Lucerne University of
Applied Sciences and Arts

HOCHSCHULE
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Engineering & Architecture

Complex fenestration & Radiance - a reality check from a user's point of view

A contribution to discuss...

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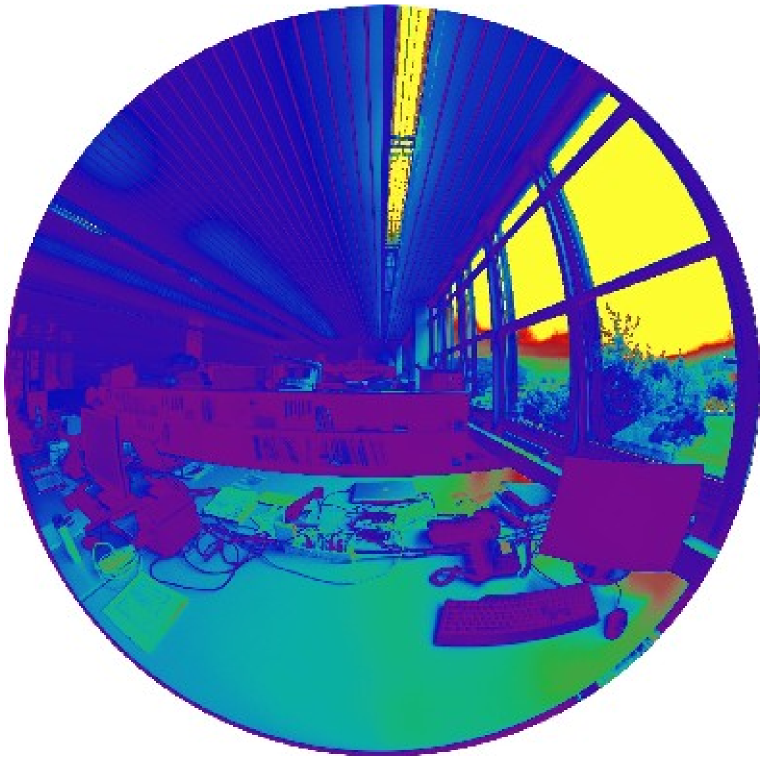
Objectives

- Review current workflows available in Radiance for modelling complex fenestration in Radiance.
- Identify missing pieces and obstacles in the puzzle of Radiance tools.
- Propose and discuss fields of future development.

Background

- Office spaces occupied at Lucerne University of Applied Scienes & Arts as a case study - currently facade variants are evaluated for later application
- Identification of potential development contributions by the Competence Centre Envelopes and Solar Energy

Luminance map using calibrated CCD camera:



Options review (examples)

- Coatings
- Blinds
  - Specularity, potential for light redirection
  - Integrated into glazing, internal or external, control
- Light shelves
  - Orientation (vertical / horizontal)
  - Reflective properties (scatter)
  - Shape (planar or curved)
- Fabrics
  - View-through, glare, transmission dependent on solar altitude

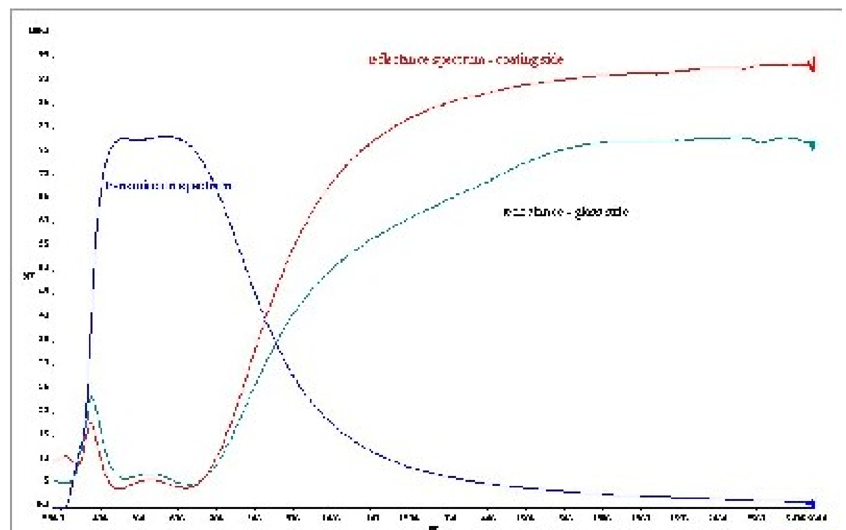
Modelling and simulation options in Radiance

- Coatings: Glass using values measured or taken from IGDB
- Blinds
  - If diffuse metal, plastic with optional mkillum & classic bw-tracing
  - If specular, photon map (with metal, plastic) or genBSDF approach
- Light shelves
  - Mirror if flat with classical Radiance bw-tracing, not possible if curved
  - Metal with photon map for any flat or curved geometry
  - BSDF of complete fenestration system generated by genBSDF
- Fabrics
  - Trans, supported by classic bw-tracing, photon map or genBSDF

Coatings

- Coatings are considered in the definition of the glass material type
- The parameters can be exported from LBL Optics combining layers from the International Glazing Database (IGDB)
- There is currently no direct access to the IGDB from Radiance
- Radiance does not provide spectrally resolved rendering natively

Transmission and reflectrion spectra of coated glass (www.perkinelmer.com):



Blinds: diffuse

- Support for complex fenestration in Radiance has been around since 1991 (mkillum). Specular, non-planar surfaces were not supported.
- mkillum greatly facilitates simulations by pre-rendering the transmission through fenestration and excluding it from the final ambient calculation

Mkillum-supported rendering of a blinds system (Lucerne Univ. of Applied Sciences & Arts):

Blinds: specular

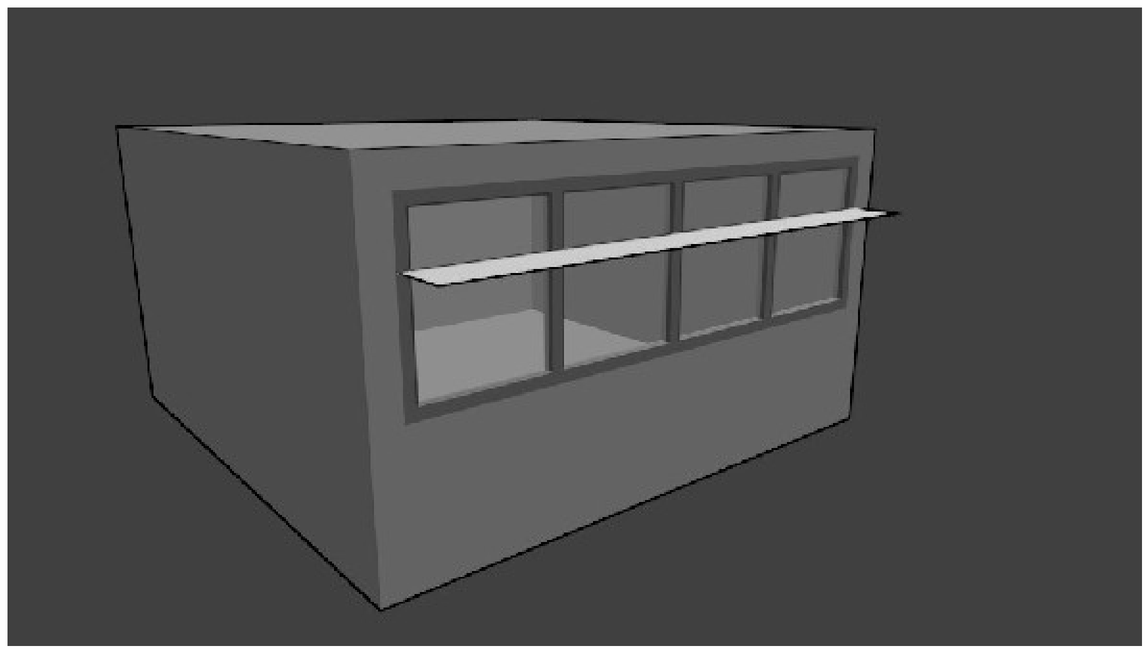
- Specular, curved blinds exposed to direct sunlight have been the typical use-cases for both the photon map extension and genBSDF / bsdf

Specular blinds system, rendered using photon map (image Jan Wienold FHG):

