Calibration Boxes Data Acquisition and Processing step-by-step manual

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Abstract

This document is intended to give a step-by-step manual to perform data acquisition and processing with the pmd calibration boxes.

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1. Frame grabber configuration

For data acquisition for the steps described in this document, the imager needs to be configured in a so-called “10-phase-configuration”. Here, each frame or “superframe” consists of 10 raw images with different configurations on their own. They can be grouped into four sequences:

Sequence 1 (raw image 1 to 4):

Standard time-of-flight “four-phase-measurement” at 80.32 MHz

Sequence 2 (raw image 5 to 8):

Standard time-of-flight “four-phase-measurement” at 60.24 MHz

Sequence 3 (raw image 9):

Gray scale/intensity measurement without illumination (60.24 MHz)

Sequence 4 (raw image 10):

Gray scale/intensity measurement with active illumination (60.24 MHz)

Optionally, an additional 11th phase can be preceded if necessary. This sequence 0 (raw image 0) completely corresponds to sequence 3 (Gray scale/intensity measurement without illumination). Its data is not used for later on calibration but only for a proper imager setting.

This default calibration configuration runs at 5 fps, meaning 5 times 10 raw frames per second. A deactivation of the illumination for sequence 3 is realized by setting the duty cycle of the illumination to 0 %.

The exposure times must be adapted for the 4 sequences independently depending on the individual calibration step described in the following sections. The exposure time is typically given in µs (microseconds) and denotes the length of an individual raw image acquisition.

For each of the 10 raw images, the IRS sensor has a dedicated exposure time register. The register values are calculated by a combination of the modulation frequency and a “prescaler” value. The calculation and formulas are shown in the document “Expo_Frate_calc_V0101.xlsx”. The frame grabber software should implement these formulas in order to adapt the exposure times depending on the required settings. *For further support on this matter, please refer to the IRS imager documentation or to Infineon directly.*

2. Boxes

The calibration process in the boxes consists of two main parts, first the raw data acquisition in the fiber-box and the LED-box, and second the calculation of the calibration data.

Step 1: Data Acquisition in the Fiber-Box

Step 2: Data stored in EEPROM

Step 3: Data Acquisition in the LED-Box

Step 4: Combine raw data at one place (one computer, one network hard disk drive, etc.)

Step 5: Calculate the calibration file

Step 6: Store the calibration file in the camera device (e.g. EEPROM)

