Validating Radiance methods for parametric analysis of non-coplanar shading system — an update

Radiance Workshop, Aug 22-24, 2017

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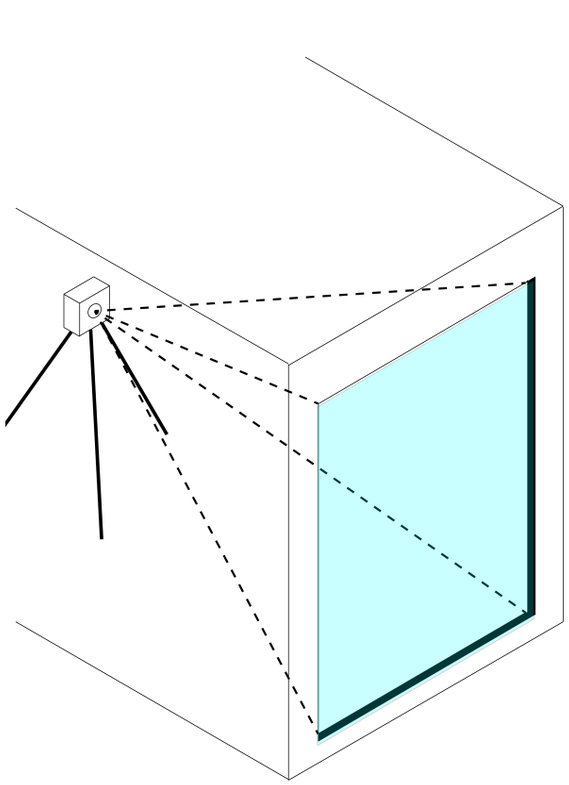
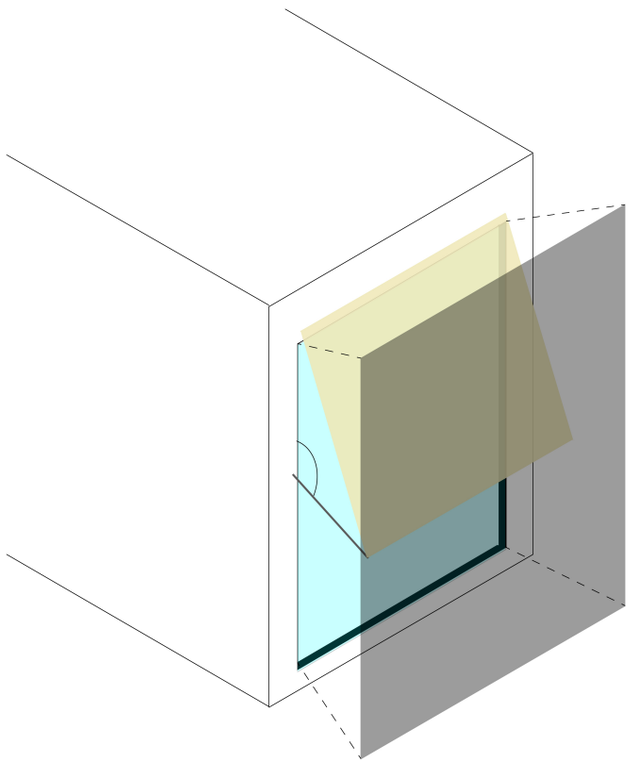
i = V T F D s



View matrix

x



Transmission matrix

x

Facade matrix

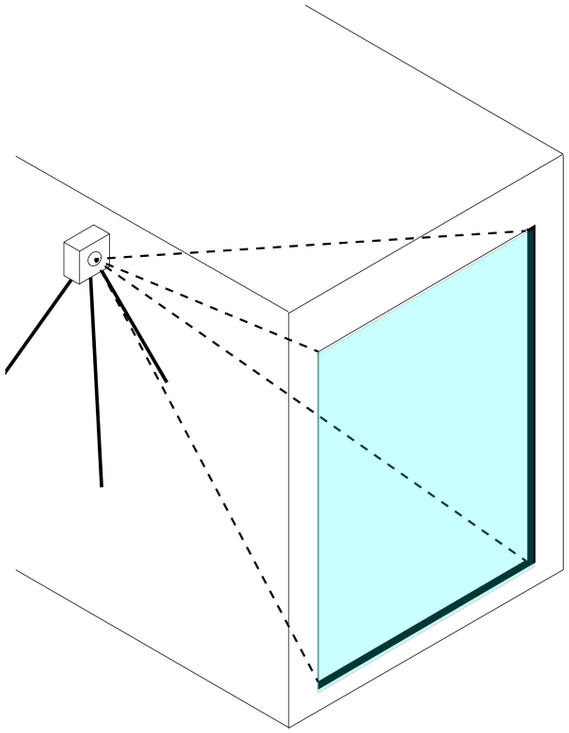
x

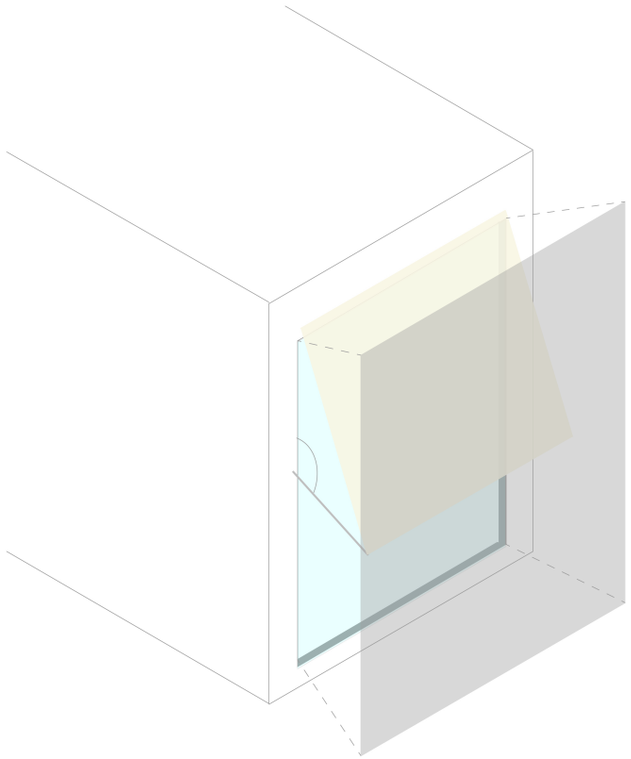
Daylight matrix

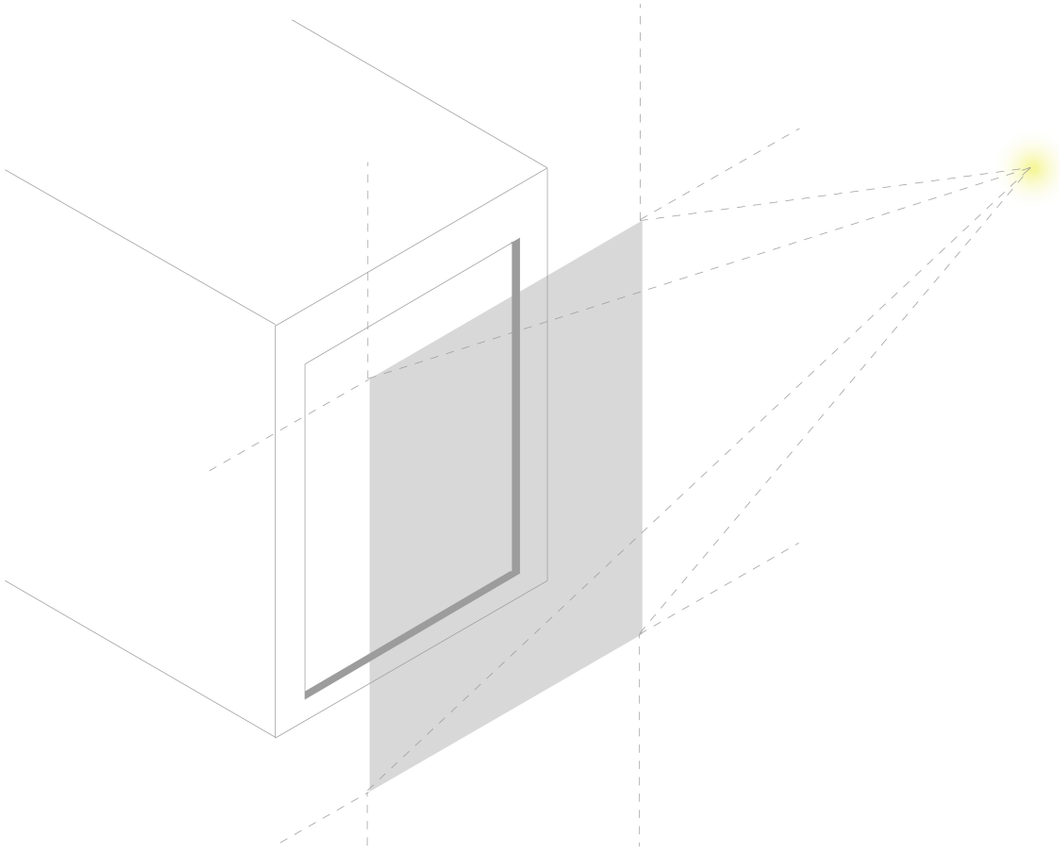
x

sky matrix

i = V T F D s



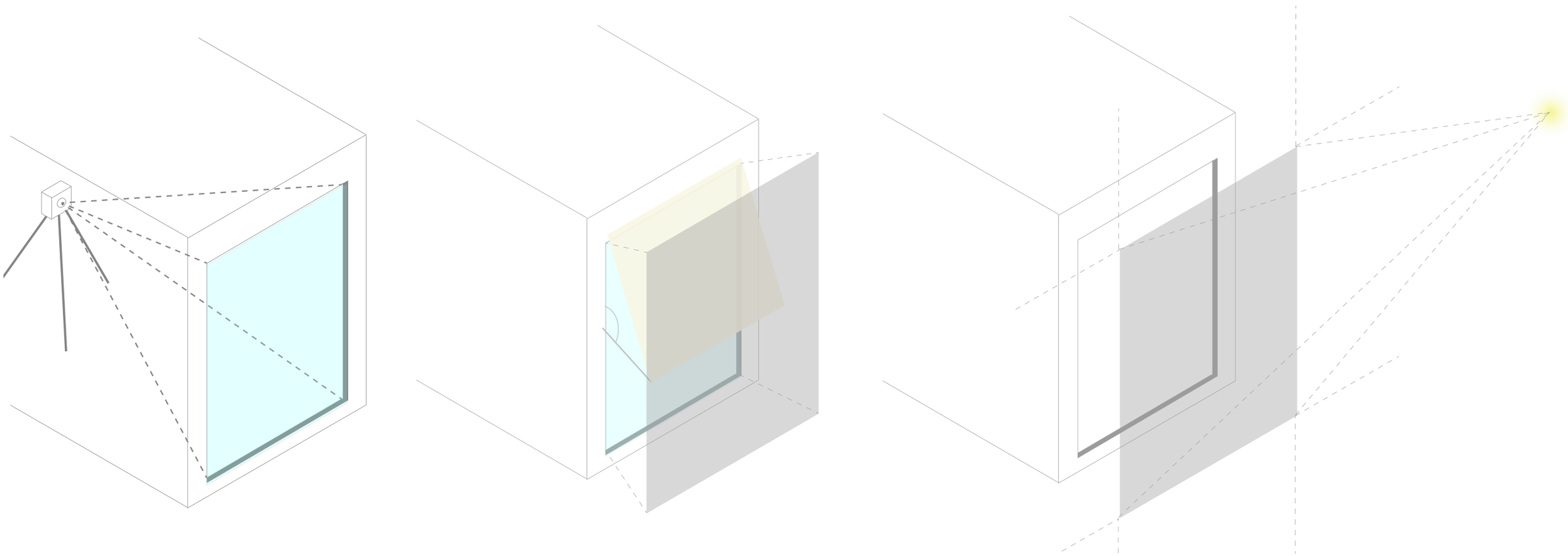




View matrix x Transmission matrix x Facade matrix x Daylight matrix x sky matrix

maps flux from coplanar window surface to a view point within the space

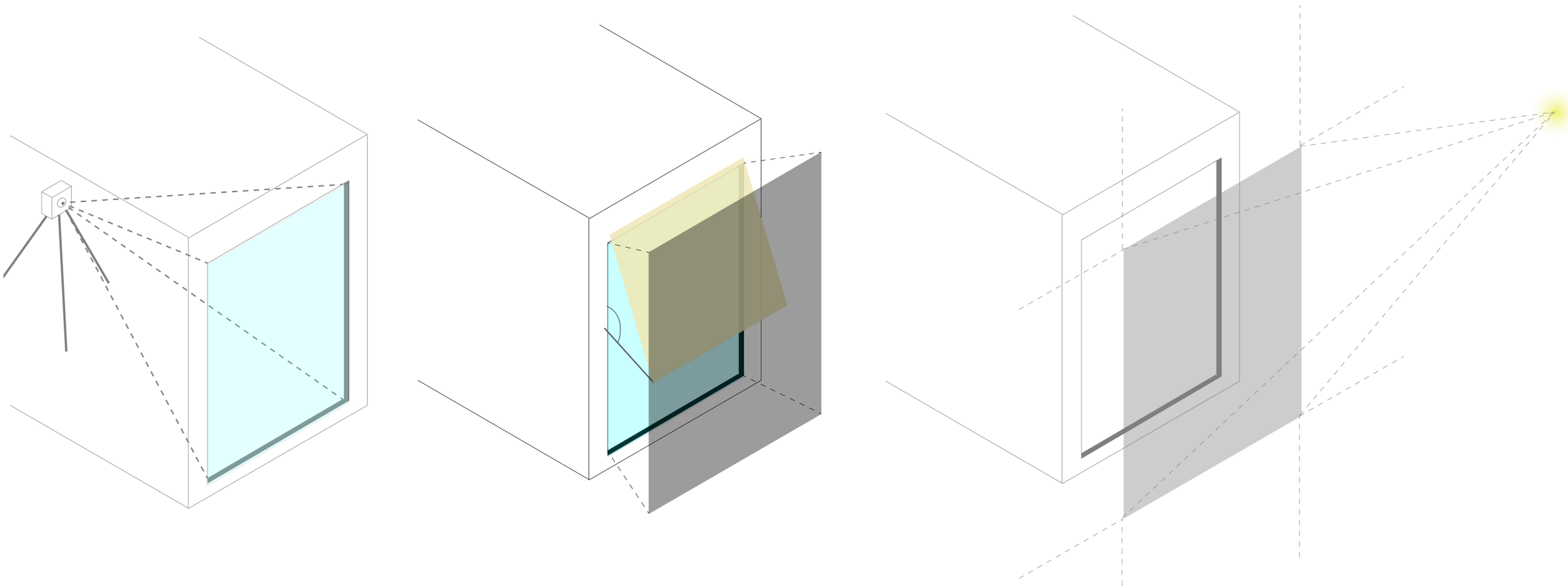
i = V T F D s



View matrix x **Transmission matrix** x Facade matrix x Daylight matrix x sky matrix

BSDF for the operable indoor coplanar shade

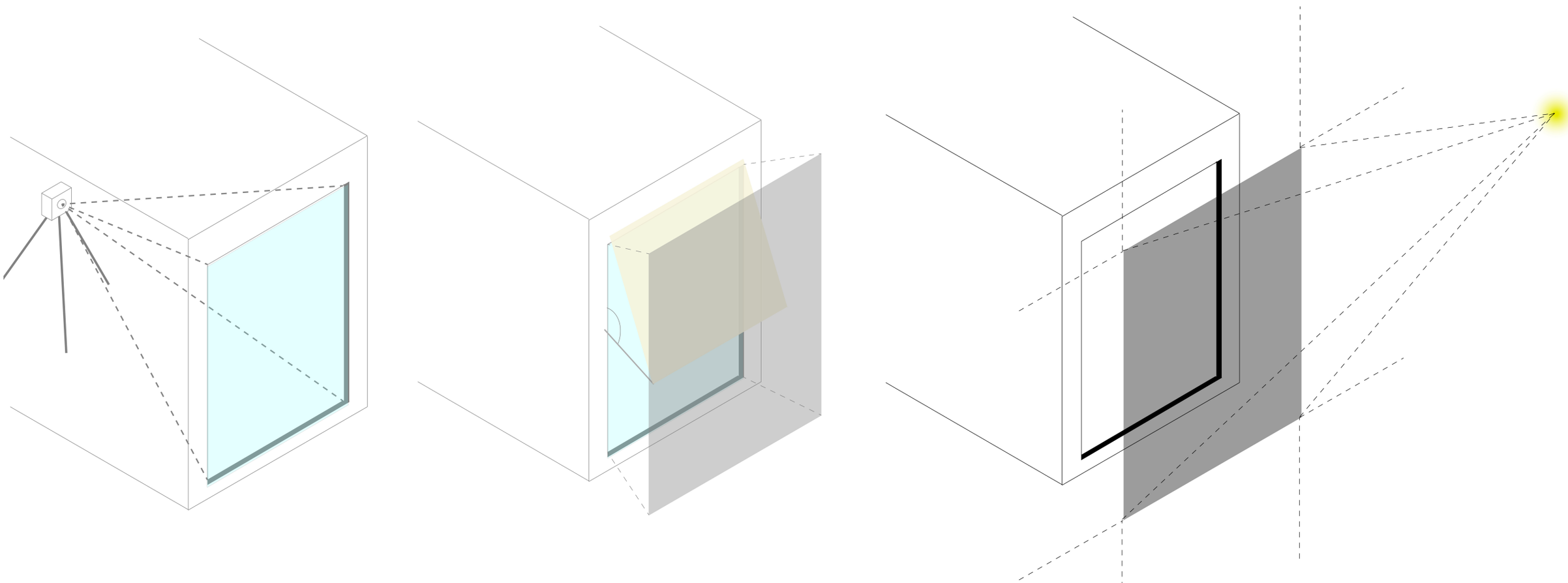
i = V T F D s



View matrix x Transmission matrix x **Facade matrix** x Daylight matrix x sky matrix

maps flux transfer from grey port to window surface including transmission and interreflections through the non-coplanar system

i = V T F D s

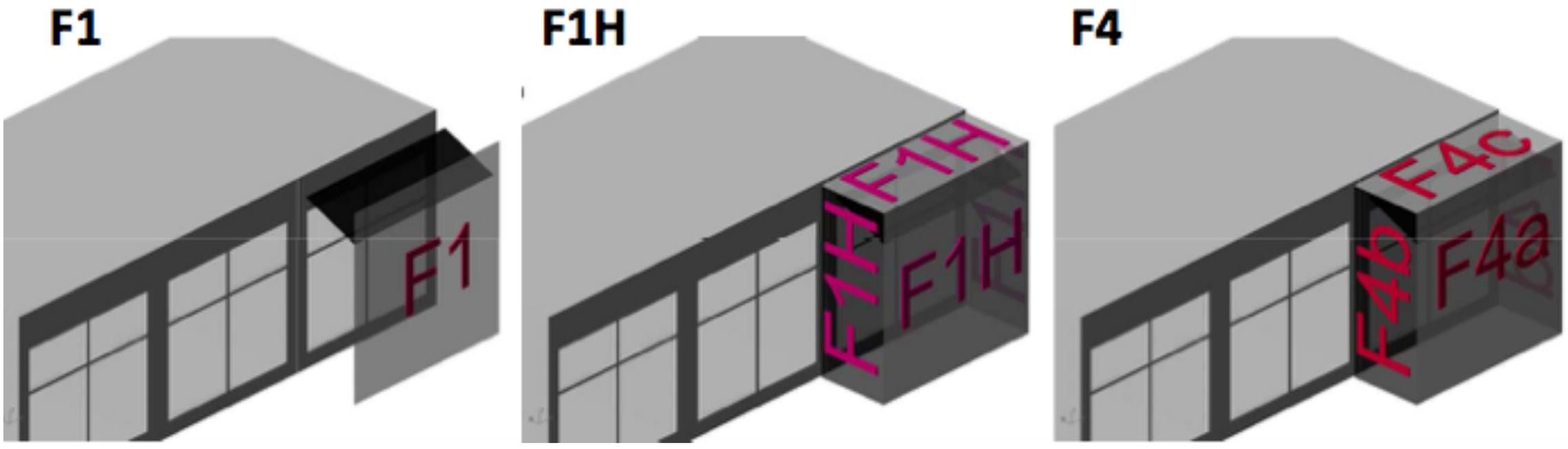


View matrix X Transmission matrix X Facade matrix X **Daylight matrix** X sky matrix

maps flux transfer from sky patches to grey port

Three ways of constructing Façade matrix ports

Rays will be traced from window to ports to capture the optical behavior of the non-coplanar shading system in-between

