LuftBlick report 2018002

ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study

Report on mFCT design and performance

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Contents

1 Introduction

This report is deliverable D3 of CCN#1 to the ESA Ground-based Air-Quality Spectrometer Validation Network Uncertainties Study project [AD1, AD2]. It describes design and performance test for a mobile field calibration tool (mFCT) prototype. The goal of the mFCT is to be able to perform stability checks or even absolute radiometric calibration on Pandoras in the field. With the mFCT we expect a big step towards the possibility to get AOD with Pandoras since drifts in the absolute calibration can be taken into account without dismounting the instrument.

1.1 Acronyms and Abbreviations

AOD	Aerosol Optical Depth
CCN	Contract Change Notice
ESA	European Space Agency
mFCT	Mobile Field Calibration Tool

1.2 Applicable Documents

[AD1] ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study, ESA contract No. 4000109703/13/I-AM, Dec 2013.

[AD2] CCN1 to ESA Ground-based Air-Quality Spectrometer Validation Network Uncertainties Study [Proposal], Proposal 201705A, Issue 2, 2017.

2 Problems with fiber solution

In the proposal of the Pandonia CCN#1, we envisioned that the mFCT will include a ~1.5m long multibundle fused silica fiber optics cable, which is mounted with an adaptor on the collimator of the Pandora on one side and with a second adaptor to the housing of the lamp. The main reason to use a fiber based solution was that the current trackers are too weak to carry significant weight in addition to the Pandora-2S headsensor. Furthermore, a mFCT with a fiber would be easy to operate in the field. Since it is known that the stability of optical fibers in the Pandoras is very critical, a fiber based mFCT was designed, built, and tested. To get a first idea about the performance we set the mFCT up in the laboratory in Innsbruck and were measuring spectra with the Pandora 110. Because different operators will use the mFCT, meaning the fiber will not always make the same turn between the lamp and the Pandora collimator, we were moving the fiber in a slight circle on both sides, the part of the fiber being closer to the lamp and the part being closer to the Pandora. Measurements have been performed three times with unplugging the fiber on both sides in between. Relative signal changes bigger than 8% appeared for all measurements. After this test we were re-thinking our design and came to the conclusion that we should not use a fiber for the mFCT. We decided to build a system without fiber. In order to do so we needed to support the system to prevent putting too much force on the tracker. This new design is described in section 3.

3 Pandora mobile Field Calibration Tool (mFCT)

The mFCT system consists of:

- 200W lamp with housing and ventilator

- Power supply
- Adapter piece
- Shortened collimators
    - One without filters
    - One with one ground glass diffuser
    - One with two ground glass diffusers
- Shaft to support the tracker

It is designed to be used in a vertical layout (figure 1). All parts of the mFCT, except for the power supply, can be packed into a single cushioned transportation box.

Figure 1: mFCT in operation at the Innsbruck measurements site

3.1 Housing & Lamp

The field calibrator system used is the Schreder KS-J1011 (http://www.schreder-cms.com/en_pdf/KS-J1011.pdf), because of its well known performance. It is a specialized enclosed spectral irradiance standard source for performing absolute calibrations. Properly placed apertures inside the calibrator make it possible to use the system in different distances to any optical detector without stray light problems. The temperature regulation of the housing is based on a 12V DC fan with an included dedicated transformer. The KS-J1011 is fitted with a 200W quartz halogen lamp. In first tests in the field, we noticed that handles on the lamp housing are necessary for easier and safer use. Therefore the KS-J1011 was modified and two handles added (figure 1). Specifications of the KS-J1011 are listed in table 1.

