NC STATE UNIVERSITY

College of Design

Daylight Simulation Analysis of an Innovative Daylighting System:

Optical Vertical Louver (OVL) System

| Masoome Haghani[1*], Wayne Place[1], Mohammad Salamati[1] |

| [1] North Carolina State University, Raleigh, NC |

Radiance Workshop 2022, Toronto, Canada

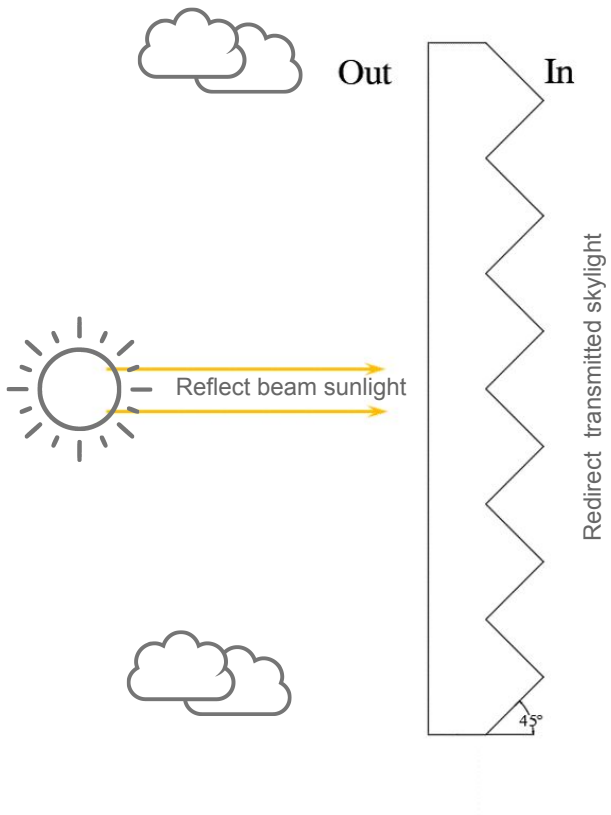
Outline

- To introduce the OVL system
- To generate the BSDF data.
- To quantify the efficiency of OVL system in comparison with state of the art daylighting systems.
- To provide the future studies of the OVL system

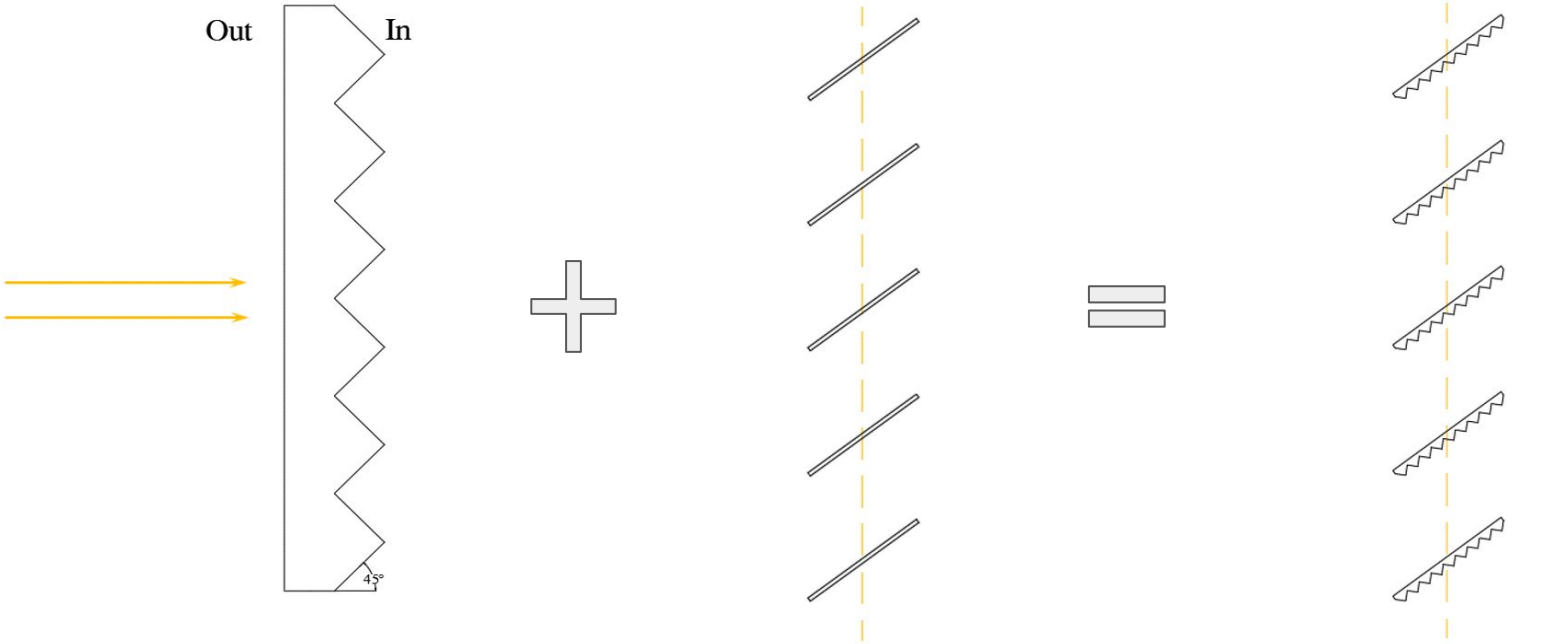
INTRODUCTION

Prismatic Panel

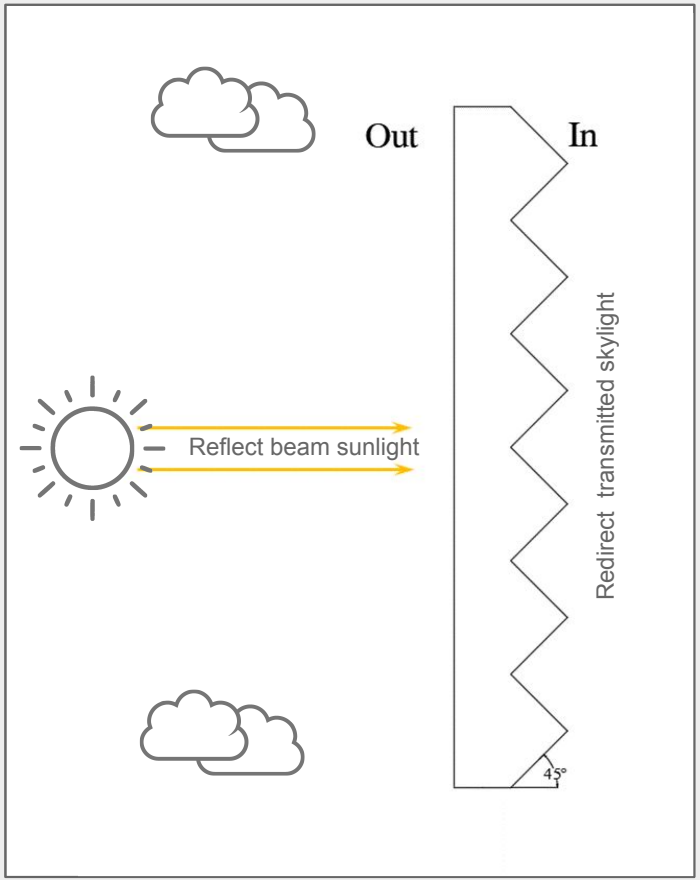
- Blocks beam sunlight while transmits diffuse skylight
- Light perpendicular to the prismatic panel is completely reflected away (around 99%).
- Light not perpendicular to the prismatic panel is partially transmitted (around 45-50%).

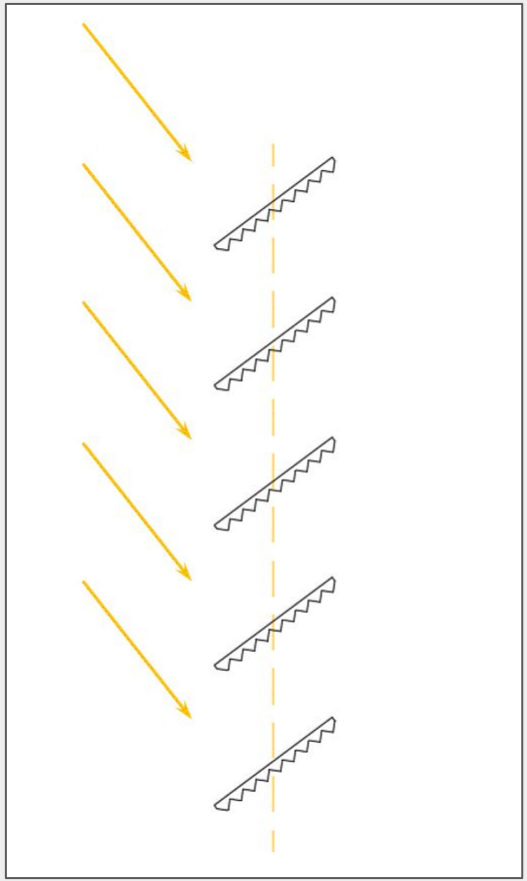


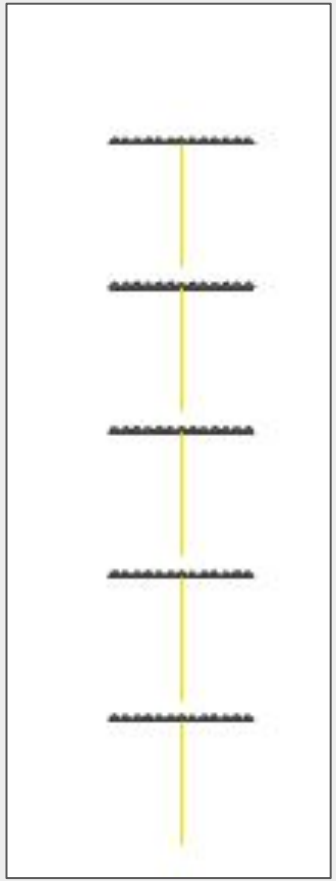
Optical Vertical Louver (OVL)



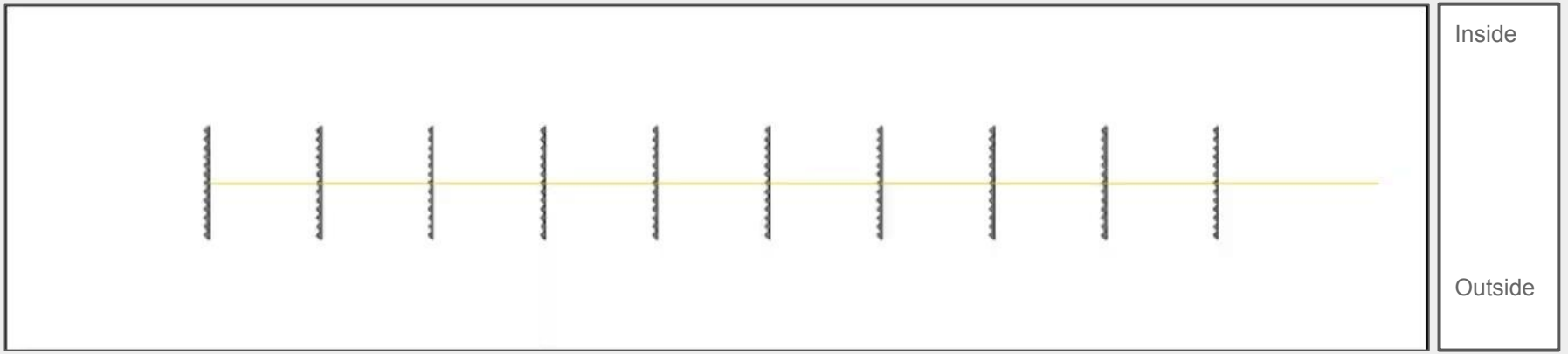
Prismatic Element | Conventional Vertical Blind(CVB) | OVL System



