Lucerne University of
Applied Sciences and Arts

HOCHSCHULE
LUZERN

Technik & Architektur

Measurement and modeling of a daylight redirecting component

Lars O. Grobe[1], Katrin Müllner[2], Stephen Wittkopf[1]
[1] Competence Centre Envelopes and Solar Energy (CC-EASE)
[2] Transsolar Energietechnik GmbH

13th International RADIANCE Workshop 2014
London, UK

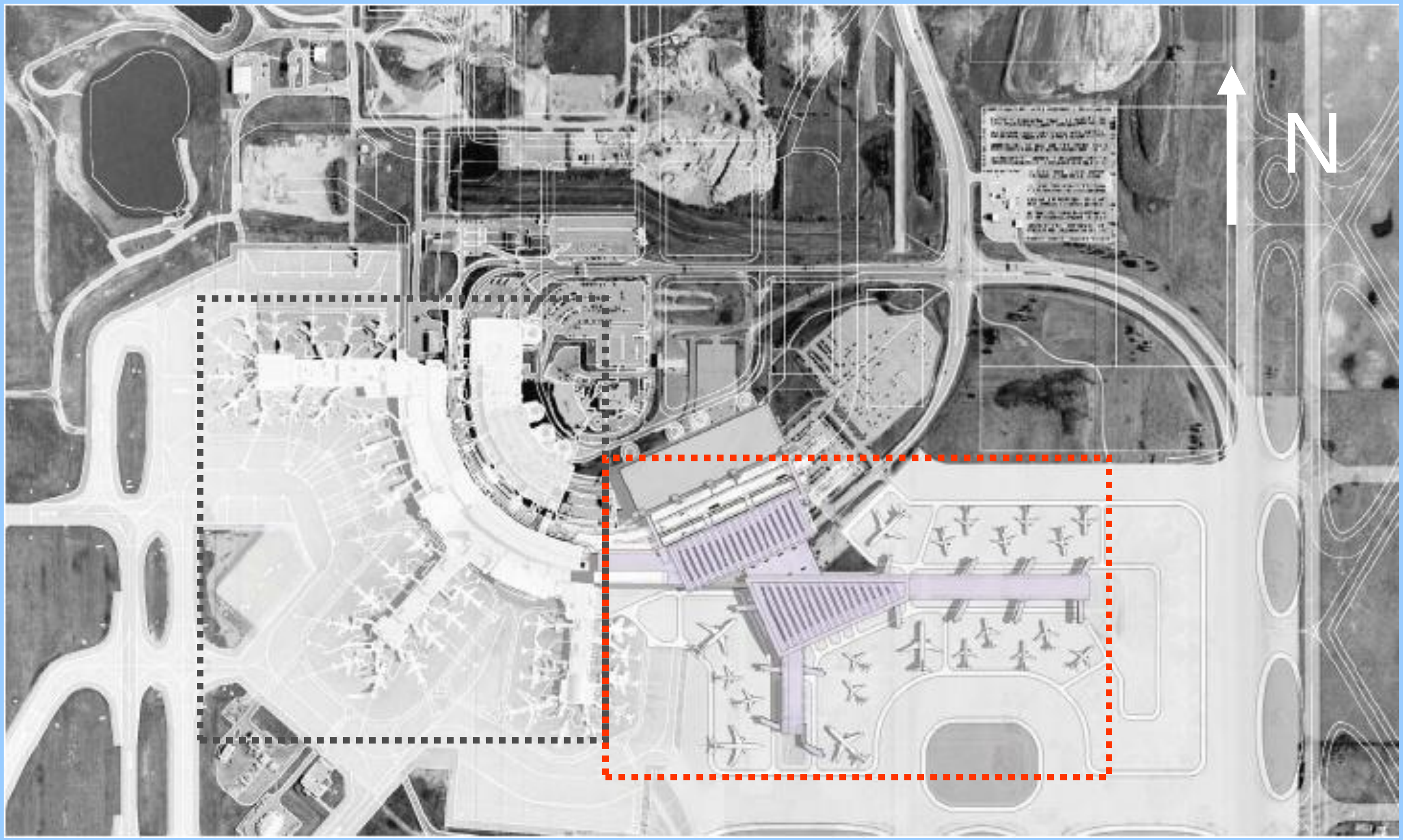
Outline

- Application: airport design
  - Role of daylight in the design
  - Controlling irradiance and daylight with glazing
- Sample: a light redirecting mirror array
- Characteristics: available data and measurements
- Modeling: modeling strategies with Radiance
  - Measured data and the data-driven BSDF modifier
  - Geometric model and genBSDF
  - Geometric model and the Radiance Photon Map extension
- Comparison
- Conclusion