Table 1: KS-J1011 Specifications

Measurements type	Spectral irradiance
Wavelength range	205-2500nm
Lamp	Quartz halogen 200W / 6.3A
Temperature regulation	12V DC fan
Weight	3.7 kg
Size	135x163x260mm
Material	Anodized aluminium

3.2 Power Supply

The mFCT requires a very stable and accurate control of output current during operation in order to have the best measurement stability and repeatability possible. The Power supply selected, because of its good stability, is the Schreder J1017-POWER300 (http://www.schreder-cms.com/en_pdf/J1017-POWER300.pdf). This constant current power supply is specifically designed for stable operation of stabilised light sources and calibration standard sources (e.g. quartz halogen, xenon, Nernst element, etc.). It offers USB and front panel control which is useful for traveling situations and rack mounted setup. The current control is based on linear regulation. High current resolution of 0.2 mA is received with an internal micro controller in combination with a high resolution 16 bit DAC. An individual programmable on/off ramp function guaranties smooth and long operation of calibration lamps. All required parameters are shown on a two-line alphanumeric display. Full remote control is possible with the USB interface. A keypad with 12 buttons allows manual setup of all parameters. The specifications of the power supply are listed in table 2.

Table 2: J1017-POWER300 power supply specifications

Main Voltage	88 to 264 VAC, 47 to 63Hz 125 to 370 VDC
Maximal Output current	6.4 A, d.c.
Maximal output voltage	48 V, d.c.
Maximal output power	300 W @ 46V
Resolution current	1 mA
Resolution curr. setting	0.2 mA
Operation	Current controlled mode
ON/OFF	Ramp function, programmable (60sec)
Interface	USB, Keypad

Display	LCD, 2 lines
Weight	6.3Kg
Dimension	47x15x32cm
Housing	Bench top

3.3 Shorter collimators

In a calibration session, the original Pandora collimator is replaced by shorter collimators, because the field calibration lamp would act as a lever when putting it on the standard Pandora collimator. To be fixed in a robust way, the thread of these adapted collimators is about 6mm deep, which is 4mm more than it is for Pandora collimators (figure 2). Each of these small collimators contains none, one or two diffusers inside and is used accordingly to prevent saturation when measuring the sensitivity of the detector for each filter combination in the Pandora. E.g. if no filters are set in the Pandora filterwheels, the collimator with the two diffusers is needed to prevent saturation even at the lowest integration time for the spectrometer in the visible spectral range.

Figure 2: Shortened collimator

3.4 Adaptor piece

Since we want to touch the system as little as possible between two calibration sessions to enhance the repeatability, we decided to add an adaptor piece to the lamp housing (figure 3). In this way the entire housing can be put over the short collimator. The adaptor piece is directly attached to the lamp and the operator just has to slide the entire unit over the shortened collimator.

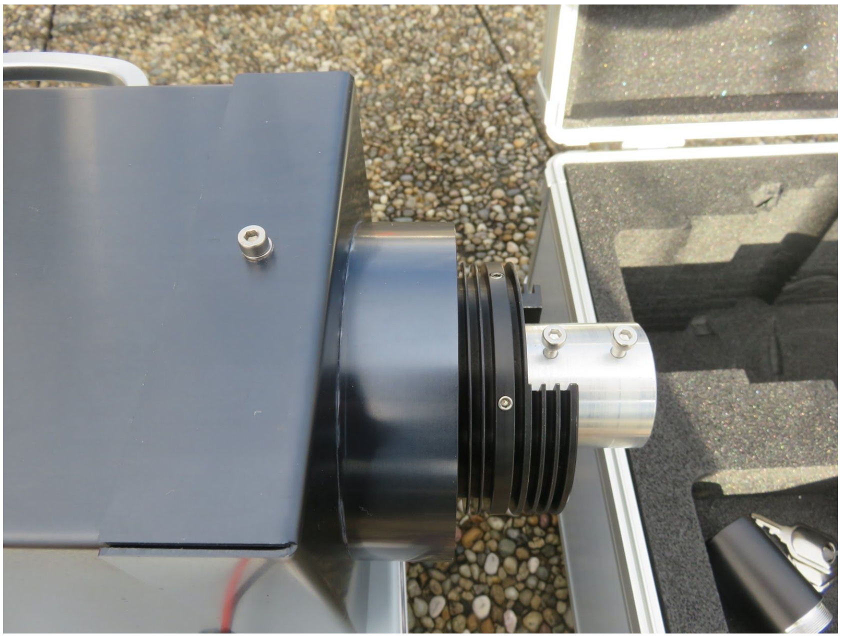


Figure 3: Adaptor piece on the lamp housing, which the operator slides over the shortened Pandora collimator.

