VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

(work in progress)

11th International Radiance Workshop

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EPFL ENAC ICARE LESO-PB

Introduction

1. Buildings located at low latitudes
2. Possible Solution: use of CFS
3. Applying CFS by the use of computer simulations

Methodology

1. Case Study: DEMONA

Results

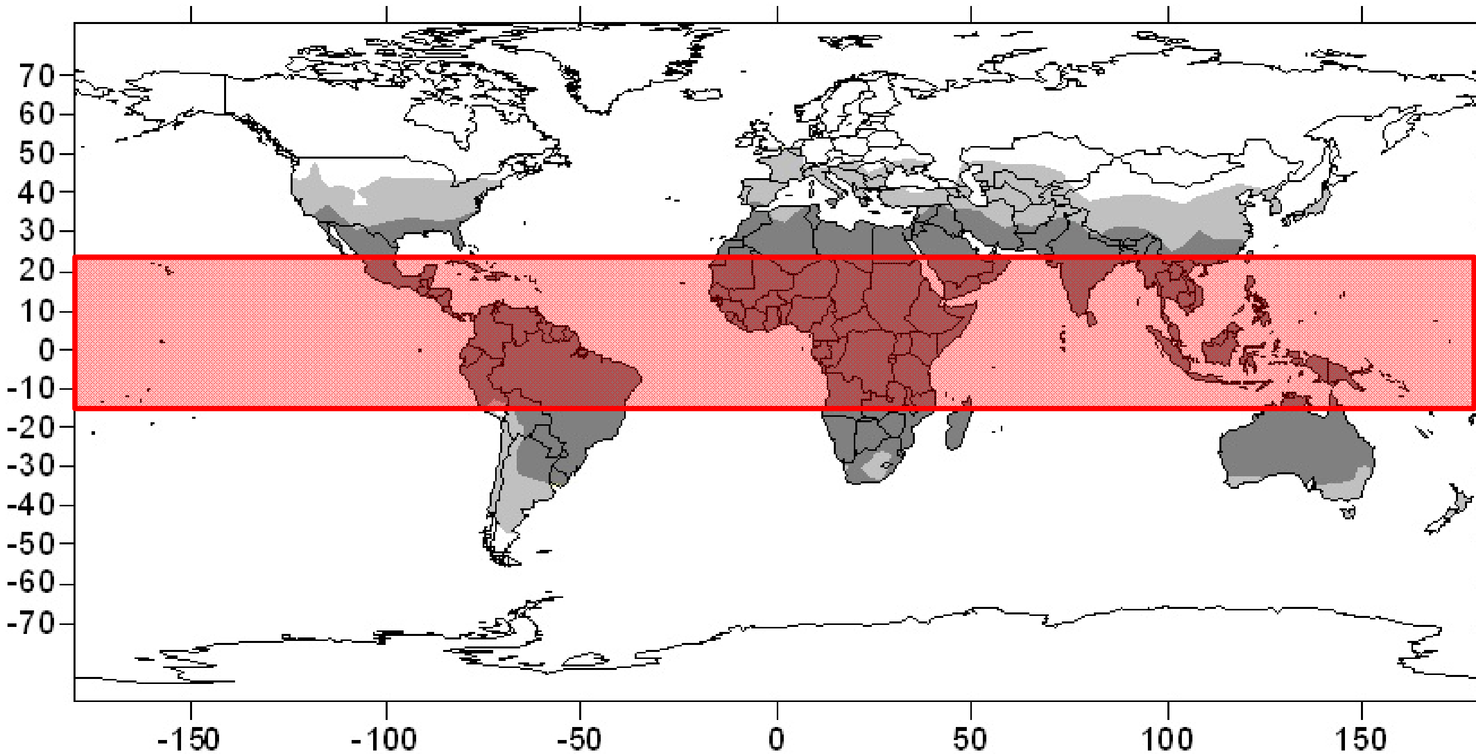
1. Double glazing window
2. CFS: Prismatic Film 3M
3. CFS: Lasercut Panel

Conclusions

Future Work

1. Tec de Monterrey
2. UAZ

1. Daylight optimization for buildings located at low latitudes



Daylight:

- Admission of heat that increases the cooling loads
- Sun rays which alter the visual comfort and perception of the indoor environment

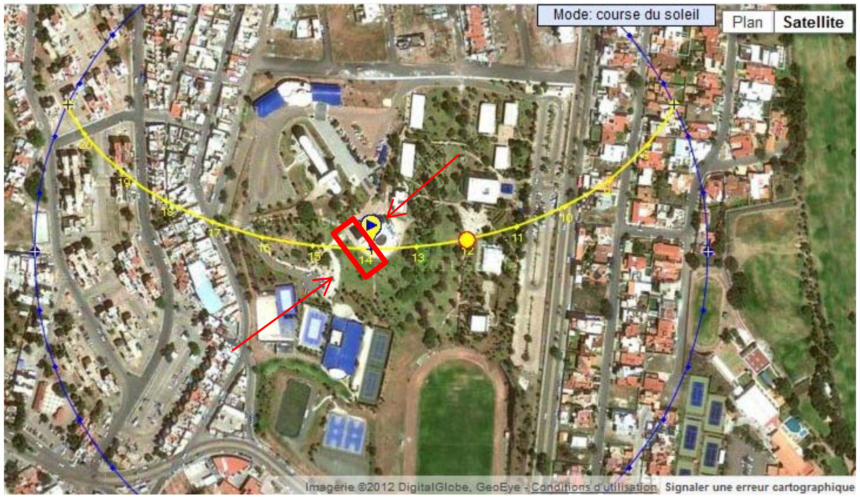
Local standard strategies:

