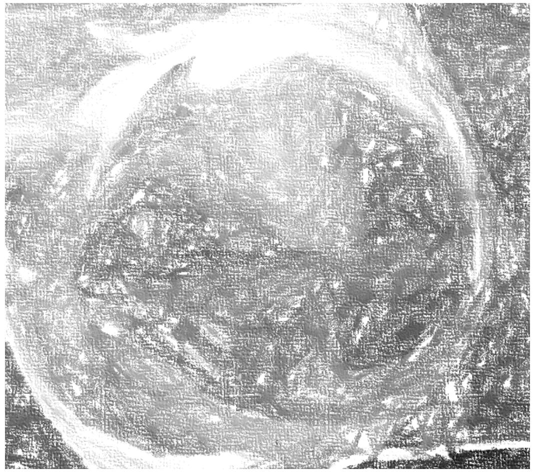
Developing An Efficient Solar Tube For Clear Sky Conditions Using Radiance Five Phase Method



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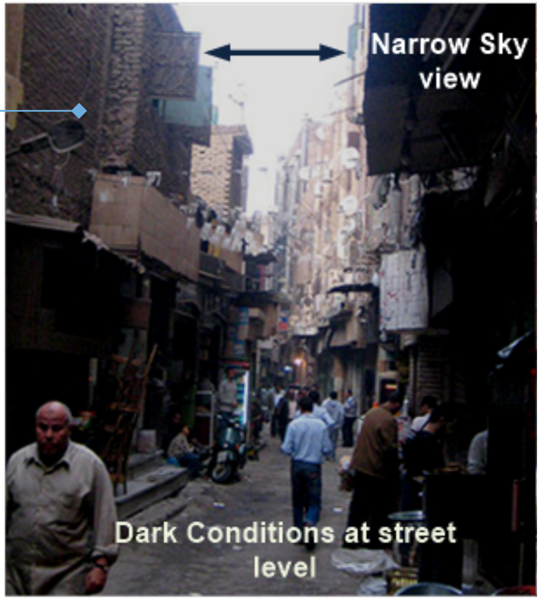
THE AMERICAN UNIVERSITY IN CAIRO

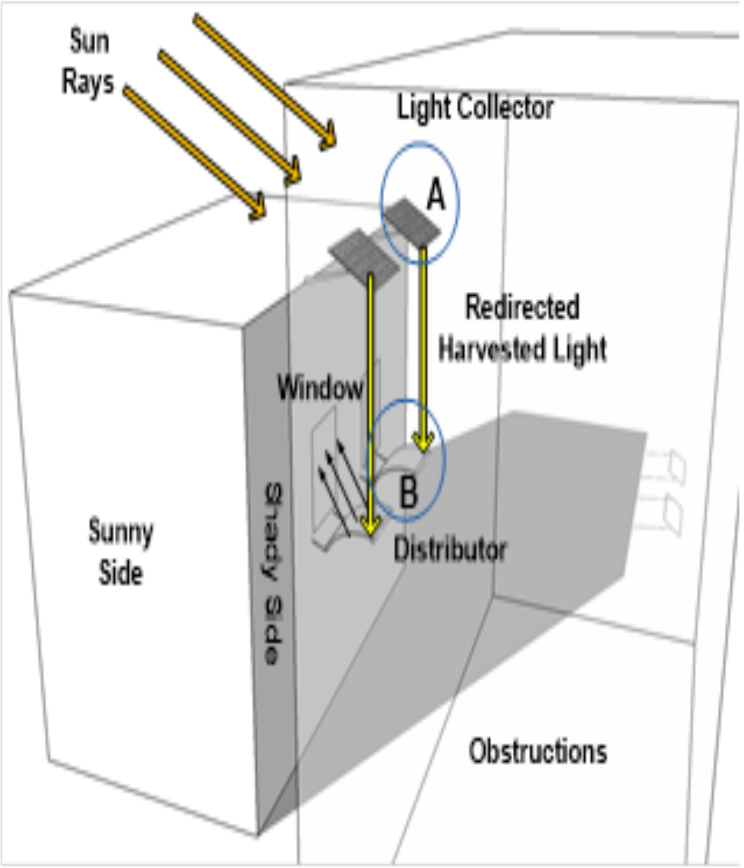
CONTENTS

PREVIOUS RESEARCH

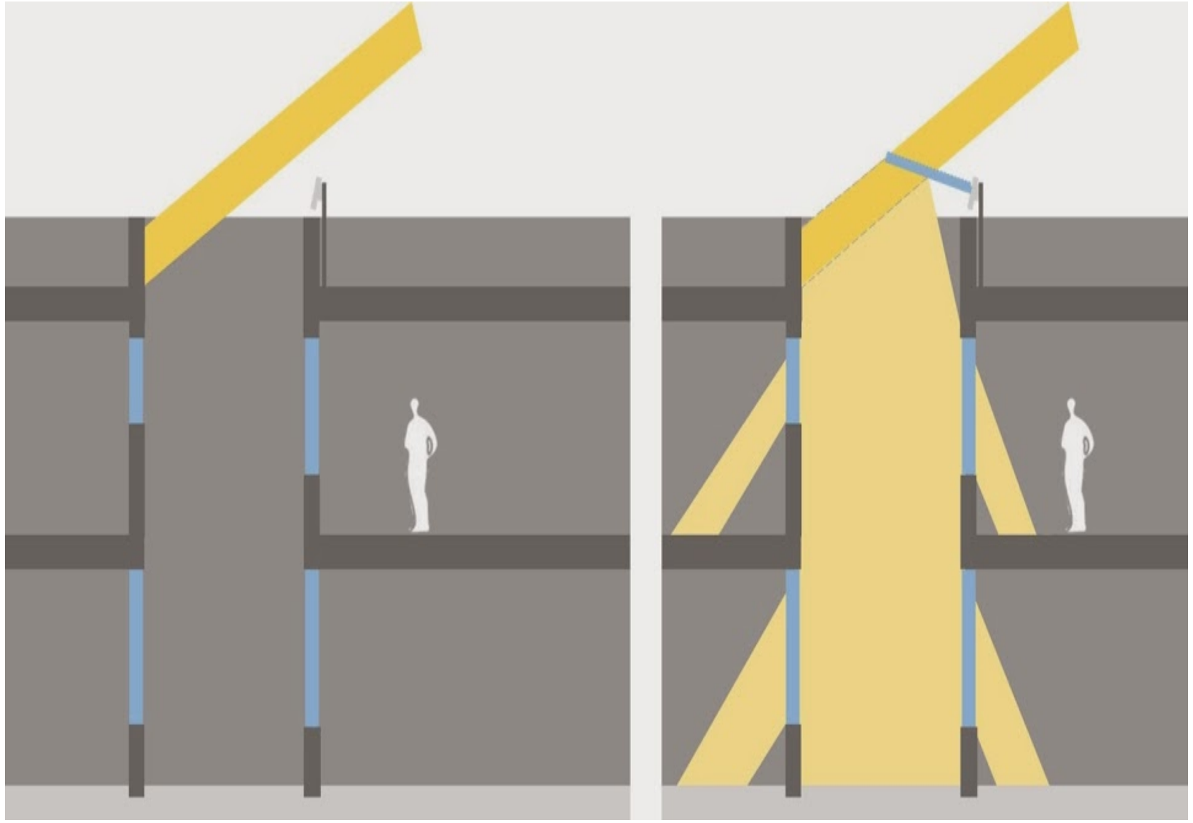
Unpainted Surfaces, low reflectivity



PREVIOUS RESEARCH



PREVIOUS RESEARCH



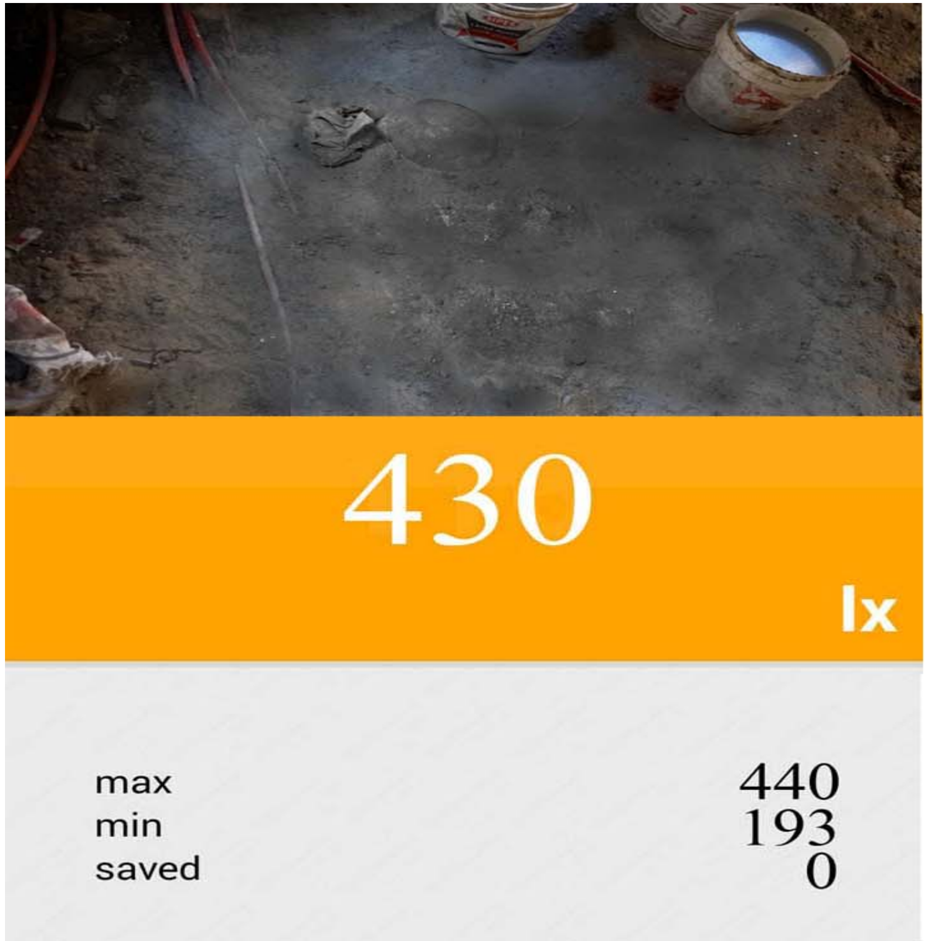
PREVIOUS RESEARCH

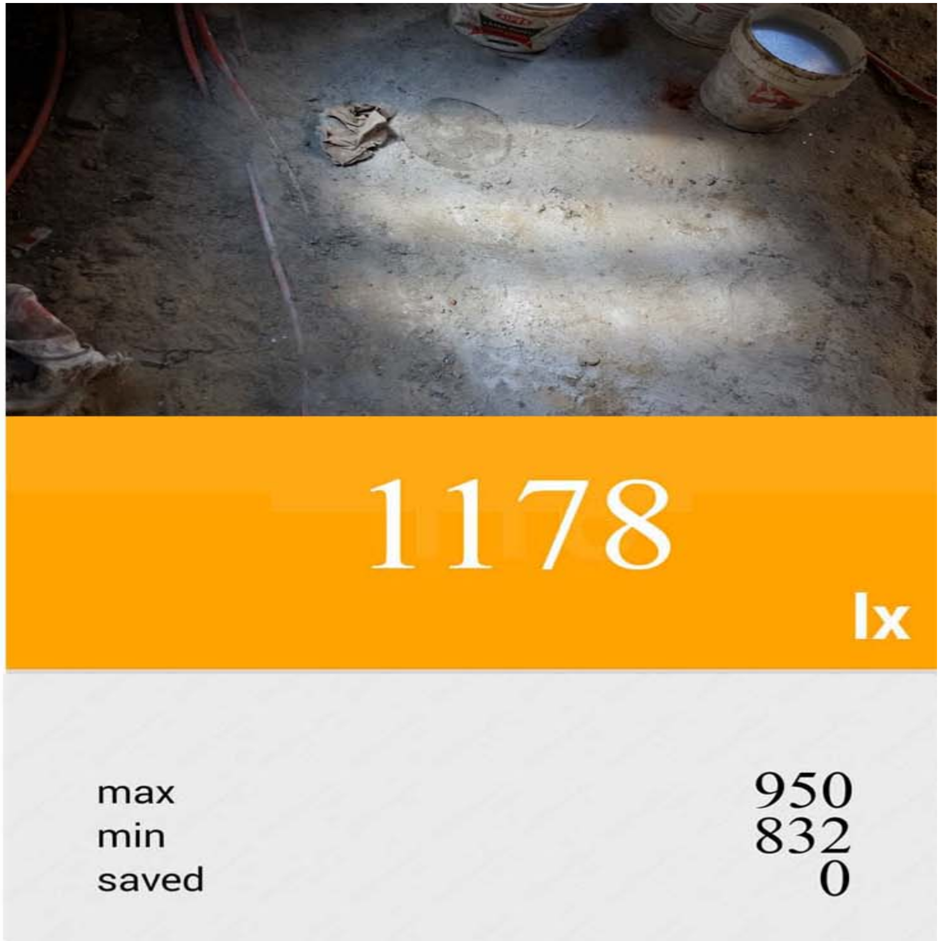
A PPMA panel shaped to transport the light down the light wells and then possibly into the adjacent rooms