3.5 Support shaft

The goal of the support shaft is to hold the Pandora head and the lamp on top in a stable vertical position. This is necessary, since the extra weight of the calibrator puts too much force on the tracker. The support shaft is a threaded aluminum rod, which is placed between the bottom of the Pandora head and the base platform (figure 4). The aluminum rod is placed on the base plate or next to it and its length is adjusted with the thread until it touches the head. Then the tracker is sufficiently supported and the calibrator housing can be mounted.

Figure 4: Pandora headsensor with support shaft.

3.6 mFCT setup

After turning on the power supply and connecting the lamp to it, the power ramp-on is initiated. This gives time to warm up the lamp (it takes approximately 10 minutes) while the system is mounted. The tracker has to be moved to the zenith and the support shaft is installed between the bottom of the head and the base platform as explained in the previous section. Next, the original Pandora collimators are removed and the one of the short collimators without diffuser is screwed-in. Then, the housing is put over the small collimator. Now the calibration can be started running a special routine that measures a set of compatible filter combinations. Since the spectrometer will saturate without external diffusers, the housing is unmounted, the small collimator is replaced by one equipped with a diffuser, and all is mounted again for the next set of filter combinations to measure. Once all filter combinations have been measured in all spectrometers, the ramp-off of the lamp is performed and the whole system is unmounted.

4 Intensity check and stability test

4.1 Signal strength test

Firsts tests have shown that both spectrometers (UV and VIS) are saturating with minimum integration time and no internal filters. The solution is to use external filters (ground glass diffusers) which are screwed into the collimators as explained in section 3.3. The advantage of using three different collimators is that the diffusers are always in the same distance to the light source and the use is fast since you just have to unscrew one collimator and screw in another one. It turned out that one diffuser is enough for the UV spectrometer to not saturate without internal filters and for the VIS spectrometer two diffusers are needed. A strong signal is obtained using the most common filters for sun measurements as seen in figures 5 and 6.

Figure 5: Signal for (left) Spec 1 at Collimator OPEN, Pandora filters ND1/OPEN, T_{int} = 4 ms and (right) Spec 2: Collimator OPEN, Pandora filters ND2/OPEN, T_{int} = 2.4 ms