Application: Calgary Airport Expansion

IFP, International Facilities Project

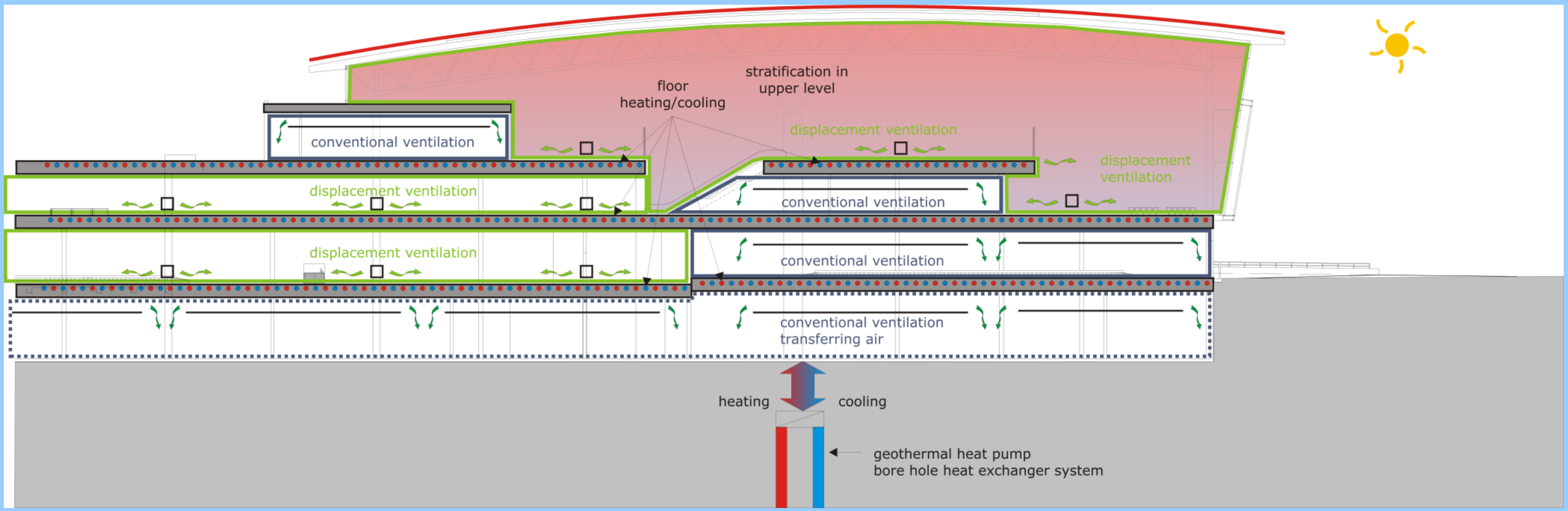
Architects: DIALOG, Calgary
Structure: RJC, Calgary
Climate/Energy: Transsolar, Munich
Mechanical / Electrical: AECOM, Calgary
Opening: fall 2015



Existing Terminals A – D
1977 - 2004
Net area: 141‘000 m²

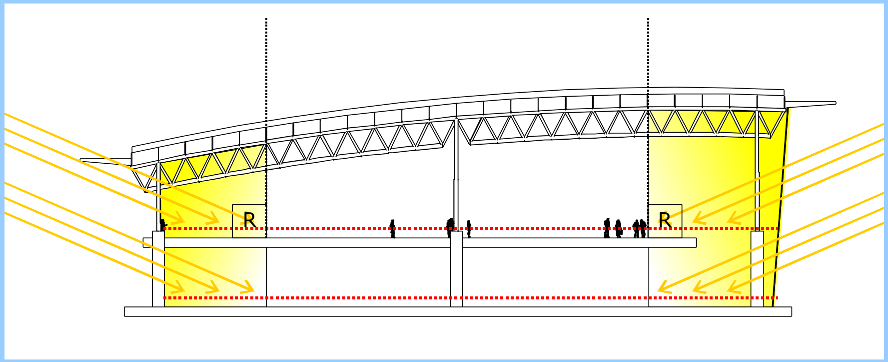
Expansion: IFP Terminal
2015
Net area: 144‘000 m²

