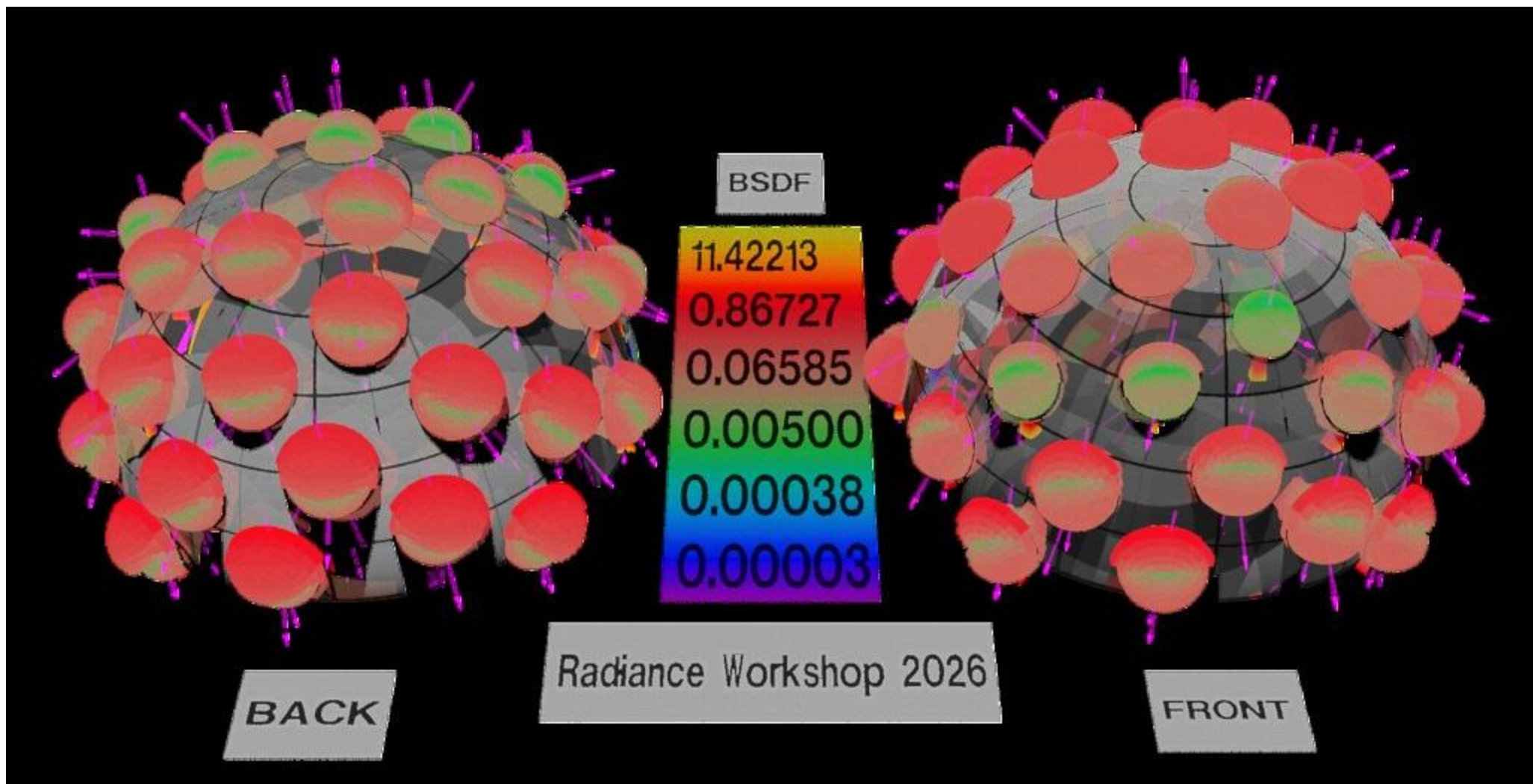




Scattering Light

Generating BSDFs and using them in Radiance

David Geisler-Moroder

24th International Radiance Workshop, August 31 – September 2, 2026, Seattle, WA

Recap of 2025
talk @ Lausanne

On the way to an ISO/CIE standard
for BSDF data generation
for complex fenestration systems

David Gauder-Moroder, Benjamin S. Lee,
Lars O. Gruber, Tachung Wang, Qing Wang
25th International Radiance Workshop
August 27-29, 2025
Lausanne, Switzerland



Today's Menu

Starter | $BSDF = \frac{dL}{dE}$

Second Course | ISO/CIE Standardization

Third Course | BSDF Generation (i) – measurement-based

Fourth Course | BSDF Generation (ii) – simulation-based

Dessert | Application of BSDFs in Radiance

Principles of BSDF & Optical Scattering

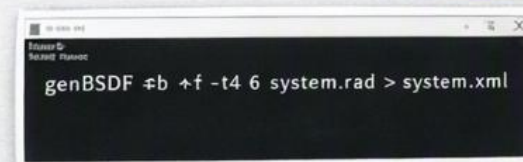
Light is an electromagnetic wave that propagates through space. When it encounters a surface, it can be reflected, refracted, or scattered. The Bidirectional Scattering Distribution Function (BSDF) describes the probability of light being scattered in a particular direction, given its incident direction and polarization.

The BSDF is a function of the incident and outgoing directions, and the polarization of the light. It is a key property of a material that determines how it interacts with light. The BSDF is used to model the optical behavior of complex surfaces, such as those found in architectural lighting and computer graphics.

Table 1: BSDF

Table 1 shows the relationship between the incident and outgoing directions, and the polarization of the light. The BSDF is a function of the incident and outgoing directions, and the polarization of the light. It is a key property of a material that determines how it interacts with light. The BSDF is used to model the optical behavior of complex surfaces, such as those found in architectural lighting and computer graphics.

Incident	Reflected	Refracted	Scattered	Transmitted	Absorbed
Direct	Specular	Refracted	Diffuse	Transmitted	Absorbed
Diffuse	Diffuse	Refracted	Diffuse	Transmitted	Absorbed
Specular	Specular	Refracted	Diffuse	Transmitted	Absorbed



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Principles of BSDF & Optical Scattering

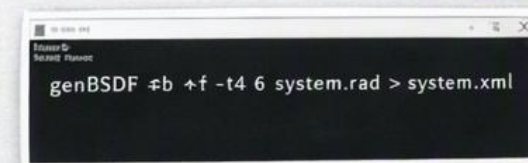
Light is an electromagnetic wave that propagates through space. When it encounters a surface, it can be reflected, refracted, or scattered. The BSDF (Bidirectional Scattering Distribution Function) describes the probability of light being scattered in a particular direction, given its incident direction and polarization.

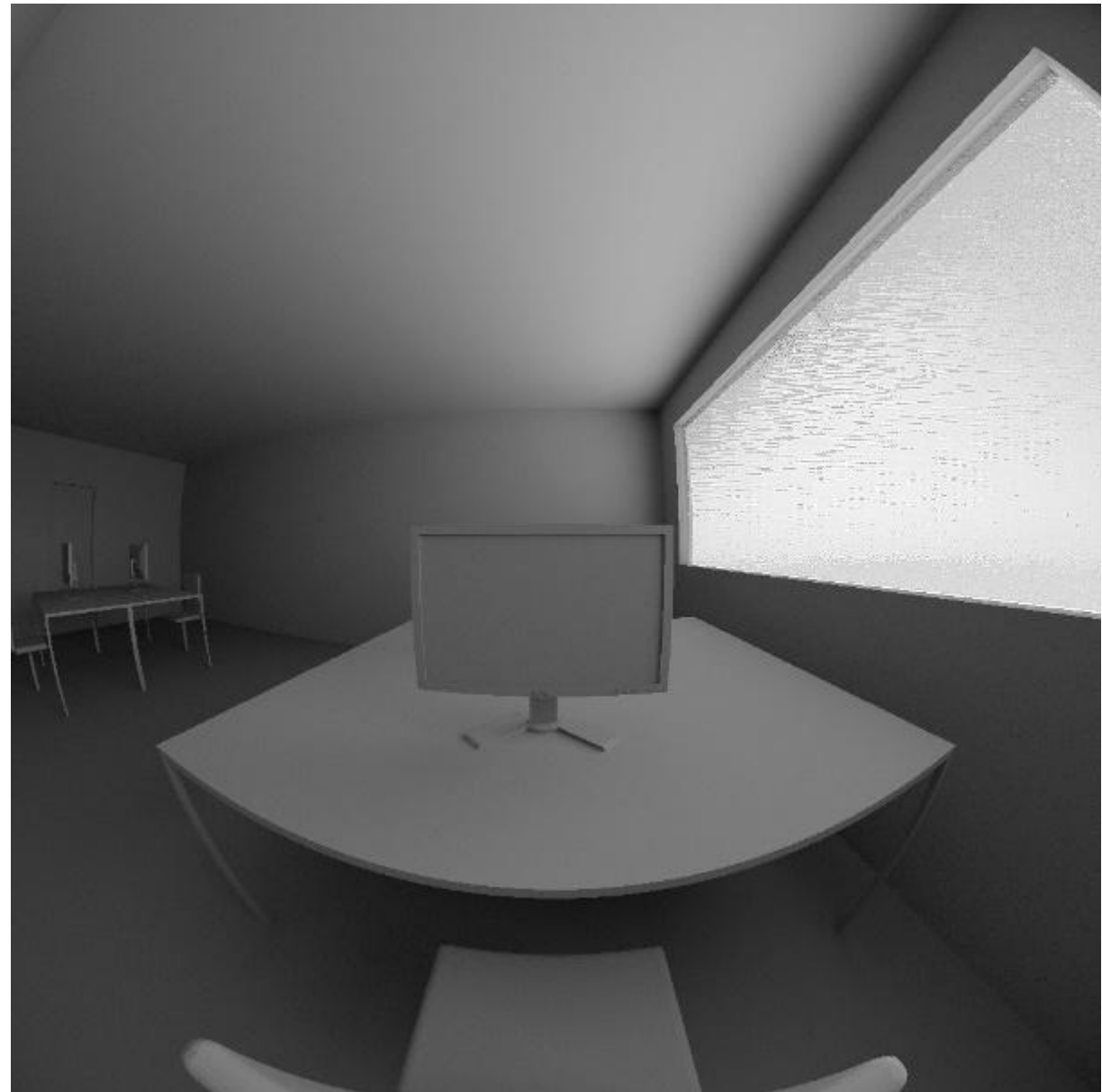
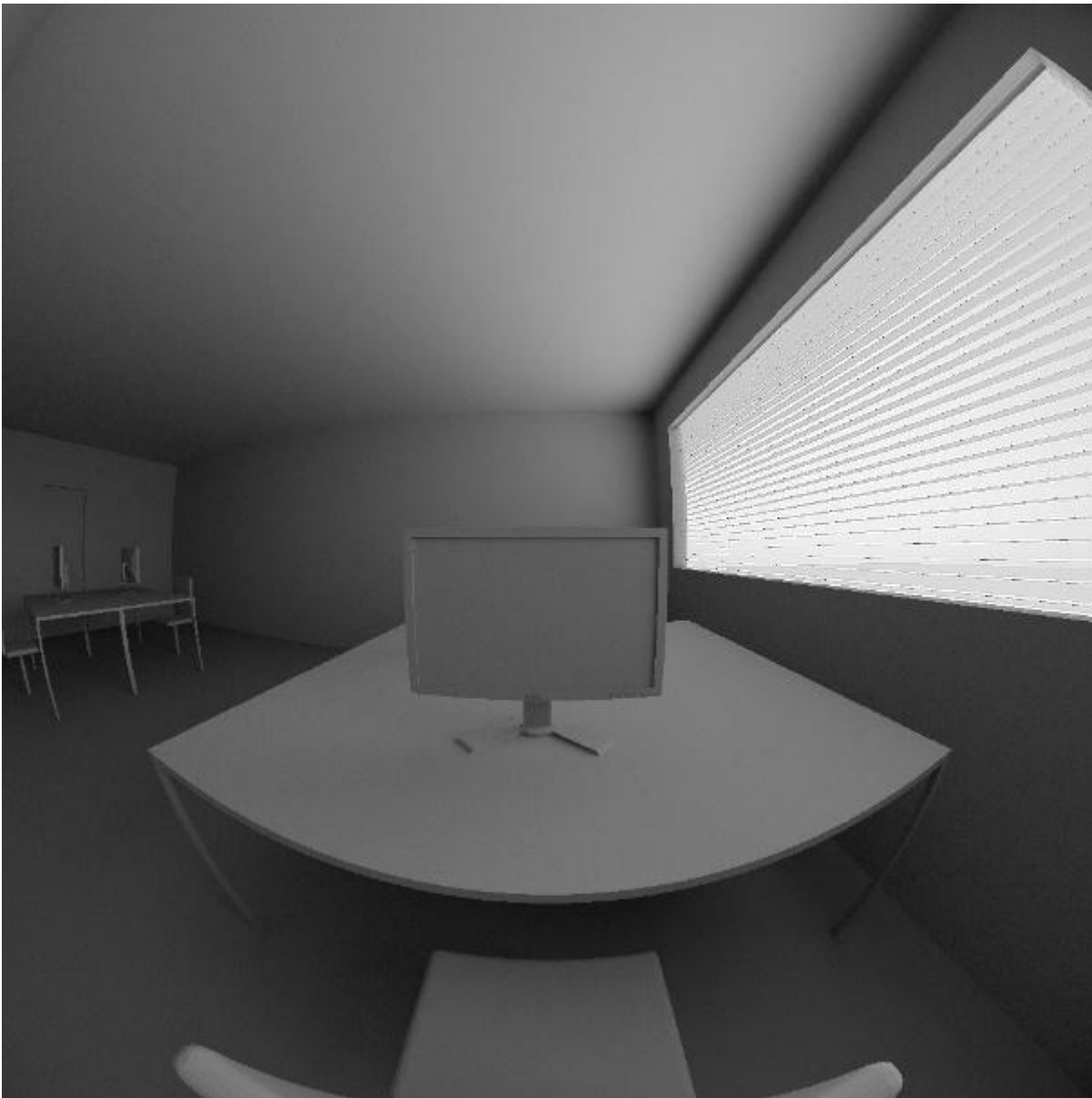
The BSDF is a function of the incident and outgoing directions, and the polarization of the light. It is a key parameter in radiance transfer simulations, used to model the optical properties of materials and surfaces.

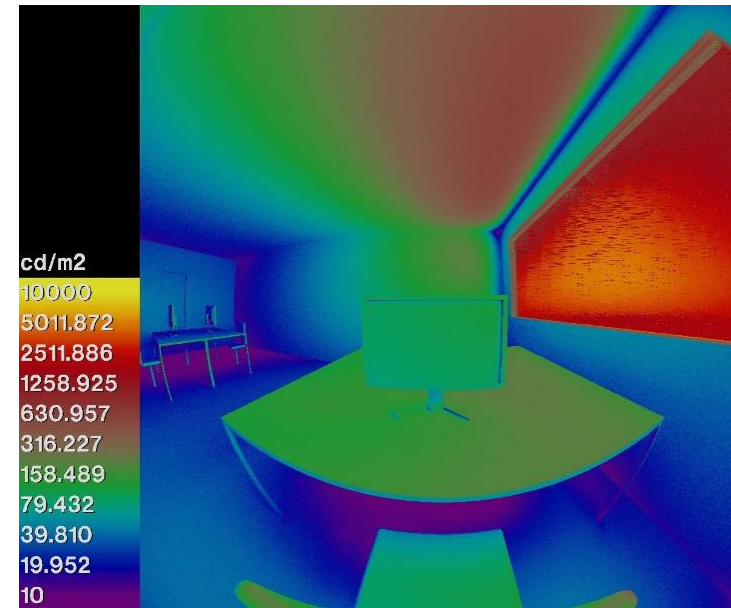
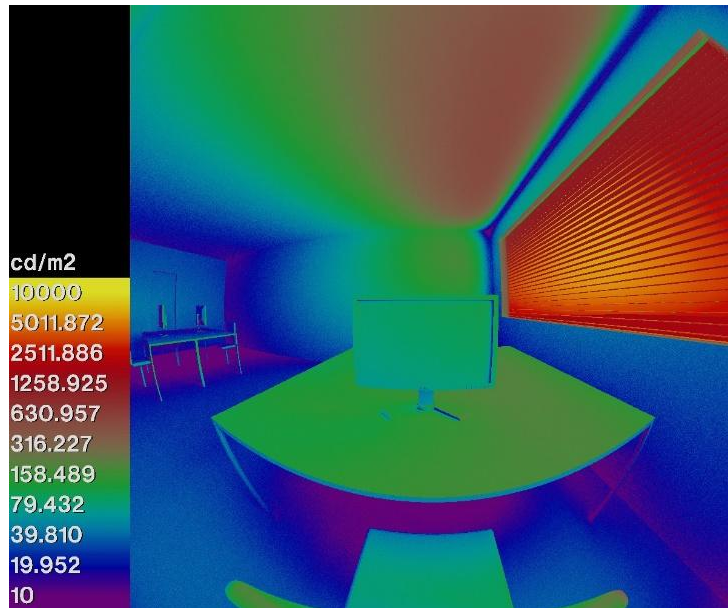
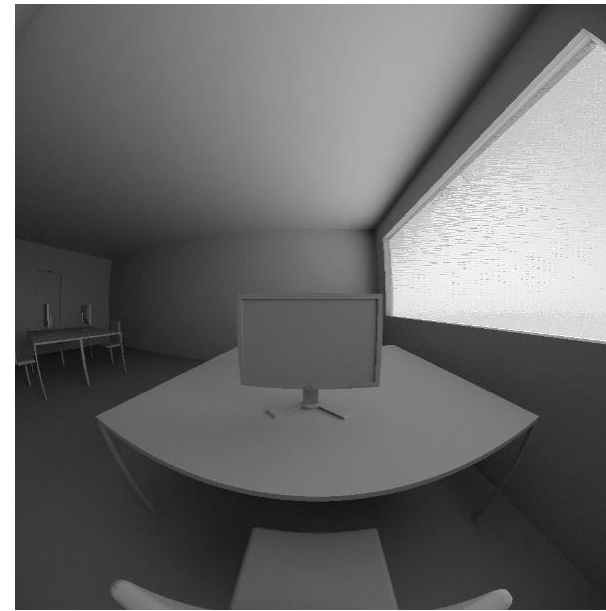
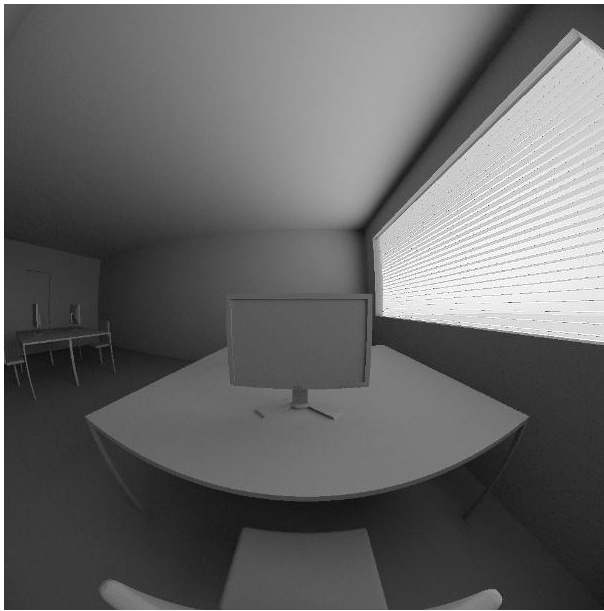
Table 1: BSDF Data

Table 1 shows the BSDF data for a specific material, calculated using a Monte Carlo simulation. The data is presented in a table format, showing the BSDF values for different incident and outgoing directions.