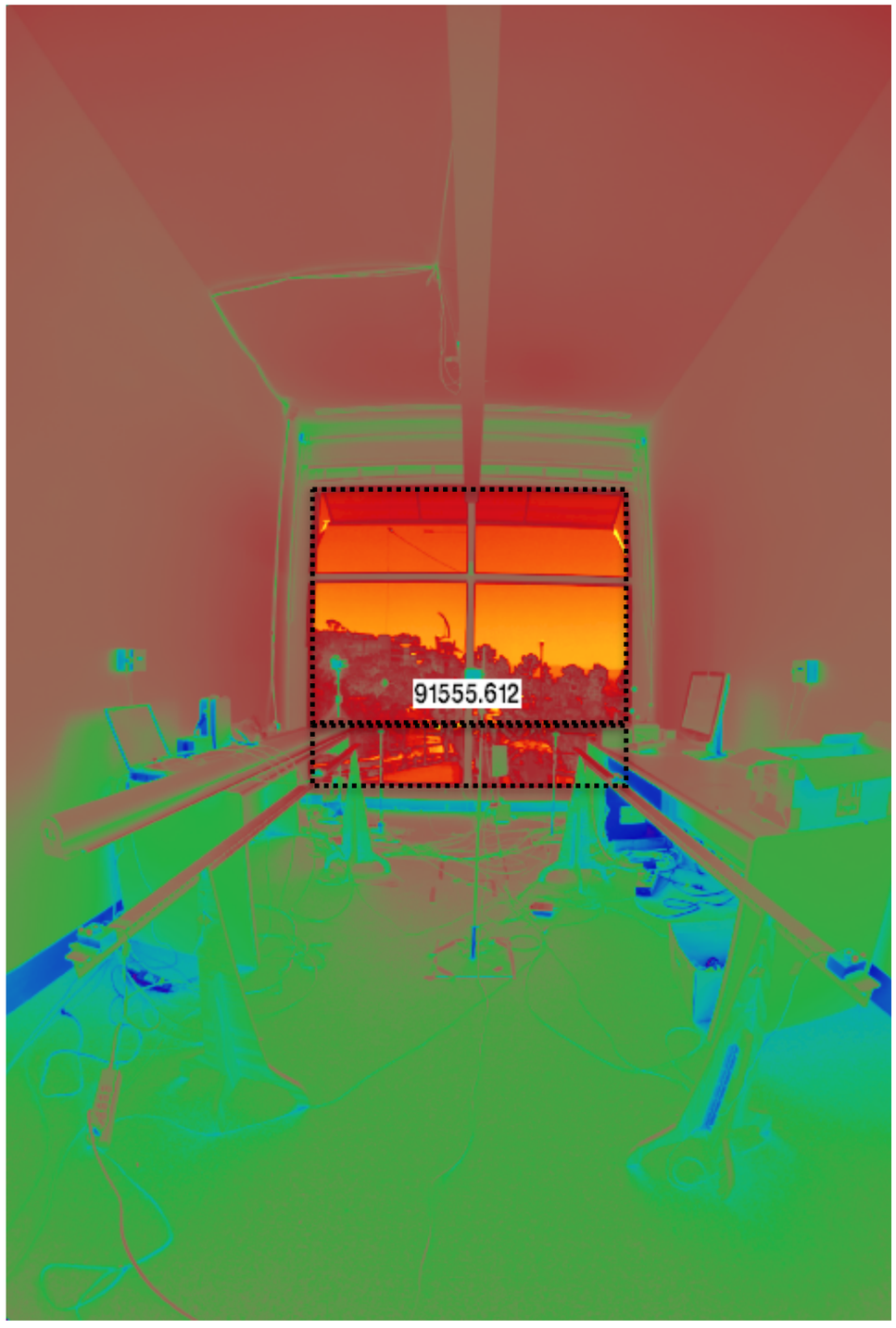


Simplest: most useful for continuous shading systems (e.g., overhang across the entire length of the building) or narrow shading systems where light coming in from sides is minor

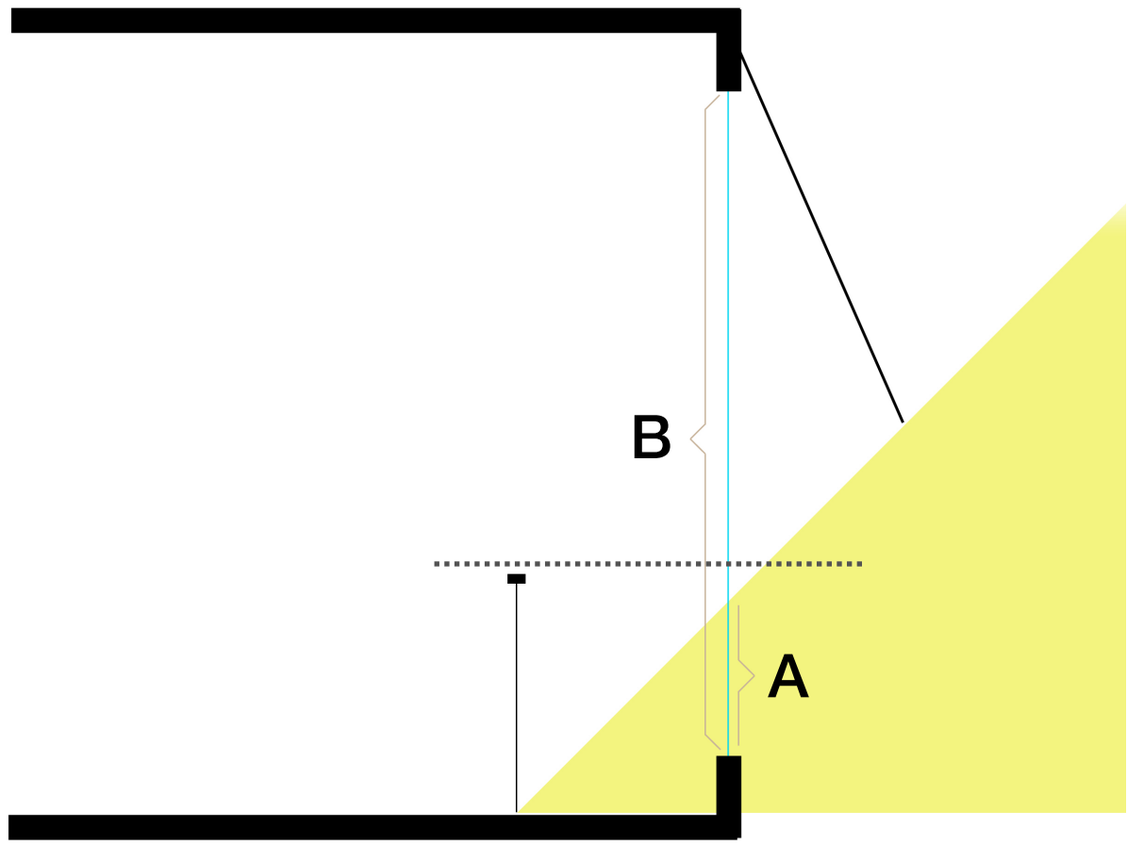
Relatively simple to construct; still a single sampling hemisphere, misses lights coming from behind the facade

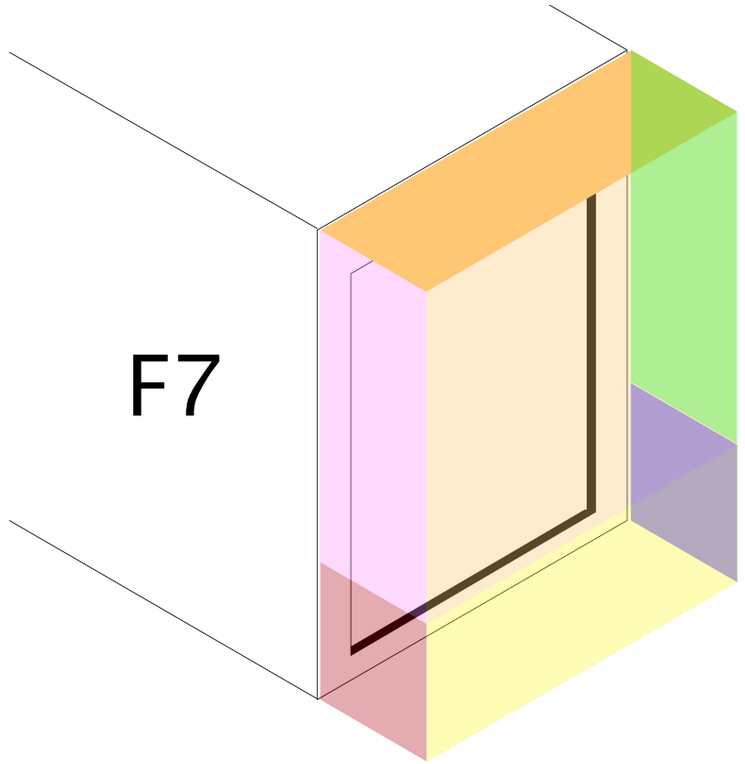
The most complicated and comprehensive; each port surface has its own sampling hemisphere, thus counting rays from all directions

Window sub-division at workplane height



Sub-divide window at workplace height to prevent rays entering through the lower portion (A) of the window from being averaged over the entire window





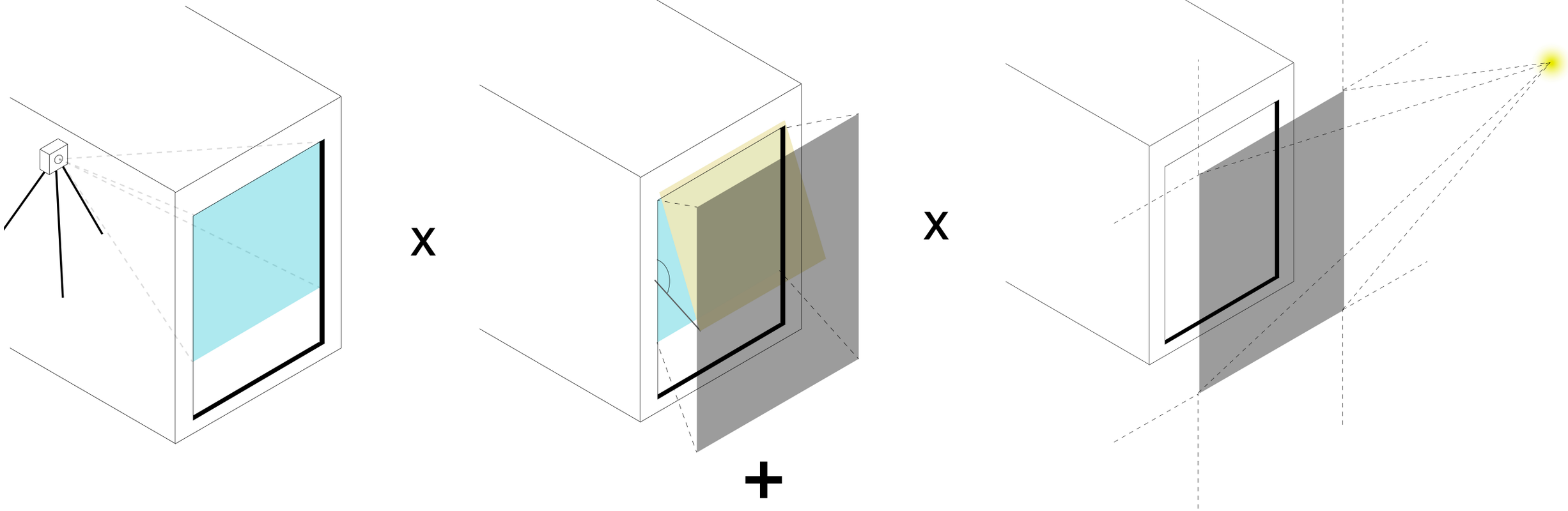
Port 1 Port 2 ... Port 7

fmx_1 x dmx_1 + fmx_2 x dmx_2 +...+ fmx_7 x dmx_7

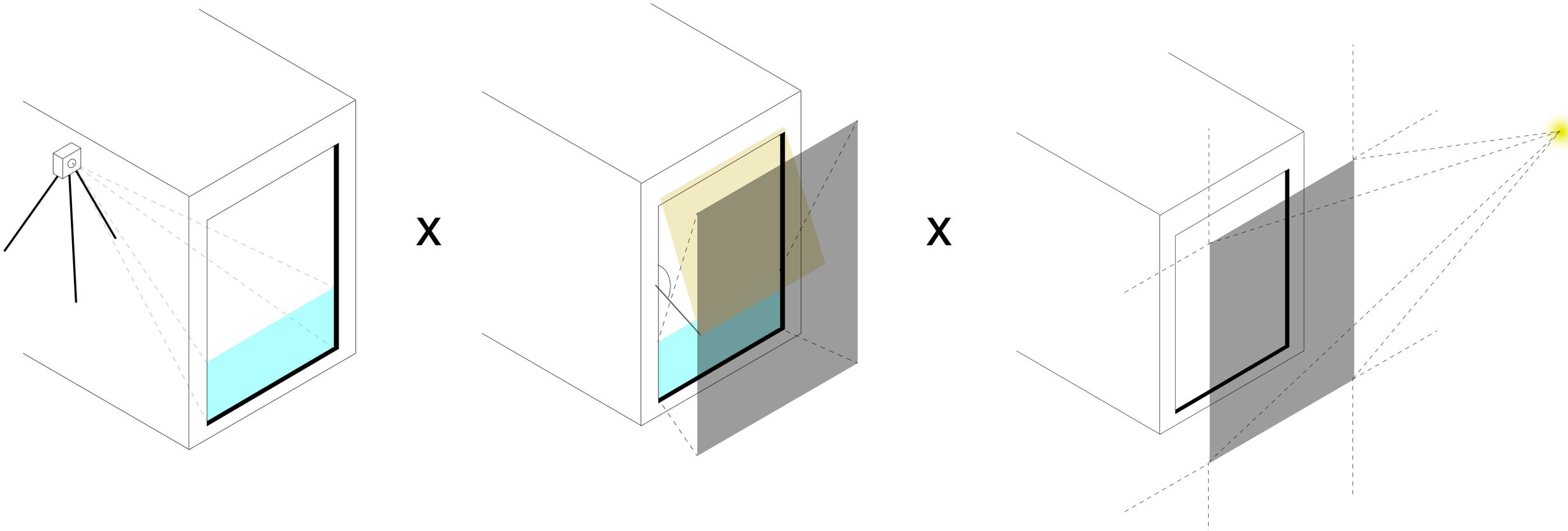
```
rfluxmtx glazing_srf(sender) port1(receiver) -i {octree} > fmx_1
rfluxmtx port1(sender) skyglow(receiver) -i {octree} > dmx_1
                                        …… >fmx_2
                                        …… >dmx_2
                                             ……
                                        …… >fmx_7
                                        …… >dmx_7
rmtxop `dctimestep -of fmx_1 dmx_1` + `dctimestep -of fmx_2 dmx_2` + .. +
`dctimestep -of fmx_7 dmx_7` > fdmx

dctimestep vmx shade.xml fdmx sky_matrix | rmtxop -fa -c 47.4 119.9 11.6
- > illuminance.txt
```

Upper section



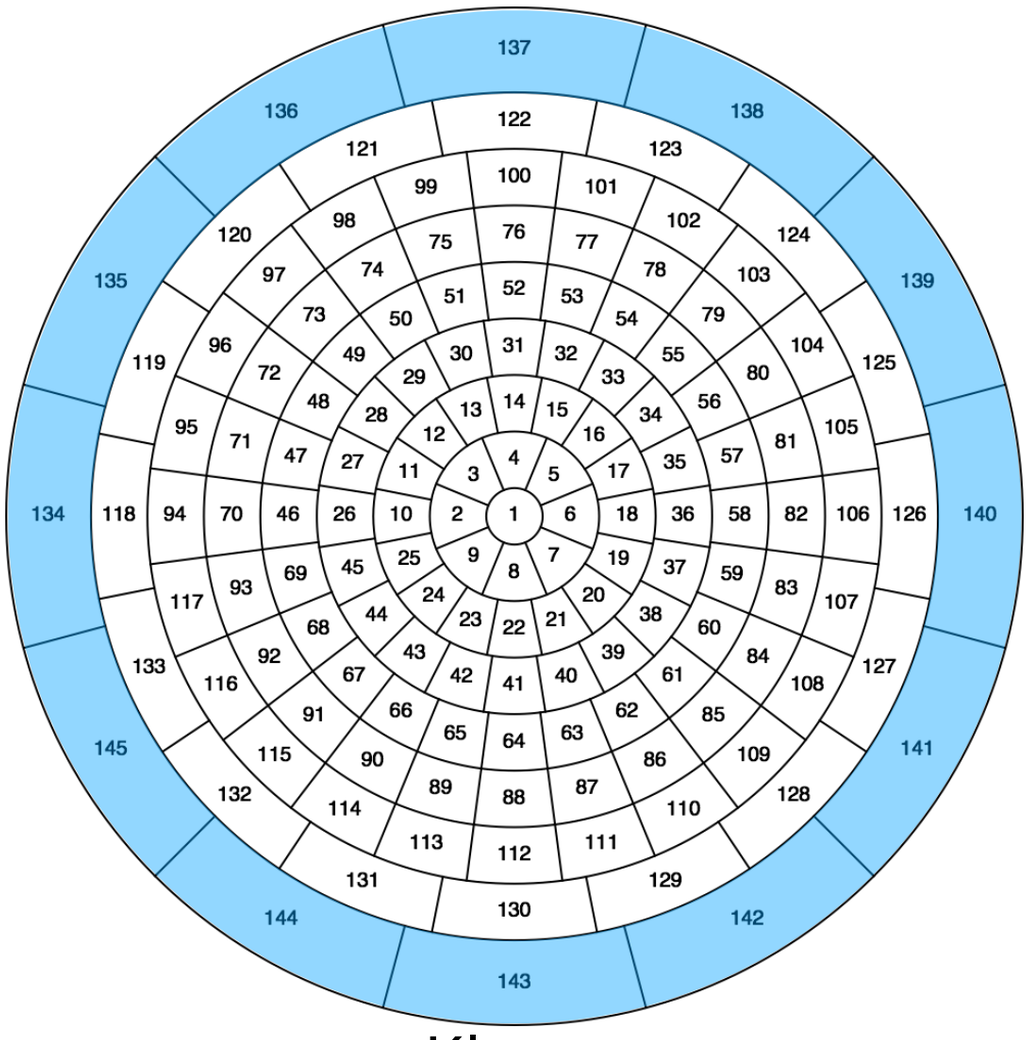
Lower section



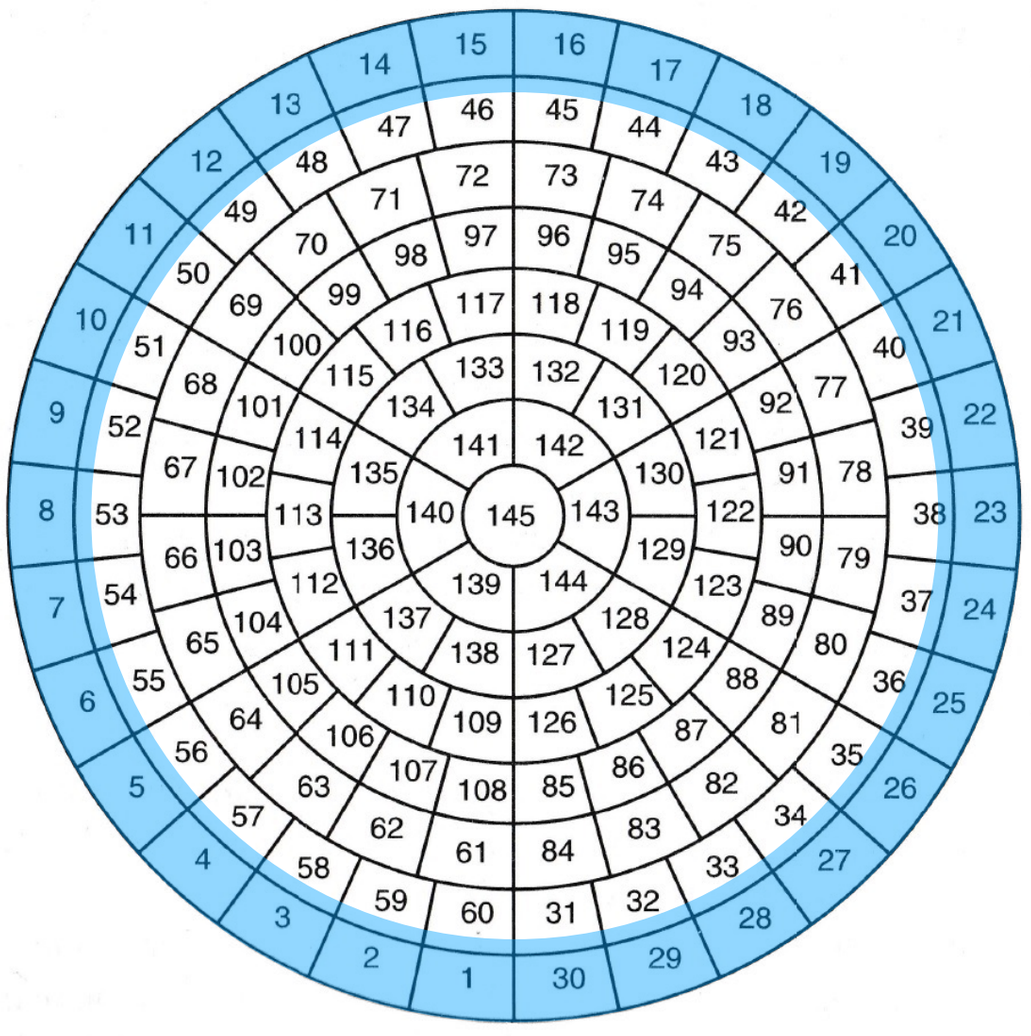
Senders and receivers support the following resolutions:

- Klems (quarter, half, full)
- Reinhart/Treganza N subdivisions
- Shirly-Chiu N square-to-circle mapping
- Uniform

note: Klems has low resolution at grazing angle, high intensity rays (direct sun) get averaged over a large solid angle



Klems



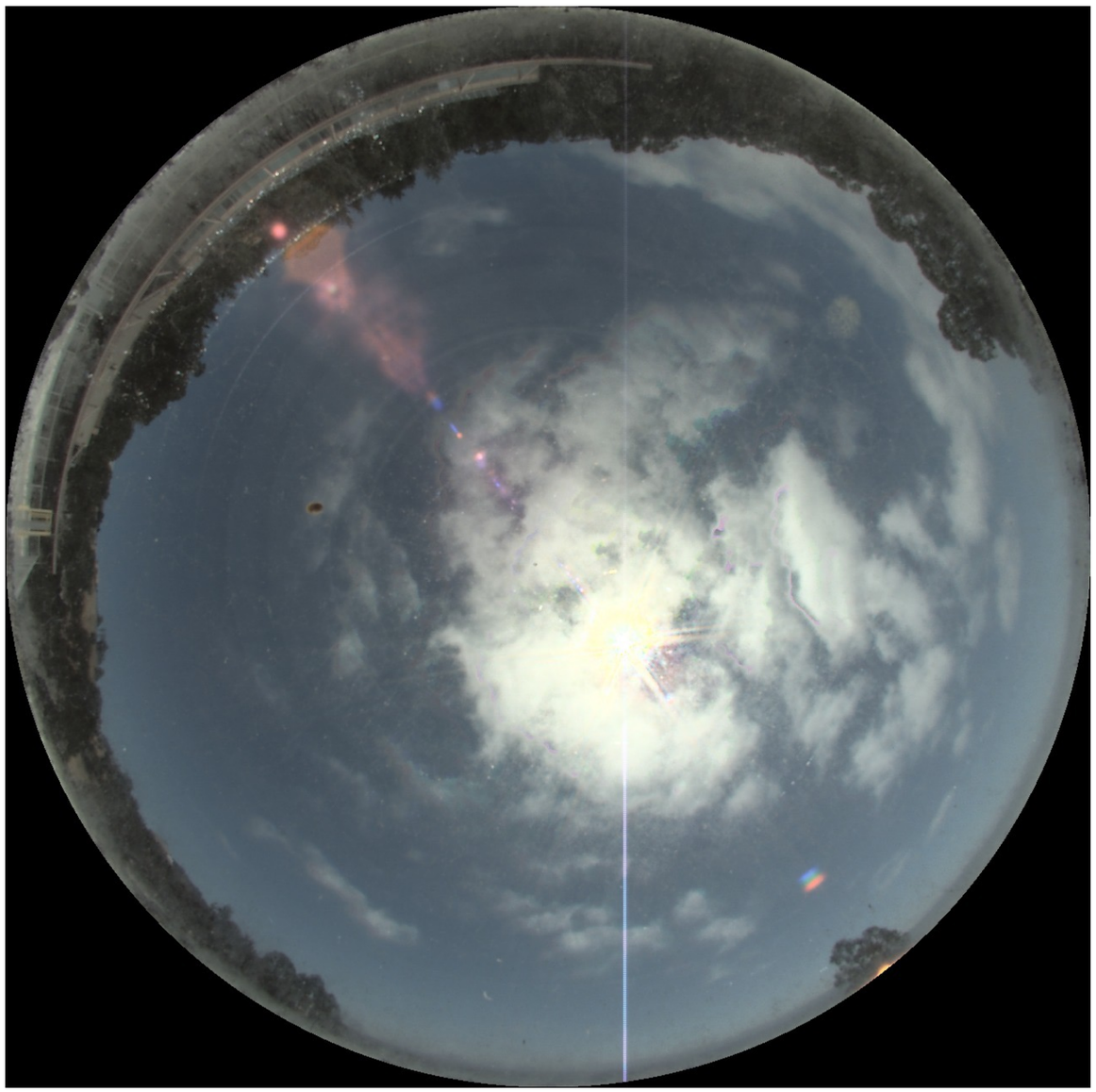
Treganza

Matrix Angle Basis Breakdown

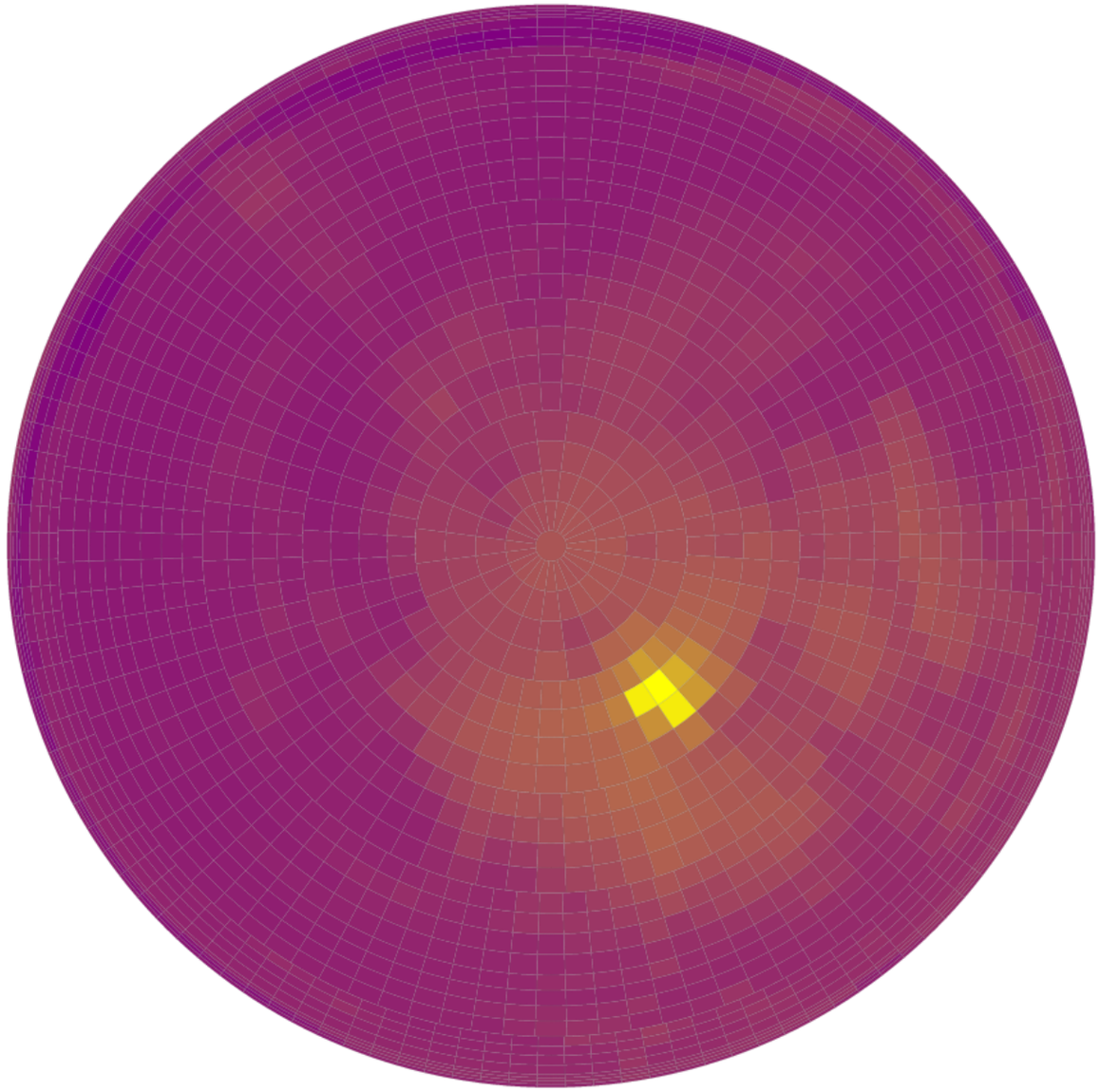
	View matrix	Transmission matrix	Facade matrix	Daylight matrix	Daylight matrix/ vector
Angle basis	Reinhart 2 sub-division	n/a	Reinhart 2 sub-division with awning represented by Klems BSDF	Reinhart 4 sub-division	Reinhart 4 sub-division

For this study, no planar shade (T matrix) is used, which enables us to use Reinhart 2 resolution for Facade and view matrix. For regular 3-phase calculation, resolution will be limited to the Klems BSDF

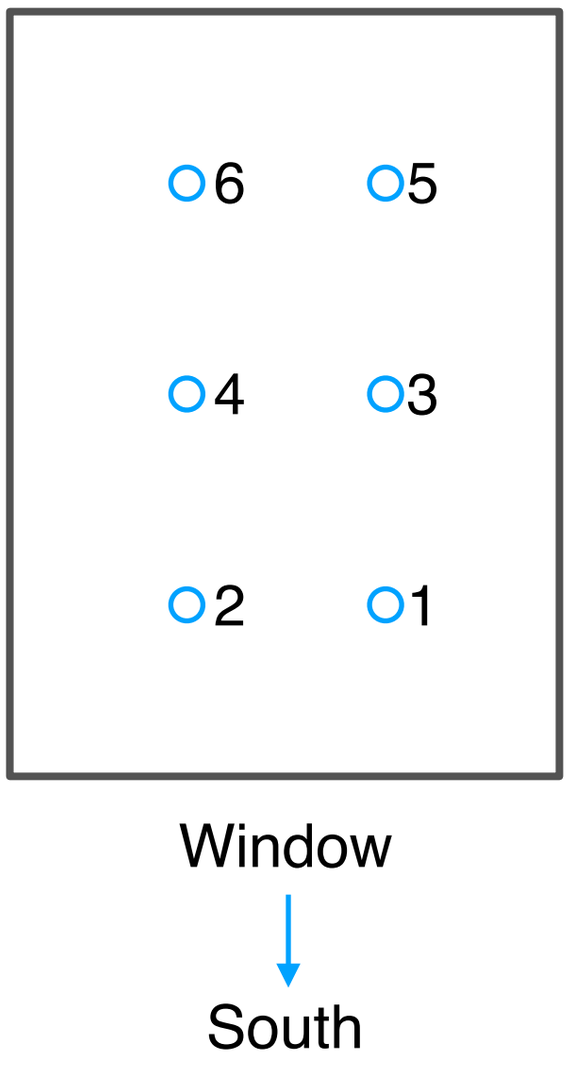
Skycam



Mapped to Reinhart Sky Subdivision



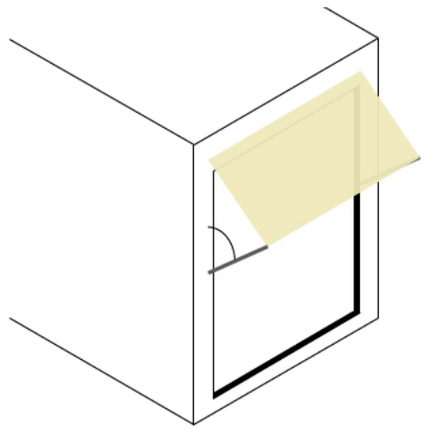
gendaylit … | genhdrvec –m 4 ... > sky.vector
Genhdrvec: modified genskyvec that uses fisheye.cal to map skydome hdr to Treganza sky subdivision

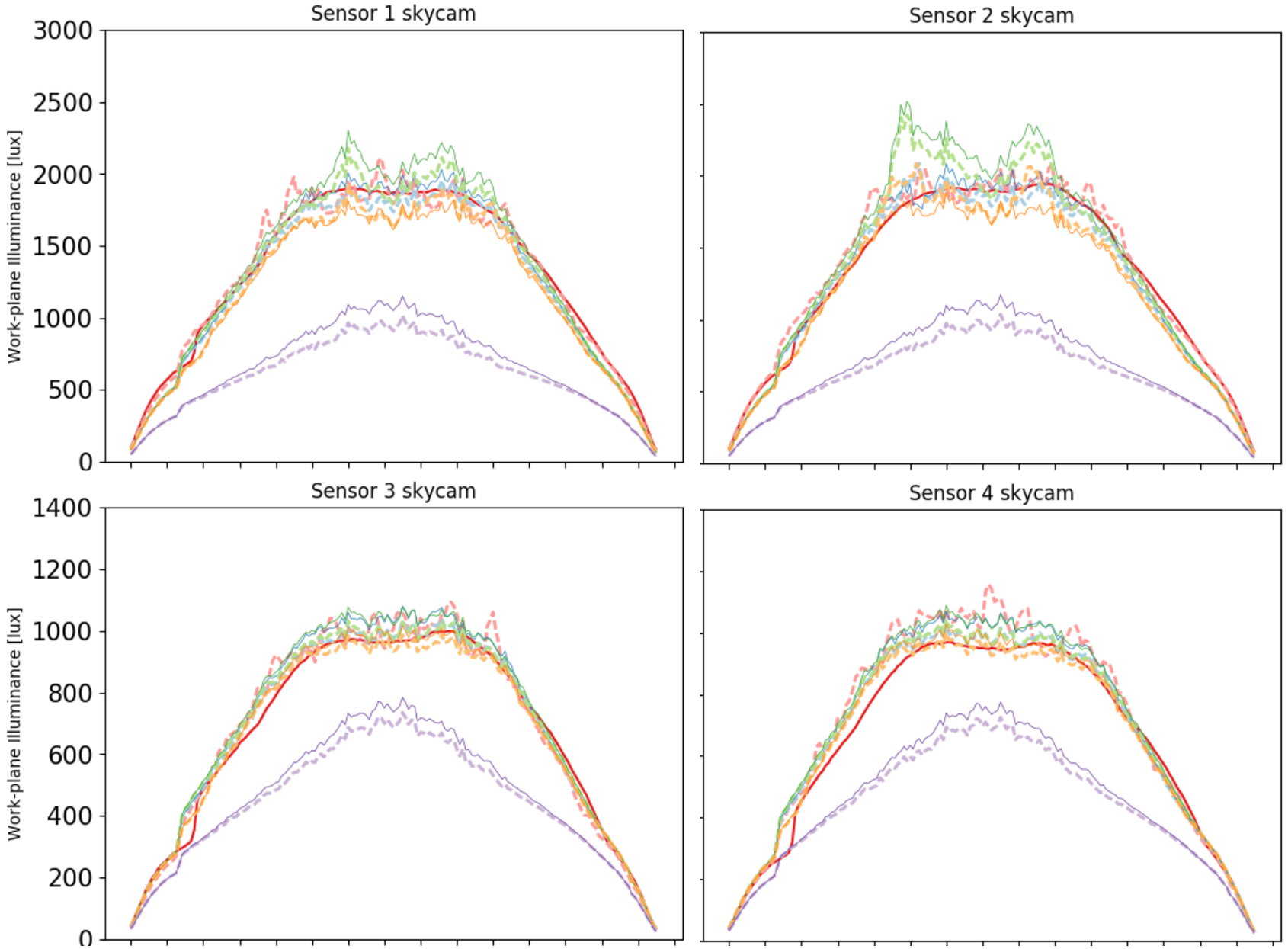


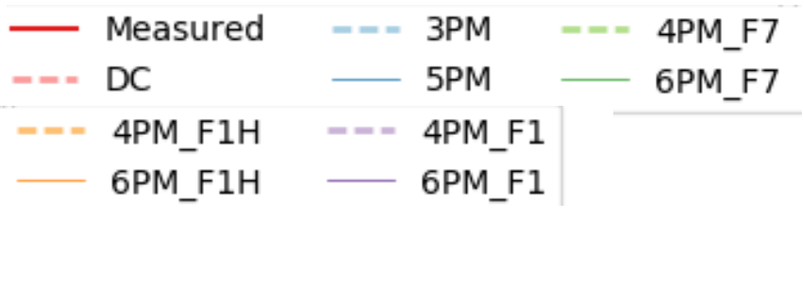
Sunbrella 4633-0000, Linen
Manufacturer's data:
Tv,n-n = 0.08
Tv, n-h = 0.044
ρv, n-h = 0.40

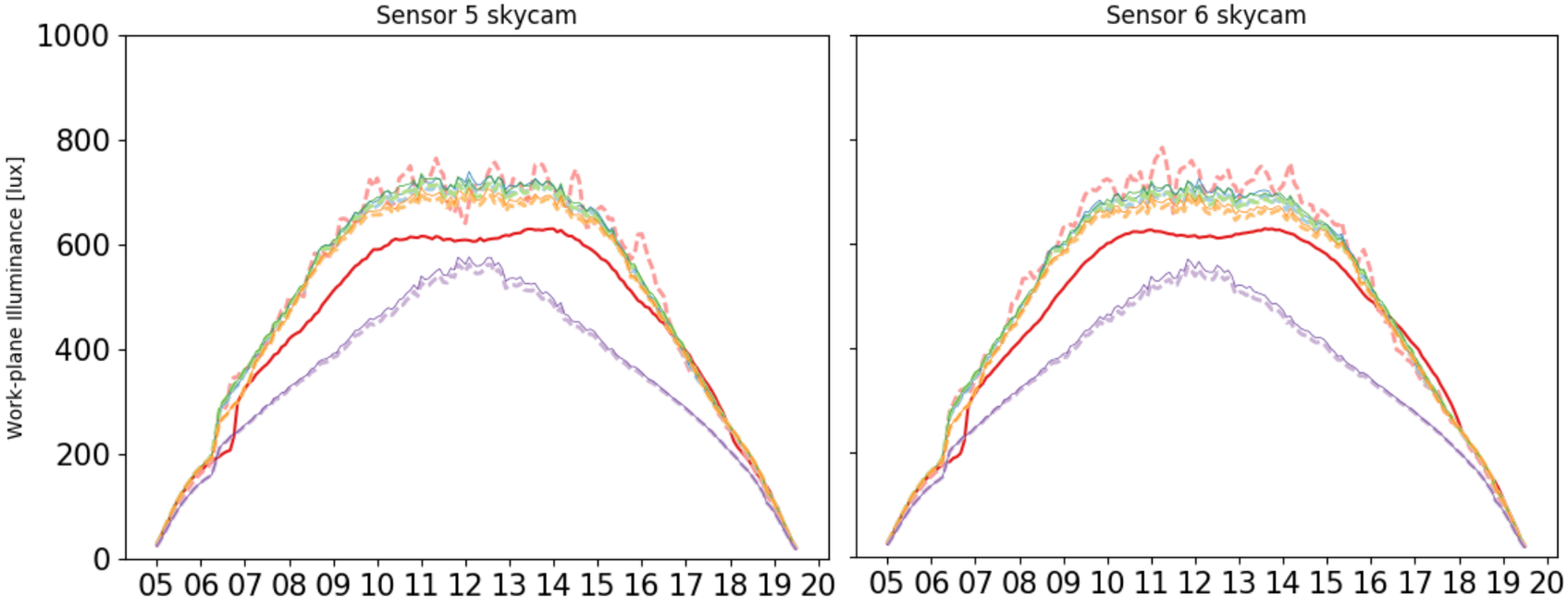
LBNL BSDF:
Lambda 950 spectrophotometer with 150 mm integrating sphere plus angle tube accessory for Lambda 950 Measure diffuse and direct transmittance & reflectance at nine angles of incidence