Climate- and Energy Concept

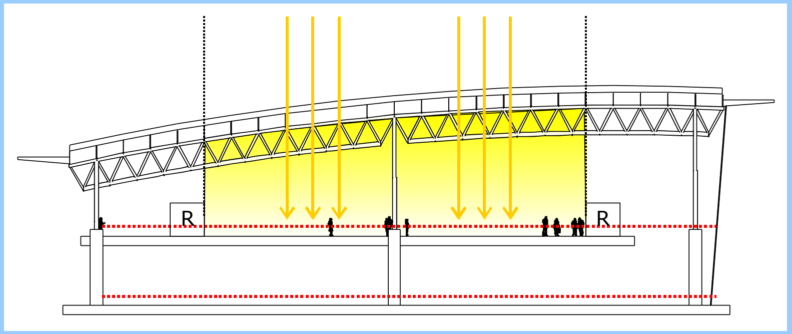


Daylight Concept: Optimize natural daylighting

reduce Energy Consumption

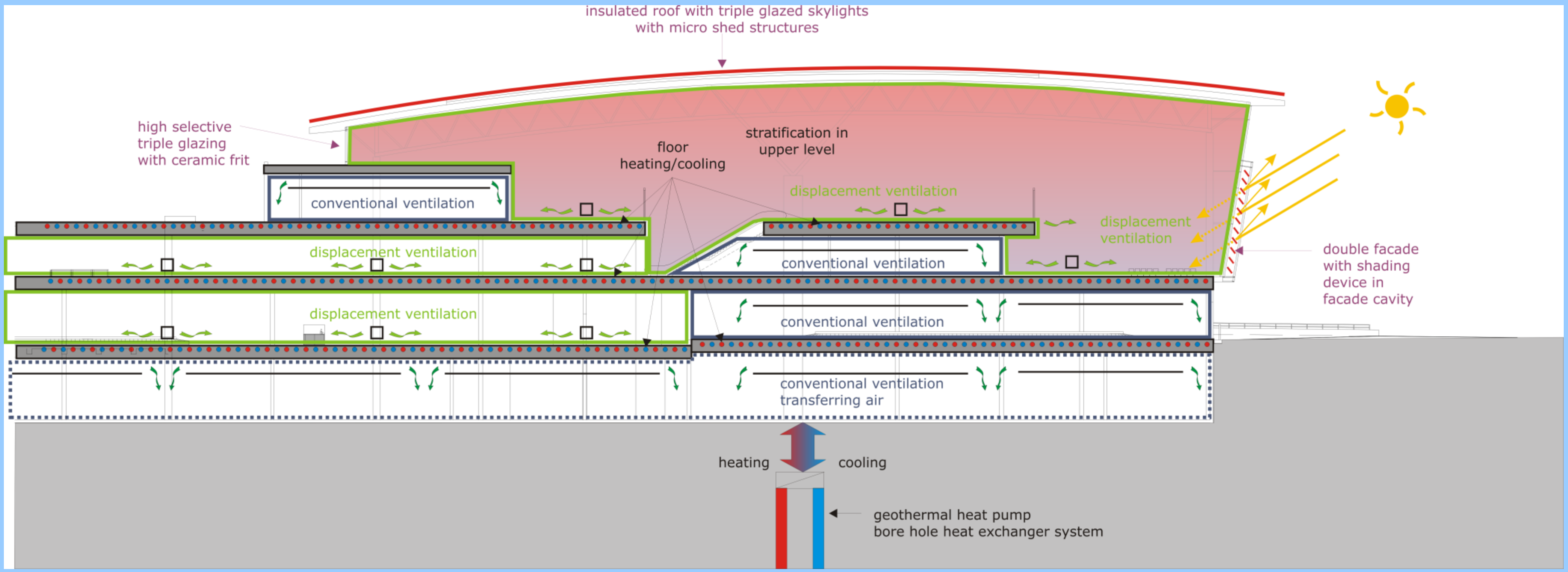


Daylight for perimeter zones via facades



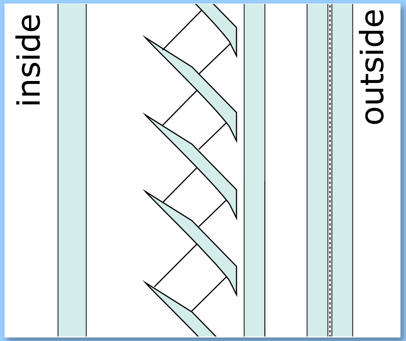
Daylight for central areas via skylights