Incident	Reflected	Refracted	Scattered	Transmitted	Absorbed
0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.1	0.1	0.1	0.1	0.1
0.2	0.2	0.2	0.2	0.2	0.2
0.3	0.3	0.3	0.3	0.3	0.3
0.4	0.4	0.4	0.4	0.4	0.4
0.5	0.5	0.5	0.5	0.5	0.5
0.6	0.6	0.6	0.6	0.6	0.6
0.7	0.7	0.7	0.7	0.7	0.7
0.8	0.8	0.8	0.8	0.8	0.8
0.9	0.9	0.9	0.9	0.9	0.9
1.0	1.0	1.0	1.0	1.0	1.0



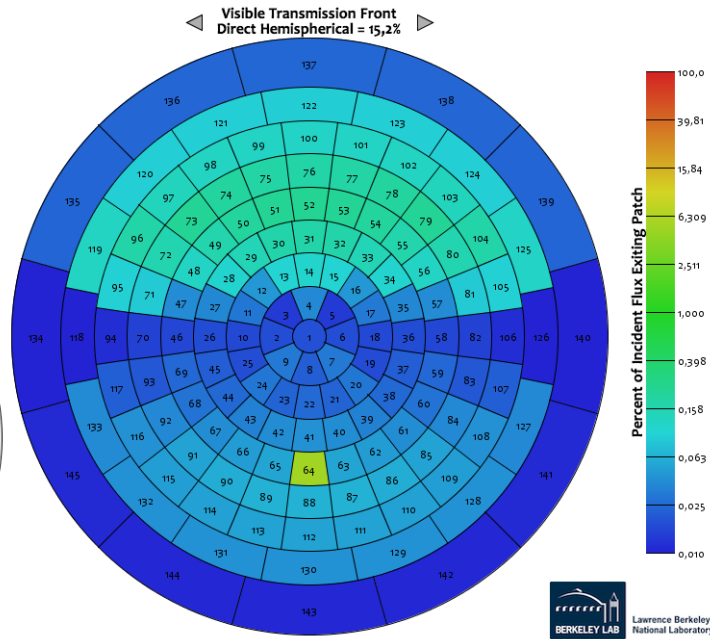
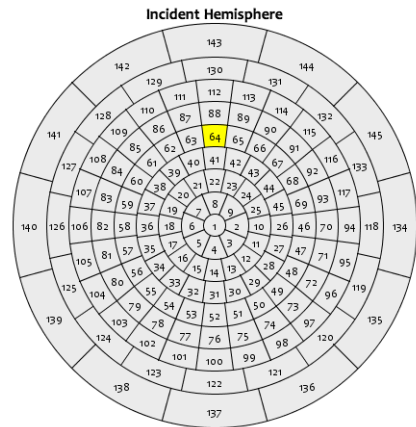




BSDF Data

Load a BSDF XML file
 Save Image
 Show Help
 Hide Patch Numbers
 Equidistant Orthographic
 Log Scale Linear Scale

Scale Maximum:
 Number of Decades:



```

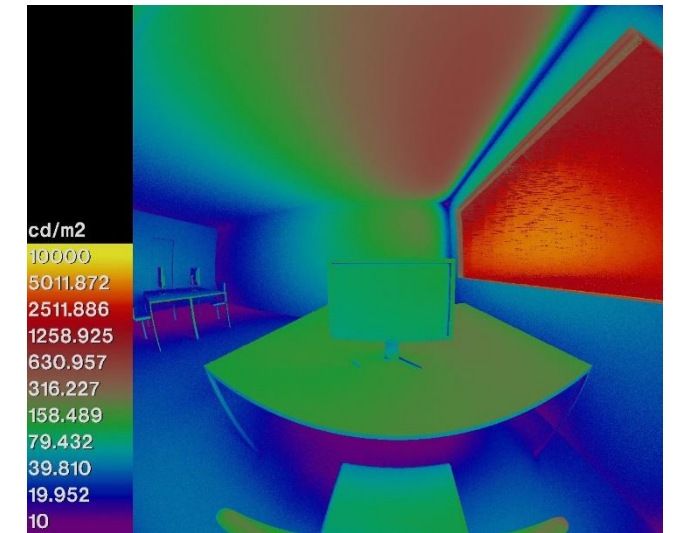
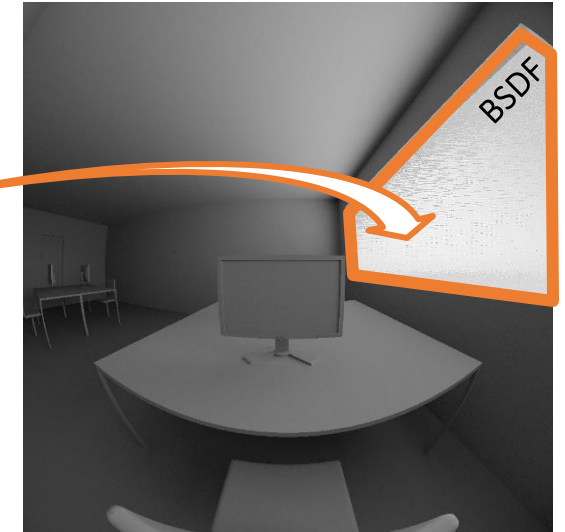
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       0.000892, 0.002718, 0.001872, 0.001692, 0.001671, 0.001690, 0.001872, 0.002617, 0.000892,
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```

BSDF Data

```

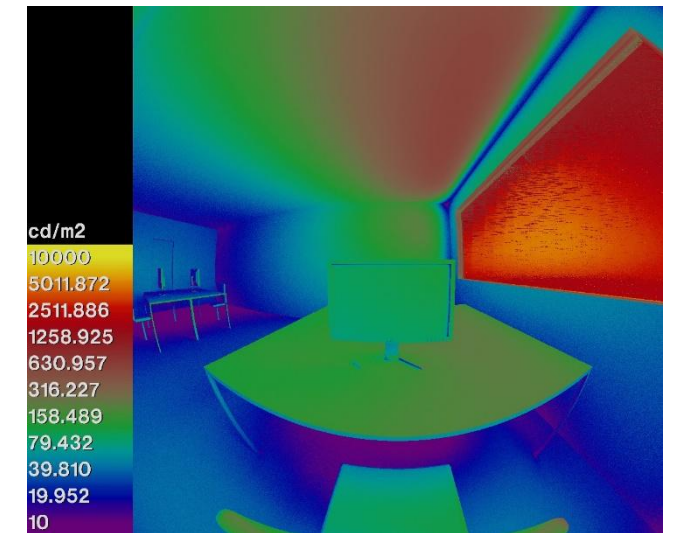
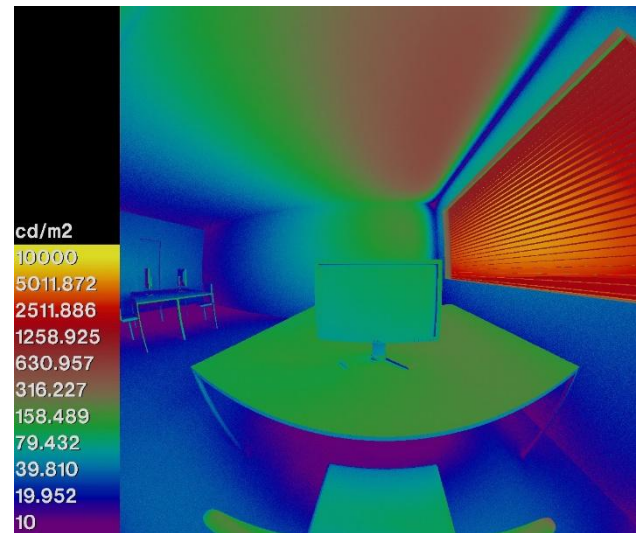
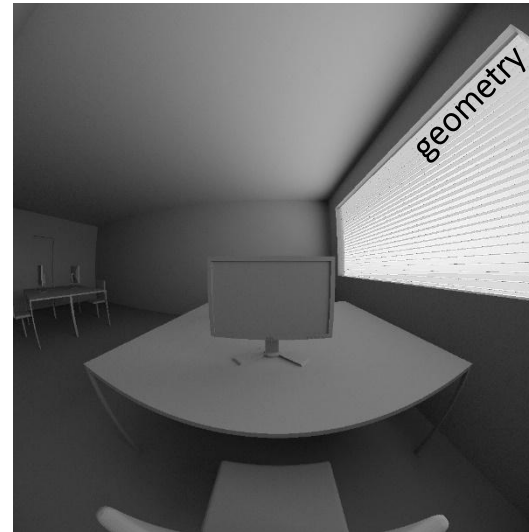
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6        <Material>
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9          <Thickness unit="Meter">0.114000</Thickness>
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11       </Material>
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...
726 <WavelengthData>
727   <LayerNumber>System</LayerNumber>
728   <Wavelength unit="Integral">Visible</Wavelength>
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731 <WavelengthDataBlock>
732   <WavelengthDataDirection>Transmission Front</WavelengthDataDirection>
733   <ColumnAngleBasis>LBNL/Klems_Full</ColumnAngleBasis>
734   <RowAngleBasis>LBNL/Klems_Full</RowAngleBasis>
735   <ScatteringDataType>BTDF</ScatteringDataType>
736 <ScatteringData>
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```



BSDF Background

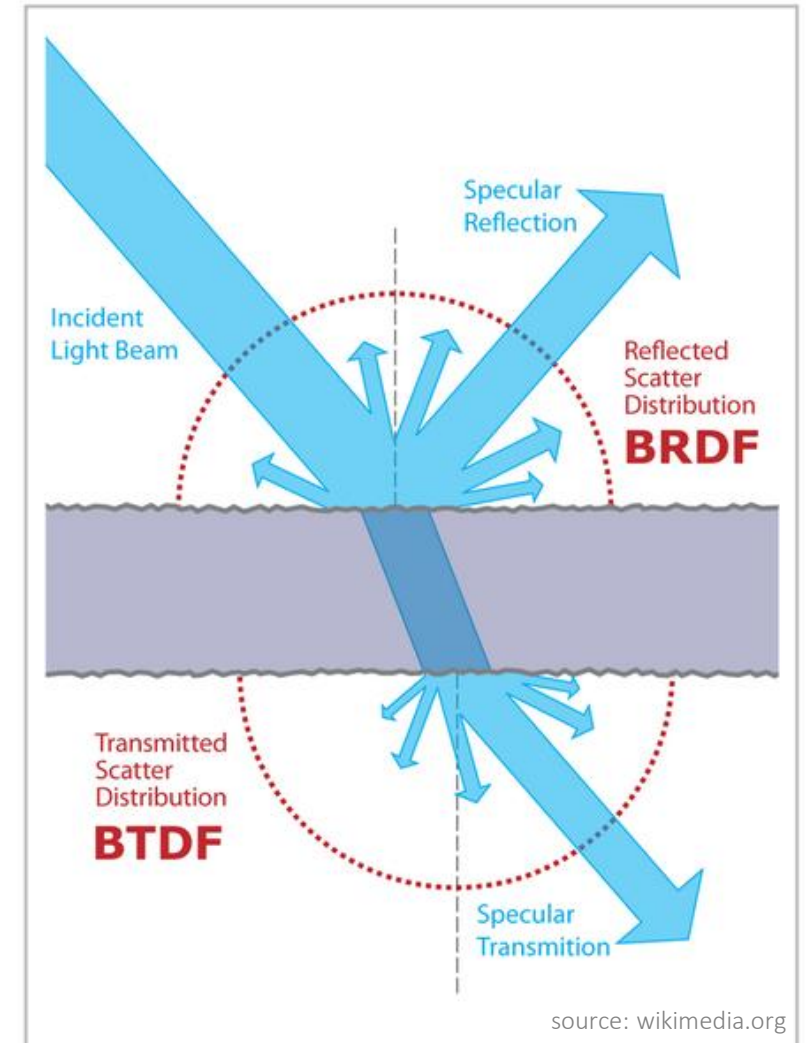
- Basis for including daylighting and shading systems in simulations
 - Lighting simulations (sun & skylight)
 - Energy simulations (angular dependent solar gains)
- Already implemented in various tools



BSDF Background

Bidirectional Scattering Distribution Function

- Photometry of façade systems (Complex Fenestration Systems – CFS)
 - BSDF: scattering
 - BRDF: reflection
 - BTDF: transmission
 - $BSDF = BRDF + BTDF$
- Light distribution as function of incident light
- Analogous to luminous intensity distributions for electric systems



BSDF Basics

Rendering equation

$$L_s(\theta_s, \varphi_s) = \int_0^{2\pi} \int_0^\pi L_i(\theta_i, \varphi_i) \text{BSDF}(\theta_s, \varphi_s; \theta_i, \varphi_i) |\cos \theta_i| \sin \theta_i d\theta_i d\varphi_i$$

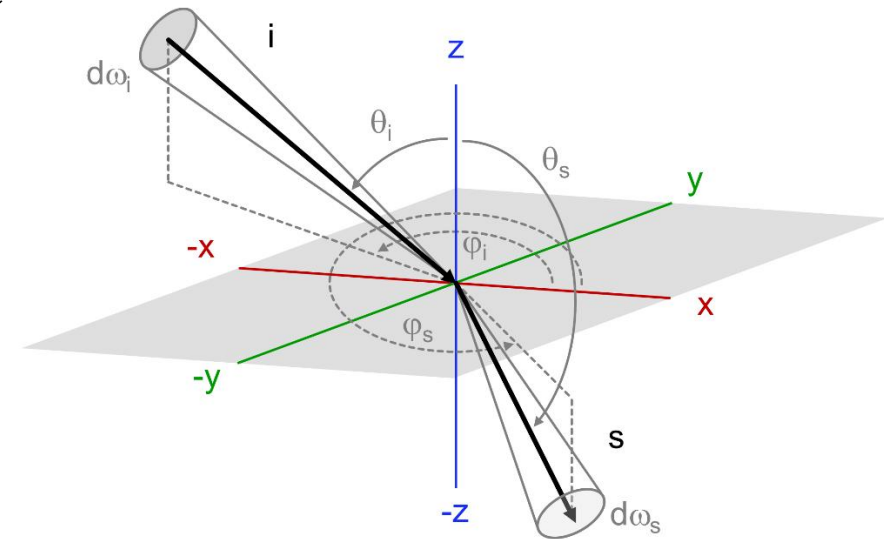
(θ_i, φ_i) incident direction

(θ_s, φ_s) scattered direction

$\text{BSDF}(\theta_s, \varphi_s; \theta_i, \varphi_i)$ BSDF

$L_i(\theta_i, \varphi_i)$ radiance/luminance in incident direction

$L_s(\theta_s, \varphi_s)$ radiance/luminance in scattered direction



further reading:

Kajiya J. T.: The rendering equation. SIGGRAPH Comput. Graph. 20, 4 (1986), 143–150.

Nicodemus et al.: Geometrical Considerations and Nomenclature for Reflectance.

NBS Monograph 160, U. S. Dept. of Commerce, 1977.

BSDF Basics

Differential definition

$$BSDF(\omega_i, \omega_s) = dL(\omega_s) / dE(\omega_i)$$

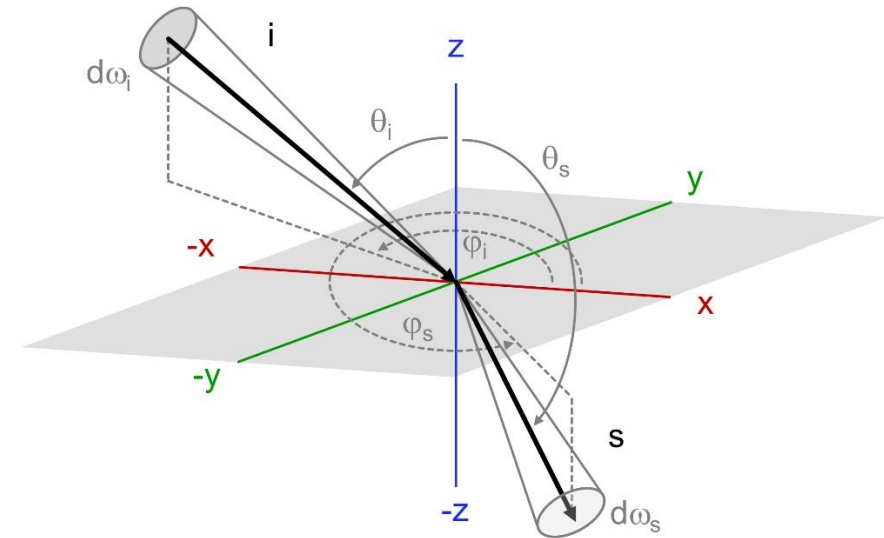
$BSDF(\omega_i, \omega_s)$ BSDF

$dL(\omega_s)$ differential radiance/luminance
to scattered direction s

$dE(\omega_i)$ differential irradiance/illuminance
from incident direction i

Differential Scattering Function, DSF

$$DSF = BSDF(\omega_i, \omega_s) * \cos(\theta_s)$$



BSDF Basics

Physical plausibility

i. Positivity

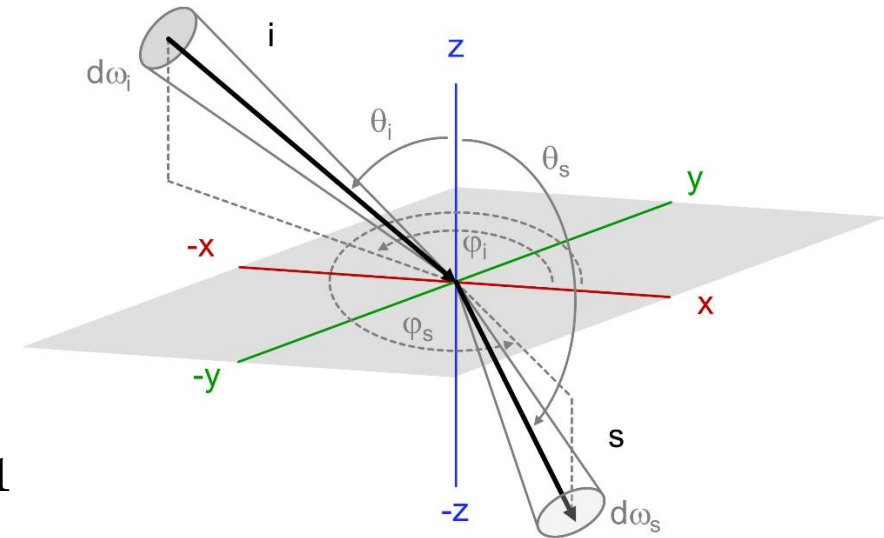
$$BSDF(\theta_s, \varphi_s; \theta_i, \varphi_i) \geq 0$$

ii. Helmholtz reciprocity

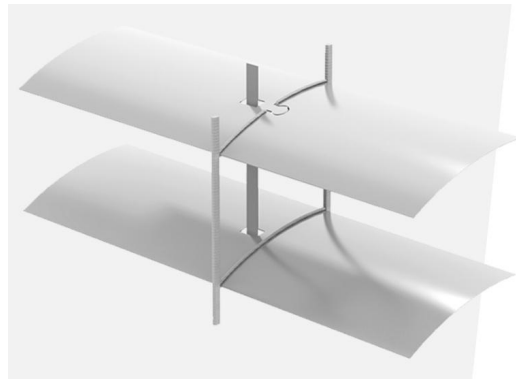
$$BSDF(\theta_s, \varphi_s; \theta_i, \varphi_i) = BSDF(\theta_i, \varphi_i; \theta_s, \varphi_s)$$

iii. Energy balance: albedo bounded by 1

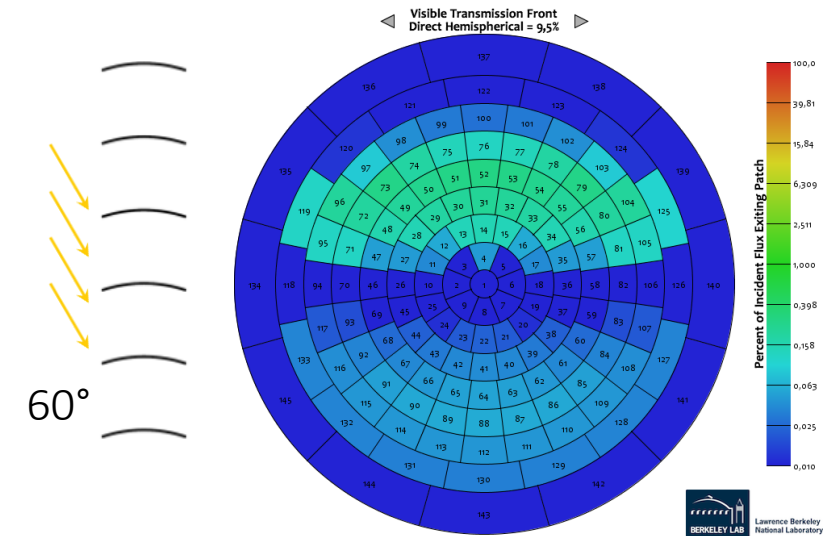
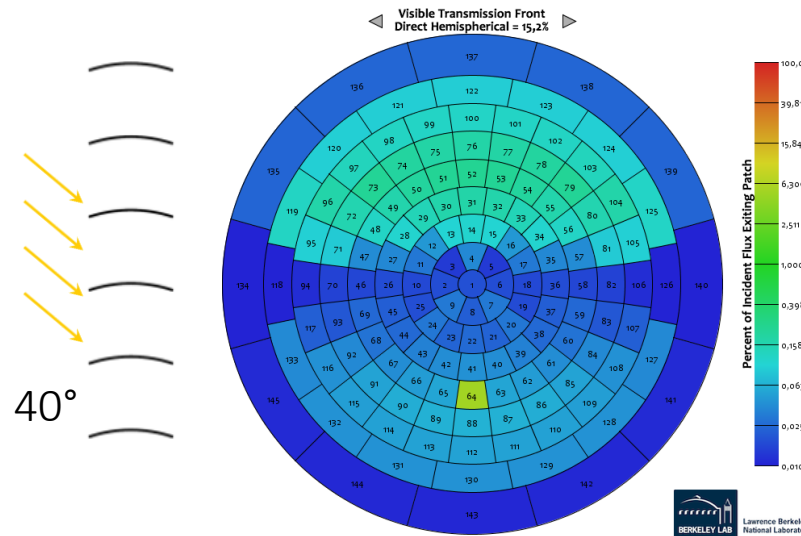
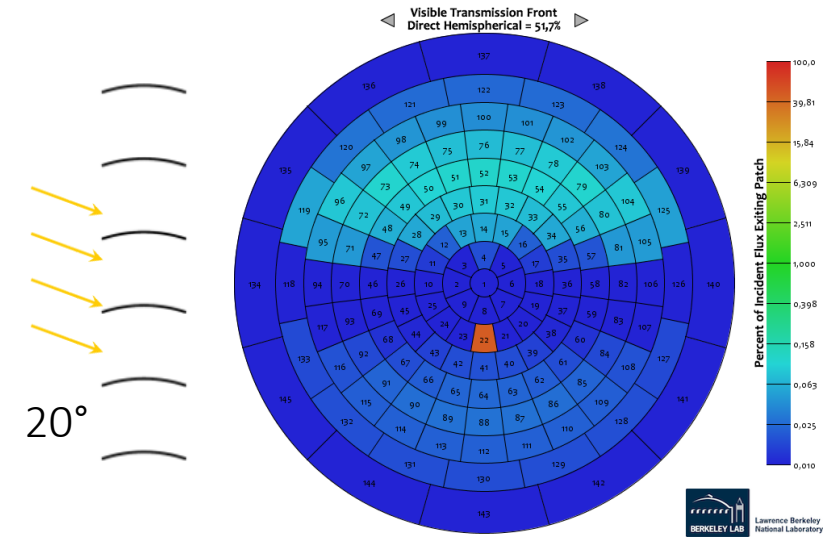
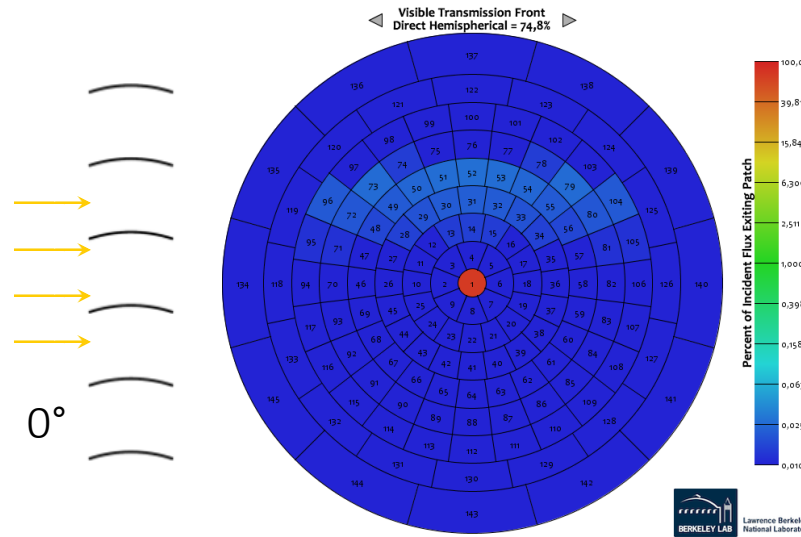
$$a(\theta_i, \varphi_i) = \int_0^{2\pi} \int_0^\pi BSDF(\theta_i, \varphi_i; \theta_s, \varphi_s) |\cos \theta_s| \sin \theta_s d\theta_s d\varphi_s \leq 1$$



