Eye safety – integrating sphere

*by **pmd**technologies*

Abstract

This document explains how to check the optical output power of a ToF camera by using an integrating sphere with a power meter connected as well as how to check the protection circuits that ensure eye safety.

Table of Contents

List of Figures

List of Tables

1. Mounting

The device has to be mounted at a fixed and reproducible position, i.e. by using a tray, in front of the aperture of the integrating sphere. Changing the device must work easy and fast.

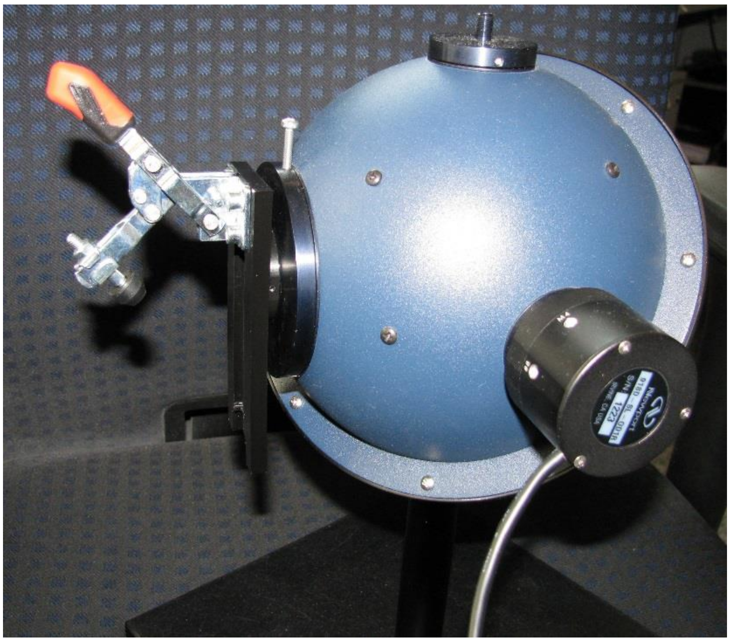

Figure 1: Integrating sphere. A tray holds the device in a defined and reproducible position. Easy switching between ToF cameras is guaranteed by using a tensioner.

2. Measurement

The measurement is performed in two steps that are explained in more detail in the following sections. It is very important not to change the order of those steps as at the end of step 2 the VCSEL illumination is permanently turned off and only a reboot of the device makes it run properly again.

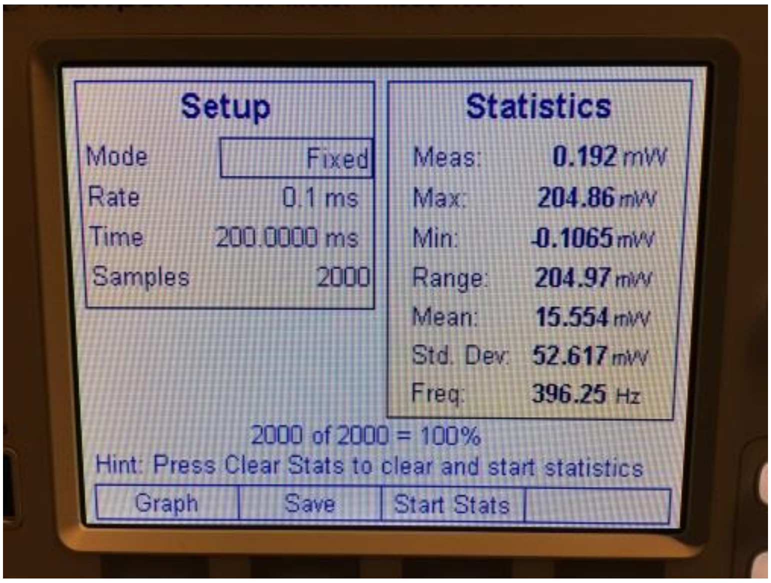

Figure 2: Optical power meter showing the measuring parameters and output values. Only optical mean power is considered.

2.1. Mean optical power test

The imager is configured in standard configuration. During the time of one frame (e.g. 5fps = 200ms) the optical power of the device is measured with the integrating sphere and the mean optical power is calculated (cf. Figure 2). Only this mean value is considered.

2.2. Peak current limiting protection circuit test

For this test the exposure times of all phases of the standard configuration are reduced to 40% of the maximum value defined in the standard use case. Afterwards the duty cycle is increased from 25% (standard configuration) to 100%.

During the time of one frame the optical output power of the device is measured with the integrating sphere and the mean optical power is calculated (cf. Figure 2). Only this mean value is considered.

