Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2017-437-RC2, 2018

Atmospheric Measurement Techniques Discussions

Interactive comment on "A highly miniaturized satellite payload based on a spatial heterodyne spectrometer for atmospheric temperature measurements in the mesosphere and lower thermosphere" *by* Martin Kaufmann et al.

Anonymous Referee #2

Received and published: 19 February 2018

This manuscript describes the optical design, radiometric characterization and calibration of a CubeSat-sized limb sounding instrument for measuring temperatures in the Earth's mesosphere and lower thermosphere using emission from the oxygen A-band. The instrument is a field-widened Spatial Heterodyne Spectrometer (SHS) with an effective spectral resolving power of 8000, an altitude resolution of 1.5 km on the limb over a 60 km field of view. My overall impression of the manuscript is positive. It provides sufficient context, a clear description of the work done and analysis of the results. That said there are a few issues that should be addressed to clarify the manuscript.

Specific Comments:

- The diffraction grating groove density (or equivalently, groove spacing) is missing from equation 1.

- The paragraph following equation 4 suggests that "the effective spectral resolution or bandpass is often limited by the detector resolution". Although the bandpass is limited by the detector resolution, as indicated by equation 5, the spectral resolution is not. The spectral resolution is independent of the detector resolution as it depends on two things: 1. The path difference provided by interferometer (as correctly captured in equation 4) and 2. any apodization functions applied to the interferogram.

- The final paragraph of section 3 indicates that the design of the instrument was performed in a collimated configuration. I assume this to mean that only incident rays parallel to the optical axis were used during the optimization of the design. It would be useful to indicate the effect of converging ("focused") beams on the interferogram. Is there any reduction of contrast of the fringes, especially at the edges of the field where the path difference is largest, due to the addition of the off-axis rays? Figure 6 and surrounding discussion suggest so.

- The description of the front optics in section 4 and table 1 indicate that the image of the limb formed on the grating plane is a circle of diameter 7 mm. If the image is circular, the highest and lowest altitude slices at the top and bottom of the image will suffer greatly reduced spectral resolution as they only sample a very small range of the interferometer aperture and only near zero difference. These altitudes will also have significantly reduced etendue due to their small spatial extent. To achieve uniform spectral resolution and etendue for each altitude slice the limb image on the grating and ultimately recorded at the detector should be rectangular as indicated in figure 4. It appears from Figure 5 that there is nothing in the entrance or exit optics that will result in a circular field and is reality limited by the grating or detector, both of which are presumably rectangular.

- The final paragraph in section 4 suggests that a simulation using focused light indicates a reduction of fringe contrast near the edges of the image where the path difference is large. It would be helpful to indicate by how much the contrast is reduced. A plot of intensity vs pixel for a slice through the image shown in figure 6 which shows the fringe reduction would quantify this statement.

- The discussion section 5 of the effect of dark current on the measurement is confusing and on its surface appears to be wrong. It is stated that the dark current at 20 deg C is a factor of 2.4 larger than the maximum atmospheric nighttime signal it does not significantly affect the signal because the multiplex noise is a factor of 5 – 10 larger. I don't believe this is the case with the spatially sampled interferogram obtained with SHS. From a noise perspective signal and dark generated electrons are equivalent so if the total number of photons detected in the signal is less than the total dark signal (either on a pixel by pixel or entire detector basis) the noise from the dark signal will dominate. As the authors point out, cooling the detector can reduce the dark signal. It would seem from the discussion that if the dark noise were to be made comparable to the maximum signal, the detector should be cooled to about 10 deg C.

- The discussion in section 6.2 on image and phase distortion correction was confusing. I agree in principle that by measuring the fringe pattern at all wavelengths in the passband of the instrument, corrections for exit optics induced image distortion, which displaces each image point by a fixed distance on the detector, and interferometer induced phase distortion, which changes the phase of a fringe by a fixed amount can be obtained. Note that phase distortion shifts the location of, say, a peak of a fringe by more pixels at low spatial frequency than at high spatial frequency while image distortion would shift a peak by the same number of pixels independent of the frequency of the fringe. That said, it is unclear from the discussion how this will be accomplished in practice. Reference is made to fitting a linear or higher order polynomial correction term to each row, however it is not clear what would be fit: phase?, visibility?, brightness? something else? More discussion here would be helpful.

- Figure 7 and surrounding discussion suggests that an improvement of factor of 2 in noise performance over conventional FFT methods can be achieved by utilizing a-priori information in the fitting process. There isn't enough information in the manuscript to evaluate this technique, however, reference is made to a manuscript in preparation describing the technique and its application to SHS. I look forward to reading this manuscript.

- Both the abstract and conclusions suggest that the instrument can deliver a 1-2 K temperature precision for a one-minute nightglow observation and a few seconds during the day. I would have liked to have seen more support for this statement in the manuscript.

Technical Corrections: - The figure 4 caption indicates that the figure will be updated. Has it?

- There are two missing "C"s to indicate degrees Centigrade in the text immediately following figure 4.

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