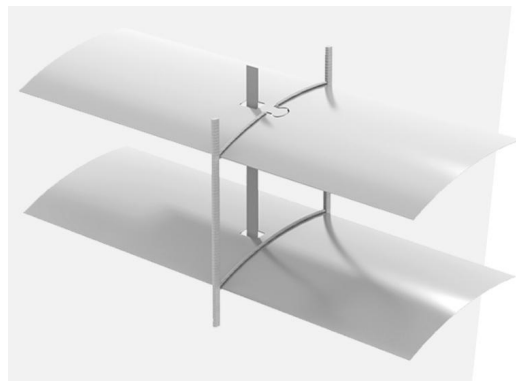
Example: Venetian blinds @ 0° tilt



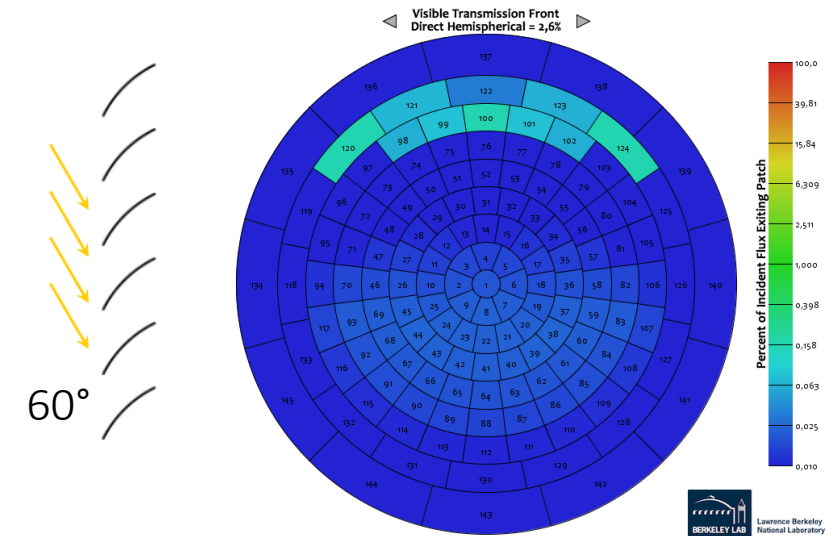
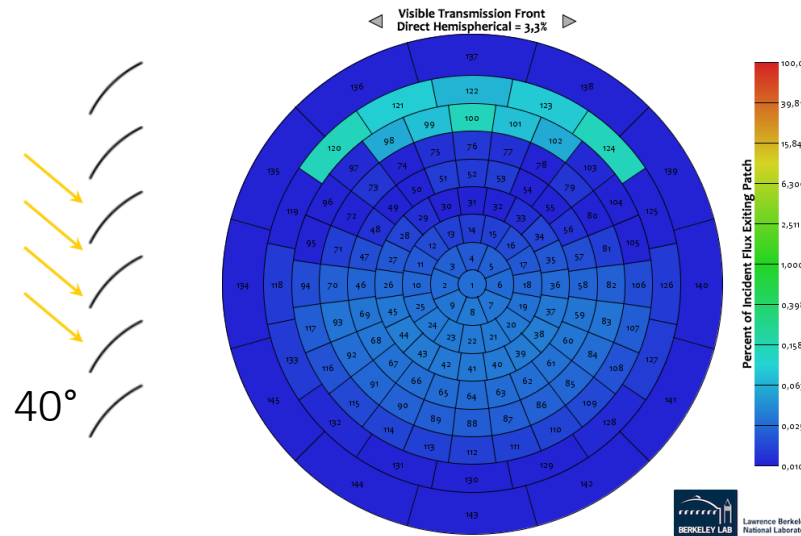
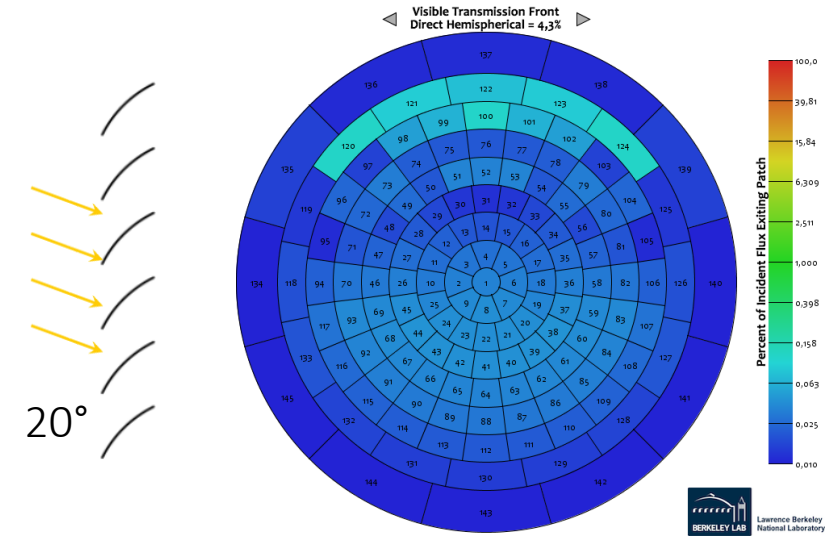
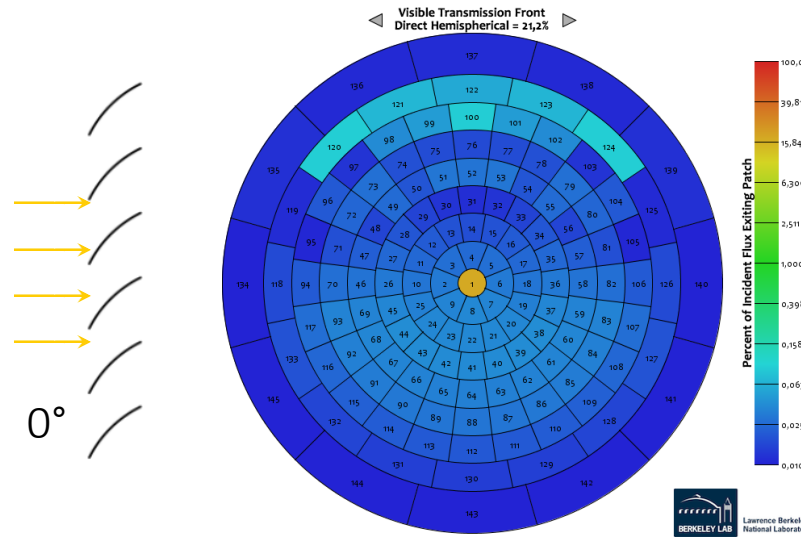
Example: HELLA AF 60
www.hella.info



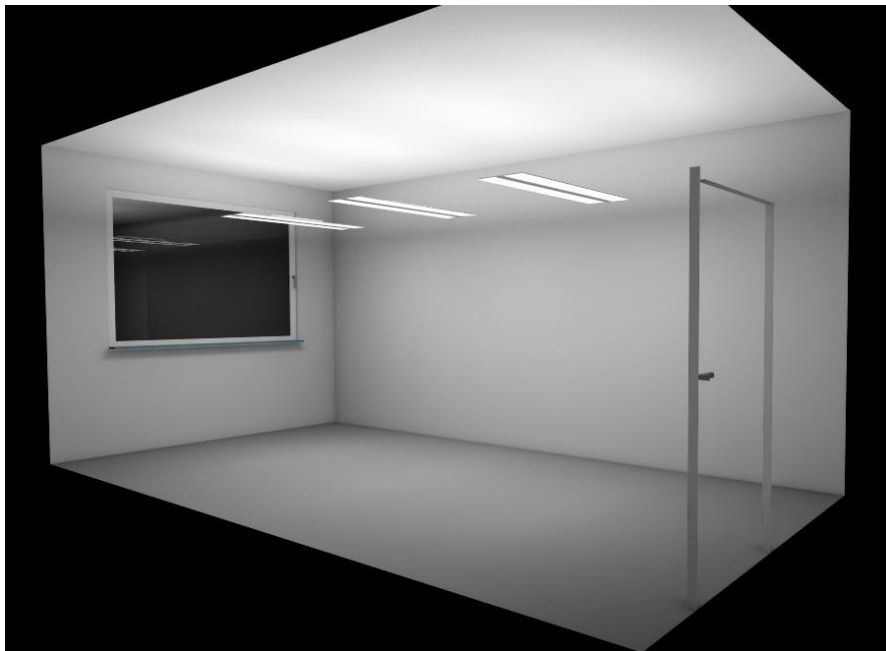
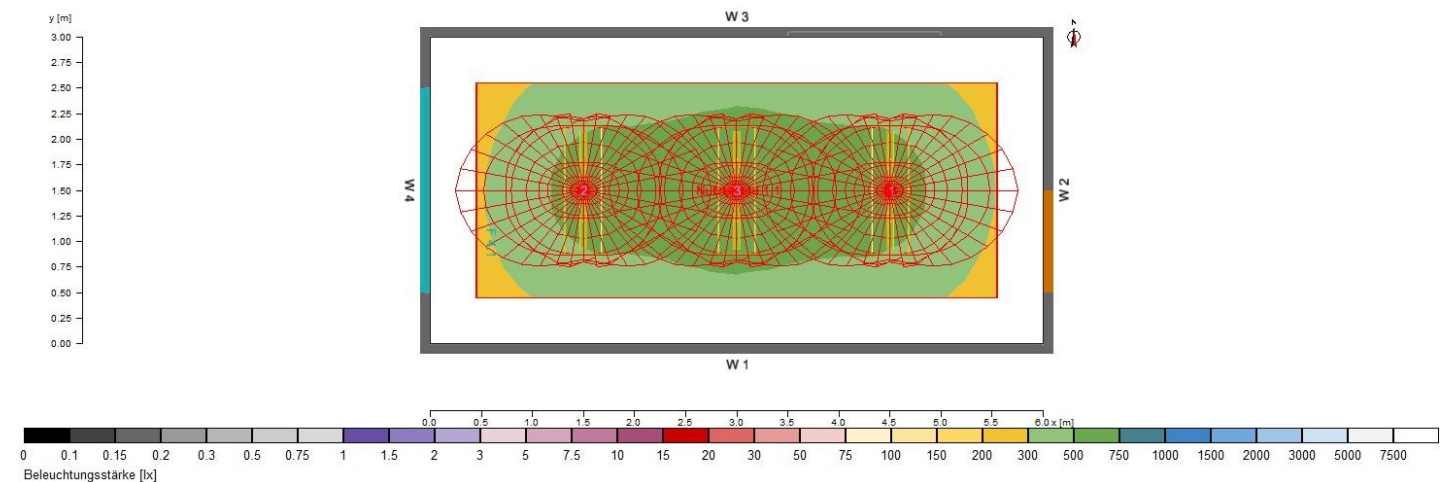
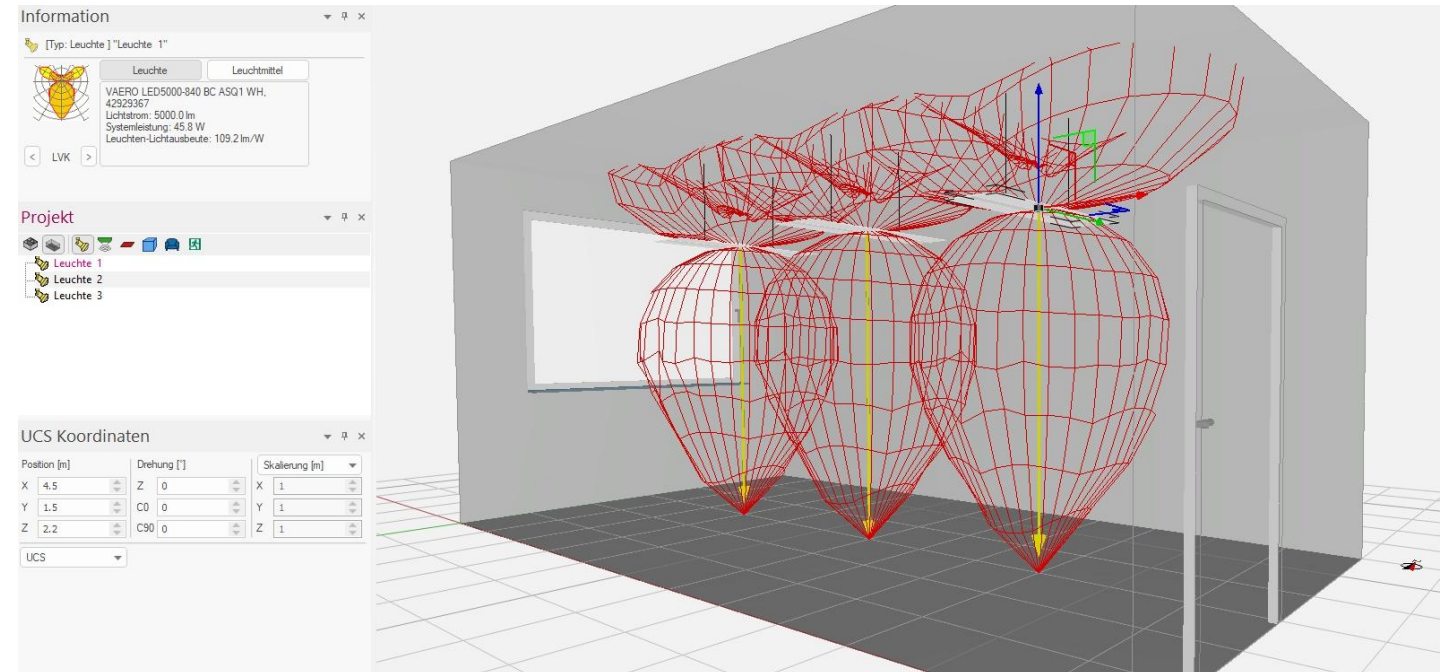
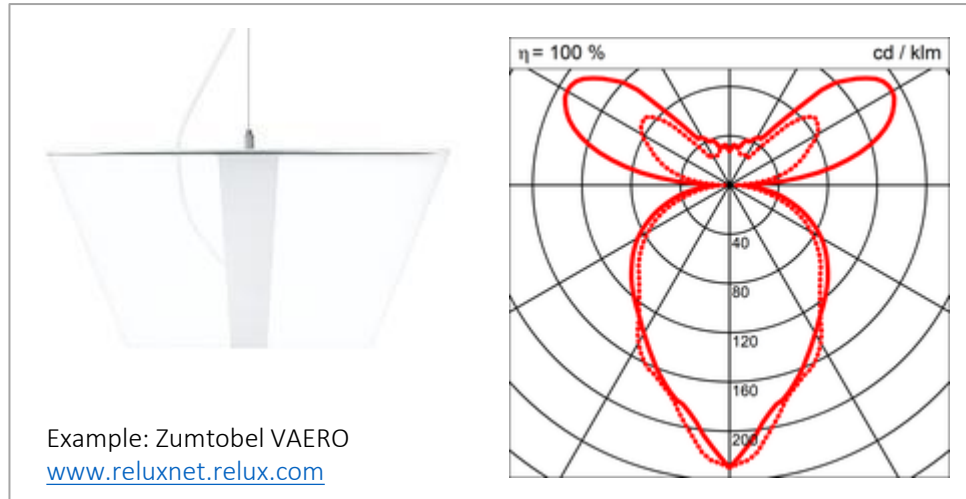
Example: Venetian blinds @ 45° tilt



Example: HELLA AF 60
www.hella.info



BSDF – Analogous to LIDCs for luminaires



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Principles of BSDF & Optical Scattering

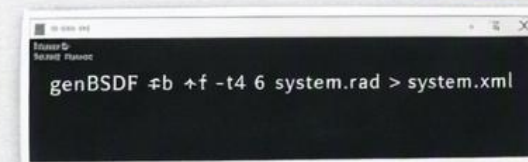
Light is an electromagnetic wave that propagates through space. When it encounters a surface, it can be reflected, refracted, or scattered. The Bidirectional Scattering Distribution Function (BSDF) describes the probability of light being scattered in a particular direction, given its incident direction and polarization.

The BSDF is a function of the incident and outgoing directions, and the polarization of the light. It is a key parameter in the calculation of light transport in complex systems, such as those found in architectural lighting design.

Table 1: BSDF Data

Table 1 shows the BSDF data for a typical material. The columns represent the incident and outgoing directions, and the rows represent the polarization of the light.

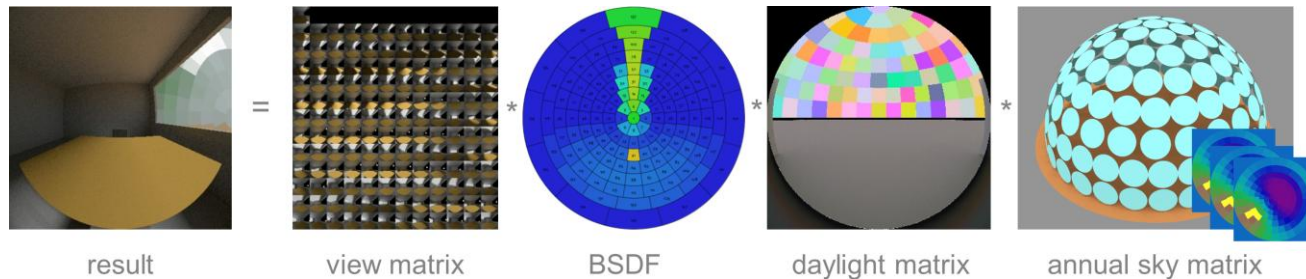
Incident	Reflected	Refracted	Scattered	Transmitted	Absorbed
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0



ISO/CIE 10916:2024

New Annex B: Comprehensive hourly calculation

- Matrix based daylight calculation method relying on BSDF data
- 3-Phase-Method



$$I = VTDS$$

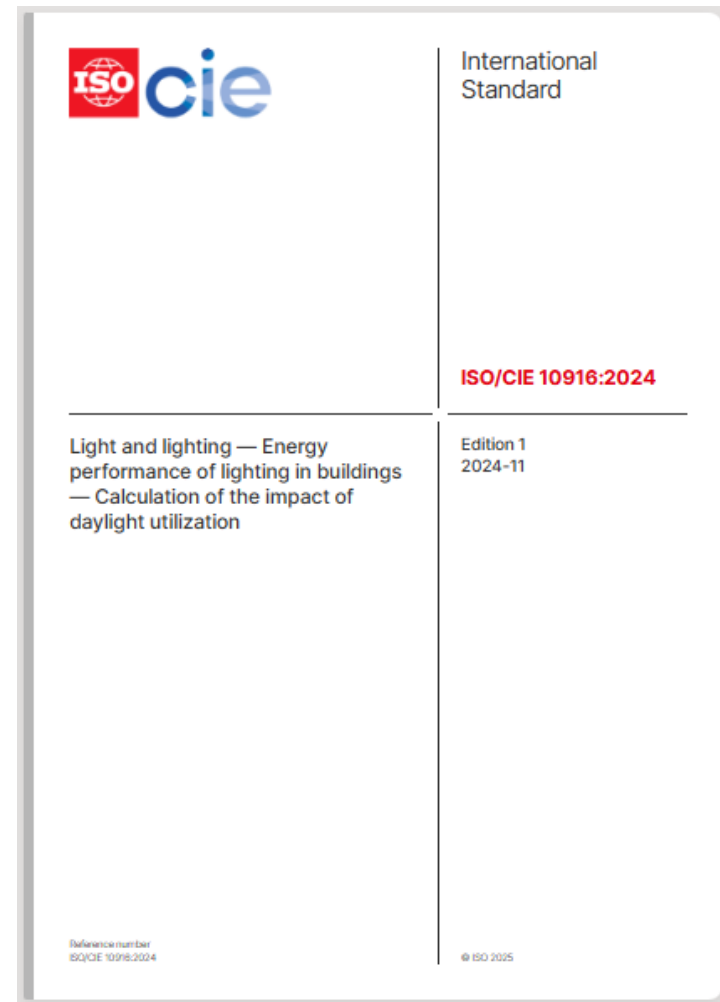
I ... result, e.g. annual illuminance values

V ... view matrix, relating measurement points with patches at interior of façade

T ... transmission matrix, i.e. BTDF (transmission component of BSDF)

D ... daylight matrix, relating patches at exterior of façade with sky patches

S ... annual sky matrix



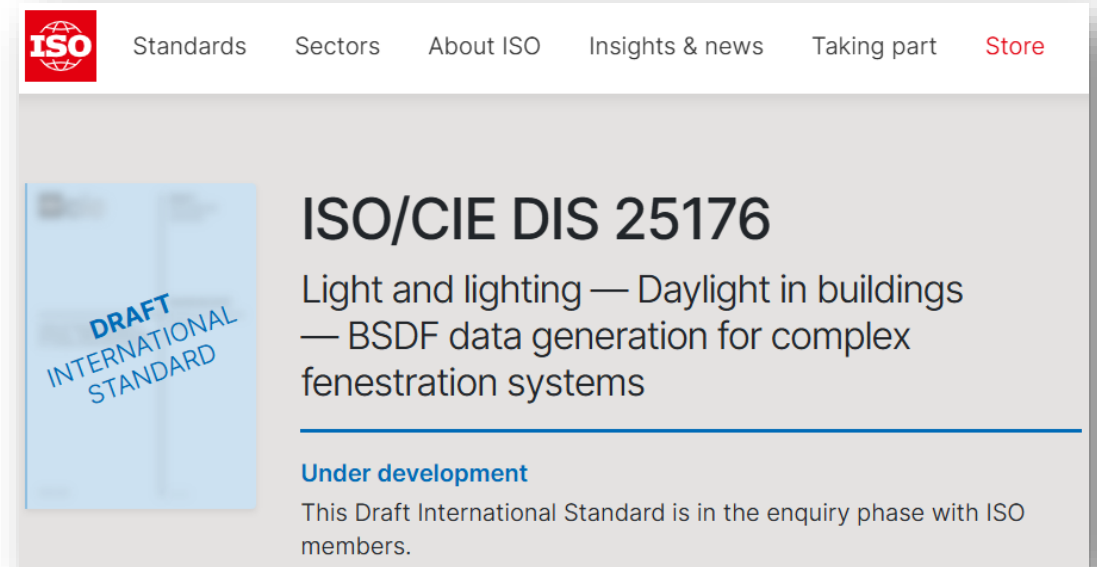
ISO/CIE 25176

SCOPE

This document applies to the broad range of materials and systems, e.g. fabric shades, venetian blinds, prismatic glass, etc., that are used on windows and skylights to control daylight, sunlight, glare, privacy, and view to the outdoors. It specifies procedures for producing comprehensive angle-dependent, solar-optical scattering data that can then be used to compute a wide range of performance metrics.

