

# TMF882X OPTICAL DESIGN GUIDE (ODG)

*Rev1 (27Sept2021): Initial version*

*Rev2 (14Oct2021): added appendix A and B containing EVM sim results using thicker CG 1.0mm and 0.75mm, respectively.*

*Rev3 (24Mar2022): added and updated 2d 3d package FoI and FoV models; changed text from: "No target within >40cm", to: "No target within 40cm"; updated for 8828.*

*Rev4 (24Oct2022): added and updated FoI and FoV models and drawings*

*Rev5 (6Sept2023): clarified crosstalk limits for HPD (slide 8), added comments to rubber boot material (slide 12)*

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6 September 2023

# TMF882X ODG

## Introduction

The TMF8820, TMF8821, and TMF8828 are a direct time-of-flight (dToF) sensor in a single modular package with associated VCSEL. The dToF device is based on SPAD, TDC and histogram technology and achieves 5000 mm detection range. Due to its lens on the SPAD, it supports 3x3, 4x4, 3x6, and 8x8 multi-zone output data and a very wide, dynamically adjustable, field of view. A multi-lens-array (MLA) inside the package above the VCSEL widens up the FoI (field of illumination). All processing of the raw data is performed on-chip and the TMF8820/TMF8821/TMF8828 provide distance information together with confidence values on its I2C interface.

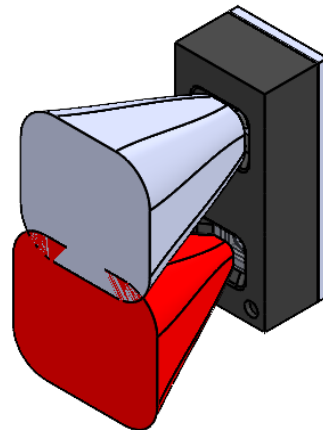
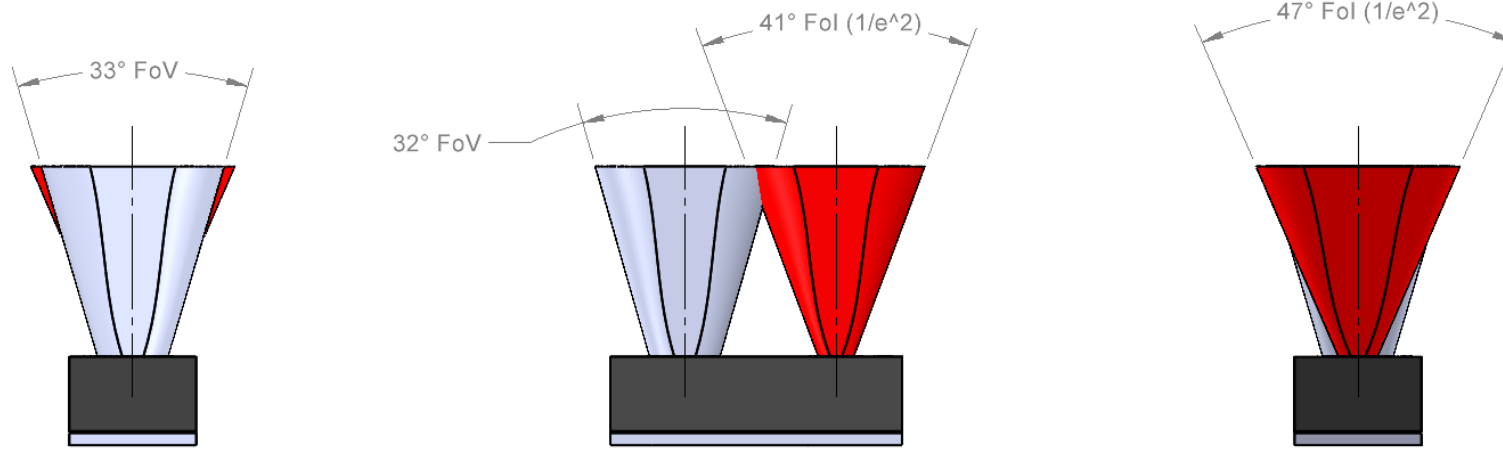
TMF8820	3x3 zone operation
TMF8821	3x3, 4x4 and 3x6 zone operation
TMF8828	8x8 zone operation

The ODG provides EVM setup and system xtalk requirement for both 3x3 and 4x4 normal modes. EVM setup and measurement examples are detailed for both 3x3 and 4x4 modes. The EVM optical stack is defined using a rubber boot. The EVM measurement results are provided for the 3x3 normal mode based on 164 test devices. The measured (Peak) xtalk results are correlated with simulated system xtalk results using 3x3 mode and similar optical stack model. This provides the basis for future design-in simulation guidance to meet the system xtalk requirements.

# TMF8820 ODG

TMF8820 (3x3 zones) normal mode FoI FoV.

Use 3d step file: *TMF8820\_FoI\_FoV\_v2.step*

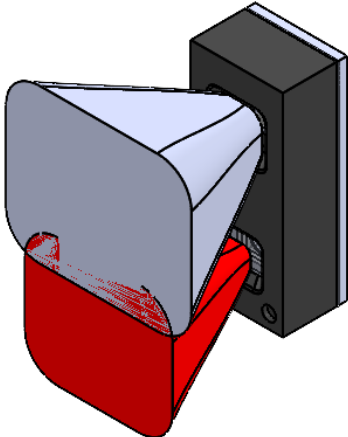
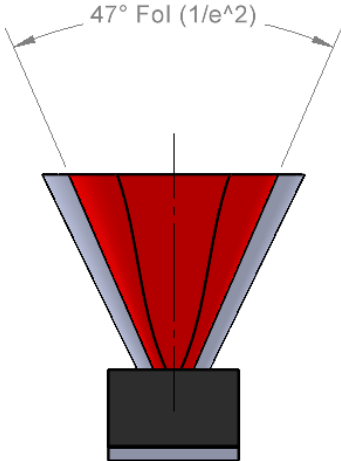
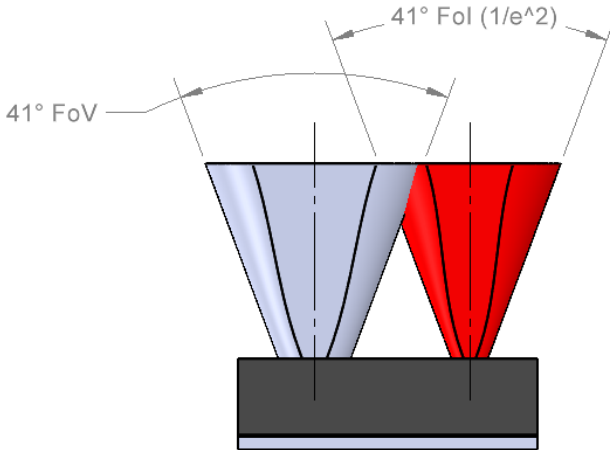
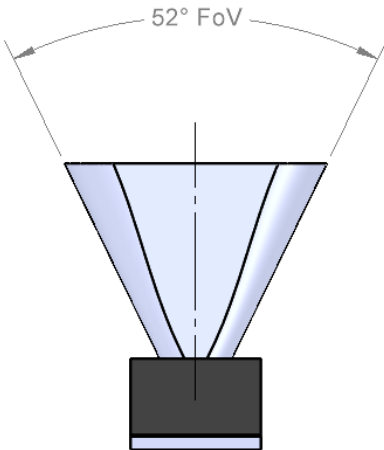


TMF8820 (3X3 ZONE)

# TMF8821 and TMF8828 ODG

TMF8821 (4x4 zones) and TMF8828 (8x8 zones) normal mode FoI FoV.

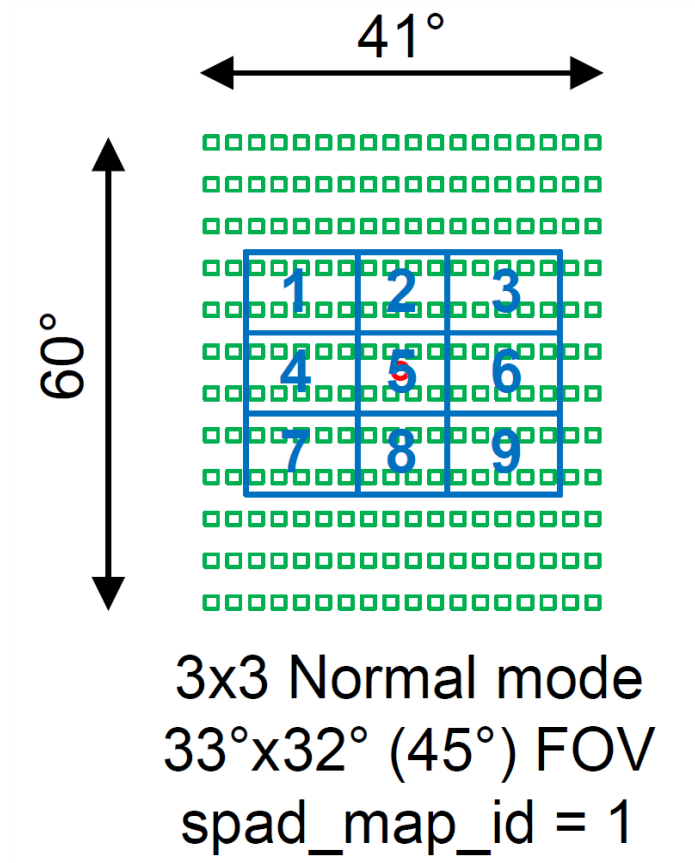
Use 3d step file: *TMF8821\_8828\_FoI\_FoV\_v2.step*



TMF8821 (4X4 ZONE)  
TMF8828 (8X8 ZONE)

# Crosstalk Levels for TMF8820

## 3x3 Normal mode setup and crosstalk requirements



### Setup

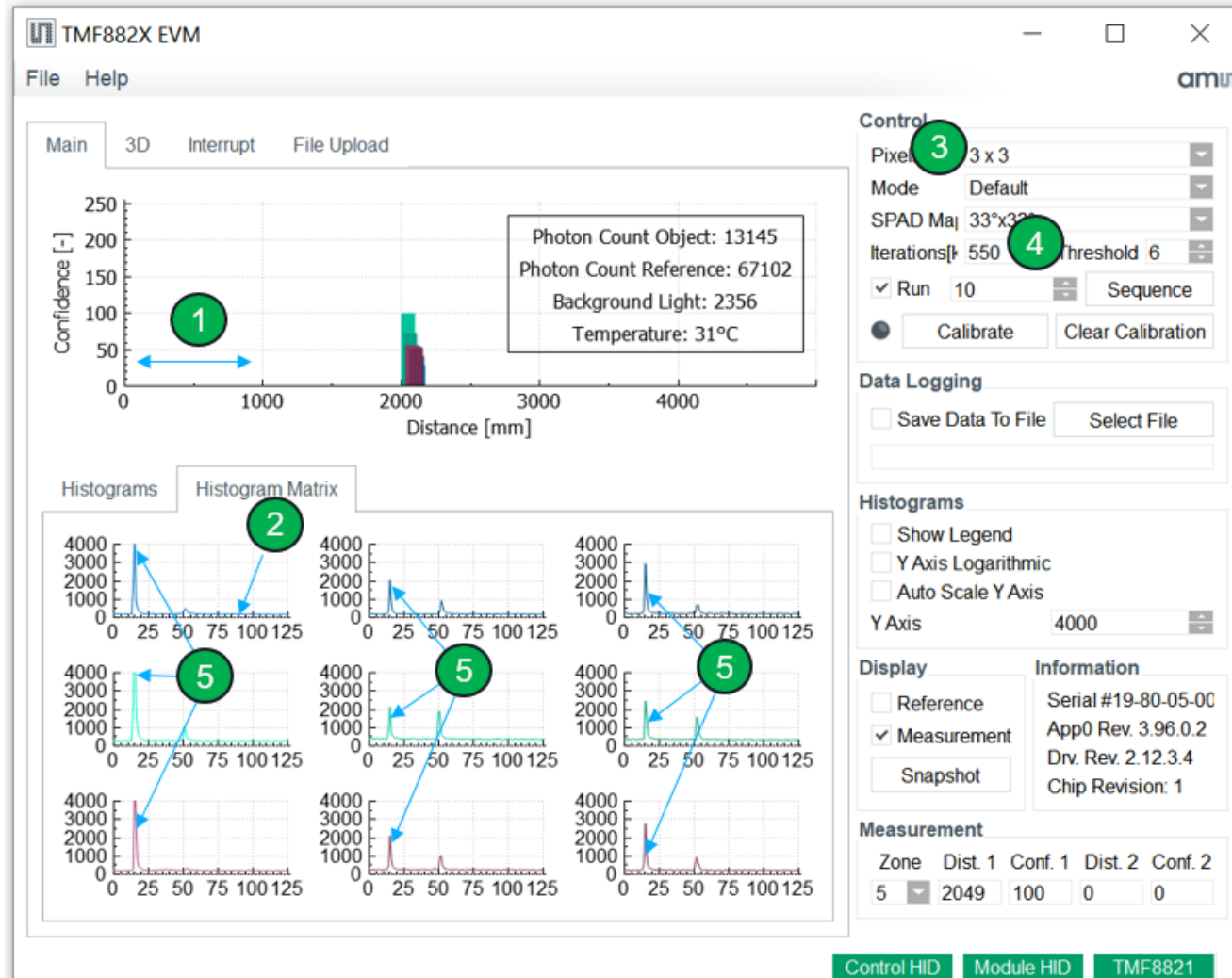
- No target within 40cm
- No IR light
- 550k iterations (= 30 Hz output data rate)
- Use 3x3 mode with 33° x 32° FOV (spad\_map\_id = 1, see datasheet)
- Optical calibration shall be done with 4M iterations.