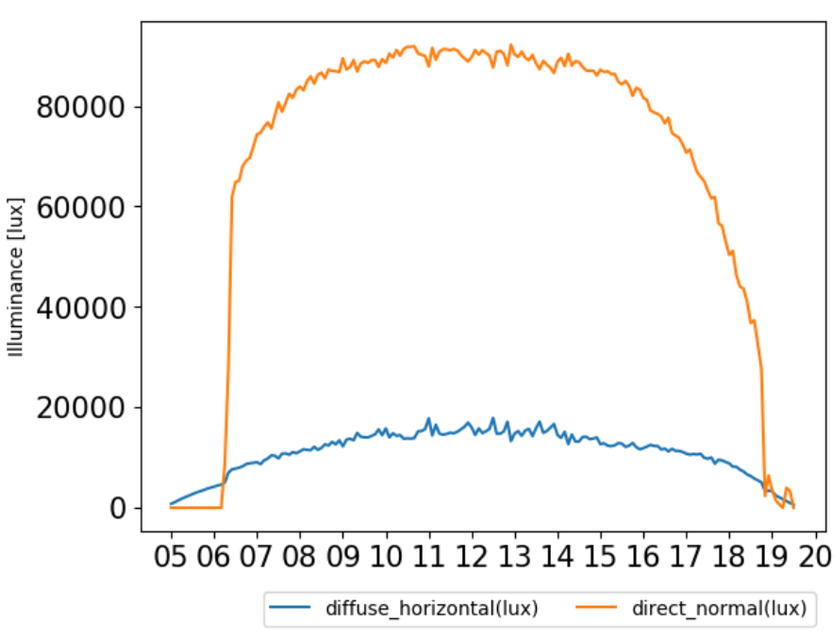
Workplane illuminance
July 10th
Awning: swing arm and facade at 70 deg







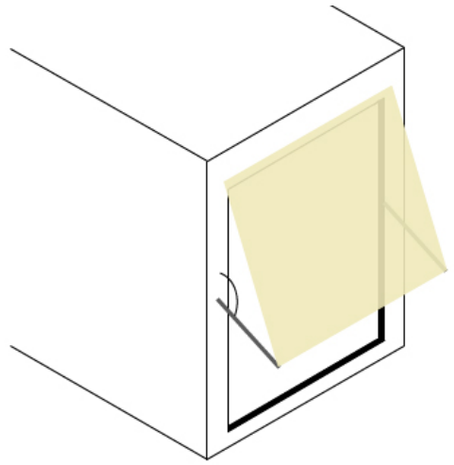




Workplane illuminance

Apr 29th, 2017

Awning: swing arm and facade at 125 deg



Sensor 1 skycam

Sensor 2 skycam

Sensor 3 skycam

Sensor 4 skycam

Sensor 5 skycam

Sensor 6 skycam

Work-plane Illuminance [lux]

Hour

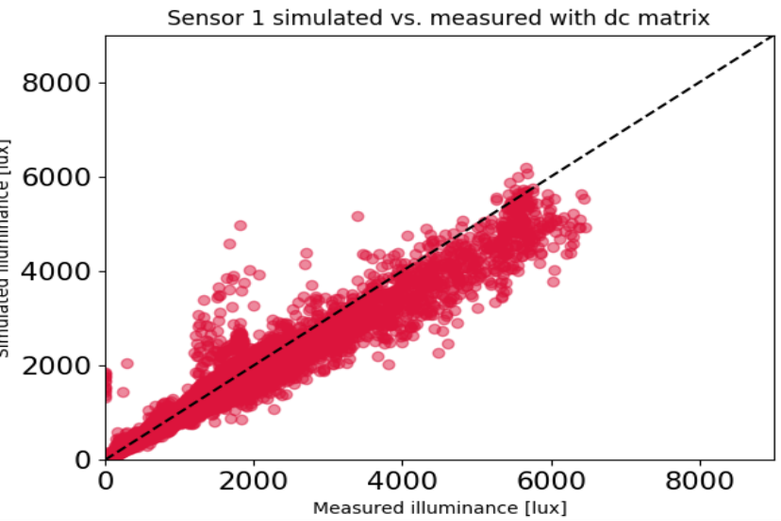
Measured
DC
4PM_F1H
6PM_F1H
3PM
5PM
4PM_F1
6PM_F1
4PM_F7
6PM_F7

Illuminance [lux]

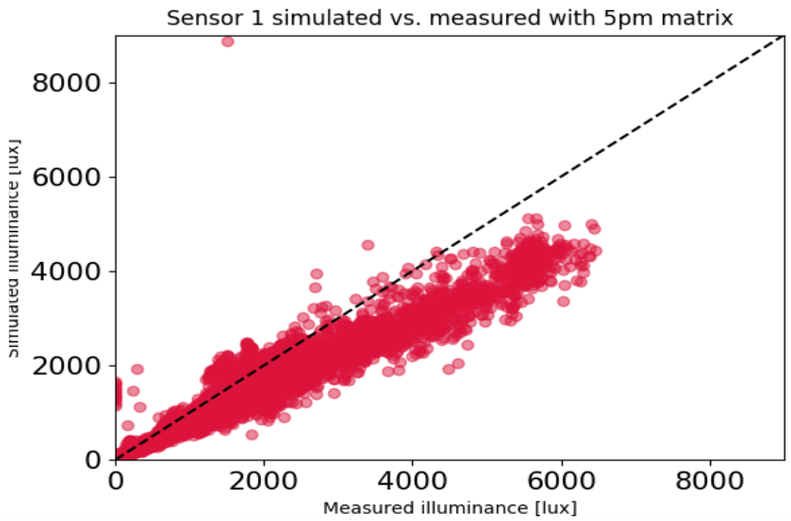
diffuse_horizontal(lux)
direct_normal(lux)

Near Window Sensors

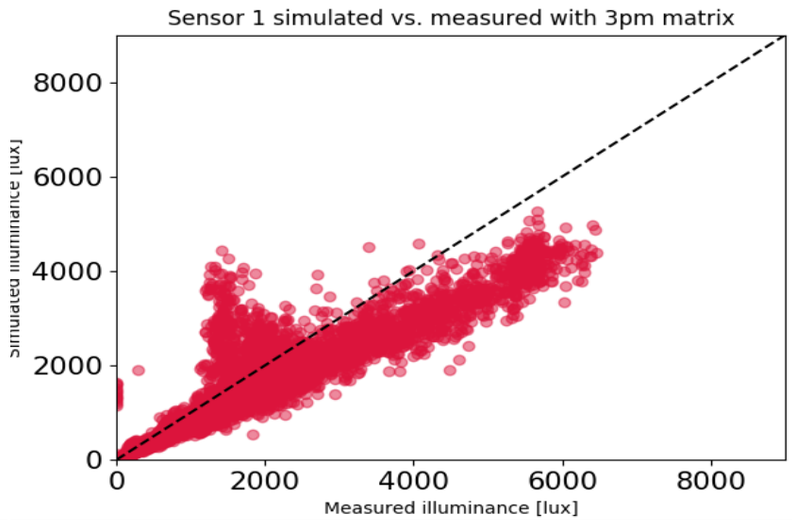
Daylight Coeffcient



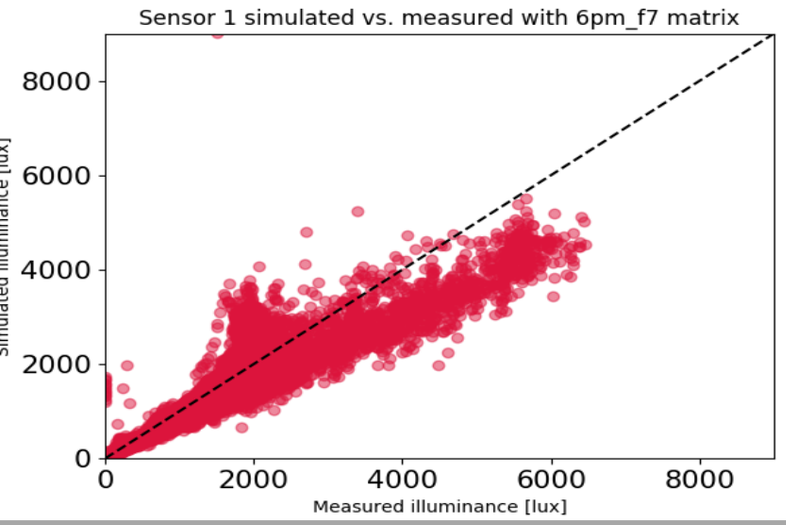
5PM



3PM



6PM_F7



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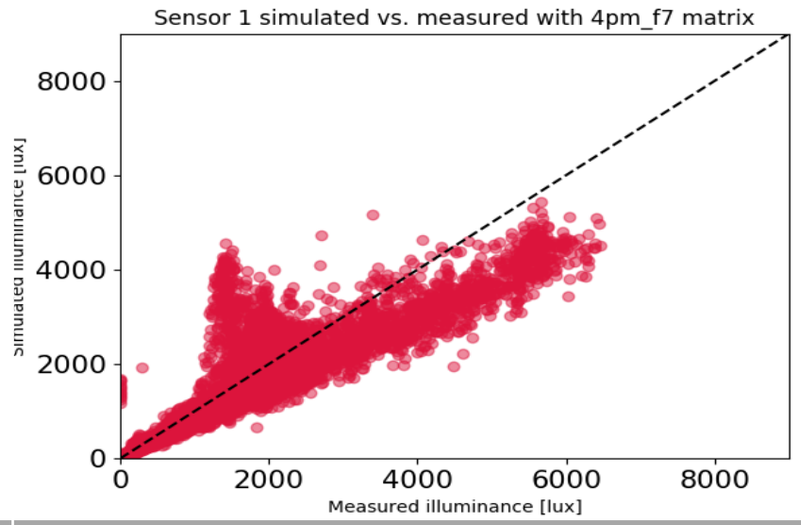

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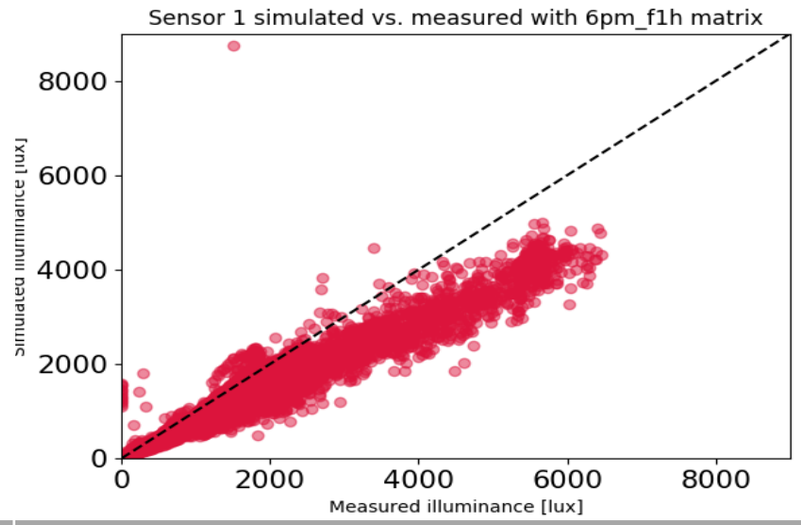

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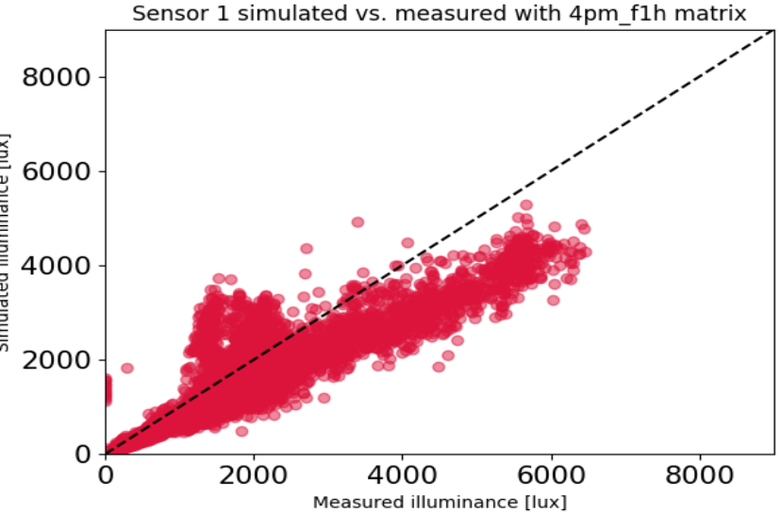

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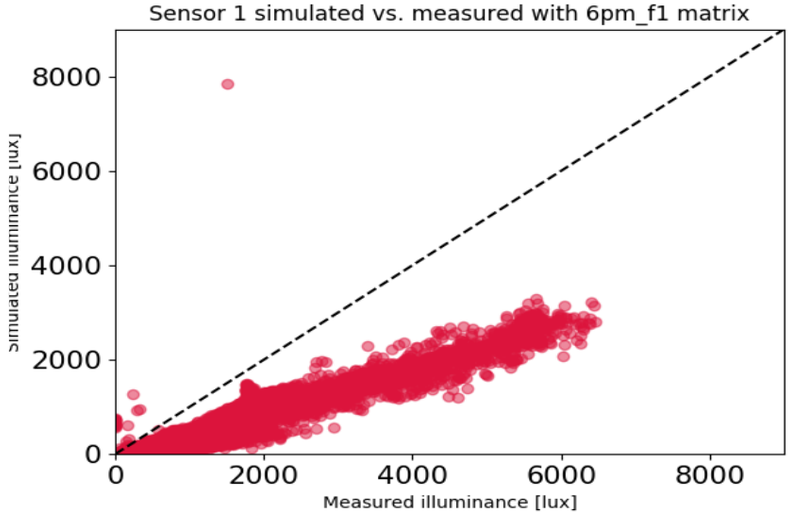
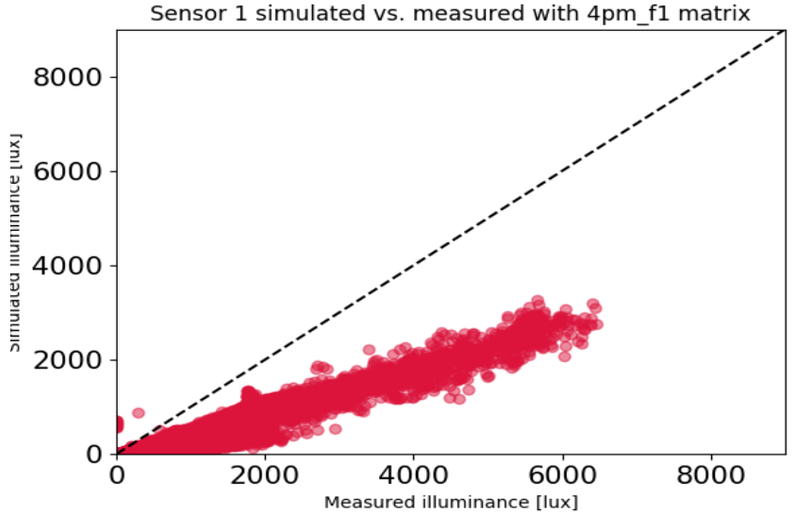
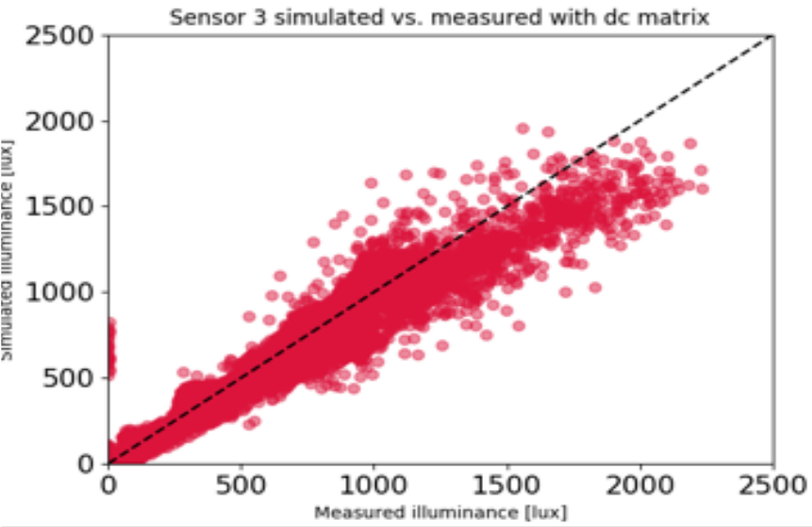


4PM_F1



Mid-room sensors

Daylight Coeffcient



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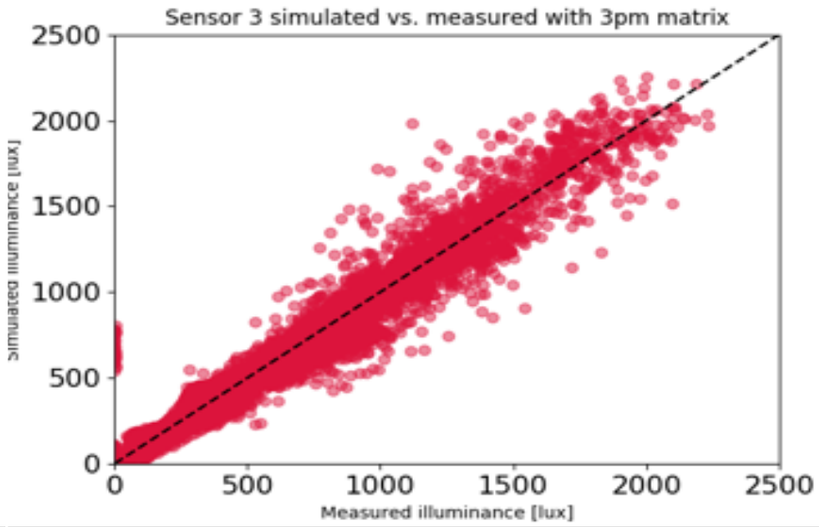

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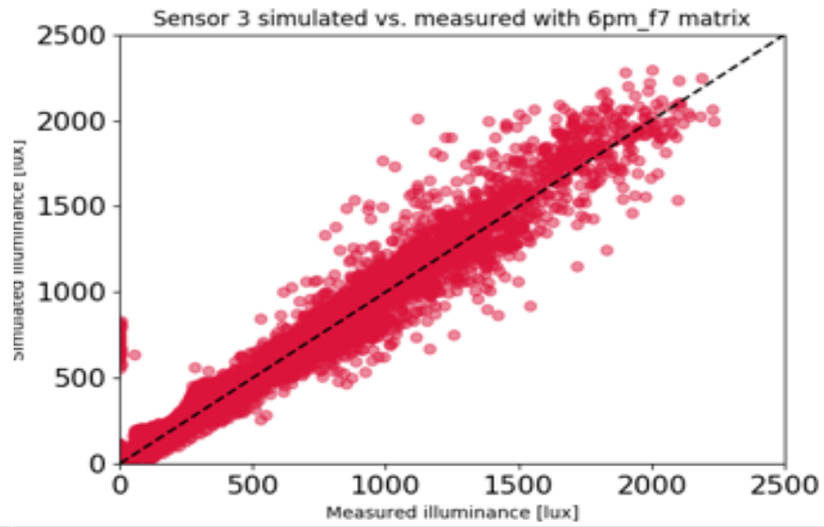
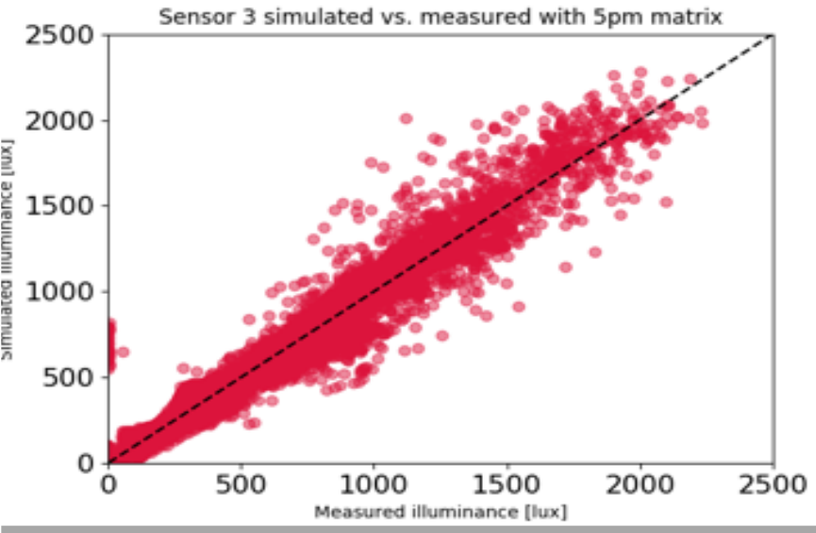