The panel was designed using TracePro and Radiance was used to simulate the daylighting performance of the panel

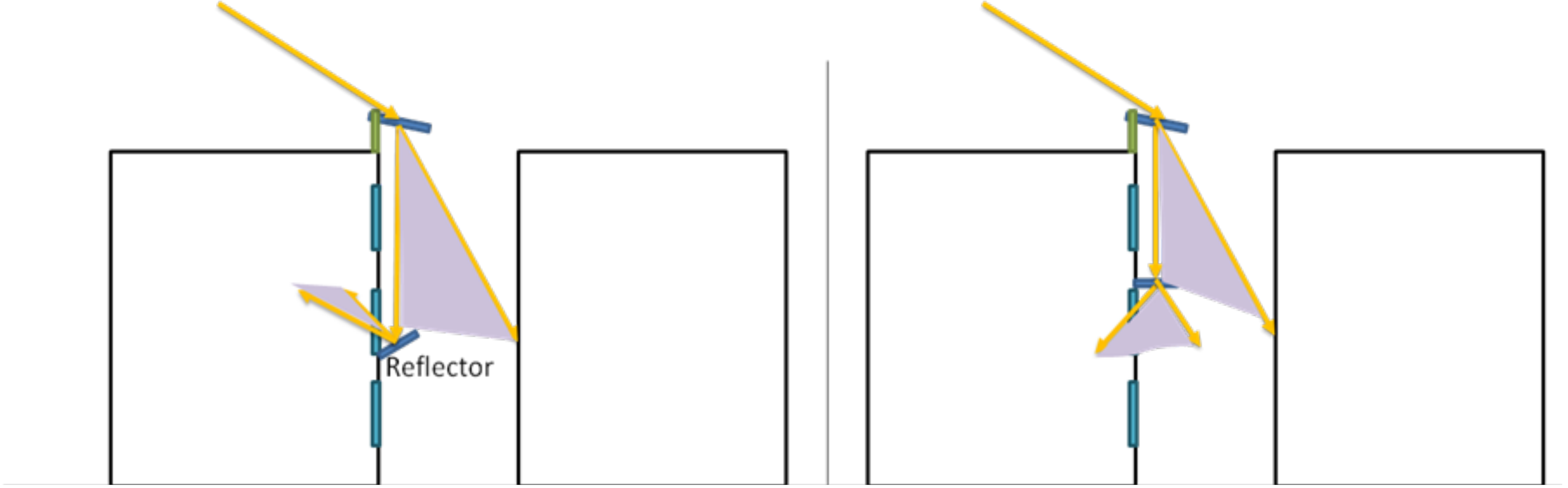
A full scale model was manufactured and real life data was compared to simulated Radiance data

PREVIOUS RESEARCH





PREVIOUS RESEARCH



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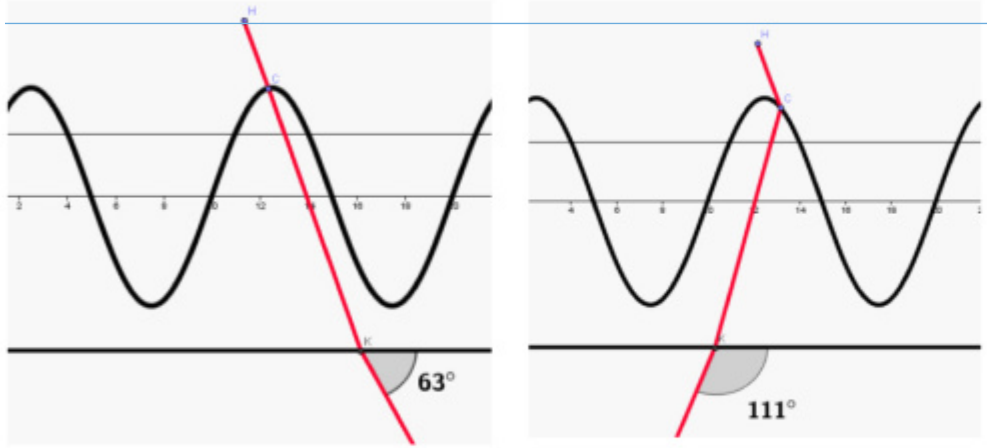
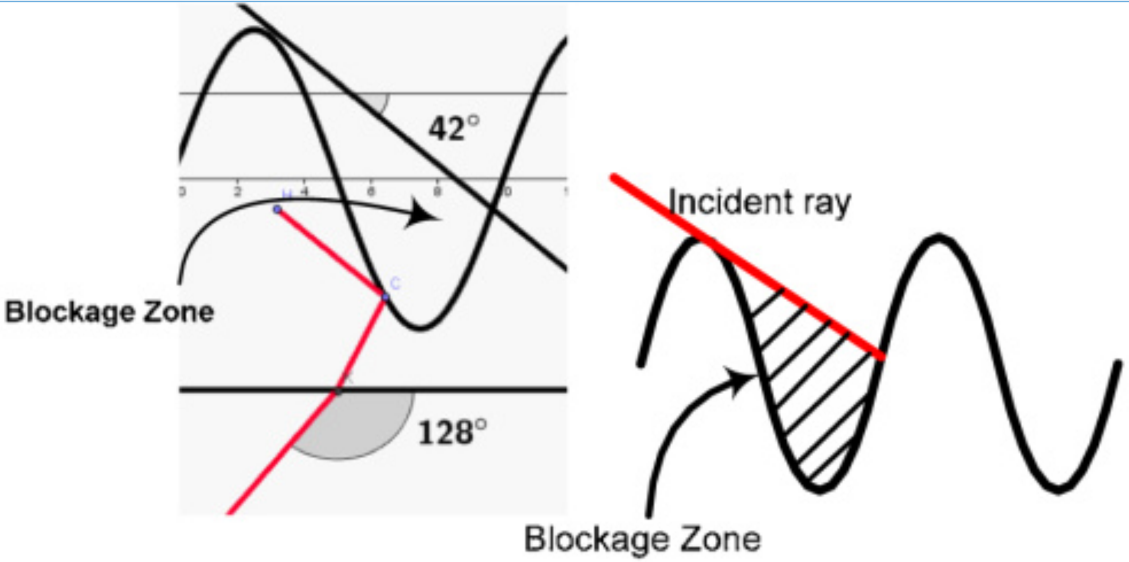
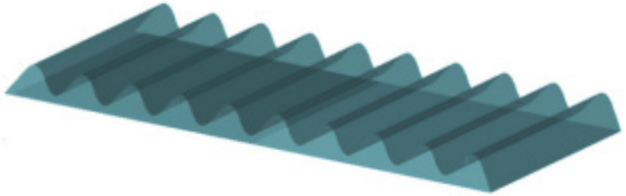






Ratio= a:p
p=period
a=amplitude

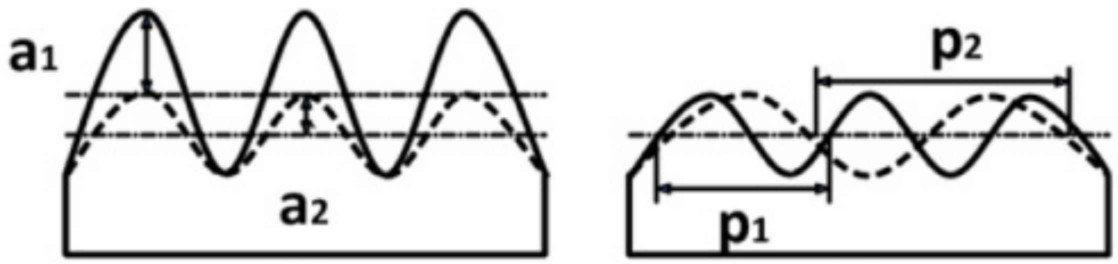
We developed a panel shaped as a sinwave that redirects the light downwards

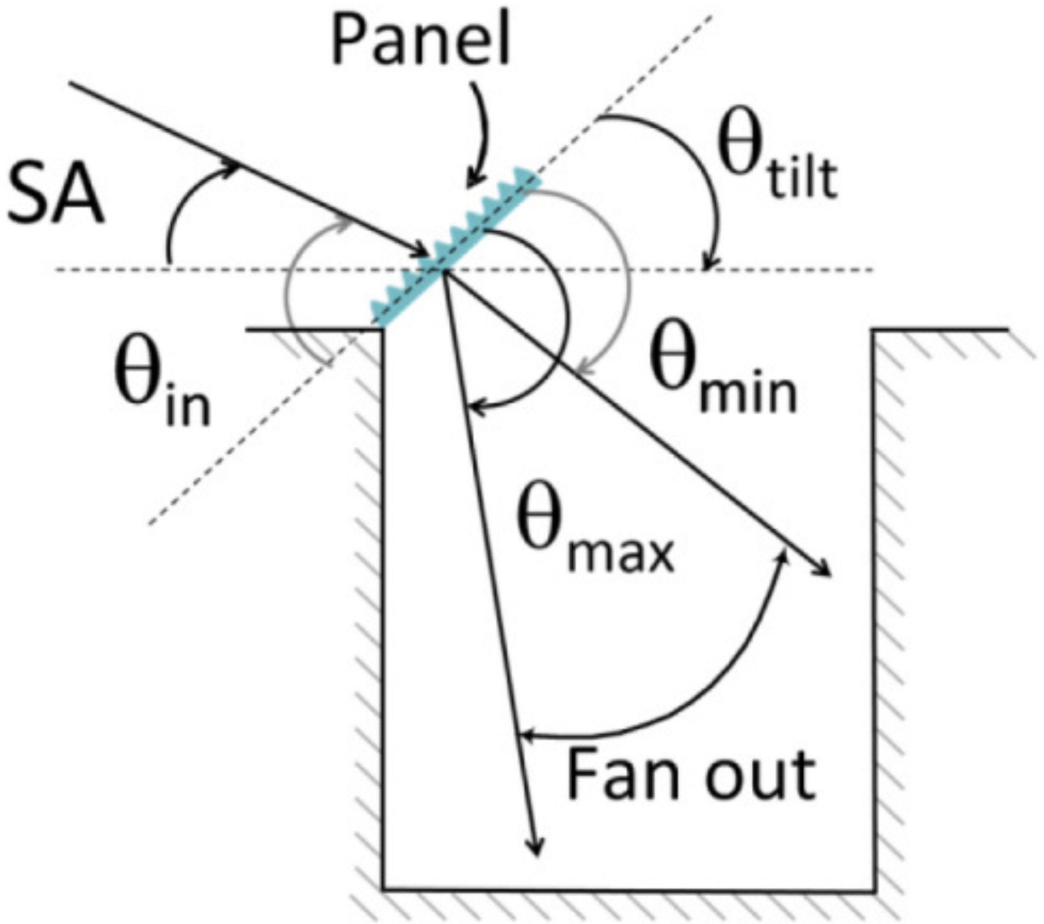
The sinwave performs better than a traditional prismatic pattern but still has an occluded zone

PREVIOUS RESEARCH

By varying the amplitude and wavelength we can change the performance of the panel