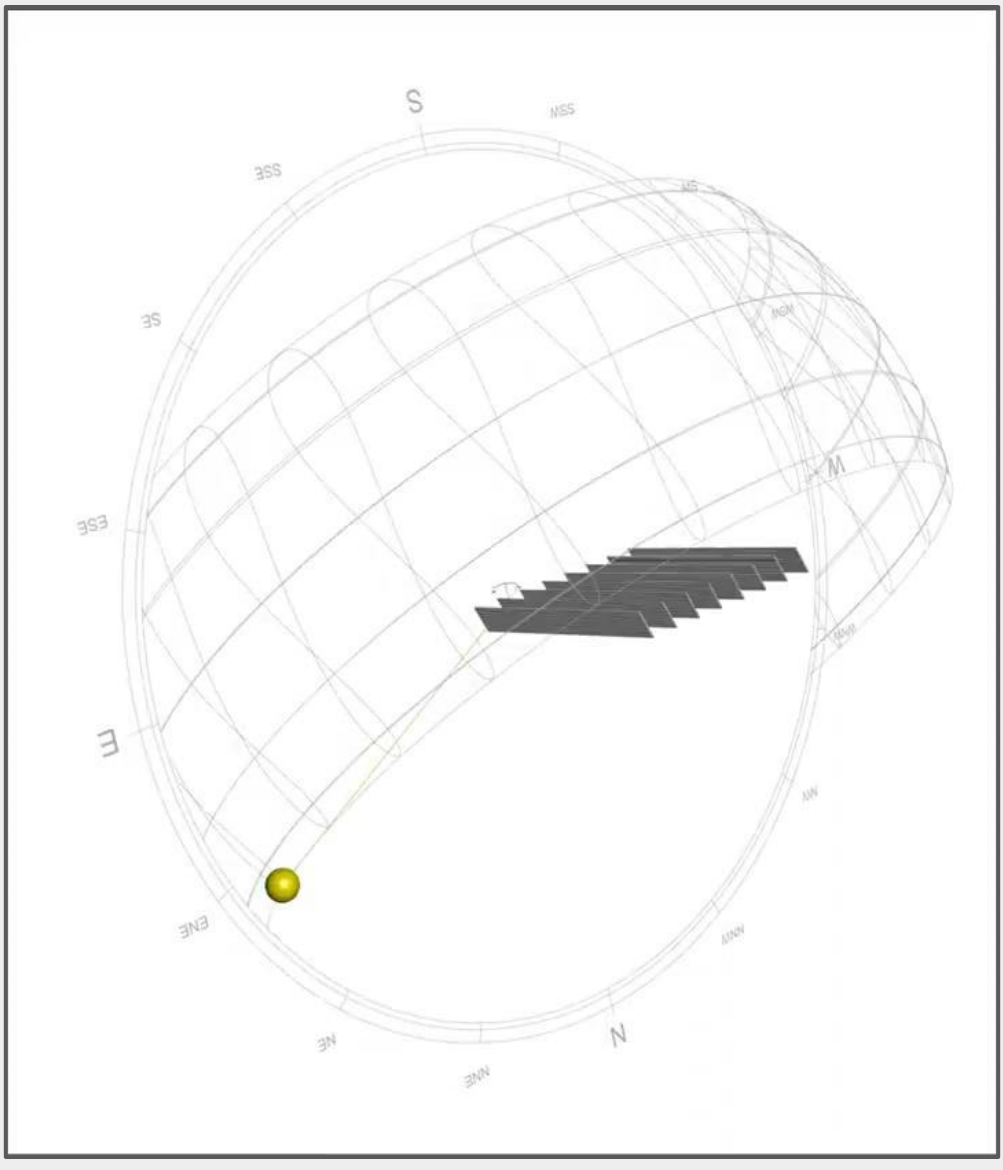




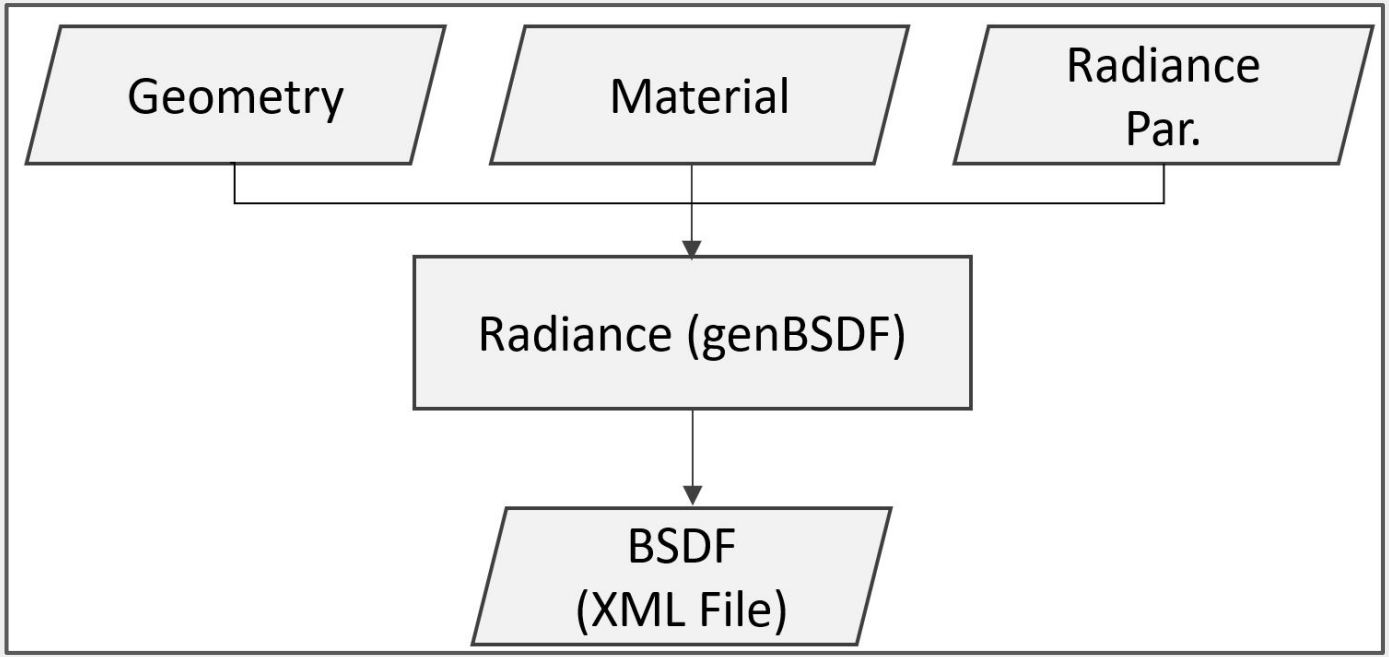
Prismatic Element as a **Solar Shading System**

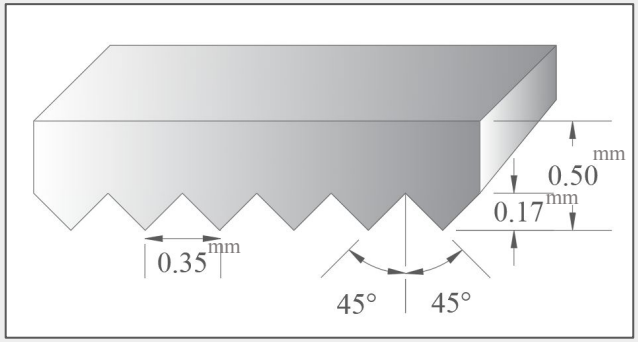


*Yellow lines show the sun azimuth angle which are perpendicular to the slat surfaces


S
SSW
SSE
SW
SE
WSW
ESE
W
E
WNW
WNW
ENE
NNW
NE
N
NNE

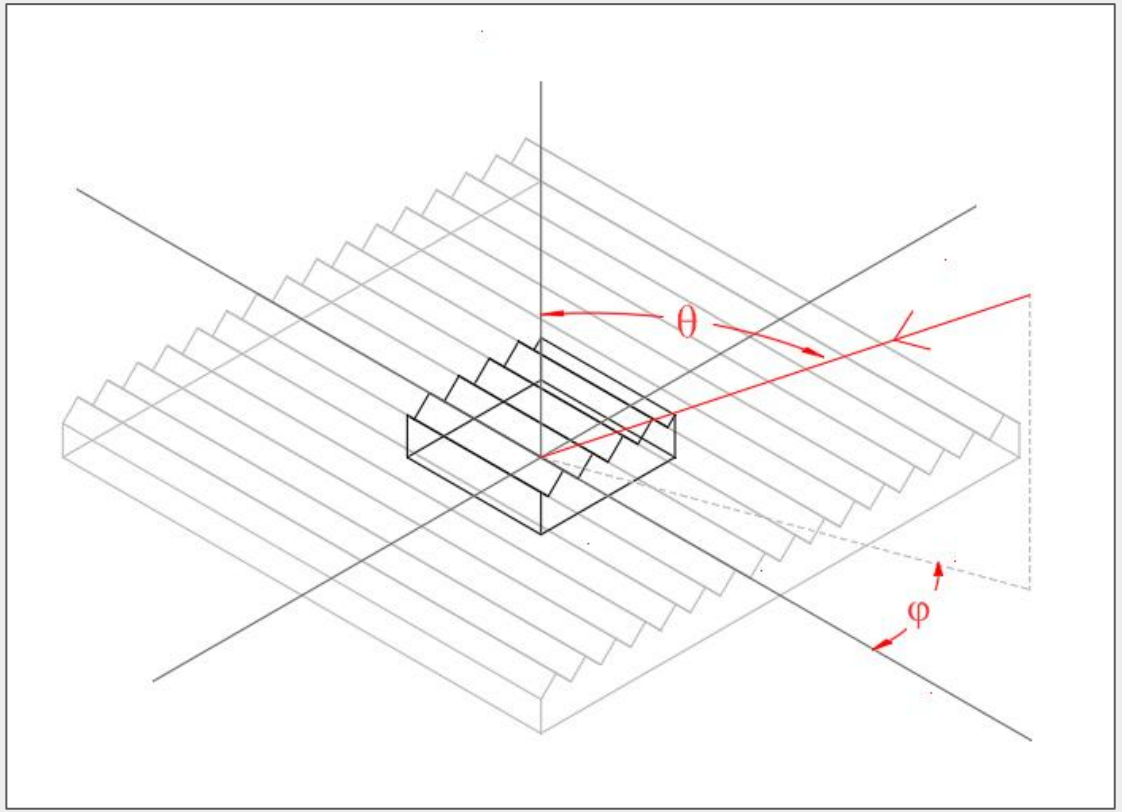
OPTICAL CHARACTERIZATION


Geometry
Material
Radiance Par.
Radiance (genBSDF)
BSDF (XML File)

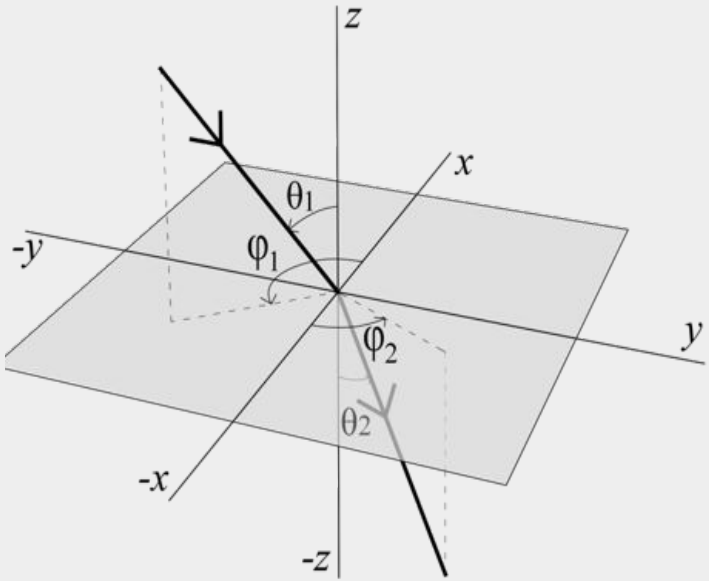


Refractive index: 1.59

```
genBSDF -n 4 -c 12288 -r "-ab 15 -ad
100 -lw 0.001" -t4 6 +f +b -geom
millimeter -dim -2.56472 3.43528
2.28433 7.71567 -1.09901 -0.09901
mat.rad 9112020.rad >BSDF.xml
```

