ISL29501 Sand Tiger Optics

This application note describes important optical and opto-mechanical features of the ISL29501 Sand Tiger distance measurement system. Topics discussed include optical system description, System Field of View (FOV), signal photocurrent vs target distance, optical crosstalk mitigation and ambient light mitigation. In the section on system FOV, the geometrical cone model is introduced and compared with the intensity distribution model of FOV. Values for the emitter, detector and system FOV are also given. Variables which affect the signal magnitude are discussed on the section on signal photocurrent vs target distance section. The methods used to mitigate optical crosstalk in Sand Tiger are provided along with suggestions for mitigating optical crosstalk in general.

Contents

1. Introduction

This application note describes important optical and opto-mechanical features of the ISL29501 Sand Tiger distance measurement system. Topics discussed include:

- Optical system description
- System field of view (FOV)
- Signal photocurrent vs target distance
- Optical crosstalk mitigation
- Ambient light mitigation

2. Optical System Description

From an optics point of view, the ISL29501 Sand Tiger optical system consists of an infrared (IR) LED emitter, a photodiode detector, a glass window (optional), and baffling to prevent optical crosstalk between the emitter and detector (Figure 1). These components are contained within an opaque, plastic chassis. Some distance away from Sand Tiger is a target, which we would like to measure the distance to.

The emitter is the OSRAM SFH 4550 LED and the detector is the OSRAM SFH 213FA photodiode. Center-to-center spacing between the emitter and detector is 12mm. Brass tubes are placed around the emitter and detector to mitigate electrical crosstalk. A foam gasket is used to prevent light leakage (optical crosstalk) between the plastic baffle and PCB. Electrical crosstalk is discussed in a separate application note.

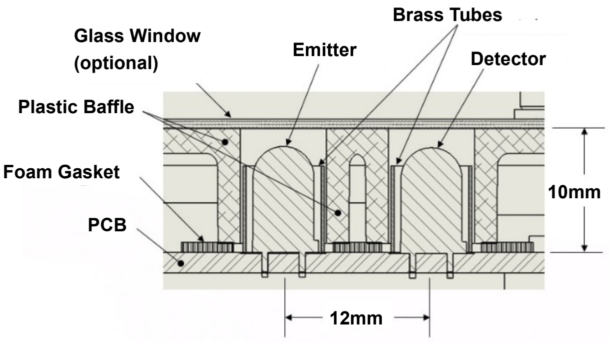

Figure 1. Sand Tiger Opto-mechanical Cross Section

3. System Field Of View (FOV)

The system field of view is the intersection of the emitter radiation distribution and the detector field of view distribution (Figure 2). Roughly speaking, the smaller of the emitter and detector distributions becomes system field of view distribution. For Sand Tiger, the emitter radiation distribution is much smaller than the detector field of view distribution, so the system field of view becomes the emitter radiation distribution (Figure 3).

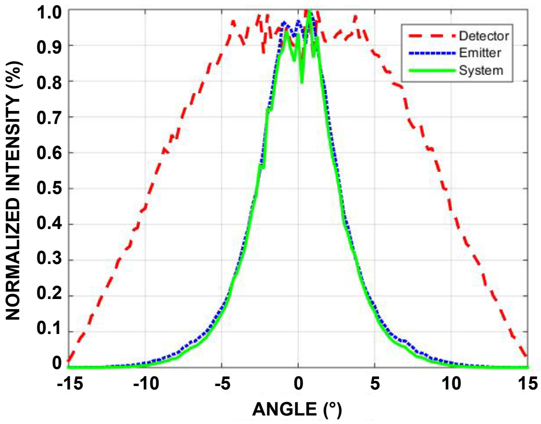

Figure 2. Simulated Sand Tiger Field of View

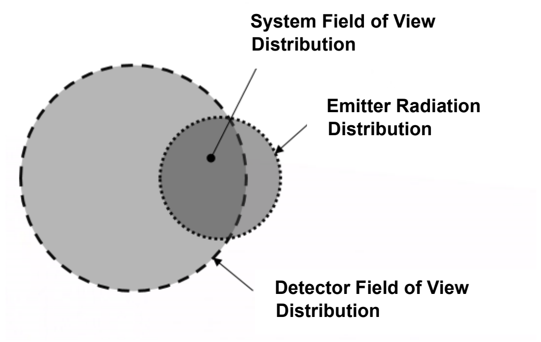

Figure 3. Venn Diagram Illustrating System FOV

To simplify our discussions and compare different systems, we often talk of FOV as being a simple geometrical cone with a discrete angular width, represented by a single number, such as ±β° (Figure 4). This is a simplification however. The FOV is actually an intensity distribution, which depends on angle and is often somewhat Gaussian in shape.