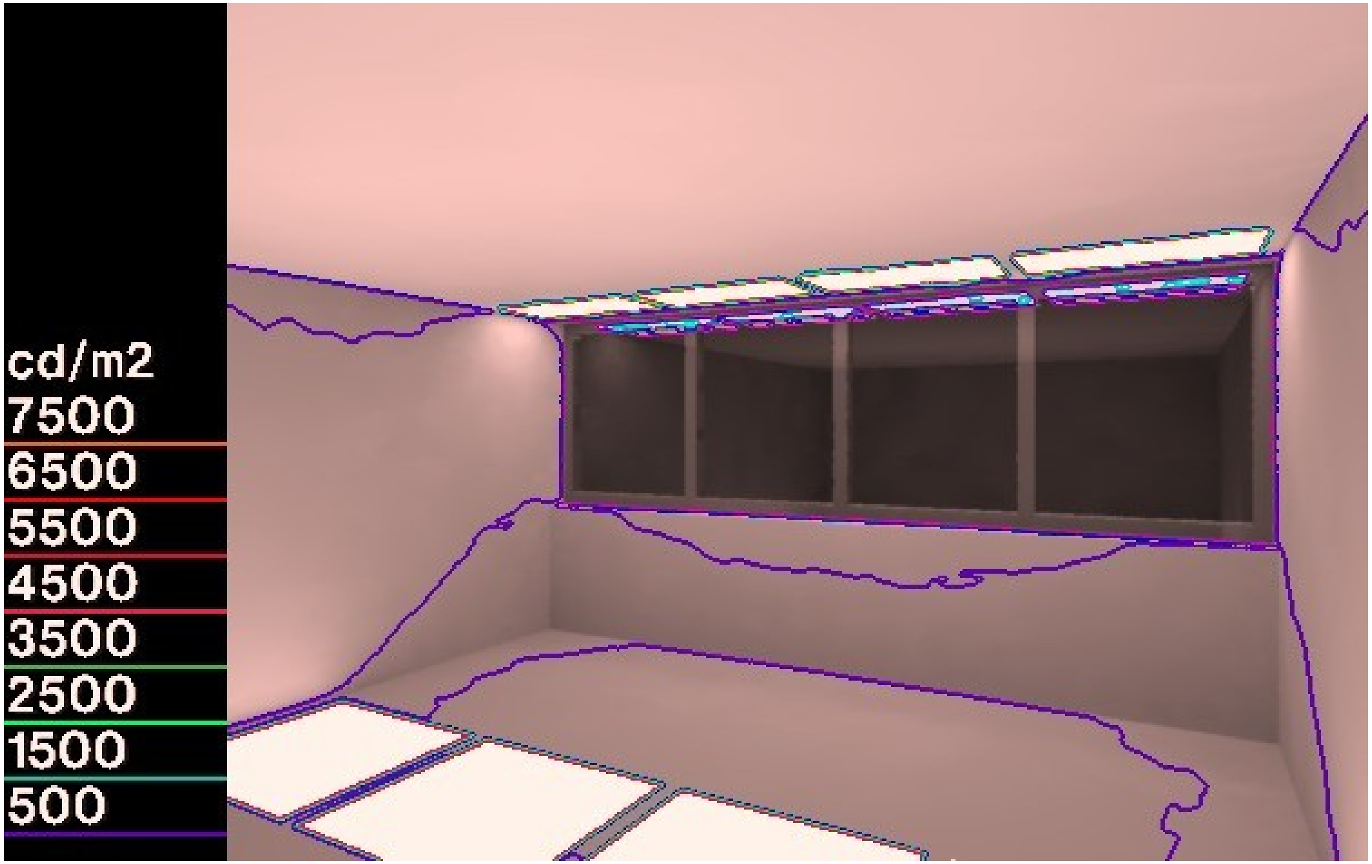
Light shelves: classic backwards Radiance example 1

- Works perfectly fine for flat geometry (mirror virtual light sources)
- No modifications to the model required

Simple test scene for classic bw-tracing:



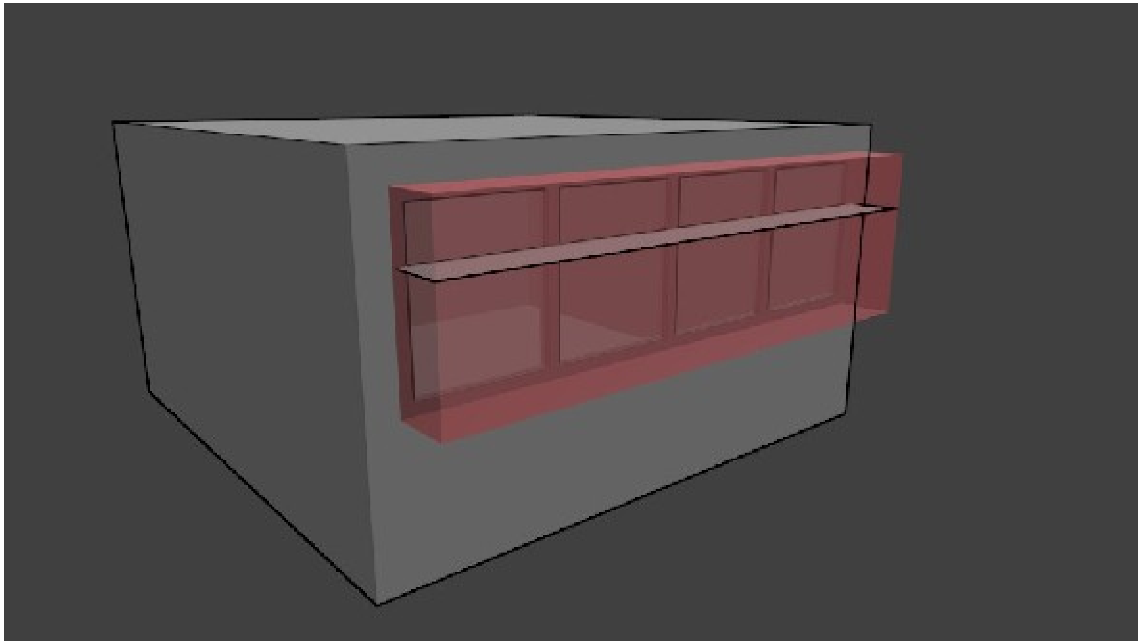
Light shelves: classic backwards Radiance example 2



Simple test scene for classic bw-tracing, clear aluminium mirror.

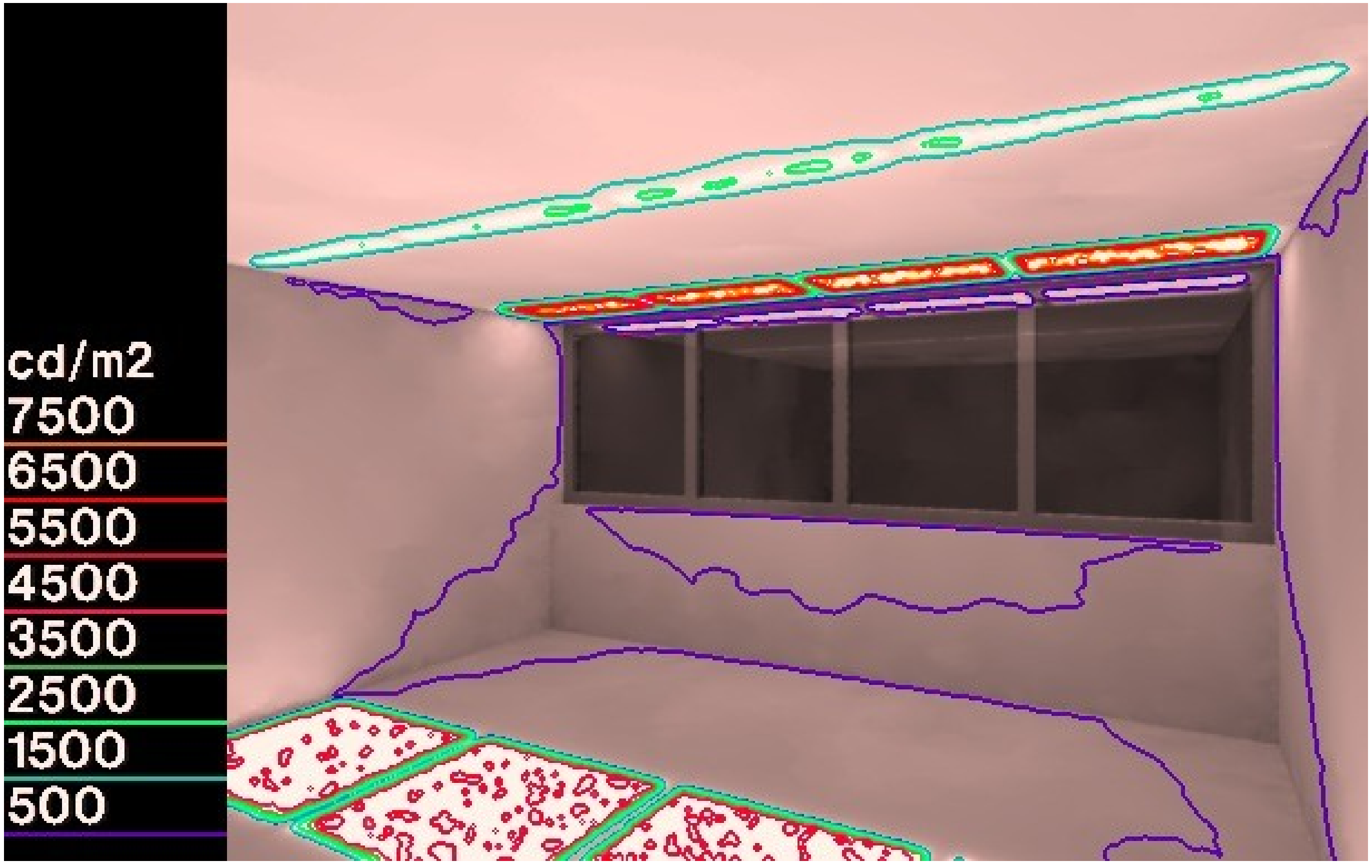
Light shelves: Photon map example 1

- No modifications required, light shelf modeled using metal material type
- Photon ports (red) added as an optimization for photon distribution