Climate- and Energy Concept



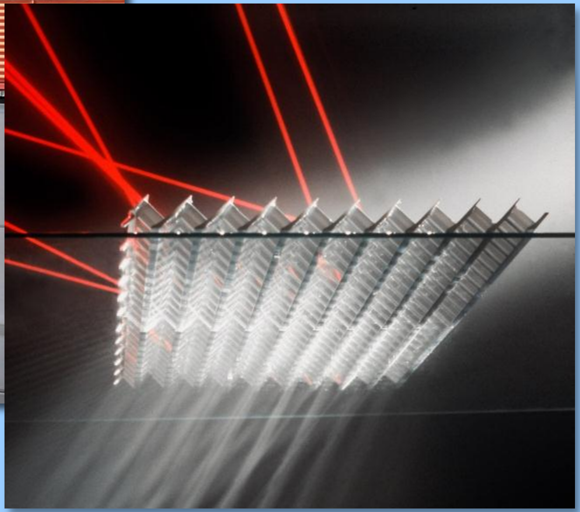
Sample: a light redirecting mirror array

Test module of the mirror grid.

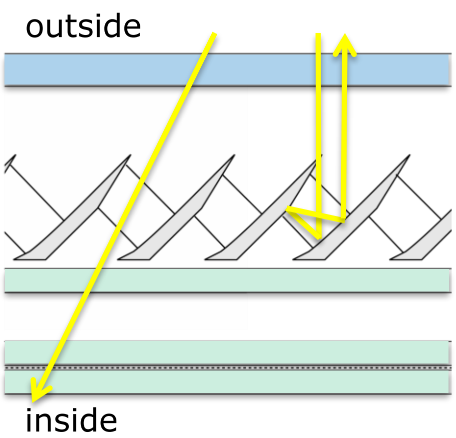


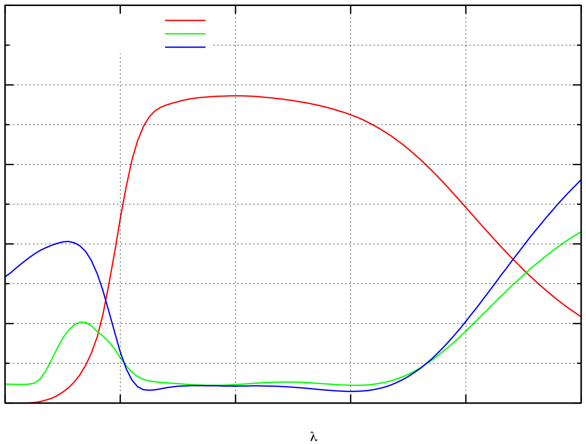
Section.

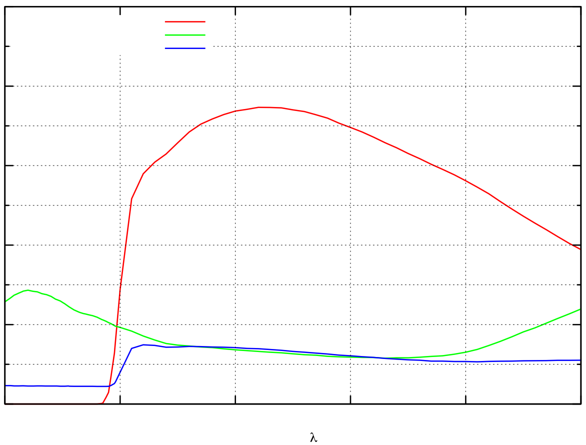
Mirror inlet.