5PM



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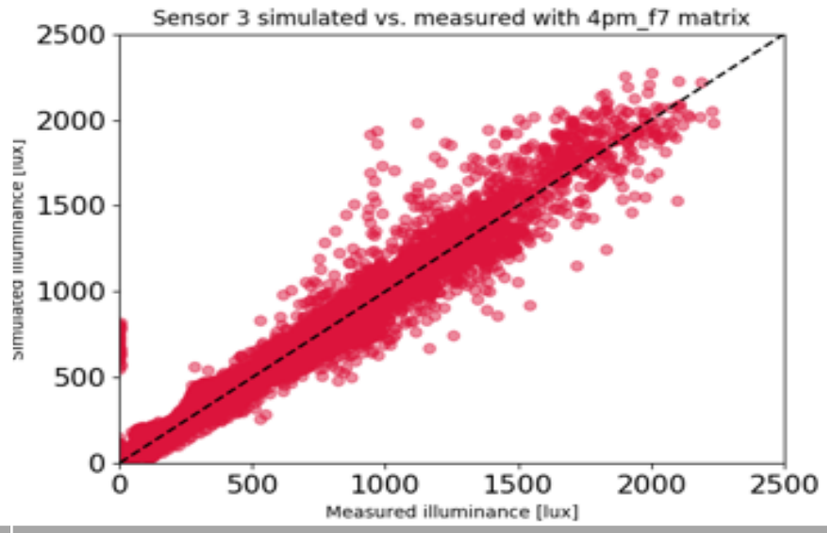

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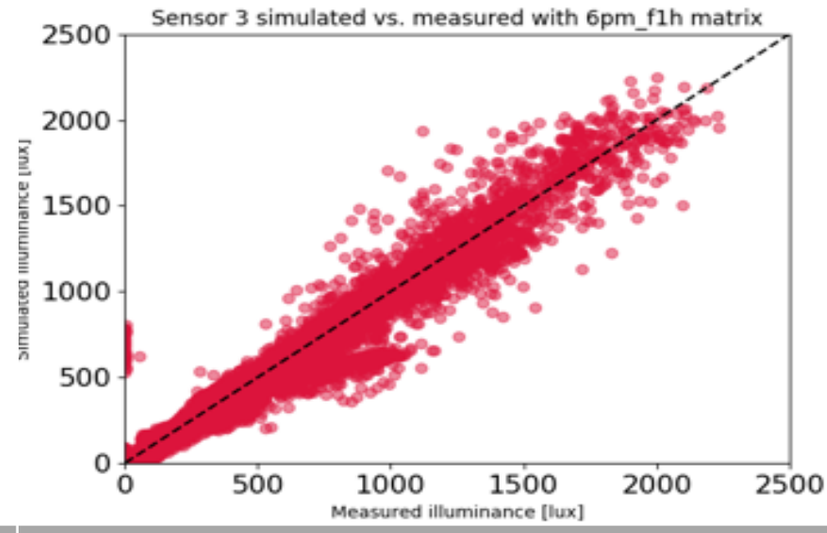

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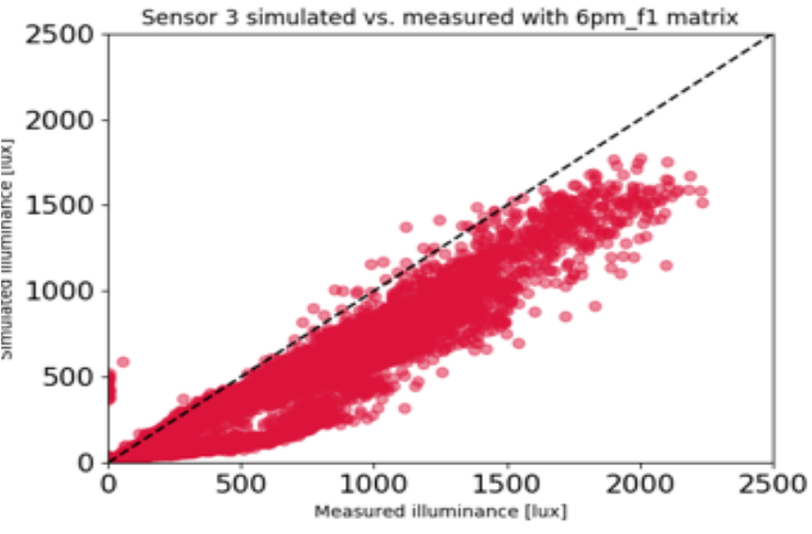

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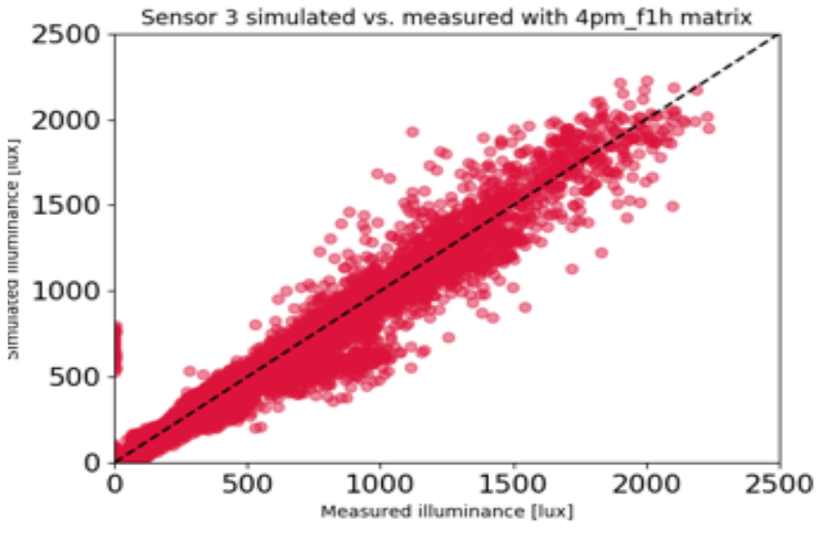

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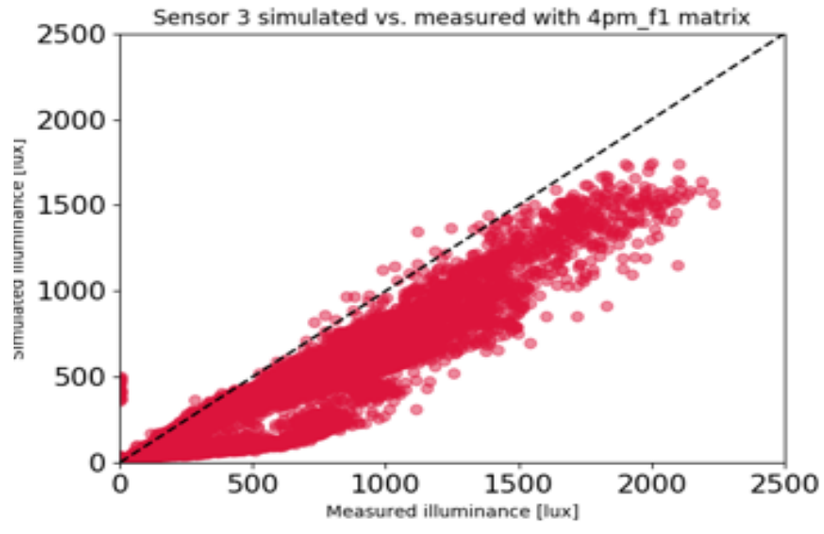
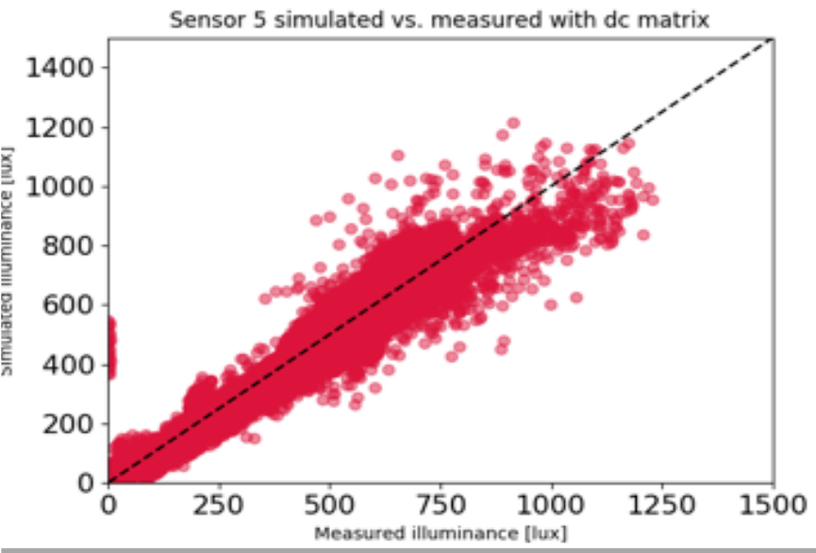


Back room sensors

Daylight Coeffcient



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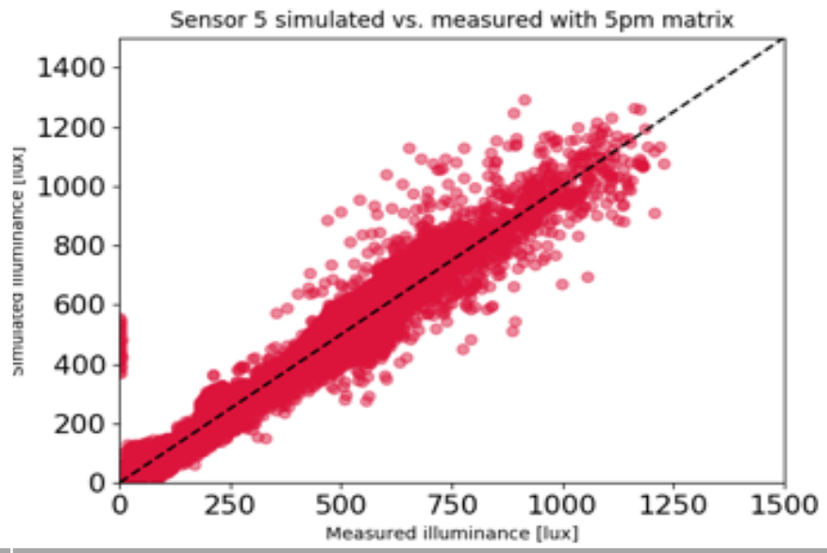

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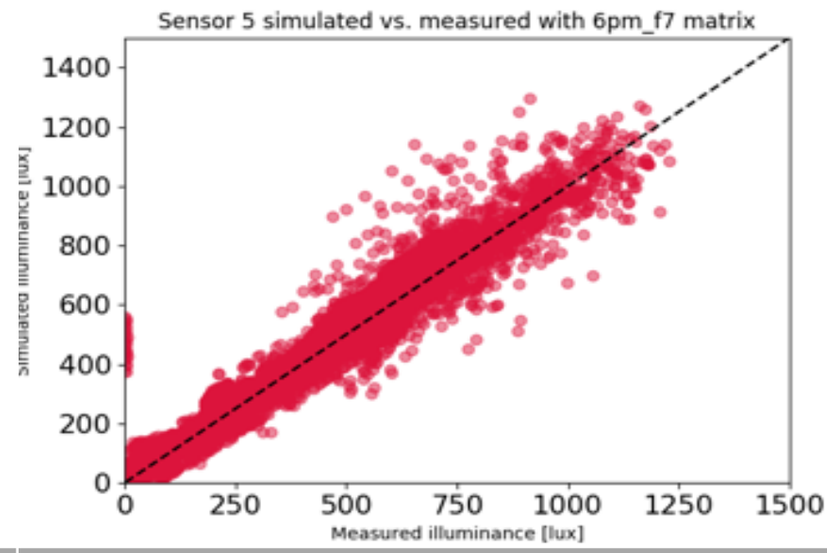

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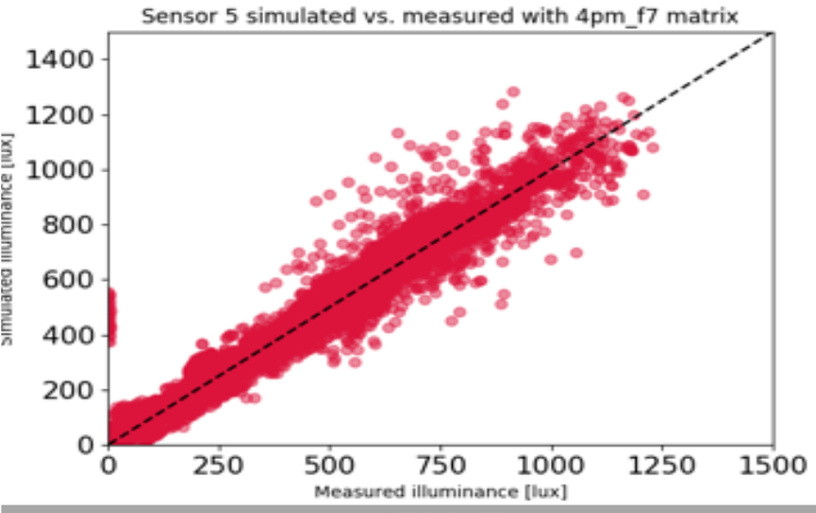

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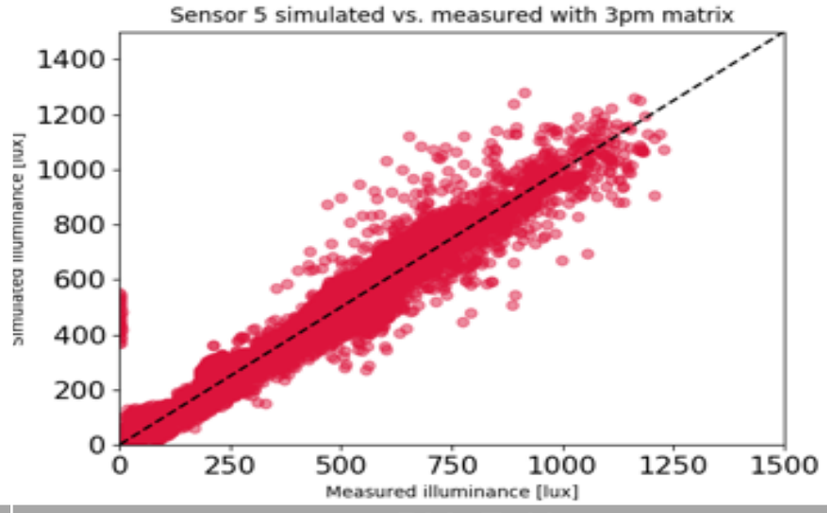

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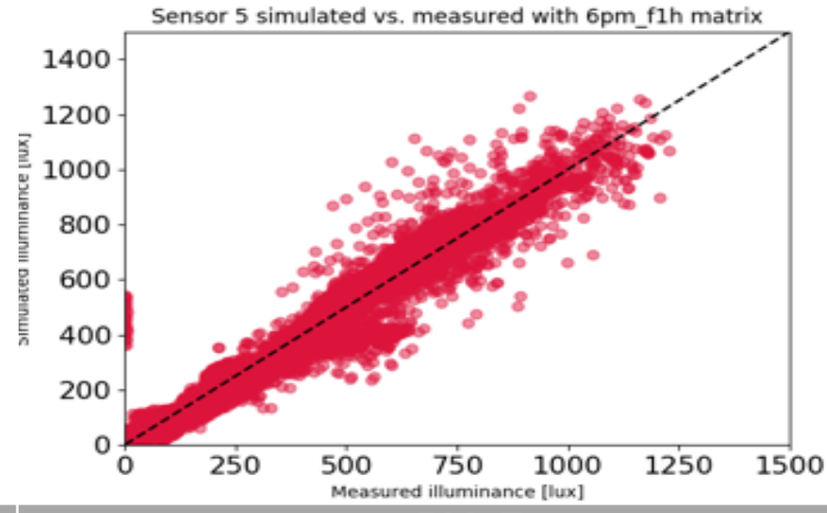
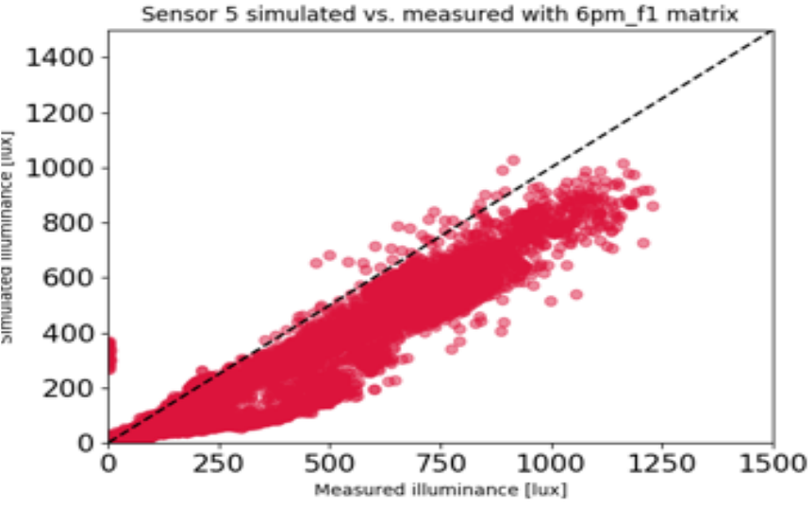
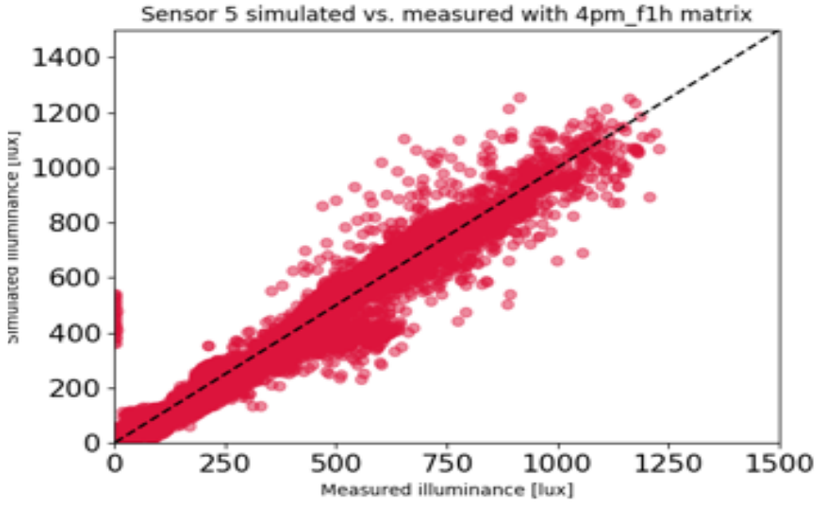