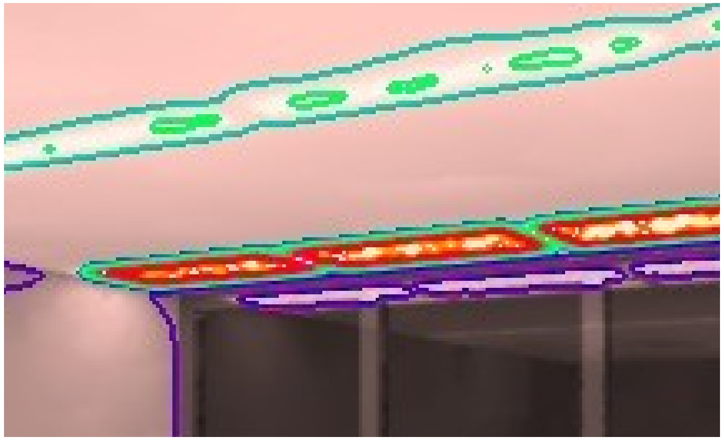
Simple test scene for
pmap fw-tracing:

Light shelves: Photon map example 2

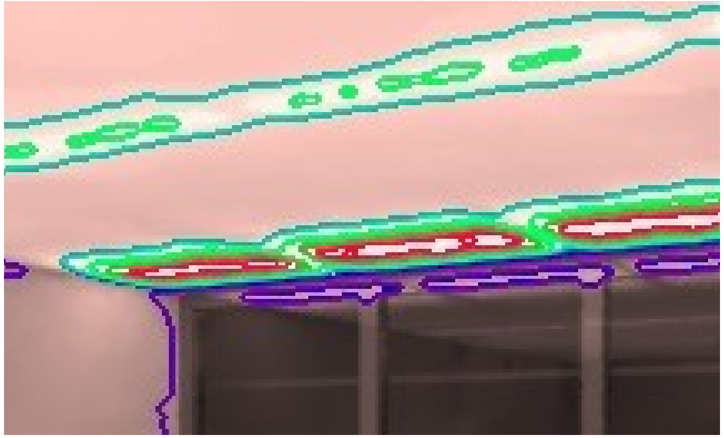


Simple test scene for pmap fw-tracing, clear aluminium mirror.

Light shelves: Photon map example 3



Detail for clear aluminium mirror.

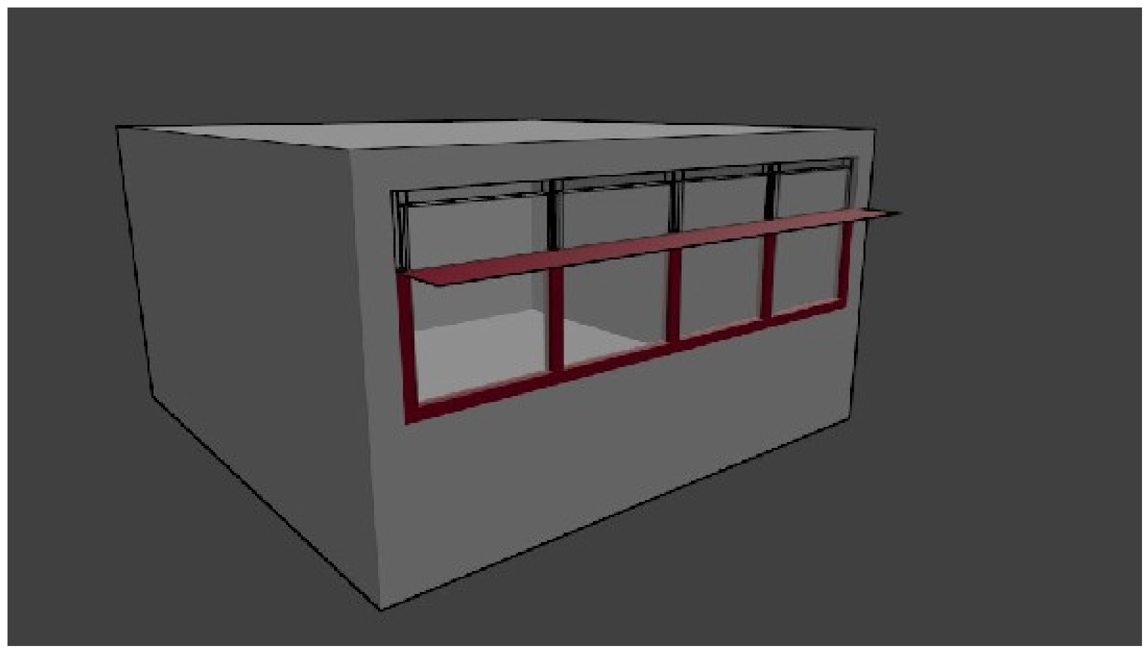


Detail for scatter aluminium mirror.

Light shelves: genBSDF example 1

- genBSDF calculates the BSDF of the fenestration system including the light shelf without virtual light sources, so curved shapes are possible
- As BSDF is averaged, manual subdivision of the fenestration is required

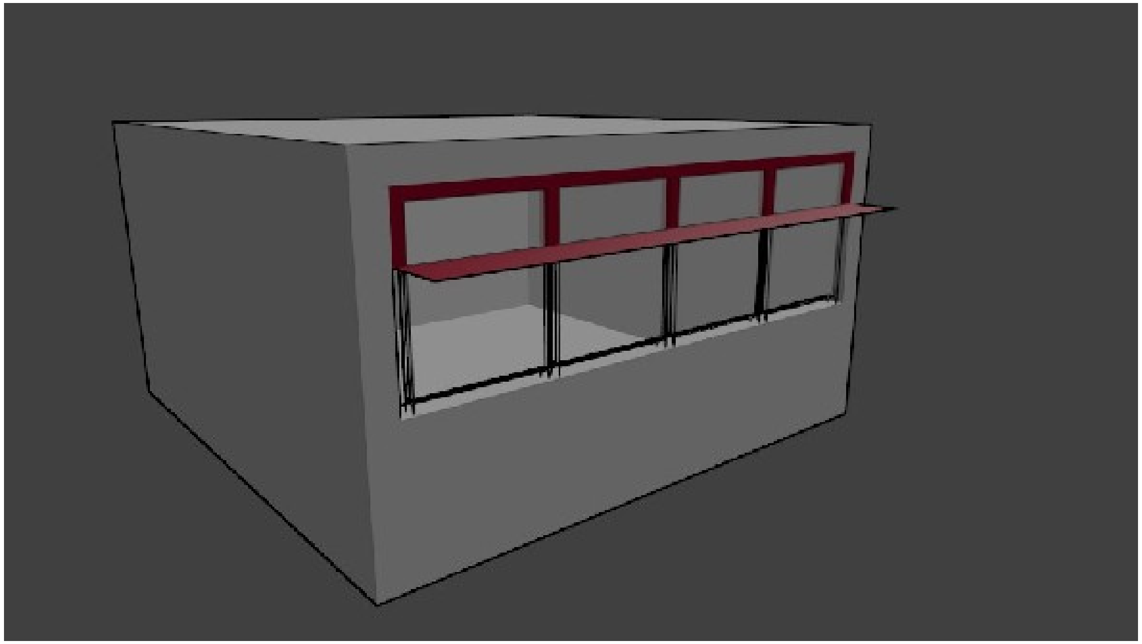
Simple test scene for genBSDF bottom part:



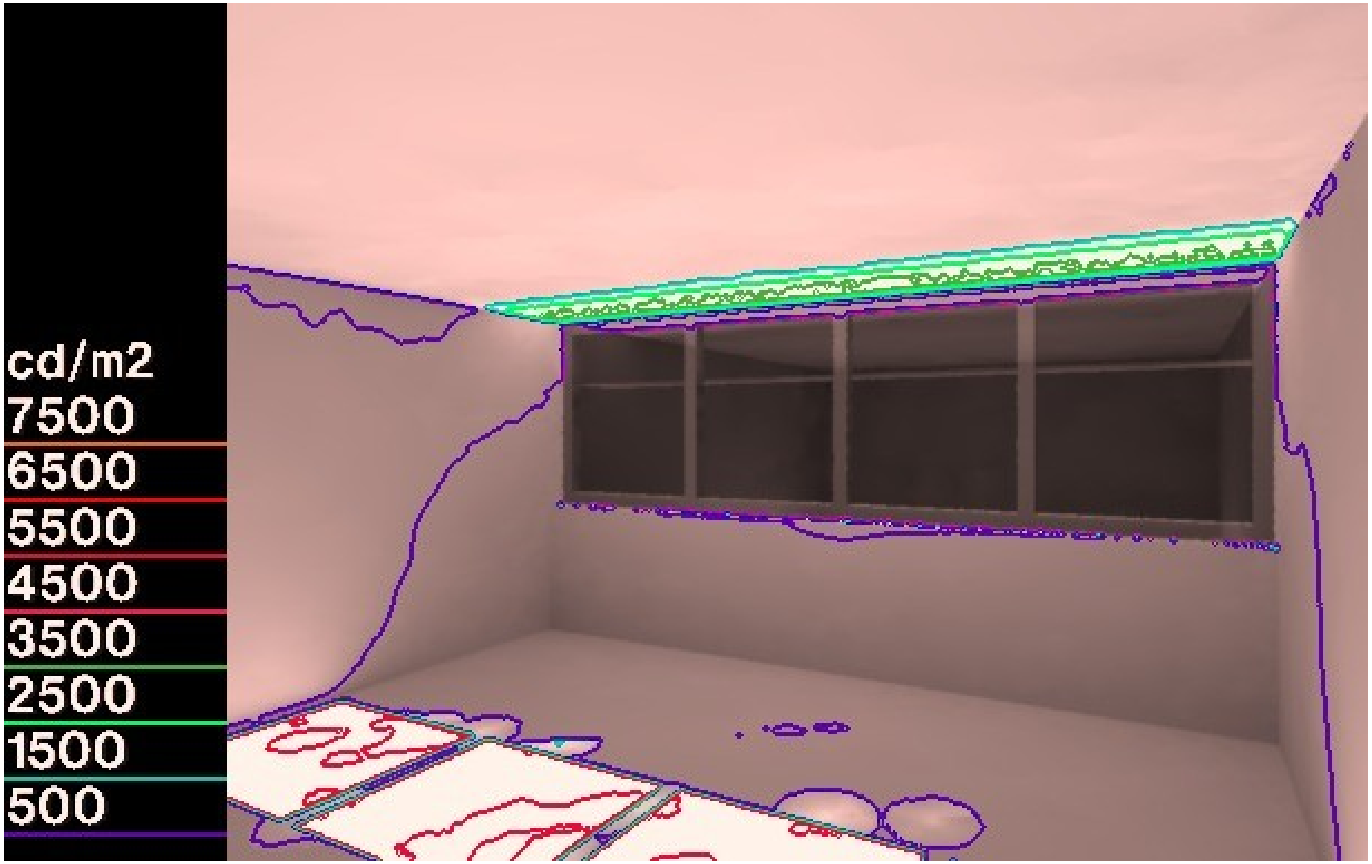
Light shelves: genBSDF example 2

- genBSDF calculates the BSDF of the fenestration system including the light shelf without virtual light sources, so curved shapes are possible
- As BSDF is averaged, manual subdivision of the fenestration is required

Simple test scene for genBSDF top part:

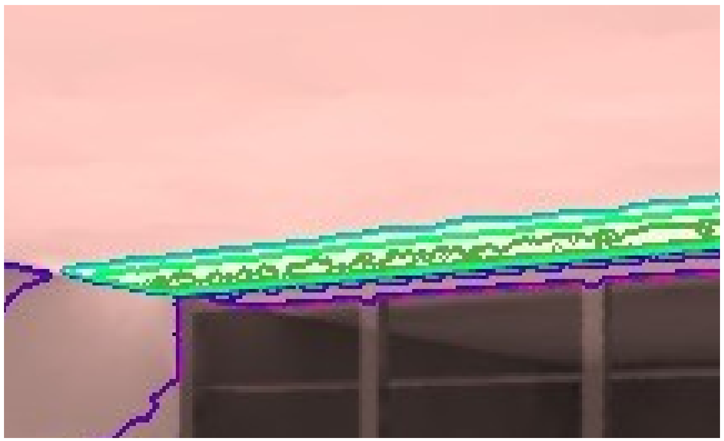


Light shelves: genBSDF example 3

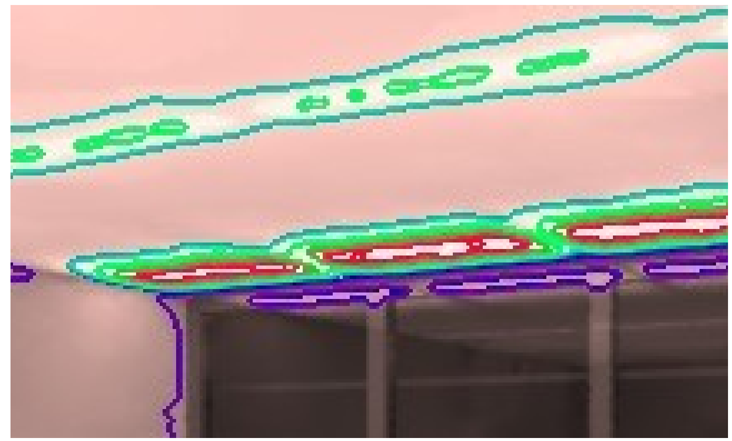


Simple test scene for pmap fw-tracing, scatter aluminium mirror.

Light shelves: genBSDF example 4



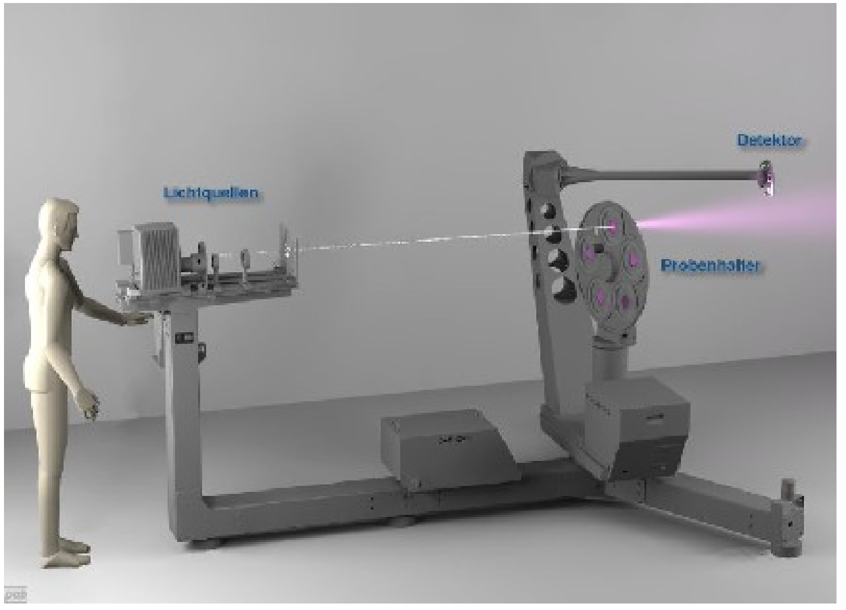
Detail for scatter aluminium mirror bsdf.



Detail for scatter aluminium mirror pmap.

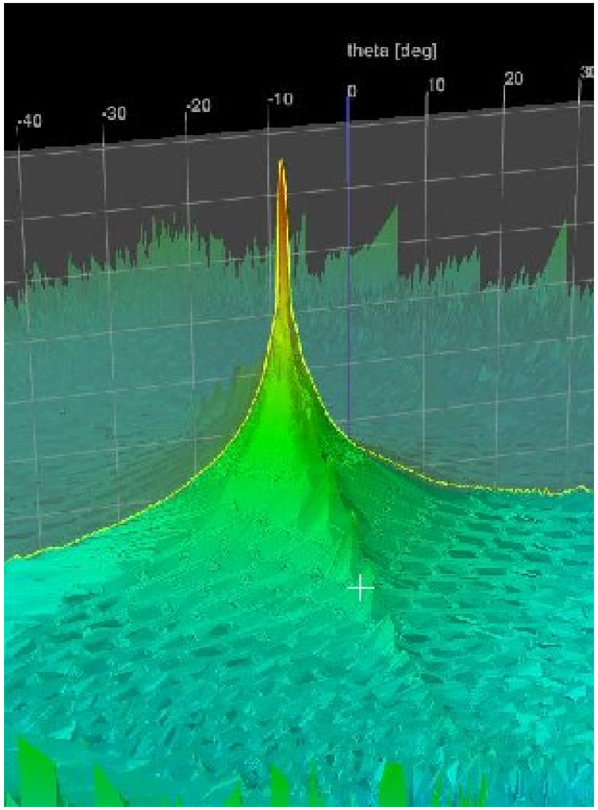
Light shelves: basic material definitions 1

- Regardless whether classic backwards Radiance, photon map or genBSDF are used, we rely on the basic metal material type
- To measure the scatter properties (and thus find A4 and A5 parameters of the metal material definition, full BSDF measurement were performed.