Characteristics: available data







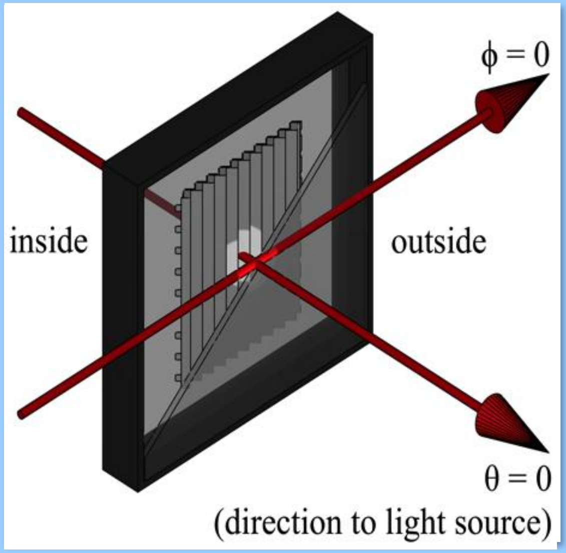
Available properties of the module: Glazing composition and transmission / reflection spectra of glass layers.

- Composed of three glass layers (one being laminate) and mirror inlet
- Mirror inlet geometry provided by manufacturer
- Glass properties from International Glazing Database (IGDB), Optics6

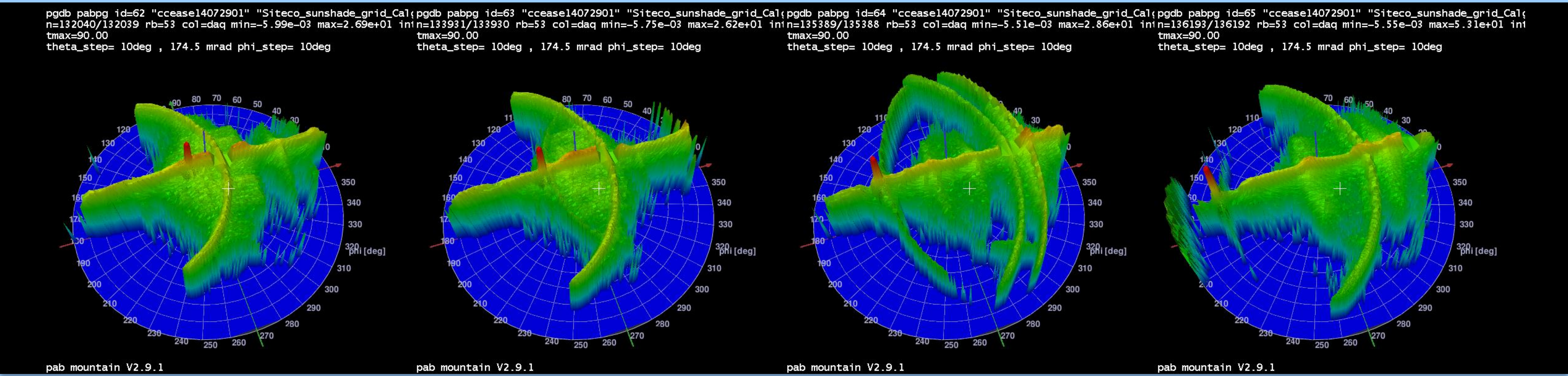
Characteristics: measurements

- Bidirectional Scatter Distribution Function
  BSDF(θ_{in},ϕ_{in},θ_{out},ϕ_{out})

- Scanning Goniophotometer by PAB
  at Lucerne University of Applied Sciences & Arts



Outgoing distributions of the mirror grid



Daylight redirecting structure. BSDF x cos (θ_{out}) for φ_{in}=0, θ_{in}=10, 20, 40 and 60 degrees.

- Visualizations of the outgoing distribution for each incident direction, interpolation by Delauny triangulation

- Projection of the transmission / reflection hemisphere of outgoing directions: – φ_{out} as azimuth angle, θ_{out} as radius

Modeling: modeling strategies with Radiance

- The distribution does not follow assumptions by any analytical model

- Radiance offers three modeling approaches:

  - Interpolation of measured data, variable-resolution BSDF *pabopto2bsdf*
    - \+ Data-driven BSDF includes any information in the measurement
    - \- High number of measurements of varying incident direction needed

  - Computation of BSDF from geometric model of the structure *genBSDF*
    - \+ Replaces geometric detail in the scene by its resulting BSDF
    - \- Any mistakes in generating the BSDF lead to entirely wrong result