### Requirements

- Scale crosstalk to 550k iterations
  - Example for 4M iterations: Crosstalk divided by  $4M/550k = 7.27$
- The peak of the crosstalk for all channels except reference channel in 3x3 default mode (33° x 32° degree FOV) shall be within **min 900** counts **max 15200** counts

# Crosstalk Levels checked with the EVM TMF8820

## EVM setup and measurement



### Setup

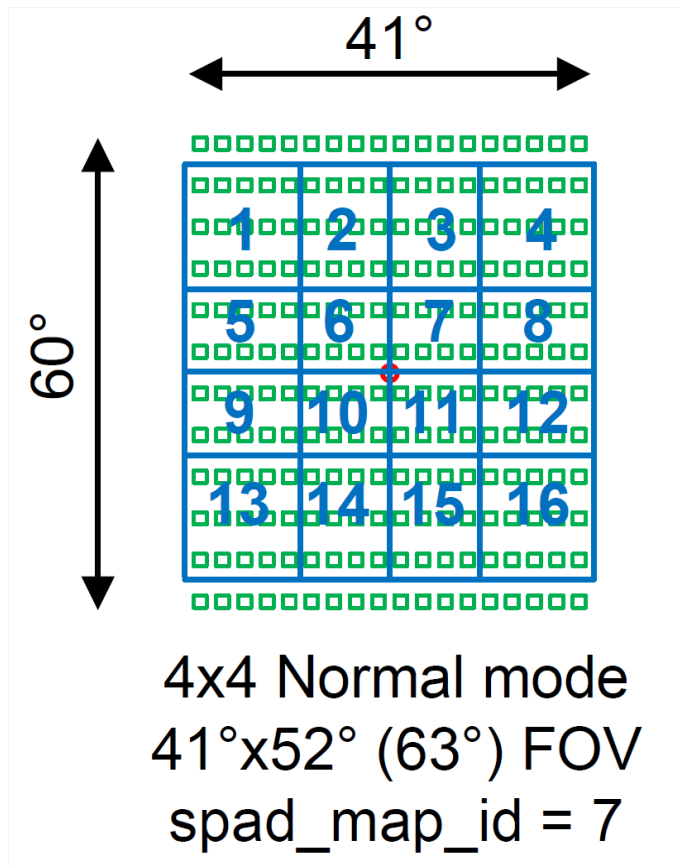
- (1) No target within 40cm
- (2) No IR light
- (3) 3x3 mode, 33° x 32° FOV
- (4) Set iterations to default (550k)

### Measurement

- (5) The crosstalk peaks of all channels shall be within **min 900** counts **max 15200** counts

# Crosstalk Levels for TMF8821

## 4x4 Normal mode setup and crosstalk requirements



### Setup

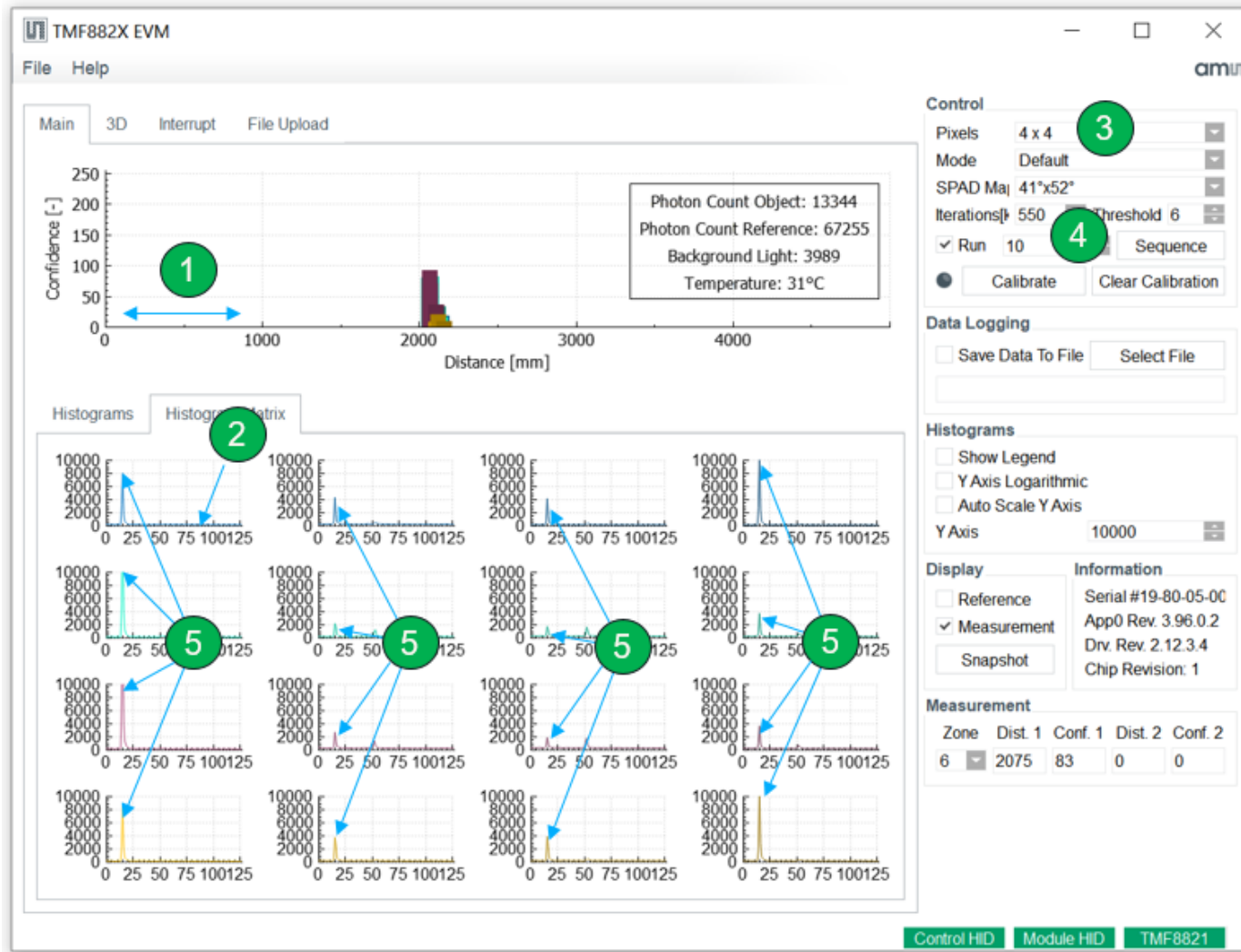
- No target within 40cm
- No IR light
- 550k iterations (= 15 Hz output data rate)
- Use 4x4 mode with 41° x 52° FOV (spad\_map\_id = 7, see datasheet)
- Optical calibration shall be done with 4M iterations.

### Requirements

- Scale crosstalk to 550k iterations
  - Example for 4M iterations: Crosstalk divided by  $4M/550k = 7.27$
- The peak of the crosstalk for all channels except reference channel in 3x3 default mode (33° x 32° degree FOV) shall be within **min 800** counts **max 16000** counts

# Crosstalk Levels checked with the EVM TMF8821

## EVM setup and measurement



### Setup

- (1) No target within 40cm
- (2) No IR light
- (3) 4x4 mode, 41° x 52° FOV
- (4) Set iterations to default (550k)

### Measurement

- (5) The crosstalk peaks of all channels shall be within **min 800 counts max 16000 counts**

### Exceptions

- If accuracy degradation, reduced tolerance to smudge and false positives detection is acceptable by the application (e.g. using it with ams-OSRAM HPD – human presence detection algorithm) the crosstalk limits can exceptionally be relaxed to min 250 counts / max 30000 counts



# Crosstalk Levels checked with the EVM TMF8828

## EVM setup and measurement

### Setup

- No target within 40cm
- No IR light
- 8x8 mode, 41° x 52° FOV
- Iterations set to 550k

### Measurement

- The crosstalk peaks of all channels shall be within **min 320** counts **max 6360** counts

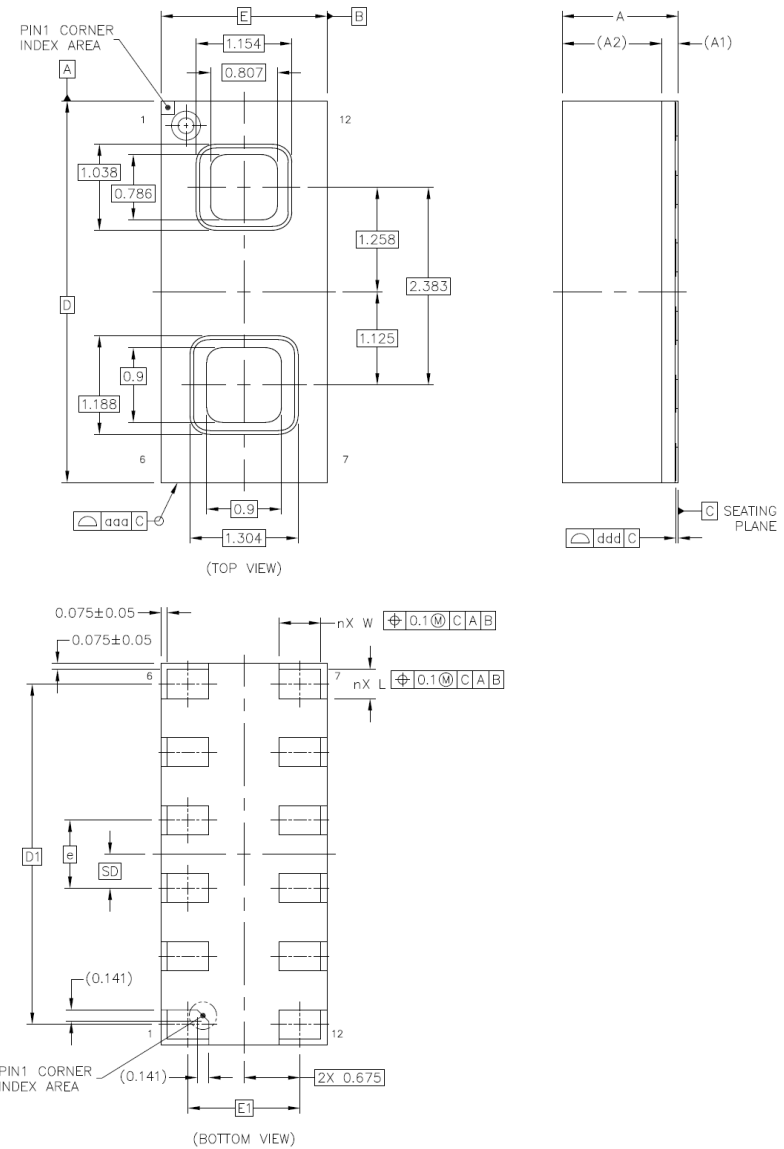
### Execute on EVM

- TMF882x\_Driver\_Linux\_v\*.zip (from <https://ams.com/tmf8828#tab/tools> ) includes Python script for checking crosstalk and executing calibration
- See zip file directory: v\*\_tmf882x\_ev\_m\_linux\aos\_tmf8820\_utils\calib
- Python script: tmf882x\_run\_all\_calibs.py (needs to be executed on PC where GUI is running)

# TMF882X ODG

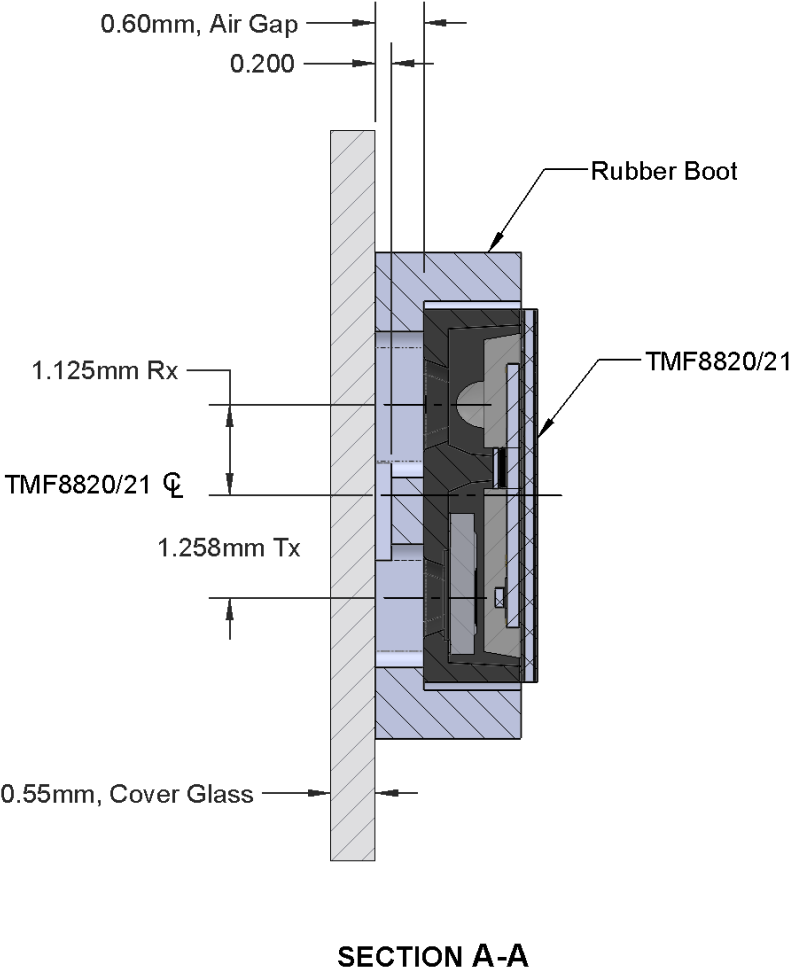
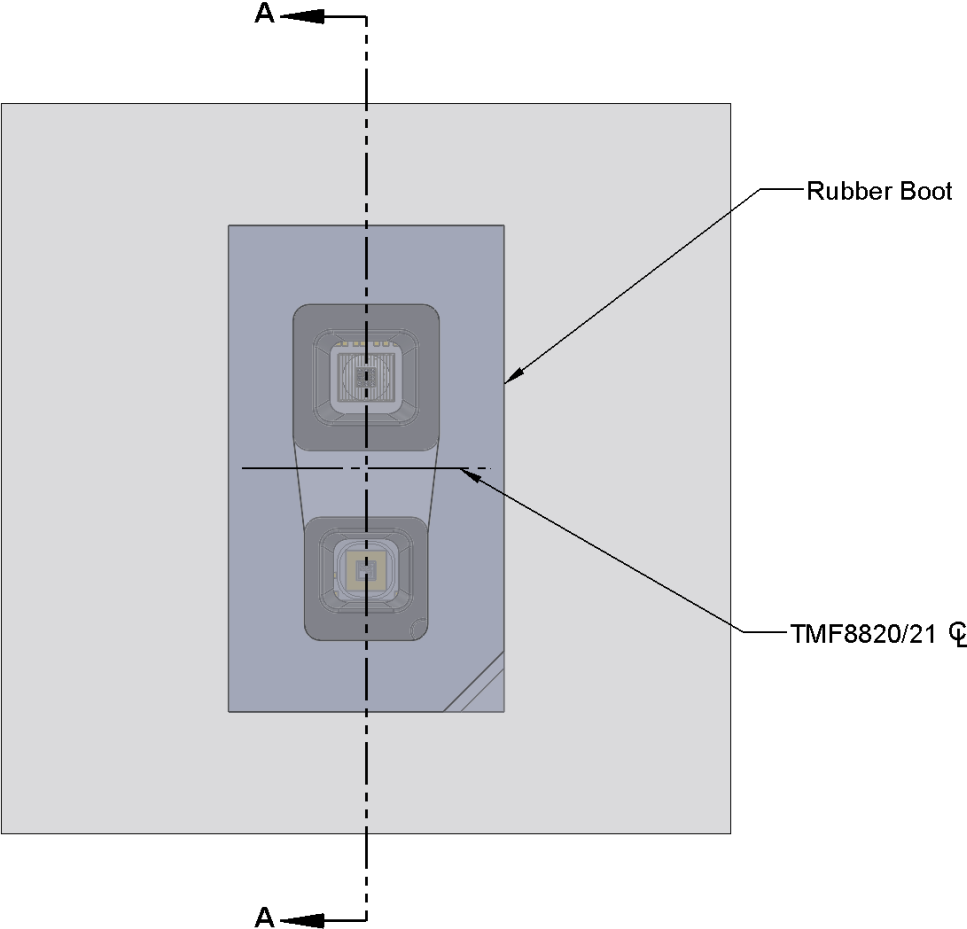
## Package Outline Drawing