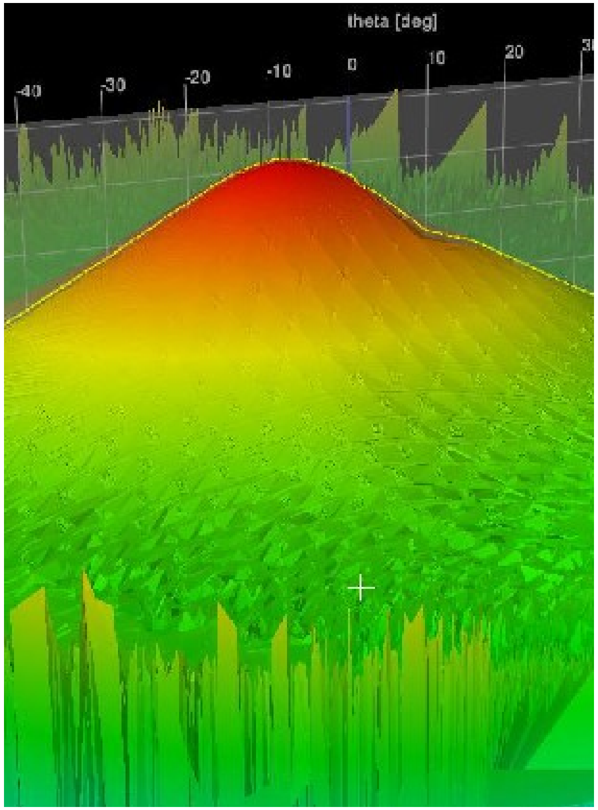


Scanning goniophotometer PAB pgII
(image: http://www.pab-opto.de)

Light shelves: basic material definitions 2



Reflection peak clear mirror (logscale).

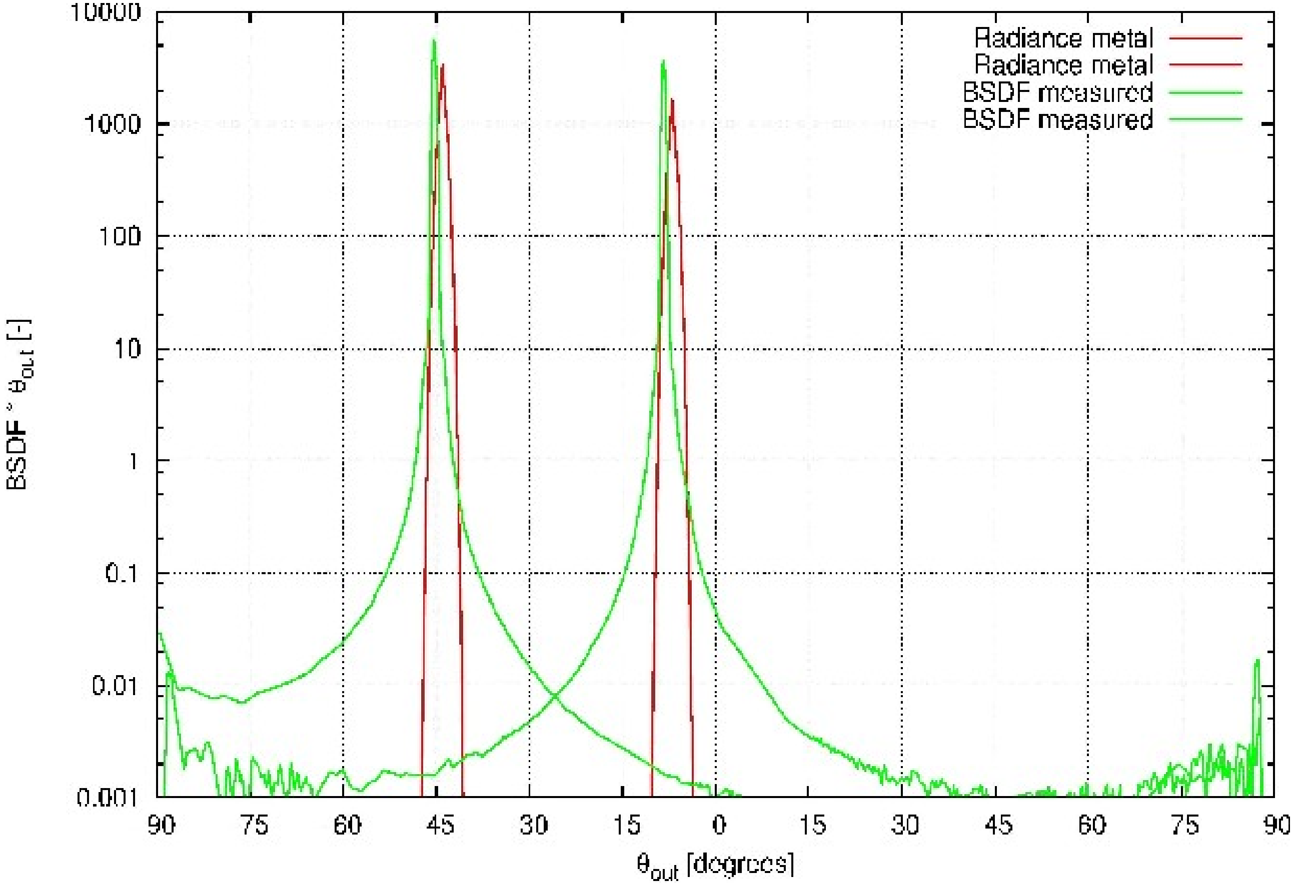


Reflection peak scatter mirror (logscale).

Thanks to Alanod for providing samples....

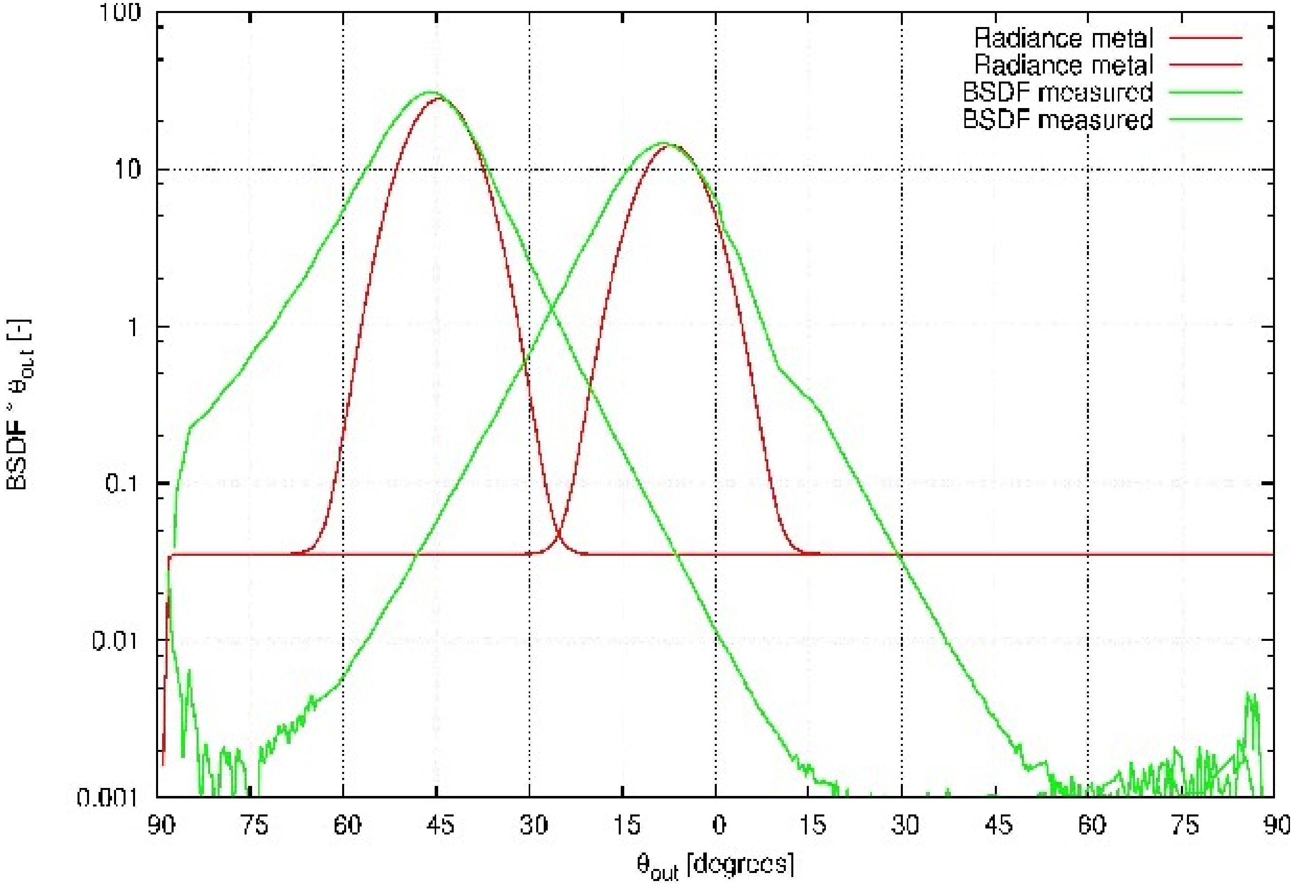
Light shelves: basic material definitions 3

- So how well does the metal model fit to data... clear mirror:



