Response to Reviewer 2

Please find the original comments of reviewer 2 in black and our replies in green.

This paper presents an open-path dual-comb spectroscopy system based on commercial frequency combs. The system was deployed to measure CO2 (and CH4) across a 3.1 km round trip path in Heidelberg. The system was operated for 6 months with high uptime. The sensitivity of the system is comparable to or better than previous demonstrations. A particularly interesting/novel aspect of the study is the direct comparison to a co-located open-path FTS running over the same path. The paper shows a remarkably good agreement between between the DCS and the FTS, with the DCS providing an order of maginitude better sensitivity. Overall, the paper is well written and suitable for publication in AMT. I do have some minor comments/corrections:

Reply: *We thank the reviewer for the overall positive review. Please find our point by point replies below.*

1. The Mead et al ref used mid-infrared DCS and detected ethane and propane as well as methane. As such, the citation location is not completely appropriate. It would be better to either cite after Giorgetta 2021 (line 59) or at the end of the oil and gas section as an extension to the mid-infrared.

Reply: *We agree and changed the placement of the reference accordingly.*

2. What dfr was used? Are the combs locked to have an integer number of points per interferogram?

Reply: *We thank the reviewer for catching this oversight on our part, since we have not reported the repetition rate difference of about 50 Hz. The combs are not locked to an exact integer number of points per interferogram. We further comment on the resulting implications in our reply to point 7.*

3. What is the transmitted beam diameter? Is it a collimated beam? I could not tell from Fig 2

Reply: *The transmitting optics are of 2-inch diameter, with the off-axis parabolic mirror collimating the beam at a $1/e^2$ diameter of 12.8 mm. So, yes, the transmitted beam is collimated, but with a Rayleigh range substantially below the kilometer distance. As a result (and as a result of atmospheric turbulence) the received beam is substantially wider. We extended the caption of Fig. 2 to better explain this.*

4. Did you use any active transceiver alignment feedback? Is the transceiver located outside or in a building?

Reply: *We did not use any active transceiver alignment. The transceiver is located inside, the reflector array outside. We added that to the manuscript.*

5. Did you try a single retroreflector instead of an array? If so, how different was the return power? Do you see any issues in the interferogram or measured spectrum due to the multiple reflectors?

Reply: *We did not. But we recently switched to an array assembled from gold-coated hollow cube corners, which improves return power significantly. As far as we can tell, there was no loss of modulation efficiency or similar effects in the interferograms as the result of using an array.*

6. What are the integrated phase noise numbers on the comb locks?

Reply: *According to the commissioning documentation, the single sideband integrated phase noise of the carrier envelope offset frequency is about 70 mrad and 76 mrad in a 100 Hz to 2 MHz interval for the two combs respectively. For the beating frequency with the reference laser, the integrated phase noise is 41 mrad in a 100 Hz to 2 MHz interval for both combs. Sporadic, quick re-measurements of these values with a spectrum analyzer resulted in similar values. Since we measure close to the mutual optical reference, the CEO lock is less relevant and the high frequency phase noise is dominated by the optical beat lock and the relative phase noise of the two combs ($\sqrt{2}\times 41$ mrad ≈ 58 mrad).*

7. When co-adding the interferograms, do you do a phase correction between interferograms? If so, could you provide more information about how this is done? Is it a single phase per interferogram, or a phase and timing correction (e.g., phase and spectral phase slope)? Related to question 2, are the interferograms resampled, or are there already an integer number of points per interferogram?

Reply: *The interferogram is not an exact integer number of points. We neither resampled the interferograms nor used a full phase correction algorithm.*
Regarding the averaging procedure: both combs share the same CEO frequency, so the relative carrier–

envelope phase slip between consecutive interferograms vanishes and the carrier position is fixed with respect to the envelope. Centering on the maximum of the interferogram is therefore unambiguous and simultaneously acts as a first-order carrier-phase correction. Since the correction is applied by shifting whole samples, it is quantized: with approximately 13 samples per carrier period, one sample corresponds to $2\pi/13 \approx 480$ mrad. As the interferogram is not an exact integer number of points, the position of the center burst within a sampling interval varies between interferograms, and we conservatively assume it to be uniformly distributed, which yields a residual phase fluctuation of approximately $480 \text{ mrad}/\sqrt{12} \approx 140$ mrad. Adding the estimated phase noise from the locks in quadrature gives approximately 150 mrad, corresponding to a modulation efficiency of about 99%, an order of magnitude below the ~1.4 rad at which the fringe contrast would drop to 1/e, which is often given as the coherence limit. We observed no degradation of fringe contrast or signal-to-noise ratio over the averaging times used in this work. We have added a corresponding discussion to Section 2.

8. For the spectral retrievals, was the FTS data fit with the same spectral parameters?

Reply: *Where the spectral coverage overlaps, the spectral parameters were the same. Where the FTS instrument had additional spectral information, we used HITRAN2024. We made this more explicitly clear in the manuscript.*

9. I was a bit confused about the uptime numbers. The abstract lists an 85% uptime; however, later a number of 76% is also given. What is the difference between these two numbers?

Reply: *The quoted 76% references the full reported period, including times where the instrument was not available, because it was used for other experiments. The 85% references the latter half of the deployment period, where the frequency combs were dedicated to the open-path measurement full time. We used this number in the abstract, because it better reflects the limitations of the method but understand that this is unnecessarily complicated to explain. For the abstract, we have now switched to the 76% for the total period.*