	SYMBOL	COMMON DIMENSIONS		
		MIN.	NOR.	MAX.
TOTAL THICKNESS	A	1.3	1.4	1.5
SUBSTRATE THICKNESS	A1	0.2		REF
LID THICKNESS	A2	1.2		REF
BODY SIZE	D	4.6		BSC
	E	2		BSC
LEAD WIDTH	W	0.45	0.5	0.55
LEAD LENGTH	L	0.3	0.35	0.4
LEAD PITCH	e	0.82		BSC
LEAD COUNT	n	12		
EDGE BALL CENTER TO CENTER	D1	4.1		BSC
	E1	1.35		BSC
BODY CENTER TO CONTACT BALL	SD	0.41		BSC
	SE	---		BSC
BALL WIDTH	b	---	---	---
PRE-SOLDER		---	---	---
PACKAGE EDGE TOLERANCE	aaa	0.1		
MOLD FLATNESS	bbb	---		
COPLANARITY	ddd	0.08		
BALL OFFSET (PACKAGE)	eee	---		
BALL OFFSET (BALL)	fff	---		



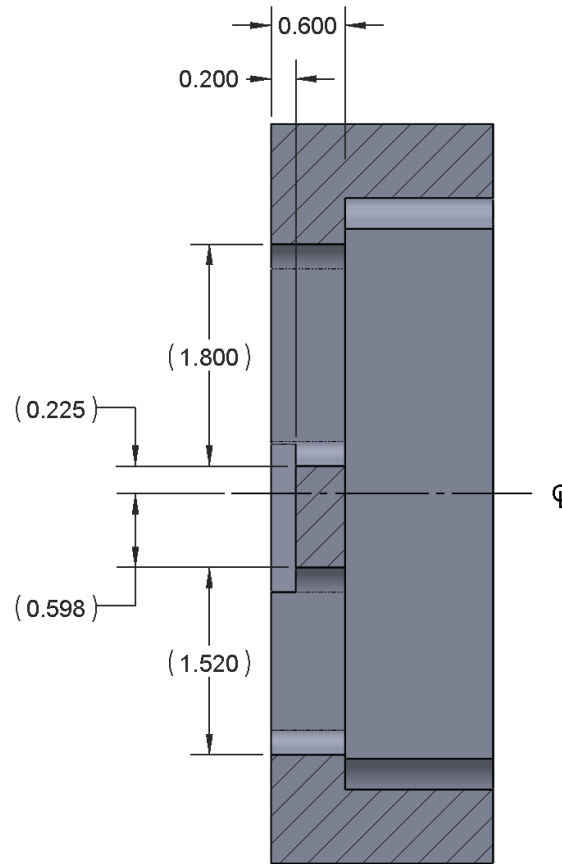
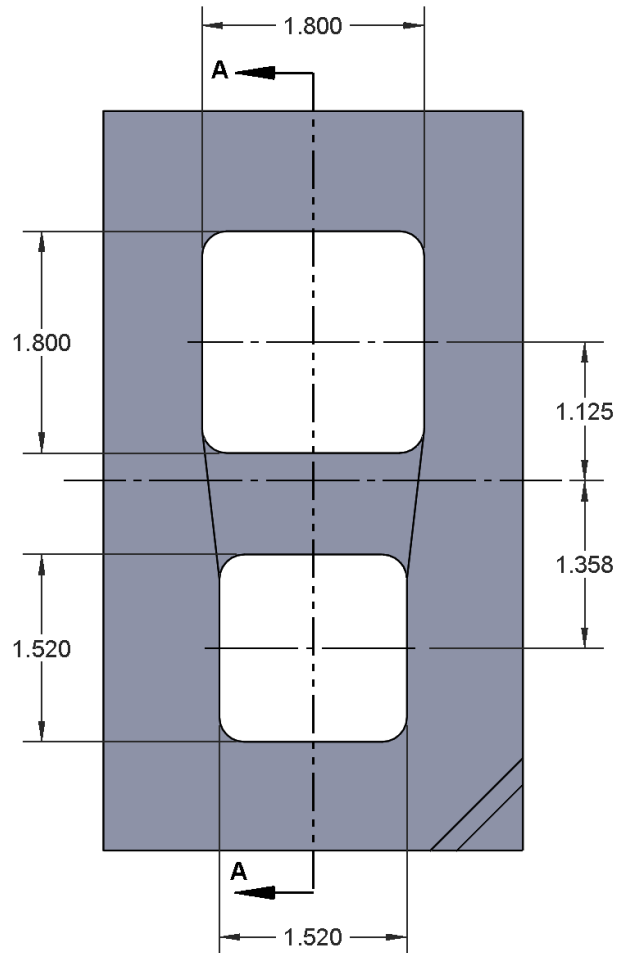
# TMF882X ODG

## Drawing, EVM Setup Optical Stack



# TMF882X ODG

## Drawing, EVM Rubber Boot (RB-V2-06-02)



SECTION A-A

The Rubber boot material shall be IR absorbing (especially for 940nm) and minimize specular reflections.

This is typically achieved by a black, opaque material which has mostly diffuse reflection properties which is not at all shiny.

Generally hard materials for rubber boot are recommended – if this is not possible, the deformation of the rubber boot needs to be considered thus likely increasing crosstalk and crosstalk variation over production.

Using a rubber boot normally reduces crosstalk variation – limits as stated in previous slides apply.

# Optical Simulation and Measurement

## Results, EVM 3x3 normal mode

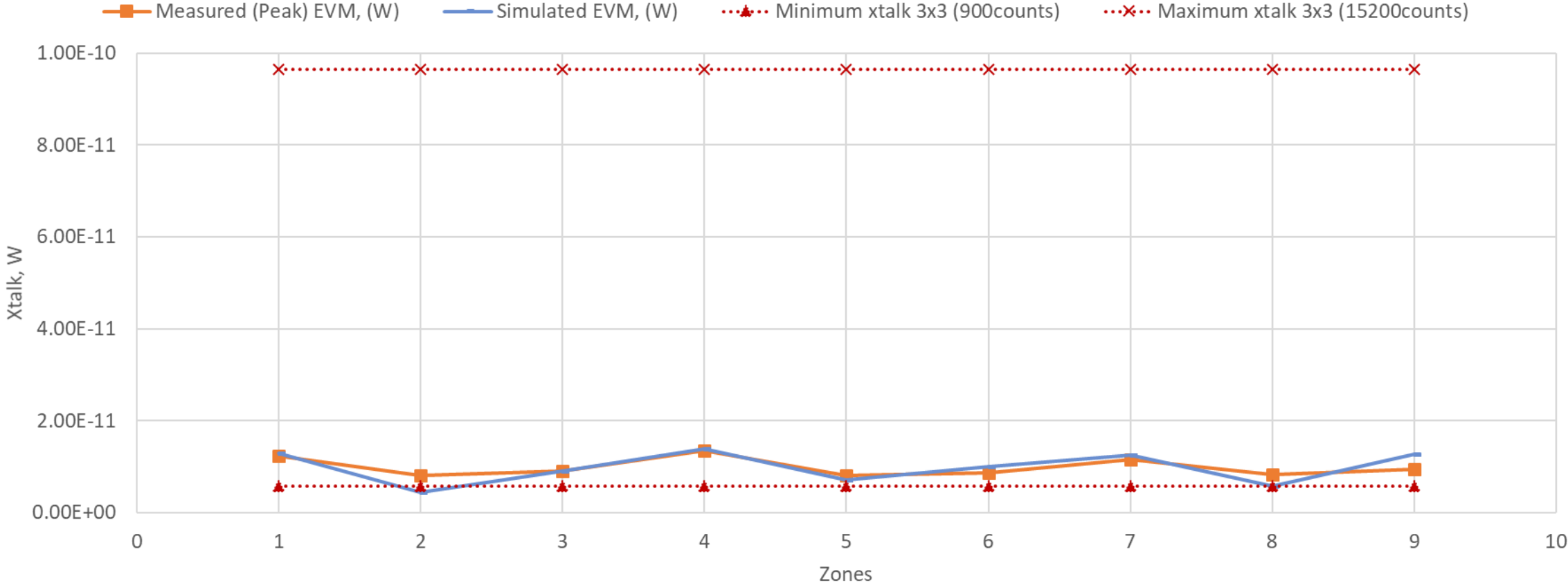
Xtalk / ZONE	1	2	3	4	5	6	7	8	9	Min	Max	Average
Measured (Peak) EVM, (counts)	2066	1082	1517	2266	1086	1446	1958	1113	1600	1082	2266	1570
Measured (Peak) EVM, (W)	1.22E-11	8.01E-12	8.99E-12	1.34E-11	8.04E-12	8.57E-12	1.16E-11	8.24E-12	9.48E-12	8.01E-12	1.34E-11	9.84E-12
Minimum xtalk 3x3 (900counts), (W)	5.71E-12	5.71E-12	5.71E-12	5.71E-12	5.71E-12	5.71E-12	5.71E-12	5.71E-12	5.71E-12	5.71E-12	5.71E-12	5.71E-12
Maximum xtalk 3x3 (15200counts), (W)	9.65E-11	9.65E-11	9.65E-11	9.65E-11	9.65E-11	9.65E-11	9.65E-11	9.65E-11	9.65E-11	9.65E-11	9.65E-11	9.65E-11
Simulated EVM, (W)	1.30E-11	4.46E-12	9.04E-12	1.38E-11	7.08E-12	9.98E-12	1.25E-11	5.81E-12	1.28E-11	4.46E-12	1.38E-11	9.83E-12

Measured (Peak) xtalk results are based the average of 164 test devices using the EVM optical stack with 0.55mm Cover Glass.

# Optical Simulation and Measurement

## Results, EVM 3x3 normal mode

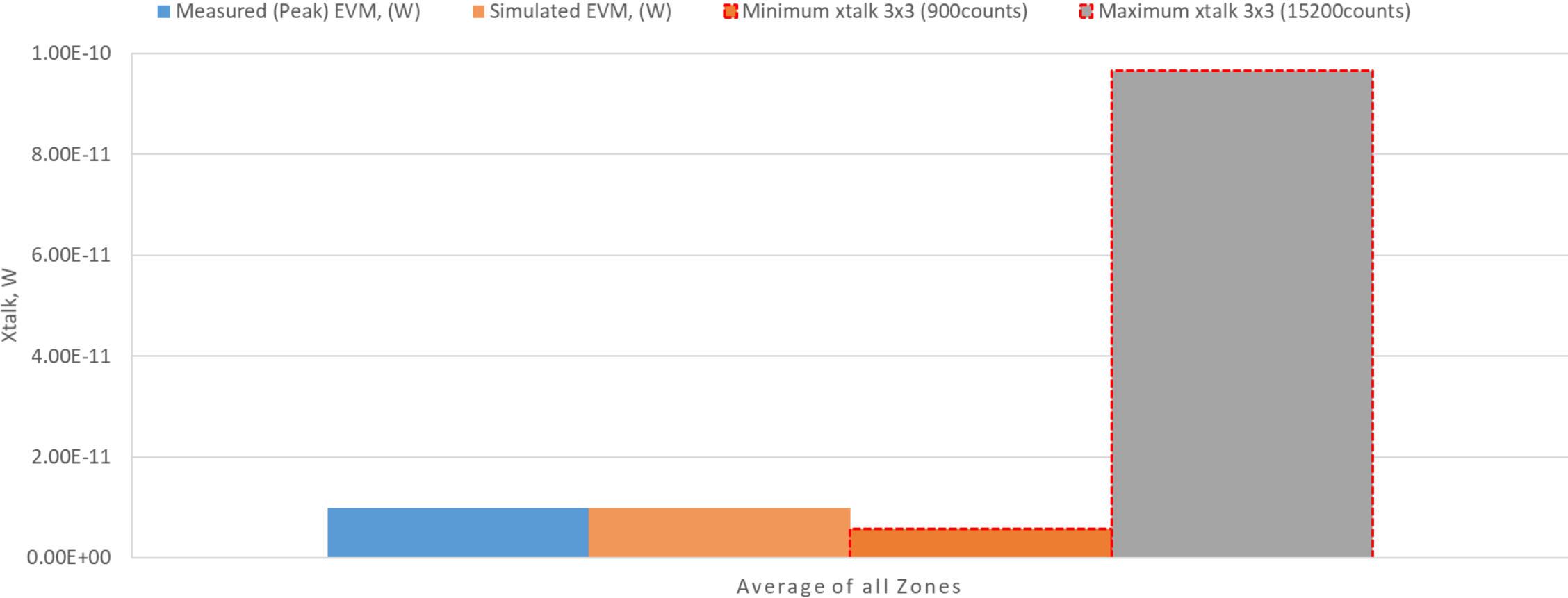
### System xtalk per zone for EVM 3x3 normal mode



# Optical Simulation and Measurement

Results, Average of all zones, EVM 3x3 normal mode

### System xtalk, average of all zones, for EVM 3x3 normal mode

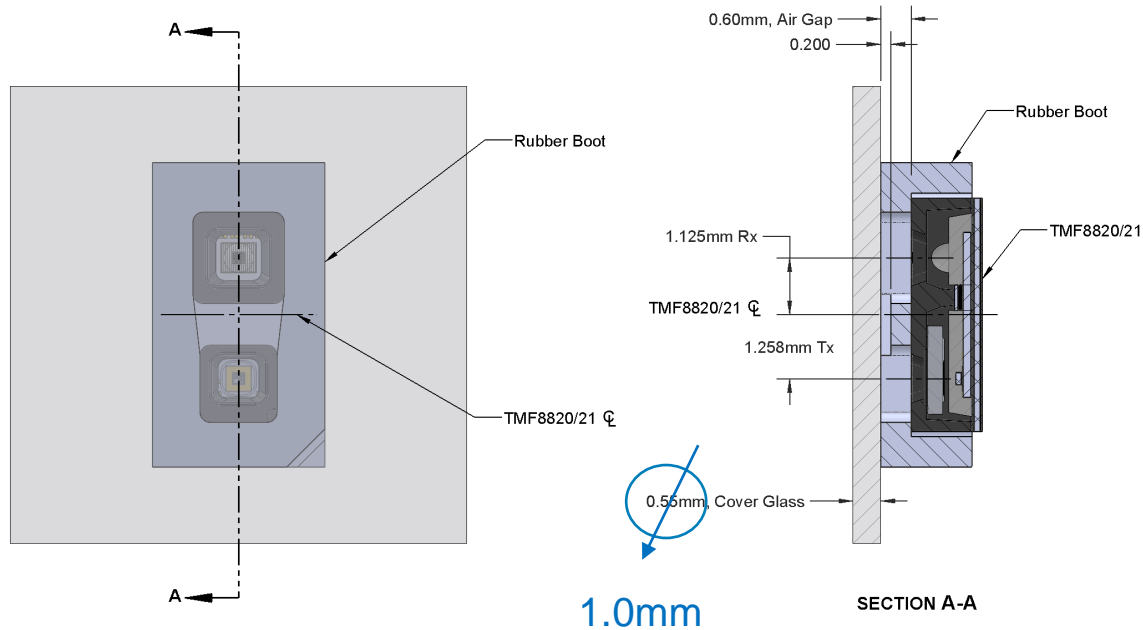


# Appendix A



# Appendix A

Drawing of EVM Optical Stack uses thicker cover glass (1.0mm) as indicated



Simulation:

EVM optical stack uses the thicker cover glass (1.0mm) to achieve average system xtalk well centered between the minimum and maximum xtalk requirements. The target xtalk centered between the minimum and maximum is  $9.86E-11$  W.