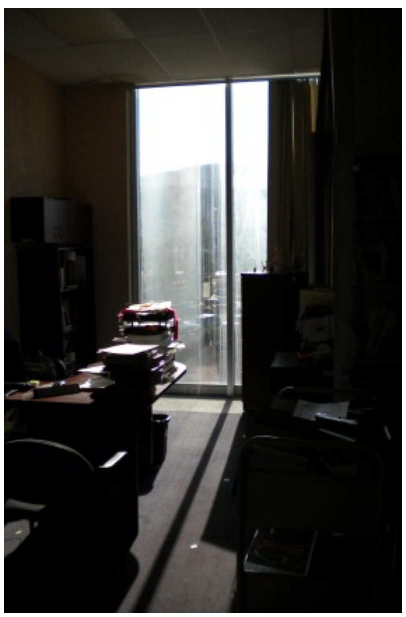
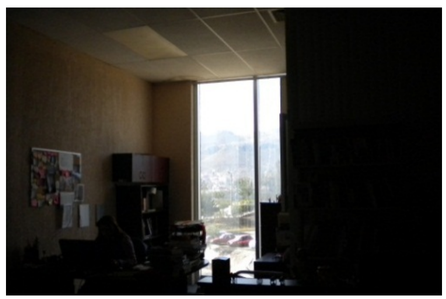
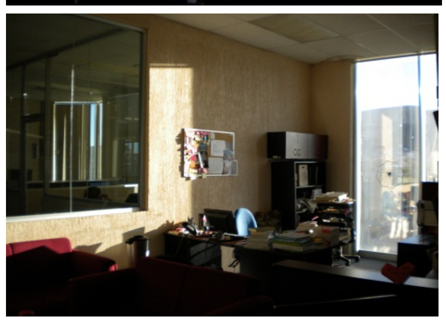
- Tinted glazing,
- Reduced window size,
- Window protection: venetial blinds.

Building Location: Zacatecas, México
Latitude: 22° 783' N.,
Longitude: 102° 583' W
Altitude: 2450m

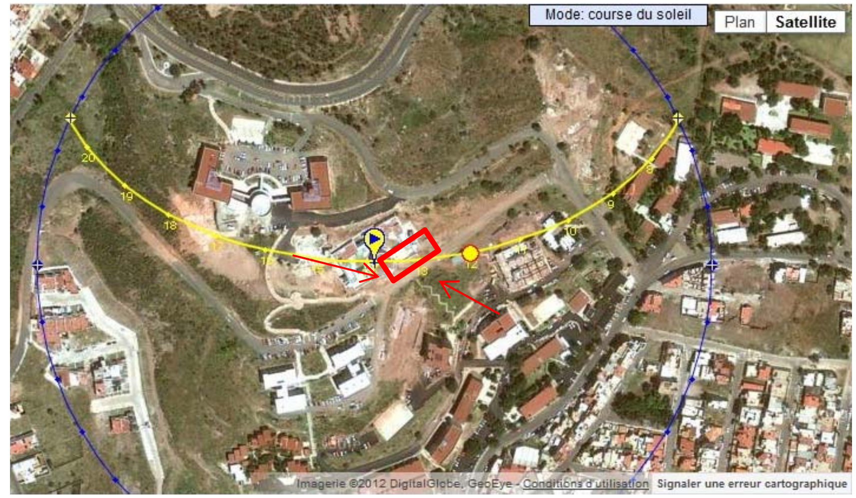
Warmest Temperature: 32°C may/june
Annual Sunshine Hours : 2676 (7.3/day)
Annual Daylight Hours: 4599 (12.6/day)

a) Tec de Monterrey -Private University-

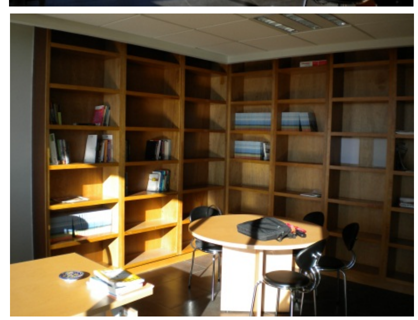
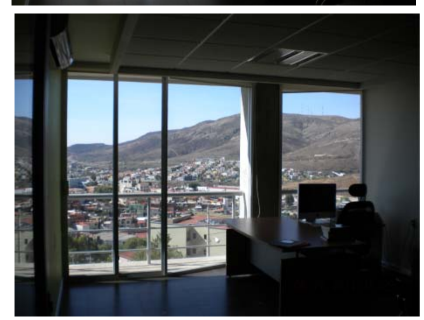