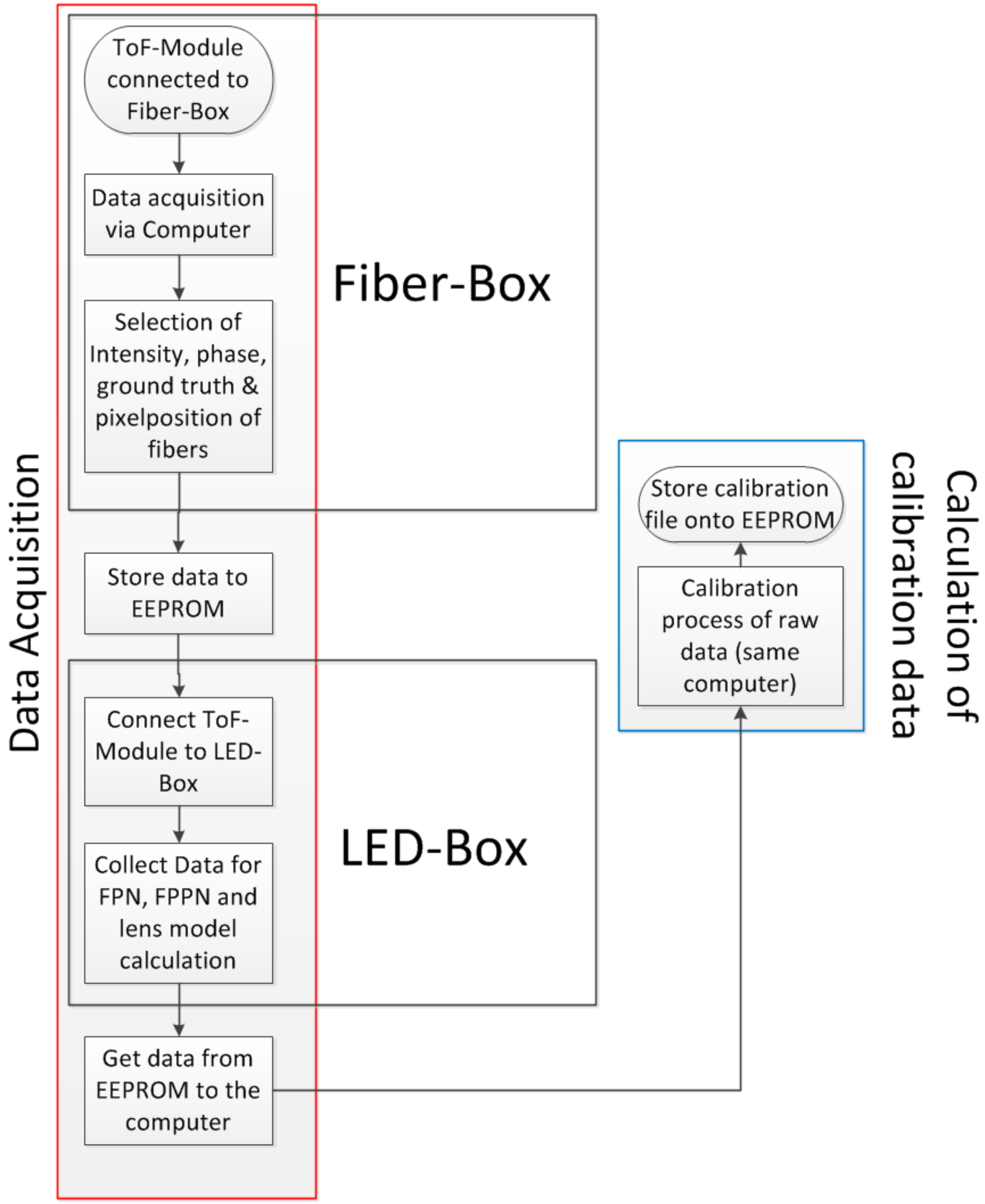

Figure 1: Overview of box concept: 1. Step Fiber-Box. 2. Step LED-Box. 3. Step Data calculation