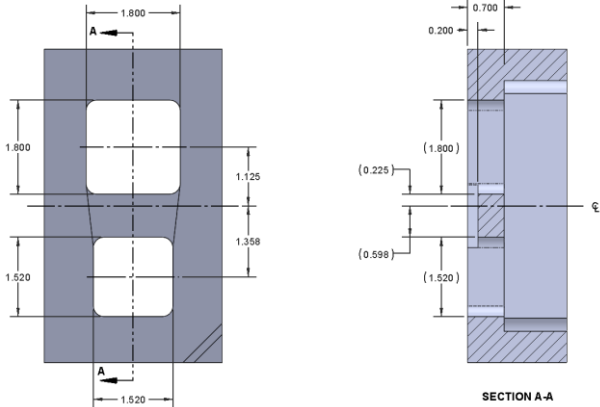
Simulation result represent 3x3 normal mode using v4 model.

The simulated results are scale by SPAD Fill Factor and x1.93 coefficient for best alignment with measure results. This assumes that measurement are correct and simulation results aren't exact.

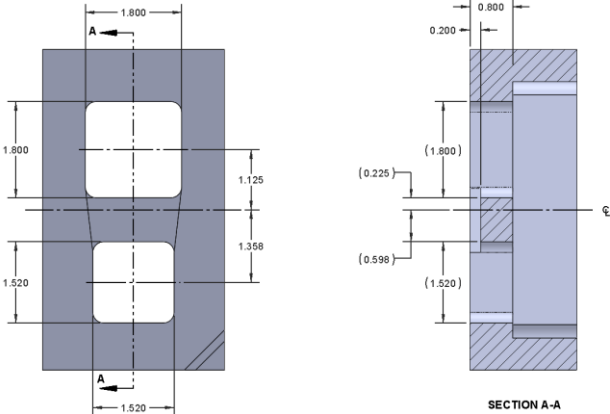
This is why the ODG-v2 Measured (Peak) EVM (W) differ from the ODG-v1 Measured results. The early ODG-v1 measured results were scaled by x1.93 instead of the simulated.

# Appendix A

## Drawing, additional Rubber Boot configurations simulated with the thicker cover glass (1mm)



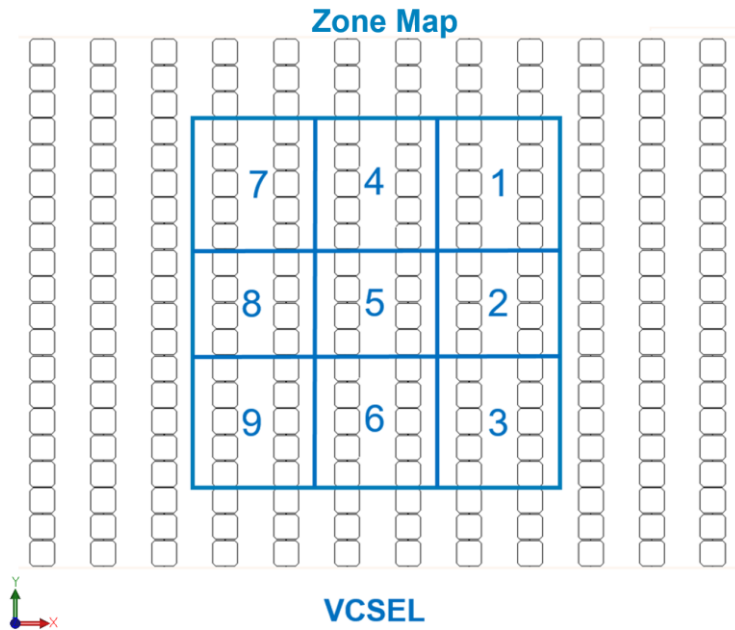
Added v2 rubber boot RB-V2-07-02  
0.7mm air gap with 0.2 cut



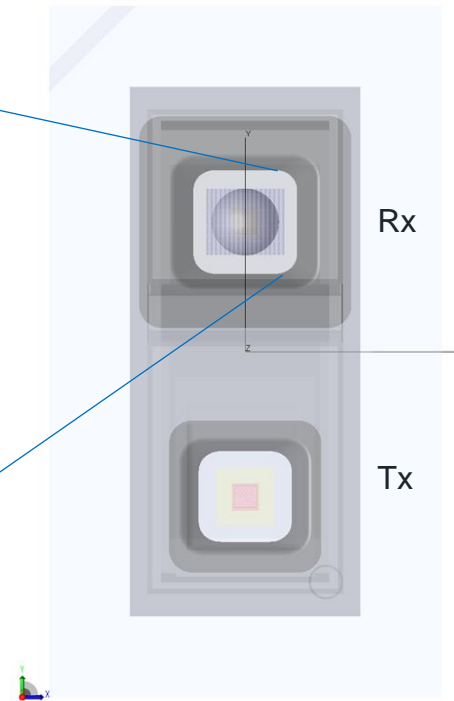
Added v2 rubber boot RB-V2-08-02  
0.8mm air gap with 0.2 cut

# Appendix A

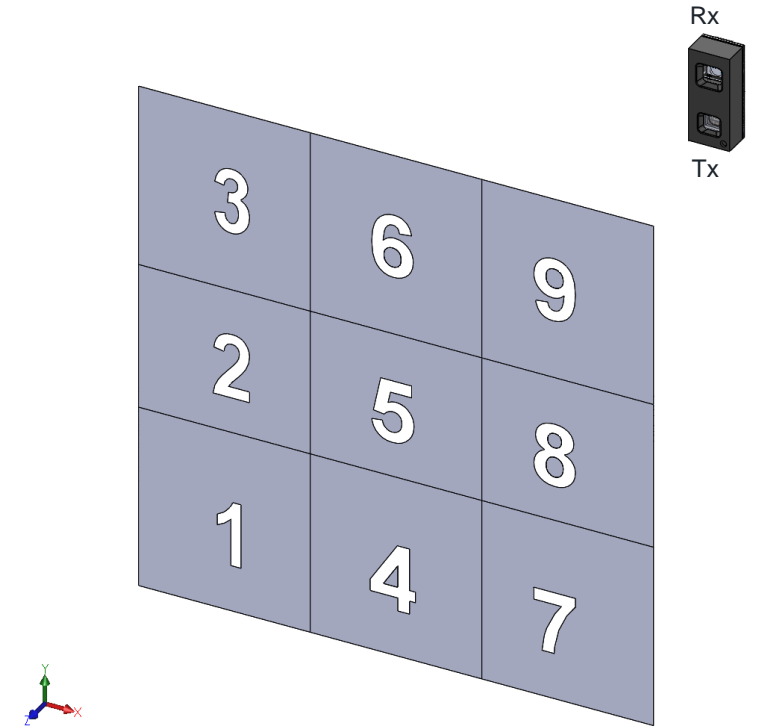
**Zone Map, definition, 3x3 normal mode, TMF8820. Note: The SPAD zones indicate the far field target zones projected and inverted from the target onto the SPAD array surface. Far field projection is inverted due to the lens.**



Zone Map defined at the SPAD array surface



Top view TMF8820 showing the SPAD array behind the lens



Zone Map defined at the target in the far field

# Appendix A

## Results, EVM 3x3 normal mode, using 1.0mm Cover Glass

ZONE	1	2	3	4	5	6	7	8	9	Min	Max	Average
Measured (Peak) EVM CG0.55_AG0.6, (counts)	2066	1082	1517	2266	1086	1446	1958	1113	1600	1082	2266	1570
Measured (Peak) EVM CG0.55_AG0.6, (W)	2.36E-11	1.55E-11	1.73E-11	2.59E-11	1.55E-11	1.65E-11	2.24E-11	1.59E-11	1.83E-11	1.55E-11	2.59E-11	1.90E-11
Minimum xtalk 3x3 (900counts), (W)	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11
Maximum xtalk 3x3 (15200counts), (W)	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10
Simulated EVM CG0.55_AG0.6, (W)	2.50E-11	8.60E-12	1.74E-11	2.67E-11	1.37E-11	1.93E-11	2.42E-11	1.12E-11	2.47E-11	8.60E-12	2.67E-11	1.90E-11
Simulated EVM CG1.0_AG0.6, (W)	1.26E-10	1.45E-10	4.26E-11	2.05E-09	1.88E-10	5.49E-11	1.24E-10	1.44E-10	8.17E-11	4.26E-11	2.05E-09	3.28E-10
Simulated EVM CG1.0_AG0.7, (W)	2.19E-10	2.66E-11	3.71E-11	3.52E-09	2.79E-11	5.40E-11	1.78E-10	3.20E-11	9.00E-11	2.66E-11	3.52E-09	4.65E-10
Simulated EVM CG1.0_AG0.8, (W)	2.53E-10	4.63E-11	7.32E-11	5.26E-09	2.16E-11	1.06E-10	2.57E-10	2.34E-11	7.20E-11	2.16E-11	5.26E-09	6.79E-10

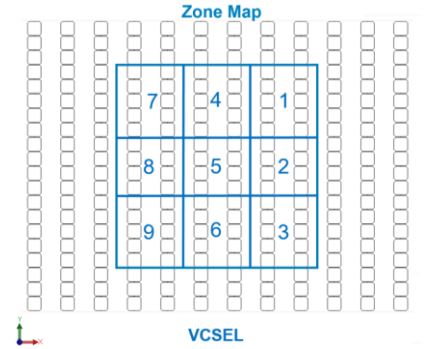
The average of Minimum and Maximum xtalk is 9.86E-11 W.

Measured (Peak) xtalk results are based the average of 164 test devices using the EVM optical stack with 0.55mm Cover Glass.

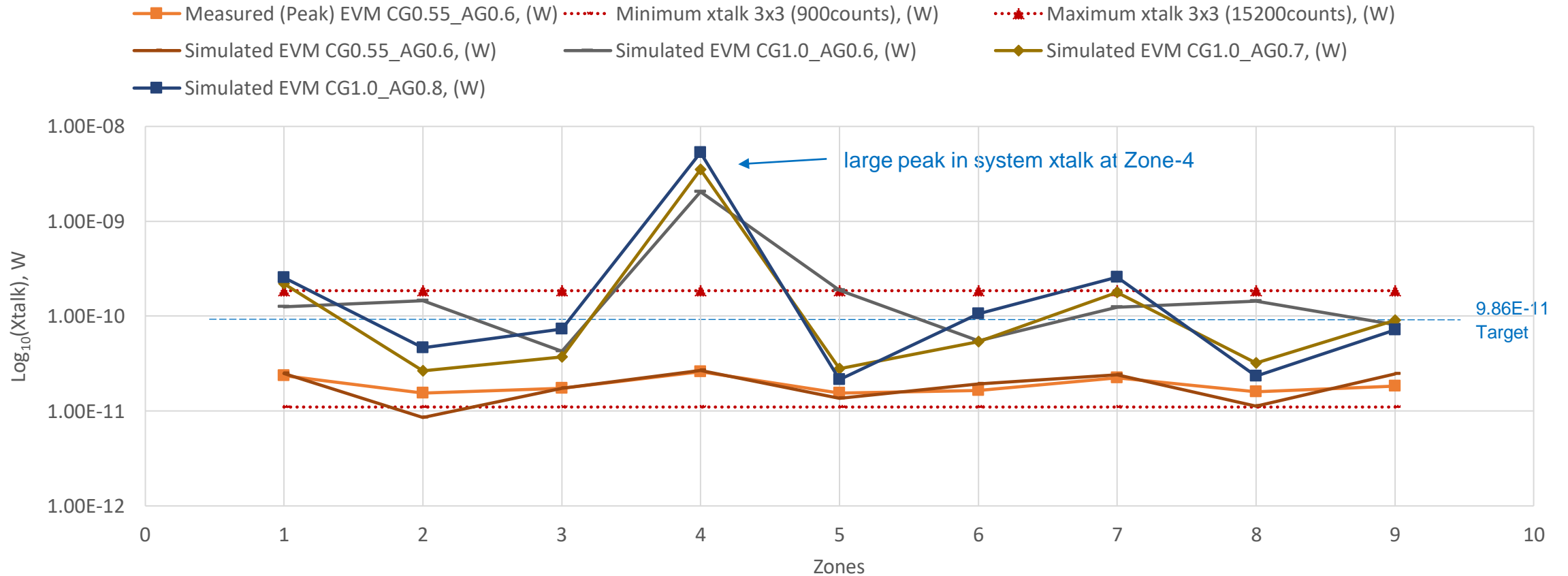
The optical stacks are the same for both the Measured (Peak) EVM xtalk and Simulated EVM CG0.55\_AG0.6 xtalk results.