b) Centro de Estudios del Desarrollo (UAZ) –Research Center-

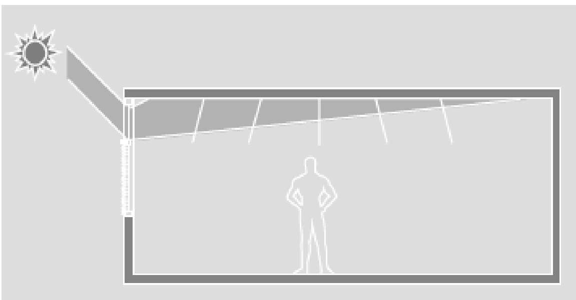


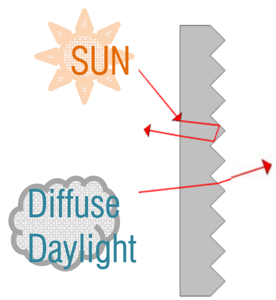


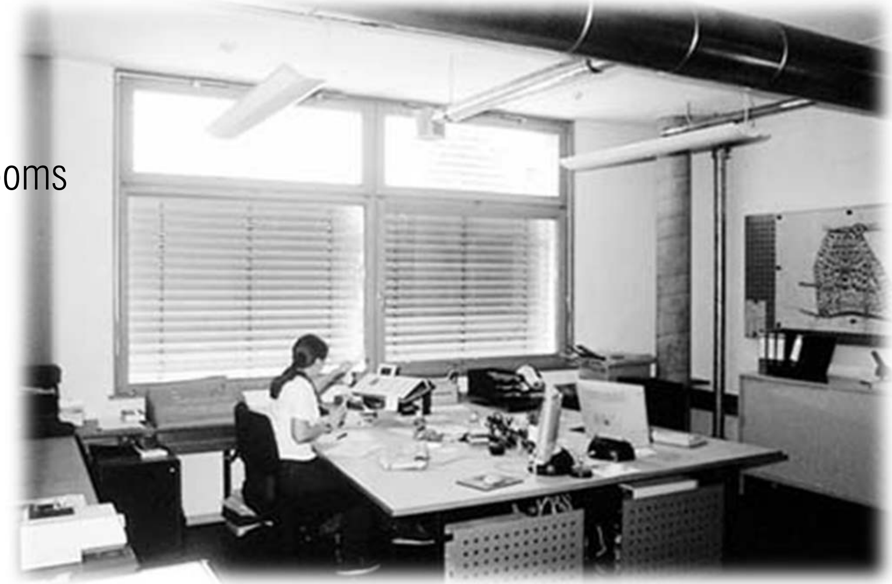



1.1 Possible Solution: Complex Fenestration Systems (CFS)

a) Solar shading: control direct sun rays
b) Improve daylight interior environment
  -lighting redirection: increase daylight levels deep within rooms
  -reduce the risk of glare



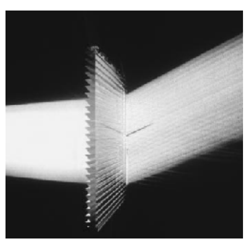




a) Reduction in the interior cooling loads in summer
b) Reduction in electricity for artificial lighting

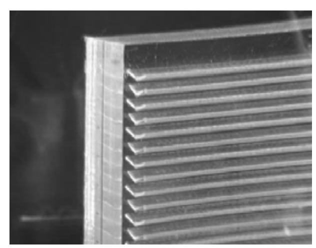
→ Reduction in the final energy consumption

Lasercut panel



Prismatic Panel

Okasolar



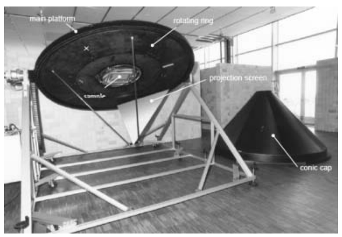
Light Channelling Panels

…testings on-site → difficult

1.2 Simulating CFS with RADIANCE

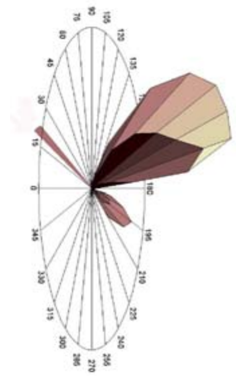
Luminous transmission properties of CFS

Bi-directional photogoniometer



IEA 21 file format
Bi-directional Transmission Distribution Function (BTDF)
International standard for BTDF data.

Photometric properties of CFS characterized in a diagram



btdf2radiance

Window 6 XML format
Multiple lighting redirections

1) BTDF data as matrix of size:
   145 x 145 / 145 x 1297
   adapted to be used with mkillum

   Btdf2mkillum145x1297.xml

2) *bsdf* material
   Without need of mkillum for lighting modelling through the window

Prism2
Only two emerging lighting directions can be determined for each incident beam direction

Btdf2prism2→translate monitored BTDF into prism2

Applied for sharp redirecting CFS:
Lasercut panel, prismatic film, holographic film

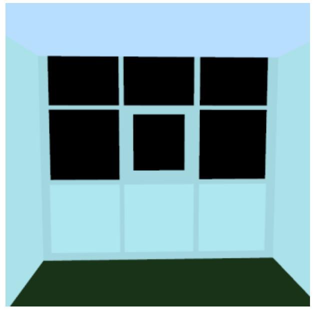
2) Methodology

Case Study: DEMONA

Module Location: EPFL, Lausanne, Switzerland
Latitude: 46.5° N
Longitude: 6.6° E
Elevation: 396m
Orientation: South

Dimensions: 6.5m x 3.05m x 2.65m
Area: 32.7 m^2
Window Area: 14.24 m^2
Proportion window/area: 0.43
Fenestration details: double insulated glazing
Single Glazing Transmittance: 80.5%

2.1 Demona virtual model



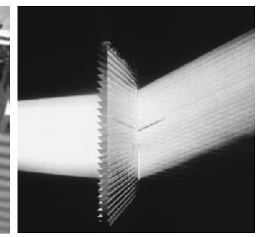
Double Glazing
28th august 11:17am
5099lx

Lasercut panel
5th april 9:13am
10765lx

Prismatic Film 3M (ext)
28th august 13:11am
19588lx

	Real Building	Virtual Model
Surface	Measured Reflectance %	
North Wall	82.6 ±	82.6
East Wall	81.5 ±	81.5
South Wall	72.1±	72.1
West Wall	82.3 ±	82.3
Ceiling	79.9 ±	79.9
Floor	16.1 ±	16.1
	Transmittance %	Transmissivity
Double Glazing Window	80.5 ±	0.8769

