specific comments below). The manuscript is well-organized and carefully written. The derivation of physical relationships used in the simulations are concisely presented in the appendices. Overall, the quality of the manuscript is very good and, upon addressing my comments, I recommend it for publication in AMT.

Specific comments:

1. An article by Stoffelen et al. (Bull. Amer. Meteor. Soc., 101, 2020) on the requirements and capabilities of future satellite-borne wind observations was recently published. As the study, amongst others, discusses the way forward toward an operational wind profiling mission, its conclusions should also be considered and referenced in the present manuscript.
2. In the entire paper and especially in the introduction, I am also missing a reference to the Optical Autocovariance Wind Lidar (OAWL) developed by Ball Aerospace (Tucker et al., J. Atmos. Ocean. Tech., 35, 2018), although the citation is included in the reference list. The OAWL instrument also relies on a quadrature Mach–Zehnder interferometer and thus represents a very similar concept as the one described in the manuscript. Therefore, I suggest expounding on the advantages and disadvantages of the proposed lidar design compared to the OAWL system.
3. Page 5, line 152: Please clarify what is meant by off-axis MI interferometer. Otherwise many readers might be lost in the following section.

4. Page 7, lines 202 ff.: The proposed design envisages the use of multimode fibers for guiding the signal and reference beams to the receiver. What is the expected signal loss introduced by the fibers? Do the authors expect speckle noise to be an issue for the measurement accuracy? How is the mode scrambler realized and what is its expected transmission based on the experience with the LNG?
5. Although the theoretical error estimation yields convincing results, it would be desirable if the authors could add some experimental results from the LNG to support their theoretical findings. Is it possible to transfer the results from Bruneau and Pelon (2015), particularly in terms of the SNR and the impact of solar background, to the proposed spaceborne lidar in order to estimate the systematic and random wind and backscatter ratio errors based on actual atmospheric measurements? In the discussion chapter, the authors state that "a better overall performance is expected to be achieved as based on realistic parameters derived from airborne operation with a minimized risk and increased design compactness and reliability". At the end of the conclusion chapter, it says "The performance analysis on the QMZ interferometer is supported by measurements performed in the frame of the UV HSRD-LNG airborne lidar developed and operated by LATMOS." Could they please elaborate on these statements?
6. The quality of the figures should be improved. In particular, the resolution of Figs. 3 to 11 is rather low which makes it difficult for the reader to get the details of the plots.

<u>Technical corrections:</u>

1. Abstract: "ADM-Aeolus was successfully launched in 2018, after the technical issues raised for the lidar development **had** been solved, […]"
2. Abstract: "The study of the random **and** systematic errors arising from the uncertainties […]".
3. Page 2, line 39: "The feasibility of such heterodyne **systems** operating on particle scattering was discussed for long in the community […]".
4. "For the Aeolus mission, a technique combining two interferometers in cascade, **one matched to the narrow aerosol spectrum (Mie channel), the other matched to the broad molecular spectrum (Rayleigh channel)** was chosen to be implemented in the space-borne Atmospheric LAser Doppler INstrument (ALADIN) […]". The backscattered radiation is first directed to the Mie and then to the Rayleigh channel, readers might interpret a wrong order of the cascade.
5. Page 9 Table 2, line 3: "pla**nn**ed".
6. Page 9, line 239: HSR instead of HRS.
7. Page 10, line 244: "A quarter-wave plate is inserted in one arm of the interferometer and polarizers at its output **to** separate the signal in four interference components in phase quadrature."
8. Page 11, line 264: "Thanks to the mode scrambler these images are well defined **disks** of homogeneous illuminations."
9. Page 11, line 265: "They **are imaged onto a 16 by 8 pixels area** of the A-CCD image zone in the same way as the Rayleigh channel of ALADIN." The two spots of the ALADIN Rayleigh channel are contained in each hemisphere of the 16 x 16 image zone of the ACCD. However, it should also be noted that the spot width (FWHM) is below 2 pixels so that only a small portion of the hemisphere is illuminated.

10. “Prior to processing actual atmospheric signals, it is necessary to perform a calibration of the MZI for determining the transmission and modulation factors $\boldsymbol{a_i}$ **and** $\boldsymbol{M_i}$ **of** the MZI defined in Eq. (1).
11. Page 14, Eq. (3): The lower bound of the integral should read R – δR/**2**.
12. Page 18, line 445: “In presence of a cirrus cloud the wind speed accuracy is improved to a fraction of ms^{-1} **due to** the increased signal return and interference modulation.”
13. In general, mathematical symbols used in the main text and the Appendix should be typeset in italics in order to be conform with the style guidelines.