# Appendix A

## Results, EVM 3x3 normal mode, using 1.0mm Cover Glass



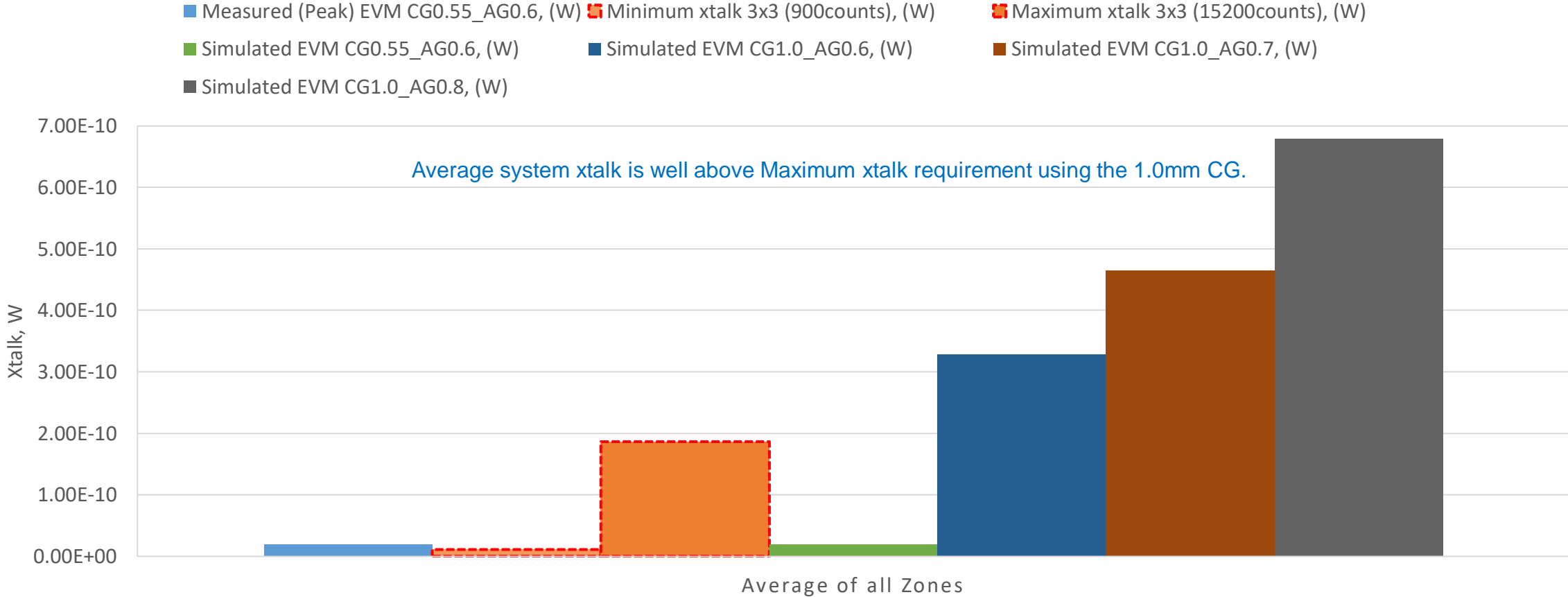
### System xtalk per zone for EVM 3x3 normal mode



# Appendix A

## Results, Average of all zones, EVM 3x3 normal mode, using 1.0mm Cover Glass

### System xtalk, average of all zones, for EVM 3x3 normal mode



# Appendix A

## Results, Ray Path Analysis with 1.0mm CG

Because of the large peak in system xtalk at Zone-4 using 1.0mm CG, ray path analysis is provided for Zone-4 and for adjacent zones, Zone-1 and Zone-5.

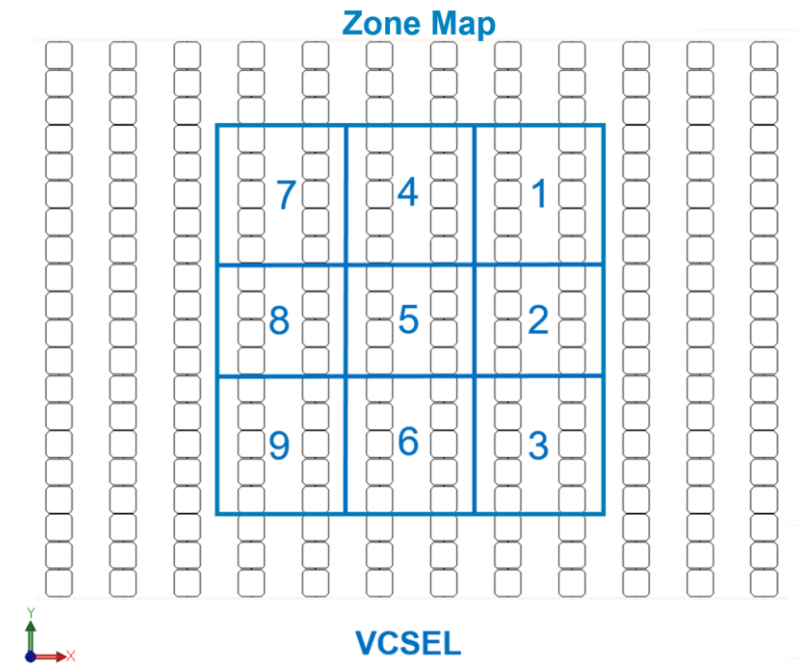
Zone-1 and Zone-5 are provided for comparison to Zone-4.

Ray trace results are provided for 3 air gaps for each zone.

Air gap 0.6mm

Air gap 0.7mm

Air gap 0.8mm



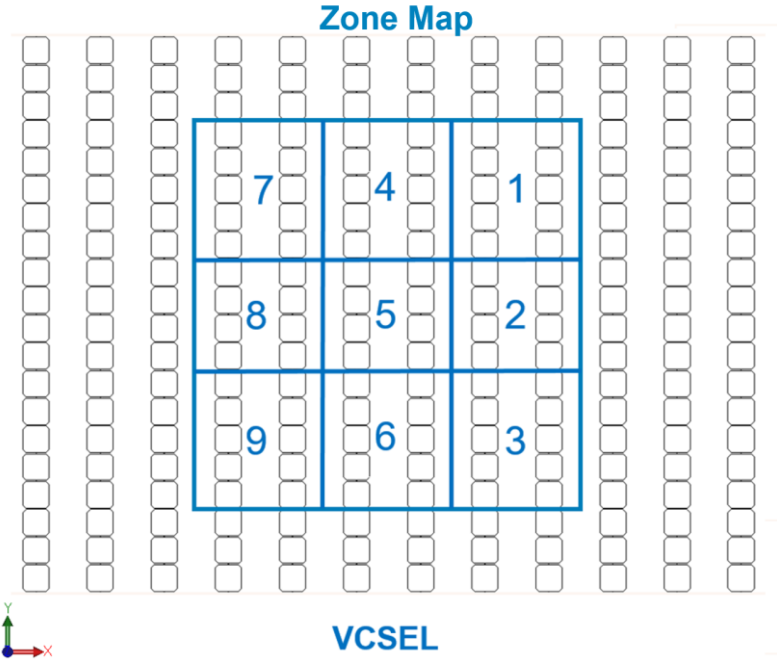
# Appendix A

Results, ray path analysis of Zone-4 peak system xtalk using 1.0mm cover glass for:

Air gap 0.6mm

Air gap 0.7mm

Air gap 0.8mm

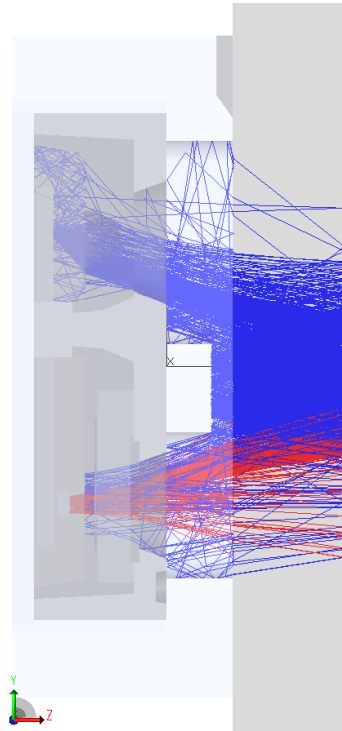




# Appendix A

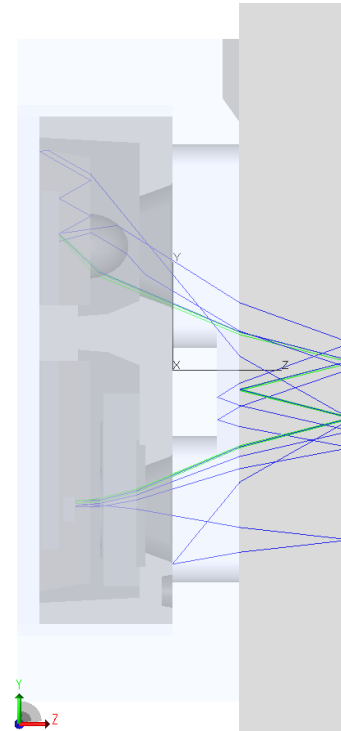
## Results, ray path analysis of Zone-4 peak system xtalk

Air gap 0.6mm using thicker cover glass (1.0mm)



Zone-4 (RB-V2-06-02)

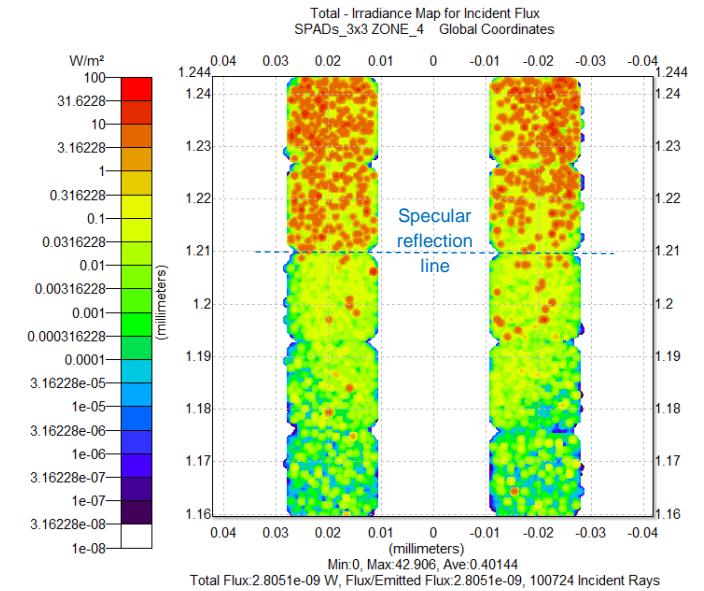
All ray paths are shown above.



Zone-4 (RB-V2-06-02)

Most intense ray paths are shown above representing >95% of total flux.

Large peak in system xtalk at Zone-4 is due to specular reflection from CG.



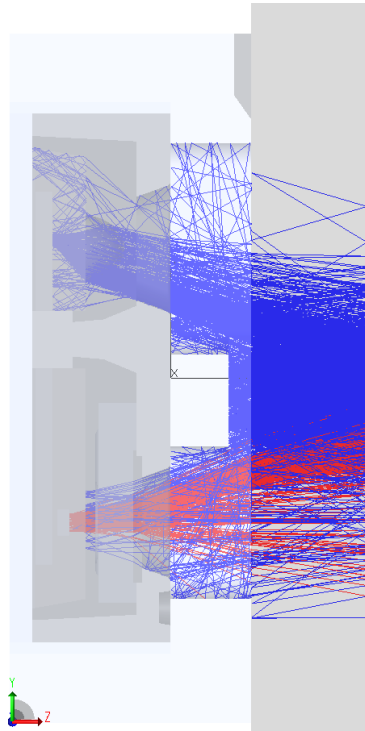
Zone-4 (RB-V2-06-02)

Irradiance Map

# Appendix A

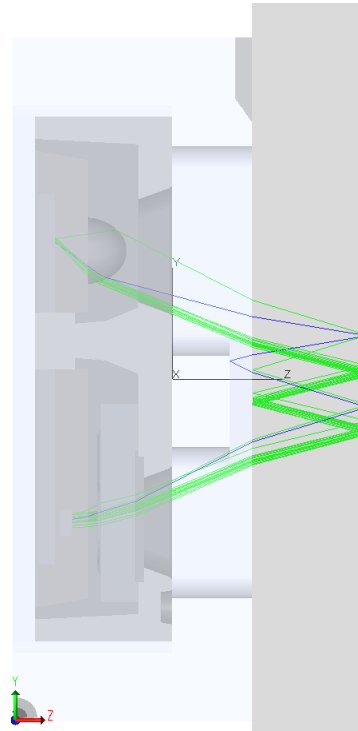
## Results, ray path analysis of Zone-4 peak system xtalk

Air gap 0.7mm using thicker cover glass (1.0mm)



Zone-4 (RB-V2-07-02)

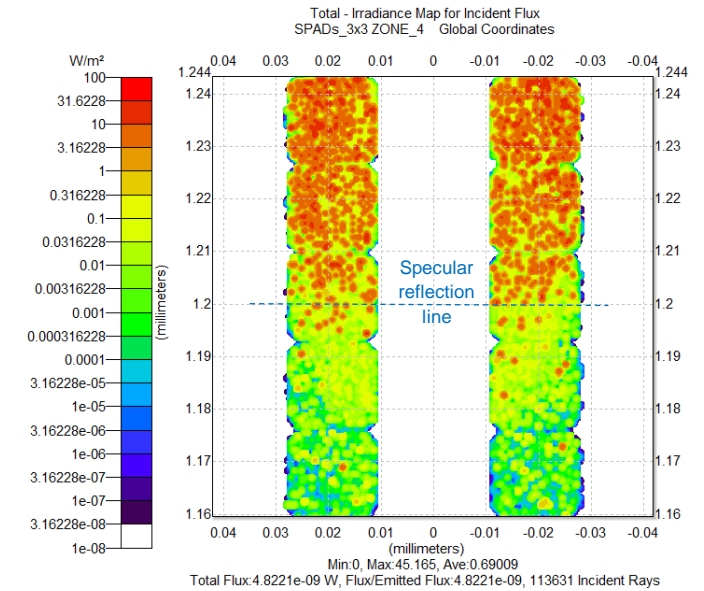
All ray paths are shown above.



Zone-4 (RB-V2-07-02)

Most intense ray paths are shown above representing >95% of total flux.

Large peak in system xtalk at Zone-4 is due to specular reflection from CG. Number of incident ray paths and flux increases with air gap.



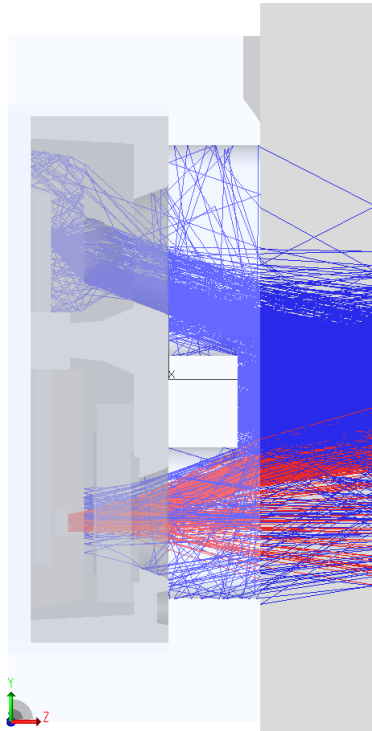
Zone-4 (RB-V2-07-02)

Irradiance Map

# Appendix A

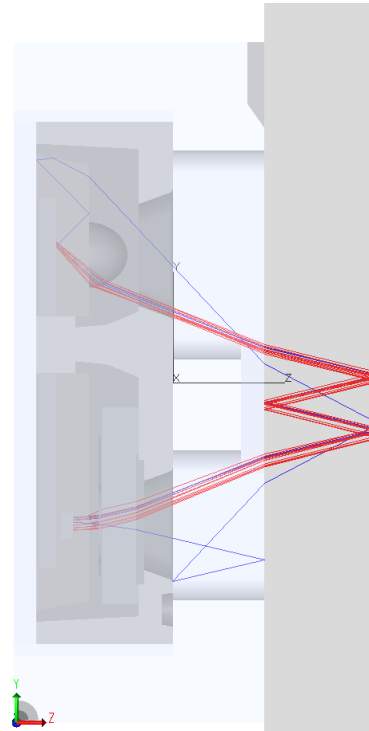
## Results, ray path analysis of Zone-4 peak system xtalk

Air gap 0.8mm using thicker cover glass (1.0mm)



Zone-4 (RB-V2-08-02)

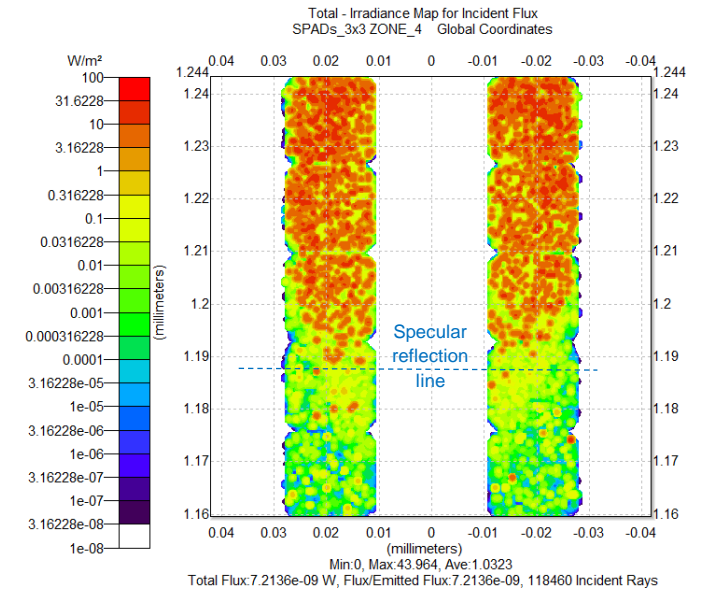
All ray paths are shown above.