Lasercut panel
6mm single acrylic
w/ 4mm parallel cuts

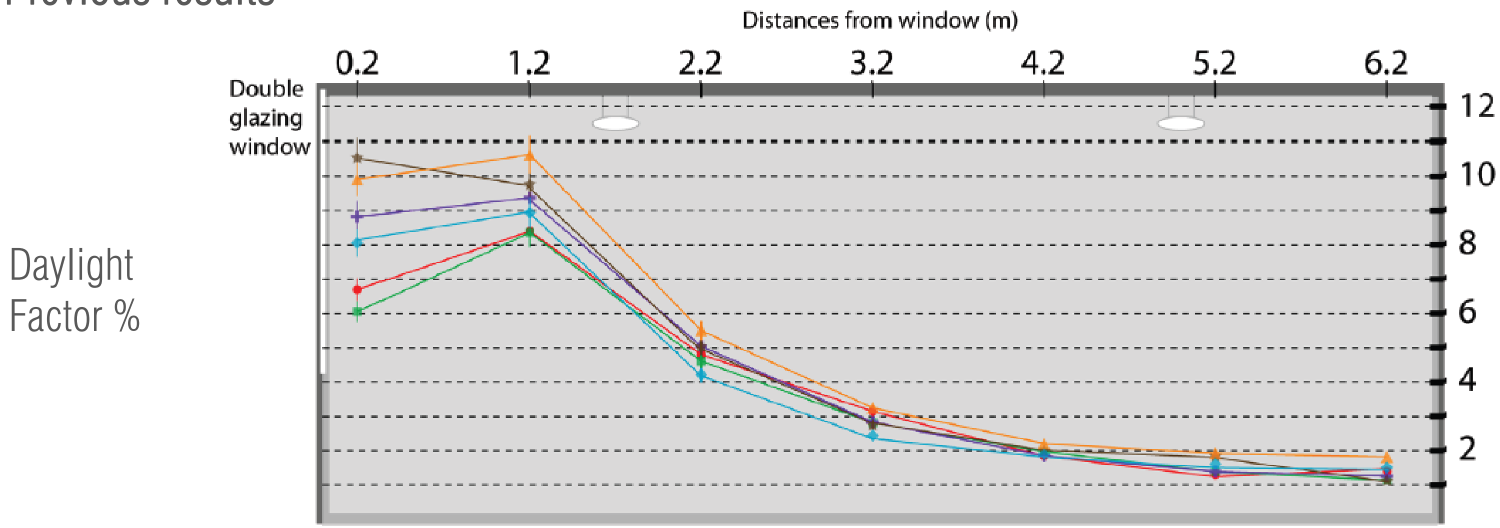


Prismatic Panel Exterior
3M Brand optical
Lighting film

Radiance Simulation Paramètres	
-ab	9
-aa	0.1
-ad	26315
-ar	128

Work performed by: Anothai Thanachareonkit
EPFL LESO-PB 2008

2.2 Previous results



Real Building, Real sky Conditions

Case A: Scaled Model 1:10, under real sky conditions

Case B: Scaled model 1:10, under sky simulator, for CIE standard ovescast sky (Type 1)

Case C: Scaled model 1:10, sky reproduced in sky-simulator. Sky luminance data obtained from sky scanner

