Author's response to Review RC2 by Anonymous Referee #2

We kindly thank the anonymous referee for the helpful comments. In the following, we repeat the reviewer comment in italic font and answer in regular font at points we find appropriate.

This paper mostly presents a theoretical investigation of the applicability of Fabry Perot interferometers (FPIs) for the fast imaging of atmospheric trace gases, of high relevance for the visualization and quantitative assessment of localized emission sources of molecules such as SO2, BrO and NO2. The study is essentially a follow-up from study by Kuhn et al. (2014) already published in AMT and where the principle and advantages of the approach are described. Here, the authors concentrate on simulations aiming at demonstrating the selectivity of the FPI correlation spectroscopy for three potential target gases: SO2, BrO and NO2. In comparison to more traditional atmospheric trace gas imaging techniques which generally only use a set of band pass filters, the FPI correlation spectroscopy is found to be highly selective, allowing to drastically reduce cross interferences with other absorbing species while maintaining high sensitivity. In short, the method seems to be very promising. The approach used for the simulations is convincing and clearly described.

In my opinion, the manuscript is overall of excellent quality, well written and concise. However, the proof of concept presented at the end of the study is a bit disappointing. One would have expected to see first results from real images. Instead only a one-pixel prototype is shown, and only applied to SO2 retrieval (which arguably is the easiest case). It is claimed that the one-pixel prototype can "easily" be transferred in a fullframe imaging instrument, however this is not demonstrated. At minimum, the authors should explain why this transfer was not attempted in the present study and what are the possible difficulties that may need to be addressed.

We were focussing our study on the applicability of the FPI-technique to further trace gases, rather than to the implementation of an imaging prototype (although the latter goal still has high priority in our research). The proof of concept was carried out with a one pixel prototype because it can easily be coaligned with a DOAS instrument for validation and thereby allows straightforward and robust validation of the presented technique.

Despite this weakness, I think that the study remains very interesting, show a good degree of innovation (first demonstration of the potential of the technique for other species than SO2) and therefore it should be published in AMT.

In fact, my only serious reservation, concerns the estimation of the added performance of the FPI correlation spectroscopy in comparison to a traditional hyperspectral imaging system (as used for imaging DOAS). Based on existing CMOS or CCD detectors coupled to grating spectrometers (commonly used in the DOAS community), and assuming hyperpixels of 100 micron size, experience shows that typically 1.5 Me-/sec/pixel can be accumulated in the visible range under normal illumination conditions. On this basis, one can estimate that a full image of 100 x 100 spatial pixels (or even 200 x 200) could potentially be recorded in a few seconds of time (using e.g. an integration time of 50 msec/hyperspectral line) leading to a S/N ratio of approximately 250 (corresponding to a NO2 dSCD uncertainty of about 5e15 molec/cm2). This level of performance is in fact very close to the performance announced in Table 3, and therefore I believe that the factor 100 announced in the text is rather optimistic (at least for a FPI system using a telecentric optics as assumed here). Of course the real proof will have to wait

for actual measurements and I look forward to see more of such measurements being attempted and published in the near future.

We thank the reviewer for this valuable comment. The 'two orders of magnitude' are mentioned in a rough comparison of the BrO simulation results for the FPI technique and an approximate exposure time of a common MAX-DOAS setup (which is not optimised for this kind of imaging measurement). Manago et al. (2018) recently published an article introducing hyperspectral imaging measurements of NO_2. They achieve a detection limit of ~1e16molec cm^{-2} in 12s exposure with a spatial resolution of 480x640 pixels, binned 3 by 3 (i.e. effectively 160x213 pixels). This is indeed only a factor 2.2 slower than we calculated for our telecentric setup for the FPI technique. If we applied the non-telecentric setup introduced in Kuhn et al. (2014) we would increase the light throughput by a factor of 32 and therefore end up with a ~70 times faster setup.

To make this point clearer in the manuscript we made the following changes:

In the introduction, we added the reference of Manago et al. (2018) and the sentence:

'Recently, Manago et al. (2018) reported NO_2 measurements with an hyperspectral camera based on the Imaging DOAS technique with considerably higher spatial resolution (~0.08 Hz).'

We changed the last part in Sect. 3.2 to:

'When comparing to corresponding DOAS measurements the enormous increase of spatio-temporal resolution becomes evident. A state of the art DOAS measurement takes around 1s to reach a detection limit of $1x10^{14}$ molec cm^{-2} BrO for one spatial pixel. To scan the ca. 2600 pixels of the assumed BrO image would take 2600s. This is, however, a comparison with an instrument that is not optimised for this kind of imaging measurements. Manago et al. (2018) recently recorded NO_2 images with a hyperspectral camera, based on imaging DOAS. A detection limit around $1x10^{16}$ molec cm^{-2} NO_2 is reached with a spatial resolution of 480 by 640 pixels and 3 by 3 pixel binning with 12 s $frame^{-1}$. This is only a factor of 2.2 slower than our calculation for the telecentric setup. By applying the standard optics introduced in Kuhn et al. 2014, (i.e. not a telecentric optics), the light throughput is increased by another factor of 32. Therefore, theoretically, the FPI technique can be by a factor of ~70 times faster. Of course this values always depends on the size of the assumed instrument optics.
Our results show that FPI Correlation Spectroscopy can be about two orders of magnitude faster than conventional DOAS measurement while maintaining a similar degree of selectivity and interference suppression.
The presented results of the exemplary calculations for SO_2, BrO and NO_2 suggest that FPI Correlation Spectroscopy can also be implemented for other trace gases with similarly strong and structured absorption, such as e.g. O_3, HCHO, IO, or OClO.'

We also mentioned the above factor of 32 in Sect 4 of our manuscript:

'Alternatively, the FPI could be placed in front of the lens using the full clear aperture and the full aperture angle of the FPI and the optics, increasing the light throughput by a factor of 32 (Kuhn et al., 2014).'