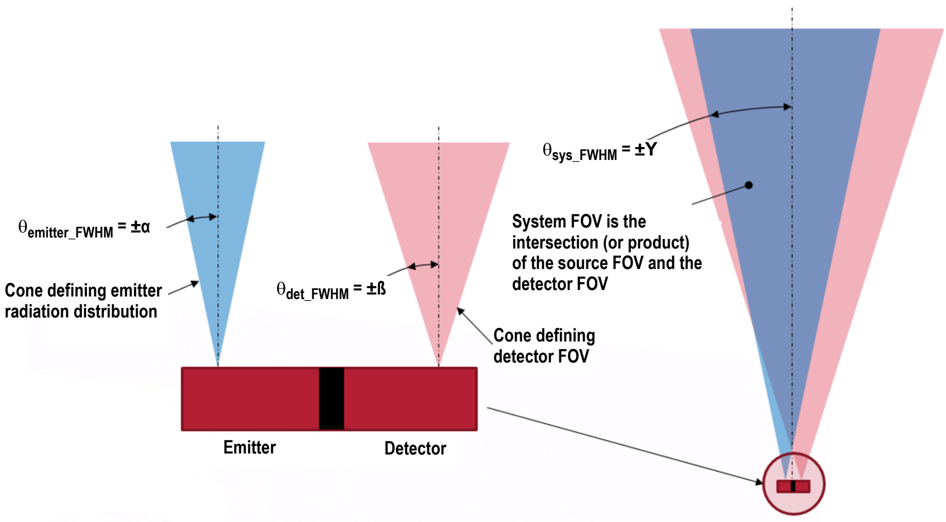

Figure 4. FOV Illustrated Using FWHM Cones

To simplify and compare different systems we define the Full Width Half Maximum (FWHM) FOV, which is found by normalizing the intensity distribution of the FOV of interest, drawing a horizontal line at the ½ maximum intensity point and then dropping vertical lines where the horizontal line intersects the intensity distribution (Figure 5).

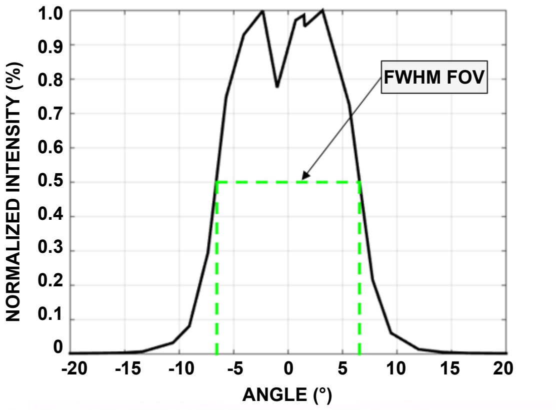

Figure 5. FWHM Definition Using Generic Distribution

Using this definition we can quantify Sand Tiger's FOV for the emitter, detector and system using a single number for each. The system FWHM FOV for Sand Tiger is ±2.75° (Table 1).

Table 1. Sand Tiger FWHM FOVs

FOV Type	FWHM FOV (°)
Detector	±10
Emitter	±2.75
System	±2.75

4. Signal Photocurrent Versus Target Distance

The range and accuracy of Sand Tiger is limited by the amount of signal light, which scatters from the target and falls on the detector. The magnitude of this return light depends on the following:

- Emitter optical power output and its angular distribution
- Effective detector area
- Detector responsitivity (usually given in A/W) at the emitter's peak or centroid wavelength
- Distance to target
- Target properties such as (size, shape, orientation, surface roughness and reflectivity)

We use a flat, infinite-extent, Lambertian target, orthogonal to Sand Tiger's optical axis to simplify and standardize our measurements and models. Lambertian means that the radiance scattering from the surface is isotropic and the intensity has a cosine falloff. Paper is an example of an object that is approximately Lambertian.