Case D: Virtual model using Radiance Gensky, under CIE standard sky distribution

Case E: Virtual model, sky reproduction using the data from the sky scanner

Work performed by: Anothai Thanachareonkit
EPFL LESO-PB 2008

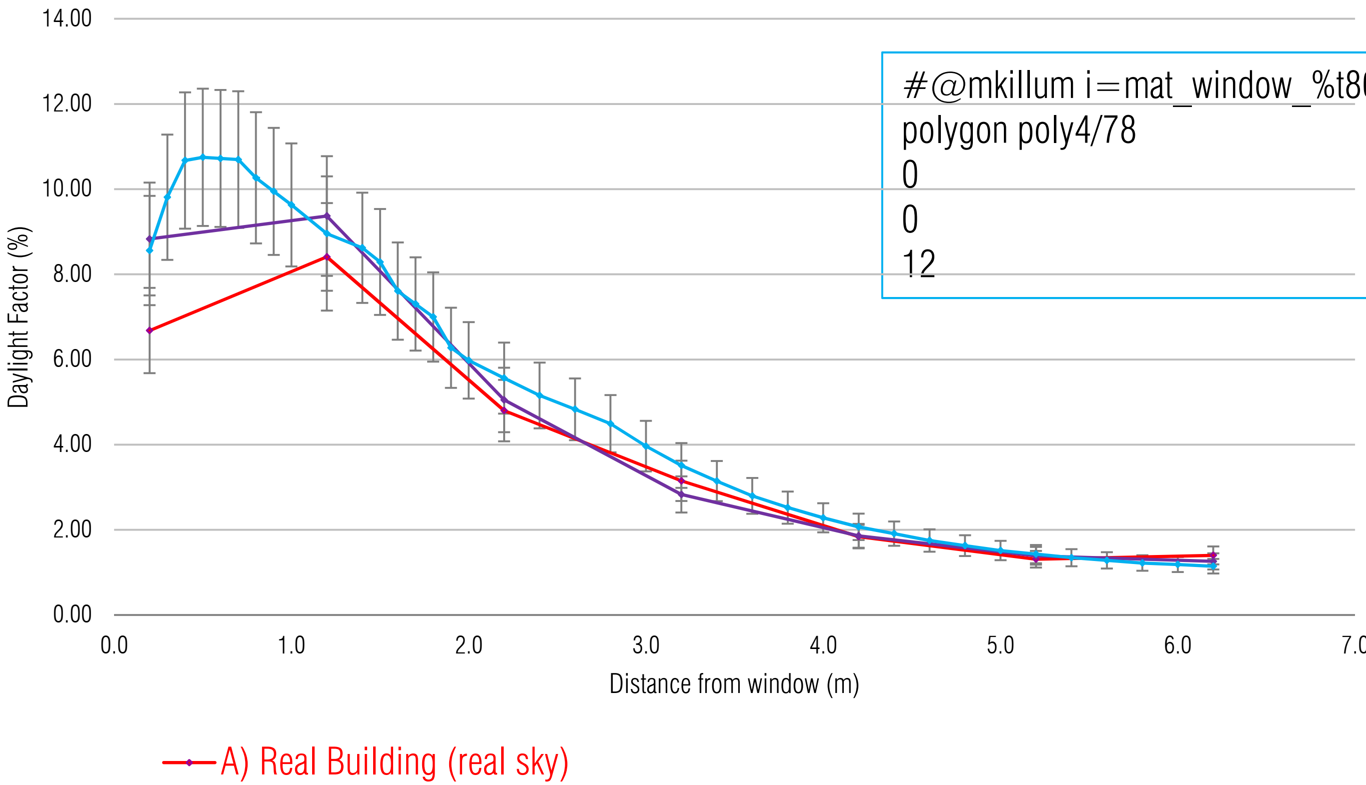
3) Results

1. Standard Module: double glazing window

Double glazing window

```
.\bin\oconv -f sim_ovc_cie_window_2012.rad material.rad model.rad window.rad > base_D_0.oct
```

```
#@mkillum i=mat_window_%t80.5 d=223 s=115 m=window1
polygon poly4/78
0
0
12
```



Computing Time

1.5h

Work performed by: Anothai Thanachareonkit
EPFL LESO-PB 2008

2. CFS: Lasercut panel

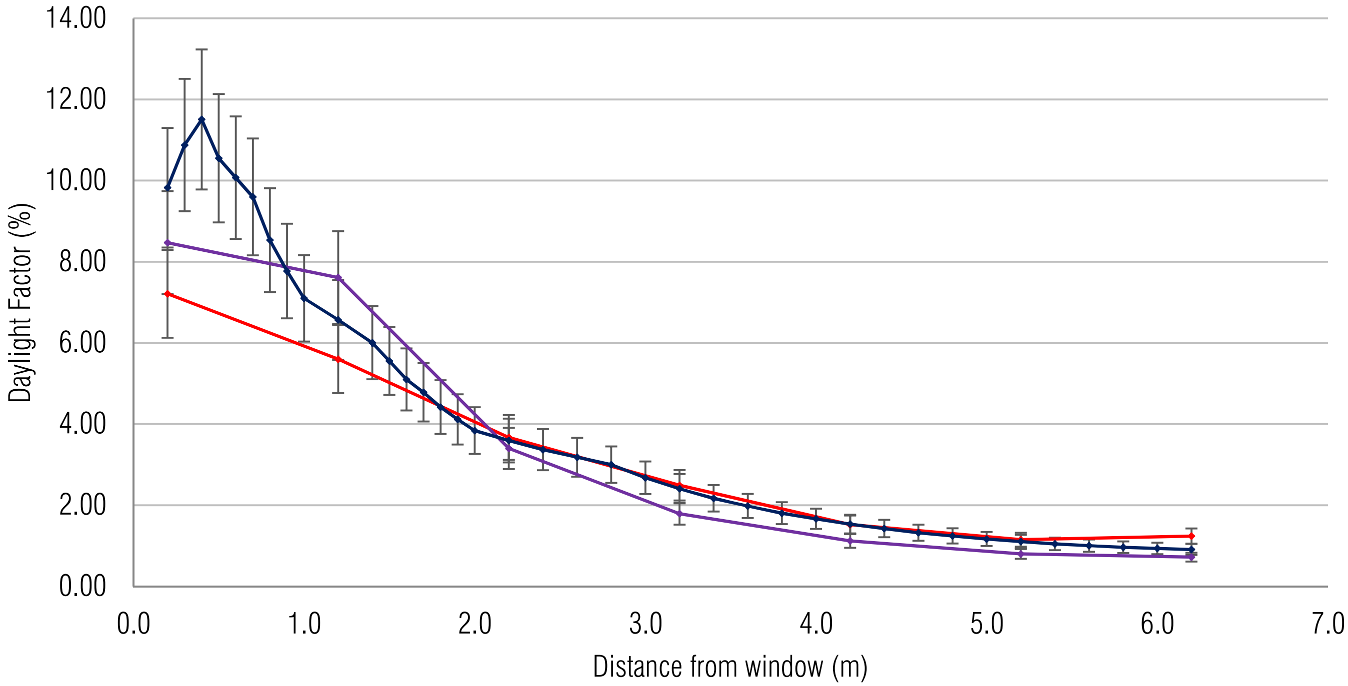
Lasercut panel

a) primitive *prism2*

```
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercut.rad > base_D_0.oct
```

a) Previous simulation 2007 — LaserCutPanel.cal

btdf2prism2_lcp.cal — b) Present simulation 2012



A) Real Building (real sky)
A) Case D simulated st. Sky (lasercutpanel.cal)
2) ovc lasercut.rad prism2 (btdf2prism2_lcp.cal)

Computing Time

~72h

Case D: simulated st. Sky (lasercutpanel.cal)

Vs.