Zone-4 (RB-V2-08-02)

Most intense ray paths are shown above representing >95% of total flux.

Large peak in system xtalk at Zone-4 is due to specular reflection from CG. Number of incident ray paths and flux increases with air gap.



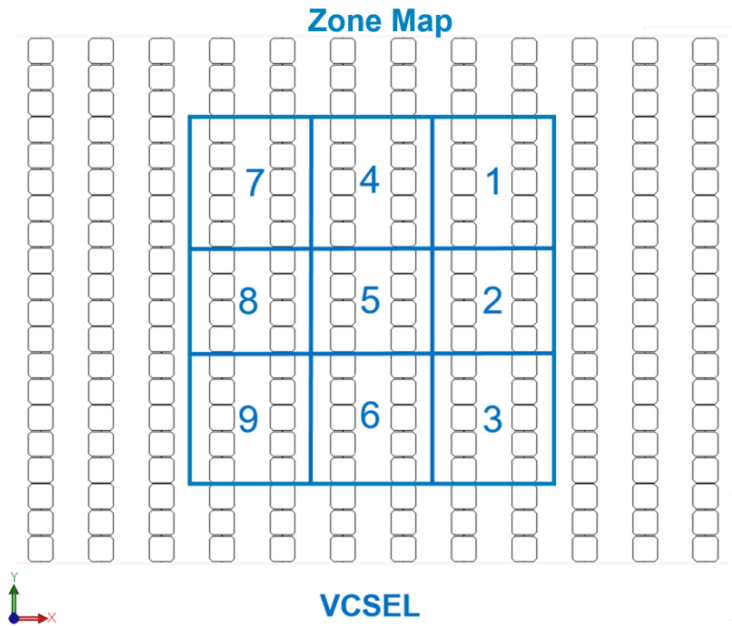
Zone-4 (RB-V2-08-02)

Irradiance Map

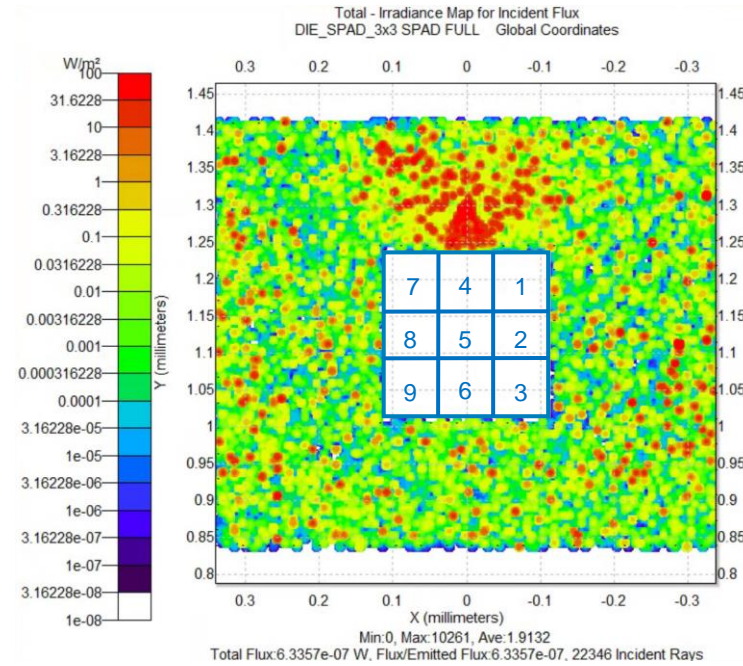
# Appendix A

Results, Full SPAD except 3x3, system xtalk

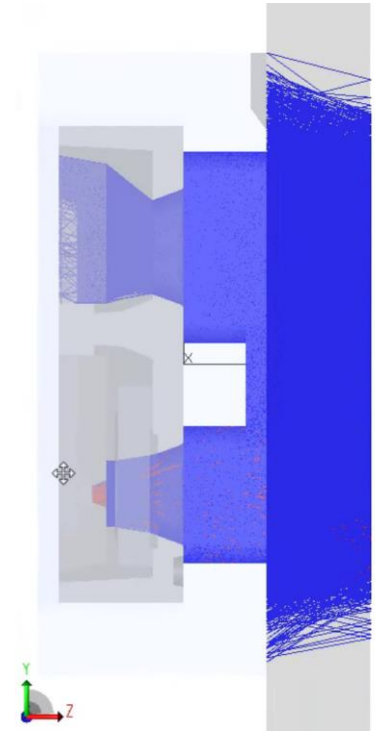
Air gap 0.8mm using thicker cover glass (1.0mm)



3x3 SPAD Map



Full SPAD except 3x3 zones



All ray paths shown

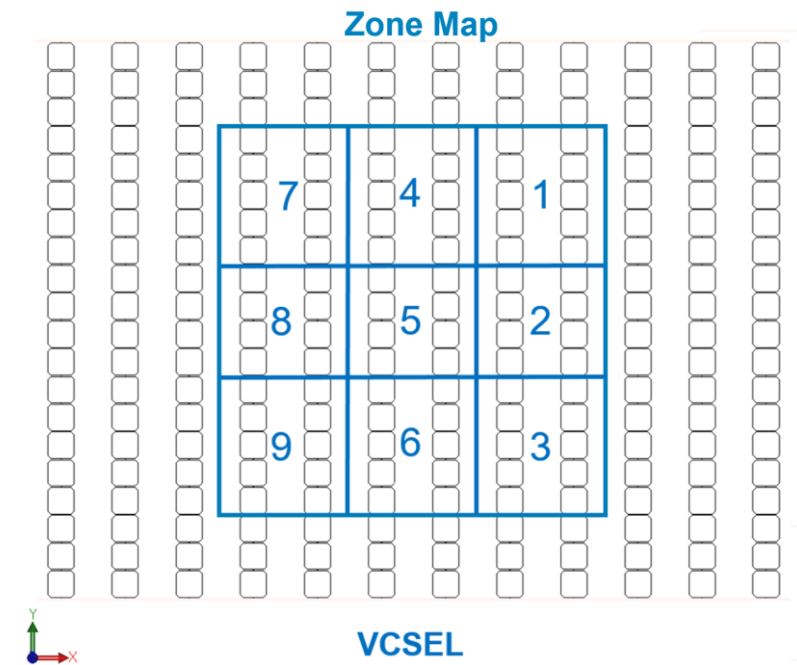
# Appendix A

Results, ray path analysis of Zone-1 peak system xtalk using 1.0mm cover glass for:

Air gap 0.6mm

Air gap 0.7mm

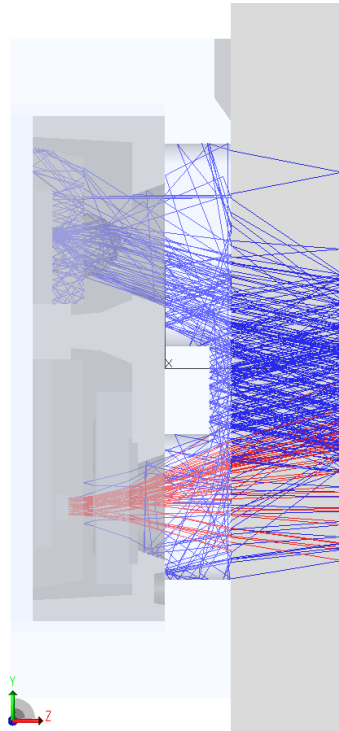
Air gap 0.8mm



# Appendix A

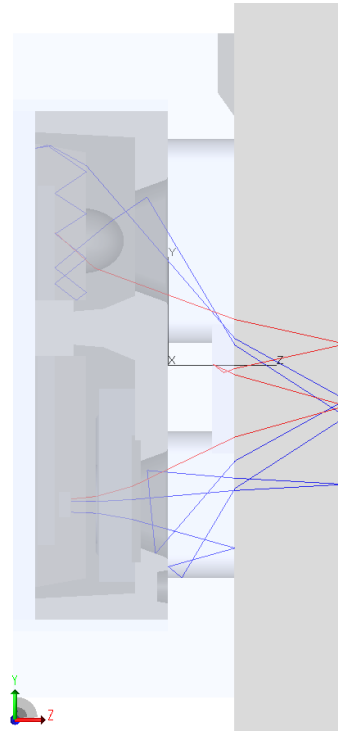
## Results, ray path analysis of Zone-1 peak system xtalk

### Air gap 0.6mm using thicker cover glass (1.0mm)



Zone-1 (RB-V2-06-02)

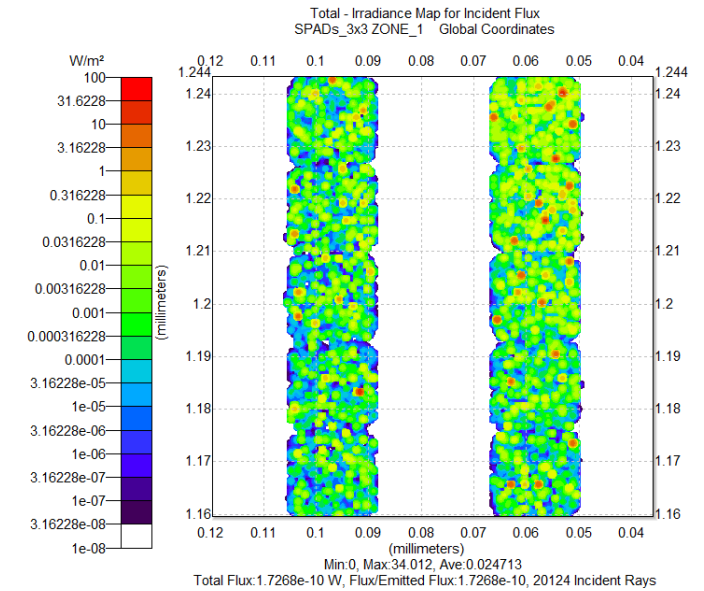
All ray paths are shown above.



Zone-1 (RB-V2-06-02)

Most intense ray paths are shown above representing >95% of total flux.

Zone-1 system xtalk does not show specular ray paths from CG contributing significantly to total flux. Number of incident ray paths and flux increases with air gap.



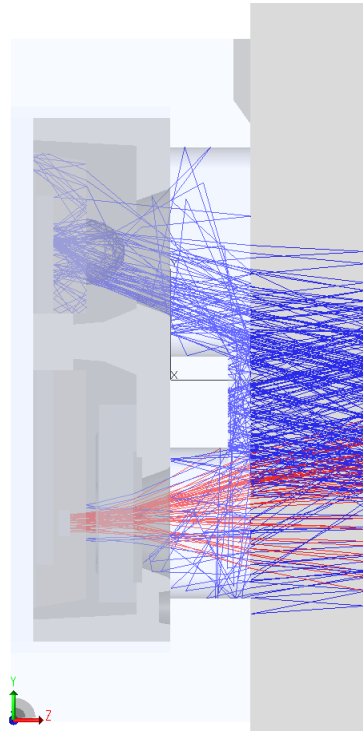
Zone-1 (RB-V2-06-02)

Irradiance Map

# Appendix A

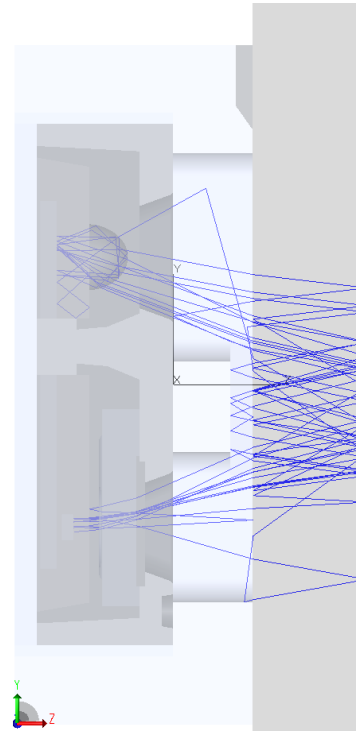
## Results, ray path analysis of Zone-1 peak system xtalk

Air gap 0.7mm using thicker cover glass (1.0mm)



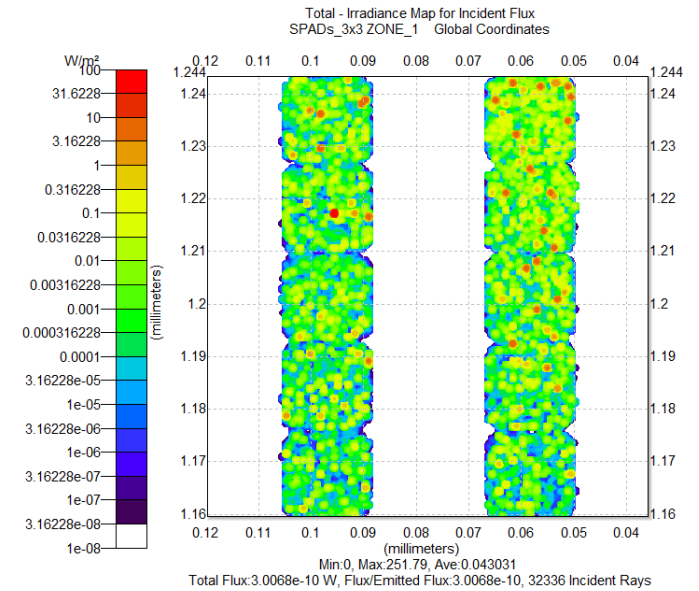
Zone-1 (RB-V2-07-02)

All ray paths are shown above.



Zone-1 (RB-V2-07-02)

Most intense ray paths are shown above representing >95% of total flux.