2.3. Average current limiting protection circuit test

In the next step the protection circuit, that turns off the VCSEL if the mean optical power is too high to be considered as eye safe, is tested. Therefore the duty cycle is set back to the standard configuration value (25%, as it was set it section 2.1). In the following two measurement steps will be performed:

1) The exposure time is increased by 10%, i.e.

   $T_{exp,meas1} = 1.1 * T_{exp,\ std\ config}$

   The optical output power of the device is measured with the integrating sphere and the mean optical power is calculated. Only this mean value is considered.
2) In a second step the exposure time is set to a value corresponding to the trigger threshold of the protection circuit. At the calculated exposure time the protection circuit is expected to disable VCSEL supply voltage and thus turns off the VCSEL. The optical output power of the device is measured with the integrating sphere and the mean

optical power is calculated. Only this mean value is considered. The optical output power of the VCSEL is expected to drop to zero, i.e. the measured mean value shows zero.

Be aware: The VCSEL stays turned off until a power cycle of the device is done.

3. Analysis

3.1. Mean optical power test

The mean optical power measured in section 2.1 is compared to an upper limit specific for each system:

$P_{opt,\ mean,\ measured} \leq P_{opt,\ mean,\ max}$

Furthermore the optical power must be larger than a lower limit defined by desired customer performance (specification):

$P_{opt,\ mean,\ min} \leq P_{opt,\ mean,\ measured}$

If both criteria are valid, the device passes this test.

3.2. Peak current limiting protection circuit test

The protection circuit is expected to limit the current driving the VCSEL below a specific current value I_{max}. By setting up the imager as described in section 2.2 a use case violating the current limit is configured. In this configuration the measured mean optical power ($P_{opt,\ mean,\ 100\%\ DC}$) has to be within a system specific corridor that can be calculated from the measurement result in section 3.1 ($P_{opt,\ mean,\ measured}$):

$a*P_{opt,\ mean,\ measured} < P_{opt,\ mean,\ 100\%\ DC} < b*P_{opt,\ mean,\ measured}$ with $a,b < 1$ and $a < b$

3.3. Average current limiting protection circuit test

To verify the correct functionality of the protection circuit, the measured $P_{opt,\ mean}$ is evaluated for two measurement steps:

1) The measured mean optical output power should be increased by 10% compared to the optical output power in standard use case

   $P_{opt,\ mean,\ meas1} \approx 1.1 * P_{opt,\ mean,\ measured}$.

2) The VCSEL is expected to be disabled if the mean optical power reaches the eye safety limit[1] $P_{opt,\ mean,\ max\ eye\ safety}$. The mean optical output power depends on the exposure time as it is linear to the exposure time in good approximation. The maximum exposure time then is defined by

   $T_{exp,\ max\ eye\ safety} = T_{exp,\ std\ config} * P_{opt,\ mean,\ max\ eye\ safety} / P_{opt,\ mean,\ measured}$.

If the VCSEL does not turn off at $T_{exp,\ max\ eye\ safety}$ the device will fail the test due to a malfunction of the protection circuit.

[1] Depends on the device and will be provided by pmd.

4. Final result

Each individual test results in a single pass/fail decision. Only if all tests are successfully passed the camera under test can be considered a good device. It is recommended to store a detailed summary of the test results of each module, e.g. to keep a record of the testing or for further analyses. These analyses might be useful for a retroactive fine tuning of the test limits, e.g. for an optimization of the production yield (in agreement with effective eye safety regulations).

5. Bill of Material

No.	QTY	Description	Drawing/ Source	pmdtec	OEM
1	1	Integrating sphere detector	http://search.newport.com/?q=*&x2=sku&q2=819D-SL-5.3-CAL2	-	Order component or define alternative product from local supplier
2	1	Optical Power Meter/Energy Meter, High-Performance Hand-Held	http://search.newport.com/?x2=sku&q2=1918-R	-	Order component or define alternative product from local supplier
3	1	Base Plate, 819 Integrating Sphere, 6 x 6 inch	http://search.newport.com/?x2=sku&q2=819M-B6	-	Order component or define alternative product from local supplier
4	1	Port Frame Reducer, 2.5 to 1 inch, Spectraflect, 819M Series	http://search.newport.com/?q=*&x2=sku&q2=819M-PFR-1.0-2.5	-	Order component or define alternative product from local supplier
5	1	Tray		-	Design the tray

Table 1: Bill of Material

Document History

Document title: Eye safety - integrating sphere – Cal-11-2-AN

Revision	Origin of Change	Submission Date	Description of Change
0	SMa, UFr	2016-02-11	New Application Note
1	BAl	2016-06-01	Corrected title and formatting
2	UFr, TWe	2016-12-22	Updated procedures for average current monitor testing
3	SMa	2017-02-17	Update exposure time and references