Eye safety measurements – Defect VCSEL detection

*by **pmd**technologies*

Abstract

This document describes the procedures to detect defect VCSEL profiles, i.e. increased illumination spots outside the normal field of illumination.

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1. Mounting

The device has to be mounted at a fixed and reproducible position on top of a hemisphere (cf. Figure 1). The position of the VCSEL is in the focal point of the hemisphere. A fisheye camera is mounted next to the device as close as possible.

Due to the modulation of optical signal the fisheye camera needs a global shutter. The lens of the fisheye must have a fixed focal length. This guarantees reproducibility of measurements.

A schematic cross section through the setup is presented in Figure 1: The ToF camera with the VCSEL (blue) and next to it the fisheye camera (green) are connected onto the hemisphere. The back of the system, where both cameras are mounted, is highly non-reflective coated (e.g. black rubber). On the other hand the hemisphere itself is coated diffuse grey.

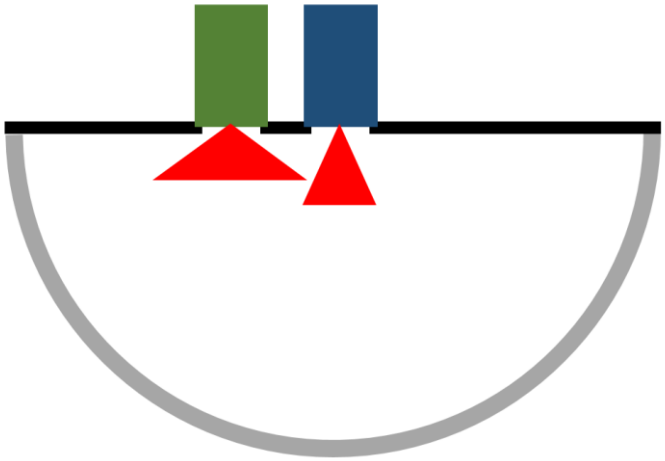

Figure 1: Diffuse grey coated hemisphere. Illumination (VCSEL) of ToF camera (blue) is centered in the focal point of the hemisphere. The fisheye camera (green) is located next to the ToF camera.

2. Measurement

The device operates in the standard use case. 25 frames from the fisheye camera are taken (to reduce noise) with active illumination of the ToF camera switched on. 25 additional frames are taken with active illumination off (to later subtract background noise). The ToF sensor itself is not used in this setup.

3. Analysis

In the following one possible method of analyzing the measured data is depicted. It is recommended to combine multiple pass/fail conditions in order to maximize the probability of detecting bad beam profiles.

3.1. Background subtraction & smoothing

The acquired data from the camera contains background noise (Figure 2, left), which is subtracted first (Figure 2, middle). A Gaussian filter with σ = 4 pixels smoothes the signal (Figure 2, right).

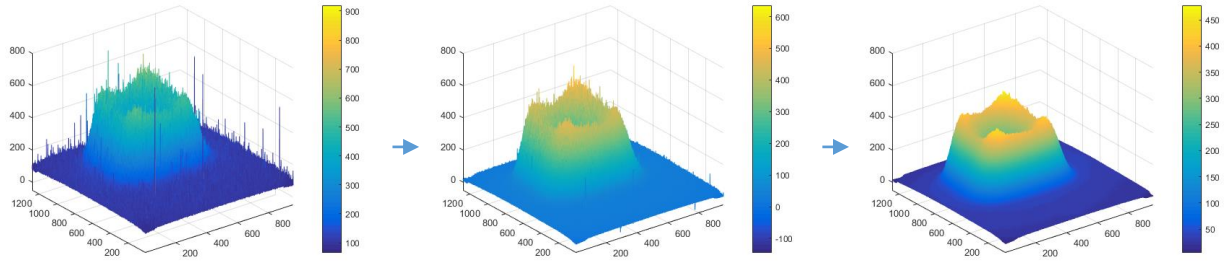

Figure 2: Background subtraction & smoothing Left: Acquired raw data, **Middle:** Background subtracted signal, **Right:** Smoothing by using a 4 pixel Gaussian filter

3.2. Defining the Field of Illumination

To define the Field of Illumination (FoI) of the active illumination a region growing algorithm is used. The pixel with the largest amplitude of the beam profile is used as the starting point and all other amplitude values are normalized to this peak value.