  - Direct use of geometric model with added forward pass *mkpmap*
    - \+ No preprocessing, no risk of applying BSDF with wrong orientation
    - \- Keeps all geometric detail in the scene

Measured data and the data-driven BSDF modifier

- Measured distributions (one for each incident direction to interpolant SIR

```
pabopto2bsdf -n 4 0*_*_r.dat > 000_070_r.sir
pabopto2bsdf -n 4 0*_*_t.dat > 000_070_t.sir
pabopto2bsdf -n 4 1*_*_r.dat > 110_180_r.sir
pabopto2bsdf -n 4 1*_*_t.dat > 110_180_r.sir
```

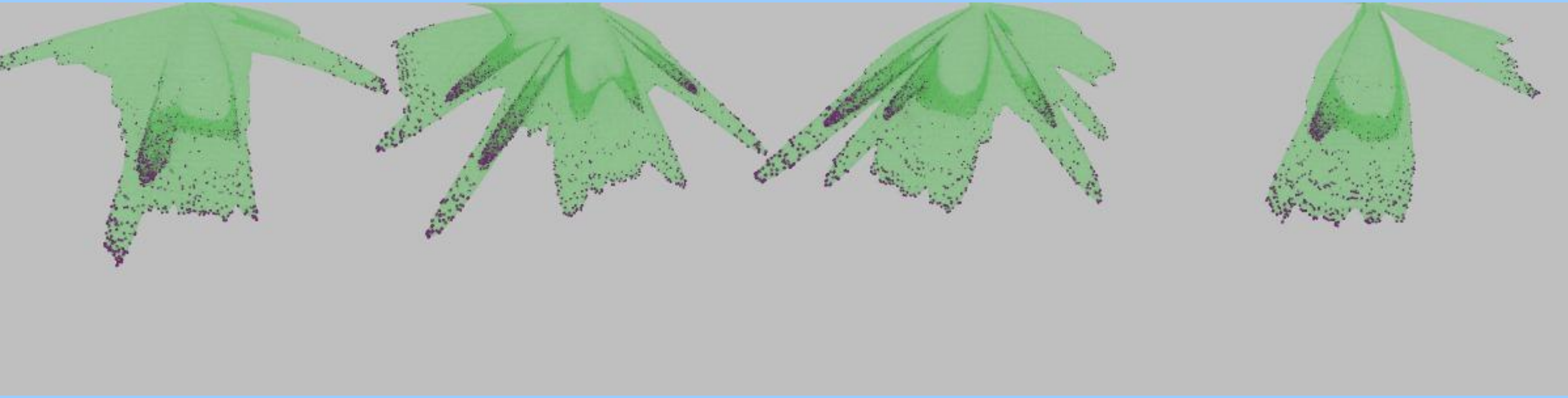
`-n <N>`: number of processes
`<.dat>`: distribution in pab-format

- Interpolation and data-reduction to BSDF in XML-format

```
bsdf2ttree -g 7 -t 85 000_070_r.sir 000_070_t.sir \
110_180_r.sir 110_180_t.sir > g7_t85.xml
```

`-g <N>`: initial tensor tree resolution 2^N
`-t <N>`: remove N % of data from tensor tree when adapting resolution