Light shelves: basic material definitions 4

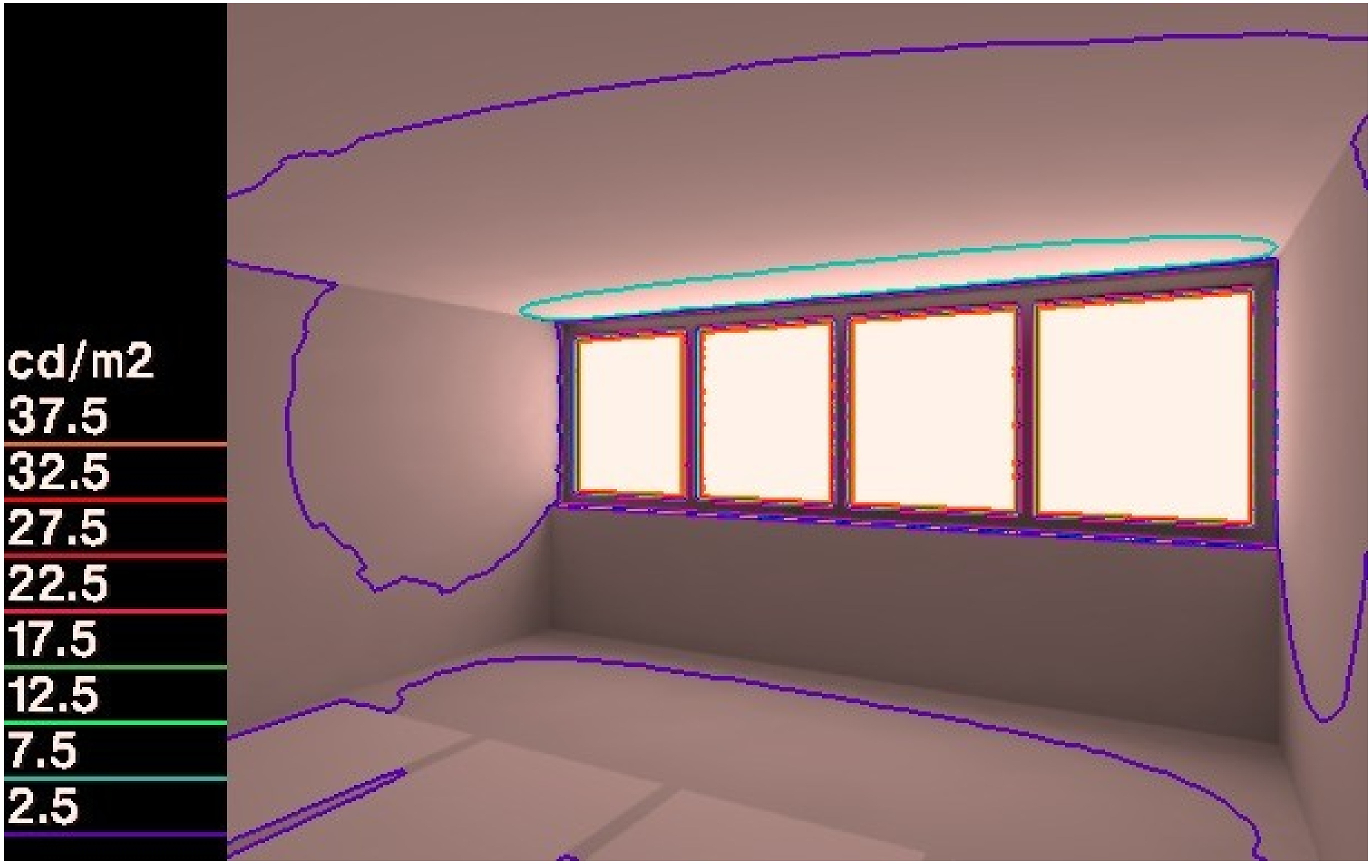
- So how well does the metal model fit to data... scatter mirror:



Light shelves: basic material definitions 4

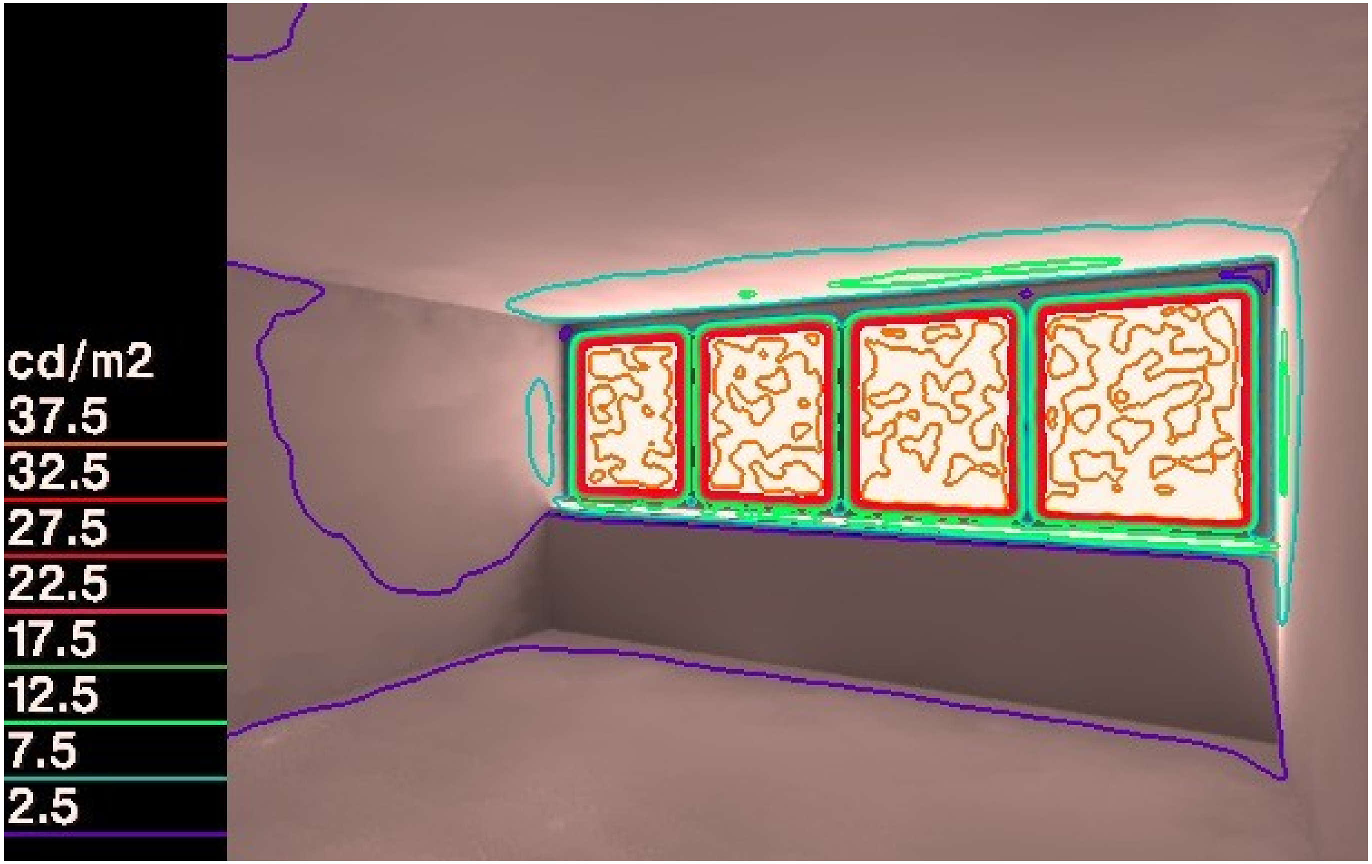
- Measured BSDFs of both samples do not match a gaussian specular peak
- For the scatter mirror, the fall-off closely follows a logarithmic function
- Fit compensates by a diffuse component for scatter mirror
- For typical simulations, this may not be relevant – but what about using this in genBSDF?
- **genBSDF results can not be more accurate then the underlying geometry and material models!**

Fabrics: classic backwards Radiance example 1



Simple test scene for Radiance bw-tracing, sunshade fabric.

Fabrics: Photon map example 1



Simple test scene for photon-map fw-tracing, sunshade fabric.

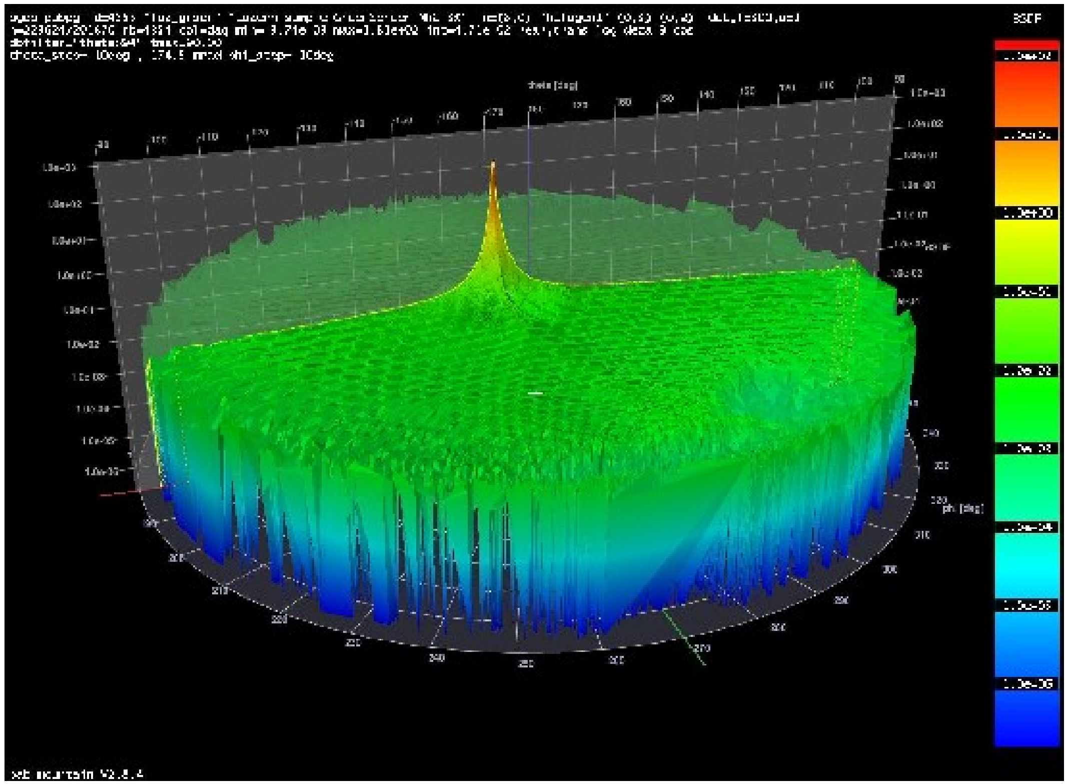
Fabrics: genBSDF example 1

Simple test scene for genBSDF, sunshade fabric.