All neighboring pixels with an amplitude larger than I_{min} are taken into account for the FoI. These pixels are the new origin for the algorithm to look at all neighboring pixel, stopping at pixels with less amplitude than I_{min}.

A hotspot factor defines the relation between the peak amplitude and the mean amplitude within the FoI.

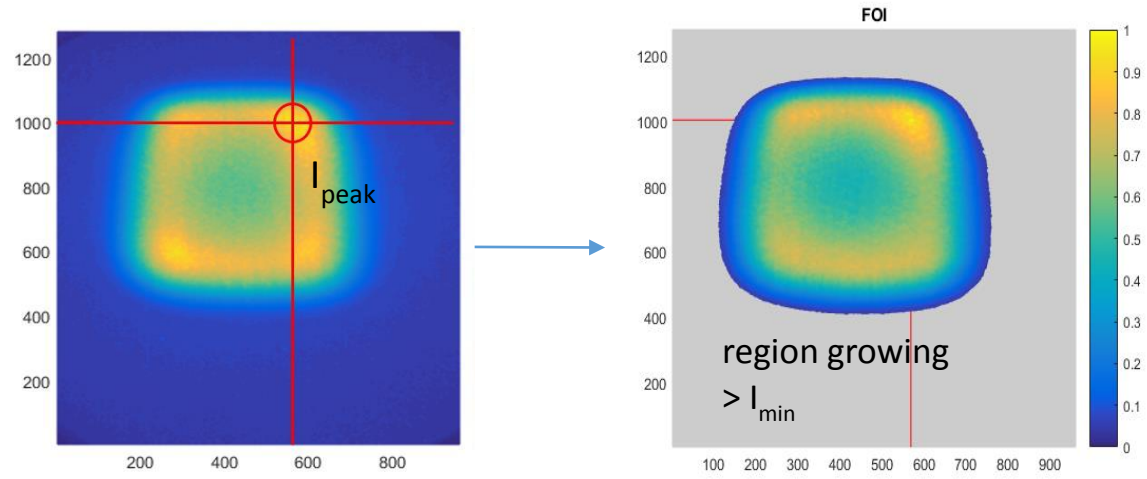

Figure 3: Defining the Field of Illumination (FOI): Left: Finding the peak amplitude, **Right:** Region growing from the peak amplitude towards the borderlines of the FOI (limit: $I_i > I_{min}$)

3.3. Defining the non-illuminated area

The non-illuminated area is the area outside the FoI (the inverse from section 3.2).

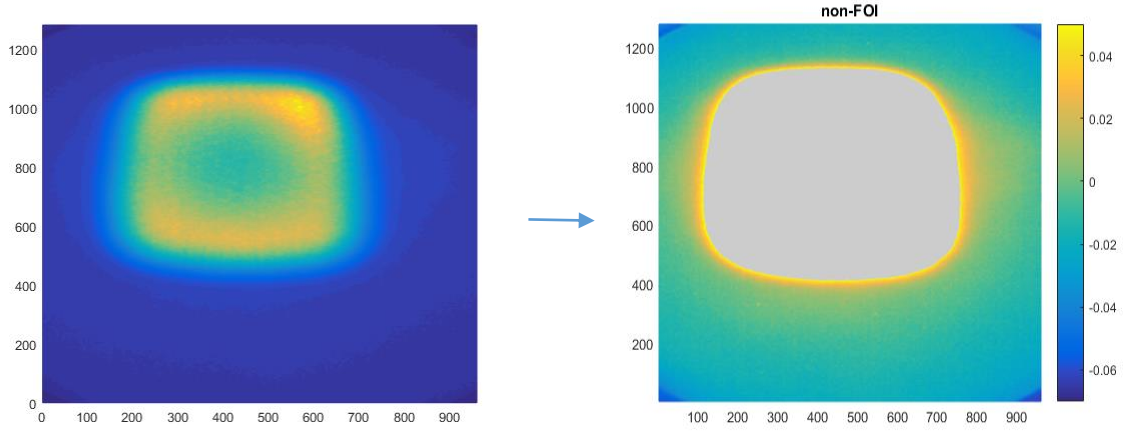

Figure 4: Defining the non-illuminated area Left: normalized amplitude image, **Right:** non-illuminated area (non-FoI)

3.4. Detecting clusters in the non-illuminated area

The left image of Figure 5 shows clusters within the non-illuminated area. The clustersizes are detected with the same growing algorithm as the FoI is defined in section 3.2 (right image).