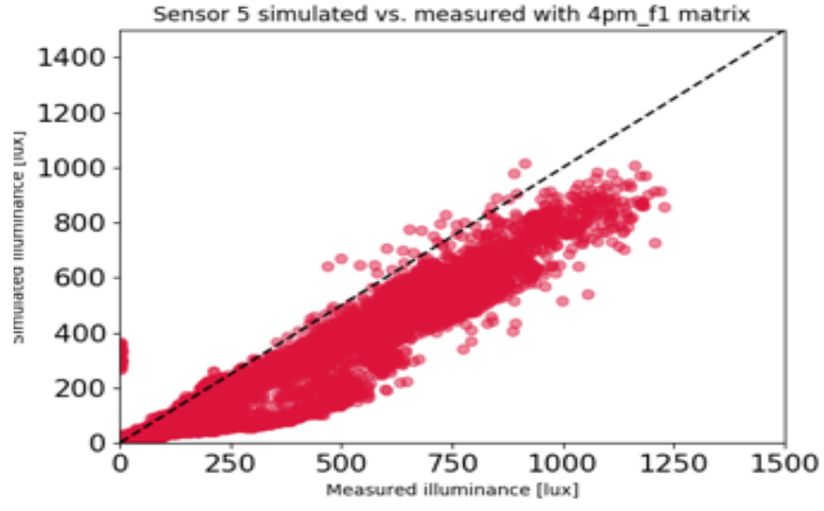
6PM_F1

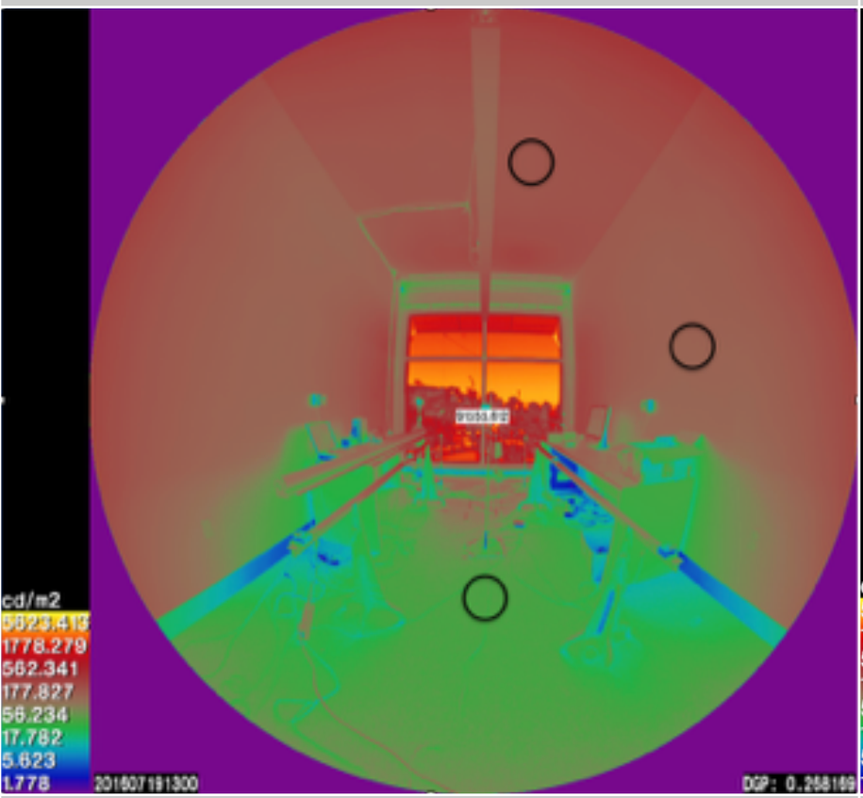
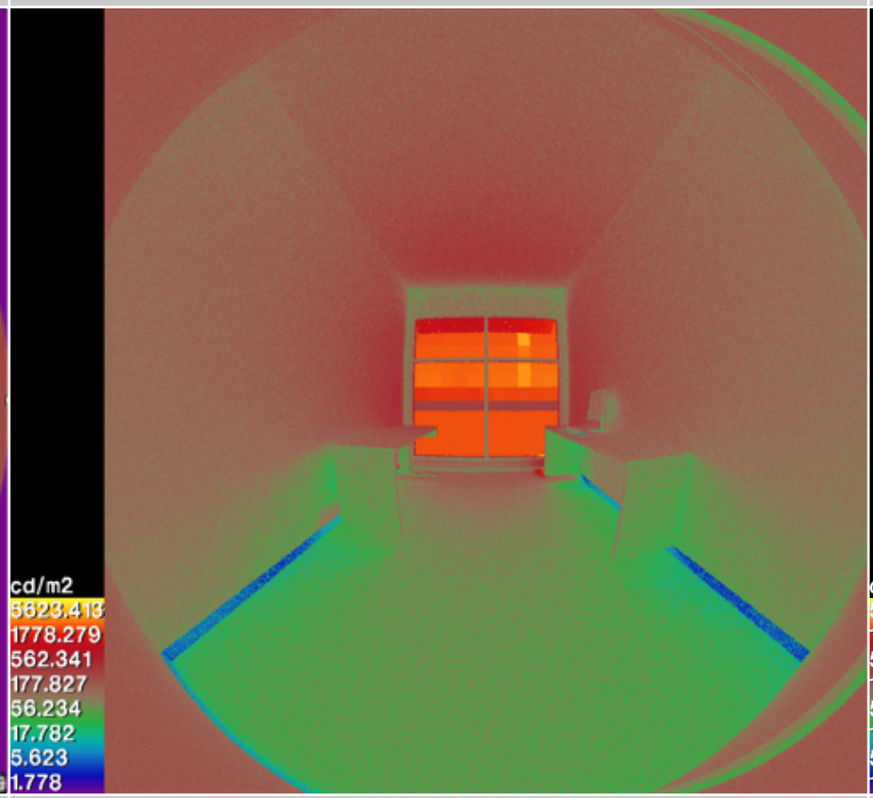
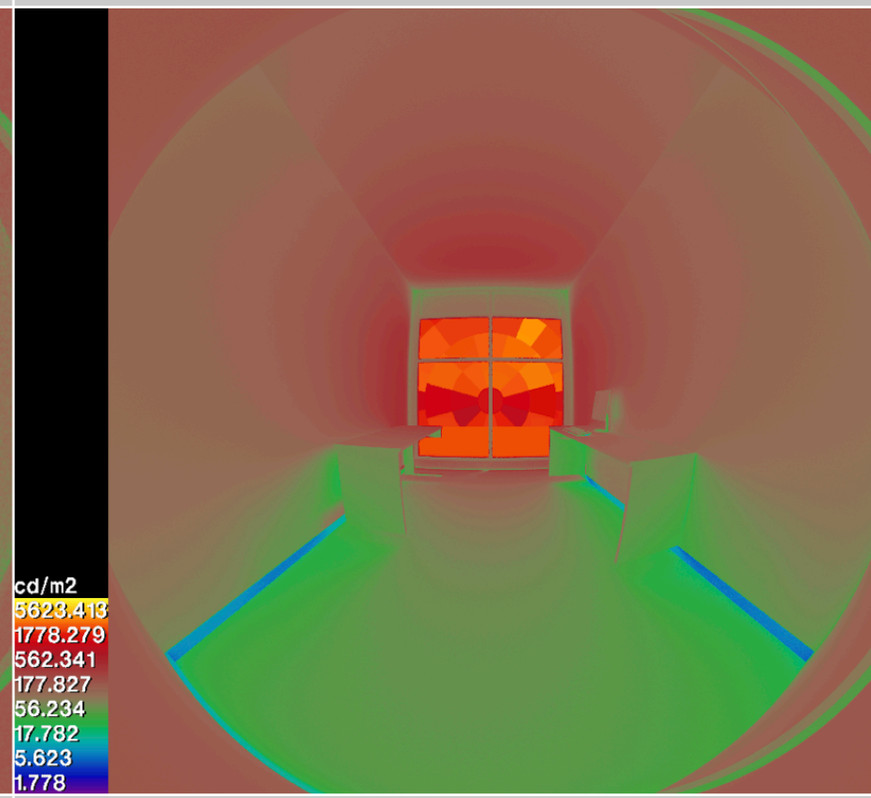


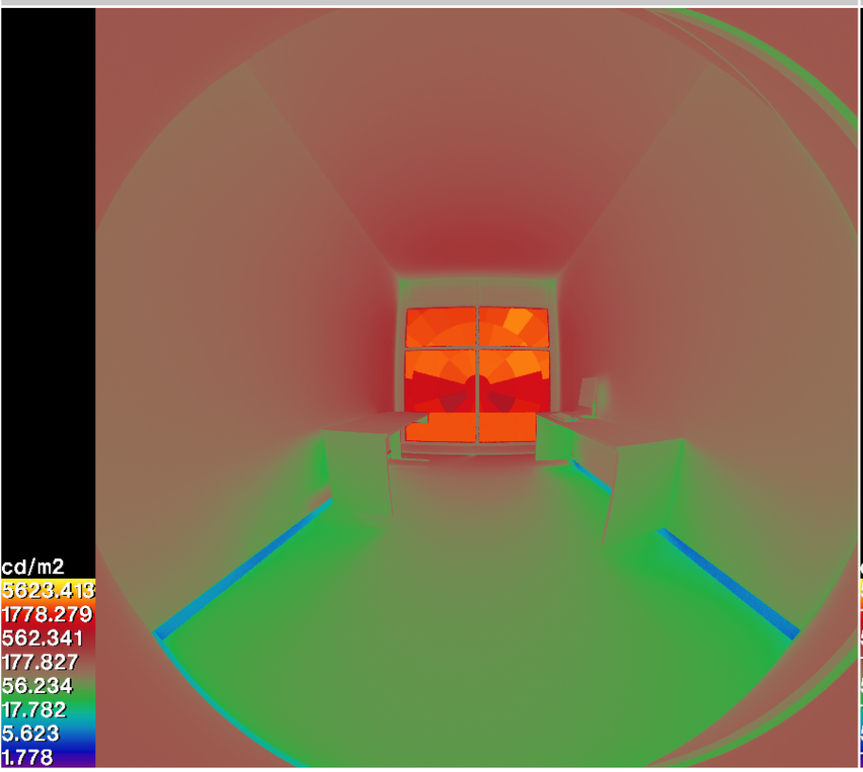
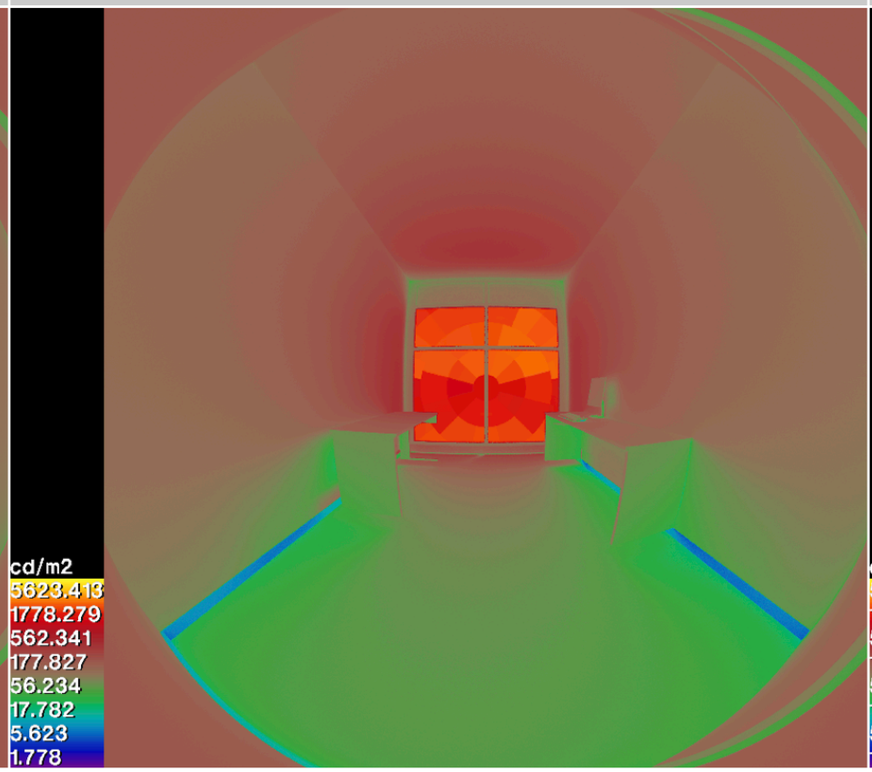
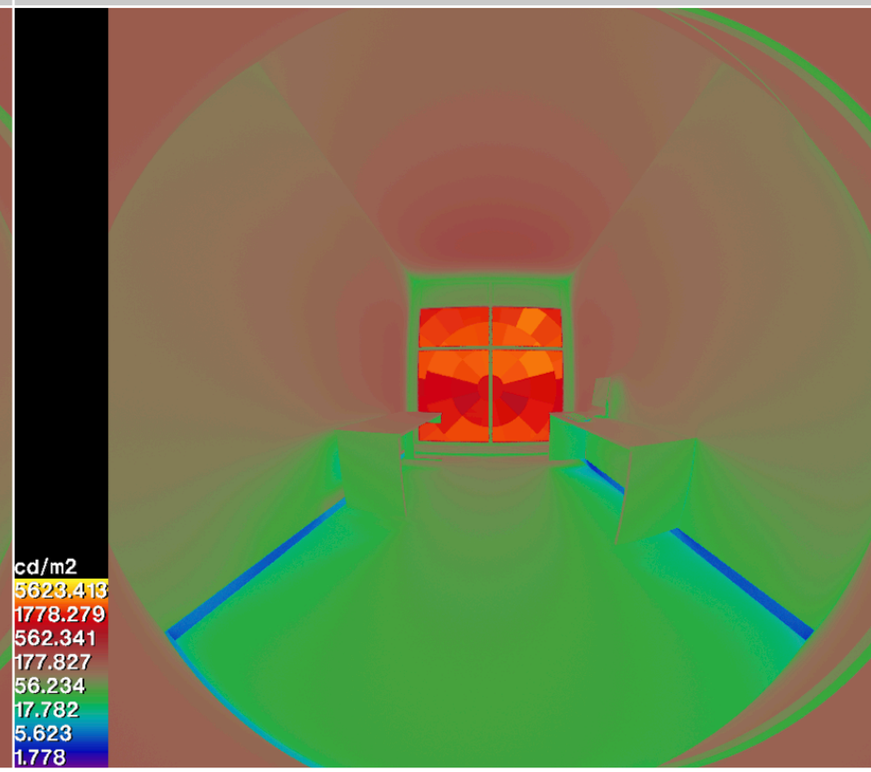
4PM_F1H

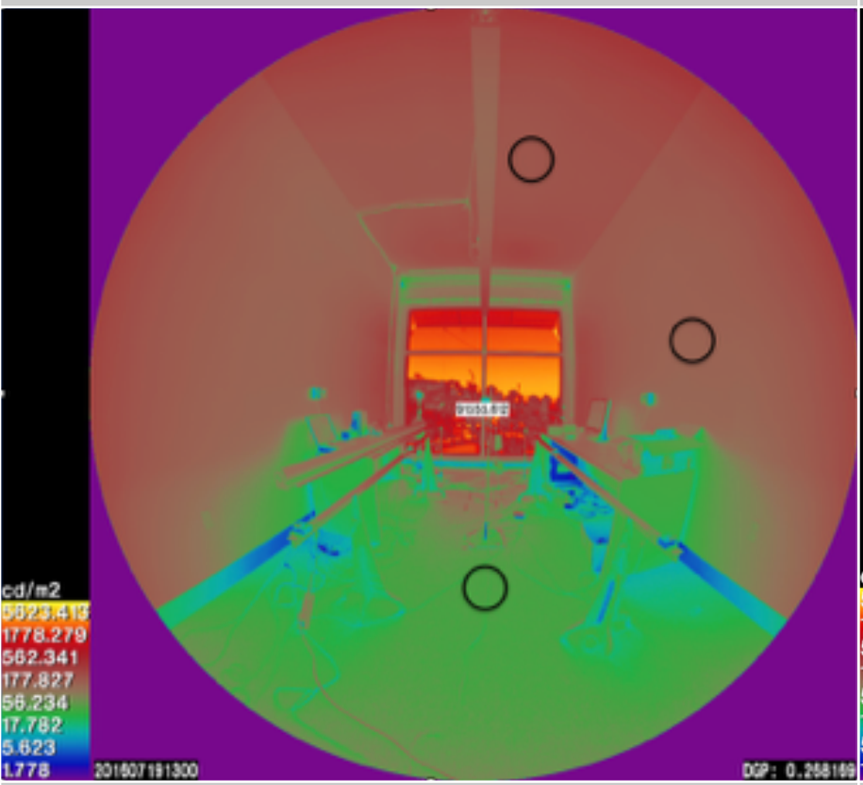
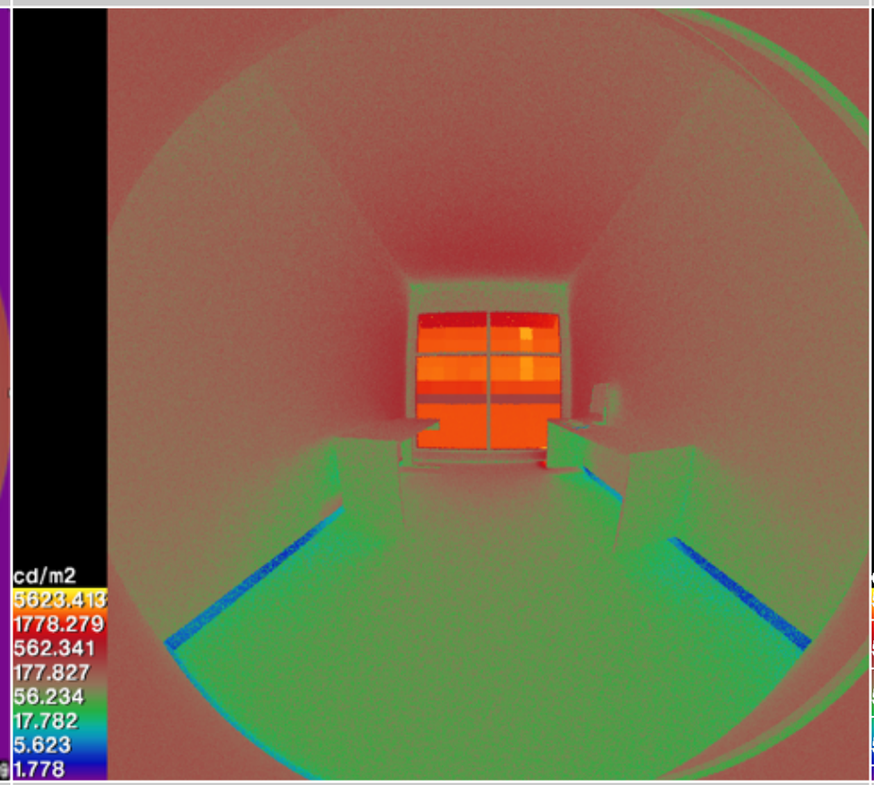
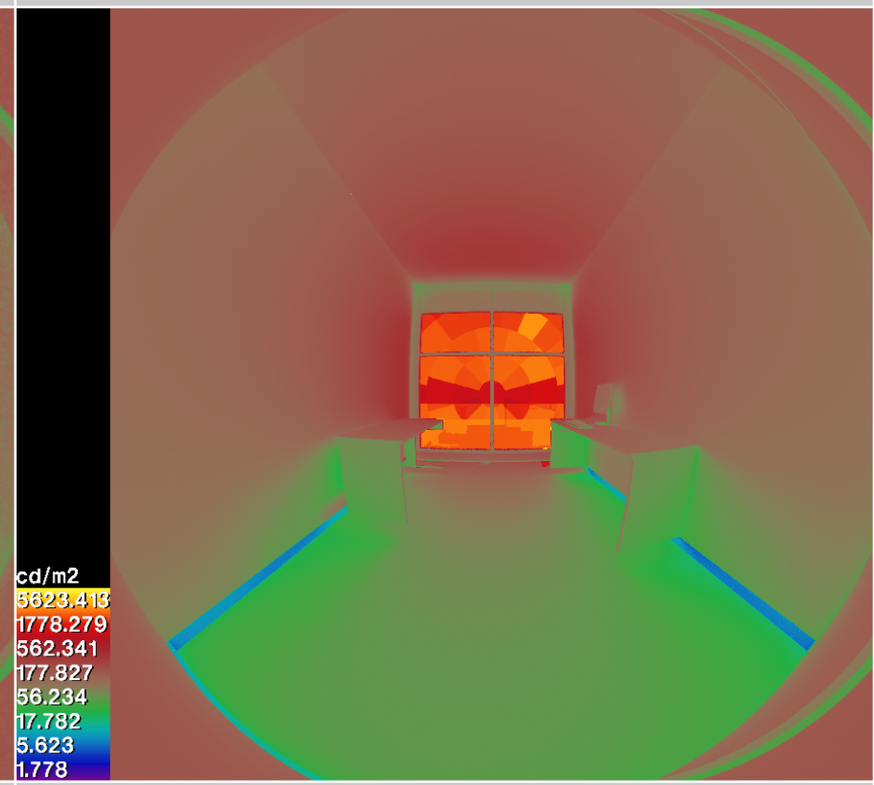