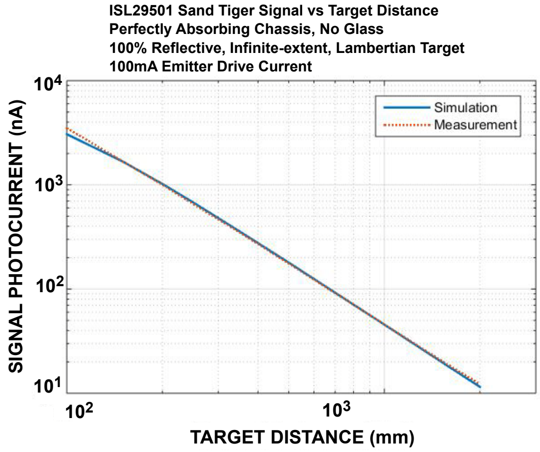

Figure 6. Signal vs Distance Plot for Sand Tiger

The effective area of the detector for Sand Tiger is the area of the lens in front of the SFH 213FA photodiode active area. This lens captures light over a ≈5mm diameter circular area and directs it to the 0.3mmx0.3mm active area. This lens greatly increases the return signal and range of the Sand Tiger system.

One of the important performance metrics for Sand Tiger is its signal photocurrent vs target distance plot, referred to from here onward as a signal-vs-distance plot (Figure 7). All signal-vs-distance plots and tables provided herein are for Sand Tiger without the optional glass window. For an infinite-extent, planar target, beginning from ≈100mm from the Sand Tiger system, the signal-vs-distance plot obeys the $1/R^2$ law, in which the magnitude of the optical power incident on the target (and the detector) falls off as the inverse squared of the distance R from the source.

For a Lambertian target, a change in target reflectivity causes a vertical shift in the signal vs distance function (Figure 8). Thus, to find the signal vs distance function for a grey or black target, just multiple the signal vs distance function (see Table 2) of the white target by the reflectivity of the desired grey or black target of the same size.

Table 2. Signal vs Distance for 100mA Emitter Current Infinite Extent, White Lambertian Target

Target Distance (mm)	Sand Tiger Measured Signal Current (nA)
100	3510
150	1677
200	1003
250	656
350	350.2
500	176
1000	45.7
1500	20.9
2000	12.2

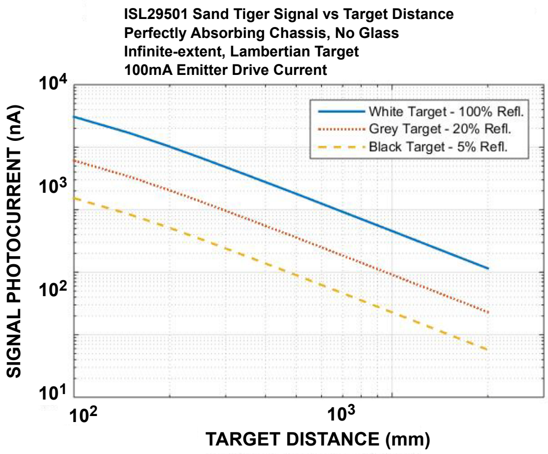

Figure 7. Sand Tiger Signal vs Distance vs Reflectivity

The signal magnitude is shown for various target sizes and target distances in Table 3. The signal magnitude is proportional to the target size when light overfills the target. When light underfills the target, a change in the size of the target has no effect on signal magnitude. In this case, the target is considered an infinite-extent target.