2.1. Fiber-Box

2.1.1. Mechanical setup

Refer to Cal-1-2-AN-Calibration_Box_1.pdf

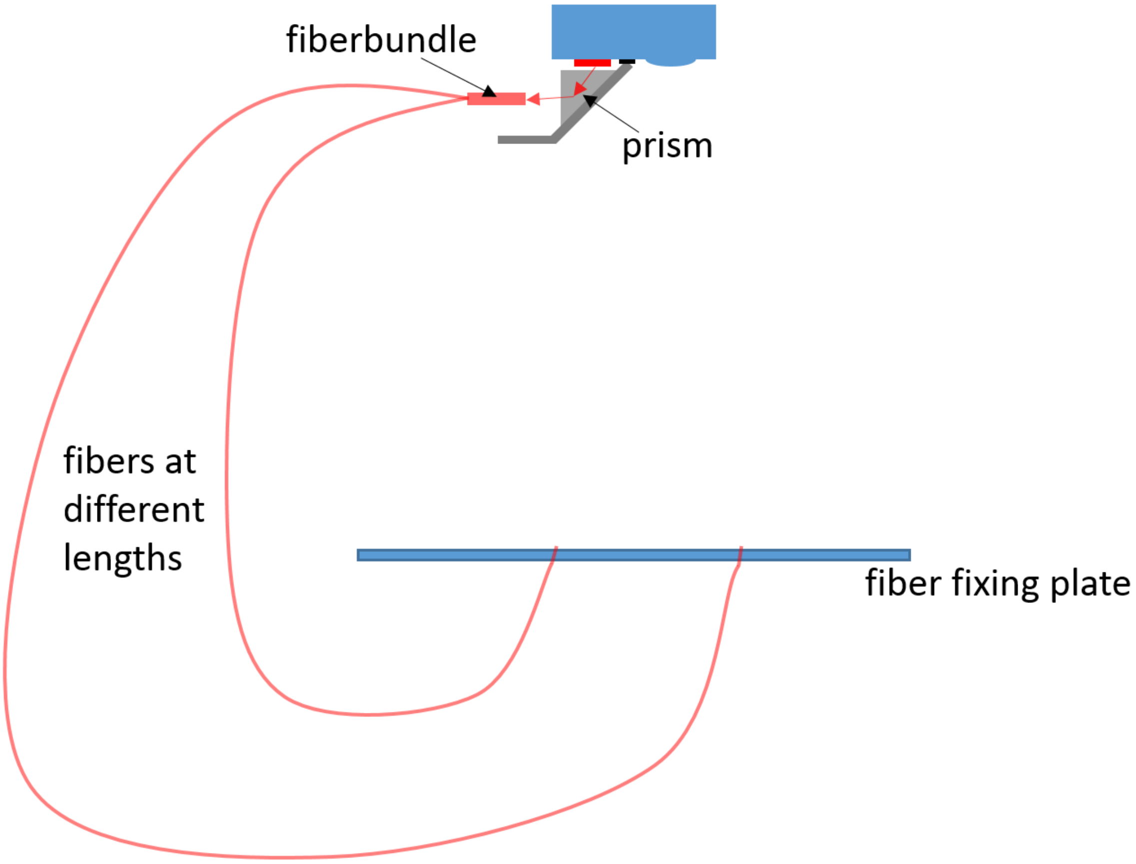

Figure 2: Working principle of the fiber-box: The VCSEL only illuminates a fiber bundle via a prism. The fibers, all of different length, stick at a precise position inside the plate.

2.1.2. Data Acquisition

CAMERA SETUP:

Sequence	1	2	3	4
# of raw images	4	4	1 (GrayScale)	1 (GrayScale)
Modulation frequency	80.32 MHz	60.24 MHz	60.24 MHz	60.24 MHz
Duty cycle (illumination)	25%	25%	0%	25%
Exposure time* / µs	1000	1000	1000	1000

Data acquisition: 20 frames

*The exposure times need to be adjusted, so that ideally all fibers have high intensities but are not saturated. This means that the amplitudes of the brightest fiber and the intensity values are within 500 to 1400 DN. This is evaluated by the provided calibration software and the routine “calcFiber”. For correct results, the exposure times of sequence 1 and 2 should be kept identical. The exposure times of sequence 3 and sequence 4 must be identical.