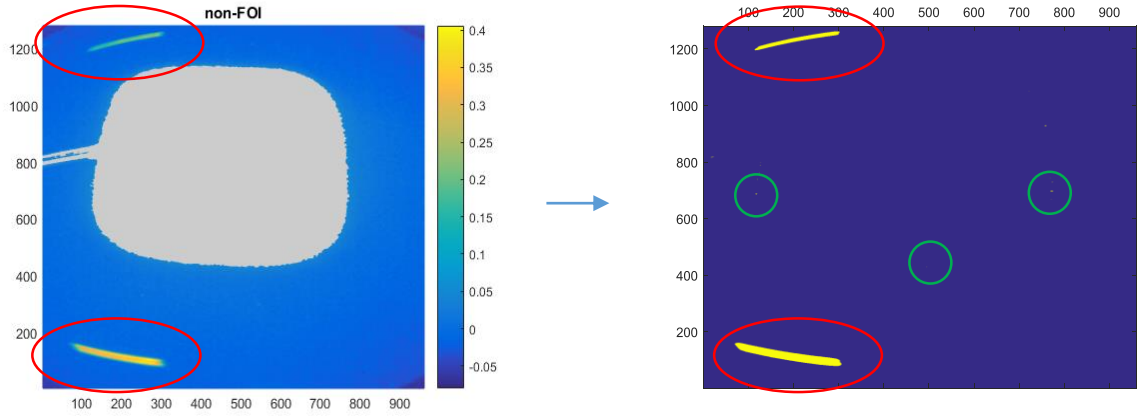

Figure 5: Detecting clusters in the non-illuminated area: Left: Non-illuminated area with clusters (areas with larger amplitude values than I_{min}), **Right:** The same region growing algorithm as in section 3.2 detects the single cluster sizes.

3.5. Defining the edge areas

The edge area is defined as the borderline between the FoI and the non-illuminated area (Figure 6 top right). Only data between I_{min} and $2 \cdot I_{min}$ are taken into account. Combined with the gradient values (Figure 6 bottom left) a gradient edge area is defined as an indicator of irregularities at the edges of the FoI.