This document specifies procedures for:

- » characterizing angle-dependent, optical properties (transmittance, reflectance, absorptance) of glazing and shading materials and systems, i.e. "complex fenestration systems" (CFS) and then
- » generating tabulated bidirectional scattering distribution function (BSDF) data sets for use as input to simulation tools or standardized calculation methods such as the comprehensive hourly calculation method defined in ISO/CIE 10916:2024.



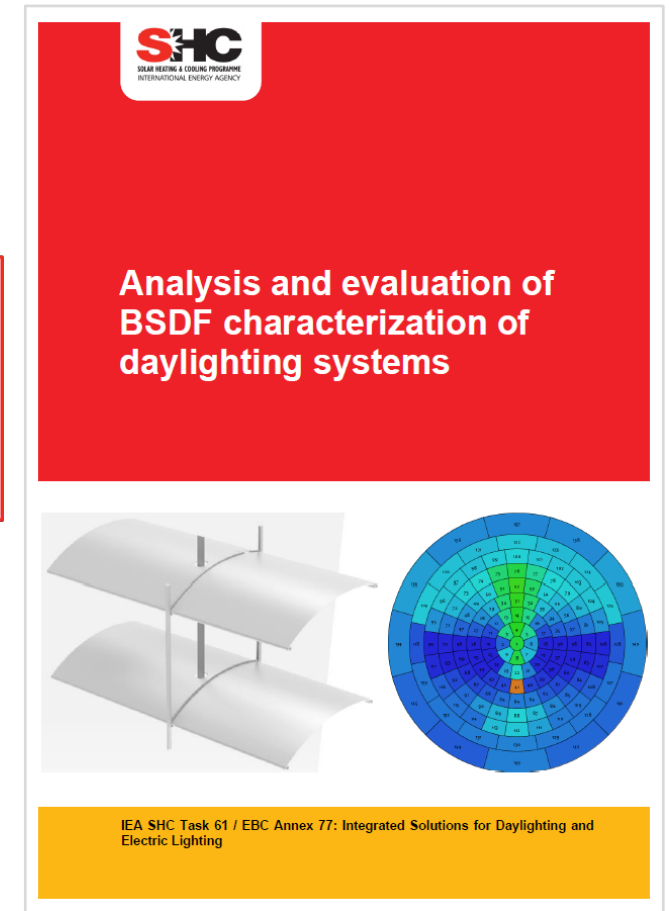
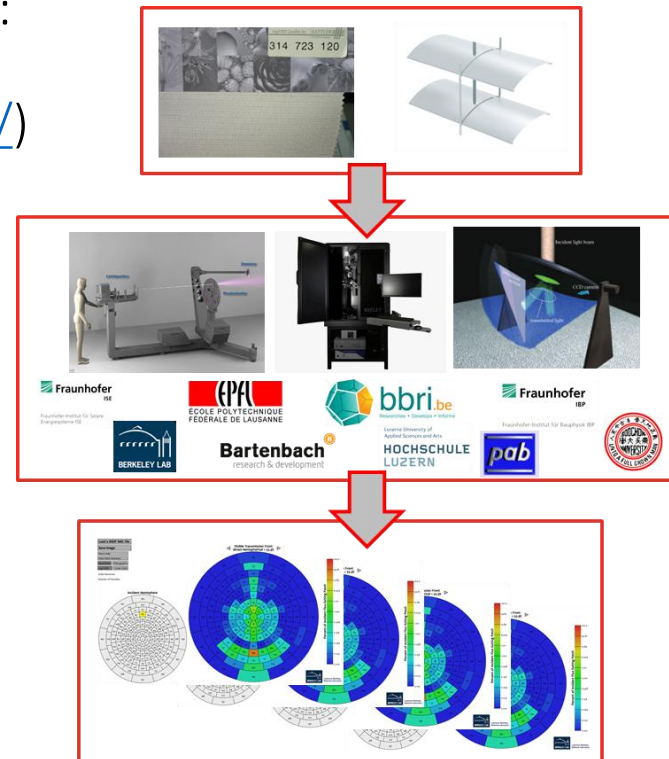
International Harmonization in IEA SHC Task 61 / EBC Annex 77

Completed IEA SHC Task 61 / EBC Annex 77:
Integrated Solutions for Daylighting and
Electric Lighting (<https://task61.iea-shc.org/>)

Analysis and Evaluation Report

- » Review of currently used methods
- » Round Robin test

Online:
<https://doi.org/10.18777/ieashc-task61-2021-0012>



International Harmonization in IEA SHC Task 61 / EBC Annex 77

Completed IEA SHC Task 61 / EBC Annex 77:
Integrated Solutions for Daylighting and
Electric Lighting (<https://task61.iea-shc.org/>)

White Paper

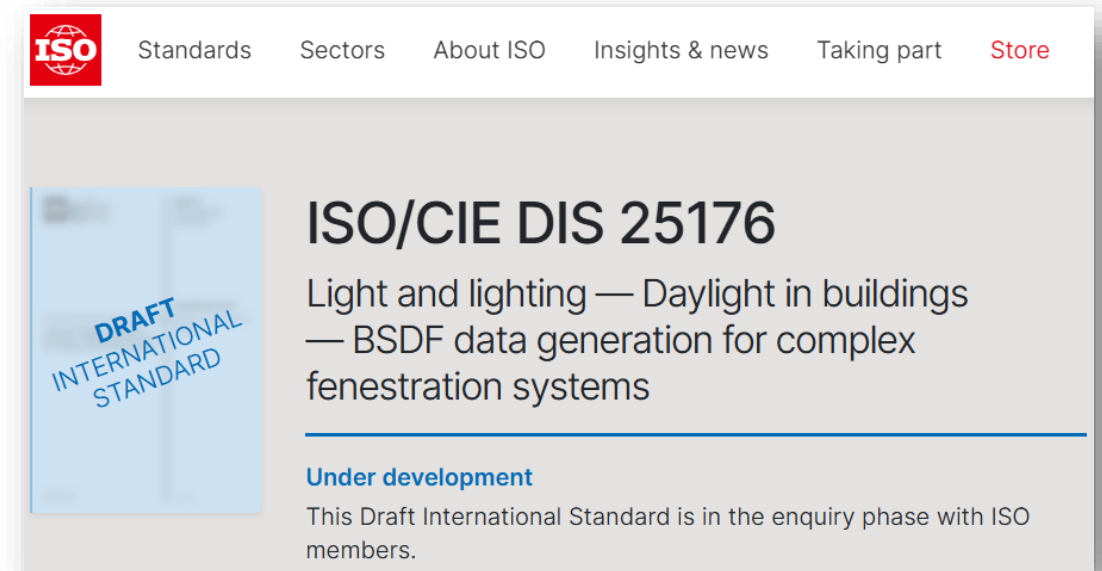
- » BSDF definitions
- » Scope
- » BSDF resolution
- » Proposed BSDF generation procedures
- » Proposed characterization types for various kinds of daylight systems

Online:
<https://doi.org/10.18777/ieashc-task61-2021-0001>



Proposed structure

- » Introduction
- » Scope
- » Normative references
- » Terms, definitions
- » BSDF data resolution
- » BSDF generation procedures
 - BSDF generation procedure for microscopic systems
 - BSDF generation procedure for macroscopic systems
- » Reporting of additional information
- » Annexes

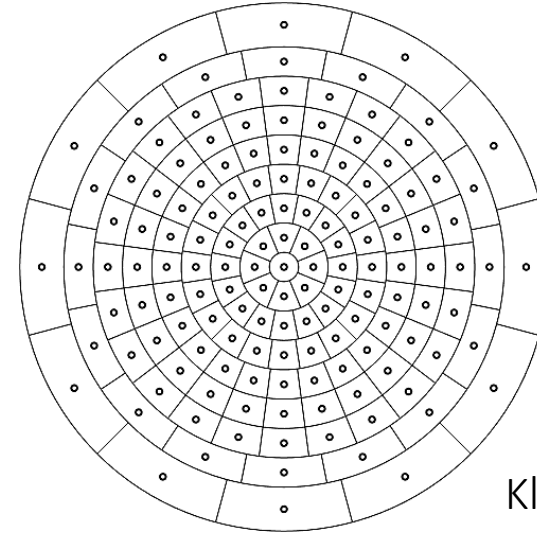


BSDF data resolution

» Low-resolution BSDF

average patch sizes between 0.0239 sr and 0.1373 sr
(i.e. cones with full opening angles of 10° to 24°)

Examples: Klems, Tregenza, Tensor tree $2^4 \times 2^4$

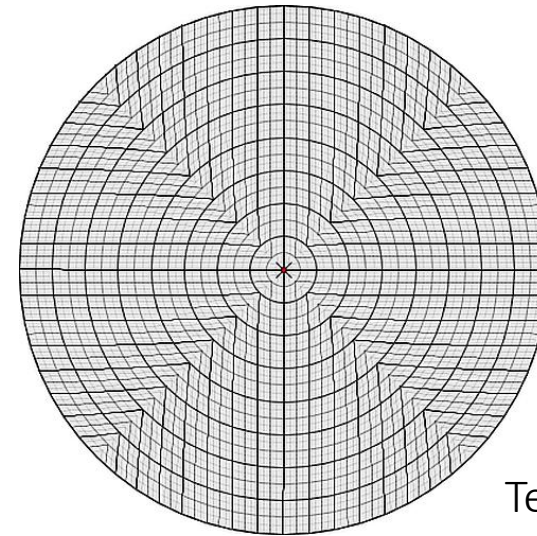


Klems (145 x 145)

» High-resolution BSDF

average patch sizes less than 0.0239 sr
(i.e. cones with full opening angles less than 10°)

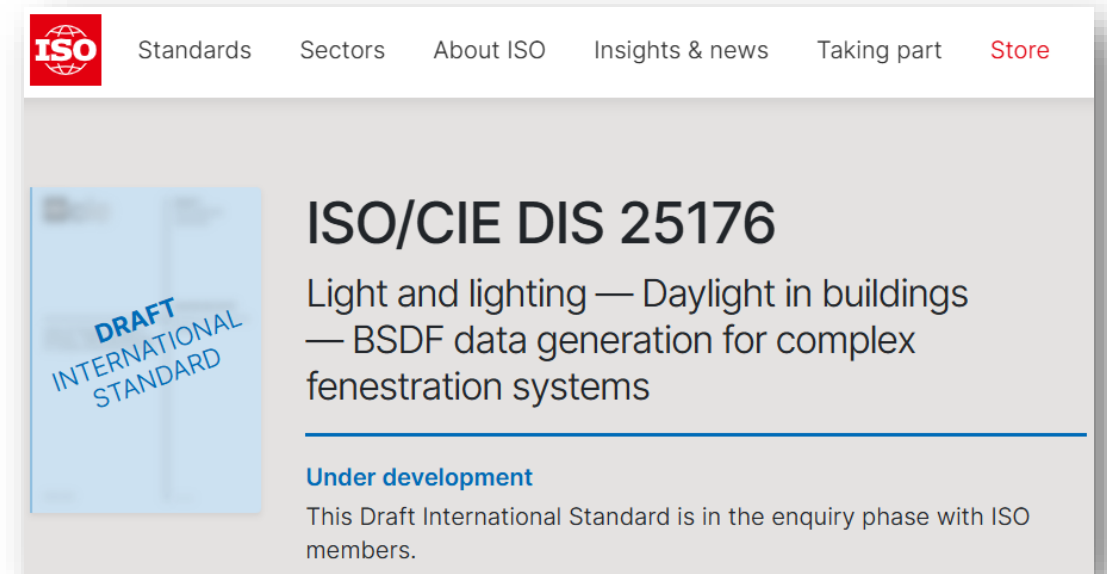
Examples: Tensor tree $2^5 \times 2^5$ or higher

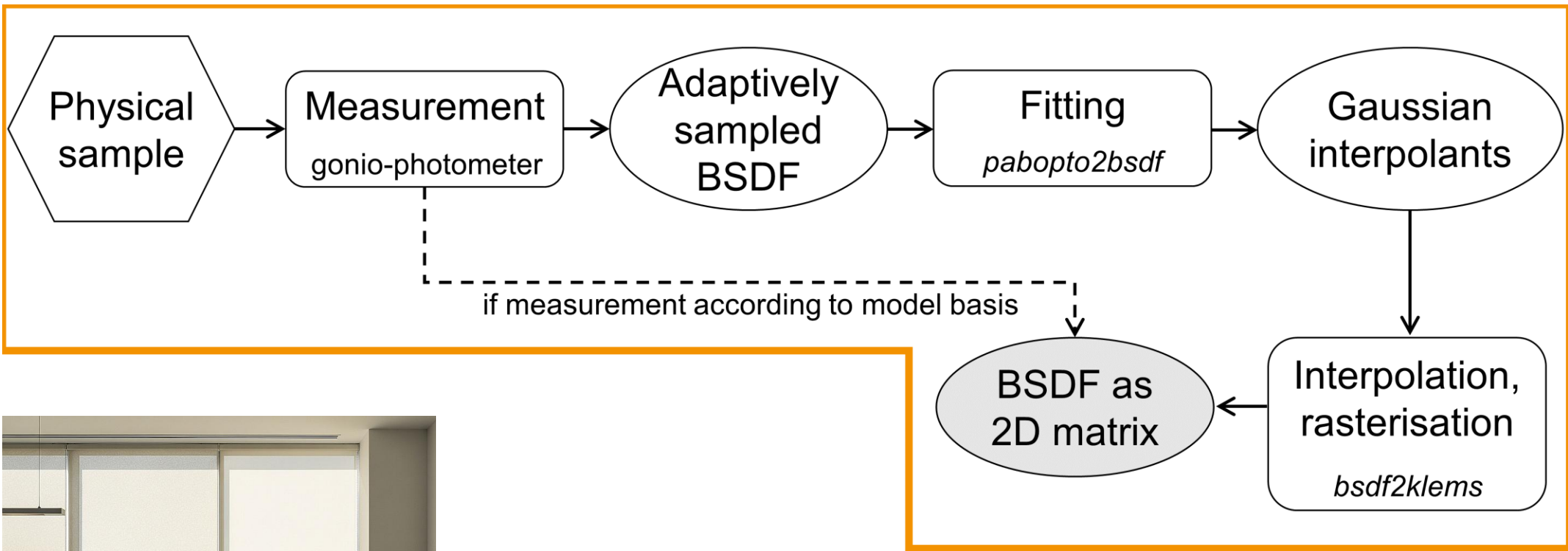


Tensor tree $2^6 \times 2^6$

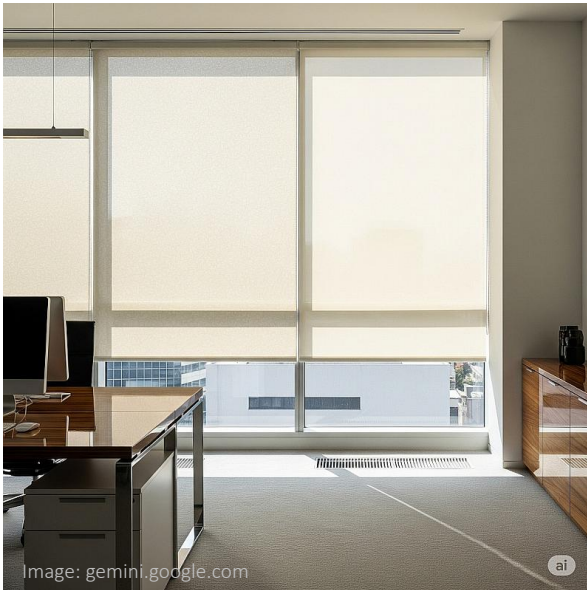
Proposed structure

- » Introduction
- » Scope
- » Normative references
- » Terms, definitions
- » BSDF data resolution
- » **BSDF generation procedures**
 - BSDF generation procedure for microscopic systems
 - BSDF generation procedure for macroscopic systems
- » Reporting of additional information
- » Annexes





Measurement-based | Microscopic systems



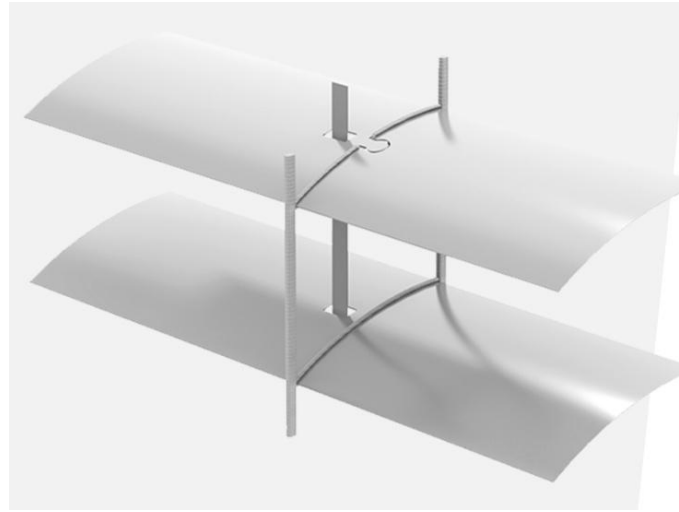
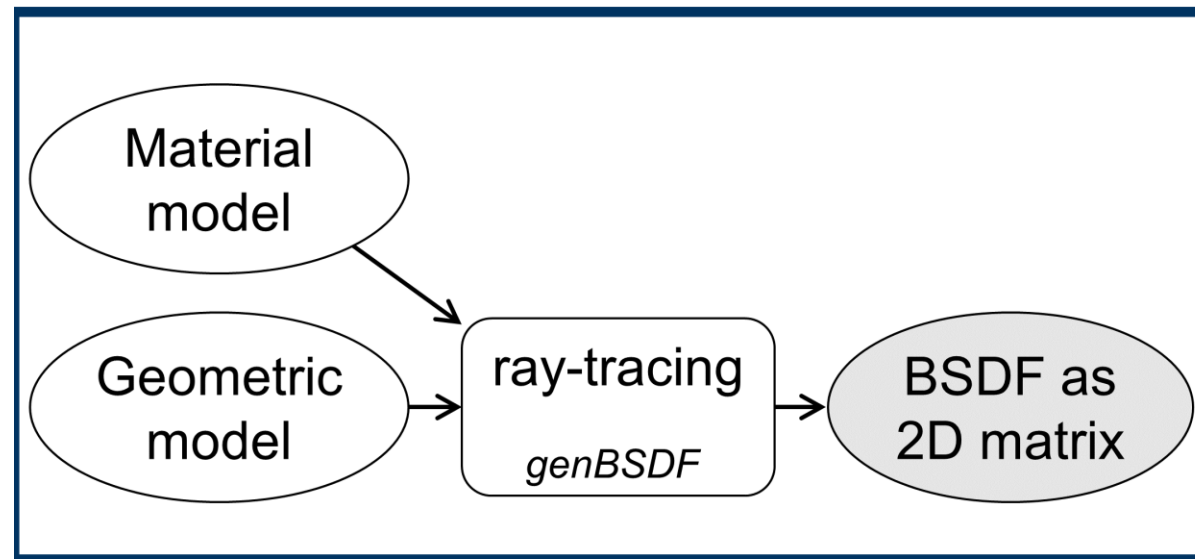
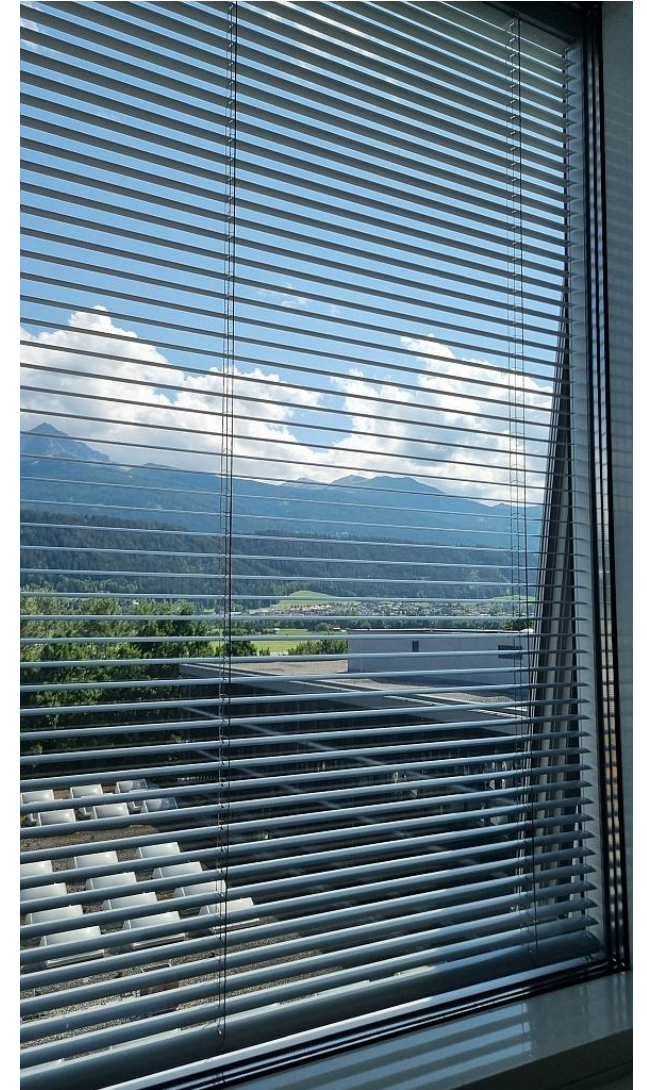
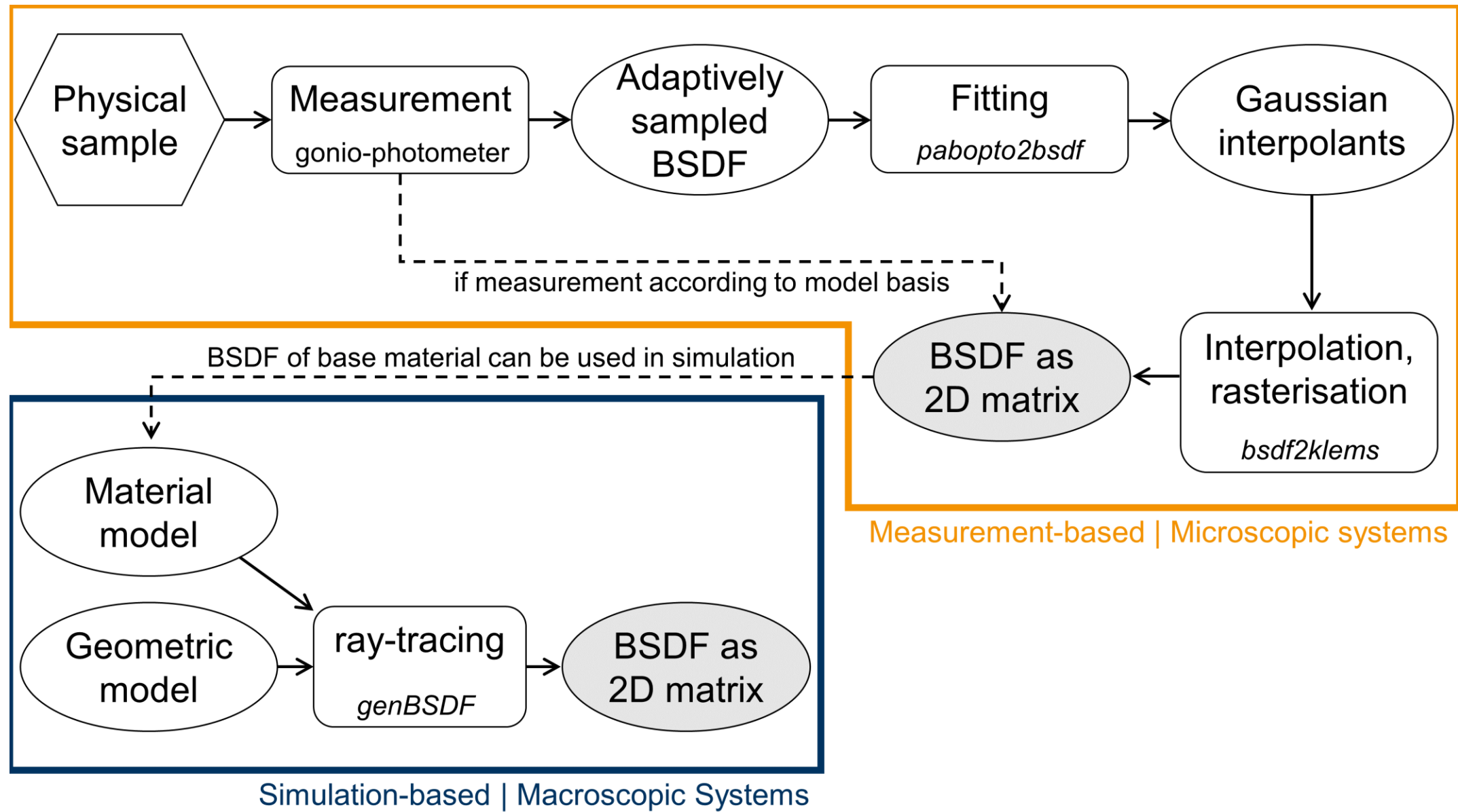