Table 1: Fiber box imager configuration

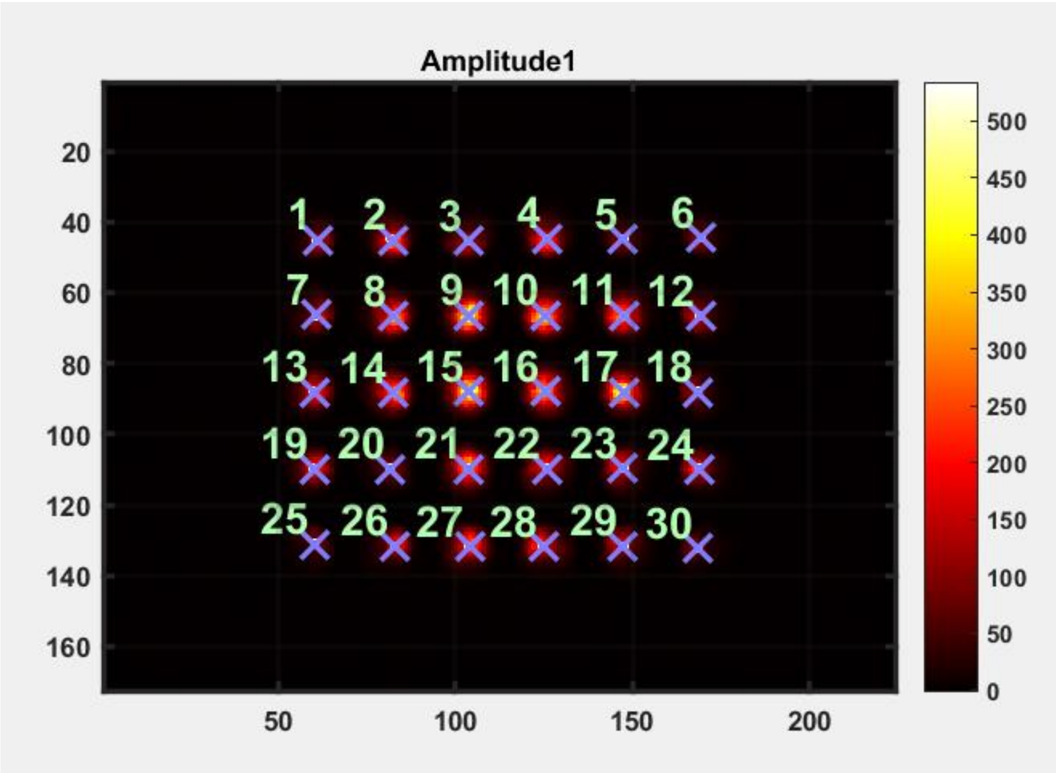

Figure 3: Single frame shot of the cameras view onto the fibers.

The camera device is plugged and fixed in the tray, via Matlab pmd3 is run and the configuration for the fiber box is chosen. Collecting the data for one ToF camera device takes only a few seconds, as – for statistical reasons - a couple of frames (e.g. 20) are recorded. After calculating the mean frame, only the data that is relevant for further calculations is stored. This results in a small amount of data space (a few KB) needed for storage (intensity, phase, amplitude, true distance and the position of each fiber are stored). To get the data accessible for further calibration processes, it can either be stored on a network hard disk drive or, if available, directly on a camera's EEPROM memory. An example frame of the amplitude image of all 30 fibers is presented in Figure 3.

2.2. LED-Box

2.2.1. Mechanical setup

Refer to Cal-1-2-AN-Calibration_Box_1.pdf

A schematic alignment is drawn in Figure 4, stating the cameras lens being directly above the red center LED and the LED plane covering the whole camera's field of view.