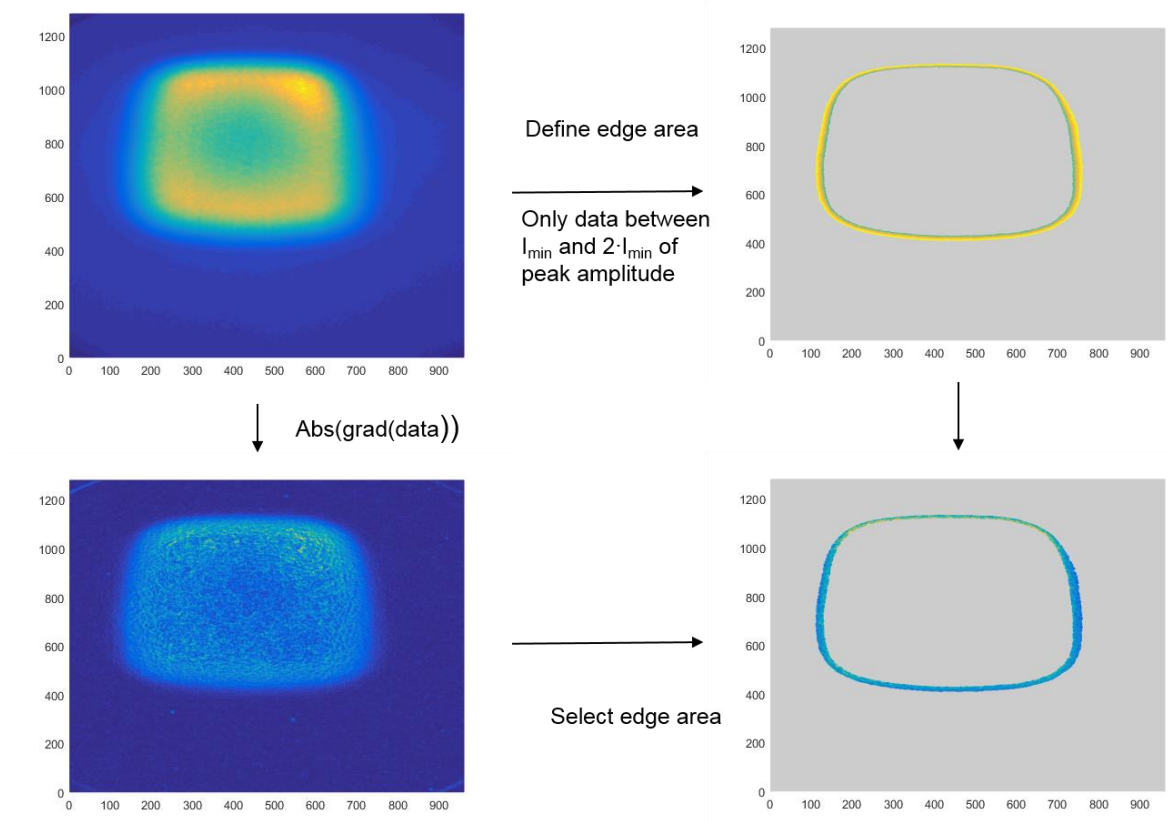

Figure 6: Defining the gradient values for the edge area: Top left: Acquired data, **Top right:** Defining the edge area (amplitudes between I_{min} and $2 \cdot I_{min}$), B**ottom left:** Absolute gradient value for all pixels, **Bottom right:** Combination of edge area and gradient value.

4. Pass-/Fail-Criteria

- The peak amplitude has to be above a threshold value (cf. section 3.2):
  $I_{peak} > I_{peak, min}$
- The mean amplitude within the Field of Illumination must be within a specific corridor (cf. section 3.2):

  $I_{mean, FoI, min} < I_{mean, FoI} < I_{mean, FoI, max}$
- The hotspot factor must be within a specific corridor (cf. section 3.2):

  $HSF_{min} < HSF < HSF_{max}$
- The size of the Field of Illumination must be within a specific corridor (cf. section 3.2):

  $FoI_{min} < FoI < FoI_{max}$
- The biggest cluster size outside the FoI must be below a threshold value (cf. section 3.4):

  $Clustersize < clustersize_{max}$
- The peak gradient in the edge area must be below a threshold value (cf. section 3.5):

  $gradient_{peak, edge\ area} < gradient_{max}$

5. Tables

No.	QTY	Description	Drawing/ Source	pmdtec	OEM
1	1	Hemisphere (e.g. 60cm diameter)	E.g. https://www.modulor.de/en/acrylic-glass-hemisphere-transparent-hollow.html	-	Order component or define alternative product from local supplier
2	1	Fisheye camera	E.g. IDS UI-3240CP-NIR-GL Rev.2 and FUJINON HF1.8HB-L1 Fisheye	-	Order component or define alternative product from local supplier
3	1	Tray		-	Design the tray
4		Strut profiles, 30x30mm² cross section	Bosch-Rexroth No. 3 842 990 720	-	Order component or define alternative product from local supplier
5	1	Back plate	Depends on tray (cf. No 3), fisheye camera notch and diameter of hemisphere		Order component or define alternative product from local supplier and find a local CNC manufacturer
6		Cellular Rubber	http://www.gummiprofile24.de/epages/64048014.sf/de_DE/?ObjectPath=/Shops/64048014/Products/80230	Help with translation to English	Order component or define alternative product from local supplier

Table 1: Bill of Materials

Document History

Document title: Defect VCSEL detection – Cal-11-1-AN

Revision	Origin of Change	Submission Date	Description of Change
0	UFr	2016-05-06	New Application Note
1	SMa	2016-05-23	Algorithm update
2	UFr	2016-12-14	Add ordering information hemisphere, camera, fisheye