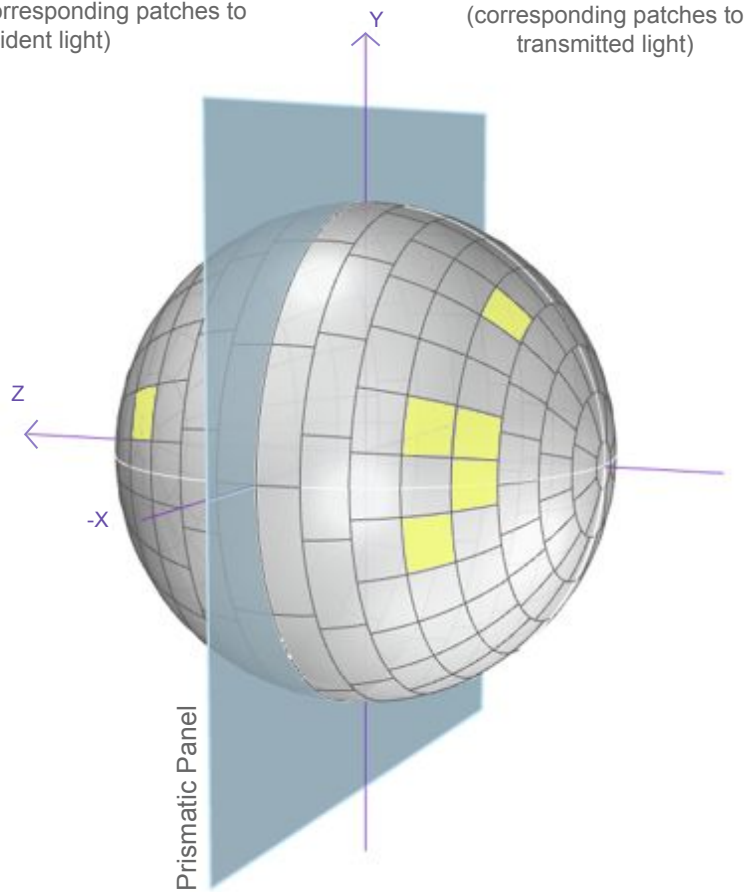


Transmission of Prismatic Element



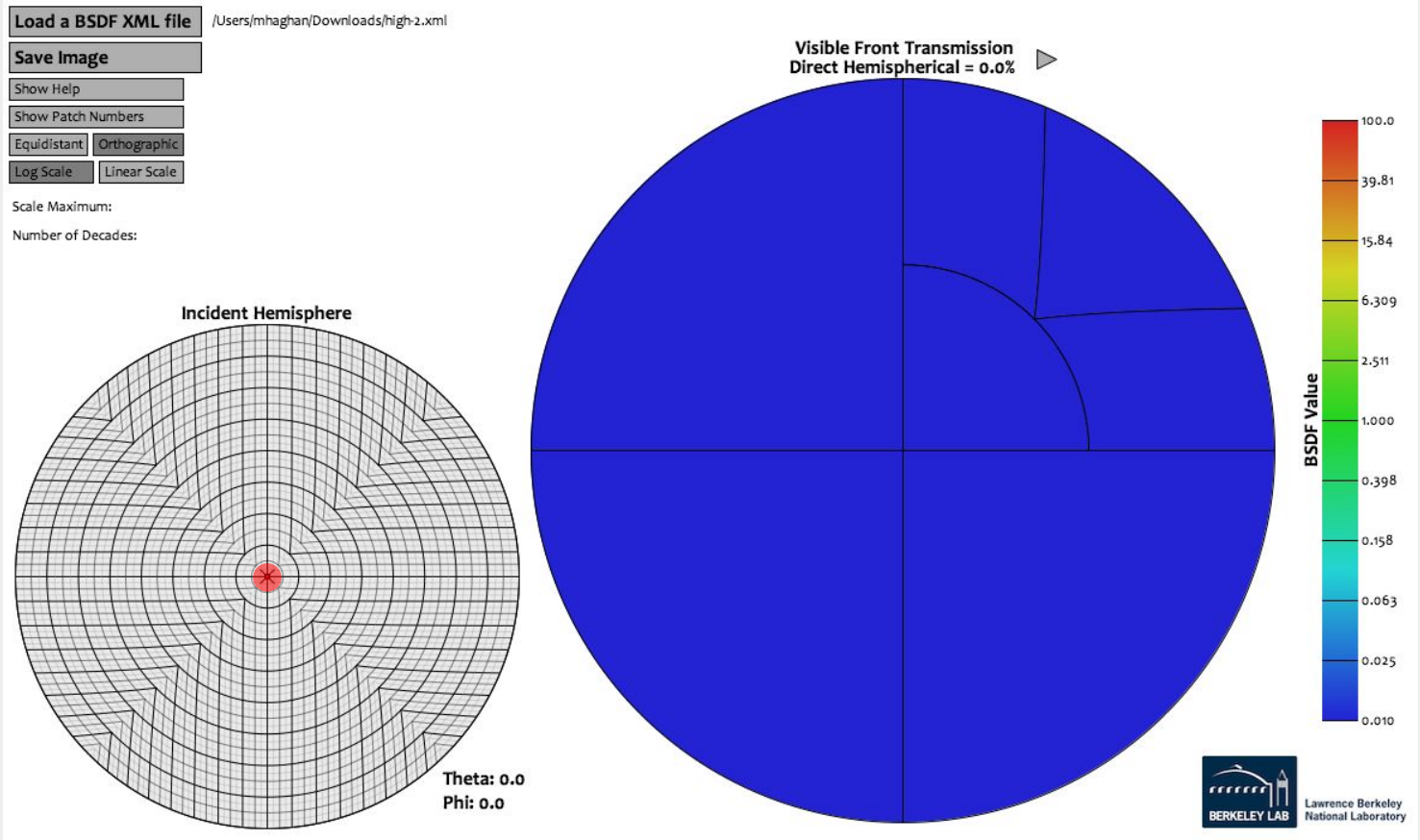
Incident Hemisphere
(corresponding patches to incident light)

Transmission Hemisphere
(corresponding patches to transmitted light)

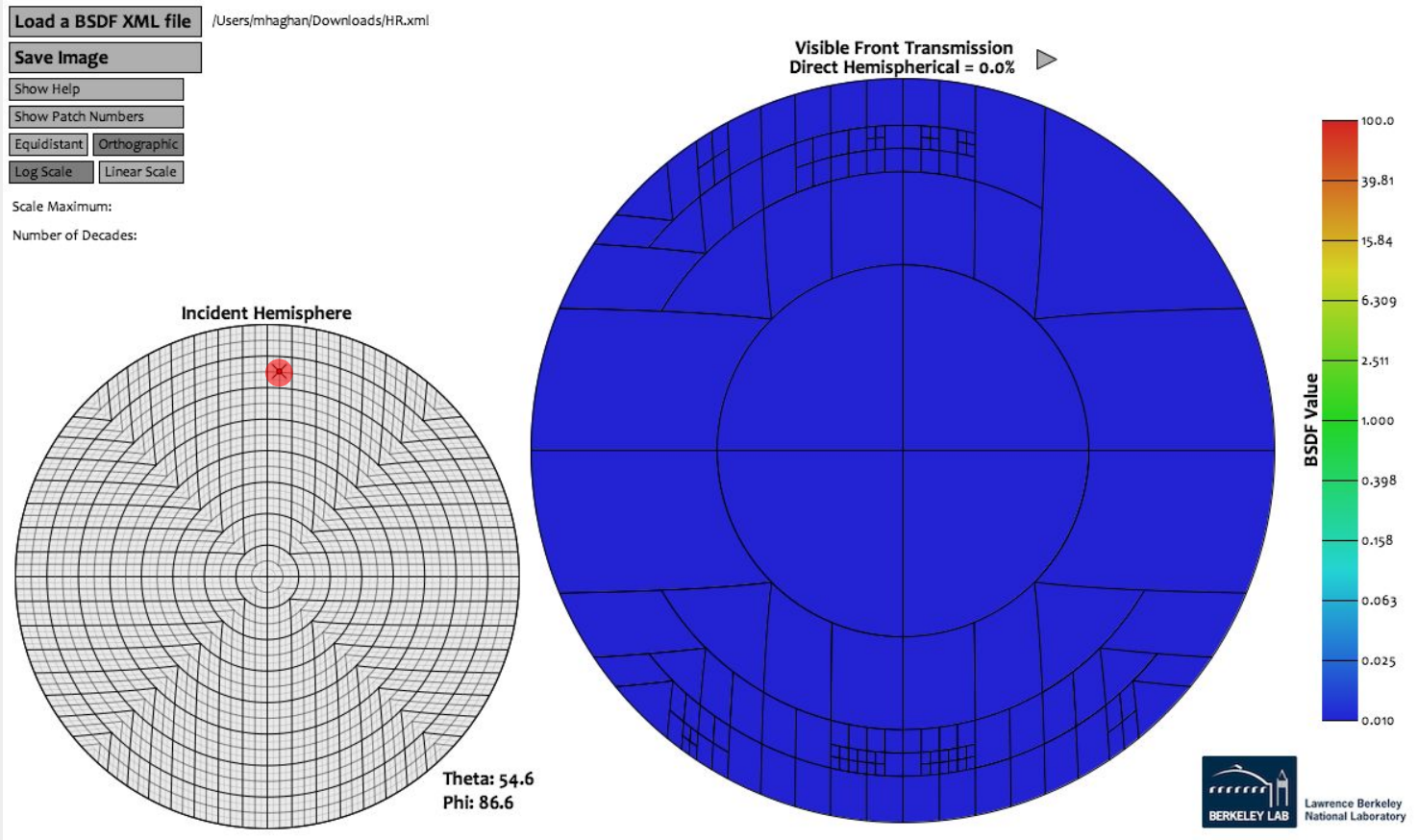


CHARACTERIZATION

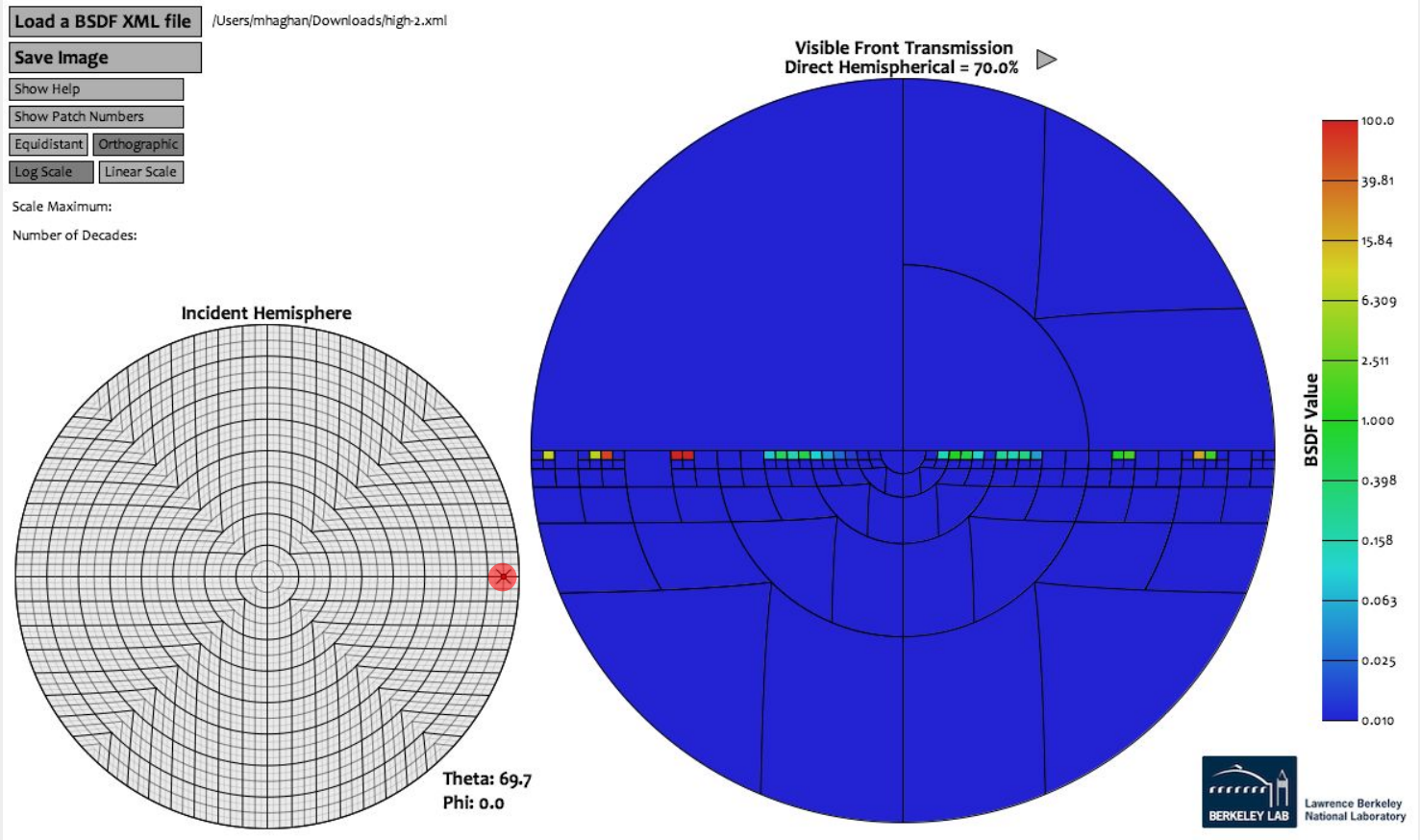
Transmission of prismatic element in different angles (genBSDF)