Image: www.hella.info



Simulation-based | Macroscopic Systems

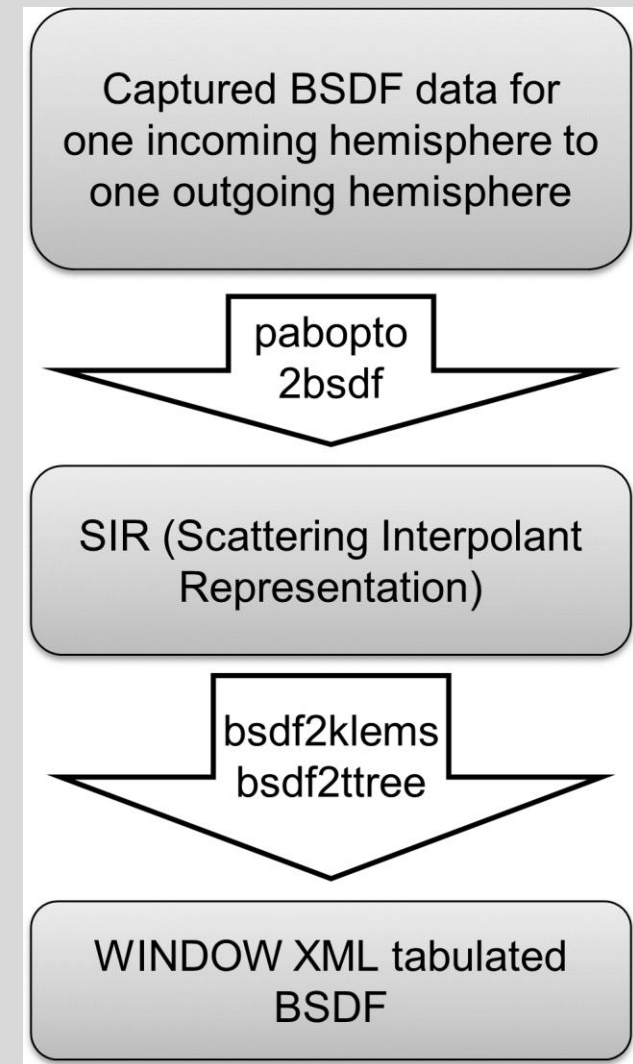


Annexes

- » Angular bases for BSDF discretization
- » Incident directions for goniophotometric measurements
- » Interpolation of goniophotometer measurements
- » Validation of the direct-hemispherical transmittance values
- » Data format for tabulated BSDF data sets
- » Preparation of proxy geometry for inclusion in BSDF data file
- » Example procedure for fabric shades
- » Example procedure for venetian blinds
- » Generation of tabulated BSDF data with high spatial resolution
- » Applicability of parametric models in the BSDF generation for macroscopic systems

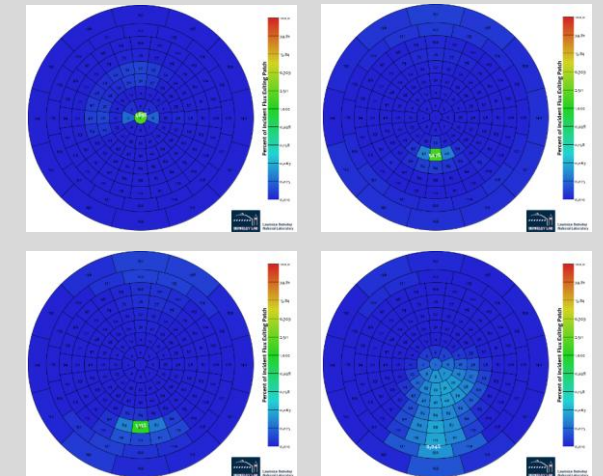
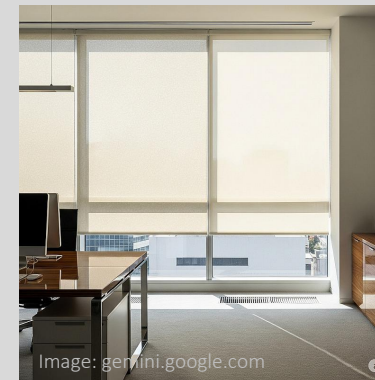
Annexes

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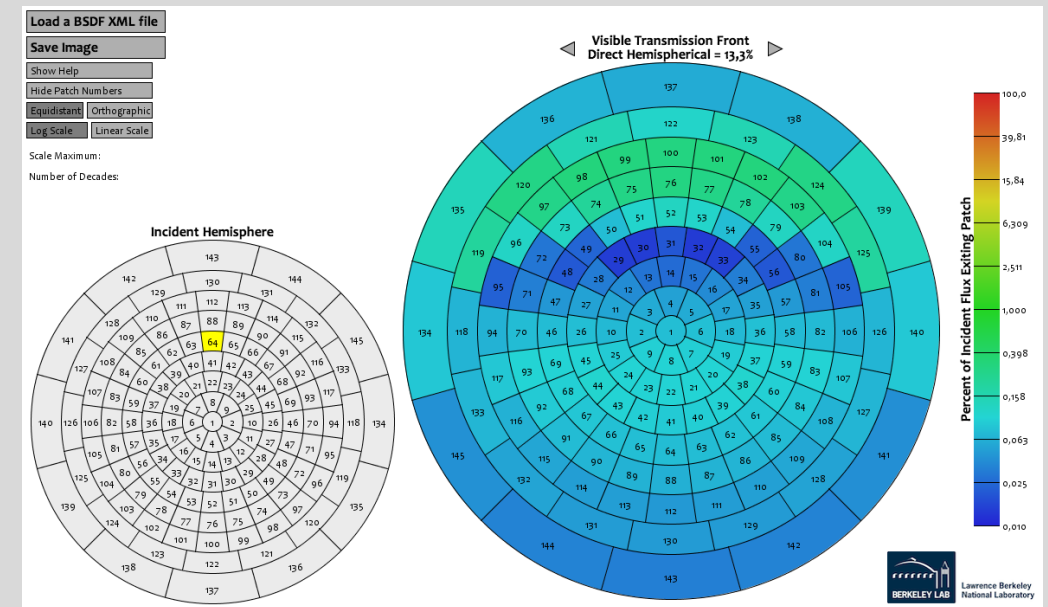
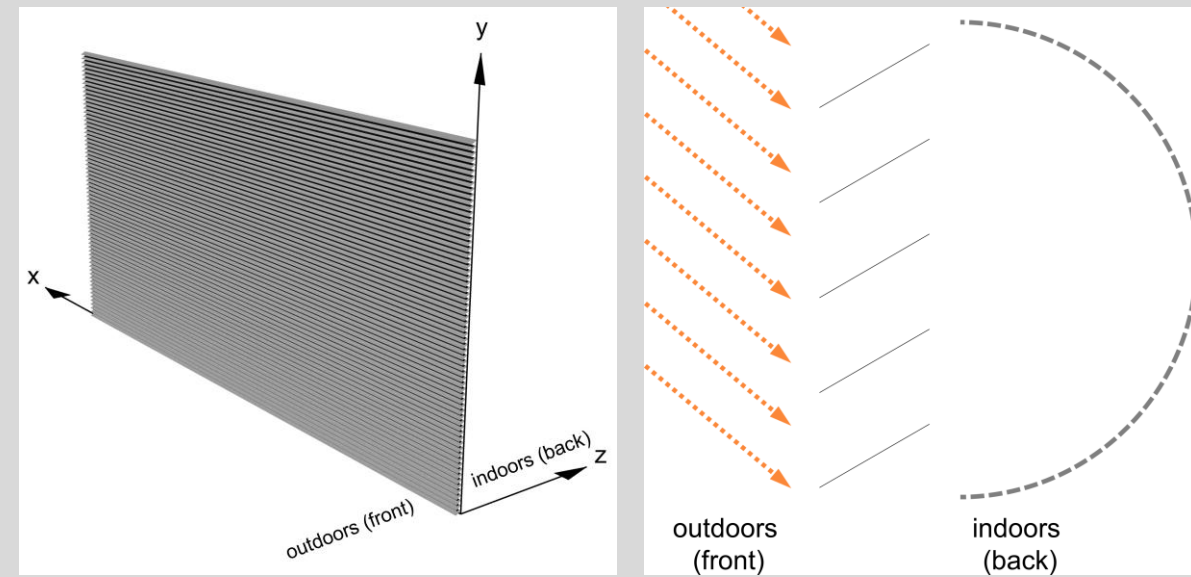
Annexes

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- » Validation of the direct-hemispherical transmittance
- » Data format for tabulated BSDF data sets
- » Preparation of proxy geometry for inclusion in BRDF
- » **Example procedure for fabric shades**
- » Example procedure for venetian blinds
- » Generation of tabulated BSDF data with high spatial resolution
- » Applicability of parametric models in the BSDF generation of macroscopic systems



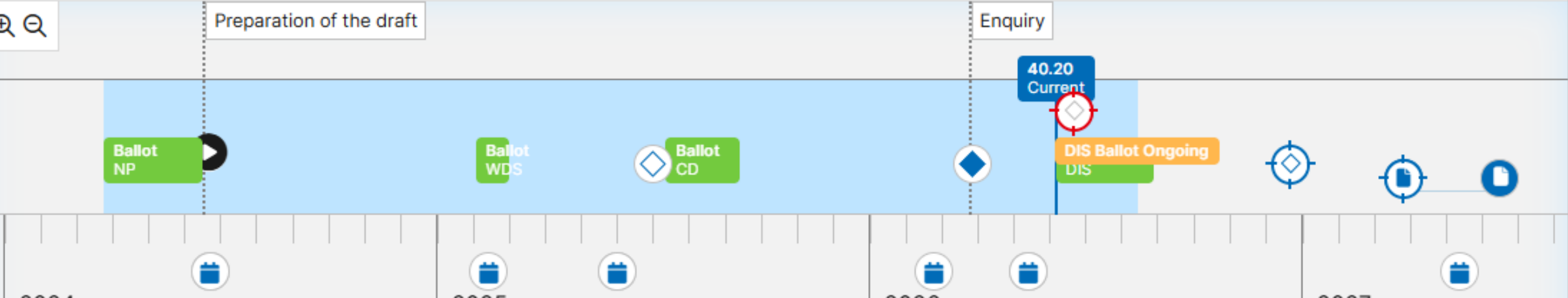
Annexes

- » Angular bases for BSDF discretization
- » Incident directions for goniophotometric measurement
- » Interpolation of goniophotometer measurement
- » Validation of the direct-hemispherical transmittance
- » Data format for tabulated BSDF data sets
- » Preparation of proxy geometry for inclusion in BR
- » Example procedure for fabric shades
- » **Example procedure for venetian blinds**
- » Generation of tabulated BSDF data with high spatial resolution
- » Applicability of parametric models in the BSDF goniophotometric macroscopic systems



Timeline

Registration date	Timeframe	Time since registration	In stage	STATUS
2024-06-20	36 months	26 months	40.20 for 2 months 9 days	en DIS ballot ongoing



- Project approved (clock starts)
- Meeting
- Past period
- Critical period

Stage

Stage	Version	Description	Go to draft	Target date	Limit date	Started	Status
40.00	1	DIS registered		2026-02-27	2026-06-20	2026-03-30	Closed
40.20	1	DIS ballot initiated		2026-06-11		2026-06-11	Current
40.60	1	Close of voting		2026-09-03			Awaiting
40.99	1	Full report circulated: DIS approved for registration as FDIS					Awaiting
50.00	1	Final text received or FDIS registered for formal approval		2026-12-24			Awaiting
60.60	1	International Standard published		2027-03-30	2027-06-20		Awaiting

Show all stages

Today's Menu

🍴 *Starter* 🍴 $\text{BSDF} = \frac{dL}{dE}$

🍴 *Second Course* 🍴 ISO/CIE Standardization

🍴 *Third Course* 🍴 BSDF Generation (i) – measurement-based

🍴 *Fourth Course* 🍴 BSDF Generation (ii) – simulation-based

🍴 *Dessert* 🍴 Application of BSDFs in Radiance

Principles of BSDF & Optical Scattering

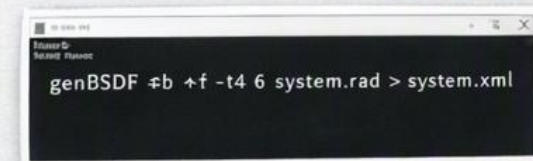
Lumen (lm) is the unit of luminous flux, the total amount of light emitted in all directions by a source. It is measured in Watts (W) for non-visible light and in Lumens (lm) for visible light. The luminous flux is the total amount of light that is emitted by a source in all directions.

Luminous intensity (cd) is the amount of light emitted by a source in a particular direction. It is measured in Candelas (cd). The luminous intensity is the amount of light that is emitted by a source in a particular direction.

Table 1: BSDF Data

Table 1 shows the BSDF data for a particular material. The BSDF is the ratio of the luminous flux to the incident luminous flux.

Wavelength (nm)	BSDF (lm/W)
400	0.000
450	0.000
500	0.000
550	0.000
600	0.000
650	0.000
700	0.000

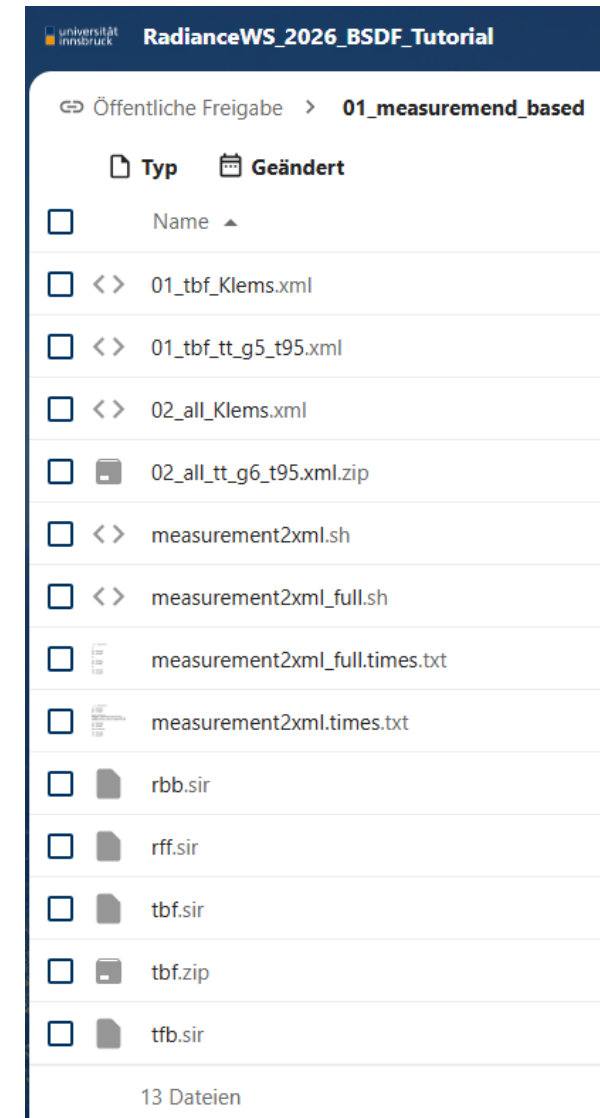


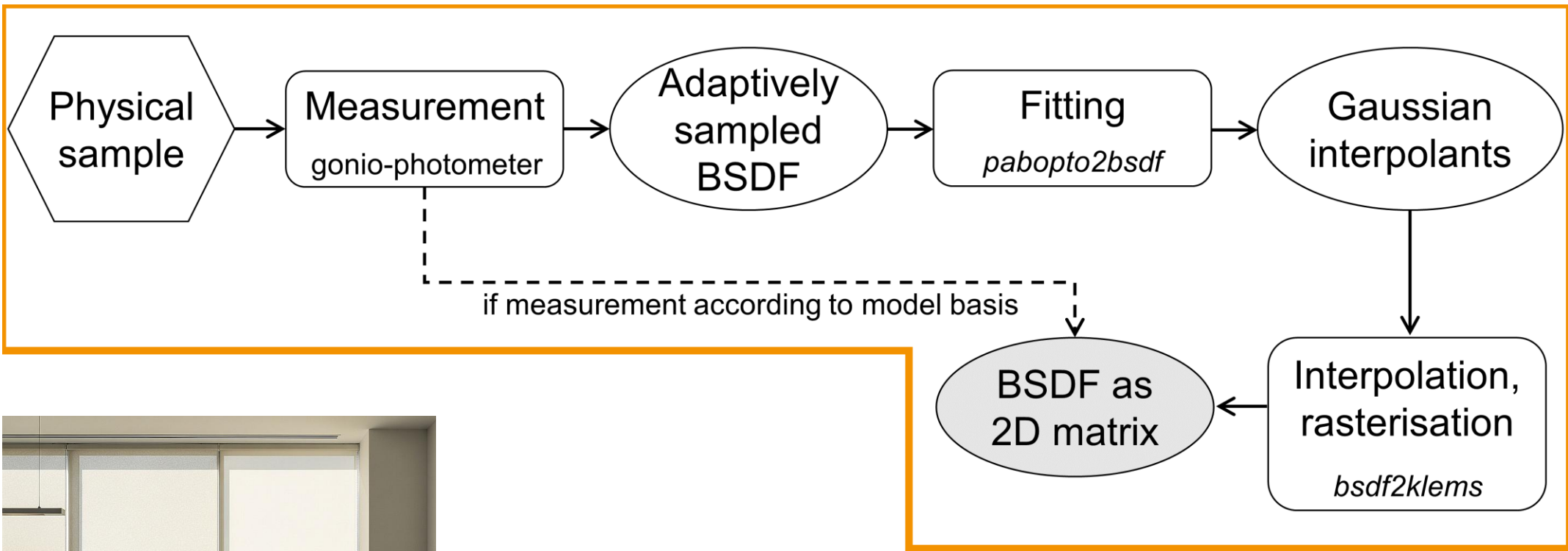
BSDF Generation (i) – Measurement-based

Get files at:

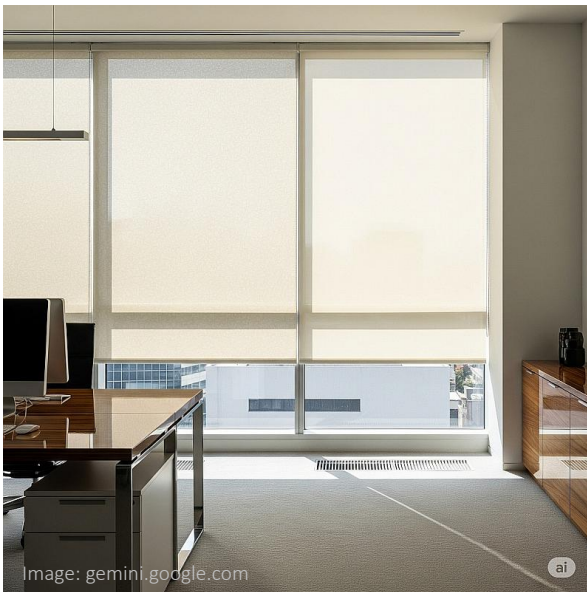
<https://universe.uibk.ac.at/s/2Waw23CYj8s8Cxz>

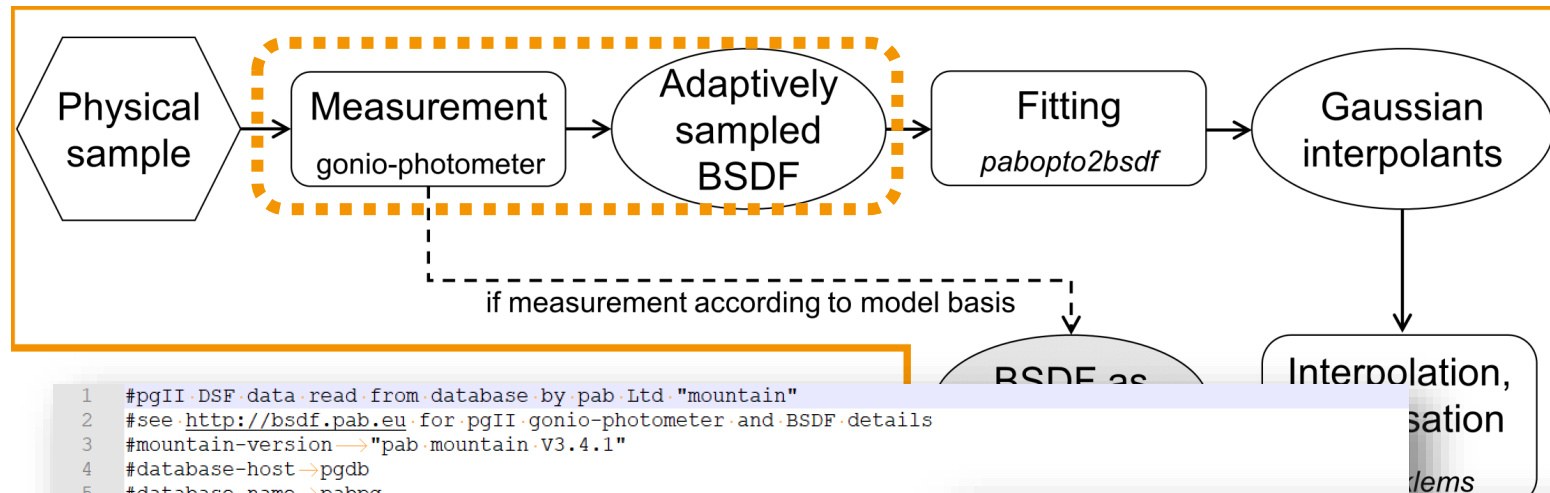
➤ 01_measuremend_based





Measurement-based | Microscopic systems





```

1 #pgII.DSF data read from database by pab.Ltd "mountain"
2 #see http://bsdf.pab.eu for pgII.gonio-photometer and BSDF details
3 #mountain-version -> "pab.mountain.V3.4.1"
4 #database-host -> pgdb
5 #database-name -> pabpg
6 #measured_at -> "2020-09-08.00:53:19"
7 #data_read_from_db -> "2020-09-18.22:11:14"
8 #database_id -> 16958
9 #datapoints_in_db -> 154022
10 #database_reference_id -> 16956
11 #sample_label -> "BIMSOL090"
12 #sample_name -> "IEA_round_robin/_fabric"
13 #lamp -> "halogen"
14 #beamshape -> "sample,f=200,a=1"
15 #filterlamp -> "IRCutoff"
16 #filterdet -> "none"
17 #comment -> "LBNL.completion.and.IEA.fabric.full.Klems"
18 #mcomment -> "$Id: do_meas_batch.c,v.1.45.2019/12/01.12:59:07.apian
    serial[1]="008".(channel.minimum)|phirot2.place=2|optfile=BIMSOL_N
    /usr/local/pab_pg/etc/RCS/userdata.pgII-hslu,v.1.14.2019/04/02.18:
    $|cxtcounter=yes|bl_armB=0|daq_ss=100|speedbend=(0,0)|pawait=150|p
    poweron=93124.[h].last_change=5887.[min]"
19 #dbfilter -> ""
20 #channels.(chan,pa)>"(1,3).(1,2)."
21 #column>daq
22 #dump-host -> pgII-hslu
23 #incident_angle>180>0
24 #intheta -> 180
25 #inphi -> 0
26 #integrated_value -> 0.0372 -> 6.28
27 #front_integral>0.0372
28 #incident_and_front_integral -> 180>0 -> 0.0372
29 #mountain_minimum_angle>0.0014.[deg]
30 #datapoints_in_file>154021
31 #format:.theta->phi>DSF
32 89.88132 -> -79.95683 -> 1.382e-03
33 89.69265 -> -79.97533 -> 7.194e-04
34 89.50714 -> -79.99422 -> 3.650e-04
35 89.30886 -> -80.01508 -> 6.384e-04
36 89.13702 -> -80.03358 -> 7.754e-04
37 88.92162 -> -80.05755 -> 4.968e-04
  
```

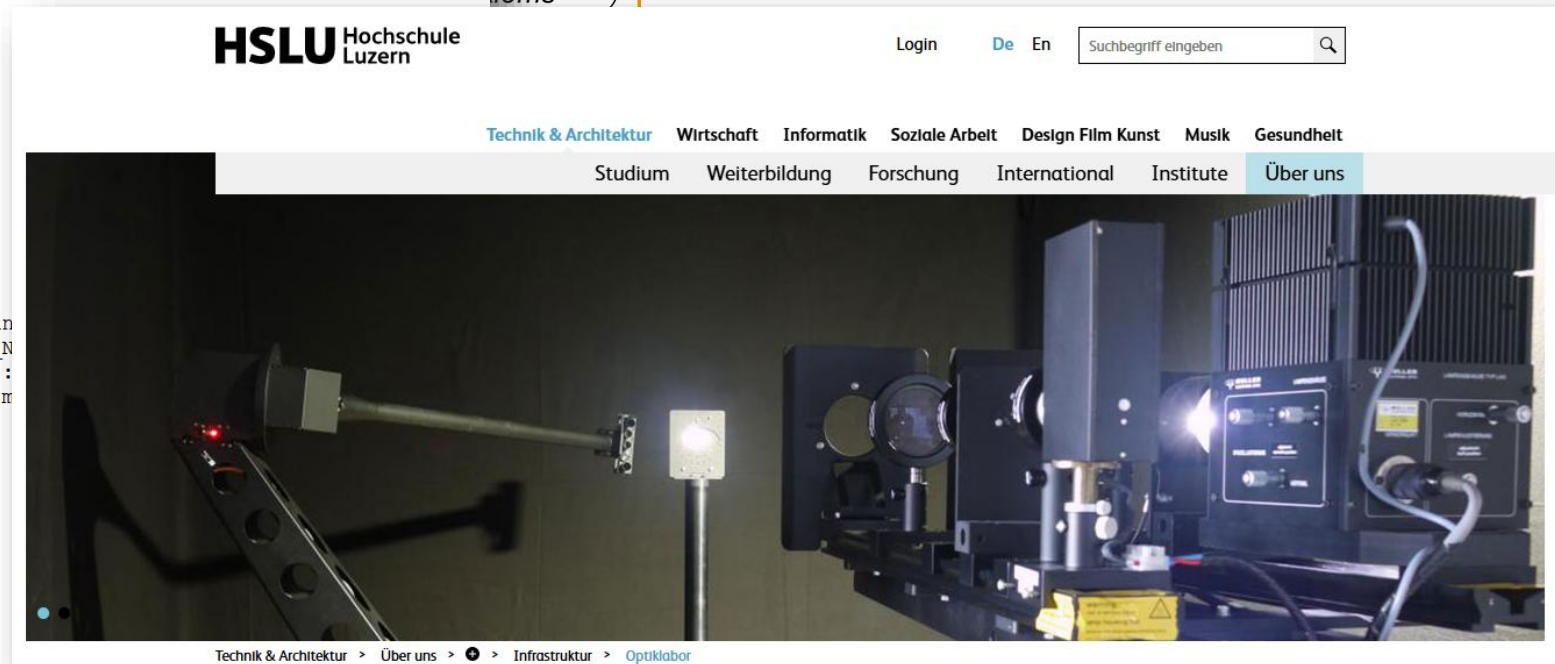
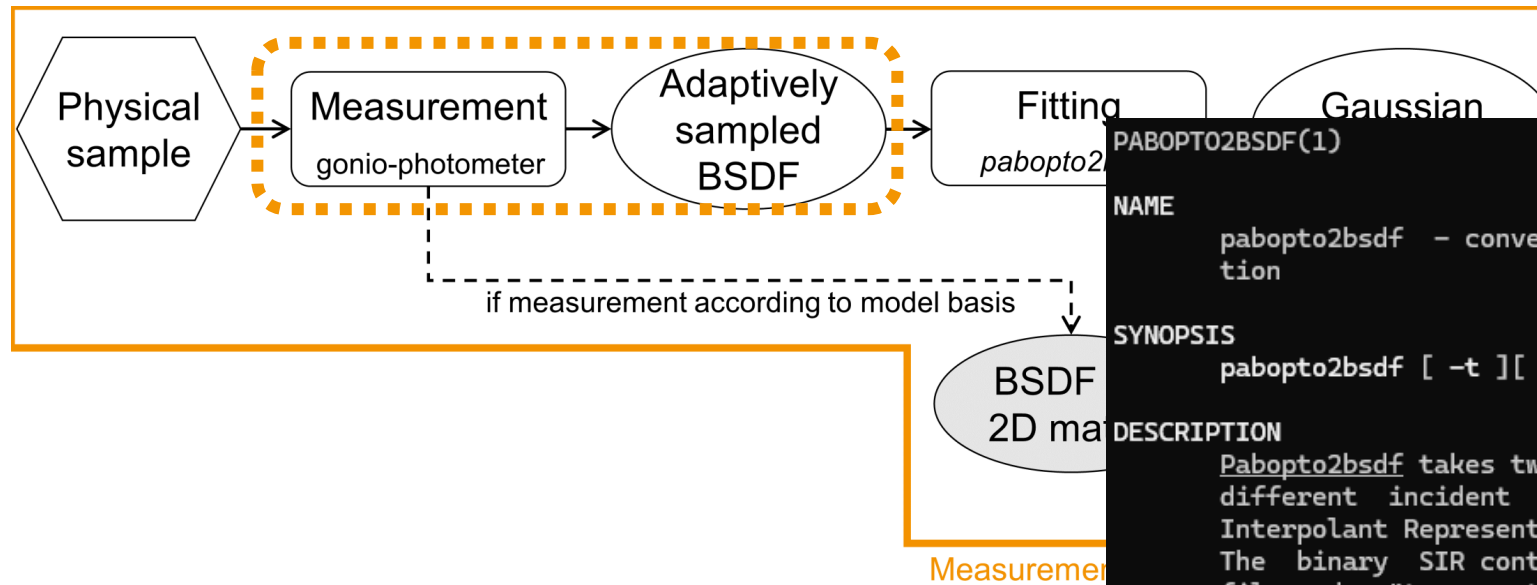


Image: <https://www.hslu.ch/.../kompetenzzentrum-gebaeudehuelle-und-ingenieurbau/infrastruktur/optisches-labor/>



PABOPTO2BSDF(1)

General Commands Manual

PABOPTO2BSDF(1)

NAME

pabopto2bsdf - convert BSDF measurements to a scattering interpolant representation

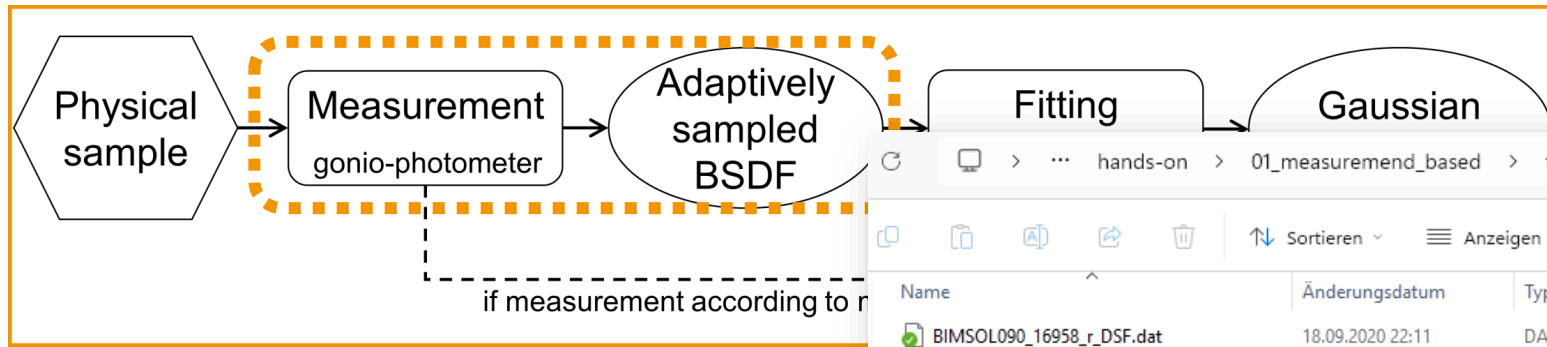
SYNOPSIS

pabopto2bsdf [-t] [-n nproc] [-s symmetry] [-g angle | 'A'] meas1 meas2 ..

DESCRIPTION

Pabopto2bsdf takes two or more pab-opto Mountain files, each nominally containing different incident beam angles or sampling patterns, and produces a Scattering Interpolant Representation (SIR) on the standard output for further processing. The binary SIR contains a Radial Basis Function fitting each incident BSDF data file and a "transport plan" matrix for each pair of neighboring RBF directions in a spherical Delaunay mesh.

```
#incident_angle 170      45
#intheta        170
#inphi          45
#format: theta  phi      DSF
89.88911        -34.67367  8.794e-04
89.77548        -34.70155  4.828e-04
89.57833        -34.75048  1.156e-03
...
```



tbf durchsuchen 🔍

Sortieren ▾ Anzeigen ▾ ⋮ Details

Name	Änderungsdatum	Typ	Größe
BIMSOL090_16958_r_DSF.dat	18.09.2020 22:11	DAT-Datei	4 503 KI
BIMSOL090_16960_r_DSF.dat	18.09.2020 22:11	DAT-Datei	4 465 KI
BIMSOL090_16962_r_DSF.dat	18.09.2020 22:11	DAT-Datei	4 472 KI
BIMSOL090_16964_r_DSF.dat	18.09.2020 22:11	DAT-Datei	4 462 KI
BIMSOL090_16966_r_DSF.dat	18.09.2020 22:12	DAT-Datei	4 467 KI
BIMSOL090_16968_r_DSF.dat	18.09.2020 22:12	DAT-Datei	4 457 KI
BIMSOL090_16970_r_DSF.dat	18.09.2020 22:12	DAT-Datei	4 468 KI
BIMSOL090_16972_r_DSF.dat	18.09.2020 22:12	DAT-Datei	4 455 KI
BIMSOL090_16974_r_DSF.dat	18.09.2020 22:12	DAT-Datei	4 465 KI
BIMSOL090_16976_r_DSF.dat	18.09.2020 22:13	DAT-Datei	4 503 KI
BIMSOL090_16978_r_DSF.dat	18.09.2020 22:13	DAT-Datei	4 515 KI
BIMSOL090_16980_r_DSF.dat	18.09.2020 22:13	DAT-Datei	4 520 KI
BIMSOL090_16982_r_DSF.dat	18.09.2020 22:13	DAT-Datei	4 513 KI
BIMSOL090_16984_r_DSF.dat	18.09.2020 22:14	DAT-Datei	4 514 KI
BIMSOL090_16986_r_DSF.dat	18.09.2020 22:14	DAT-Datei	4 517 KI
BIMSOL090_16988_r_DSF.dat	18.09.2020 22:14	DAT-Datei	4 515 KI
BIMSOL090_16990_r_DSF.dat	18.09.2020 22:14	DAT-Datei	4 506 KI
BIMSOL090_16992_r_DSF.dat	18.09.2020 22:14	DAT-Datei	4 500 KI
BIMSOL090_16994_r_DSF.dat	18.09.2020 22:15	DAT-Datei	4 506 KI
BIMSOL090_16996_r_DSF.dat	18.09.2020 22:15	DAT-Datei	4 506 KI
BIMSOL090_16998_r_DSF.dat	18.09.2020 22:15	DAT-Datei	4 506 KI
BIMSOL090_17000_r_DSF.dat	18.09.2020 22:15	DAT-Datei	4 496 KI
BIMSOL090_17002_r_DSF.dat	18.09.2020 22:15	DAT-Datei	4 498 KI
BIMSOL090_17004_r_DSF.dat	18.09.2020 22:16	DAT-Datei	4 506 KI
BIMSOL090_17006_r_DSF.dat	18.09.2020 22:16	DAT-Datei	4 511 KI
BIMSOL090_17008_r_DSF.dat	18.09.2020 22:16	DAT-Datei	4 509 KI
BIMSOL090_17010_r_DSF.dat	18.09.2020 22:16	DAT-Datei	4 518 KI
BIMSOL090_17012_r_DSF.dat	18.09.2020 22:17	DAT-Datei	4 523 KI
BIMSOL090_17014_r_DSF.dat	18.09.2020 22:17	DAT-Datei	4 519 KI
BIMSOL090_17016_r_DSF.dat	18.09.2020 22:17	DAT-Datei	4 519 KI
BIMSOL090_17018_r_DSF.dat	18.09.2020 22:17	DAT-Datei	4 515 KI
BIMSOL090_17020_r_DSF.dat	18.09.2020 22:18	DAT-Datei	4 517 KI
BIMSOL090_17022_r_DSF.dat	18.09.2020 22:18	DAT-Datei	4 523 KI

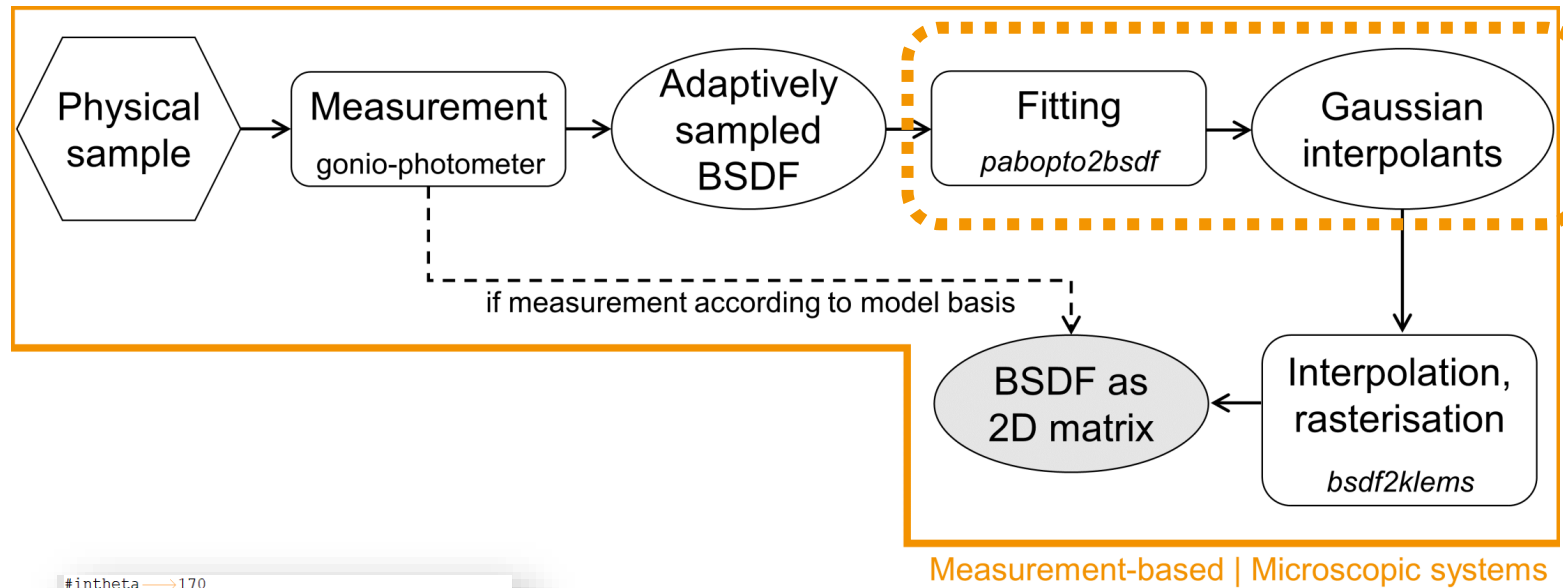
tbif (145 Elemente)

Wählen Sie eine einzelne Datei aus, um weitere Informationen zu erhalten und Ihre Cloudinhalte zu teilen.

```

#intheta -> 170
#inphi -> 0
#integrated_value -> 0.0376 -> 6.28
#front_integral -> 0.0376
#incide: #intheta -> 170
#mount: #inphi -> 45
#datap: #integrated_value -> 0.0374 -> 6.28
#format: #front_integral -> 0.0374
89.978: #incide: #intheta -> 170
89.798: #mount: #inphi -> 90
89.605: #datap: #integrated_value -> 0.0361 -> 6.28
#format: #front_integral -> 0.0361
89.8891: #incide: #intheta -> 170
89.7754: #mount: #inphi -> 135
89.5783: #datap: #integrated_value -> 0.0357 -> 6.28
#format: #front_integral -> 0.0357
89.9667: #incident_and_front_integral -> 170>135 -> 0.0357
89.7864: #mountain_minimum_angle -> 0.0014 [deg]
89.5937: #datapoints_in_file -> 152535
#format: theta -> phi -> DSF
89.98839 -> 55.34972 -> 7.716e-04
89.80800 -> 55.30569 -> -5.620e-05
89.62844 -> 55.26131 -> 1.425e-03
  