We need to control the amount of light redirected (Watts) as well as the “fanout” angle





SOLAR TUBES

A school project utilizing solar tube and LED

School hours in the morning only

All lighting load covered by PV

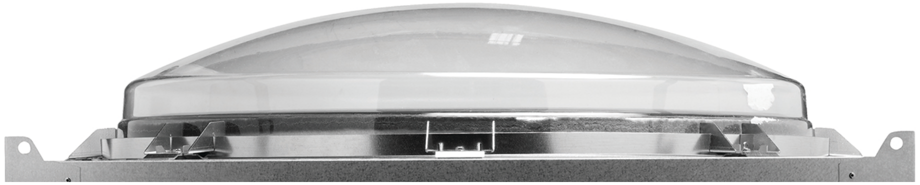
Generated new idea about the shape of the solar tube

SOLAR TUBES

Pointed Dome

Multi-tiered
Dome

Tend to be larger in dimensions and shape due to size and manufacturing limitations rather than light performance



Hemi-spherical or
Flat Dome

We could find three main shapes for solar tubes prevalent in the market

Some are clear but most are prismatic

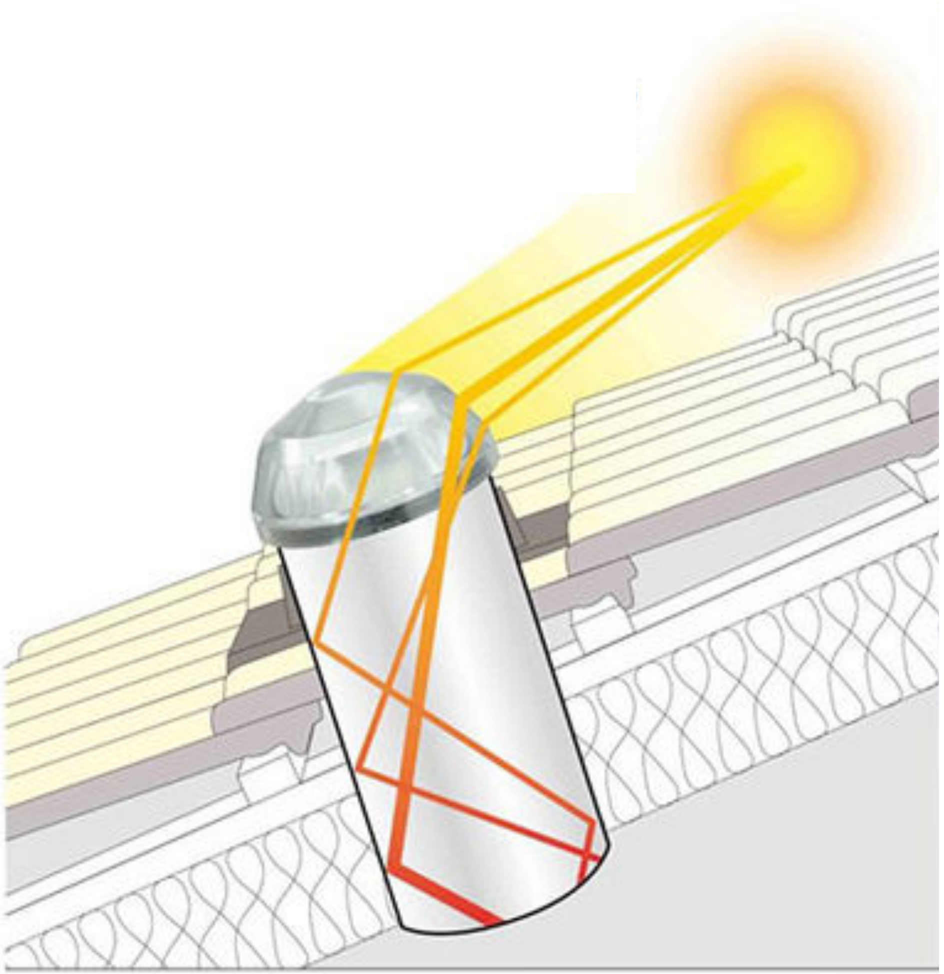
Most common is the Multi-tiered Dome and largest market share

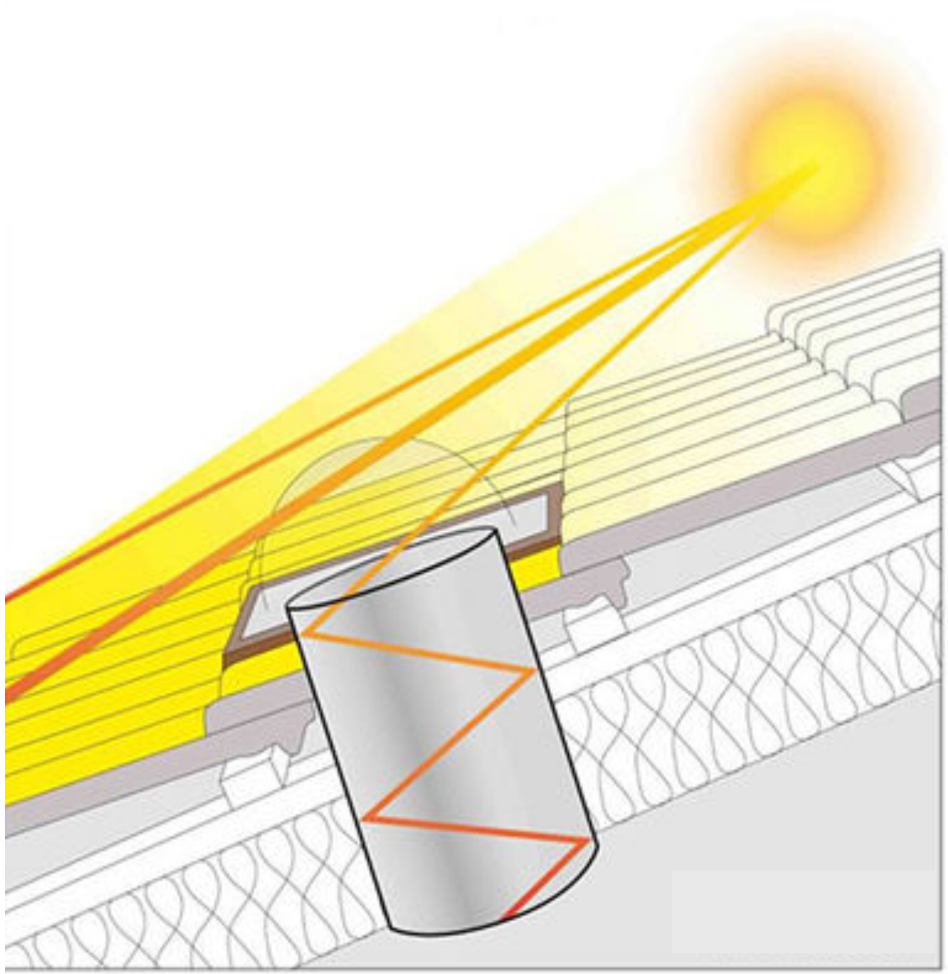
SOLAR TUBES

Tend to be Proprietary Designs

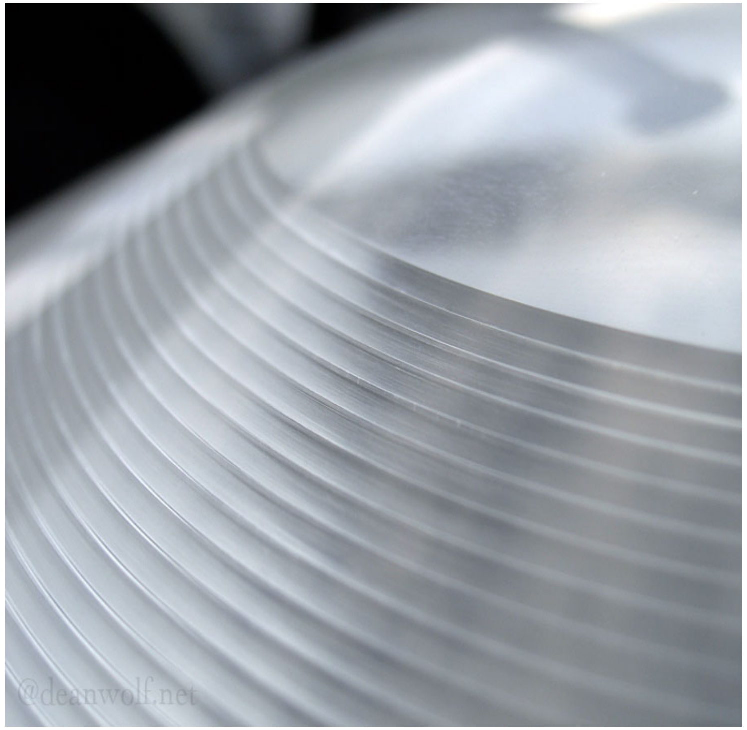
Primary Installations on Sloped Roofs for Residential Applications

Optimized for Northern Sky with lower solar altitudes





SOLAR TUBES

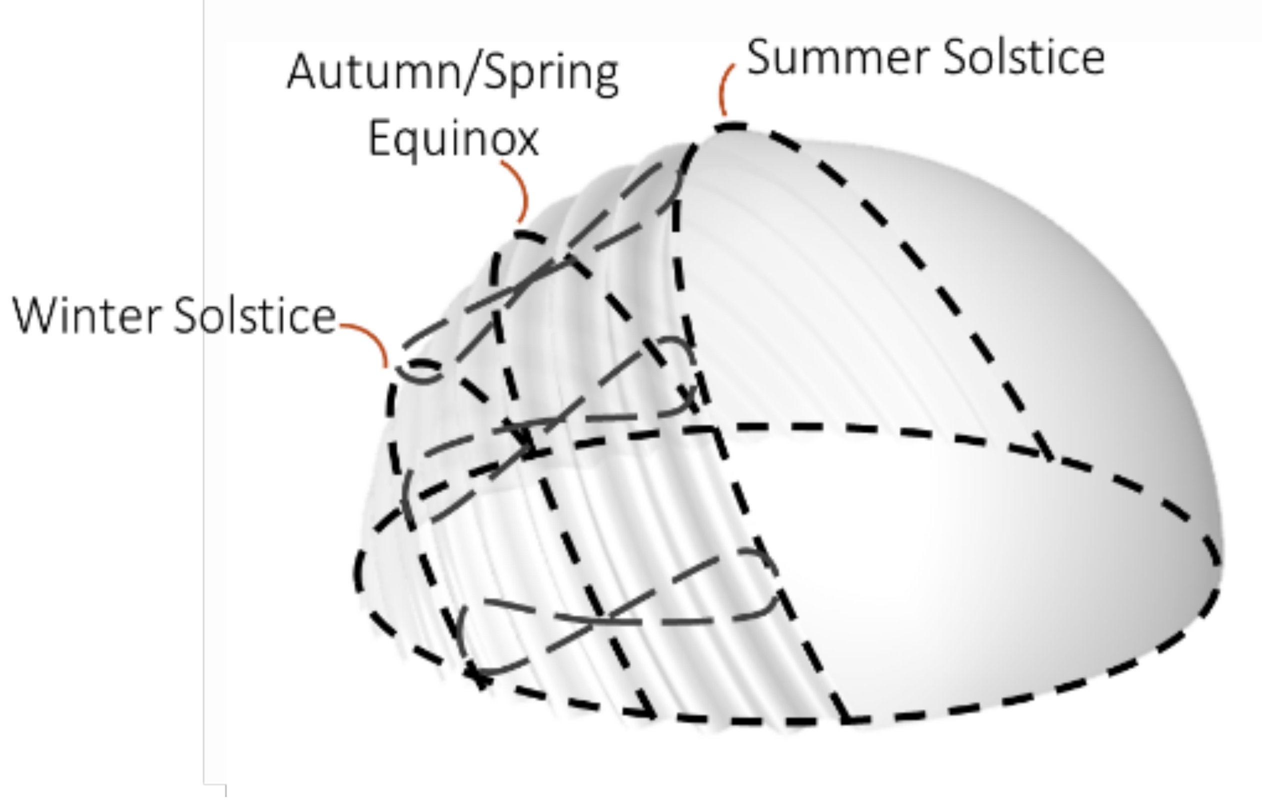


- Design is optimized for northern sky conditions with specific solar altitudes
- Reverse engineered this design as much as possible to compare it
- We then will compare with this design with our design and with a clear sky dome