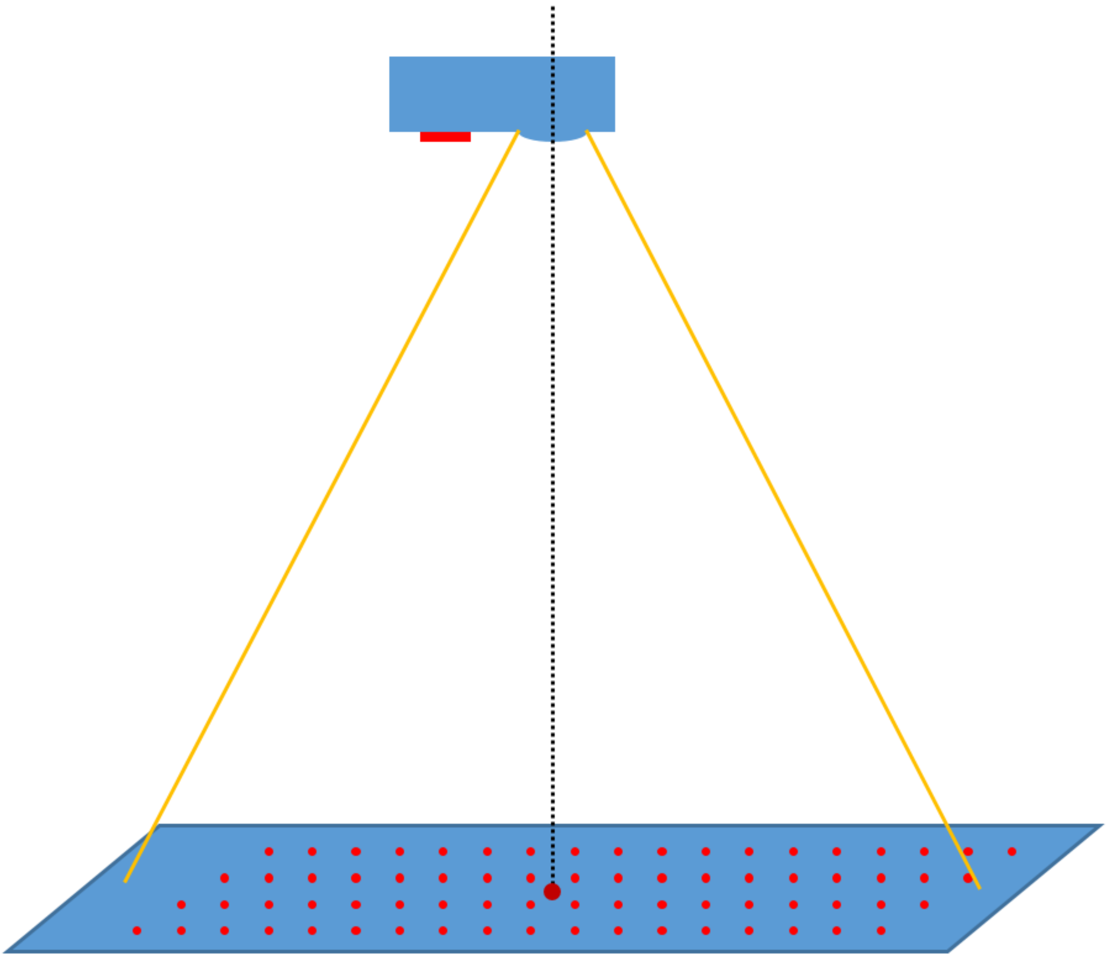

Figure 4: Alignment of the ToF camera towards the LED plate. The Lens center is directly above the center red LED (thick spot). The distance between plate and ToF camera depends on the lens' opening angle (plate must cover whole camera's field of view)

2.2.2. Data Acquisition for data sets "LEDsON" / "LEDsOFF"

CAMERA SETUP:

Sequence	1	2	3	4
# of raw images	4	4	1 (GrayScale)	1 (GrayScale)
Modulation frequency	80.32 MHz	60.24 MHz	60.24 MHz	60.24 MHz
Duty cycle (illumination)	25%	25%	0%	25%
Exposure time* / µs	700	700	200	500

Data acquisition:

1) 20 frames with "box leds on"
2) 20 frames with "box leds off".

*The exposure times need to be adjusted according to below specifications, but kept identical in both measurements ("box leds on" and "box leds off"):

- Exposure times for sequence 1 and 2:
    - The maximum amplitudes should be within 1000 DN to 1400 DN. The exposure times of sequence 1 and 2 should be kept identical.
- Exposure times for sequence 3:
    - The maximum raw value of sequence 3 with "box leds on" should be within 3048 and 3448.
- Exposure times for sequence 4:
    - The maximum raw value of sequence 4 with "box leds off" should be within 3048 and 3448.

Table 2: LED box imager configuration

The limits in the provided calibration software are set to verify this. Adjustments to the exposure time settings should only be necessary once for a camera type, because the individual camera systems behave similar.

2.2.3. Data Acquisition for data set "FPN"

CAMERA SETUP:

Sequence	1	2	3	4
# of raw images	4	4	1 (GrayScale)	1 (GrayScale)
Modulation frequency	80.32 MHz	60.24 MHz	60.24 MHz	60.24 MHz
Duty cycle (illumination)	25%	25%	0%	25%
Exposure time / µs	1	1	1	1

Data acquisition: 20 frames with box leds "off"

Table 3: FPN imager configuration

3. Data processing

The data processing steps proceed in one specific sequence and are not arbitrarily changeable.