```

One file per incident direction (tbif/*)

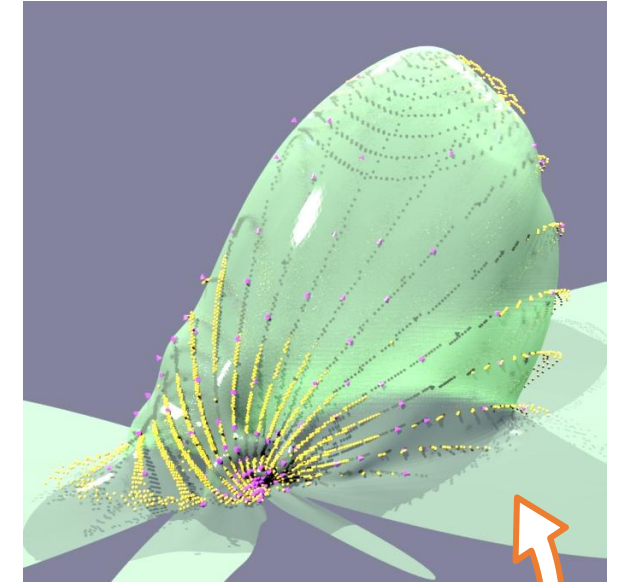


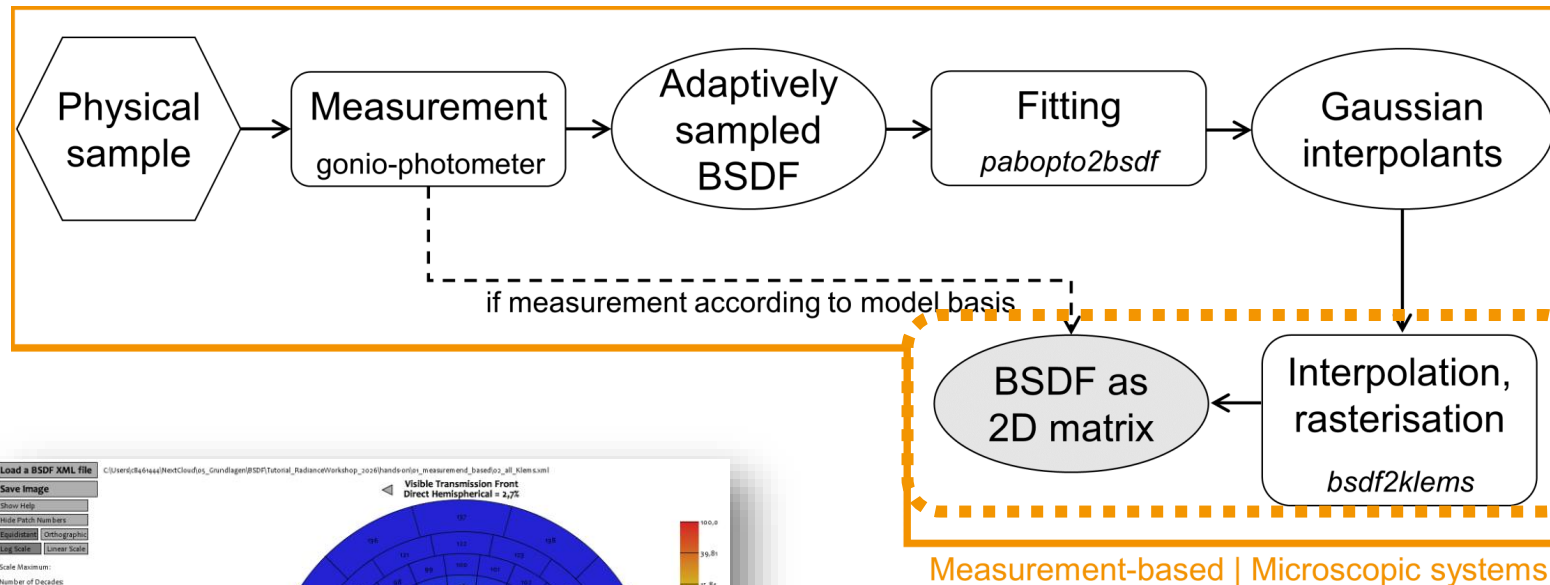
Measurement-based | Microscopic systems

```

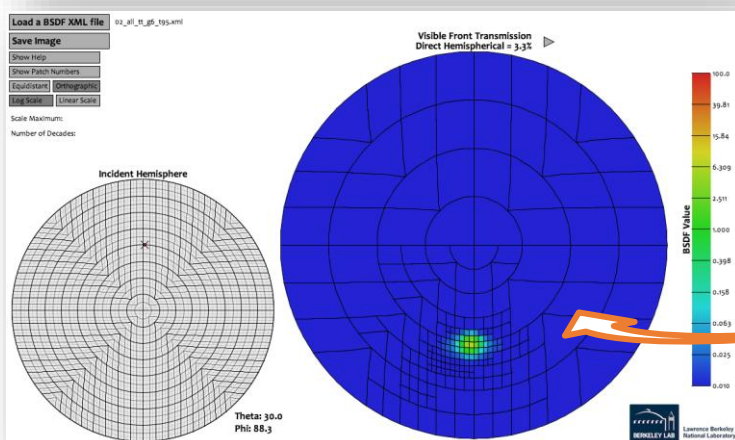
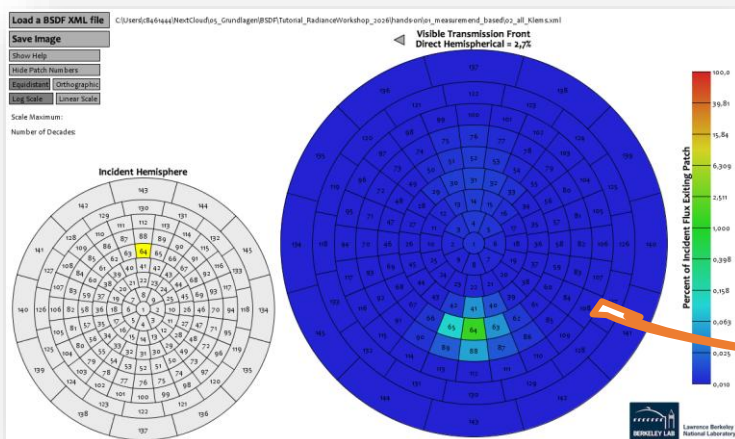
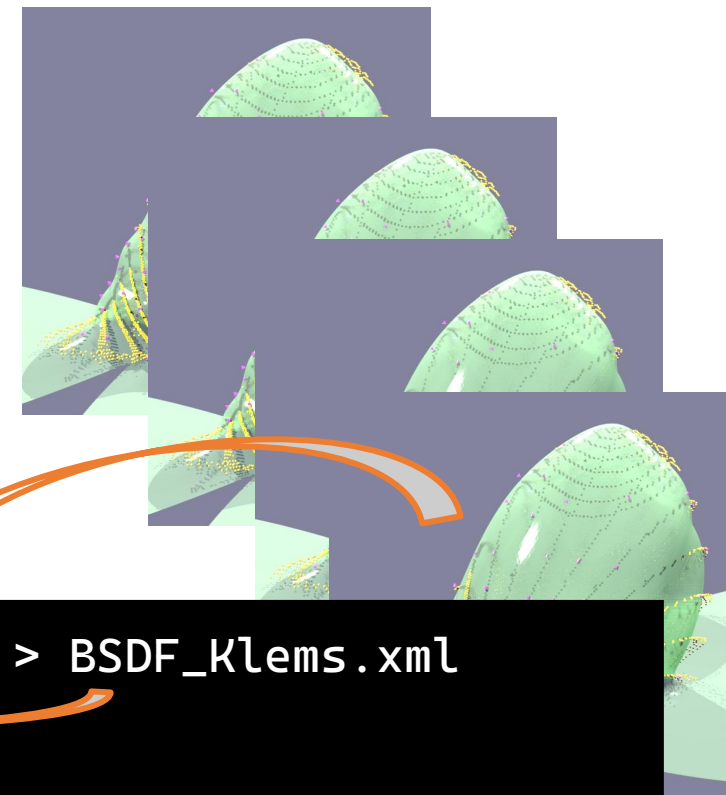
#intheta -> 170
#inphi -> 0
#integrated_value -> 0.0376 -> 6.28
#front_integral -> 0.0376
#incide
#intheta -> 170
#mounta
#inphi -> 45
#datap
#integrated_value -> 0.0374 -> 6.28
#forma
#front_integral -> 0.0374
89.978: #incide
89.798: #intheta -> 170
89.605: #mounta
#inphi -> 90
#datap
#integrated_value -> 0.0361 -> 6.28
#forma
#front_integral -> 0.0361
89.8891: #incide
89.7754: #intheta -> 170
89.5783: #mounta
#inphi -> 135
#datap
#integrated_value -> 0.0357 -> 6.28
#forma
#front_integral -> 0.0357
89.9667: #incident_and_front_integral -> 170>135 -> 0.0357
89.7864: #mountain_minimum_angle -> 0.0014 [deg]
89.5937: #datapoints_in_file -> 152535
#format: theta -> phi -> DSF
89.98839 -> 55.34972 -> 7.716e-04
89.80800 -> 55.30569 -> -5.620e-05
89.62844 -> 55.26131 -> 1.425e-03
  
```

```
pabopto2bsdf -t -n 20 tbf/*.dat > tbf.sir
```





measurement2xml.sh



```
bsdf2klems -n 4096 *.sir > BSDF_kleml.xml
```

```
bsdf2ttree -p -g 6 -t 95 *.sir > BSDF_tt_g6_t95.xml
```

Today's Menu

🍴 *Starter* 🍴 $\text{BSDF} = \frac{dL}{dE}$

🍴 *Second Course* 🍴 ISO/CIE Standardization

🍴 *Third Course* 🍴 BSDF Generation (i) – measurement-based

🍴 *Fourth Course* 🍴 BSDF Generation (ii) – simulation-based

🍴 *Dessert* 🍴 Application of BSDFs in Radiance

Principles of BSDF & Optical Scattering

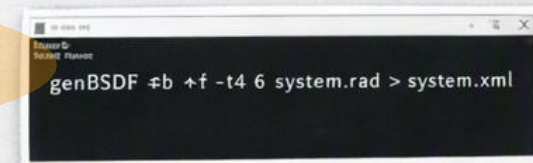
Lumen (lm) is the SI unit of luminous flux, the total amount of light energy emitted by a source in all directions. It is defined as the luminous flux of a source that emits monochromatic red light of frequency 440 THz with a radiant flux of 683 W.

Luminous flux is the total amount of light energy emitted by a source in all directions. It is defined as the luminous flux of a source that emits monochromatic red light of frequency 440 THz with a radiant flux of 683 W.

Table 1: BSDF

Lumen (lm) is the SI unit of luminous flux, the total amount of light energy emitted by a source in all directions. It is defined as the luminous flux of a source that emits monochromatic red light of frequency 440 THz with a radiant flux of 683 W.

BSDF	BSDF	BSDF	BSDF	BSDF	BSDF
BSDF	BSDF	BSDF	BSDF	BSDF	BSDF
BSDF	BSDF	BSDF	BSDF	BSDF	BSDF

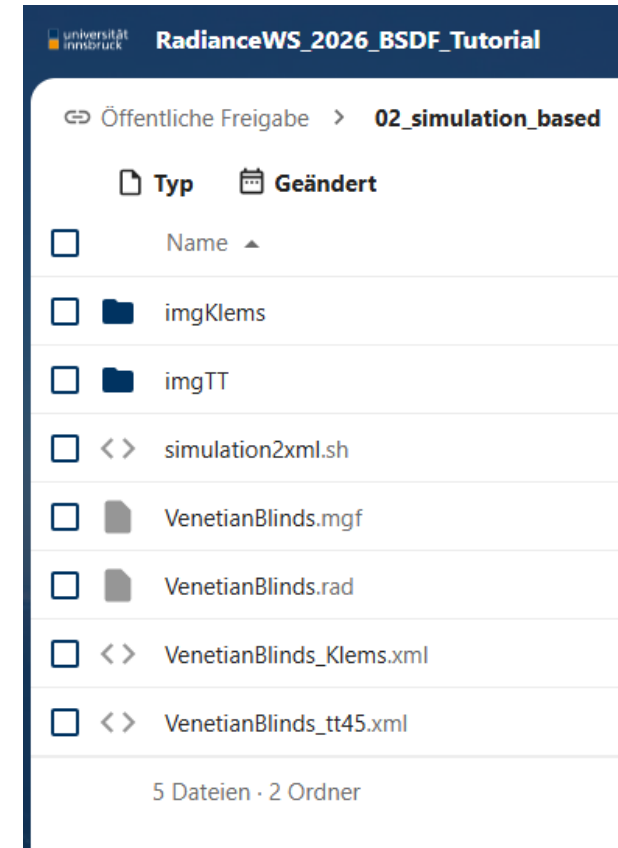


BSDF Generation (ii) – Simulation-based

Get files at:

<https://universe.uibk.ac.at/s/2Waw23CYj8s8Cxz>

➤ 02_simulation_based

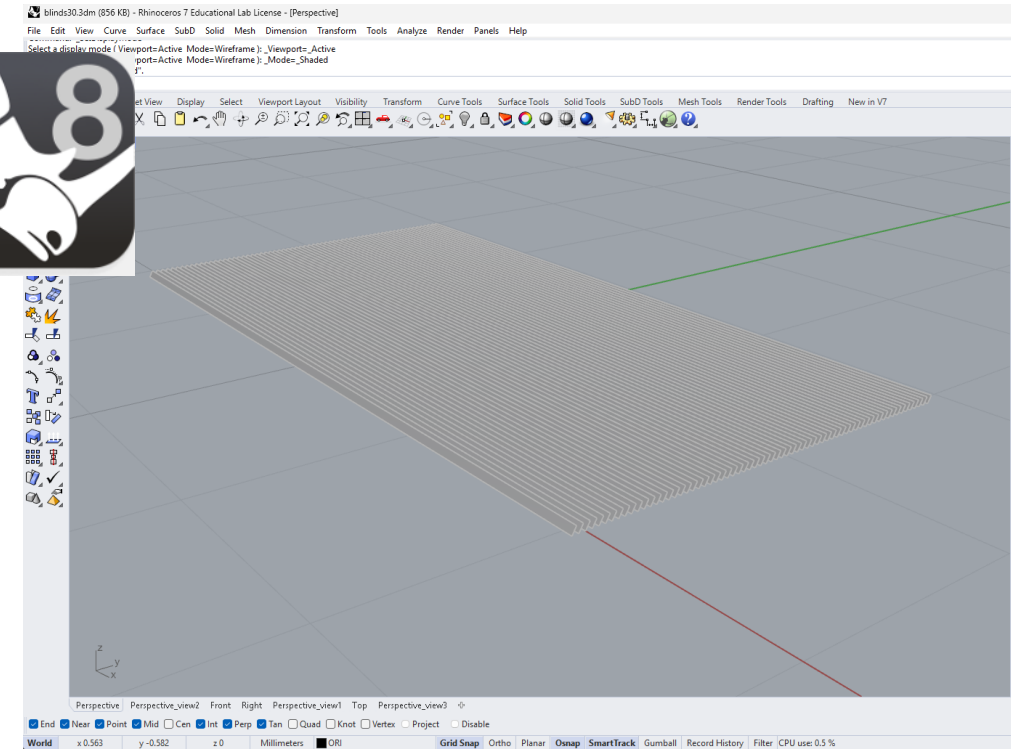


```
# Y-axis points "up", Z-axis into room, right-handed coordinates
m LightGreyLambert =
  rd .7
  rs .0 .0
  sides 2
o VenetianBlinds
xf -rx -30 -a 67 -t 0 .03 0
  o Slat
    v v1 =
      p -2 0 -.04
    v v2 =
      p 2 0 -.04
    v v3 =
      p 2 0 0
    v v4 =
      p -2 0 0
    f v1 v2 v3 v4
  o
xf
o
```

VenetianBlinds.mgf



OR

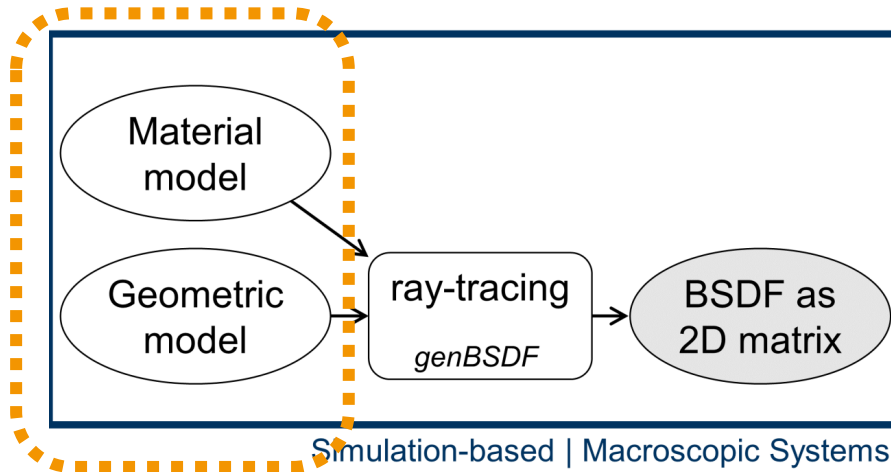


OR

```
void plastic lGrey
0
0
5 0.7 0.7 0.7 0 0

!genblinds lGrey venBlinds 0.04 4 2.01 67 -30 | \
xform -rz 90 -t 2 0 0 -rx -90
```

VenetianBlinds.rad



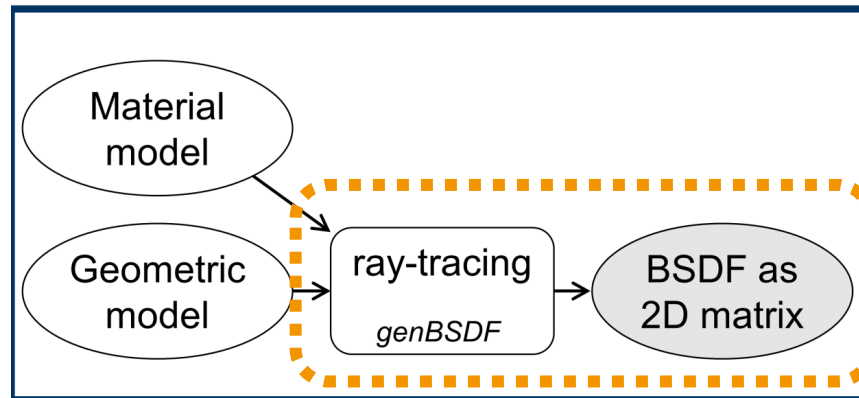
Simulation-based | Macroscopic Systems

```
# Y-axis points "up", Z-axis into room, right-handed coordinates
m LightGreyLambert =
    rd .7
    rs .0 .0
    sides 2
o VenetianBlinds
xf -rx -30 -a 67 -t 0 .03 0
    o Slat
        v v1 =
            p -2 0 -.04
        v v2 =
            p 2 0 -.04
        v v3 =
            p 2 0 0
        v v4 =
            p -2 0 0
        f v1 v2 v3 v4
    o
xf
o
```

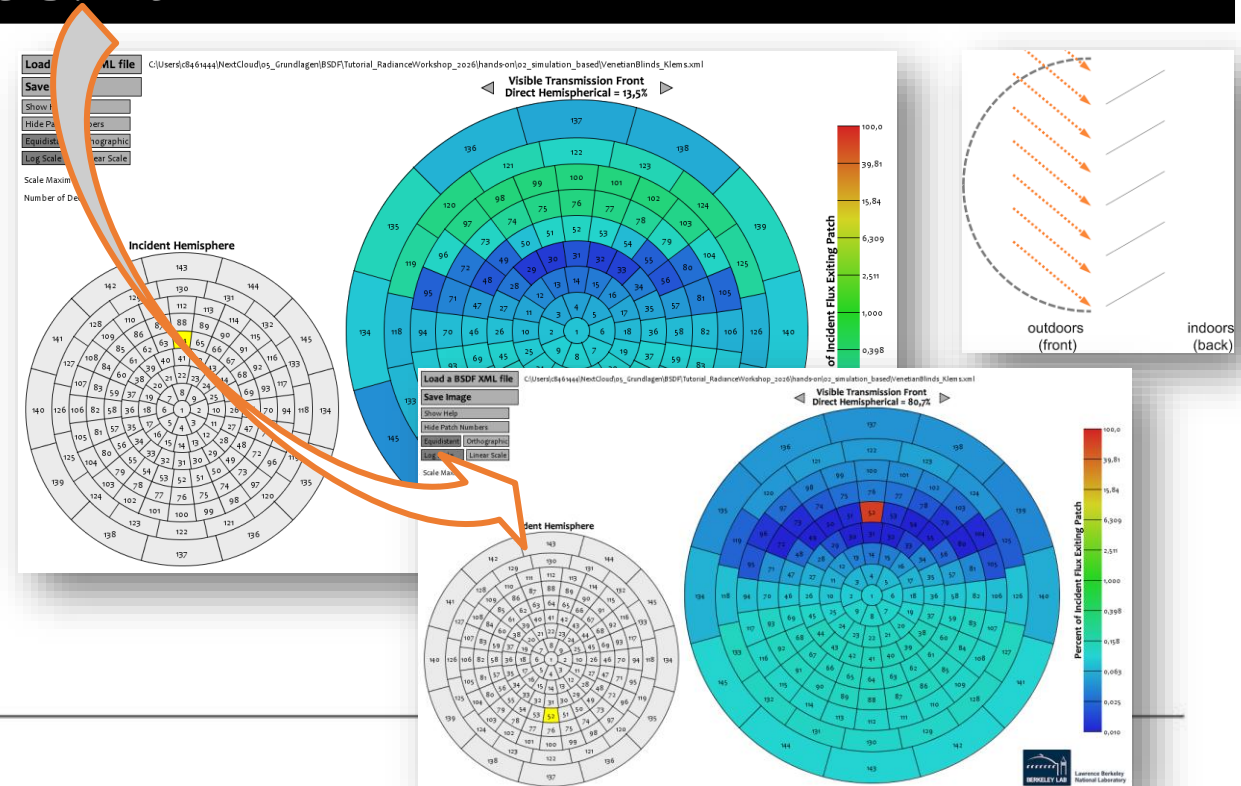
simulation2xml.sh

```
genBSDF -n 20 +geom meter +mgf +f +b -c 1450 VenetianBlinds.mgf >
VenetianBlinds_Klems.xml
## OR ##
genBSDF -n 20 +geom meter +f +b -c 1450 VenetianBlinds.rad >
VenetianBlinds_Klems.xml
```