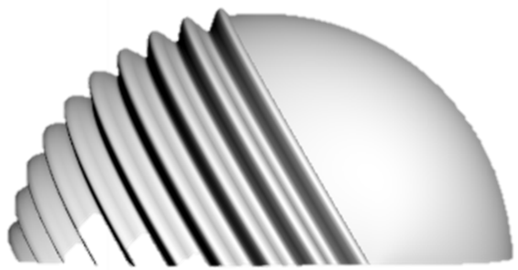
A NEW DESIGN FOR A SOLAR TUBE

- Goal is to design a new solar tube specifically for:
  - Makes use of the sinwave design
  - Solar altitude range common in the MENA region
  - Optimize Dynamic Measures
  - Easily manufactured

SOLAR TUBES



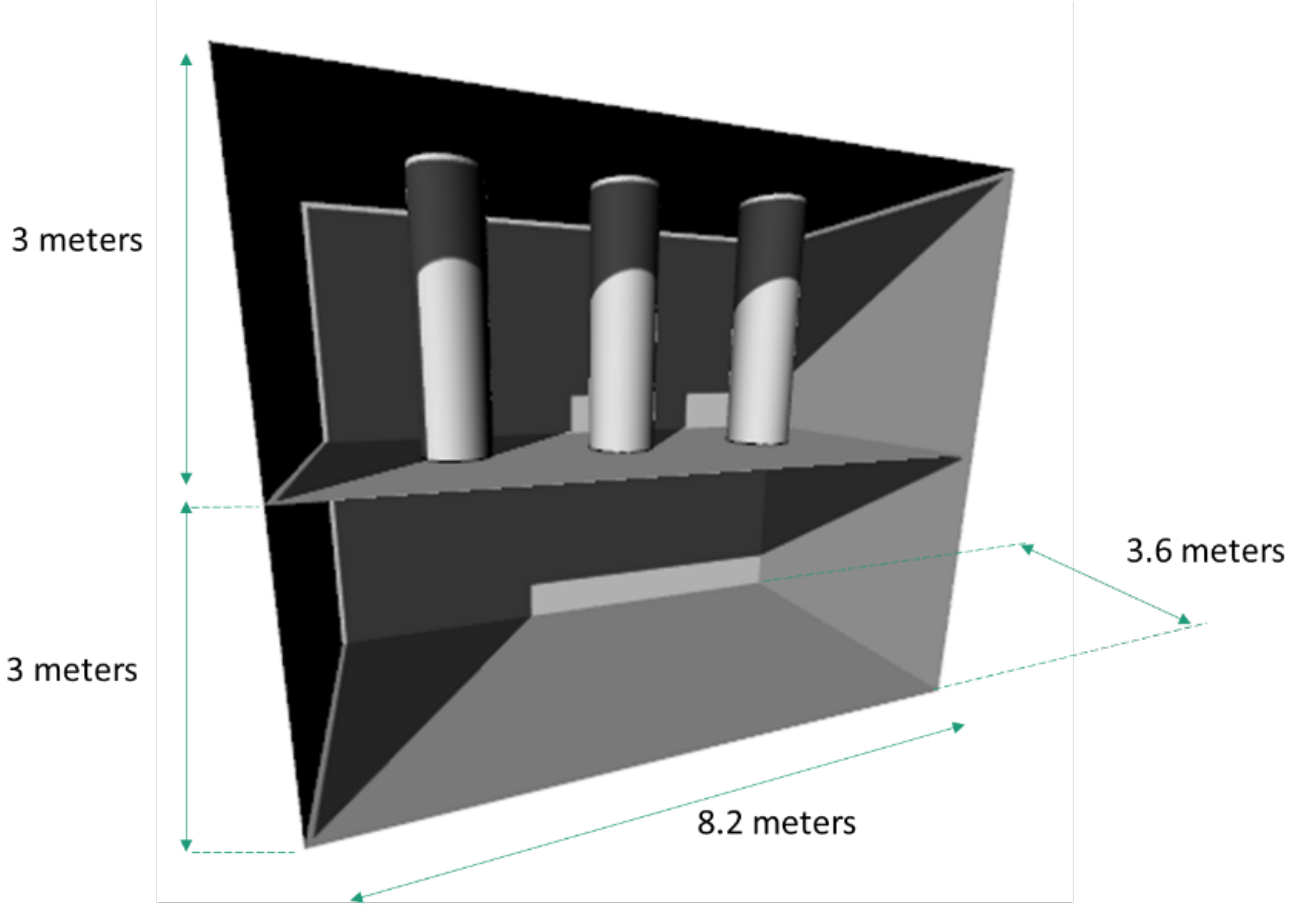
The idea is to follow the solar path and see if that provides better results. We follow the winter and summer solstice for the range of locations we are after