Ovc_lasercut.rad prism2 (btdf2prism2_lcp.cal)

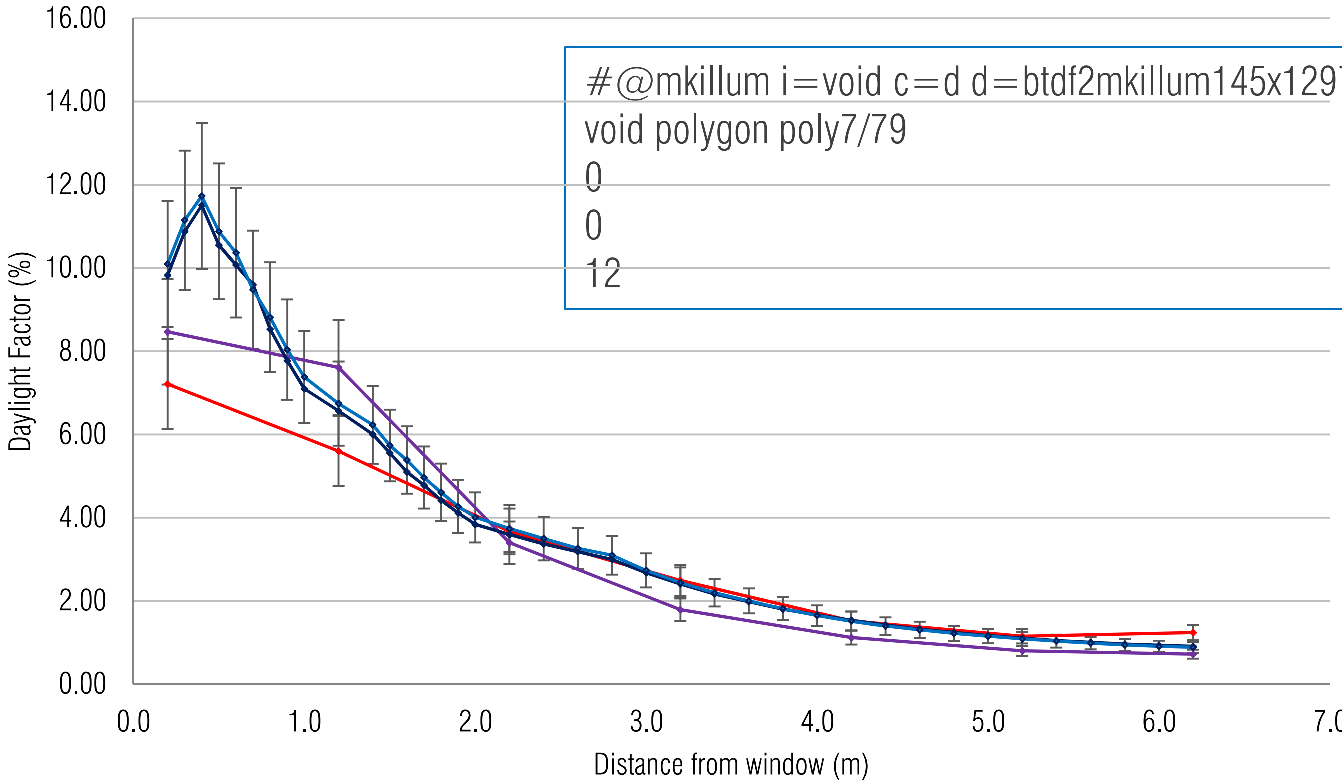
Work performed by: Anothai Thanachareonkit
EPFL LESO-PB 2008

Lasercut panel

b) BTDF data

```
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercutBTDF_1297.rad > base_D_0.oct
```

```
#@mkillum i=void c=d d=btdf2mkillum145x1297_LCP.xml s=40000 l+ u=+Z
void polygon poly7/79
0
0
12
```



A) Real Building (real sky)

A) Case D simulated st. Sky (lasercutpanel.cal)

2) ovc lasercut.rad prism2 (btdf2prism2_lcp.cal)

3b) ovc LCP_BTDF.rad (btdf2mkillum145x1297_LCP.xml)

Computing Time

~64h

Case D: simulated st. Sky (LaserCutPanel.cal)

Vs.

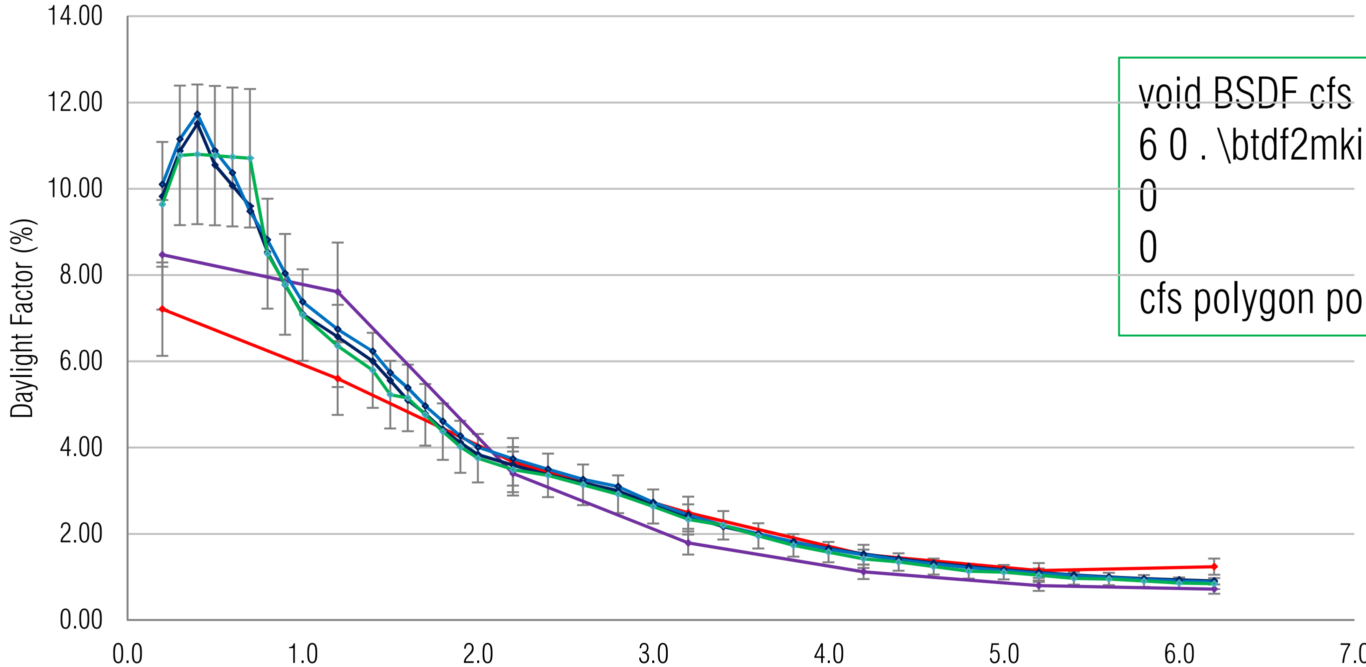
Ovc_LCP_BTDF.rad (btdf2mkillum145x1297_lcp.xml)