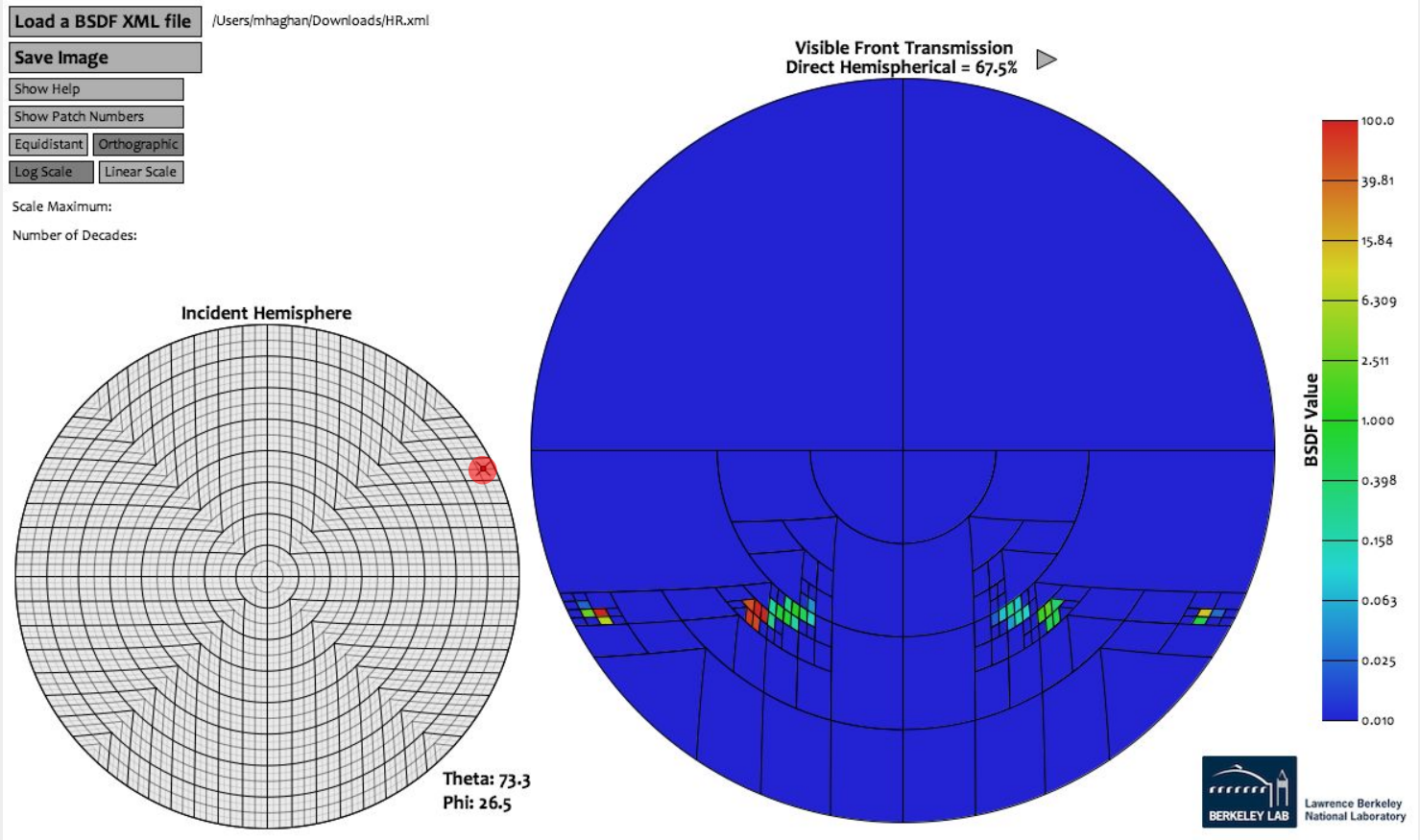
Transmission of prismatic element in different angles (genBSDF)



Transmission of prismatic element in different angles (genBSDF)

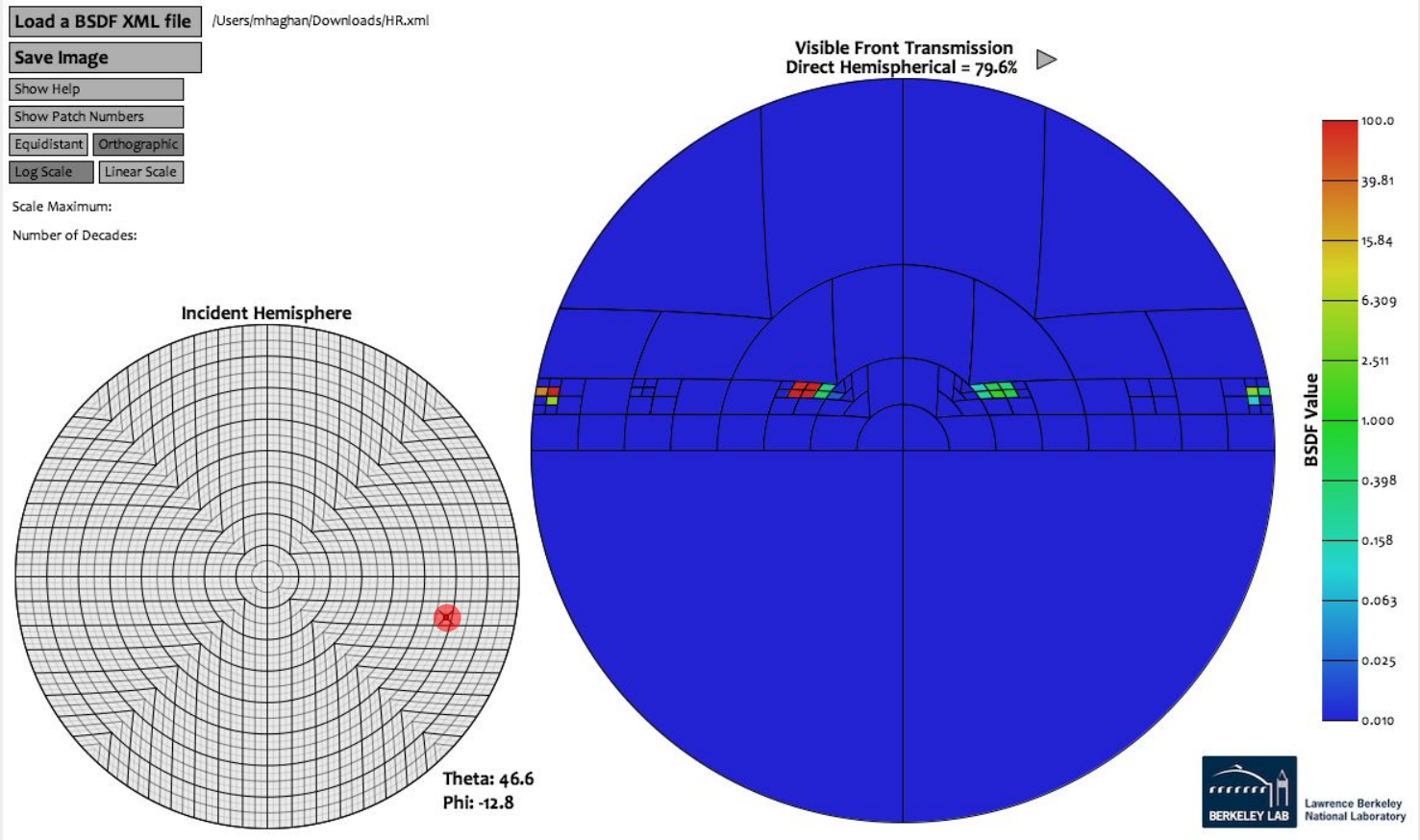


Transmission of prismatic element in different angles (genBSDF)

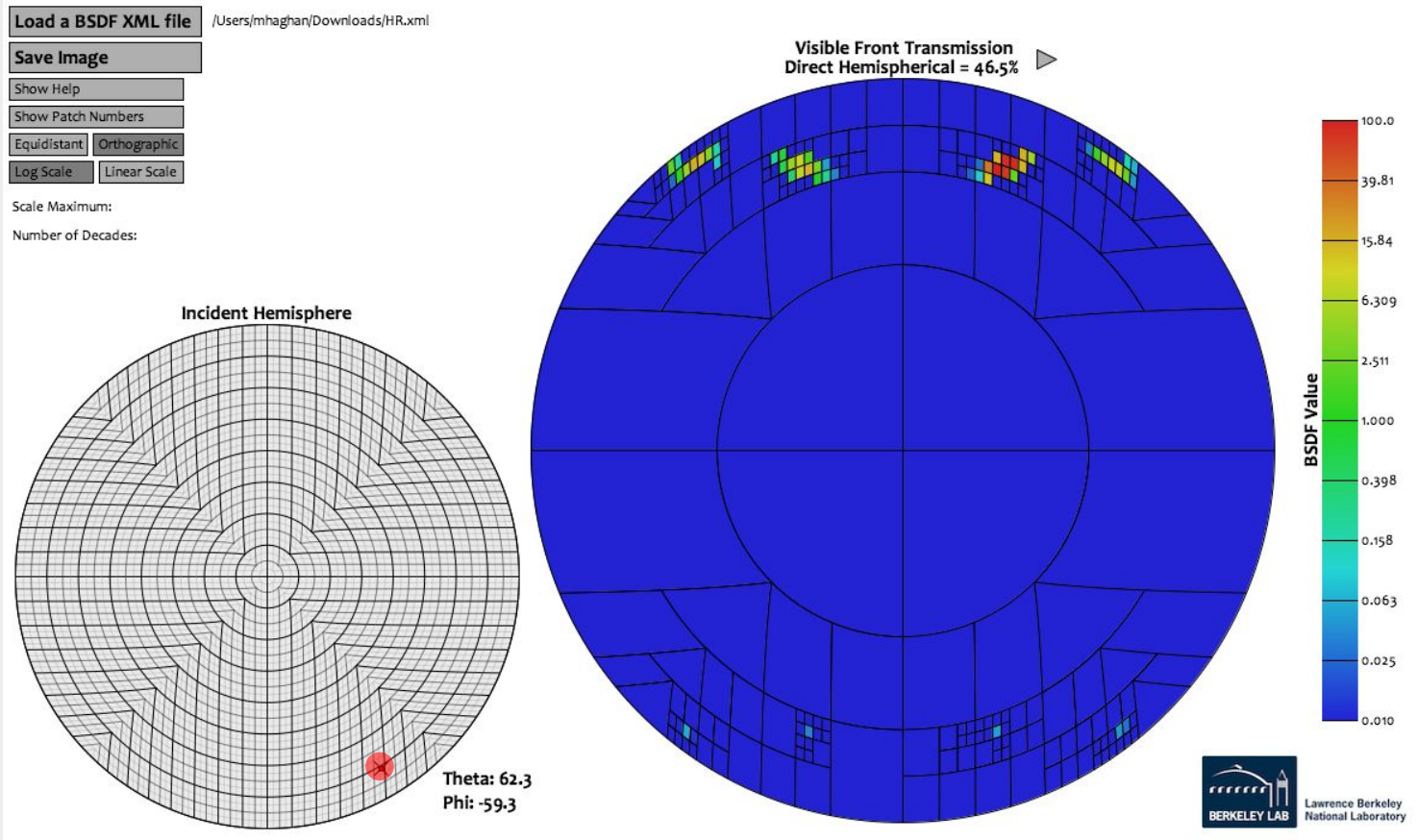


CHARACTERIZATION

Transmission of prismatic element in different angles (genBSDF)