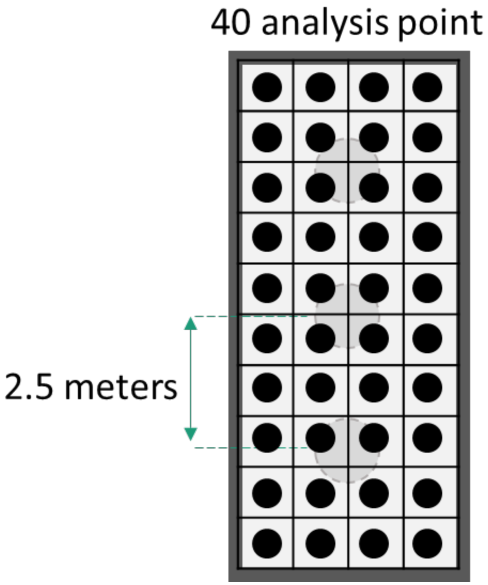


Side

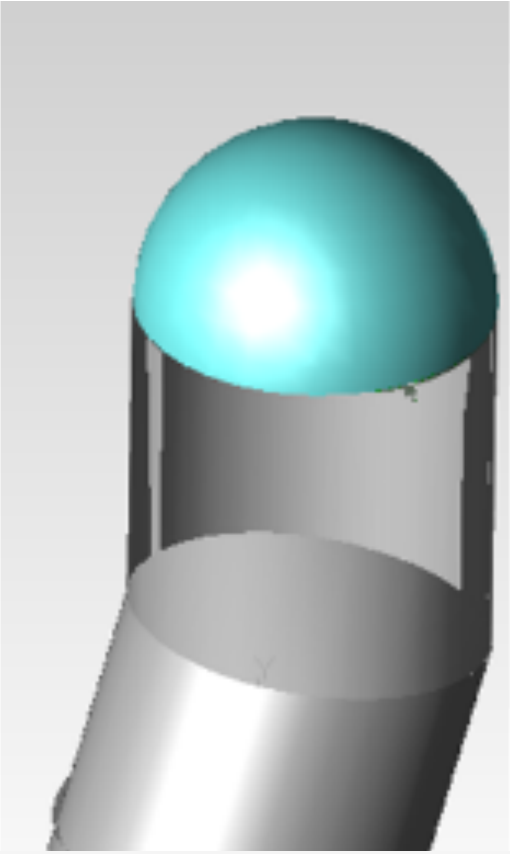
Top

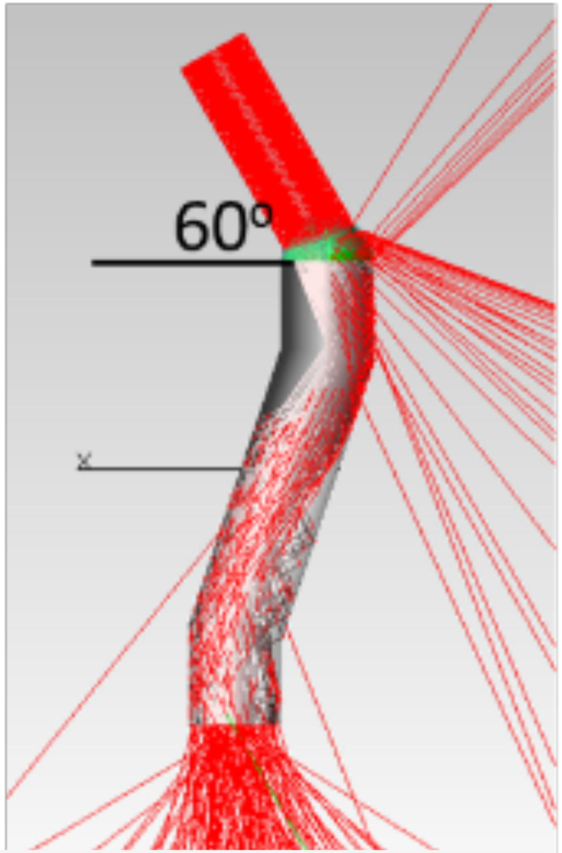
THE SETUP – STANDARD ROOM

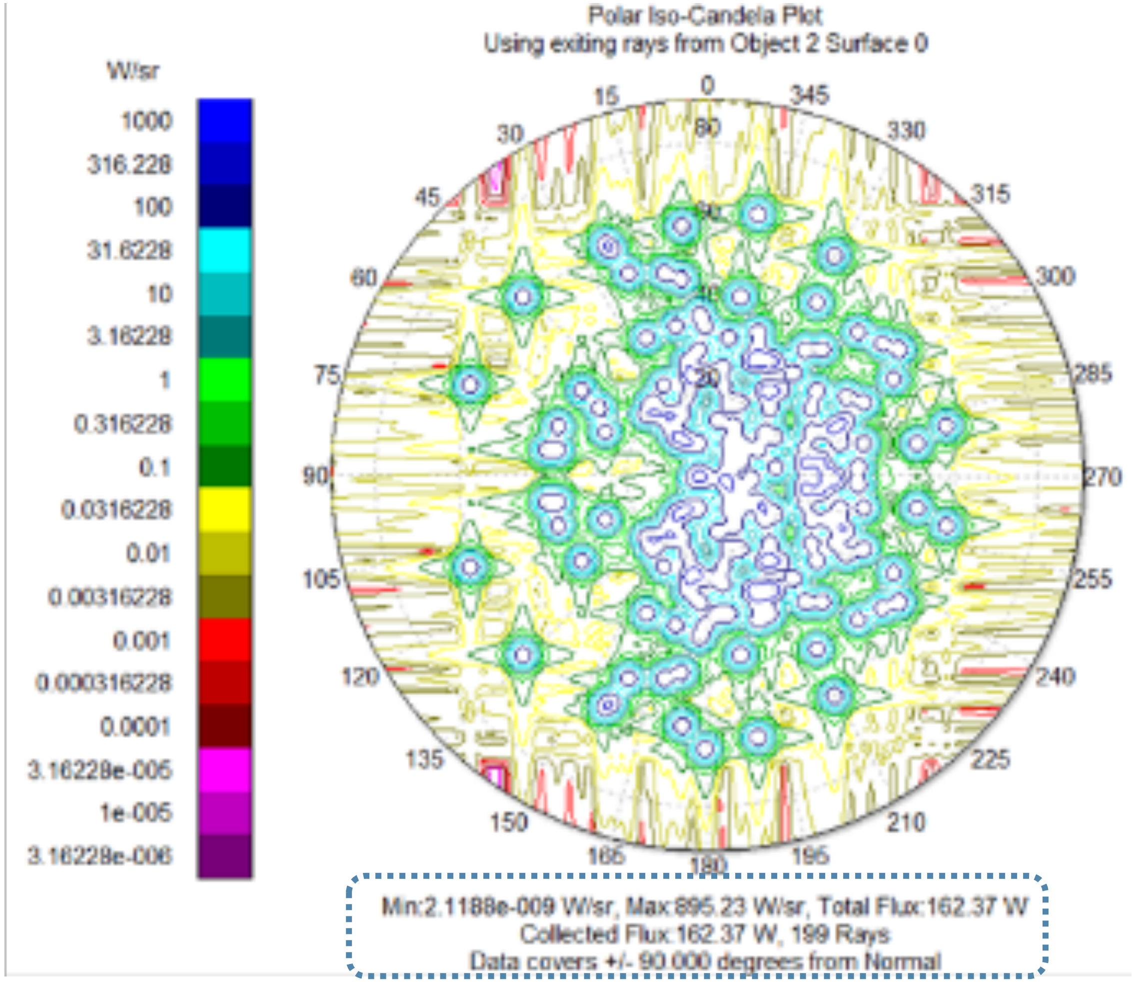




RAY TRACING USING TRACE-PRO



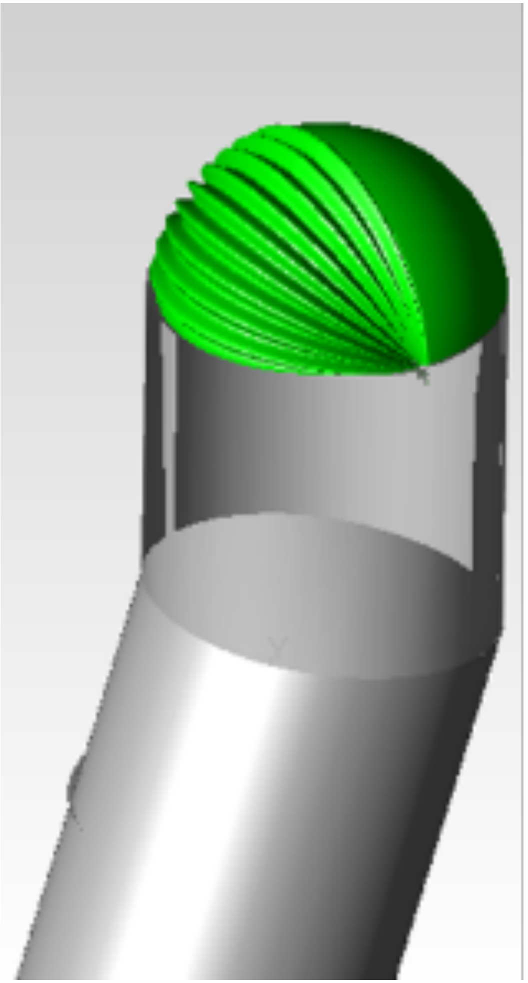


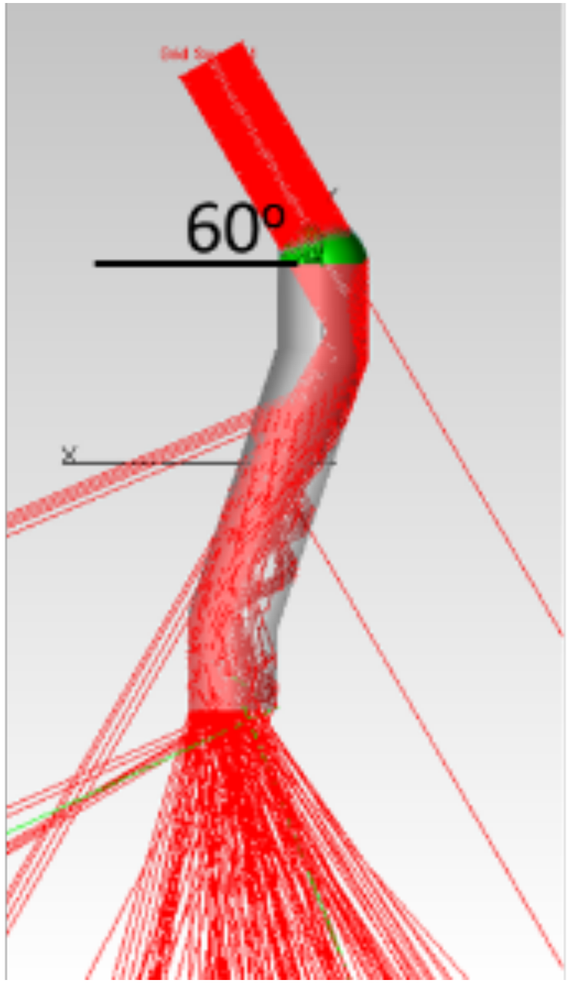


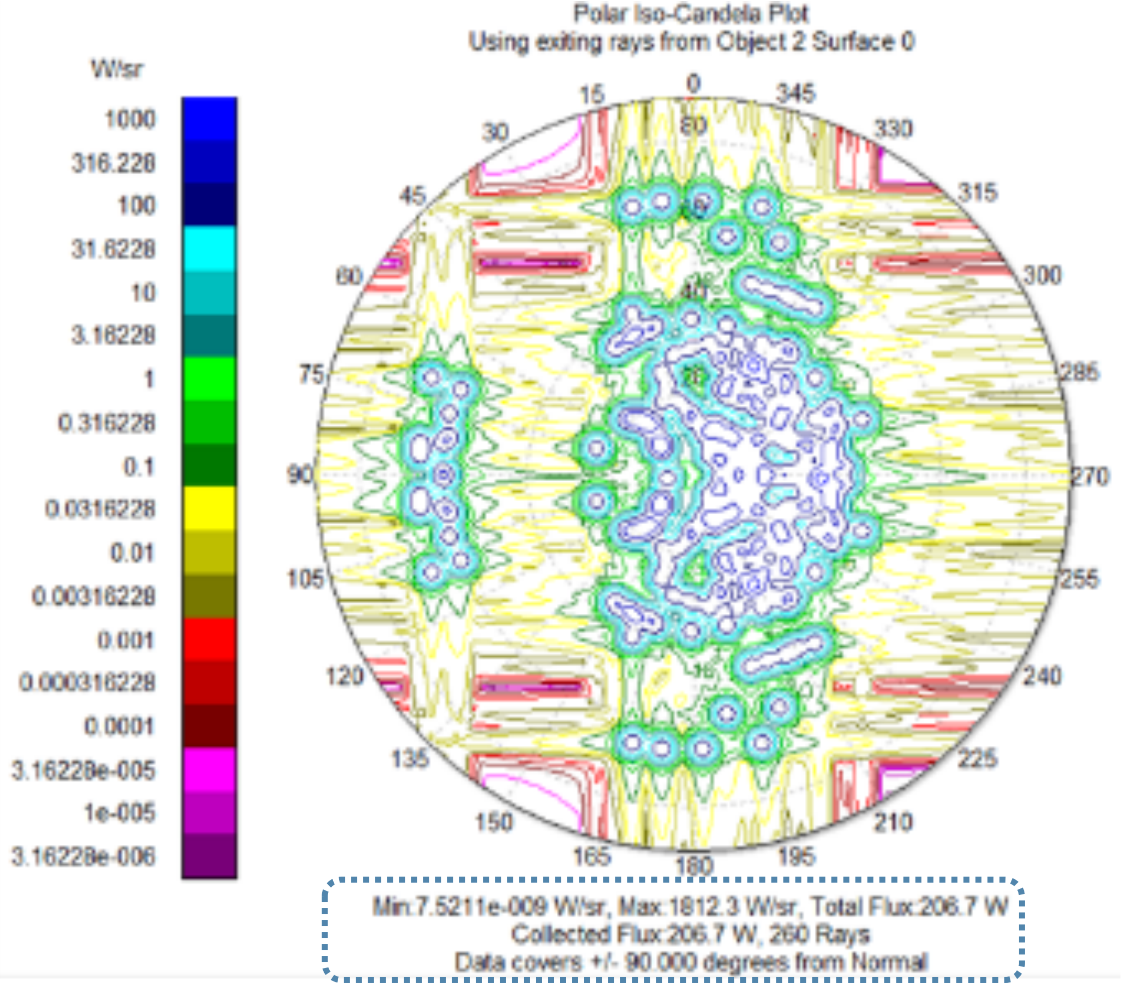
Commercial ray tracer

Used time weighted average of the solar altitude angle

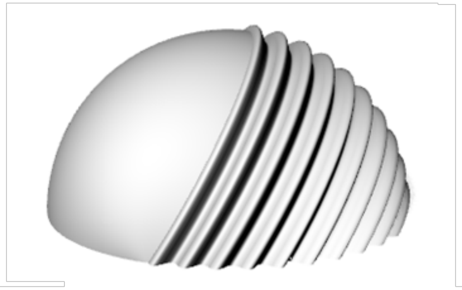
RAY TRACING USING TRACE-PRO

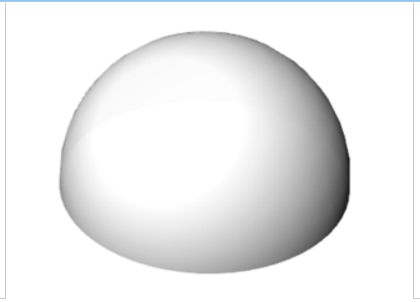


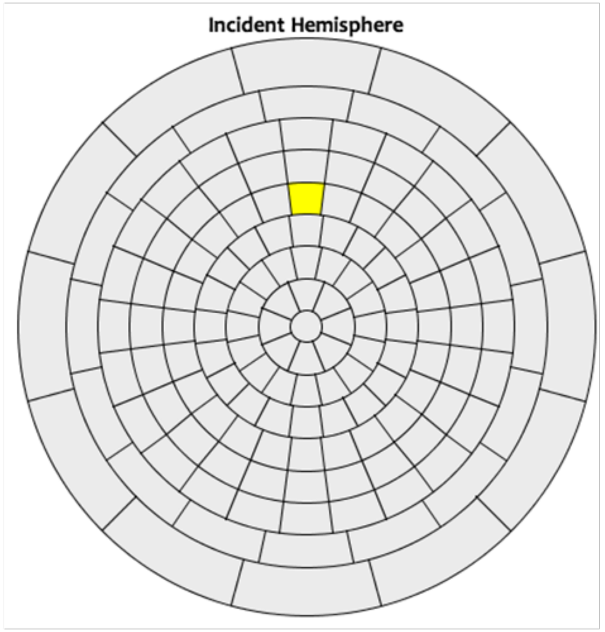


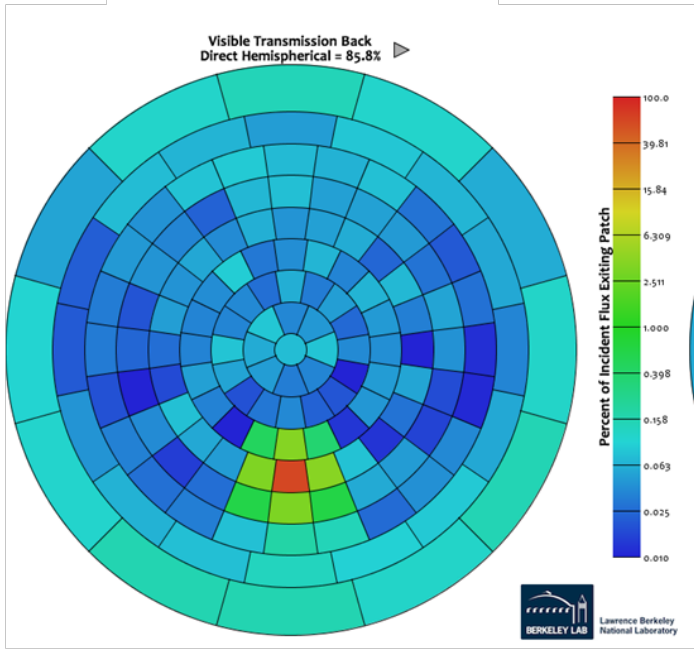


BSDF GENERATED – using tracepro

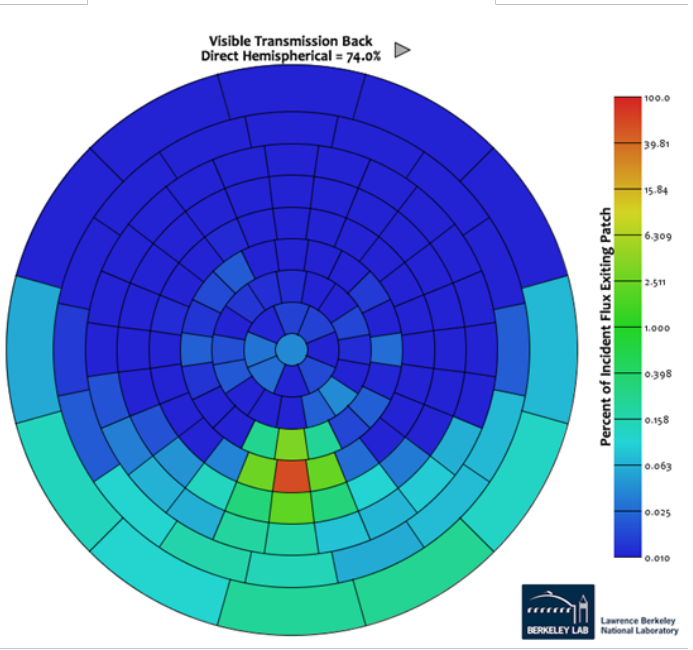








Visible Transmission = 86%



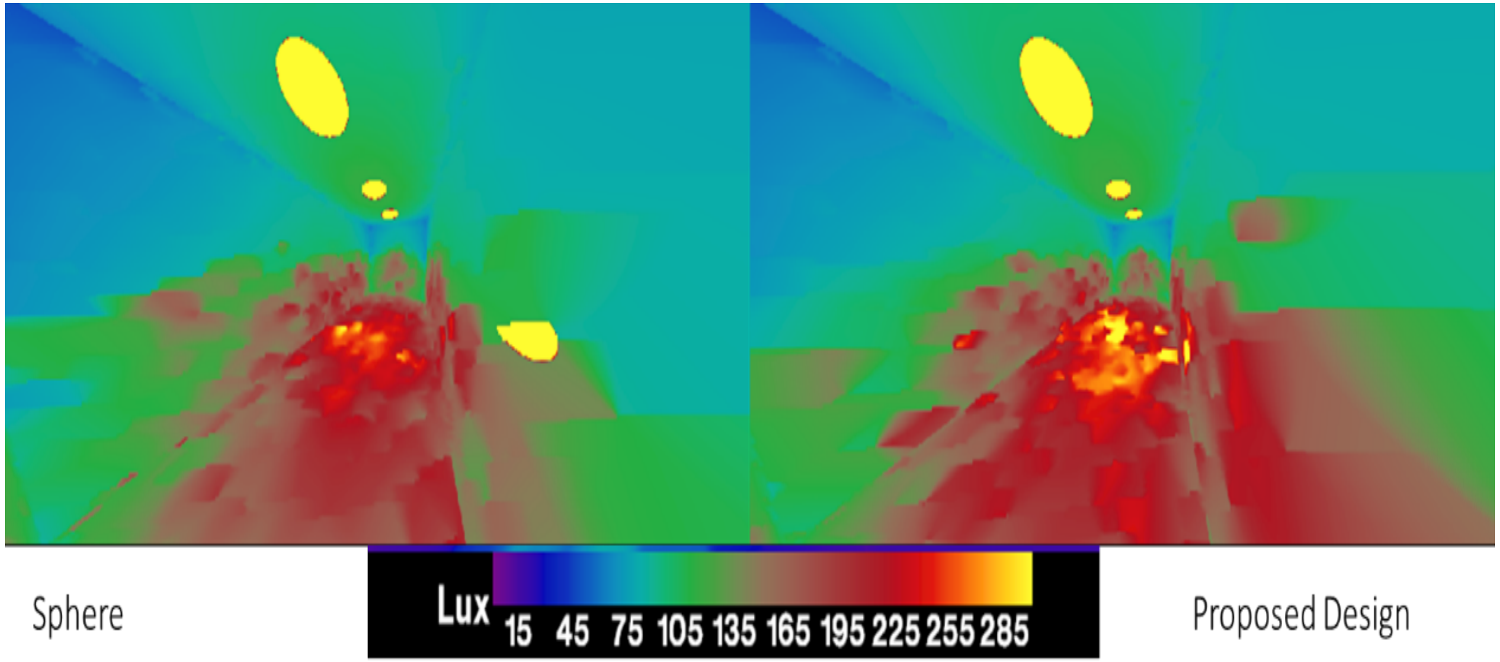
Visible Transmission = 74%

RADIANCE RENDERING

Single time step rendering

Meaningless by itself but gives an idea on the design