c) *bsdf* material

Lasercut panel

```
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercutBSDF.rad > base_D_1.oct
```

```
void BSDF cfs
6 0 . \btdf2mkillum145x1297_LCP.xml 0 0 1.
0
0
cfs polygon poly7/79
```



A) Real Building (real sky)

A) Case D simulated st. Sky (lasercutpanel.cal)

2) ovc lasercut.rad prism2 (btdf2prism2_lcp.cal)

3b) ovc LCP_BTDF.rad (btdf2mkillum145x1297_LCP.xml)

4b) ovc LCP_BSDF (btdf2mkillum145x1297)

Case D: simulated st. Sk
y (lasercutpanel.cal

Vs.

Ovc_LCP_BSDF.rad
(btdf2mkillum145x1297_lcp.xml)

Computing Time
60h

d) *bsdf* material + mkillum

Lasercut panel

```
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercutBSDF_MK.rad > base_D_0.oct
```

```
void BSDF cfs
6 0  . \btdf2mkillum145x1297_LCP.xml 0 0 1.
0
0

#@mkillum i=cfs d=223 s=115 m=window4
cfs polygon poly7/79
```

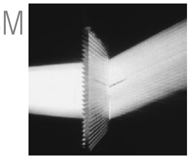
Case D: simulated st. Sky
(LaserCutPanel.cal)

Vs.

Ovc_LCP_BSDF_MK.rad
(btdf2mkillum145x1297_lcp.xml)

3. CFS: Prismatic Film 3M exterior

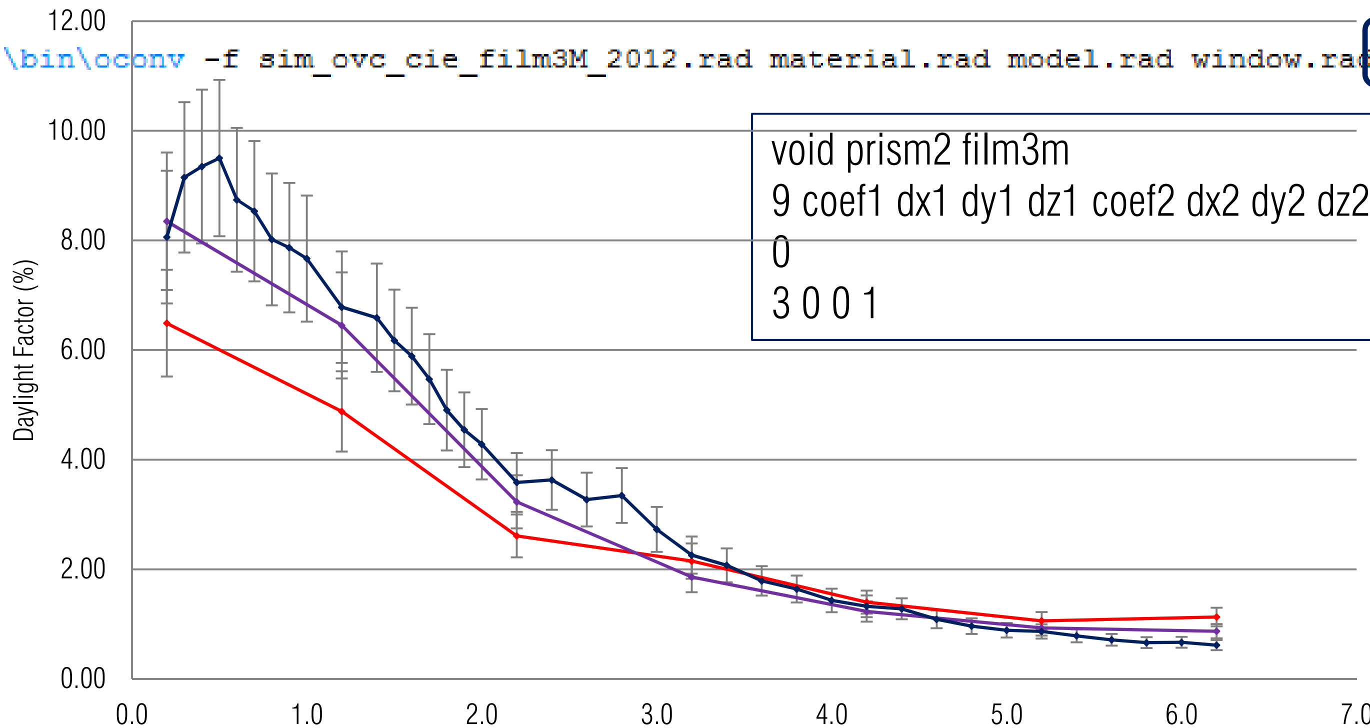
Prismatic Film 3M



a) primitive *prism2*

```
.\bin\oconv -f sim_ovc_cie_film3M_2012.rad material.rad model.rad window.rad film3M.rad > base_D_0.oct
```

```
void prism2 film3m
9 coef1 dx1 dy1 dz1 coef2 dx2 dy2 dz2 btdf2prism2_film3Mext.cal
0
3 0 0 1
```