3.1. Lens calibration

For the lens calibration data from section 2.2.2 is necessary. Taking the difference between raw image 9 with “box leds on” and “box leds off” eliminates the FPN and dark current or white pixels from the recorded data and reveals a clean image of the calibration pattern. The calibration software will detect the calibration pattern and perform the lens calibration. It is not necessary to have all >100 LEDs in the camera’s field of view, but the more LEDs there are in the image and especially the image corners, the more accurate the algorithm can calibrate the lens. The quality of the final results will be verified by the provided calibration software via lens calibration parameter limits.

For calibration the LED pattern is pre-programmed and the software will overlay the measured led positions with its template. A successful overlay result is presented in Figure 5. The green spots represent the measured LED spot positions and the lens distortion adapted in that way, that the measured spots perfectly match the pattern model.

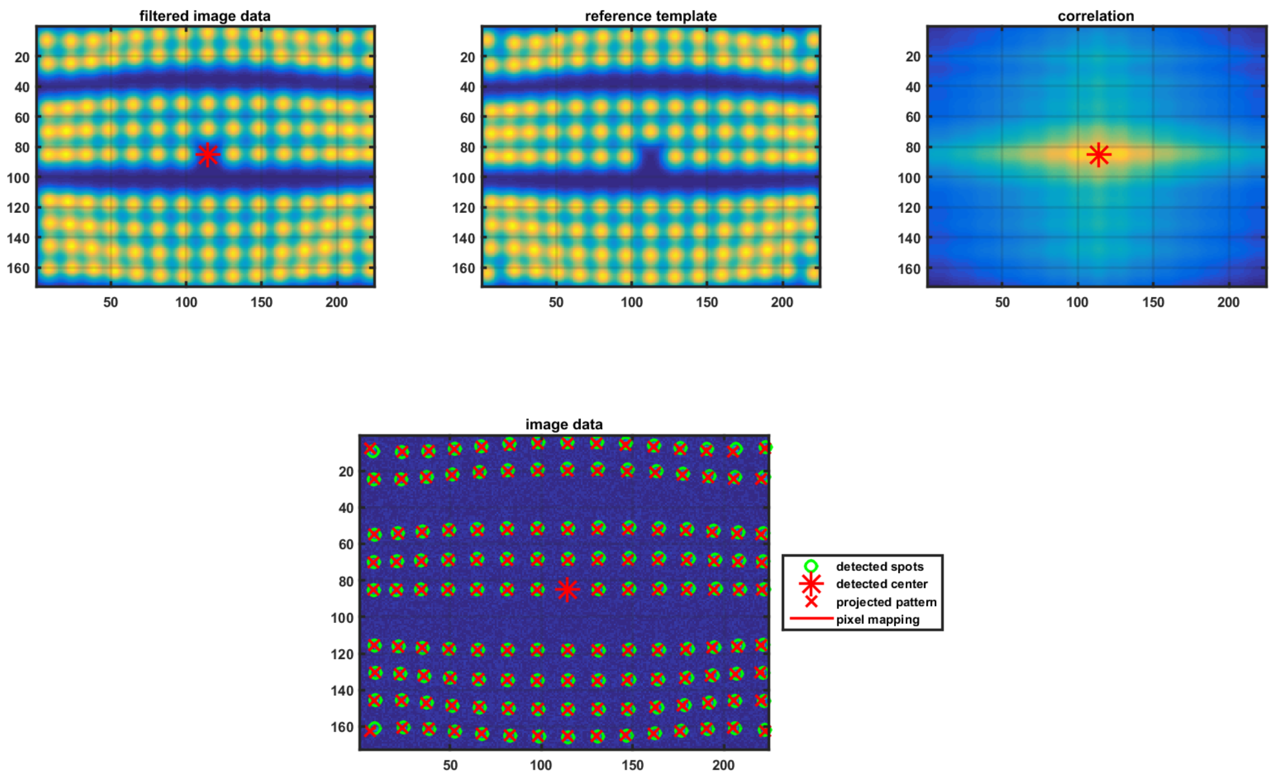

Figure 5: LED pattern for lens calibration: from left to right: filtered image data with the center as a red cross (missing LED), the reference template, correlation between measurement and reference. Bottom: overlay of detected spots with projected pattern to validate the lens model.