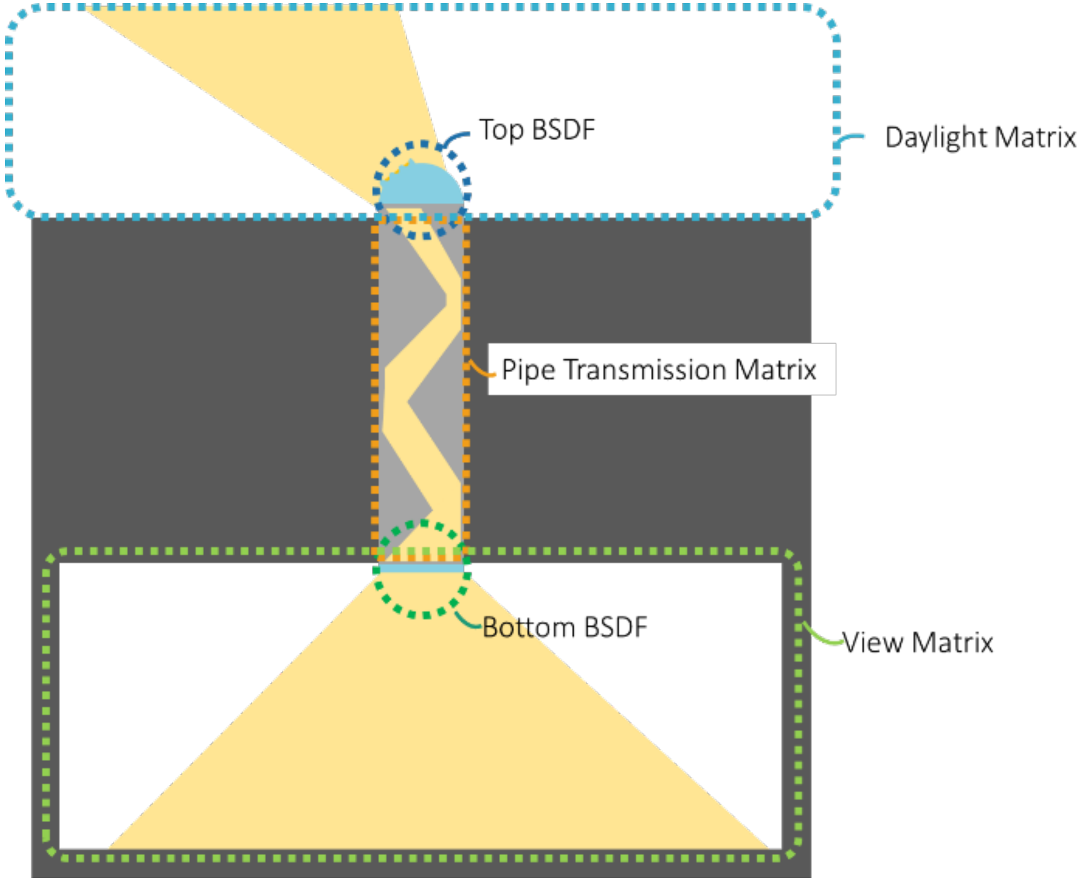
Need to conduct a Dynamic Daylight Simulation. Enter Radiance



SIMULATION USING RADIANCE 5 PHASE METHOD

We follow the same steps as introduced by Andy last year's presentation for a three phase simulation

Then we also tried a 5-phase simulation and compared the results



5 PHASE METHOD FOR SOLAR TUBES

- $I_{5ph} = VTDS - V_d T_d D_d S_d + C_{ds} S_{sun}$

- T for solar tubes = BSDF top + PIPE + BSDF bot
- T_d = BSDF top + $PIPE_d$ + BSDF bot

- We have to consider the direct and specular light transmitted through the tube
- C_{ds}: rcontrib.exe < points.pts –I –ab 1 – ad 65000 –dc 1 –dt 0 –dj 1 –st 1 –ss 0 –faa –e MF:1 –f reinhart.cal –b rbin –bn Nrbins – m solar full_model.oct > directsun.dsmx
- Full_model includes pipe too

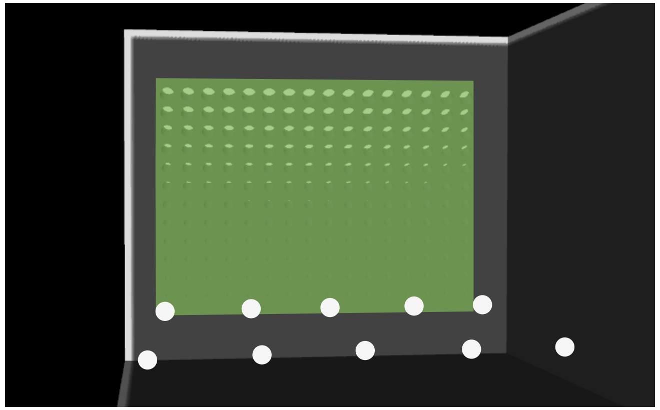
VIEW MATRIX

- rfluxmtx.exe -faa -I+ -ab 6 -ad 20000 -lw 1.52e-5 -y 45 <points.pts - viewsurf.rad materials.rad room.rad > viewmatrix.vmx