Measured data and the data-driven BSDF modifier



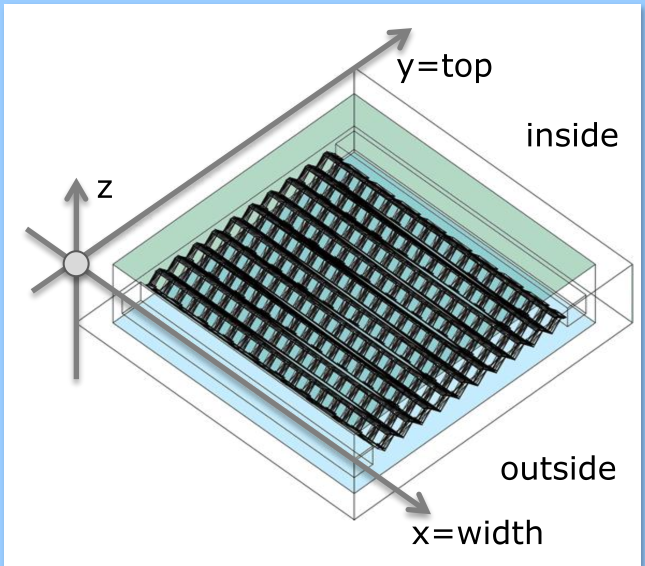
Geometric model and genBSDF

- genBSDF can compile BSDF of either variable resolution or based on Klems

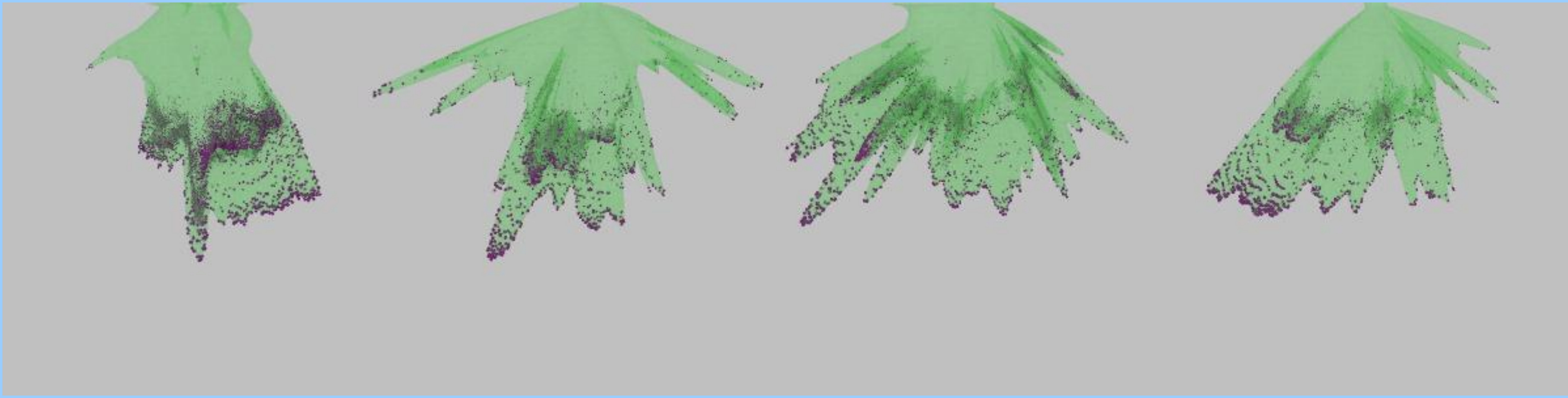
```
genBSDF -c 10240 -n 12 -t4 6 +f +b +geom meter \
-dim -.1 .1 -.1 .1 -.063 0 module_genBSDF.rad > c_10240_t4_6.xml
```

`-c <N>`: number of samples
`-t4 <N>`: anistropic 4D BSDF, 2^N incident x 2^N outgoing directions
`-f+`: front side BSDF `-b+`: back side BSDF `-geom <unit>`: units
`-dim <xmin> <xmax> <ymin> <ymax> <zmin> <zmax>`:
bounding box computation of BSDF

- Beware.... genBSDF expects specific orientation:



Geometric model and genBSDF



Geometric model and the Radiance Photon Map extension

- Most transparent approach – just model the fenestration as anything else

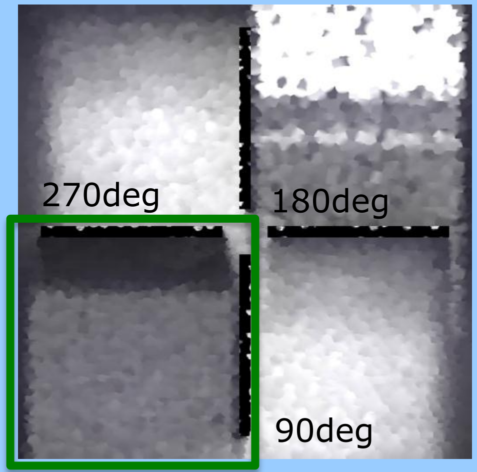
- Use of photon ports to „guide“ photons into the space of interest