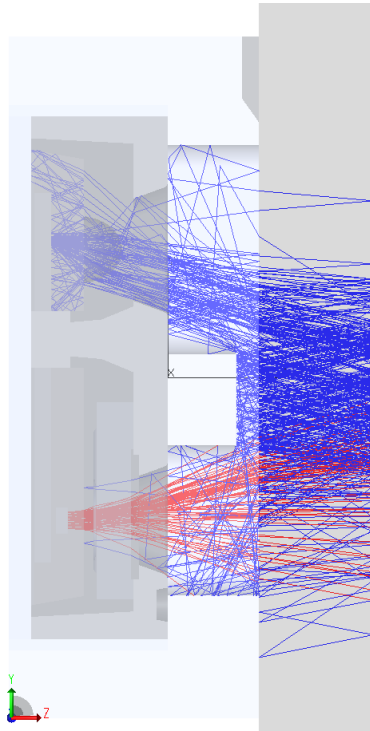
Zone-1 (RB-V2-07-02)

Irradiance Map

# Appendix A

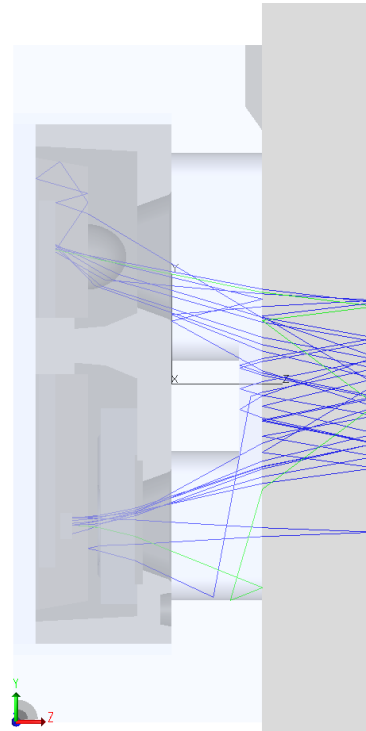
## Results, ray trace analysis of Zone-1 peak system xtalk

Air gap 0.8mm using thicker cover glass (1.0mm)



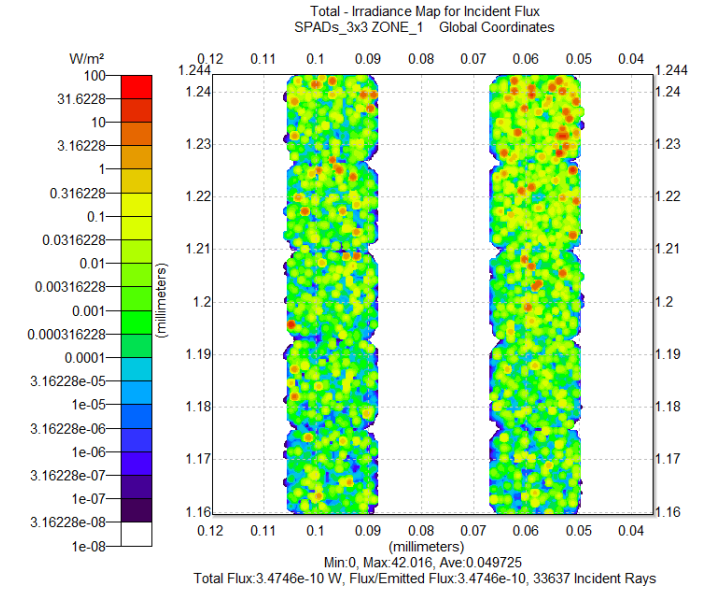
Zone-1 (RB-V2-08-02)

All ray paths are shown above.



Zone-1 (RB-V2-08-02)

Most intense ray paths are shown above representing >95% of total flux.



Zone-1 (RB-V2-08-02)

Irradiance Map



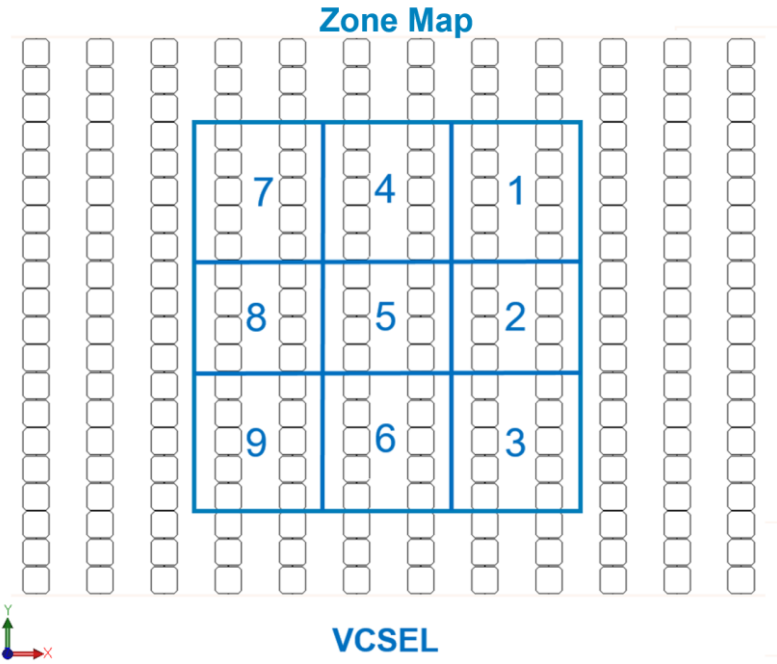
# Appendix A

Results, ray path analysis of Zone-5 peak system xtalk using 1.0mm cover glass for:

Air gap 0.6mm

Air gap 0.7mm

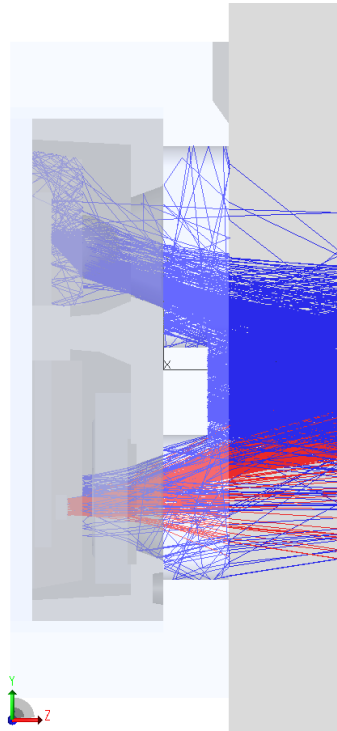
Air gap 0.8mm



# Appendix A

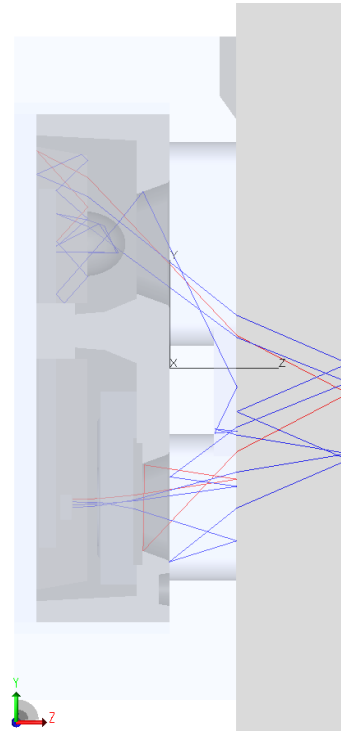
## Results, ray path analysis of Zone-5 peak system xtalk

Air gap 0.6mm using thicker cover glass (1.0mm)



Zone-5 (RB-V2-06-02)

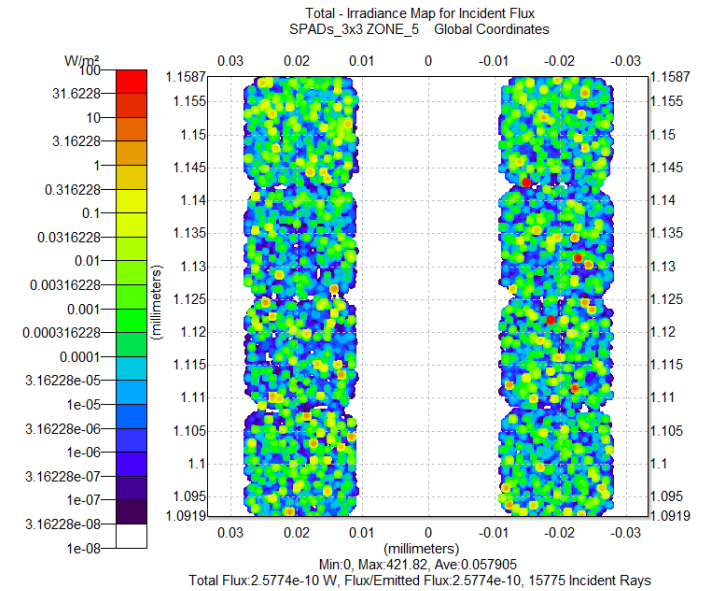
All ray paths are shown above.



Zone-5 (RB-V2-06-02)

Most intense ray paths are shown above representing >95% of total flux.

Zone-5 system xtalk does not show specular ray paths from CG contributing significantly to total flux. Number of incident ray paths and flux increases with air gap.



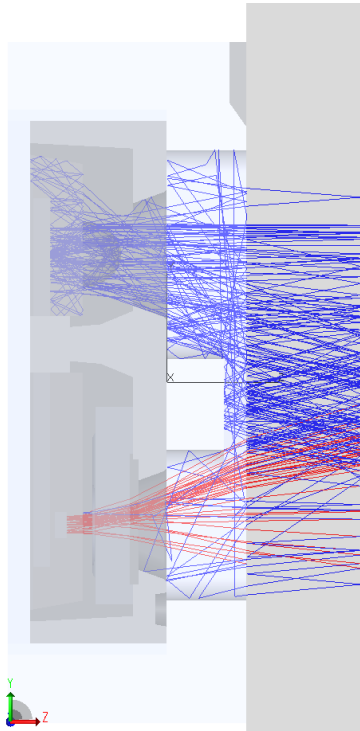
Zone-5 (RB-V2-06-02)

Irradiance Map

# Appendix A

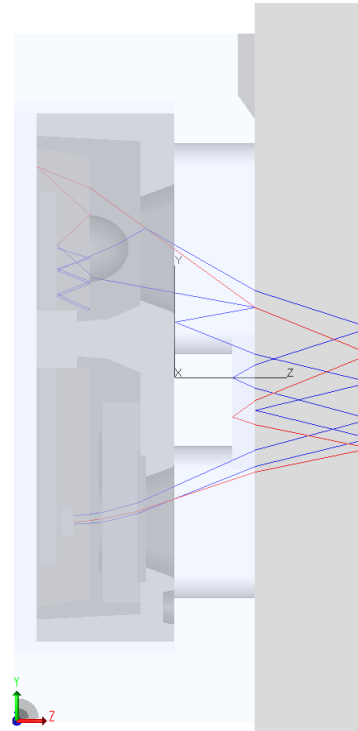
## Results, ray path analysis of Zone-5 peak system xtalk

Air gap 0.7mm using thicker cover glass (1.0mm)



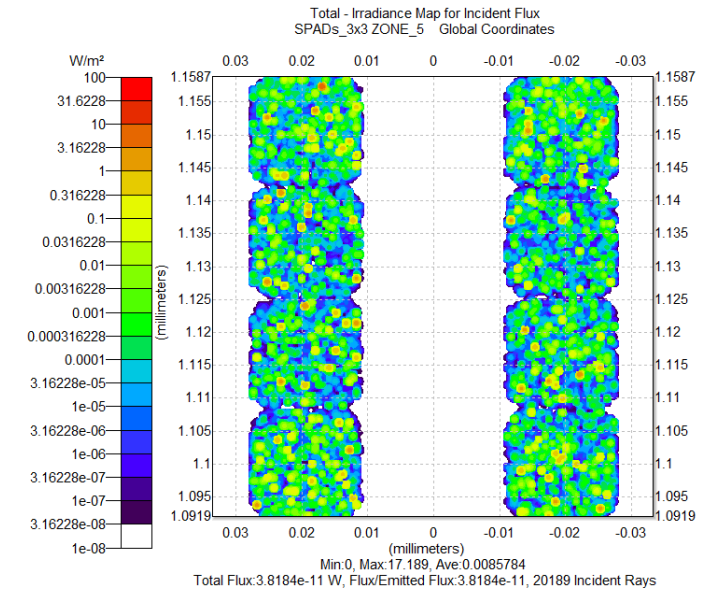
Zone-5 (RB-V2-07-02)

All ray paths are shown above.



Zone-5 (RB-V2-07-02)

Most intense ray paths are shown above representing >95% of total flux.



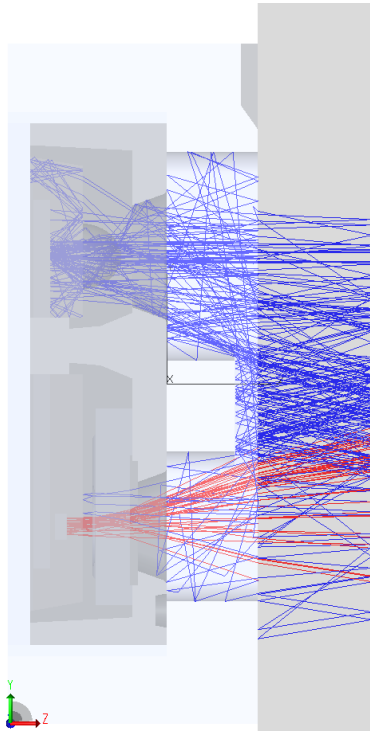
Zone-5 (RB-V2-07-02)

Irradiance Map

# Appendix A

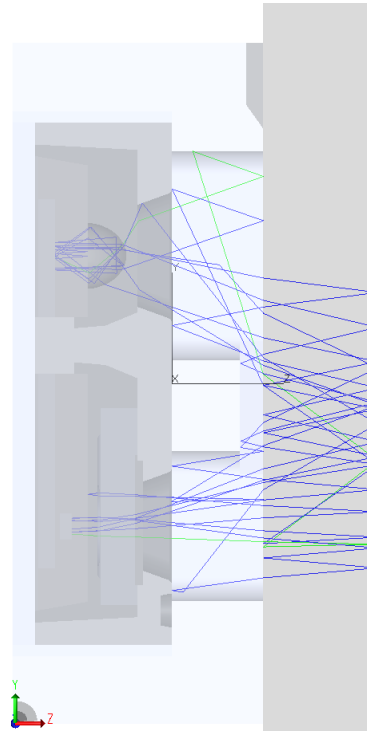
## Results, ray path analysis of Zone-5 peak system xtalk

Air gap 0.8mm using thicker cover glass (1.0mm)



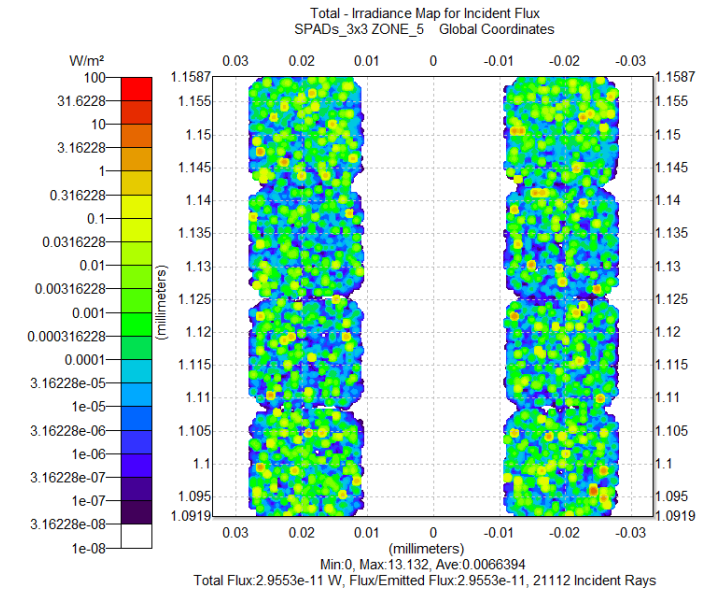
Zone-5 (RB-V2-08-02)

All ray paths are shown above.



