Review of manuscript amt-2020-487 –ATC1

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

By Didier Bruneau & Jacques Pelon

Summary and General Assessment

This paper builds on the decades of work performed and published by the authors (and their colleagues) on using Quadrature Mach Zehnder interferometry for wind and aerosol lidar systems. The paper represents an update on the QMZI approach and how it may provide an alternative to the Double Edge Fabry Perot an Fizeau spectrometers used on Aeolus, to simplify the mission, potentially without making many changes in other areas. Using a radiometric model and interferometer receiver model, the authors demonstrate optimization of the system for full tropospheric coverage, resulting on a QMZ design with 3.2 cm OPD to optimize fringe contrast (and thus optimize wind retrievals) from molecular backscatter. The modeling approach is validated using a slightly different design on demonstrated on an airborne platform.

The paper has several appendices, making for an extensive paper, however much of the content has been presented in previous publications and is provided for ease of reference. The new section on comparing the HSRD-LNG system to performance studies is important, though there are some new questions regarding the comparisons (see detailed comments).

The paper points out important advantages of the QMZ approach (e.g., a reduced need for frequency stability, high efficiency/optical throughput, and high angular acceptance/field of view) and its potential value for future wind mission systems. With minor edits, as listed below, I recommend this paper for publication in AMT.

General Editorial Suggestions

The figures have been improved in this version and include legible text, and references appear to have been fixed. The paper does still contain some confusing wording and sentence structure that would benefit from editing by a native-English speaker. In case this is not feasible, and because AMT will not provide such editing, some additional suggestions have been provided here (but no effort is made to maintain the symbols/subscripts).

Technical Comments

- Line 75: Is this really the first airborne HSRL? Sroga, Eloranta, et. al., 1983 - (airborne HSRL demonstration in 1980). Also see Shipley et al. 1983. Also important to recognize the work of Eloranta et. al with NCAR –the (HIAPER) GV-HSRL system.

- Line 77-84 – this addition of more background information on the LNG is quite helpful, especially on connection with the new Appendix C.

- Lines 270-274: The cat-eye arrangement described in Tucker et al. 2018 (based on Wang et al. 2000) provides an 8 mrad FOV for a QMZ with a 90 cm OPD (challenging for a solid MZI) ; and the description indicates it does not require delicate mechanical stability for the same reasons that QMZs do not require delicate laser frequency stability if one is capturing the reference phase.

  Suggest replacing:

- "An alternative design of a field-compensated MZI is given by the cat-eye arrangement (Tucker et al., 2018). This fully reflective design eliminates the light path through the glass which can cause a wavefront distortion but leads to a bulkier arrangement which requires a delicate mechanical stability. Additionally, as discussed in section 3.4, an all-prism MZI design with a small OPD can achieve high quality and the thermally induced wavefront distortion can be easily controlled."

with

- "An alternative approach to field-compensating an MZI is to use cat-eye arrangement as demonstrated for a 90 cm OPD in Tucker et al., 2018.**"**

- Line 412-419: While this new discussion on speckle is highly useful, it appears to interrupt the discussion on sampling and accumulation. Perhaps move it to just before the line starting with "Appendix C shows measurements performed with…."
- Line 423: Regarding this sentence "The signals are summed on 14 elementary samples corresponding to a total of Ns=700 shots for an observation horizontal resolution of 50 km" –
  - What is an "elementary sample" – this appears to be the first mention of the term. Some readers might understand that it refers to a 50 shot ACCD accumulation, but please clarify.
  - Assuming that elementary samples refers to sets of 50 shots (0.5s accumulations at 100Hz PRF), then if the signals are summed over that time (14 x 0.5s = 7s) does the laser frequency actually need to be stable over 700 shots (7 seconds)?
  - Perhaps the word "summed" could be replaced with "reference phase adjusted and accumulated" ?
- Figure 4: While two of the figure subplot titles now list the wavelength in their title, it would still be helpful to indicate the wavelength (for all the profiles and subplots) in the figure caption.
- Lines 543-545: The second half of the sentence is unclear: "… but in regions where the aerosol load is significant ($R_{\tilde{\omega}} \geq 2$) the contributions of the uncertainty on βmol and Mmol are of the same order of magnitude" The contributions of which uncertainty on Bmol and Mmol are of the same order of magnitude? Do the authors mean to say "…but in regions where the aerosol load is significant ($R_{\tilde{\omega}} \geq 2$), contributions to the total error from uncertainty in βmol and Mmol are of the same order of magnitude."
- Appendix C: It is important that that authors have added a new section to show validation of the instrument performance model.
  - Regarding Figure C1b - Is the standard deviation (sigma) estimate (provided in equation A-17) a minimum sigma, or a lower bound on sigma? If so, how is it that the measured sigma is sometimes lower than the calculated sigma? Wouldn't one expect that with the added natural atmospheric variability, the measured standard deviation would always be larger than the model?
  - Line 808: The equation A-17 used in the comparison shown in Figure C1b does not include "N" (number of shots, number of samples) used in the estimate. What parameters were used in A-17 for SNR, Mo, Matm, and how were the accumulations accounted for in the measurements vs. the model? This can probably be addressed with a few simple parameters including SNR, Mo, and Matm used in A-17, as well as a 1/sqrt(N) factor to account for the various pulses used in the estimates.