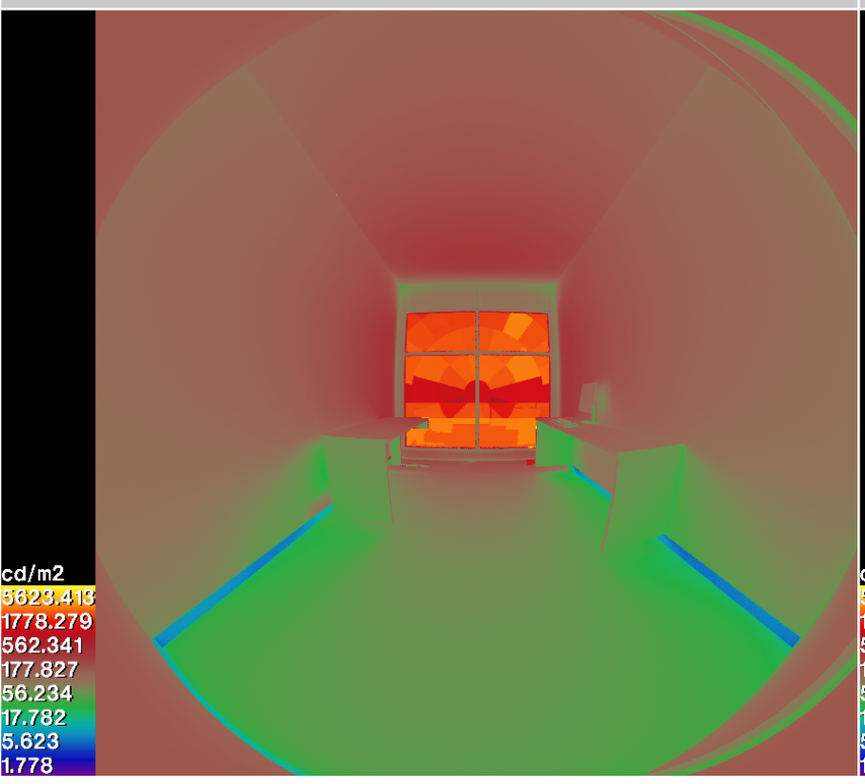
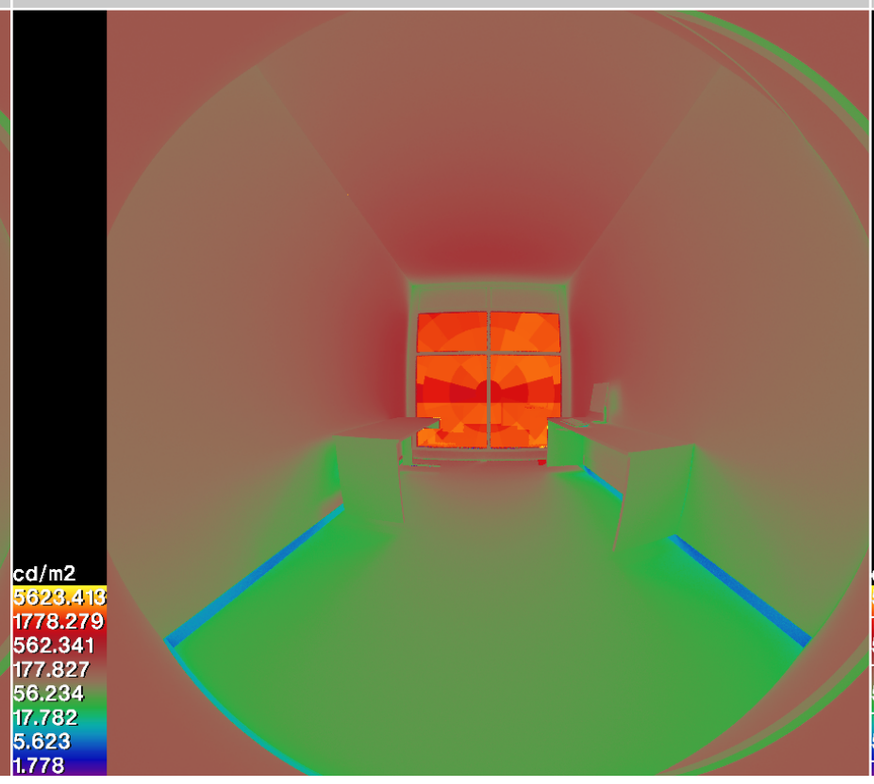
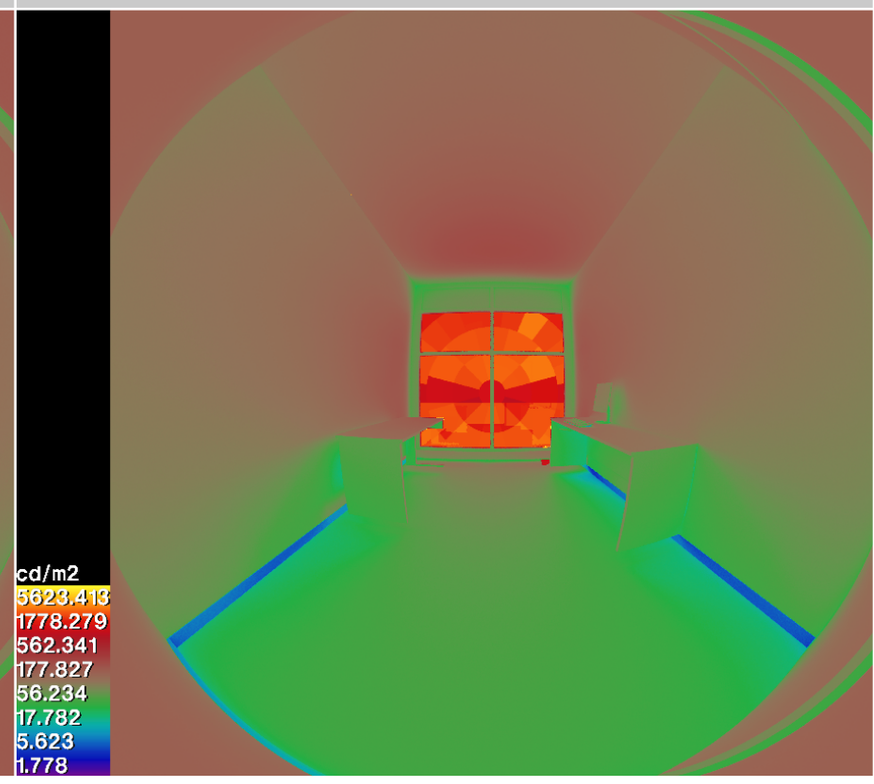
4PM_F1