Fabrics: basic material definitions 1

- All the algorithms support the trans material type and produced plausible results.
- It is not clear to me yet why the fabric itself appears black with bsdf.
- Again we need to find the parameters to define a trans material.
- The parameters are not all that intuitive, and various approaches have been followed to find them – using manual measurements, guesses,...
- A full BSDF measurement was performed again. The trans model was fit only to the transmission data to get a better match with the model.

Fabrics: basic material definitions 2

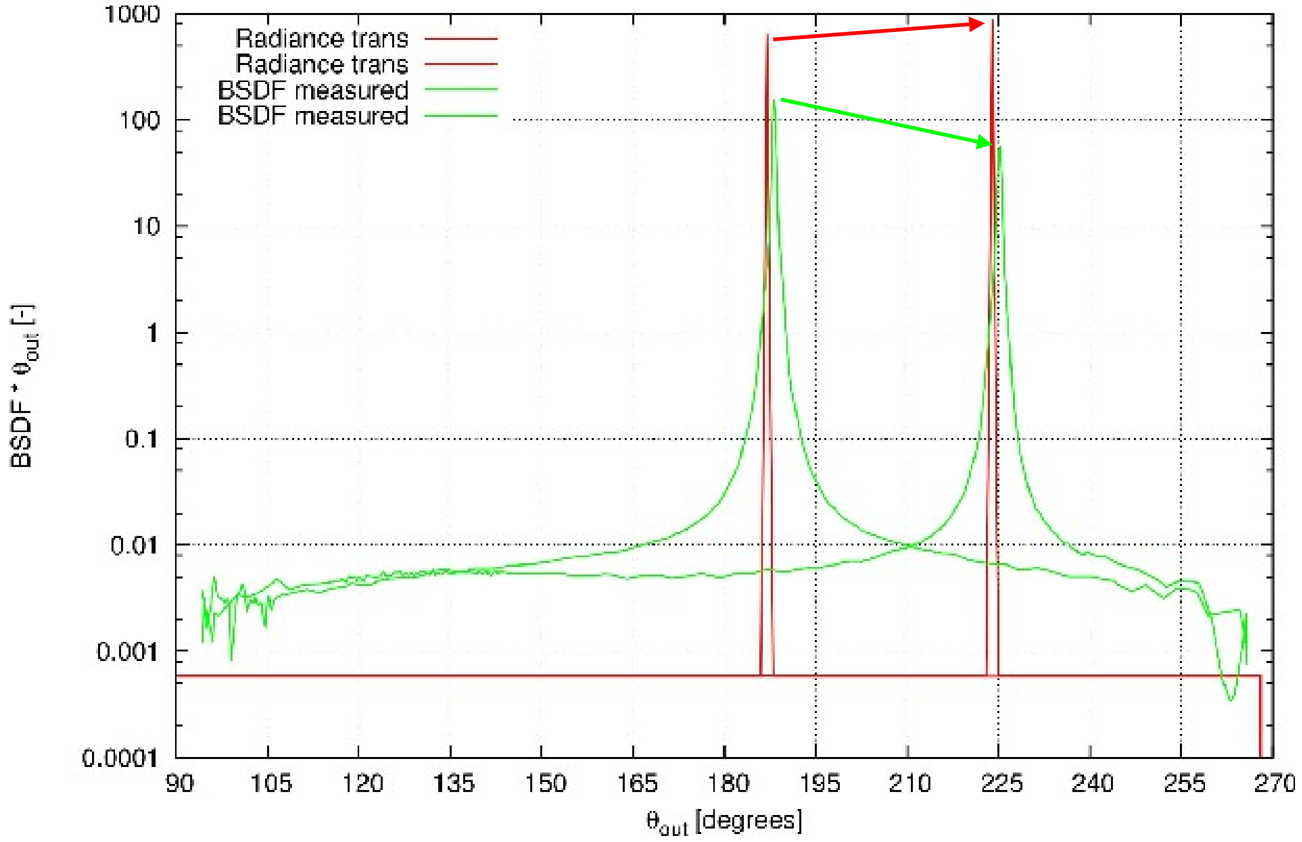


Fabric sample: Amazingly diffuse transmission with specular peak.

Thanks to Hunter-Douglas for providing samples....

Fabrics: basic material definitions 3

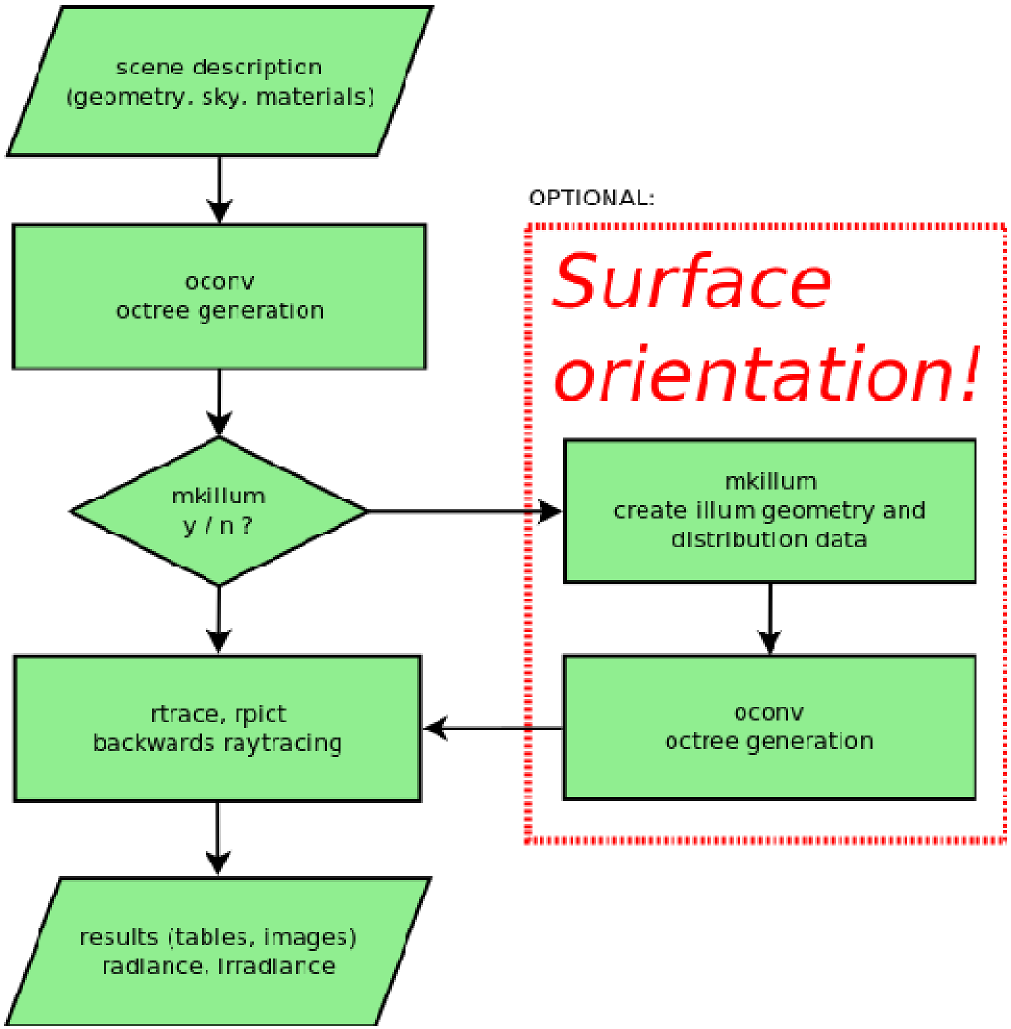
- So how well does the trans model fit to data... fabric:



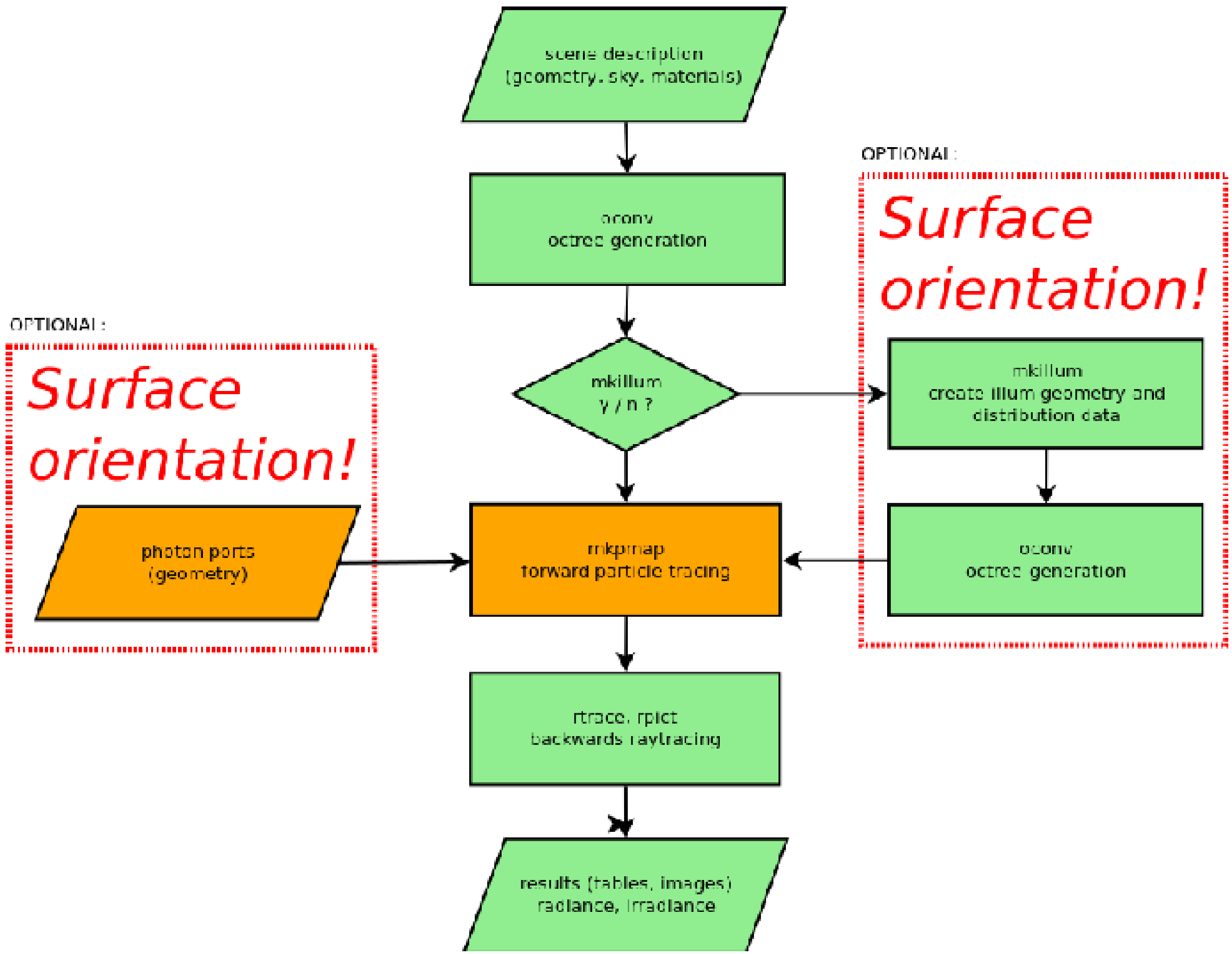
Fabrics: basic material definitions 4

- Again, the specular peak does not follow the gaussian shape.
- More criticial in daylighting applications, the model expects the specularity to increase with the incident angle. The opposite is the case for fabrics.
- **This may lead to wrong conclusions from simulations especially for glare.**
- What about fabrics with a clear cut-off angle for specular transmission?
- Might be a candidate for mixfunc... but fitting this to measured data?
- trans is a very handy but generic model, applying the reflection model of plastic to transmission.

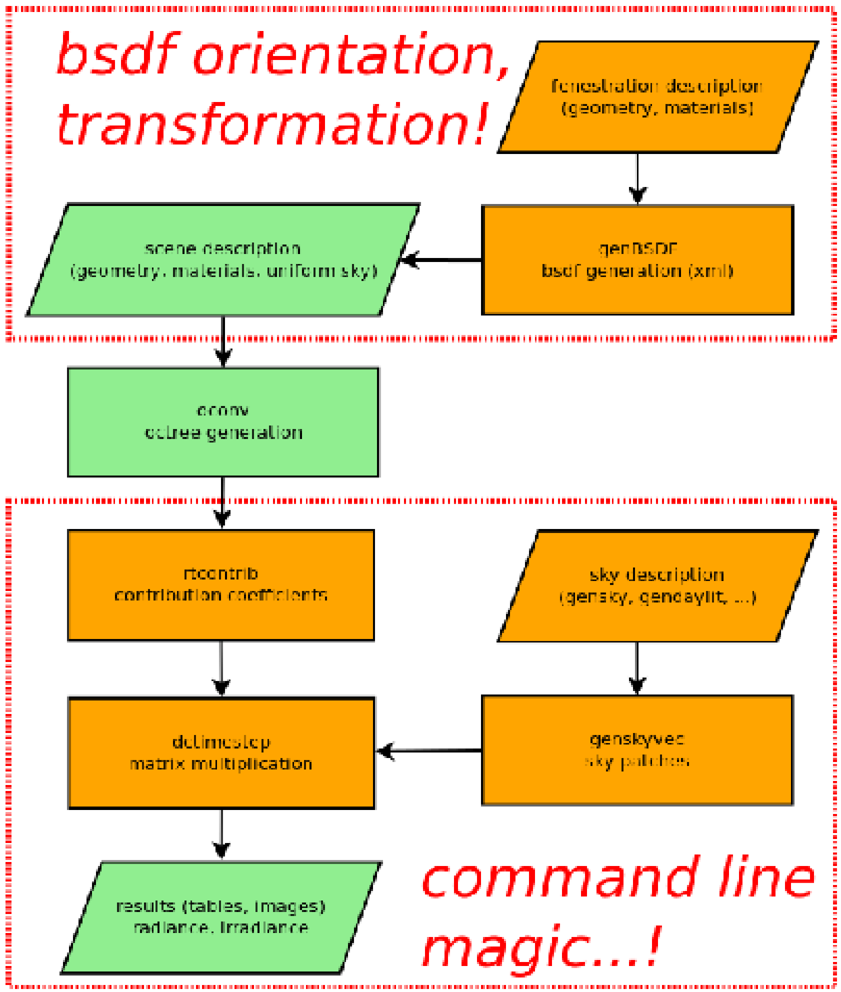
Complexity: Pure Radiance backwards workflow.



Complexity: Photon map workflow.



Complextity: Climate-based workflow with genBSDF.



Note that part of the increase in complexity results from climate based simulation.

Performance: r(t)contrib and complex scenes.

- Glare analysis often requires high detail.
- rcontrib on complex scenes leads to rendering times hard to handle, when noise is to be kept low (very high -ad or -c).
- bsdf has kind of replaced mkillum for the transmission through fenestration, but cannot replace the external interreflection calculation.

Conclusions: First – the motivation.

- We want to discuss potential future developments.
- This is not to demand changes – but to allow contribution to development in a coordinated manner.
- Lucerne University of Applied Sciences & Arts CC Envelopes and Solar Energy is extending its activities in lighting and daylighting. We are currently investigating where we could contribute to developments matching our fields of interest.

Conclusions: One direction? Back/forward-tracing, genBSDF4all?

- Currently, there are parallel (=confusing) developments based on photon map (Daysim & Co) and genBSDF (main Radiance releases):
- The bsdf modifier is a perfectly integrated means to get data-driven BSDF into Radiance. genBSDF allows to produce such data from models.
- genBSDF is a perfect tool to build up libraries of reuseable BSDF, especially for systems that are uniform over the covered area and flat.
- genBSDF is rather slow when compared to the photon map algorithm. In cases where the reuseability are not guaranteed, the photon map is more efficient.
- If the approximation to a surface does not match the system, or the spatial uniformity is not given, the pmap is more transparent to the user.

Conclusions: One direction? pmap & bsdf for different uses!

- Having the pmap extension available for classic Radiance users and communicating the use cases for both approaches would help users.
  - A pmap extension or a comparable forward algorithm in sync with Radiance is needed.
  - The existing shortcomings in the implementation (glow, functional bsdf, ...) are to be identified and corrected.
- The initial support tool for complex fenestration, mkillum, is not available with rcontrib. Would adding support for contribution coefficients to mkillum be of help?

Conclusions: The basic BSDF models.

- The existing BSDF models in Radiance are difficult to fit to measured data.
- Can we count on the data-driven bsdf type for everything in the future?
  - Transfer of measured data into variable-resolution BSDF xml?
- Or should we consider new functional BSDF models?
  - Can the development of materials be de-coupled from Radiance core?
  - Modular approach like e.g. in PBRT? libmetal.so, libtrans.so, libfabric.so...?

Questions? Answers? Discussion?

Thank you!

http://www.hslu.ch