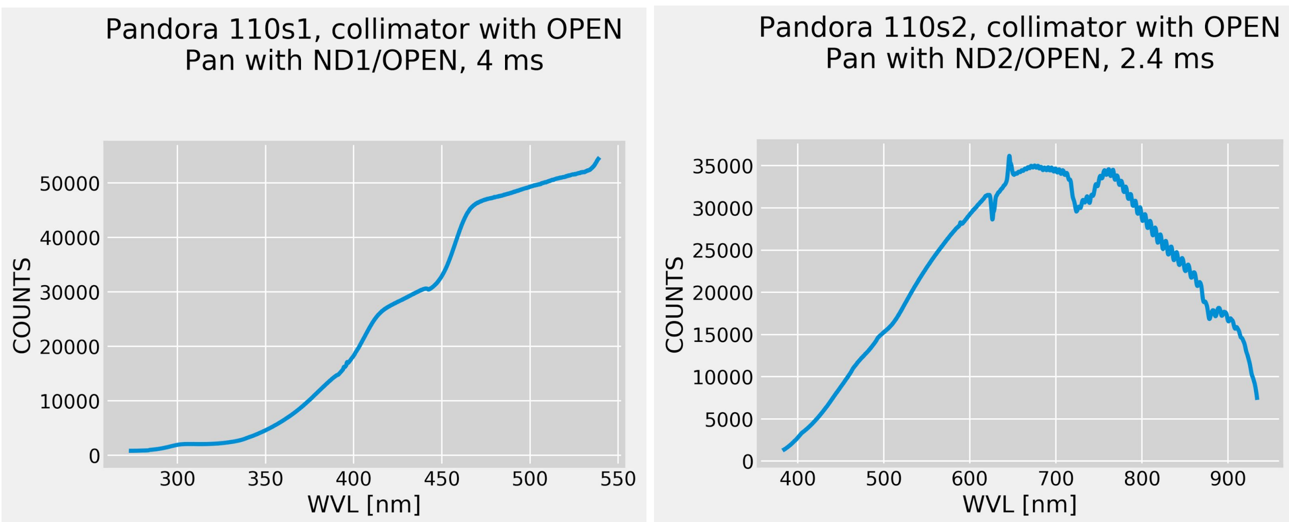
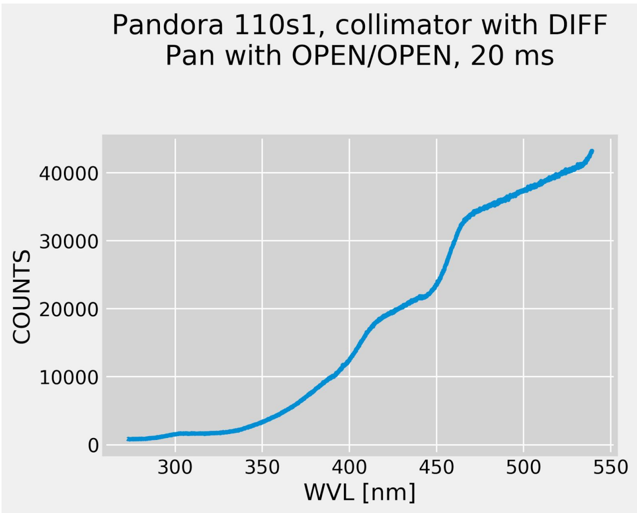
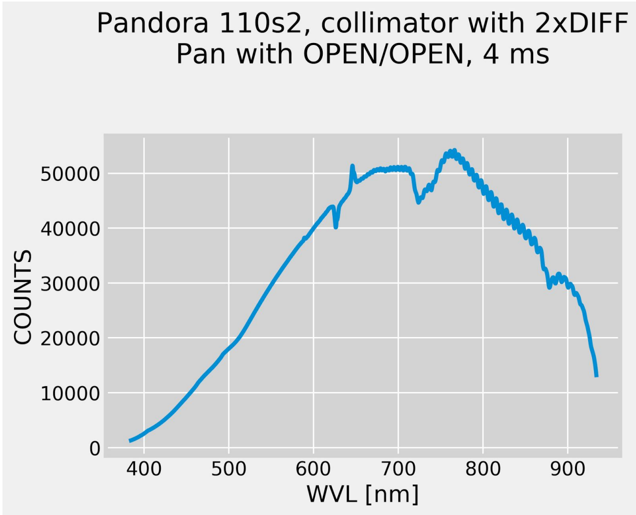


Figure 6: Signal for (left) Spec 1: Collimator DIFF, Pandora filters OPEN/OPEN, T_{int} = 20 ms and (right) Spec 2: Collimator 2XDIFF, Pandora filters OPEN/OPEN, T_{int} = 4 ms