3.2. Dark current

Dark current in digital numbers / second (DN/s). Calculation:

I_{dark} = (raw image 9 of “box leds on” minus raw image 9 of “fpn”) / time difference

3.3. FPN

The FPN calculation is done by taking the raw image 9 of section 2.2.3 and subtracting the dark current (c.f. section 3.2). A typical FPN image is plotted in Figure 6. The FPN offset of each pixel is approximately by 2000 DN +- 150 DN.

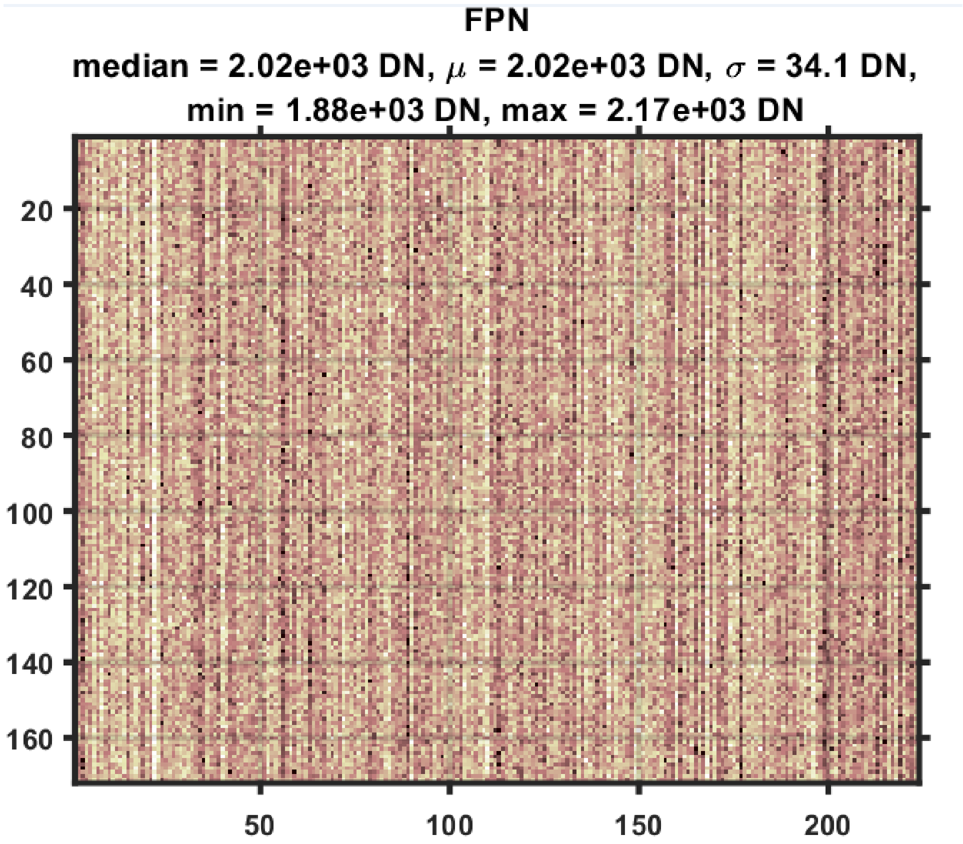

Figure 6: FPN measurement without active illumination

3.4. Mask

The field of view of the lens and VCSEL have to be aligned and all pixels beyond a maximum viewing angle are flagged due to small intensities (no overlap of VCSEL and imager with lens).

3.5. Wiggling and FPPN

Wiggling and FPPN calculation with the two-box-calibration-method cannot be separated but have to be done iteratively while having all data sets from both boxes available (for the fiber box, only the reduced data set needs to be available as described in section 2.1.2).

3.5.1. Phase wiggling

The phase wiggling correction is done with the data from the fiber box. Each fiber simulates one time of flight length, covering the whole unambiguous range (2pi-phase) in approximately equidistant intervals. This data is used to do perform a sinusoidal fit for the wiggling compensation as shown in Figure 7.