Zone-5 (RB-V2-08-02)

Most intense ray paths are shown above representing >95% of total flux.



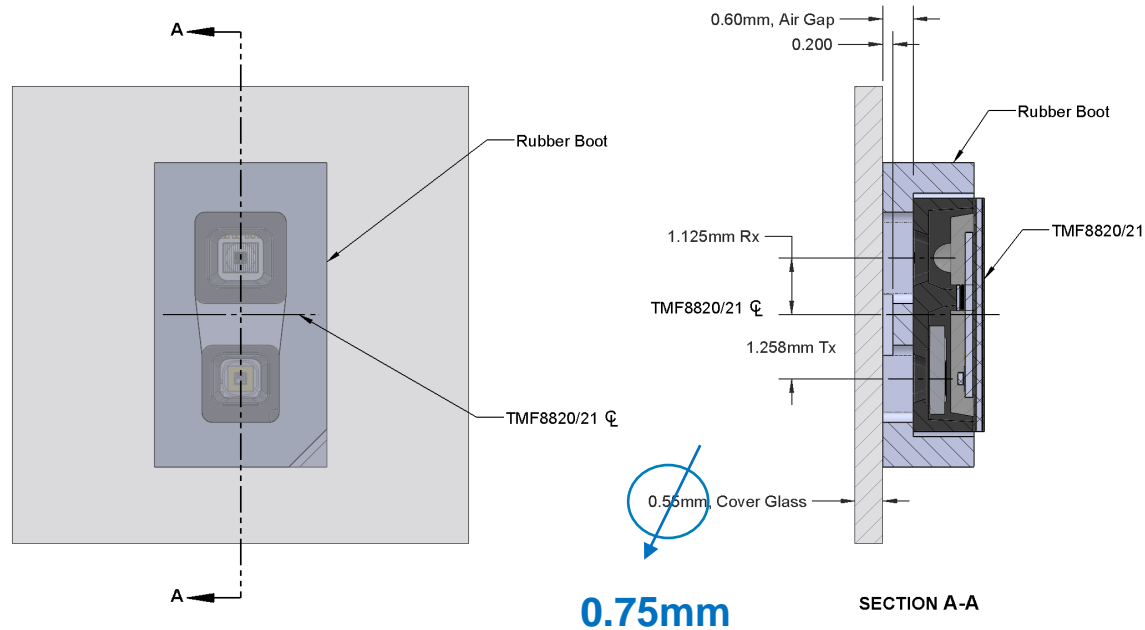
Zone-5 (RB-V2-08-02)

Irradiance Map

# Appendix B

# Appendix B

## Drawing of EVM Optical Stack uses thicker cover glass (0.75mm) as indicated



Simulation:

EVM optical stack uses the thicker cover glass (0.75mm) to achieve average system xtalk well centered between the minimum and maximum xtalk requirements. The target xtalk centered between the minimum and maximum is  $9.86E-11$  W.

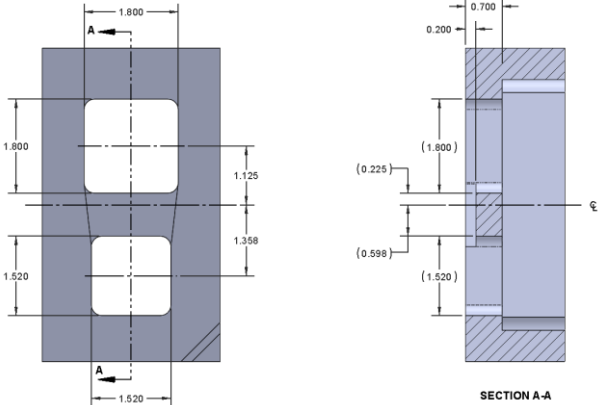
Simulation result represent 3x3 normal mode using v4 model.

The simulated results are scale by SPAD Fill Factor and x1.93 coefficient for best alignment with measure results. This assumes that measurement are correct and simulation results aren't exact.

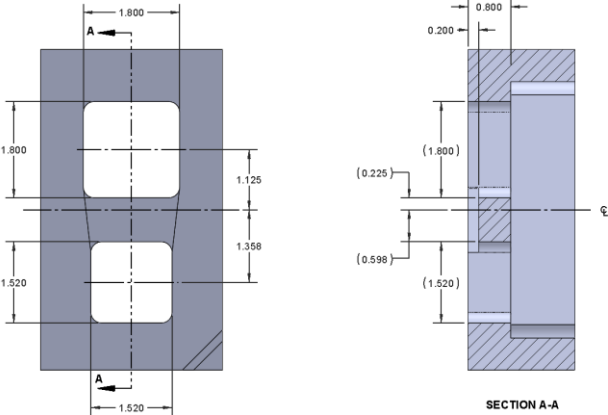
This is why the ODG-v2 Measured (Peak) EVM (W) differ from the ODG-v1 Measured results. The early ODG-v1 measured results were scaled by x1.93 instead of the simulated.

# Appendix B

## Drawing, additional Rubber Boot configurations simulated with the thicker cover glass (0.75mm)



Added v2 rubber boot RB-V2-07-02  
0.7mm air gap with 0.2 cut



Added v2 rubber boot RB-V2-08-02  
0.8mm air gap with 0.2 cut

# Appendix B

## Results, EVM 3x3 normal mode, using 0.75mm Cover Glass

ZONE	1	2	3	4	5	6	7	8	9	Min	Max	Average
Measured (Peak) EVM CG0.55_AG0.6, (counts)	2066	1082	1517	2266	1086	1446	1958	1113	1600	1082	2266	1570
Measured (Peak) EVM CG0.55_AG0.6, (W)	2.36E-11	1.55E-11	1.73E-11	2.59E-11	1.55E-11	1.65E-11	2.24E-11	1.59E-11	1.83E-11	1.55E-11	2.59E-11	1.90E-11
Minimum xtalk 3x3 (900counts), (W)	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11	1.10E-11
Maximum xtalk 3x3 (15200counts), (W)	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10	1.86E-10
Simulated EVM CG0.55_AG0.6, (W)	2.50E-11	8.60E-12	1.74E-11	2.67E-11	1.37E-11	1.93E-11	2.42E-11	1.12E-11	2.47E-11	8.60E-12	2.67E-11	1.90E-11
Simulated EVM CG0.75_AG0.6, (W)	3.33E-11	1.72E-11	2.12E-11	1.13E-10	2.93E-11	2.27E-11	5.45E-11	1.38E-11	3.17E-11	1.38E-11	1.13E-10	3.74E-11
Simulated EVM CG0.75_AG0.7, (W)	5.16E-11	2.71E-11	2.98E-11	3.24E-10	9.92E-12	6.80E-11	4.93E-11	3.17E-11	3.25E-11	9.92E-12	3.24E-10	6.93E-11
Simulated EVM CG0.75_AG0.8, (W)	9.93E-11	2.27E-11	5.34E-11	8.95E-10	1.27E-11	3.39E-11	9.22E-11	1.18E-11	4.78E-11	1.18E-11	8.95E-10	1.41E-10

The average of Minimum and Maximum xtalk is 9.86E-11 W.

Measured (Peak) xtalk results are based the average of 164 test devices using the EVM optical stack with 0.55mm Cover Glass.

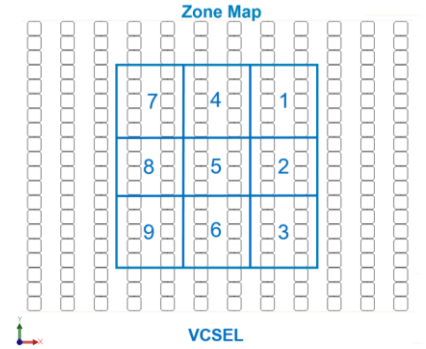
The optical stacks are the same for both the Measured (Peak) EVM xtalk and Simulated EVM CG0.55\_AG0.6 xtalk results.



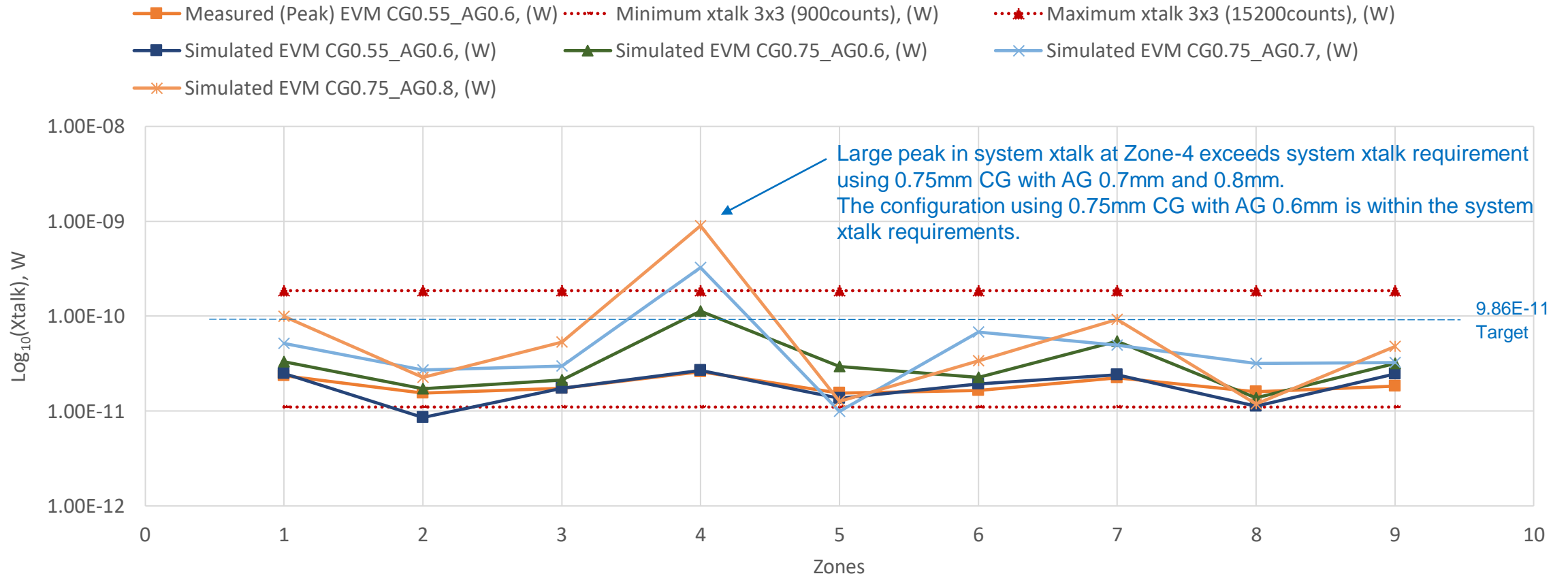
# Appendix B

Results, EVM 3x3 normal mode, using 0.75mm Cover Glass

Simulated EVM CG0.75\_AG0.6 fits well between the system xtalk requirements.



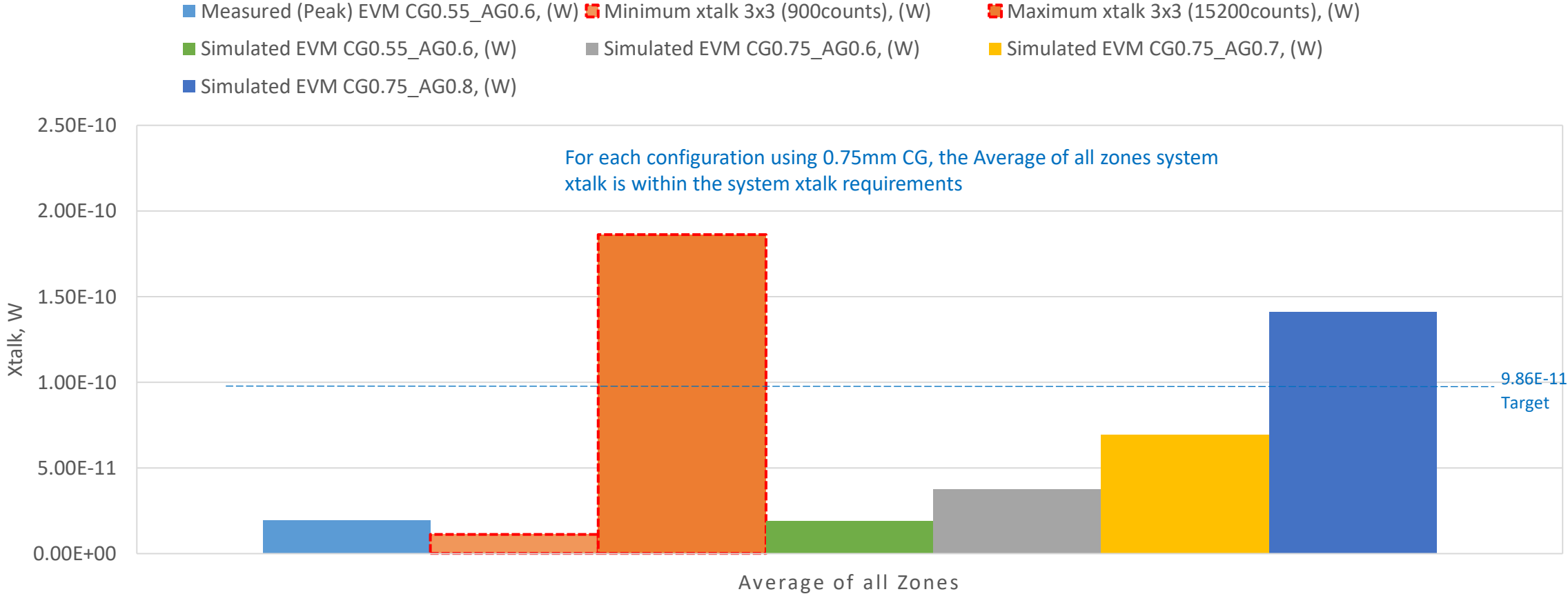
System xtalk per zone for EVM 3x3 normal mode



# Appendix B

## Results, Average of all zones, EVM 3x3 normal mode, using 0.75mm Cover Glass

### System xtalk, average of all zones, for EVM 3x3 normal mode



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