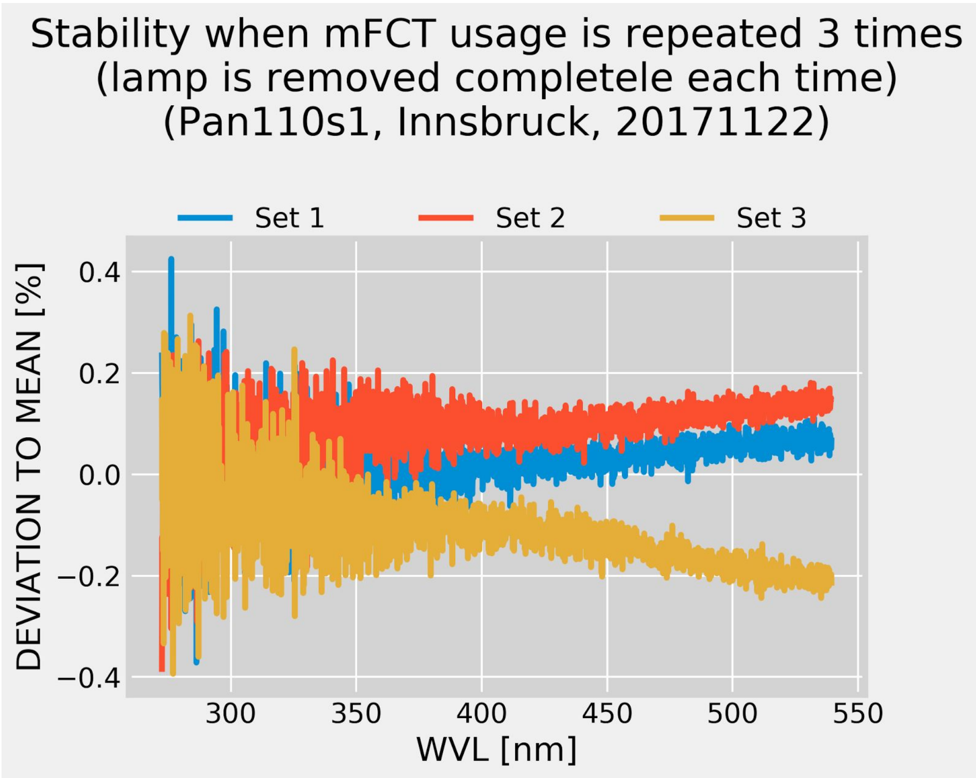




4.2 Repeatability tests without switching off the lamp

In order to test the repeatability of the system, three consecutive mFCT measurements have been performed with the first prototype. Measurements have been taken with the UV channel of Pandora 110 in Innsbruck with unmounting the entire mFCT system each time. The deviation respect the mean measurement was about 0.2% (figure 7).

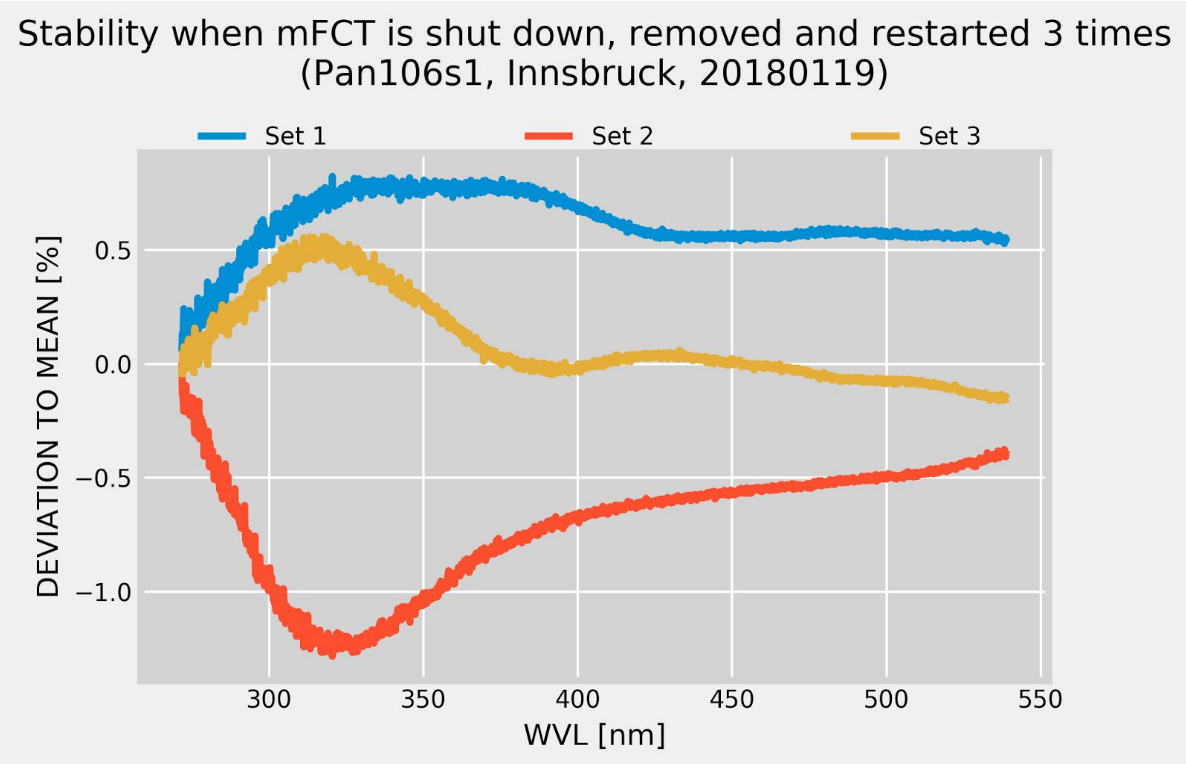
Figure 7: Repeatability test without switching off the lamp