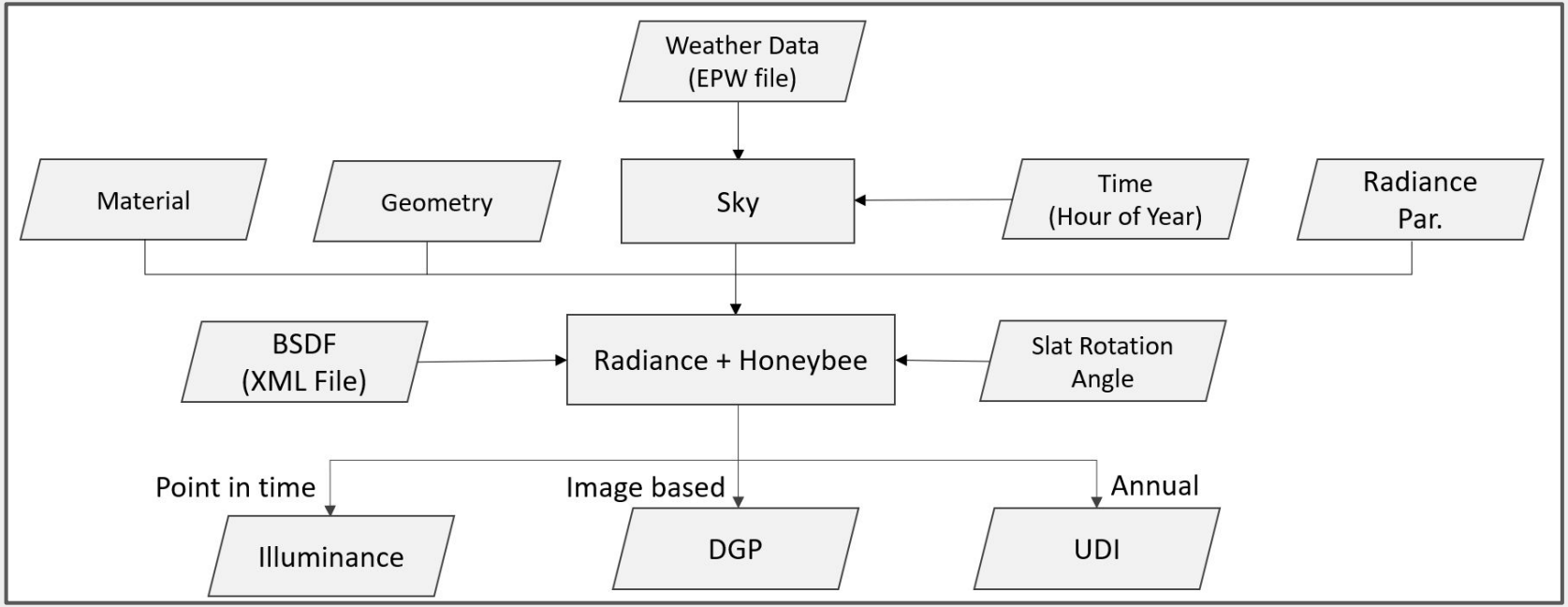


Transmission of prismatic element in different angles (genBSDF)

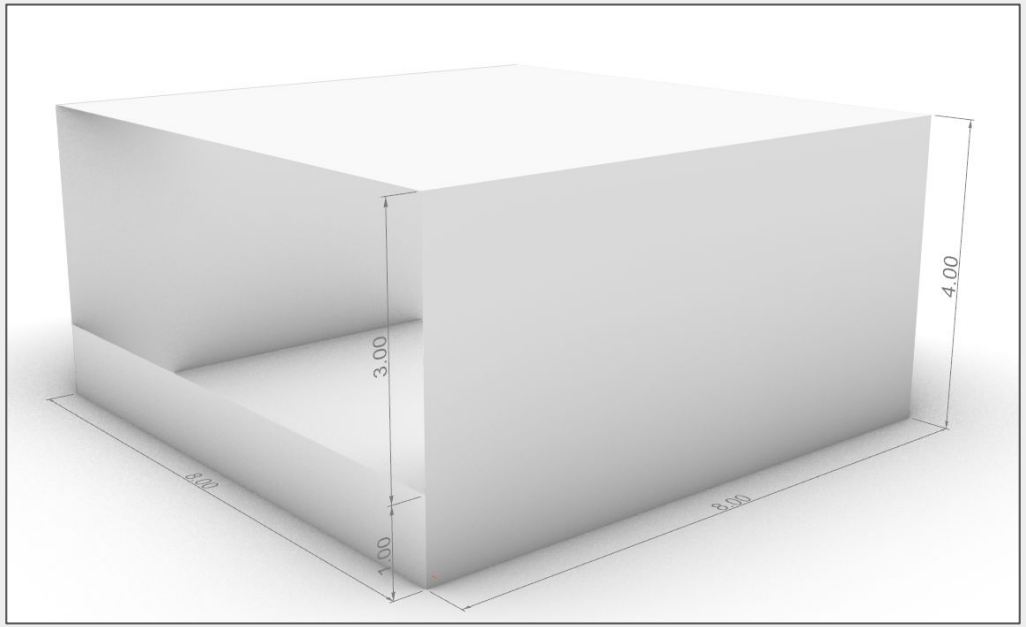


SIMULATION

SIMULATION


Weather Data
(EPW file)
Material
Geometry
Sky
Time
(Hour of Year)
Radiance
Par.
BSDF
(XML File)
Radiance + Honeybee
Slat Rotation
Angle
Point in time
Image based
Annual
Illuminance
DGP
UDI

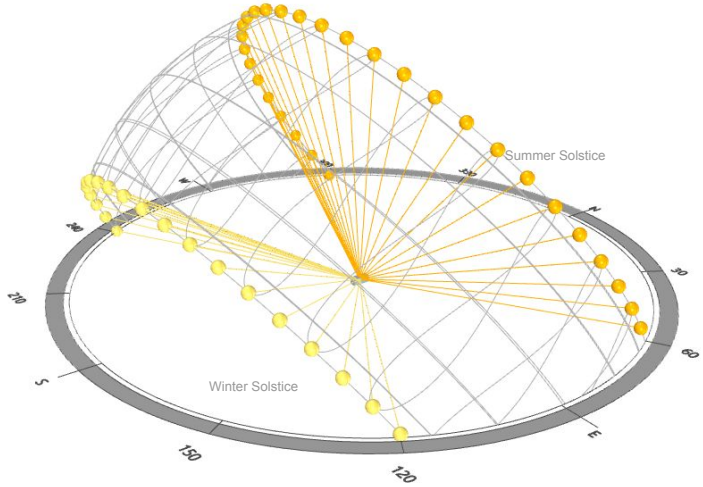
SIMULATION

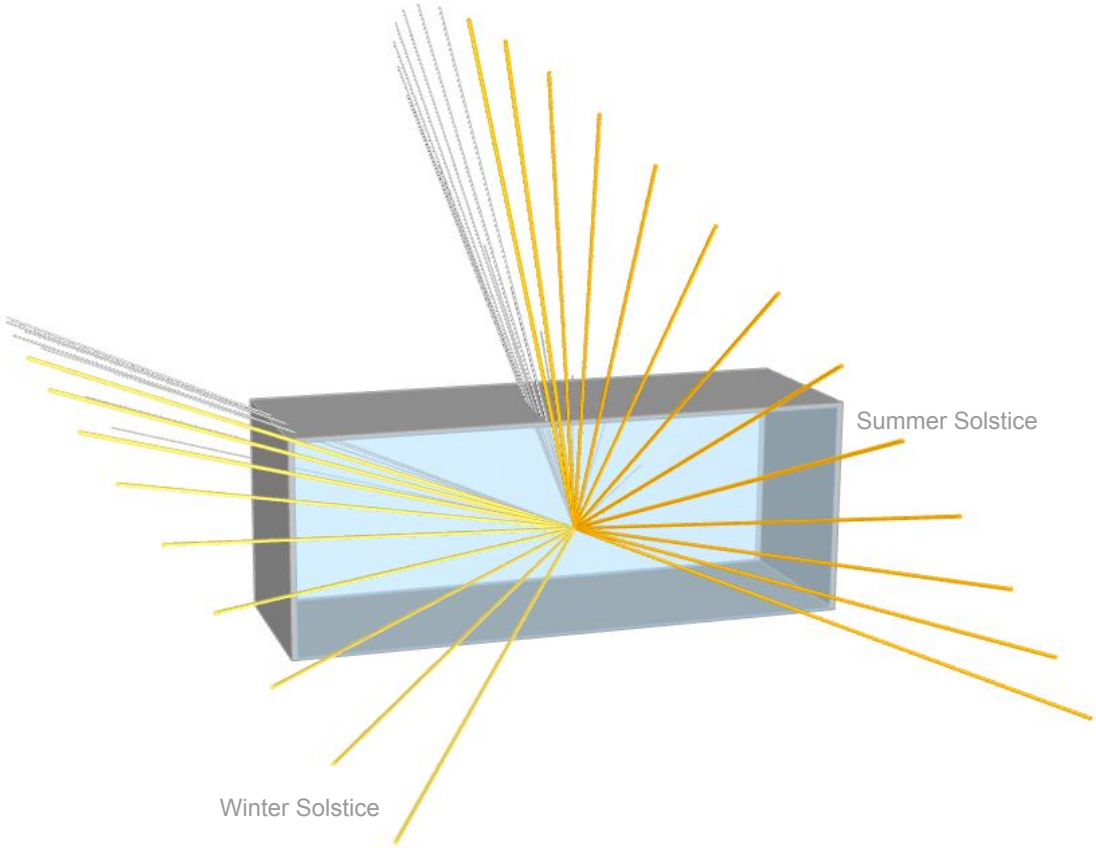


Width to depth ratio = 1:1
Width to height ratio = 2:1
Window to wall ratio = 75%