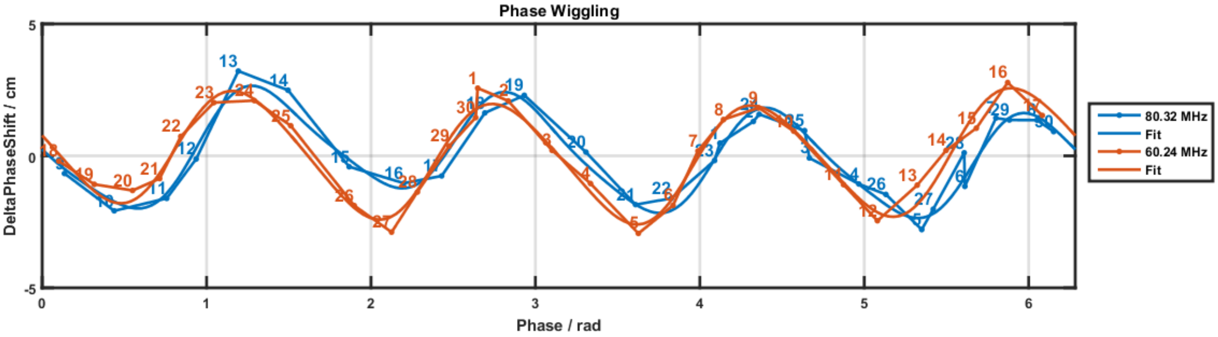

Figure 7: Calculated phase wiggling compensation (each number refers to one specific fiber measurement).

3.5.2. FPPN

The pixel individual offset is described by FPPN. To measure this individual offset, the true distance between the target plane and the camera must be well known. After wiggling compensation the pixel individual offset can be calculated as the remaining offset when using the data set “box leds off” from section 2.2.2 (shown in Figure 8 for a modulation frequency of 80.32 MHz).

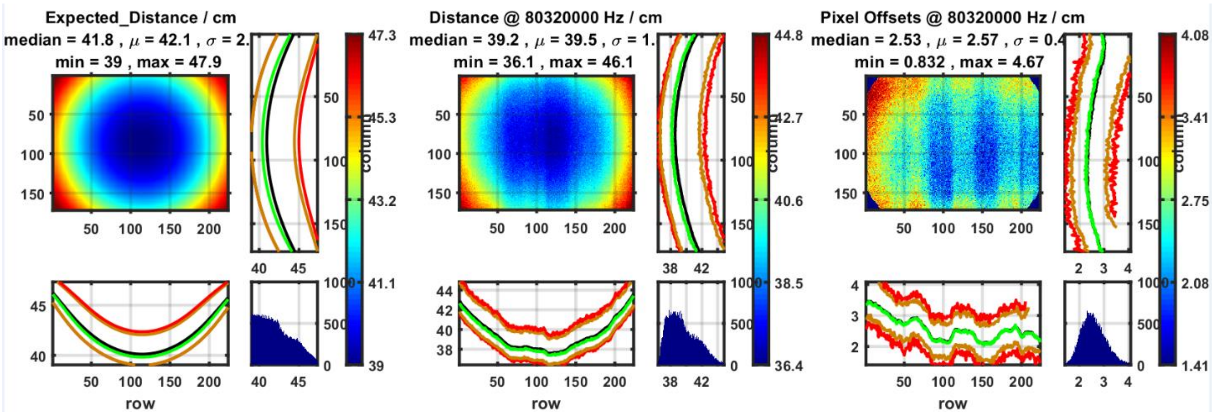

Figure 8: Distance and FPPN:
left: Expected distance, middle: measured distance, right: pixel offset as a difference between measured and expected distance

Document History

Document title: Data Acquisition and Processing – Cal-4-1-AN

Revision	Origin of Change	Submission Date	Description of Change
0	SBe	2016-04-13	New Application Note
1	SBe	2016-05-25	remove register settings
2	SMa	2016-06-13	Add 11th phase