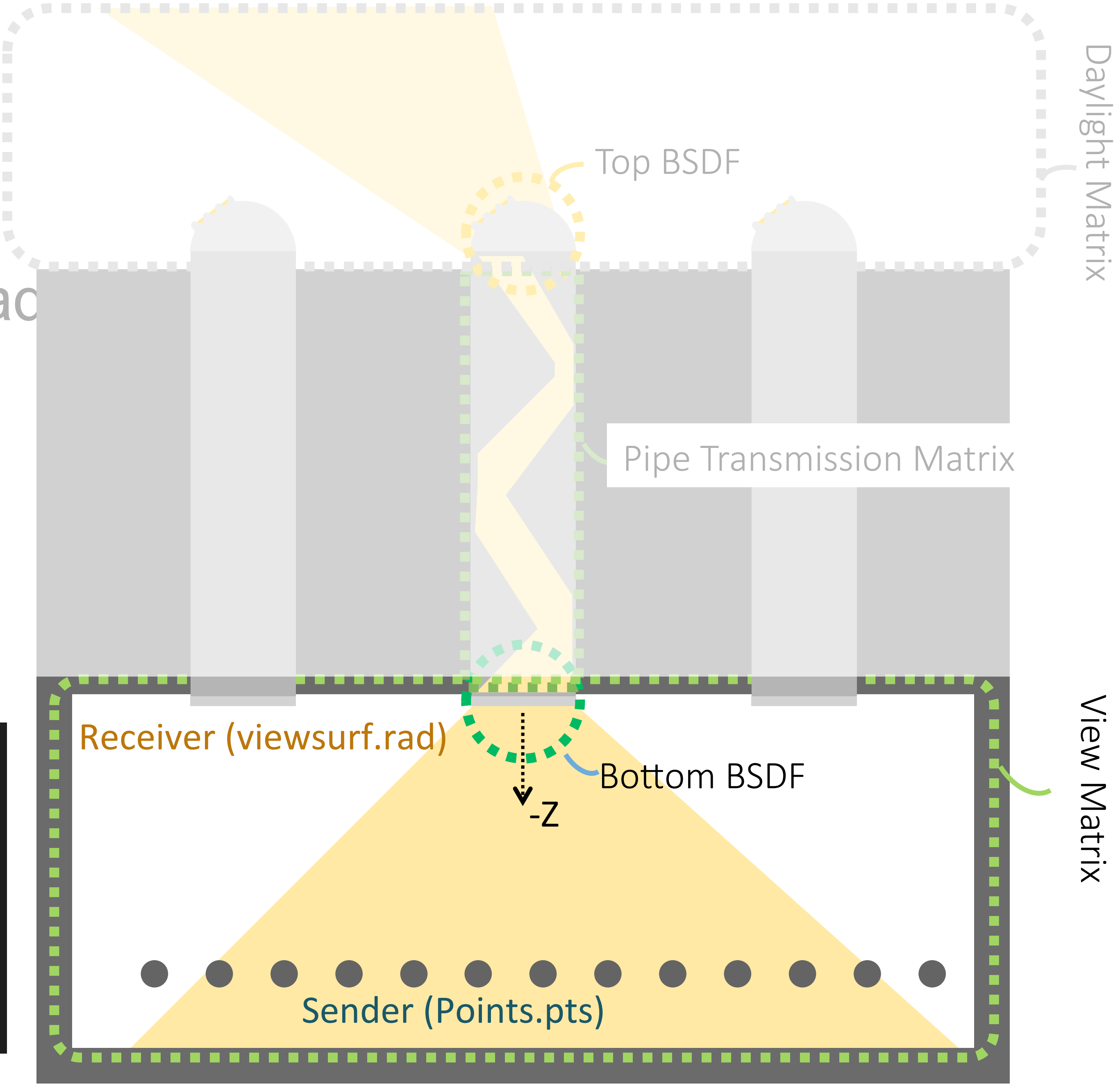
<u>For 5 phase</u>

Black material

-ab 1



View Matrix

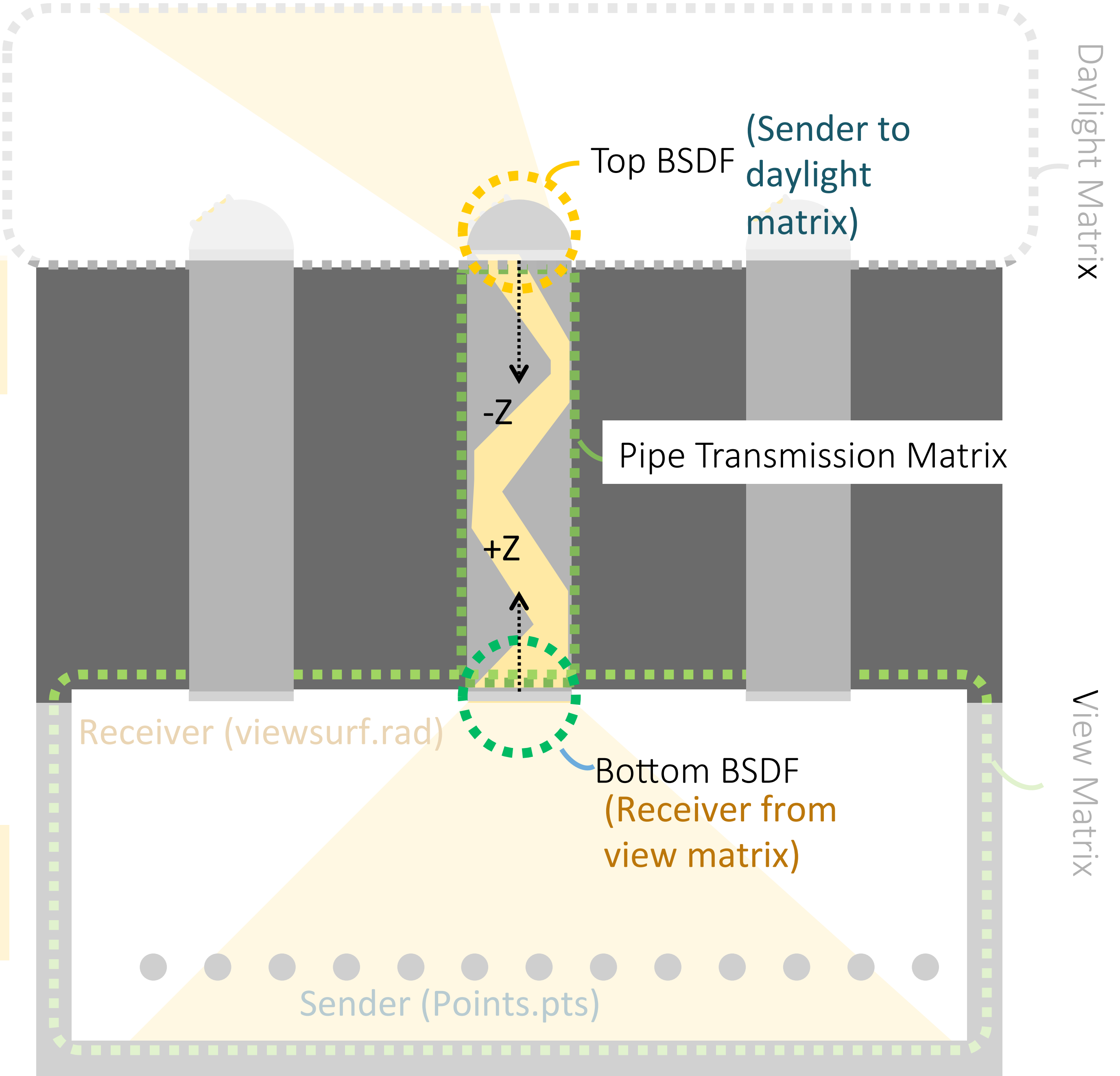


BSDF TRANSMITTER

- genbsdf.exe materialbsdf.rad bsdf.rad > topbsdf.xml

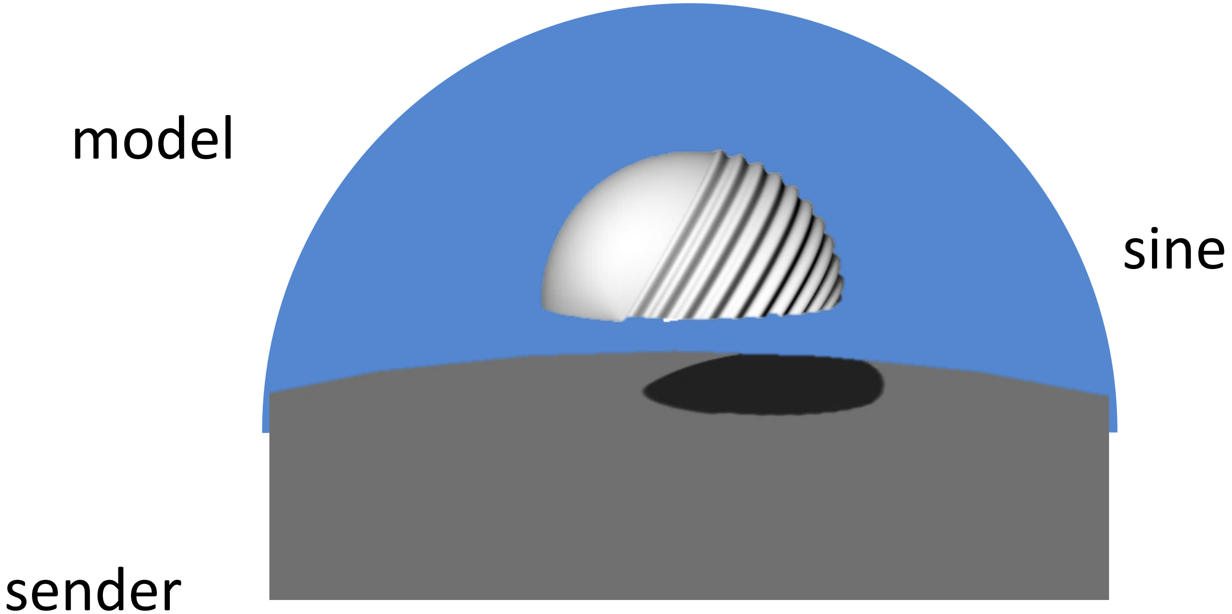
- rfluxmtx -n 4 -ab 12 -ad 1000 -lw 1e-4 view\bot.rad top.rad materials.rad SolarTube.rad > pipe.mtx

- genbsdf.exe materialbsdf.rad bsdf.rad > botbsdf.xml



ALTERNATIVE WAY FOR BSDF

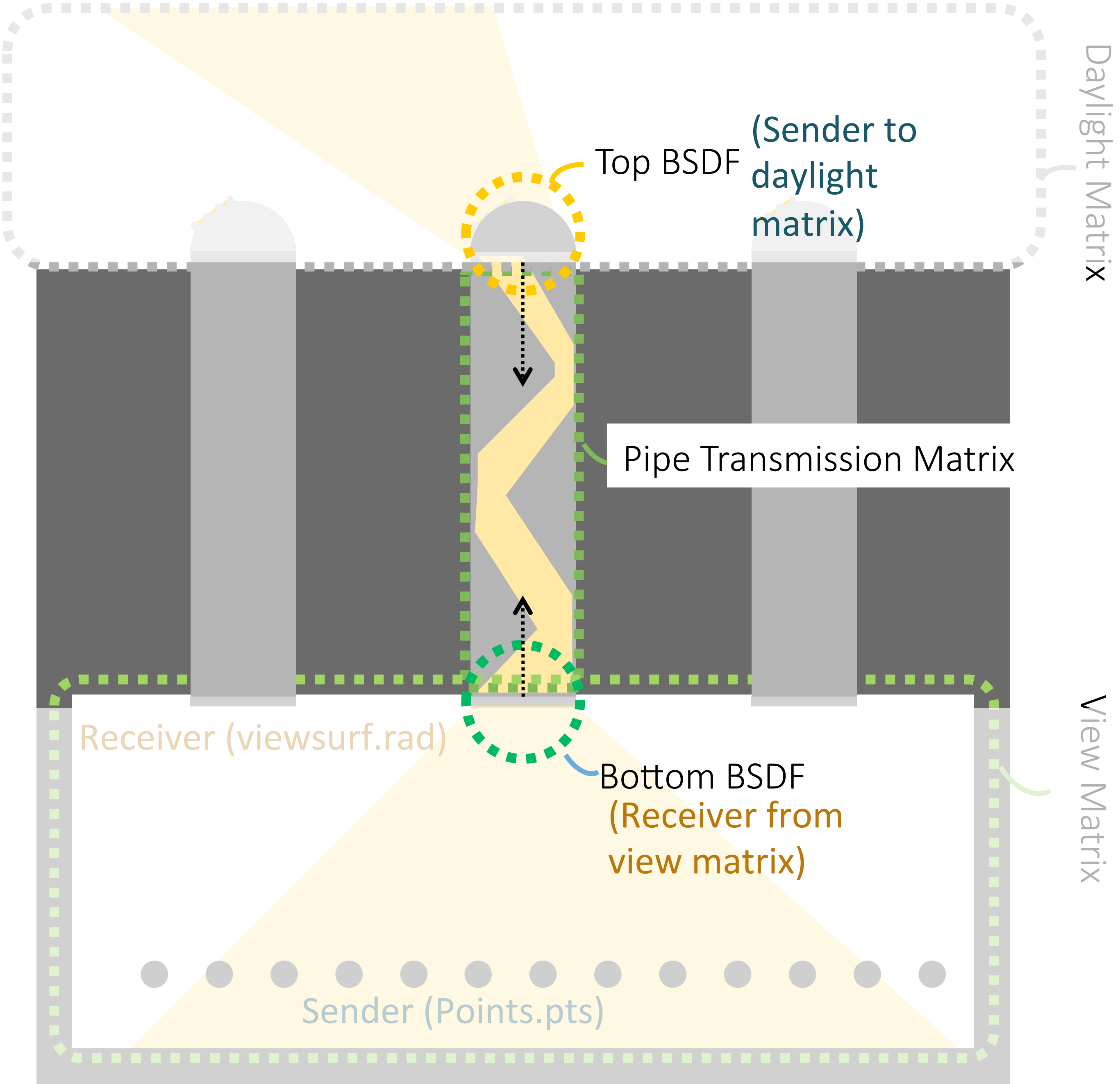
```
C:\Radiance\bin
\rfluxmtx.exe -n 4 -ab 12
-ad 5000 -lw 1e-4 -c
10000 sender.rad sky
\sky.rad mat.rad sine.rad
> results\bsdfalt.txt
```



BSDF TRANSMITTER FOR 5 PHASE

- rfluxmtx -n 4 -ab 1 -ad 1000 -lw 1e-4 view\bot.rad top.rad materials.rad SolarTube_black.rad > pipe.mtx