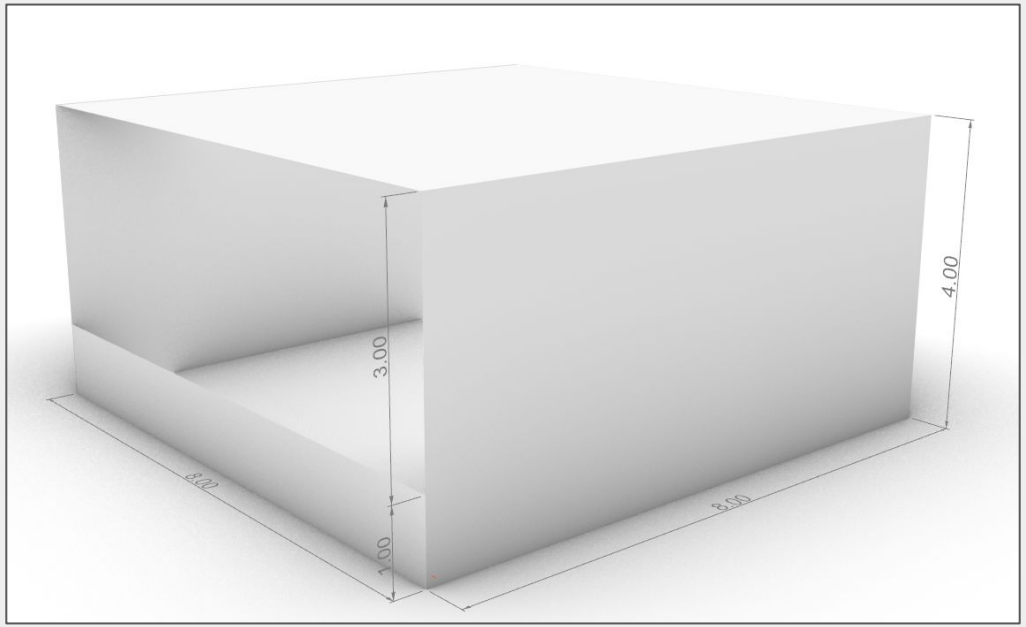
SIMULATION

Hourly Sun Angle in East Aperture





SIMULATION

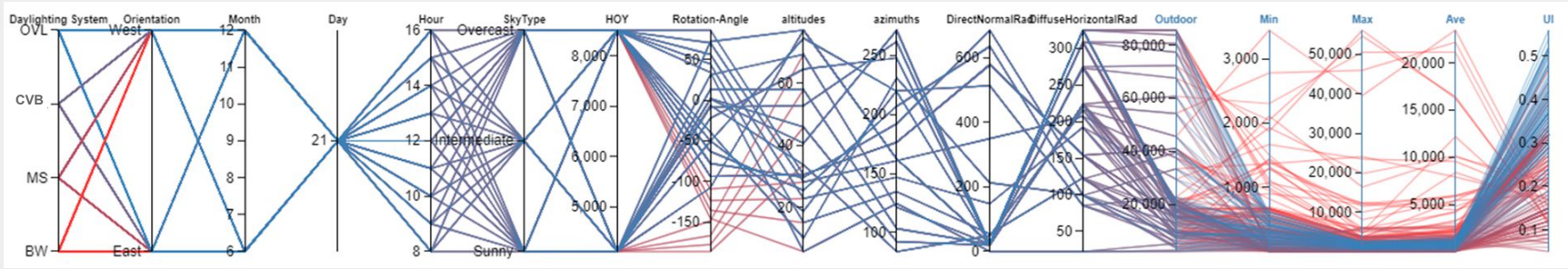


Bare Window	Mesh Shading	CVB	OVL

SIMULATION

Input variables (240 cases)

Output



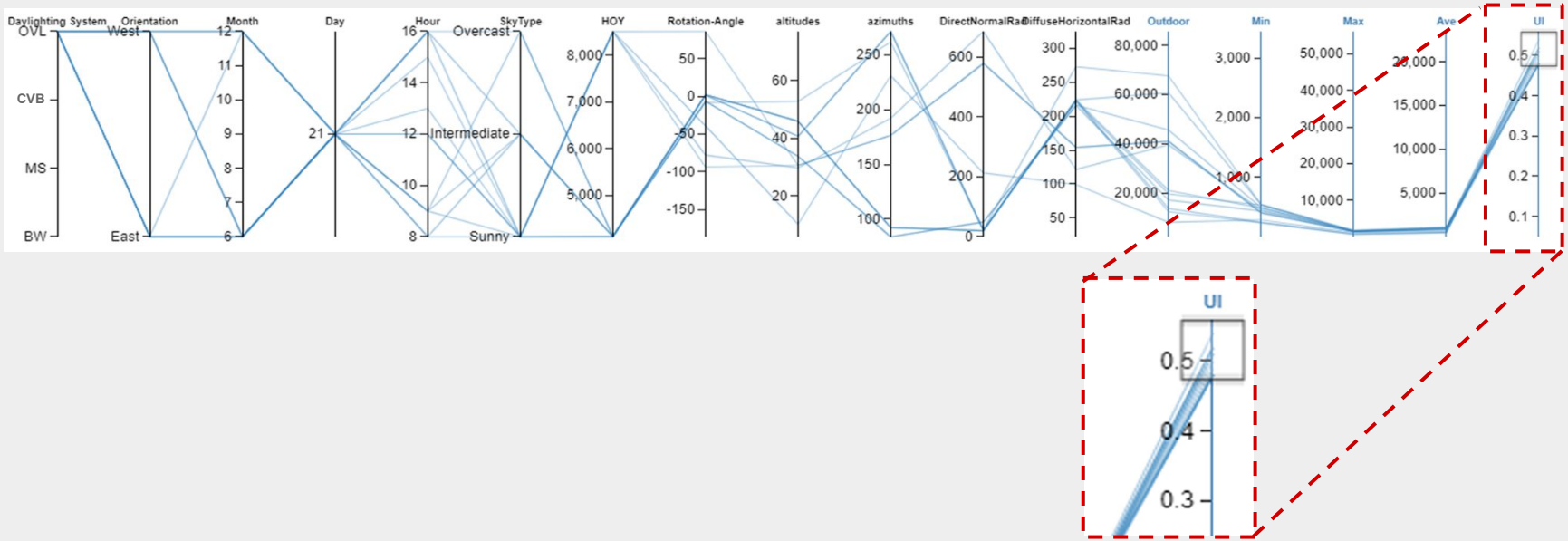
$$\textit{Uniformity Index (UI)}^{*} = \frac{\textit{Min Illuminance}}{\textit{Average Illuminance}}$$

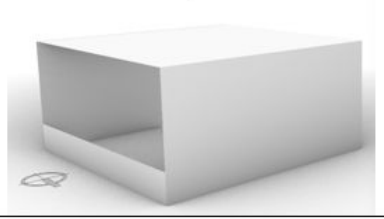
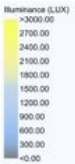
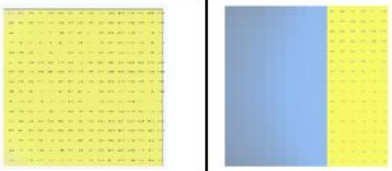
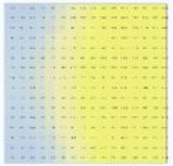
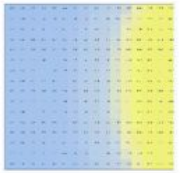
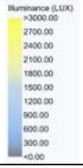
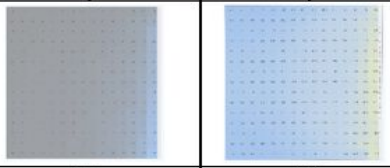
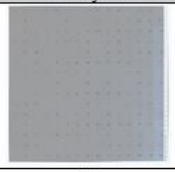
* Wagiman, K.R.; Abdullah, M.N.; Hassan, M.Y.; Radzi, N.H.M. A new metric for optimal visual comfort and energy efficiency of building lighting system considering daylight using multi-objective particle swarm optimization. J. Build. Eng., 2021, 43, 102525

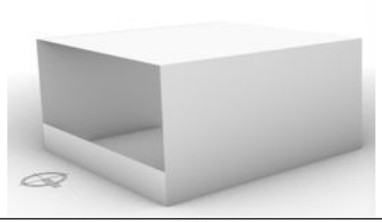
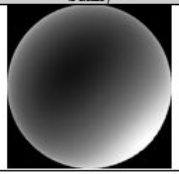
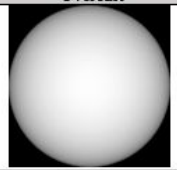
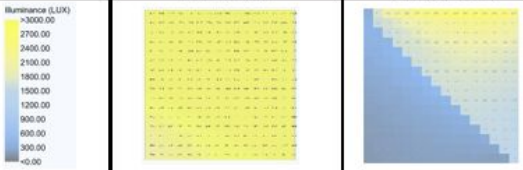
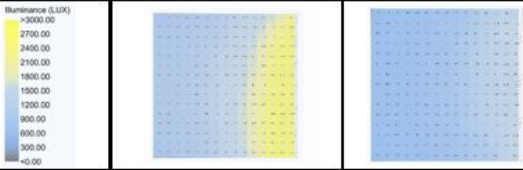
SIMULATION

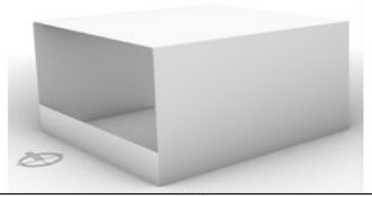
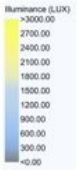
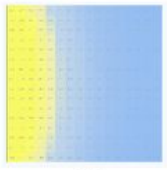
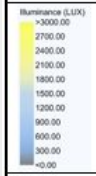
Input variables (240 cases)

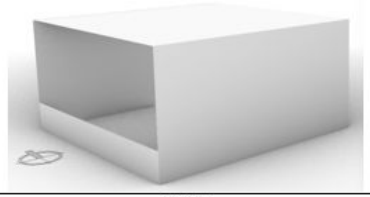
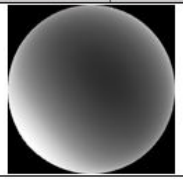
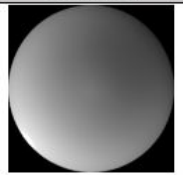
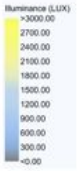
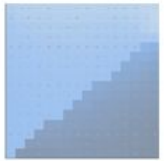
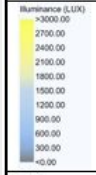
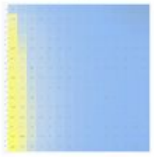
Output



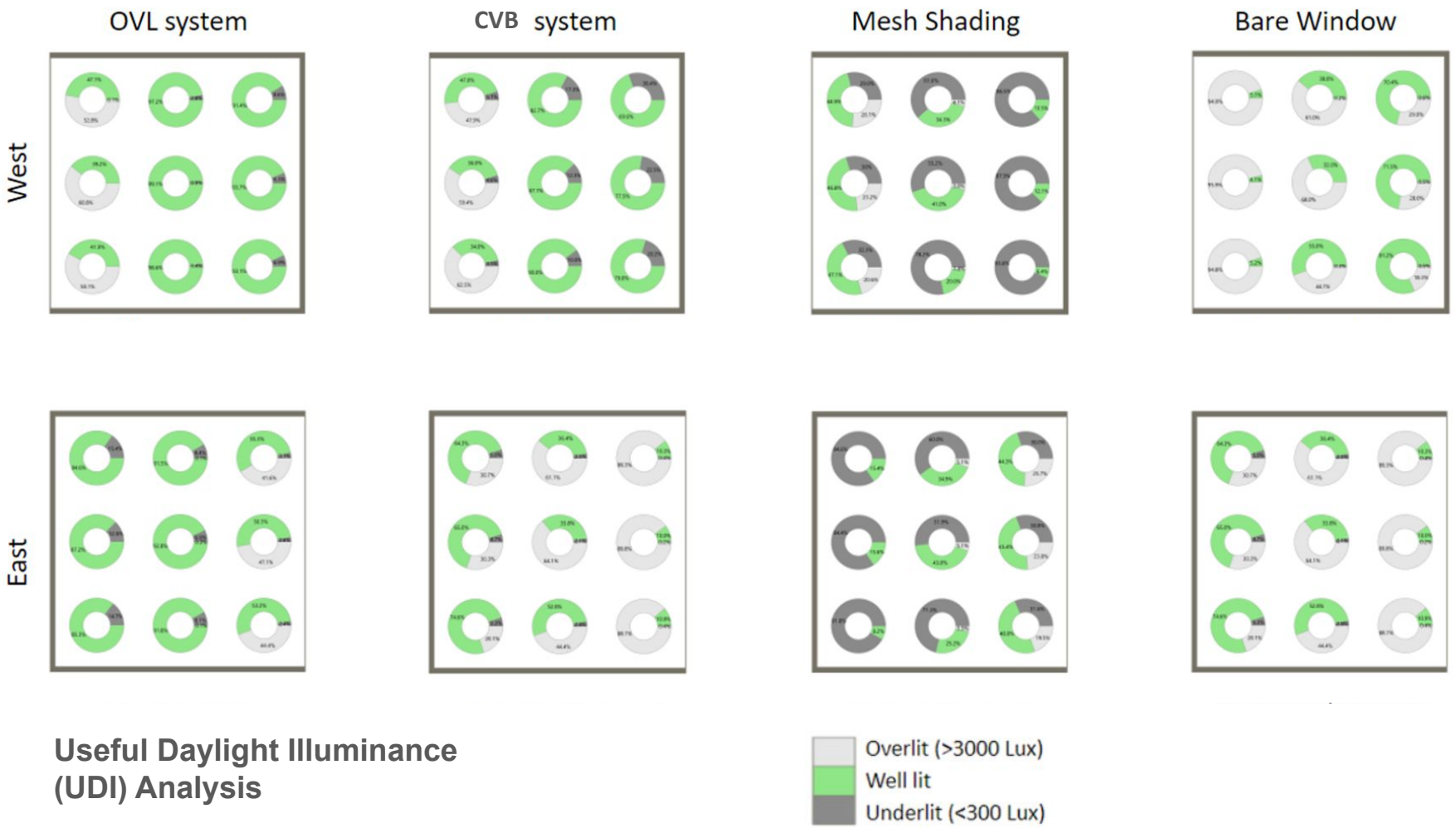
	East Aperture					
Geometry						
Altitude	45.94					
Azimuth	92.36					
Slat Rotation	-92.36°					
Sky Type	Sunny		Intermediate		Overcast	
Sky Pattern						
Outdoor illuminance	60706 Lux		20949 Lux		13599 Lux	
	Bare Window	Mesh Shading	Bare Window	Mesh Shading	Bare Window	Mesh Shading
						