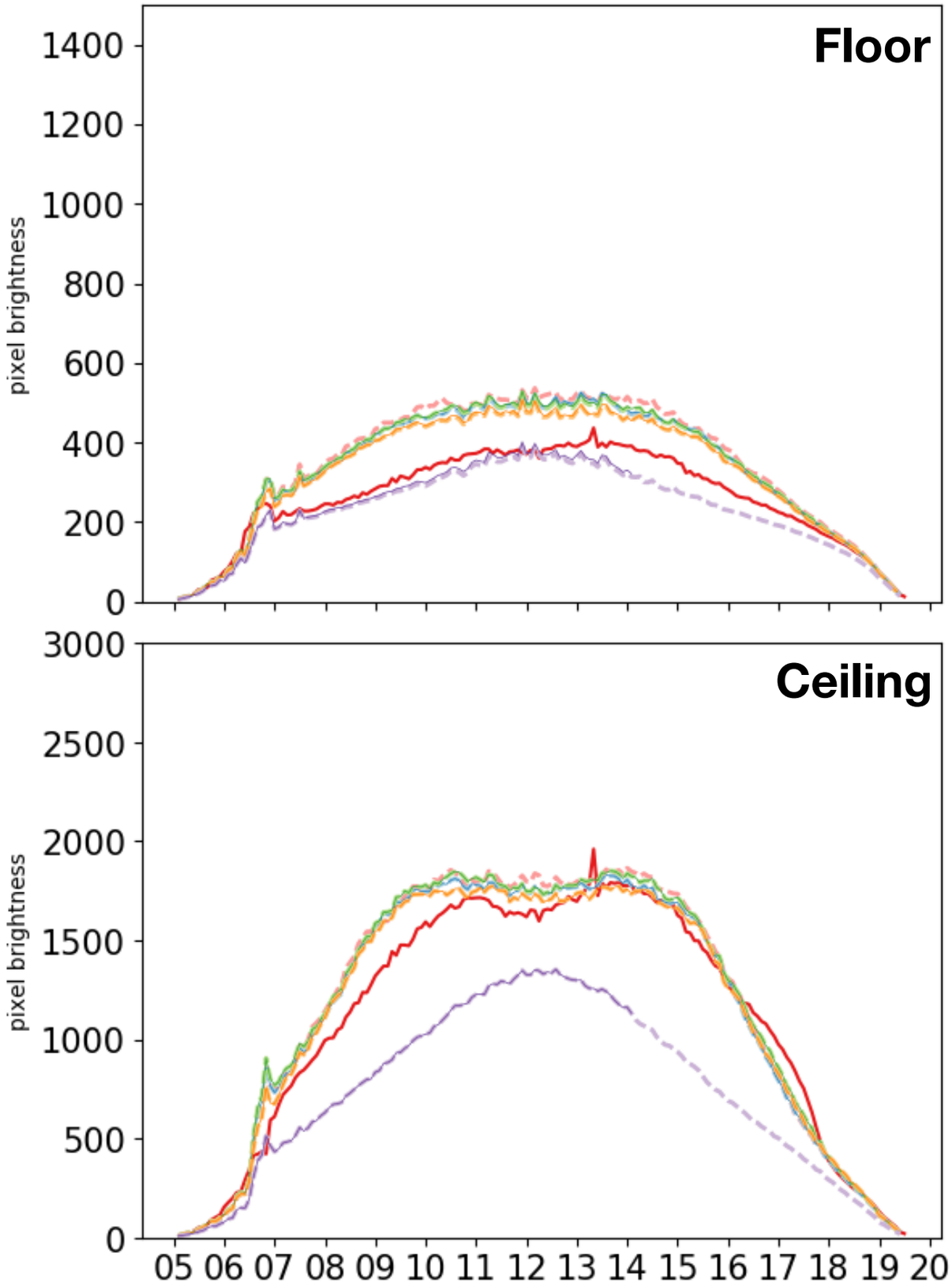


HDR Imaging	Daylight Coefficient	3PM
		

4PM_F7	4PM_F1H	4PM_F1
		

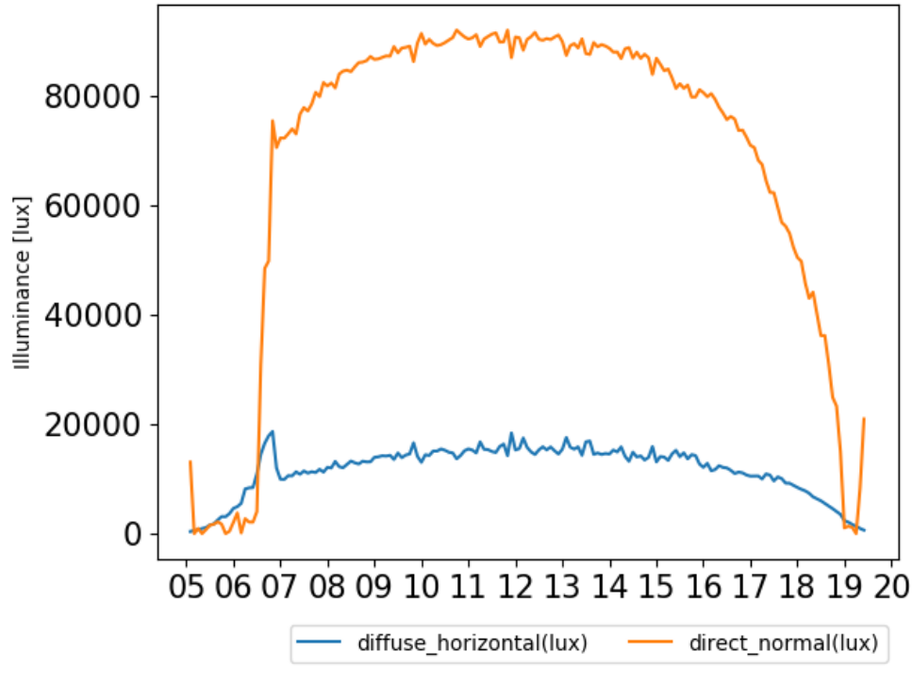
HDR Imaging	Daylight Coefficient	5PM
		

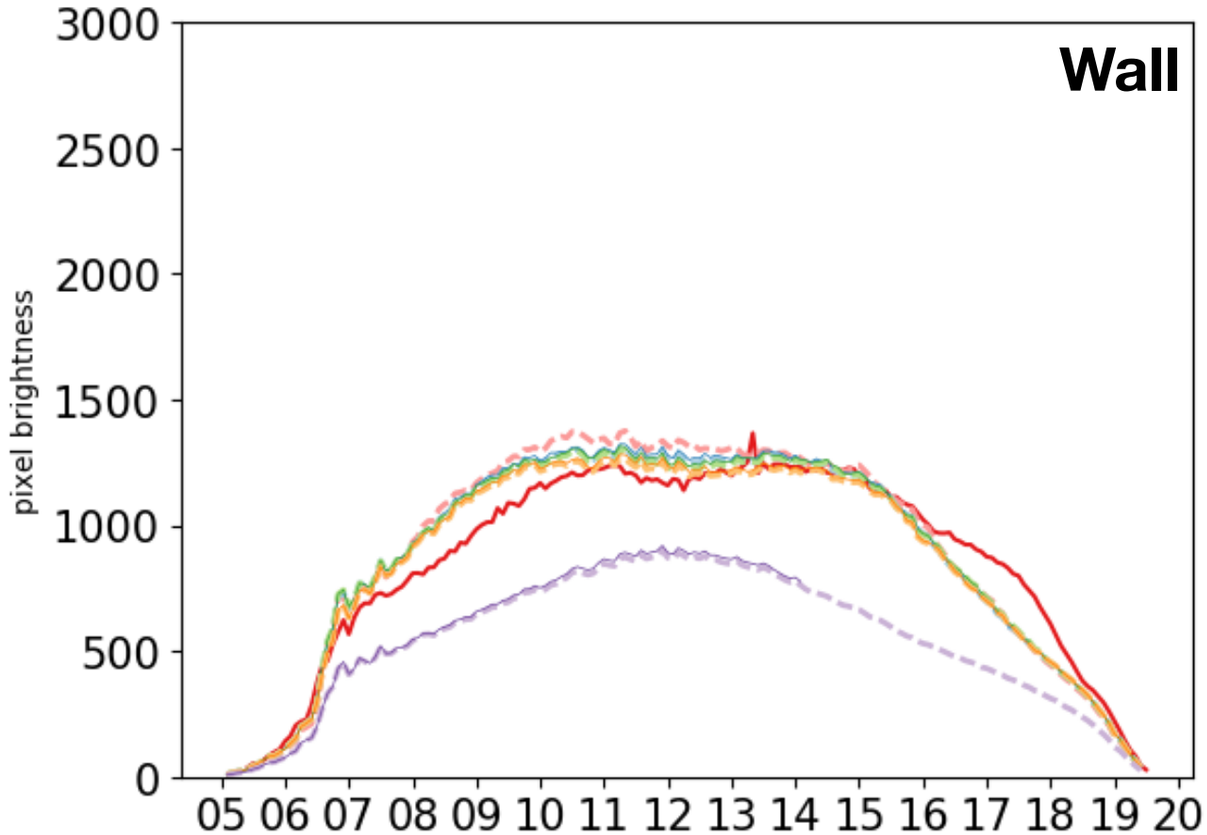
6PM_F7	6PM_F1H	6PM_F1
		



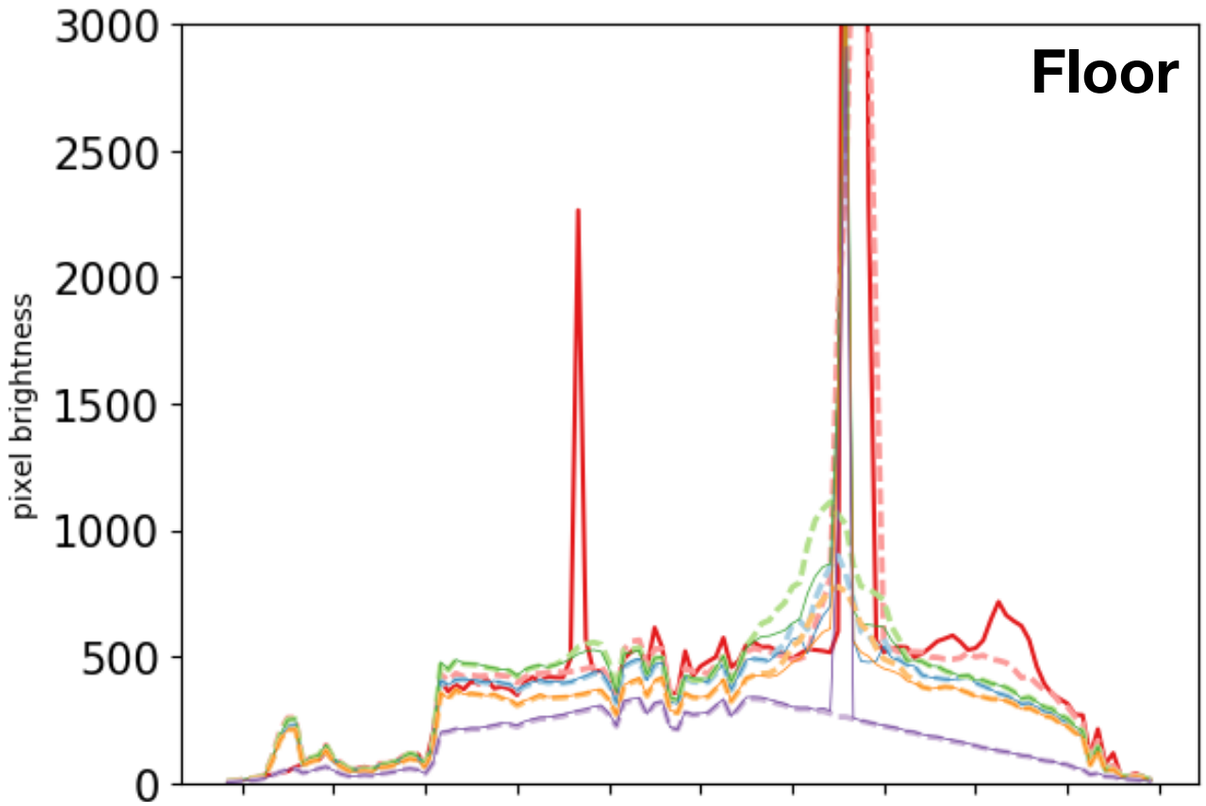
Luminance July 20th

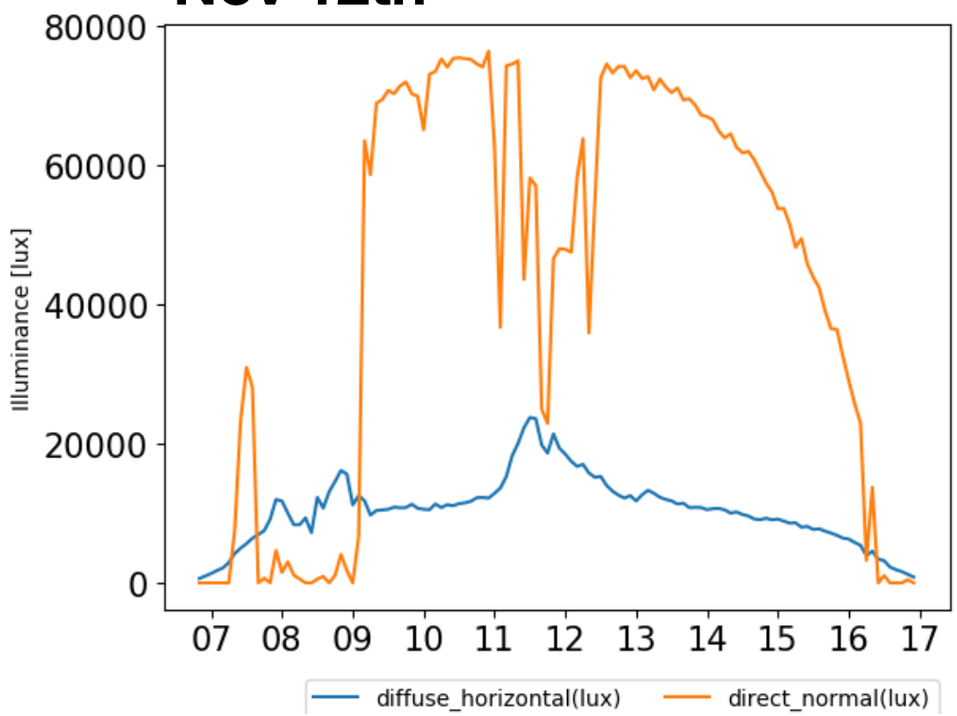
Awning: swing arm and facade at 125 deg

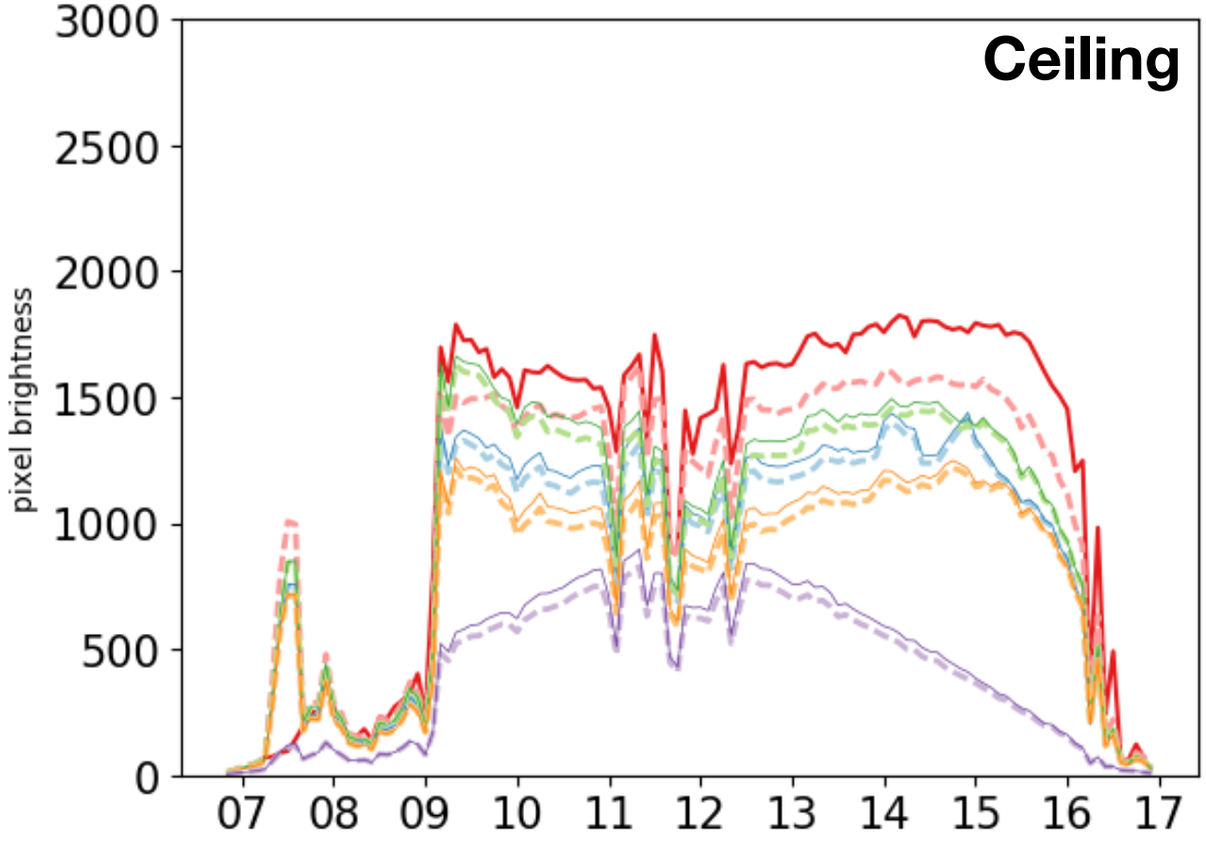


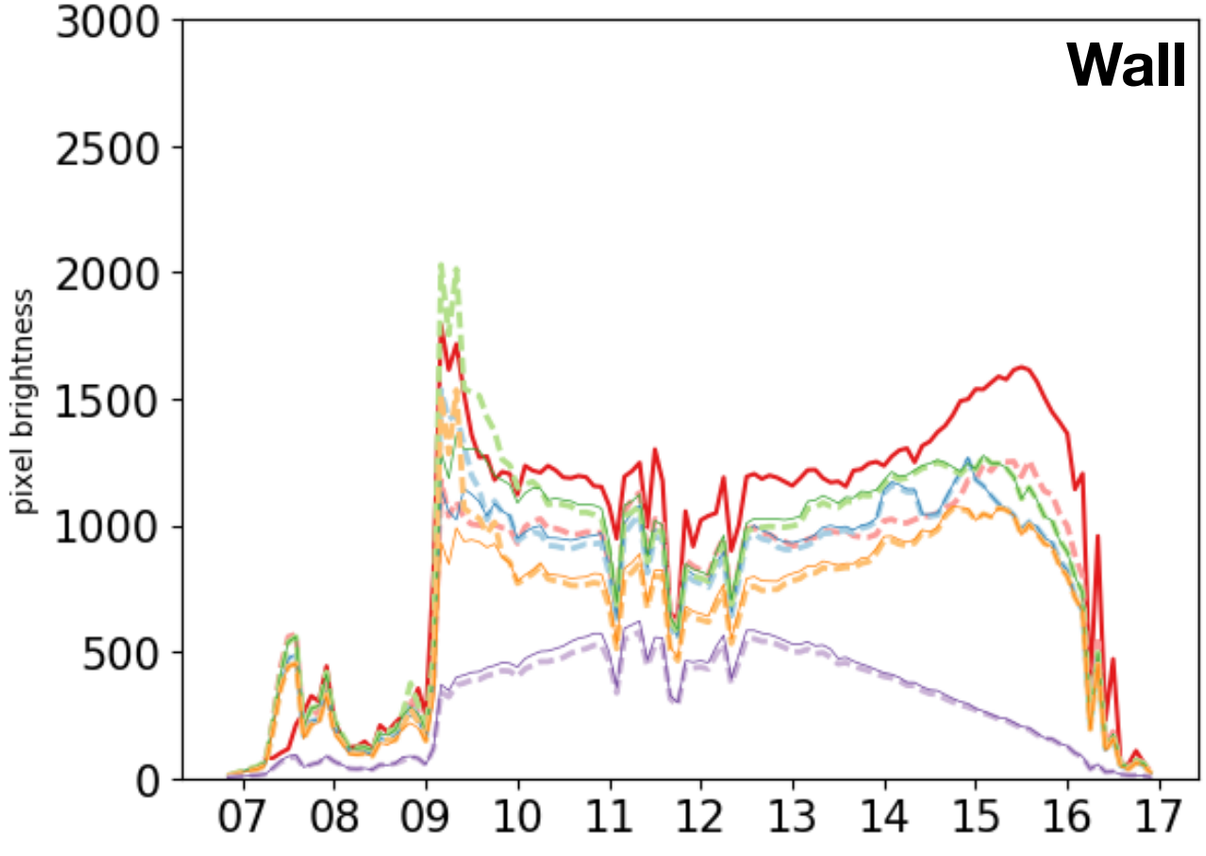


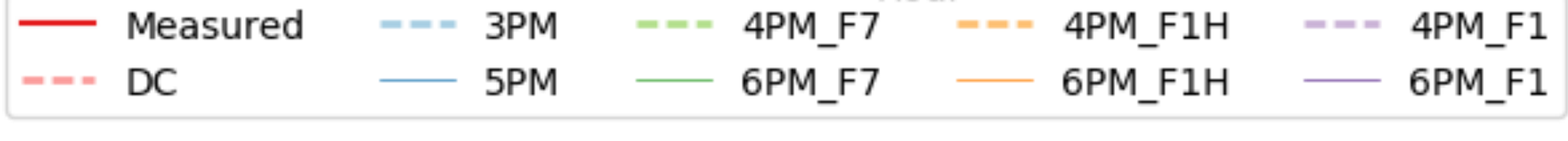
Measured
DC
3PM
5PM
4PM_F7
6PM_F7
4PM_F1H
6PM_F1H
4PM_F1
6PM_F1


Floor
pixel brightness
3000
2500
2000
1500
1000
500
0
07
08
09
10
11
12
13
14
15
16
17


Luminance
Nov 12th
Awning: swing arm and facade at 125 deg
Illuminance [lux]
80000
60000
40000
20000
0
07
08
09
10
11
12
13
14
15
16
17
diffuse_horizontal(lux)
direct_normal(lux)

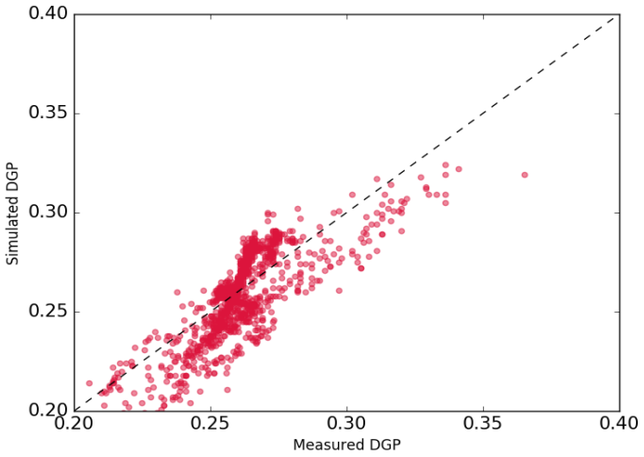

Ceiling
pixel brightness
3000
2500
2000
1500
1000
500
0
07
08
09
10
11
12
13
14
15
16
17


Wall
pixel brightness
3000
2500
2000
1500
1000
500
0
07
08
09
10
11
12
13
14
15
16
17

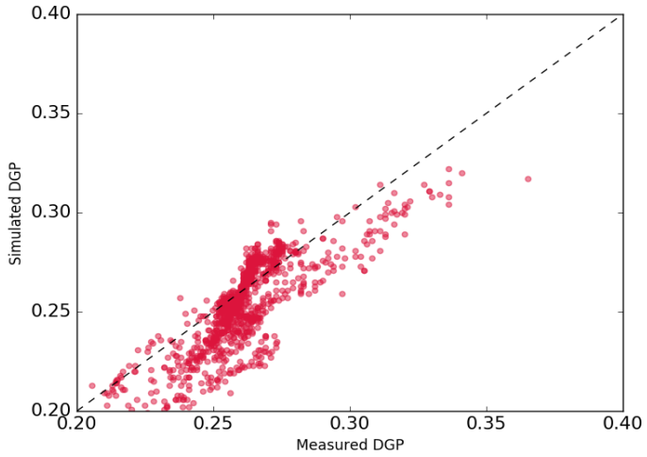

Measured
DC
3PM
5PM
4PM_F7
6PM_F7
4PM_F1H
6PM_F1H
4PM_F1
6PM_F1

DGP

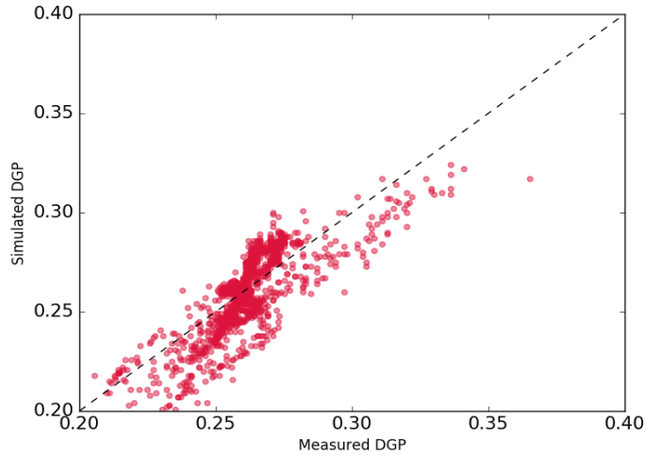
5PM



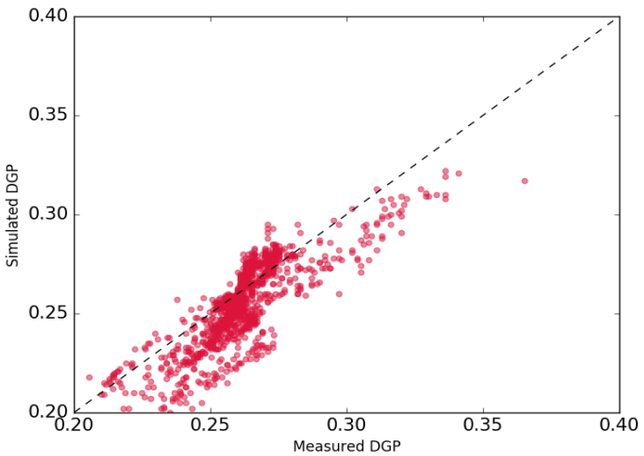
3PM



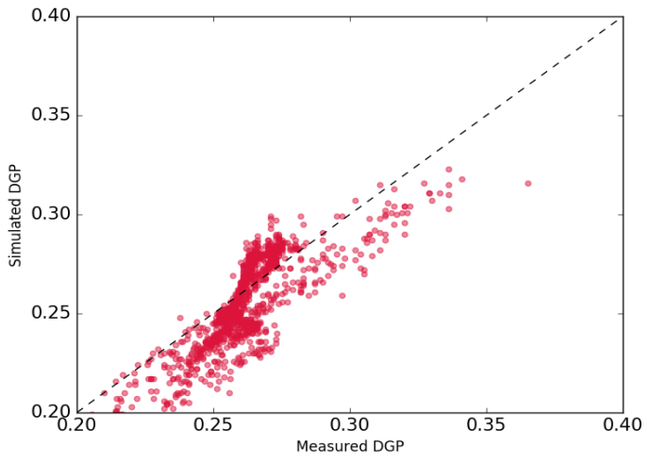
6PM_F7



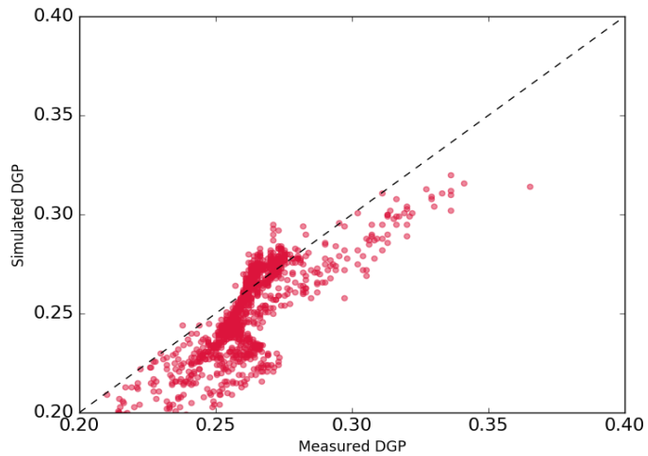
4PM_F7



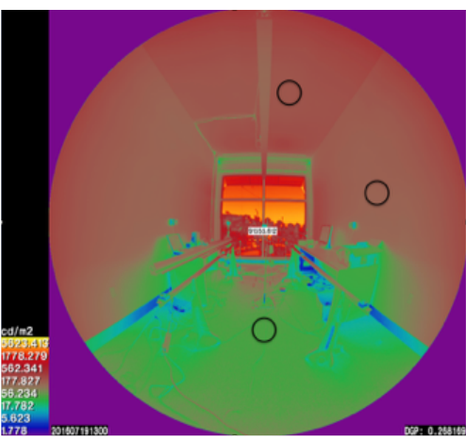
6PM_F1H



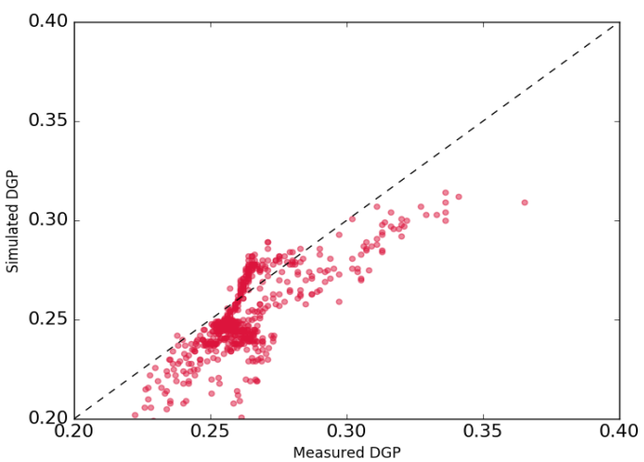
4PM_F1H



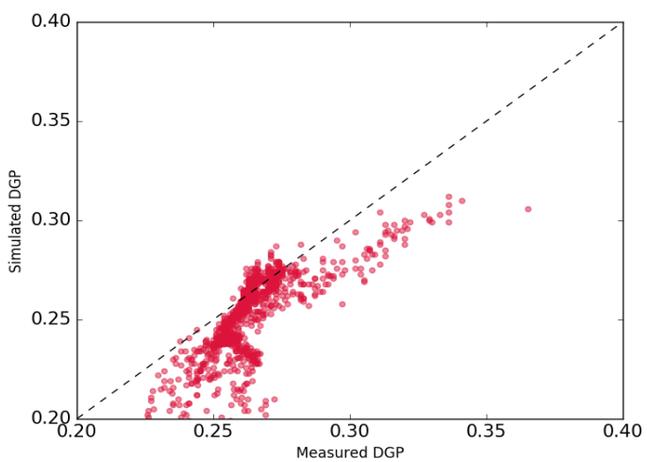
Simulated



6PM_F1

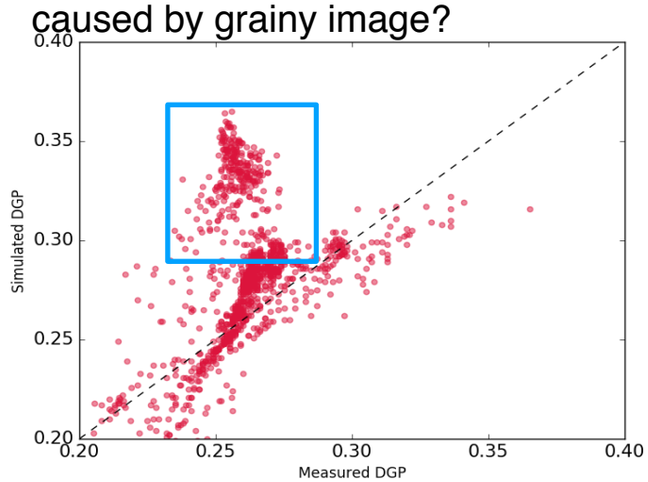


4PM_F1



DC

caused by grainy image?



Measured

July 4th - 31st & Nov 11th – 18th (2016) & Apr(2017) 25th – 30th

Normalized Mean Absolute Error (%)

workplane illuminance simulated vs. measured

Sensor	Near Window	Mid Room	Back Room	All
6pm_f7	18.9	8.0	9.0	11.6
dc	13.9	9.8	11.5	11.7
4pm_f7	19.9	6.9	8.5	11.7
3pm	19.7	7.2	8.8	11.9
5pm	18.8	8.2	9.3	12.1
4pm_f1h	21.5	8.2	8.9	12.9
6pm_f1h	21.3	8.3	9.3	13.0
6pm_f1	48.9	28.2	23.6	33.6
4pm_f1	51.1	30.2	24.5	35.3

Sample area luminance simulated vs. measured

	Floor	Wall	Ceiling	ALL
dc	18.6	17.7	8.2	14.8
6pm_f7	21.8	15.0	9.1	15.7
5pm	20.4	17.1	10.1	15.9
4pm_f7	22.6	16.0	9.6	16.1
3pm	20.8	16.9	10.5	16.1
6pm_f1h	21.6	18.9	11.8	17.4
4pm_f1h	21.9	18.4	12.2	17.5
6pm_f1	22.6	26.8	19.2	22.9
4pm_f1	26.3	35.9	28.1	30.1

Conclusion:

1. Constructing a façade matrix enables parametric analysis of non-coplanar shading systems;

2. The optical behavior of the non-coplanar system can be adequately captured given appropriate sampling basis (e.g. Klems vs. Reinhart) and simulation parameters (e.g. '-c -ab -ad -lw')

3. Out of the three methods of constructing a façade matrix, the FN methods yields the most accurate results against the measured data. FH methods seems to work reasonably well for the test case. F1 demonstrated the worst case scenario, and thus yielded the least accurate result.

Acknowledgment

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Https://facades.lbl.gov/