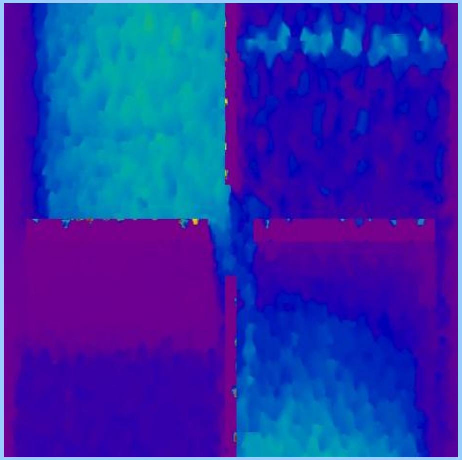
- Example: 1M global, 8M caustic photons:

```
mkpmap -apo photonPortMat \
-apg pmap/global.pmap 1M -apc pmap/caustic.pmap 8M \
oct/module_pmap.oct
```

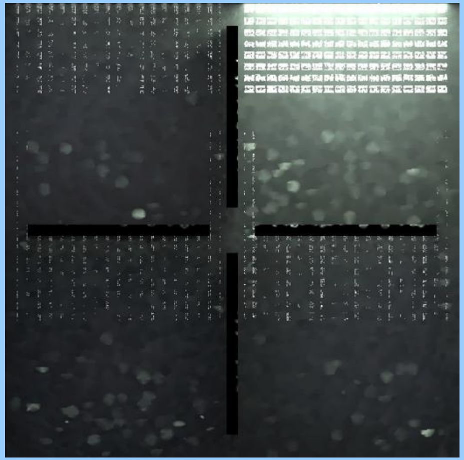
Comparison

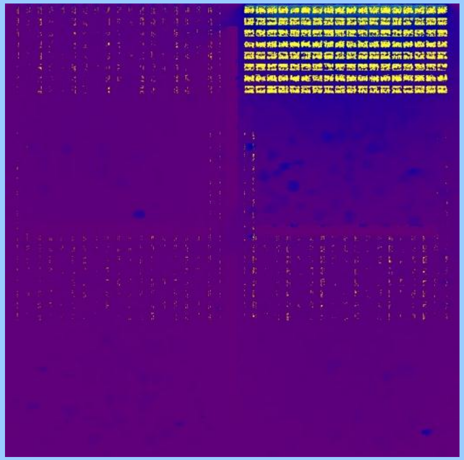
Interpolated measurement



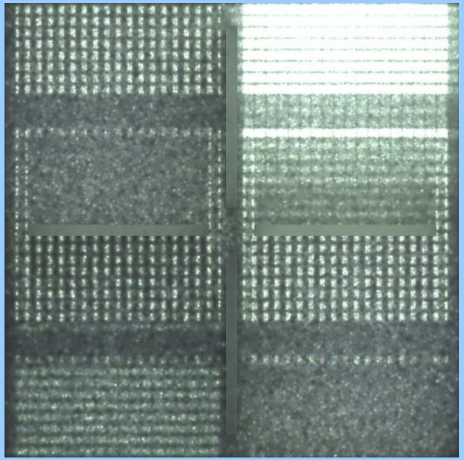


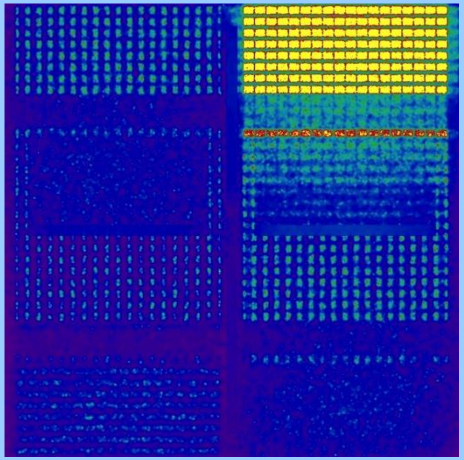
genBSDF





Photon map





Conclusion

- Recent developments in Radiance provide us with working methods to model daylight redirecting components

- genBSDF, photon map and interpolated measured BSDF lead to qualitatively comparable results – even for more complex systems

- Geometry will still be required to consider detail of glazing systems, as Radiance does not support spatially resolved BSDF

- Measurements are required to make data-driven BSDF models available and to evaluate computation-based models (genBSDF)

Thank you for your attention!

larsoliver.grobe@hslu.ch, +41 41 349 36 32
muellner@transsolar.com, +49 89 590 688 49

Supported by the Swiss National Science Foundation