Min	2302	166	1286	52	485	11
Average	21163.96	2429	5832.25	531	1559.07	80
UI	0.11	0.07	0.22	0.10	0.31	0.14
	CVB system	OVL system	CVB system	OVL system	CVB system	OVL system
						
Min	26	594	7	538	2	274
Average	83.04	1114.02	149	1016.52	74	521.65
UI	0.31	0.53	0.21	0.53	0.15	0.53

	East Aperture					
Geometry						
Altitude	15.2					
Azimuth	134.76					
Slat Rotation	-134.76°					
Sky Type	Sunny		Intermediate		Overcast	
Sky Pattern						
Outdoor illuminance	60670 Lux		20975 Lux		13622 Lux	
	Bare Window	Mesh Shading	Bare Window	Mesh Shading	Bare Window	Mesh Shading
						
Min	2108	177	621	37	192	3
Average	10024.5	1092	2342.5	214	605.23	30
UI	0.21	0.16	0.27	0.17	0.32	0.10
	CVB system	OVL system	CVB system	OVL system	CVB system	OVL system
						
Min	562	371	171	202	50	96
Average	1506.4	759.07	544.25	503.35	237.1	294.16
UI	0.37	0.49	0.31	0.40	0.21	0.33

Geometry	West Aperture					
						
Altitude	40.68					
Azimuth	271.48					
Slat Rotation	-91.48°					
Sky Type	Sunny		Intermediate		Overcast	
Sky Pattern						
Outdoor illuminance	54316 Lux		19587 Lux		12324 Lux	
	Bare Window	Mesh Shading	Bare Window	Mesh Shading	Bare Window	Mesh Shading
						
Min	2777	222	1385	50	456	10
Average	22198.1	2704	5972.45	578	1437.22	73
UI	0.13	0.08	0.23	0.09	0.32	0.14
	CVL	OVL	CVL	OVL	CVL	OVL
						
Min	14	619	4	530	1	235
Average	43.86	1100.82	16.42	979.45	5.68	450.06
UI	0.32	0.56	0.24	0.54	0.18	0.52

Geometry	West Aperture					
						
Altitude	10.22					
Azimuth	231.11					
Slat Rotation	-51.11°					
Sky Type	Sunny		Intermediate		Overcast	
Sky Pattern						
Outdoor illuminance	8072 Lux		4139 Lux		3465 Lux	
	Bare Window	Mesh Shading	Bare Window	Mesh Shading	Bare Window	Mesh Shading
						
Min	1445	126	399	22	127	3
Average	5417.56	611	1307.66	122	402.34	20
UI	0.27	0.21	0.31	0.18	0.32	0.15
	CVB system	OVL system	CVB system	OVL system	CVB system	OVL system
						
Min	309	282	83	125	30	66
Average	862.54	581.81	292.93	301.37	139.59	182.42
UI	0.36	0.48	0.28	0.41	0.21	0.36

SIMULATION

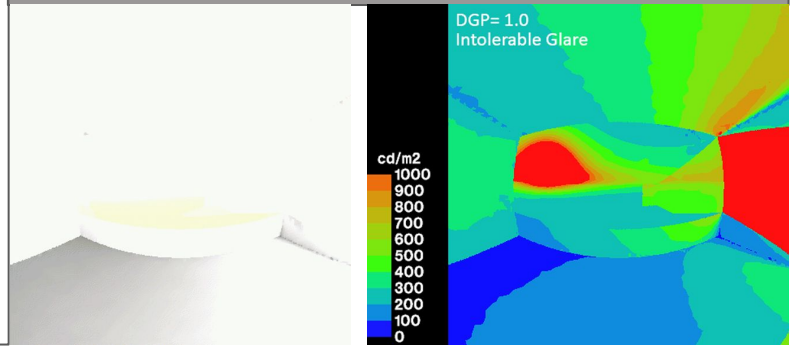


Useful Daylight Illuminance (UDI) Analysis

SIMULATION

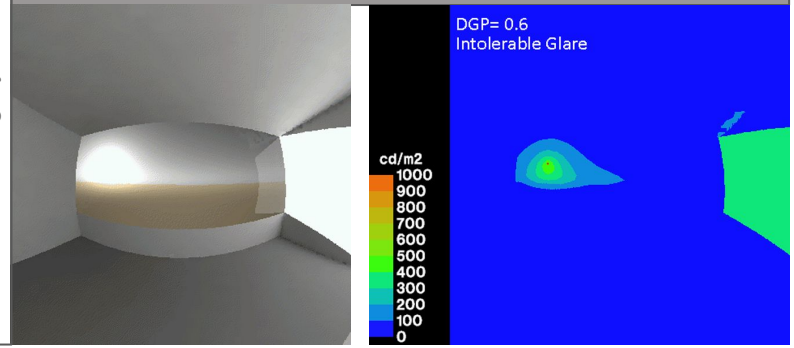
Bare Window

DGP = 1.0, Intolerable Glare



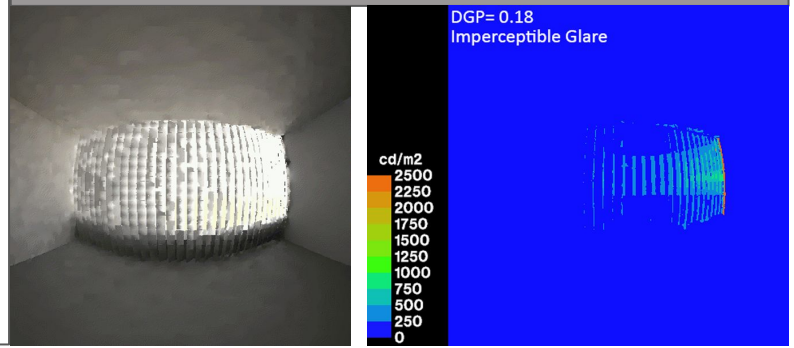
Mesh Shading System

DGP = 0.6, Intolerable Glare



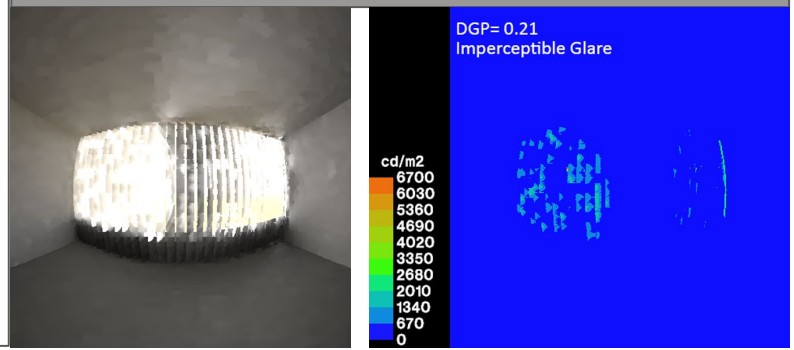
CVB System

DGP = 0.18, Imperceptible Glare



OVL System

DGP = 0.21, Imperceptible Glare



Daylight Glare Probability (DGP) analysis;

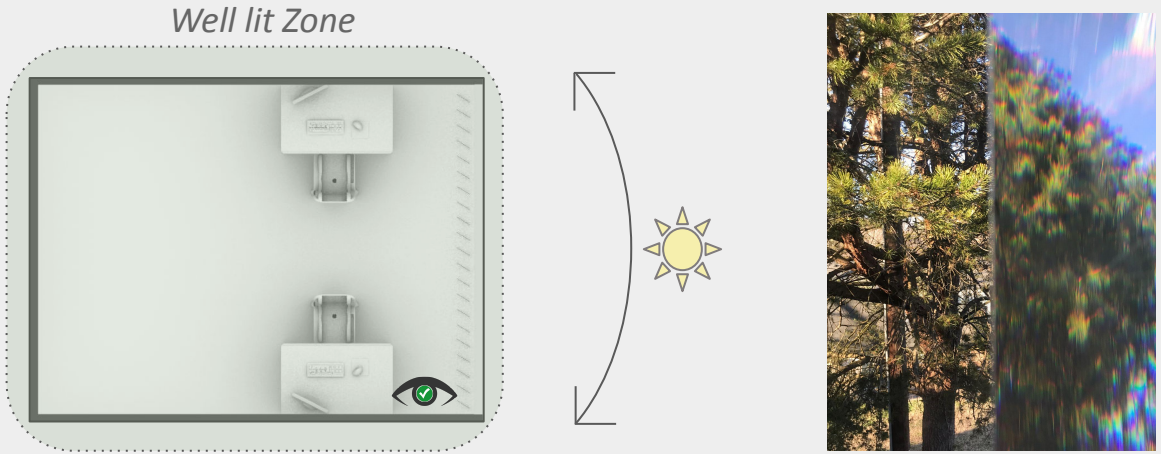
December 21, 4 PM

- DGP<0.35, Imperceptible Glare
- 0.35<DGP<0.40, Perceptible Glare
- 0.4<DGP<0.45, Disturbing Glare
- DGP>0.45, Intolerable Glare

SIMULATION

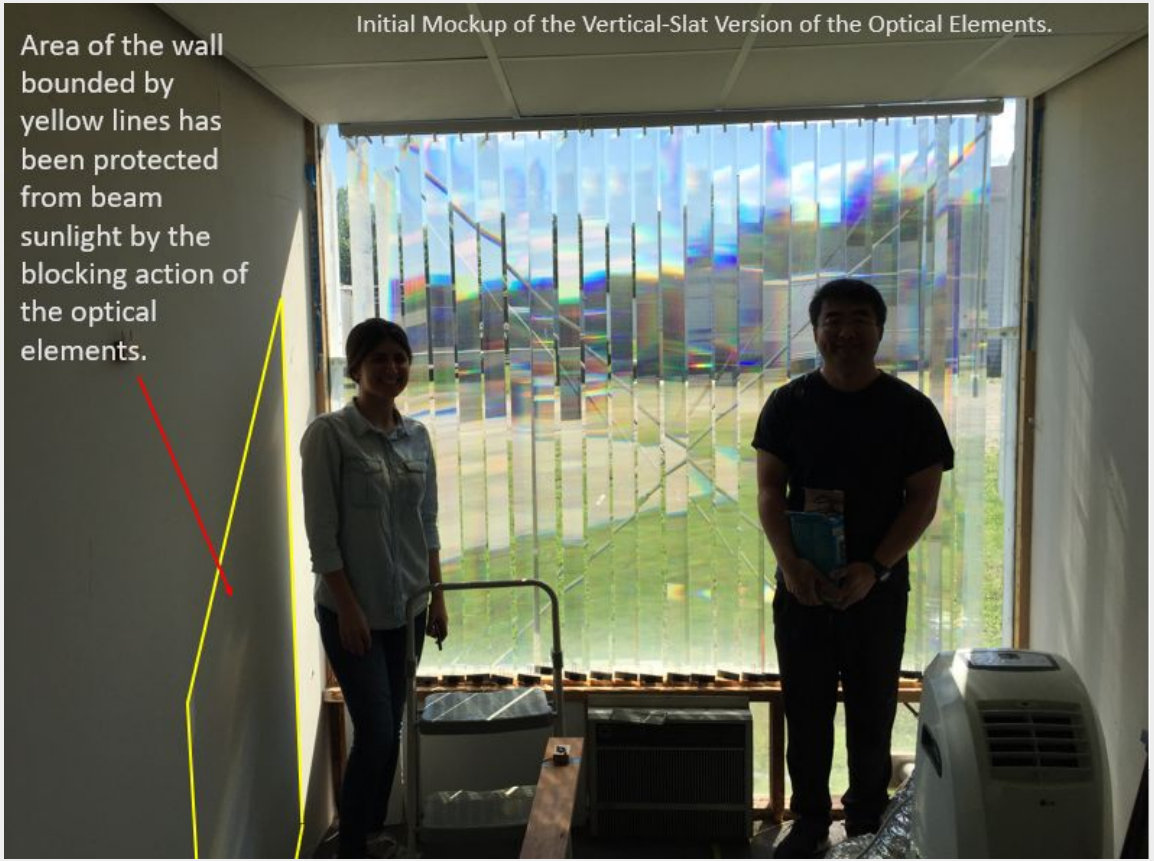
Optical Vertical Louver (OVL)

- Improve indoor daylight availability
- Improve visual comfort and connection to the outside environment



Initial Mockup of the Vertical-Slat Version of the Optical Elements.