—A) Real Building (real sky)

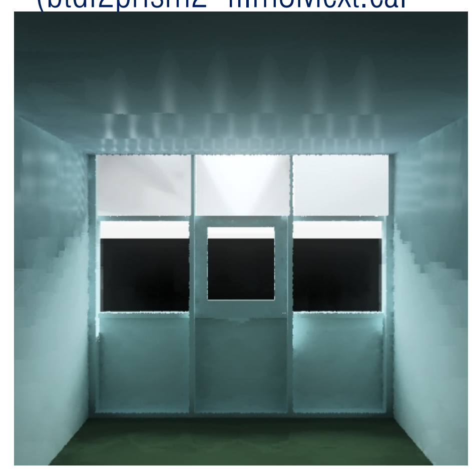
—A) Case D simulated st. Sky (film3M.cal)

—2) ovc film3M.rad prism2 (btdf2prism2_film3Mext.cal)

Case D: simulated st. Sky (Film3M_Int.cal)

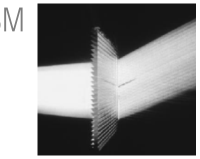
Vs.

Ovc_lasercut.rad prism2 (btdf2prism2_film3Mext.cal



Computing Time
76h

Prismatic Film 3M



b) BTDF data

```
.\bin\oconv -f sim_ovc_cie_film3M_2012.rad material.rad model.rad window.rad film3MBTDF_1297.rad > base_D_0.oct
```

```
#@mkillum i=void c=d d=btdf2mkillum145x1297_film3Mext.xml s=40000 l+ u=+Z
void polygon poly7/79
```

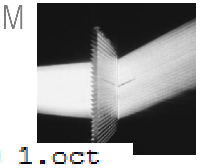
Case D: simulated st. Sky
(film3M_Int.cal)

Vs.

Ovc_film3M_BTDF.rad
(btdf2mkillum145x1297_film3Mext.xml)

c) *bsdf* material

Prismatic Film 3M



```
.\bin\oconv -f sim_ovc_cie_film3M_2012.rad material.rad model.rad window.rad film3MBSDF.rad > base_D_1.oct
```

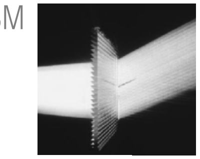
```
void BSDF cfs
6  0 .\btdf2mkillum145x1297_film3Mext.xml 0 0 1 .
0
0
cfs polygon poly7/79
```

Case D: simulated st. Sky (lasercutpanel.cal

Vs.

Ovc_film3M_BSDF.rad (btdf2mkillum145x1297_film3Mext.xml)

Prismatic Film 3M



d) *bsdf* material + mkillum

```
.\bin\oconv -f sim_ovc_cie_film3M_2012.rad material.rad model.rad window.rad film3MBSDF_MK.rad > base_D_0.oct
```

```
void BSDF cfs
6 0 .\btdf2mkillum145x1297_film3Mext.xml 0 0 1.
0
0
#@mkillum i=cfs d=223 s=115 m=window4
cfs polygon poly7/79
```

Case D: simulated st. Sky
(Film3M_Int.cal)
Vs.
Ovc_film3M_BSDF_MK.rad
(btdf2mkillum145x1297_film3Mext.xml)

4) Preliminar conclusions

1) The results obtained in this verification suggests that the use of the procedures available today **are reliable**.

2) Results using the new procedures were slightly closer to those using the primitive ***prism2*** when simulating sharp redirecting CFS than when simulating less sharp redirecting CFS.

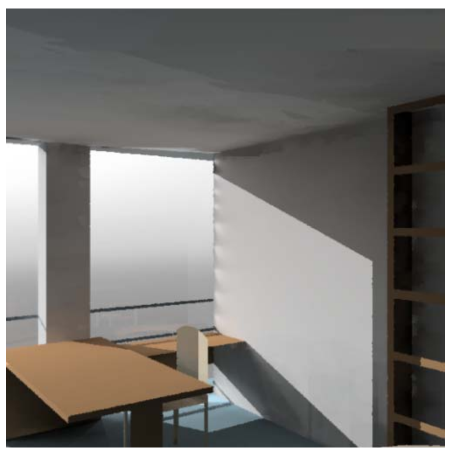
3) **Computing time** doesn't increase when applying Window 6 XML file, and in some cases its even reduced.

4) The use of the new available procedures gives the possibility of testing more CFS as allows the use of not only sharp redirecting CFS.

5) Future Work

a) Tec de Monterrey -Private University-


b) Centro de Estudios del Desarrollo (UAZ) –Research Center-

PRESENT WORK

*Illuminance and Luminance measurements were already taken on-site during winter and summer solstice (clear and overcast sky conditions)

*Calibration of the virtual model: ongoing process

NEXT:

*Testing of different CFS on both virtual models:

-LCP
-Prismatic Film 3M interior and exterior
-Light channeling panel
-Sun directing Glass (lumitop)
-Others

Thank you!