4.3 Repeatability test with switching the lamp off

For the second repeatability test we also have been measuring three times. But between the different measurements, the lamp was switched off, cooled down and we were waiting for half an hour until the next measurement was performed. The deviation to the mean was within ±1.2% which is still considered small enough for our purpose. The measurements of the second tests are less noisy because we were measuring 1000 cycles instead of 100 cycles as in the first test.

Figure 8: Repeatability test with switching off the lamp



5 Conclusions

- The support shaft seems to be a good solution to not put too much force on the current Pandora tracker. With the new tracker the weight of the mFCT will not be a problem anymore. Anyway, the support shaft could be improved with a bigger bearing surface which would make it more stable and easier to use.
- The short collimator with a roughly 6mm thread can maintain the 4 kg calibrator aligned and attached in a vertical position.
- It was a little bit tricky to screw in the short collimator into the Pandora 106 headsensor because the thread of this instrument was corroded. This could also cause that the short collimators of the mFCT are not screwed in until the end of the thread and we would have different distances from the lamp to the entrance window from one field calibration session to another. The solution could be a tapping tool to re-mill the entrance thread of the Pandora headsensor.

- The lamp signal itself is very stable (very good power supply and lamp housing).
- Two handles make the operation of the mFCT also possible on stations which are hardly to access.
- We believe that the heat production/absorption of the lamp housing is very weak, but have not tested this in warmer situations, just in the ~ 5°C ambient temperature during the test in wintertime in Austria. Nevertheless it is known that a similar system has been also used to maintain the Brewer Instruments triad at Izaña without any temperature problems (around 10-20°C ambient temps).
- With a set of three short collimators with none, one and two diffusers included, all radiometric calibration steps can be carried out for both spectrometers in a Pandora-2S model, as well as in a Pandora-1S.
- The reproducibility of the lamp signal was tested to be very good (< 1.2 %)
- In order of having the highest reproducibility possible, a short and comprehensible user manual will be written to go sure the mFCT will always be used in the same way, also if different people are doing measurements.
- The plan is that the entire mFCT can be acquired from a single provider, Schreder CMS, for a total price below 10000 Euro. We are currently in negotiations with about this.

Figure 9: Pandora 106 on the Innsbruck Atmospheric Observatory with the final mFCT prototype. In the background one can see Pandora 119 which is being tested before shipping it to Athens. Right next to the screen there is the power supply for the lamp and right to it is the suitcase in which the lamp with the housing is stored.