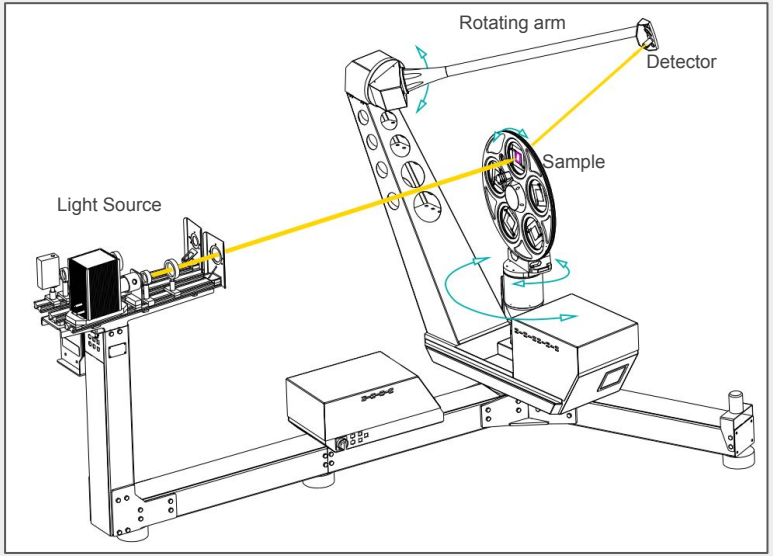
Area of the wall bounded by yellow lines has been protected from beam sunlight by the blocking action of the optical elements.



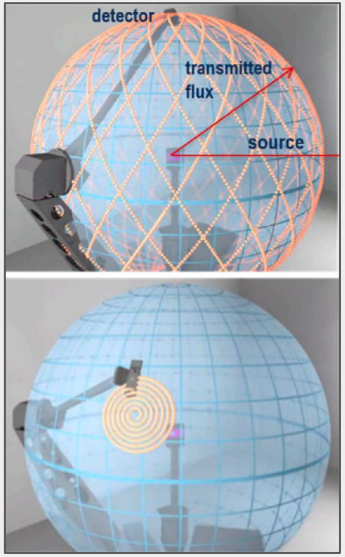
FURTHER STUDIES

FURTHER STUDY

- To conduct the annual glare probability analysis for different systems
- To validate the simulation result of BSDF data with Goniophotometer analysis
- To validate the daylight simulation result with experimental evaluation in a built environment
- To evaluate human visual experience in three different environments outfitted with different daylighting systems

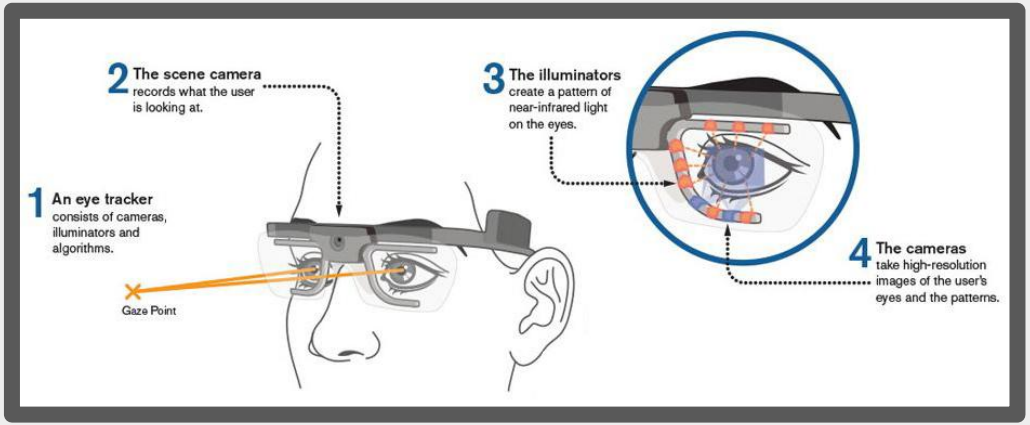


Path of the full hemispherical scan

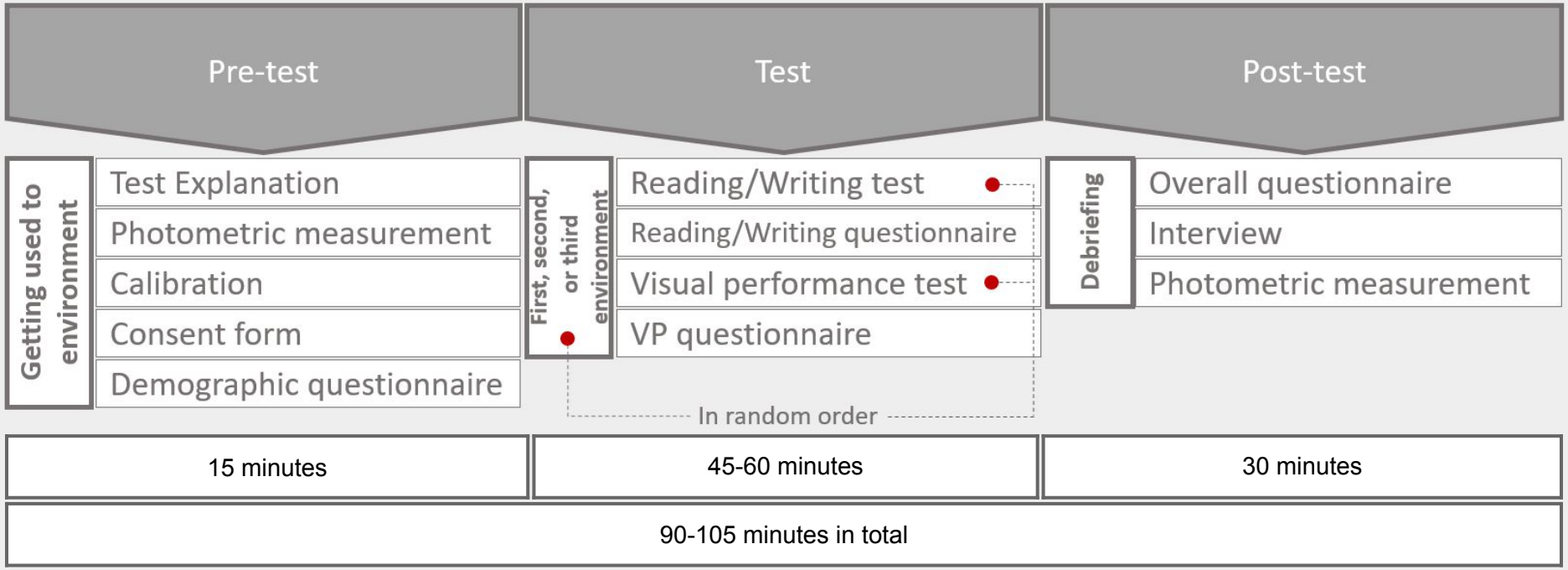


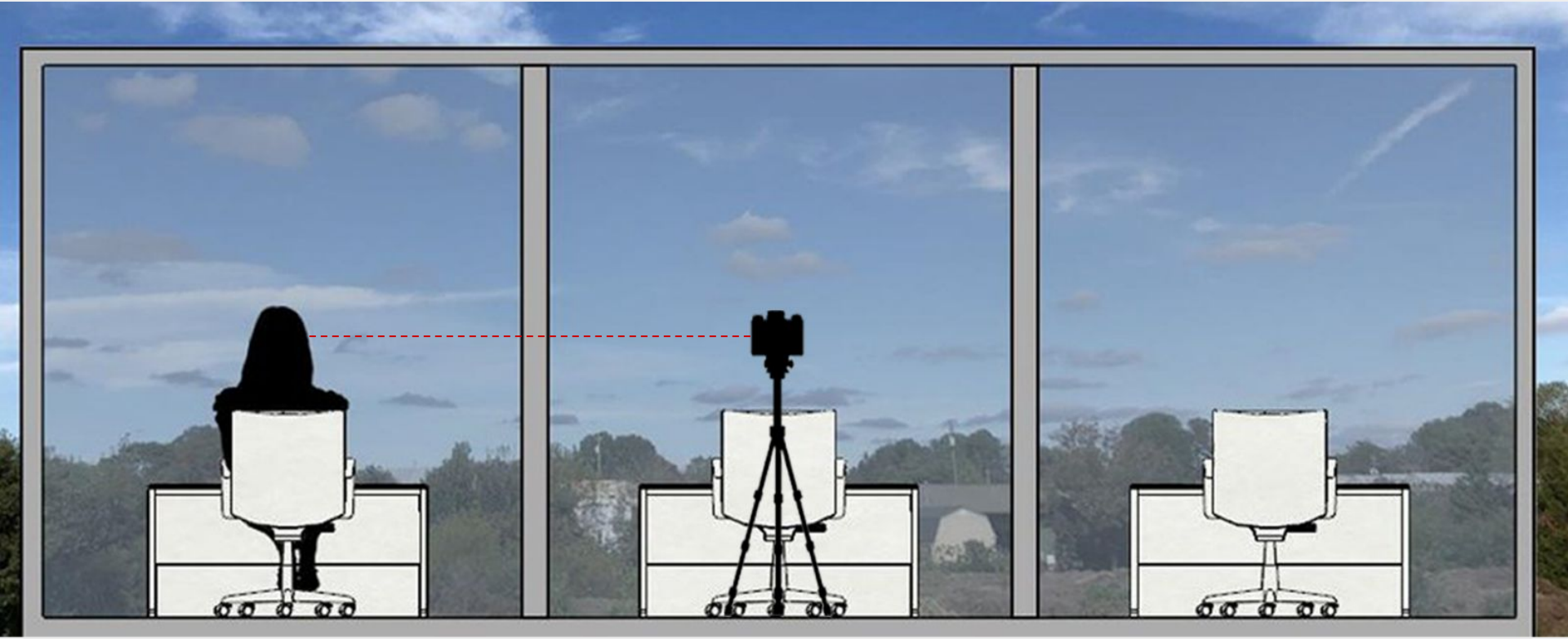
detailed spiral or square scan of a peak region

24 Participants



To ask participants for their response of different questions regarding their visual comfort, and perception in terms of interior daylight.


Pre-test
Test
Post-test
Getting used to environment
Test Explanation
Photometric measurement
Calibration
Consent form
Demographic questionnaire
First, second, or third environment
Reading/Writing test
Reading/Writing questionnaire
Visual performance test
VP questionnaire
In random order
Debriefing
Overall questionnaire
Interview
Photometric measurement
15 minutes
45-60 minutes
30 minutes
90-105 minutes in total



OVL outfitted

CVB outfitted

Mesh Shading outfitted

Questions/Comments!

Thank YOU!

Masoome Haghani
mhaghan@ncsu.edu