Table 3. Signal vs Distance for 100mA Emitter Current White Lambertian Targets of Various Sizes

Target Distance (mm)	Sand Tiger Simulated Signal Current for Various Target Sizes (nA)				
-	10mmx10mm	32mmx32mm	100mmx100mm	320mmx320mm	1000mmx1000mm
100	896.8	3068	3191.9	3174.2	3191.9
150	309.2	1421.9	1740.5	1740.5	1740.5
200	130.4	713.9	1056.1	1056.1	1056.1
250	63.7	391.8	702.1	702.1	702.1
350	20.2	144	355.2	371.1	371.7
500	5.3	44.4	154.6	185.9	185.9
1000	0.4	3.5	21.7	46.6	47
1500	0.1	0.7	5.7	18.3	21.1
2000	0.0	0.2	2	8.7	11.9

5. Optical Crosstalk Mitigation

Optical crosstalk in the Sand Tiger system occurs when light travels from the LED to the photodiode without scattering from the target. To mitigate optical crosstalk, Sand Tiger uses the following:

- An opaque barrier between the emitter and detector
- A sufficiently large emitter-to-detector spacing
- A foam gasket between the chassis and PCB.

The Sand Tiger chassis was designed to be opaque to 850nm light. The chassis is made from black acetal homopolymer. The plastic-injection molded version of the Sand Tiger chassis uses Delrin 500 P (BK602) and the CNC-machined version uses Delrin 150. Both of these versions of acetal homopolymer contain carbon black, which absorbs light. Further, the semi-crystalline structure of this plastic causes light to be more greatly scattered at its grain boundaries when compared to light propagating within an amorphous plastic. The combination of the scattering caused by the semi-crystalline structure and absorption by the carbon black particles make Sand Tiger's plastic more opaque than amorphous plastics and those not containing carbon black.

The foam gasket (Figure 1 and Figure 8) used to prevent light leakage between the plastic baffle and PCB is die cut from a sheet of Poron foam (Rogers Corporation part number 4701-60-20031-04). Like the chassis plastic, this foam is also very opaque to 850nm light. It too is made from a semi-crystalline plastic (in this case PET) and contains carbon black. It also contains titanium oxide particles, which cause greater scattering of light, and increases the chance of absorption by the carbon black particles.

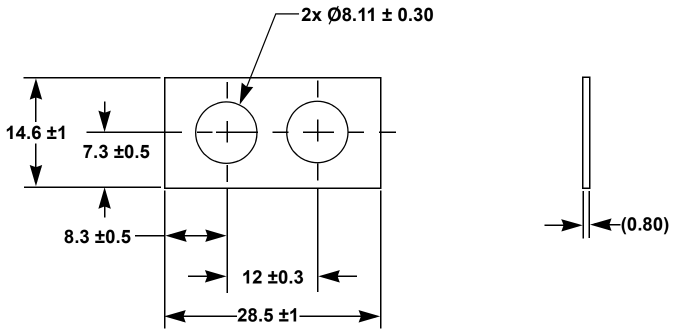

Figure 8. Sand Tiger Foam Gasket (Dimensions in Millimeters)

If no window is used in the Sand Tiger system, the spacing between the emitter and detector could be reduced (via redesign) since the brass tubes provide a sufficiently opaque barrier to mitigate optical crosstalk. However, when a 0.7mm thick glass window is placed on top of the Sand Tiger chassis, the existing emitter-to-detector spacing of 12mm prevents light from propagating through the window, from the emitter to the detector, causing optical crosstalk.

A 0.7mm thick clear glass window, does not create any additional optical crosstalk in the Sand Tiger system relative to the case of no window being present. However, when IR-transmissive ink is added to the inner surface of the window, as is common in some consumer electronic applications, light scatters into a wide angle from this ink layer and propagates through the window to the detector. Thus, increasing the optical crosstalk by as much as 60x. This high level of optical crosstalk can be mitigated through the use of the following:

- An anti-reflection window coating
- Lower-scattering, higher transmission IR ink (for 850nm light)
- Larger emitter-to-detector spacing
- A black coating in contact with the inner surface of the window glass
- Replacing the single window with two separate windows and opaque barrier in between them

These mitigation techniques are provided as general recommendations and have not been verified or quantified in a detailed way.

6. Ambient Light Mitigation

The Sand Tiger's OSRAM 213FA photodiode incorporates a visible blocking filter which rejects light below 700nm wavelength. This limits ambient light, possibly capable of degrading Sand Tiger's performance if of sufficiently high power, to a wavelength range of 700nm to 1150nm.

7. Revision History

Revision	Date	Description
1.00	Apr 6, 2022	Applied new template.
0.00	Sep 24, 2015	Initial release.

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