- If the authors are short on room, the authors could remove lines 814-833 and just reference the Bruneau 2015 (or 2020 conference paper "Operation of the airborne 355 nm high spectral resolution and doppler lidar LNG) instead. Unless perhaps other reviewers have requested validation of the general QMZ approach It's not clear that the newly added radiosonde comparisons for the airborne campaign are critical to the main paper.
- Figure C3: like for Figure C1b, it's unclear how the measured standard deviation can be smaller than the ideal calculated standard deviation unless the calculation is itself based on an uncertain variable (e.g. SNR?). Which parameters

General English editing/grammatical suggestions

- Lines 19-21 – still some grammatical confusion in the abstract, suggest the following for this sentence: "This ability to profile wind and cloud/aerosol radiative properties enables meeting the two highest priorities of the meteorological forecasting community regarding atmospheric dynamics and radiation."
- Line 22: suggest

  "We discuss the optimization of the key parameters necessary in the selection of a high performance system…"
- Line 31: suggest

  "The chosen design further allows addition of a dedicated channel for aerosol and cloud polarization analysis."
- Line 96: Perhaps replace "take over" with "extend and improve upon" (if indeed it will improve)
- Line 103: remove the comma after "2", "in section 2 we…"
- Line 120: replace "reading noise" with "read noise"
- Line 121-122: suggest replacing
  - "but the interferometer configuration has revealed operation and performance constraints proper to the choice made"
    with
  - "but operation has revealed performance constraints set by the Rayleigh channel fabry perot interferometer designs and configurations."
- Line 170: Remove "besides"
- Table 2 caption:
  - Suggest replacing "Parameters are compared to Aeolus ones as a reference actual in space values reported by Reitebuch et al., 2019"
  - With "Parameters for the proposed system as compared to those from the on-orbit Aeolus, as reported by Reitebuch et al., 2019."
- Line 235: Replace "consists in two lenses,…" with "consists of two lenses,.."
- Line 285: Replace "a 8x8 pixels area" with "an 8x8 pixel area"
- Line 338: Replace "…leads for the chosen parameters" with "…leads to the chosen parameters"
- Line 409: Replace "reading noise" with "read noise"

- Line 410: Replace “that add” with “that adds”
- Line 442: Replace “similar to that used” with “similar to those used” as it refers to multiple equations used.
- Line 521: suggest: “The particle backscatter and extinction retrieval (Eq. A8 –A10) requires ~~the~~ knowledge of βmol and Mmol.”
- Line 538: suggest replacing
    - “Note that the wind speed variation or turbulence in the probed volume can induce a variation in Mpar. With a Doppler shift of 5.6 MHz per ms-1 the broadening of the particle backscattered spectrum is very small as compared to an emitted linewidth of 100-200 MHz and the incidence on Mpar is negligible. We can then consider that Mpar is not affected by the atmospheric conditions”

      With

    - “ Note that wind speed variation or turbulence in the probed volume could slightly reduce Mpar, however with a Doppler shift of 5.6 MHz per ms-1 the broadening of the particle backscattered spectrum is much less than the emitted laser linewidth of 100-200 MHz, and thus the impact on Mpar is negligible. We therefore consider that Mpar is not affected by the atmospheric conditions.”
- Line 547: suggest replacing “quadratically added to…” with the common term “root square summed (RSS) with…”
- Line 621: suggest replacing “Unlike usual HSRL…” with “Unlike the usual filter-based HSRL…”
- Line 647: replace “similarly to” with “similar to”
- Line 670-671: replace “meteorological analyzes” with “meteorological analyses” (analyses being the plural of analysis).
- Line 790: suggest replacing
    - “With our instrumental parameters we have finally a the residual wavefront distortion σRMS = 3.7 10-2 nm due to the field compensation”

      with

    - “With our instrument parameters we find a residual wavefront distortion of σRMS = 3.7 10-2 nm due to field compensation.”
- Line 800: suggest replacing,
    - “allowing to obtain several LOS measurements at various levels in the cloud, 800 allowing to perform a velocity azimuth display …”

      with

    - “providing several LOS wind measurements at various levels in the cloud, allowing performance of a velocity azimuth display…”
- Line 855: should “6.10-3” be “6x10-3”?