-ab 1: To Remove direct and specular reflections inside the pipe

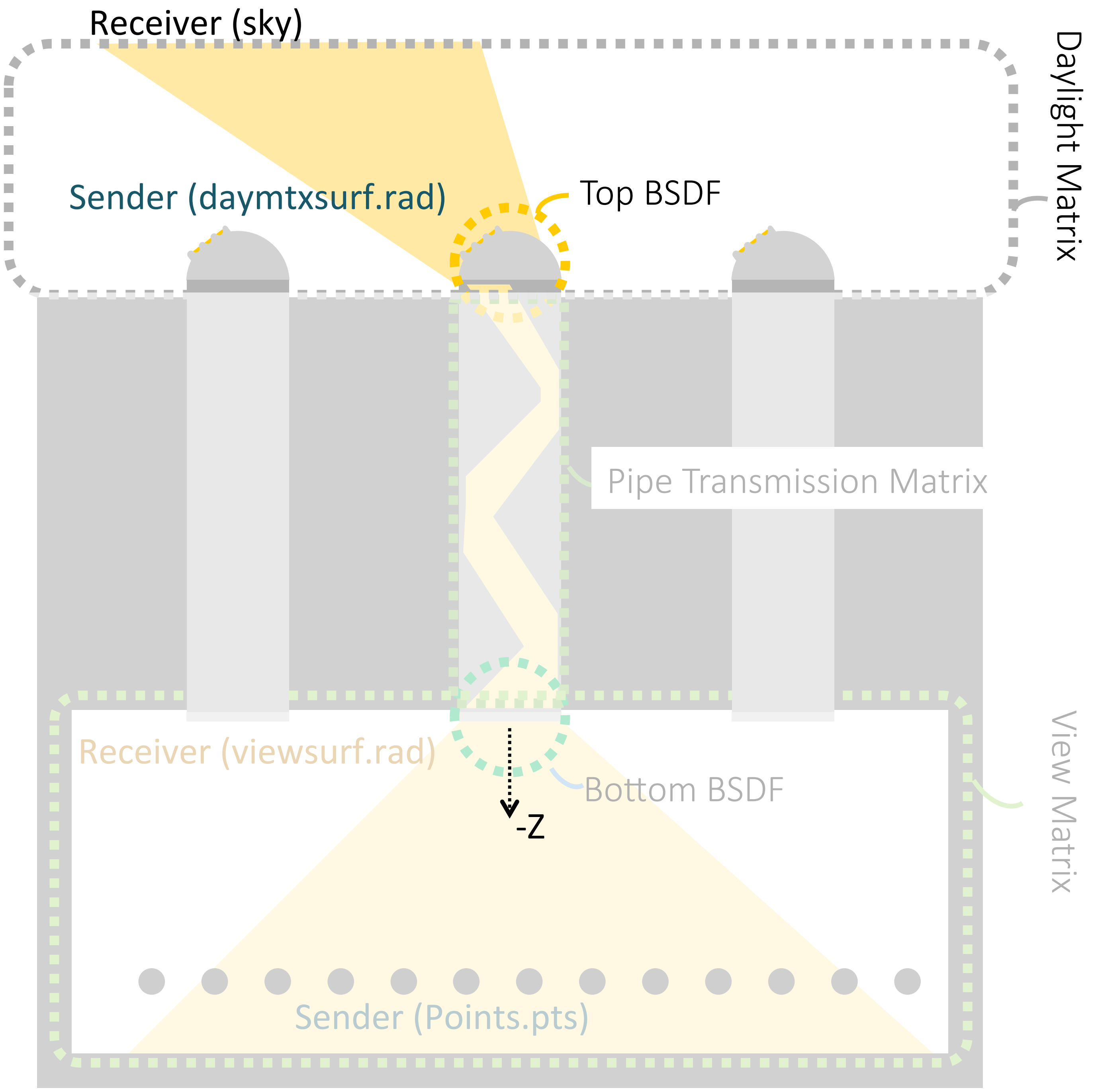


DAYLIGHT MATRIX

- rfluxmtx.exe -faa -c 10000 -ab 2 -ad 5000 -lw 1e-4 daymtxsurf.rad sky.rad materials.rad room.rad > daylight.dmx

<u>For 5 phase</u>

- rfluxmtx.exe -faa -c 10000 -ab 0 -ad 5000 -lw 1e-4 daymtxsurf.rad sky.rad materials.rad room_black.rad > daylight.dmx

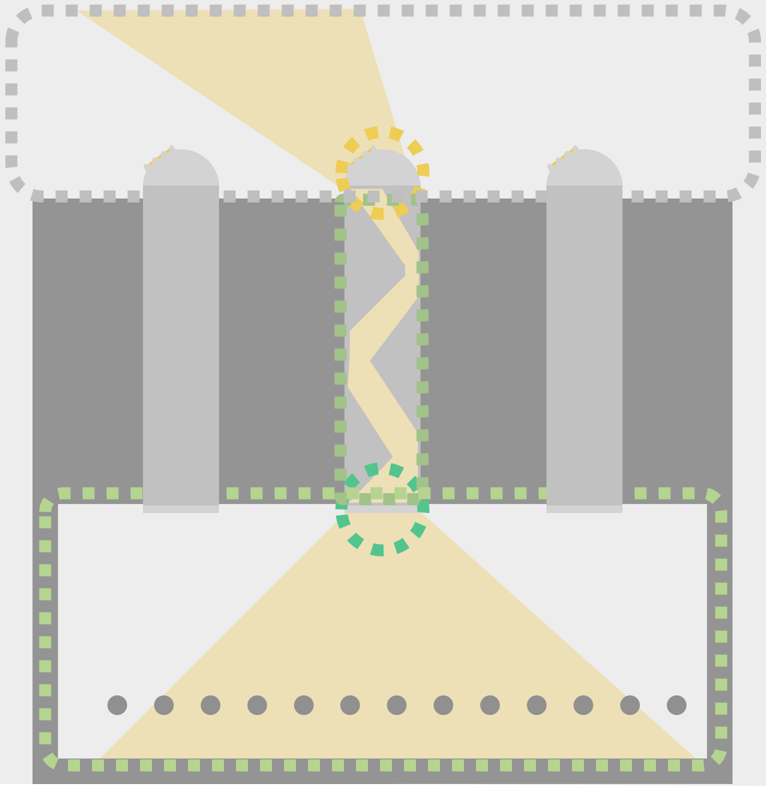


SKY MATRIX

- gendaymtx.exe cairo.wea > cairo.smx

<u>For 5 phase</u>

- gendaymtx.exe -d cairo.wea > cairo_d.smx
- gendaymtx.exe –m 1 -5 cairo.wea > cairo_m1.smx



RESULTS

We tried different designs in terms of the sinwave amplitude and period as well as other parameters

Trying to determine the best design using a trial and error approach

These SDA & ASE data and it shows variation in performance

Obviously the performance would differ if you vary the number tubes but it gives an indication

18%	18%	19%	20%
20%	19%	18%	18%
18%	24%	19%	50%
21%	19%	76%	18%
31%	92%	40%	61%
92%	19%	97%	32%
18%	37%	19%	33%
32%	19%	80%	18%
18%	19%	19%	20%
20%	20%	19%	18%

0%	0%	0%	0%
0%	0%	0%	0%
0%	1%	0%	1%
0%	0%	6%	0%
0%	9%	4%	2%
10%	0%	12%	2%
0%	2%	0%	0%
2%	0%	6%	0%
0%	0%	0%	0%
0%	0%	0%	0%

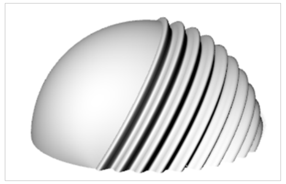
11%	12%	13%	12%
12%	12%	12%	13%
17%	8%	2%	25%
17%	18%	30%	3%
18%	53%	25%	13%
57%	13%	65%	17%
11%	16%	13%	24%
24%	15%	41%	13%
12%	10%	13%	12%
13%	12%	11%	12%

0%	0%	0%	0%
0%	0%	0%	0%
0%	0%	0%	0%
0%	0%	1%	0%
0%	0%	0%	0%
1%	0%	0%	0%
0%	0%	0%	0%
0%	0%	2%	0%
0%	0%	0%	0%
0%	0%	0%	0%

RESULTS

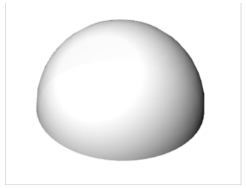
3 Phase Method

$sDA_{300lx/50\%}$



50%	51%	51%	51%	50%
50%	50%	51%	51%	50%
51%	49%	52%	52%	51%
50%	51%	51%	52%	51%
51%	51%	52%	52%	51%
51%	52%	50%	50%	50%
50%	51%	50%	50%	51%
50%	49%	50%	50%	49%

78%

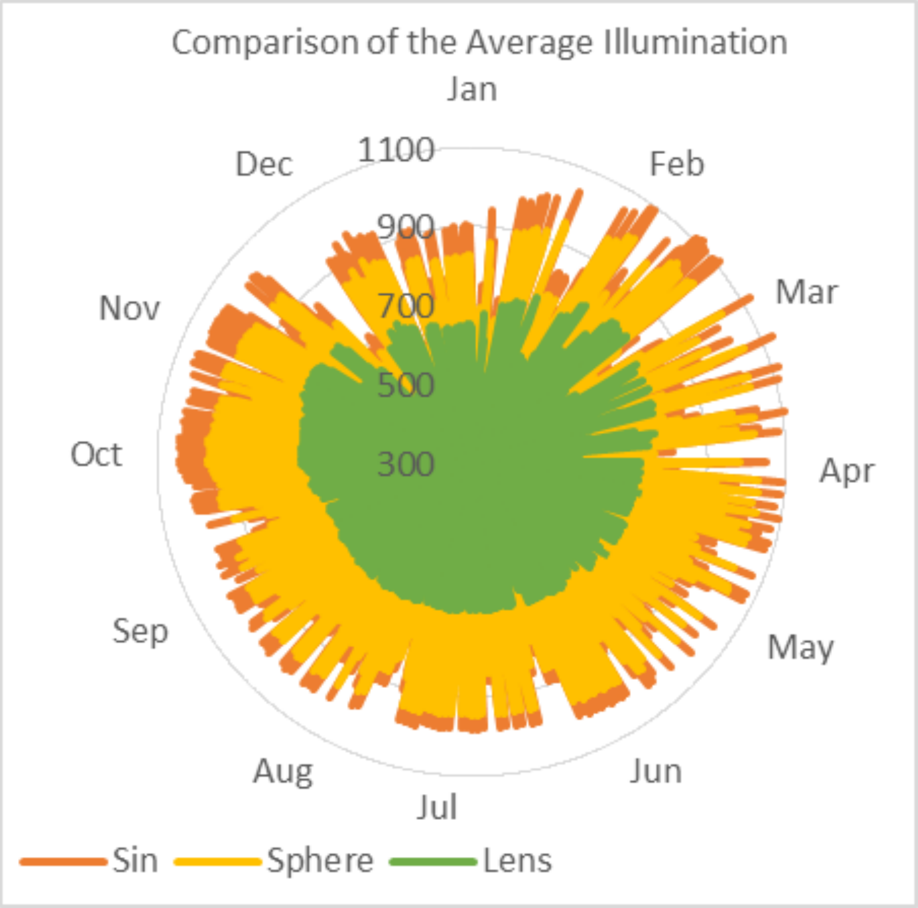


49%	50%	50%	50%	49%
49%	49%	50%	50%	49%
51%	49%	51%	51%	51%
50%	51%	50%	51%	50%
51%	51%	51%	51%	50%
50%	51%	50%	50%	49%
50%	50%	50%	50%	50%
50%	49%	50%	49%	49%

45%

46%	46%	47%	47%	46%
46%	46%	46%	47%	46%
47%	45%	47%	48%	47%
46%	47%	46%	48%	47%
47%	47%	47%	47%	47%
46%	47%	46%	46%	45%
46%	46%	45%	45%	46%
45%	44%	45%	45%	44%

0%



FUTURE WORK: ATTEMPTS AT FABRICATION

We CNC 'ed a plastic mould out of an acrylic to form the negative of our shape

We then heated a sheet of PPMA in an oven in a controlled manner

Then we pressed it the sheet onto the mould

THE END