VenetianBlinds.mgf



Simulation-based | Macroscopic Systems

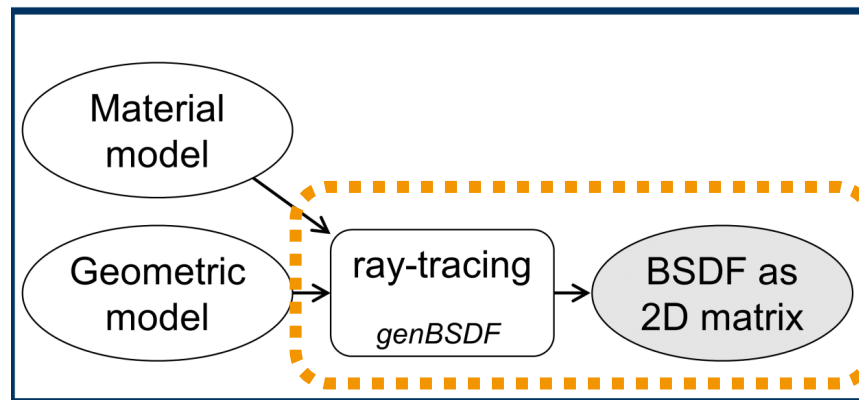


```
# Y-axis points "up", Z-axis into room, right-handed coordinates
m LightGreyLambert =
    rd .7
    rs .0 .0
    sides 2
o VenetianBlinds
xf -rx -30 -a 67 -t 0 .03 0
    o Slat
        v v1 =
            p -2 0 -.04
        v v2 =
            p 2 0 -.04
        v v3 =
            p 2 0 0
        v v4 =
            p -2 0 0
        f v1 v2 v3 v4
    o
xf
o
```

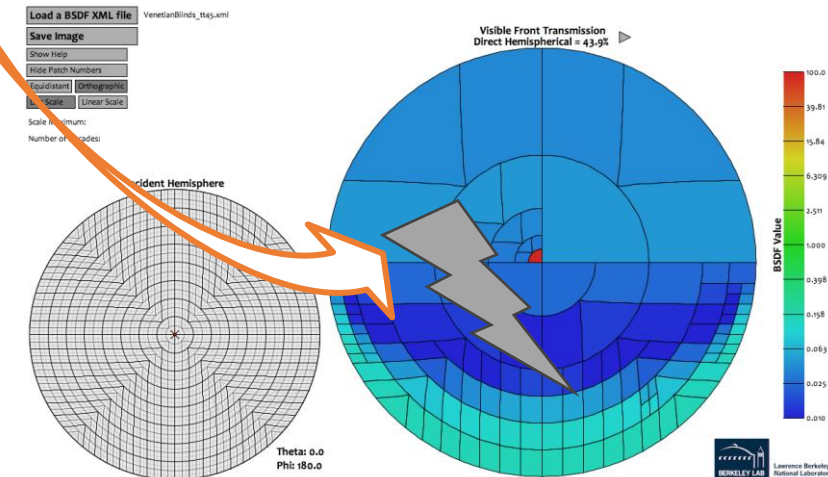
simulation2xml.sh

```
genBSDF -n 20 +geom meter +mgf +f +b -t4 5 -c 1024 VenetianBlinds.mgf
> VenetianBlinds_tt45.xml
## OR
genBSDF -n 20 +geom meter +f +b -t4 5 -c 10240 VenetianBlinds.rad >
VenetianBlinds_tt45.xml
```

VenetianBlinds.mgf



Simulation-based | Macroscopic Systems



genBSDF Tutorial

Andy McNeil's genBSDF Tutorial

https://www.radiance-online.org/learning/tutorials/Tutorial-genBSDF_v1.0.1.pdf

genBSDF Tutorial

Andy McNeil, LBNL

Revision History

29 September 2015 Version 1.0
23 October 2015 Version 1.0.1 fixed material name for example 1.

Abstract

This tutorial demonstrates how to use genBSDF to create a BSDF for a fenestration system component from a 3D model of the system. Three examples are provided, a venetian blind, an arbitrary shading system, and a prismatic daylight-redirecting device.

Contents:

- 1 - Introduction
- 2 - BSDF file format
- 3 - Using genBSDF (overview)
- 4 - Example 1 (venetian blind)
- 5 - Example 2 (arbitrary shading layer)
- 6 - Example 3 (prismatic daylight redirecting device)

Today's Menu

🍴 *Starter* 🍴 $\text{BSDF} = \frac{dL}{dE}$

🍴 *Second Course* 🍴 ISO/CIE Standardization

🍴 *Third Course* 🍴 BSDF Generation (i) – measurement-based

🍴 *Fourth Course* 🍴 BSDF Generation (ii) – simulation-based

🍴 *Dessert* 🍴 Application of BSDFs in Radiance

Principles of BSDF & Optical Scattering

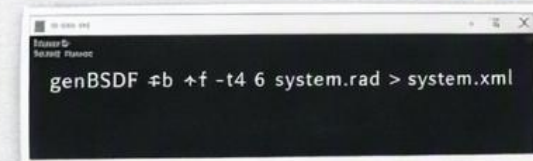
Light is a form of energy that travels in waves. When it strikes a surface, it can be reflected, refracted, or absorbed. The way light interacts with a surface is described by its Bidirectional Scattering Distribution Function (BSDF).

The BSDF is a mathematical function that describes the probability of light being scattered in a particular direction. It is a function of the incident and outgoing directions, and the material properties of the surface.

Table 1: BSDF Data

Table 1 shows the BSDF values for a surface with a refractive index of 1.5. The values are normalized to the incident light intensity.

Incident Angle	Reflected Angle	BSDF Value
0°	0°	0.5
30°	30°	0.4
60°	60°	0.3
90°	90°	0.2
120°	120°	0.1
150°	150°	0.05



BSDFs in Radiance

- » Viewing BSDFs
- » Using BSDFs as material
- » BSDFs in Matrix-based Methods
- » Combining BSDFs with spectral data

Viewing BSDFs (i)

*C:\Users\c8461444\NextCloud\05_Grundlagen\BSDFTutorial_RadianceWorkshop_2026\hands-on\02_simulation_based\VenetianBlinds_Klems.xml - Notepad++

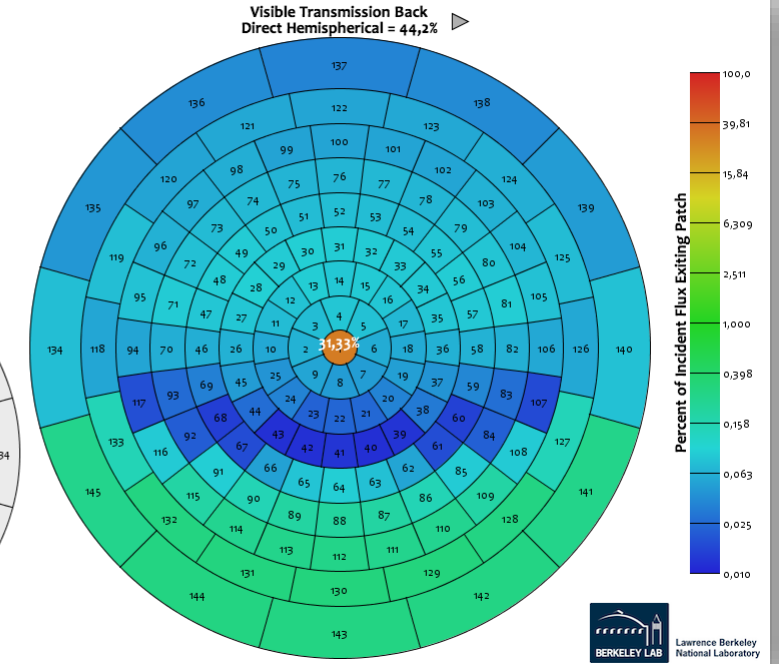
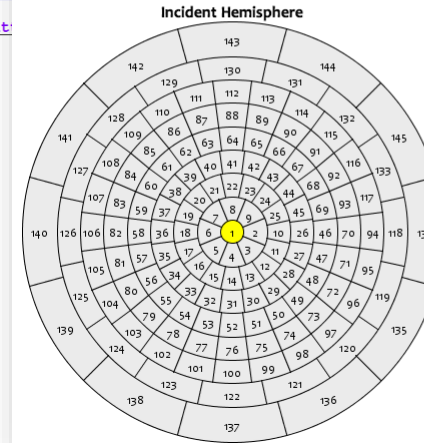
```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Created by: genBSDF -n 20 -geom.meter -mgf +f +b -c 1450.VenetianBlinds.mgf -->
<WindowElement xmlns="http://windows.lbl.gov" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.w3.org/2001/XMLSchema-instance http://www.w3.org/2001/XMLSchema-instance">
  <WindowElementType>System</WindowElementType>
  <FileType>BSDF</FileType>
  <Optical>
    <Layer>
      <Material>
        <Name>Name</Name>
        <Manufacturer>Manufacturer</Manufacturer>
        <DeviceType>Other</DeviceType>
        <Thickness unit="meter">0.034641</Thickness>
        <Width unit="meter">4</Width>
        <Height unit="meter">2</Height>
      </Material>
      <Geometry format="MGF">MGFblock unit="meter">xf -t 0.000000 -0.980000 0
      # Y-axis points "up", Z-axis into room, right-handed coordinates
      m LightGreyLambert =
      rd .7
      rs .0 .0
      sides 2
      o VenetianBlinds
      xf -rx -30 -a 67 -t 0 .03 0
      o Slat
      v v1 =
      p -2 0 -.04
      v v2 =
      p 2 0 -.04
      v v3 =
      p 2 0 0
      v v4 =
      p -2 0 0
    </Layer>
  </Optical>
</WindowElement>
```

```
<WavelengthDataBlock>
  <WavelengthDataDirection>Transmission Back</WavelengthDataDirection>
  <ColumnAngleBasis>LBNL/Klems.Full</ColumnAngleBasis>
  <RowAngleBasis>LBNL/Klems.Full</RowAngleBasis>
  <ScatteringDataType>BTDF</ScatteringDataType>
  <ScatteringData>
```

```
1.313e+01 2.677e-02 3.370e-02 3.383e-02 3.157e-02 2.677e-02 1.969e-02 1.846e-02 2.051e-02 2.670e-02 3.344e-02 3.791e-02 3.816e-02 3.810e-02 3.864e-02 3.686e-02
3.788e-02 2.490e-02 1.865e-02 1.426e-02 1.161e-02 9.552e-03 9.221e-03 1.382e-02 2.142e-02 2.661e-02 3.386e-02 3.896e-02 3.832e-02 3.559e-02 3.535e-02 3.430e-02
3.786e-02 3.788e-02 3.353e-02 2.606e-02 1.688e-02 1.065e-02 4.605e-03 4.348e-03 4.356e-03 3.986e-03 4.801e-03 1.067e-02 1.819e-02 2.789e-02 3.531e-02 3.673e-02
3.542e-02 3.535e-02 3.368e-02 3.300e-02 3.473e-02 3.363e-02 3.569e-02 3.894e-02 3.692e-02 2.680e-02 1.737e-02 7.778e-03 6.153e-03 2.229e-02 3.515e-02 3.689e-02
3.190e-02 2.328e-02 5.817e-03 7.256e-03 1.578e-02 2.695e-02 3.764e-02 3.476e-02 3.328e-02 3.225e-02 3.082e-02 3.016e-02 2.986e-02 3.049e-02 3.291e-02 3.616e-02
3.841e-02 2.554e-02 1.295e-02 8.115e-03 3.716e-02 6.247e-02 8.248e-02 8.971e-02 8.122e-02 6.619e-02 3.490e-02 7.742e-03 1.208e-02 2.763e-02 3.725e-02 3.363e-02
2.920e-02 2.780e-02 2.630e-02 2.605e-02 2.755e-02 2.689e-02 3.058e-02 3.196e-02 3.703e-02 2.505e-02 8.723e-03 3.942e-02 8.918e-02 1.148e-01 1.233e-01 1.237e-01
1.237e-01 1.152e-01 9.084e-02 4.043e-02 8.638e-03 2.491e-02 3.105e-02 2.443e-02 2.397e-02 2.311e-02 2.383e-02 2.585e-02 3.072e-02 2.515e-02 6.487e-02 1.224e-01
1.283e-01 1.263e-01 1.263e-01 1.228e-01 6.239e-02 3.775e-02 2.365e-02 1.987e-02 2.082e-02 2.174e-02 2.426e-02 3.771e-02 1.258e-01 1.270e-01 1.256e-01 1.289e-01
1.228e-01
2.746e-02 1.376e+01 3.342e-02 3.308e-02 3.207e-02 2.649e-02 1.960e-02 1.778e-02 2.042e-02 2.635e-02 3.195e-02 3.602e-02 3.975e-02 3.733e-02 3.839e-02 3.858e-02
3.322e-02 2.668e-02 2.000e-02 1.581e-02 1.079e-02 9.361e-03 1.086e-02 1.548e-02 2.049e-02 2.832e-02 3.616e-02 3.942e-02 3.929e-02 3.698e-02 3.786e-02 3.567e-02
```

Load a BSDF XML file
Save Image
Show Help
Hide Patch Numbers
Equidistant Orthographic
Log Scale Linear Scale

Scale Maximum:
Number of Decades:



$$\Omega_{pr}(P1) = \pi \cdot \sin^2(5^\circ)$$

$$\tau(P1 \rightarrow P1) = 13.13 \cdot \pi \cdot \sin^2(5^\circ) = 0.3133$$

Viewing BSDFs (ii)

```
bsdfview -q Med -v 0 VenetianBlinds_{Klems,tt45}.xml
```

```
File: 'VenetianBlinds_Klems.xml'
Manufacturer: 'Manufacturer'
BSDF Name: 'Radiance Workshop 2026'
Dimensions (W x H x Thickness): 400 x 200 x 3.4641 cm
Type: Klems_Full
Color: 0
```

Has Geometry: 1

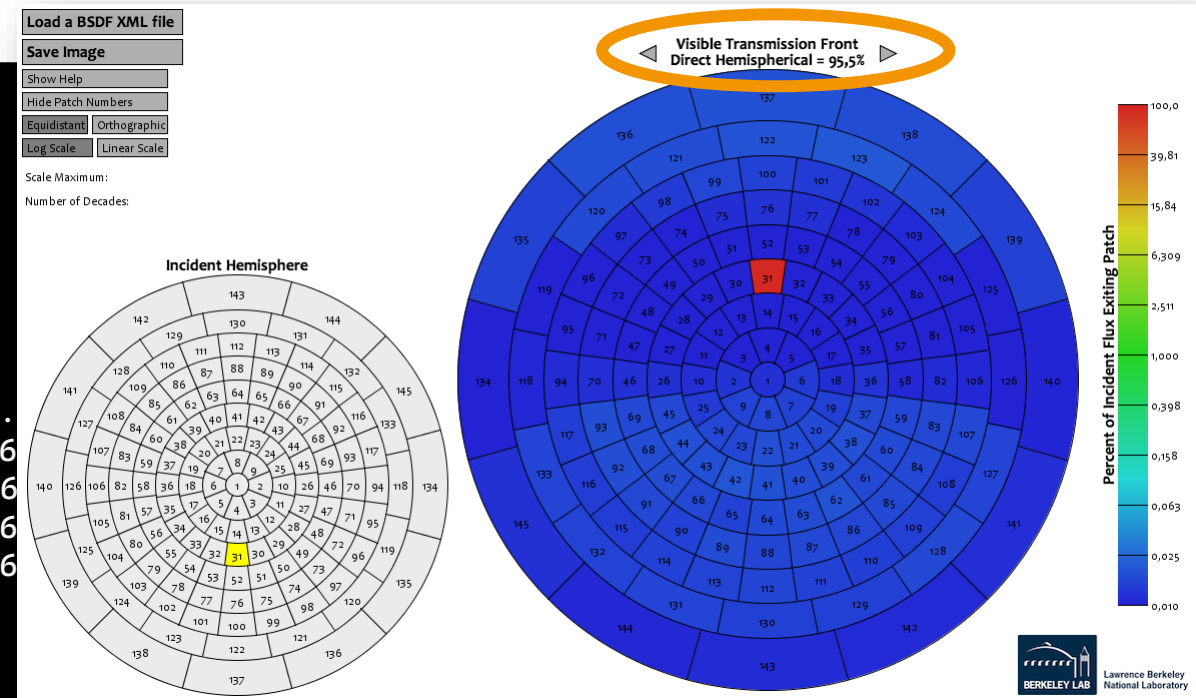
Component	Lambertian XYZ (%)			Max. Tot. Dir	Min.
Interior Refl	0.0	0.0	0.0	53.5%	8.56
Exterior Refl	0.0	0.0	0.0	53.5%	8.56
Int→Ext Trans	0.0	0.0	0.0	96.0%	8.56
Ext→Int Trans	0.0	0.0	0.0	95.5%	8.56

Component Reciprocity Error (min avg max %)

Interior Refl	0.0	4.6	55.7
Exterior Refl	0.0	4.8	50.5
Transmission	0.0	6.1	78.7

```
bsdfview: creating rad input file 'VenetianBlinds_Klems.rif'
```

```
oconv -w -f "!bsdf2rad VenetianBlinds_Klems.xml" > /tmp/dUSVpxYAFH/bv12914.oct
```



Viewing BSDFs (ii)

```
bsdfview -q Med -v 0 VenetianBlinds_{Klems,tt45}.xml
```

add "-ss 0" to render settings in VenetianBlinds_{Klems,tt45}.rif

```
rad -N 20 VenetianBlinds_{Klems,tt45}.rif
```

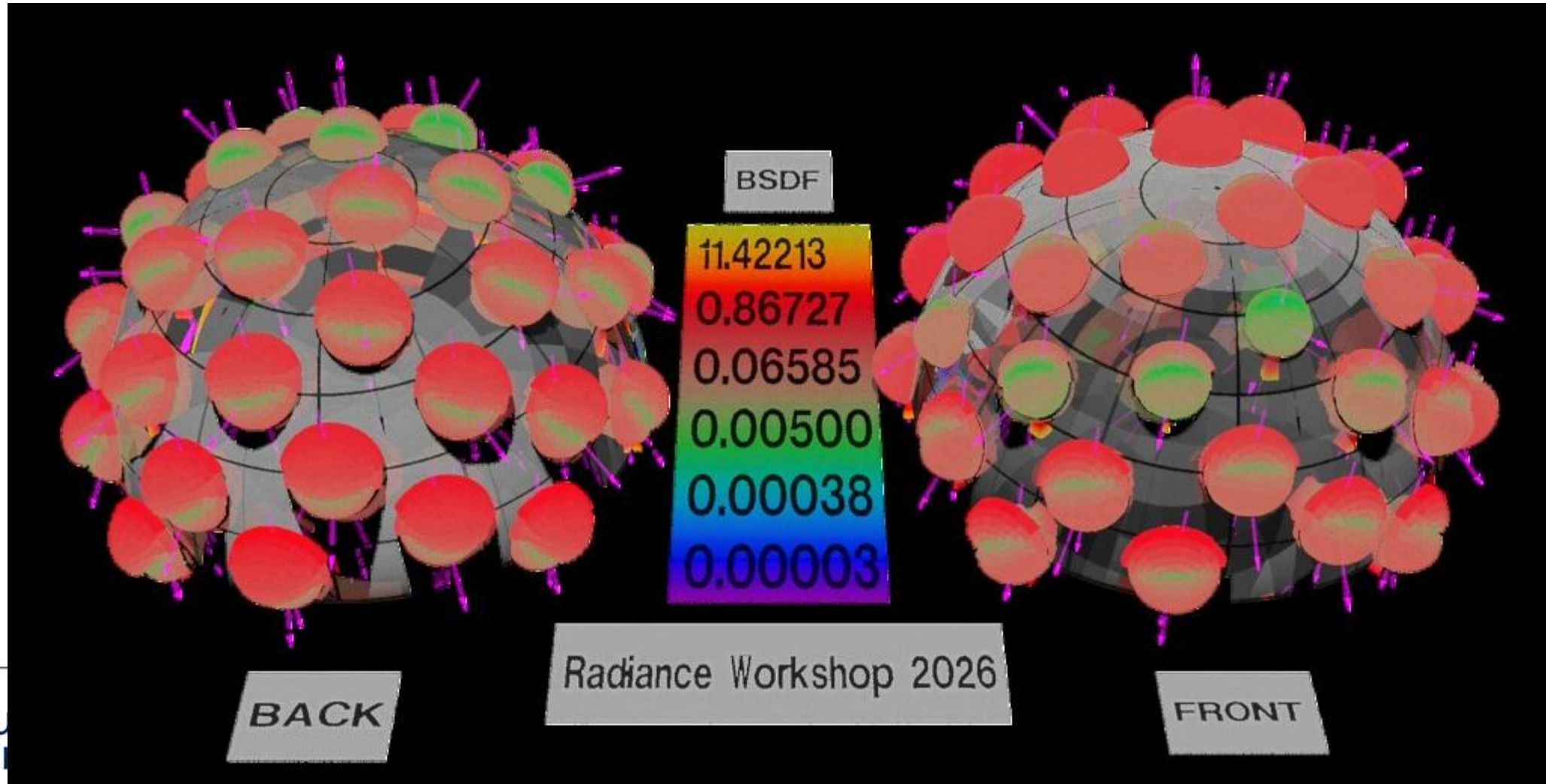
```
man bsdfview
```

The program creates a number of views accessible via the rvu(1) "L" command:

def	The default view, showing the back and front BRDFs.
fr	A view of the front reflection hemisphere.
br	A view of the back reflection hemisphere.
ft	A fisheye view of the front transmission hemisphere (from underneath).
bt	A fisheye view of the back transmission hemisphere.
pr	A parallel view of both reflection hemispheres from directly overhead.
pt	A parallel view of both transmission hemispheres from directly underneath.

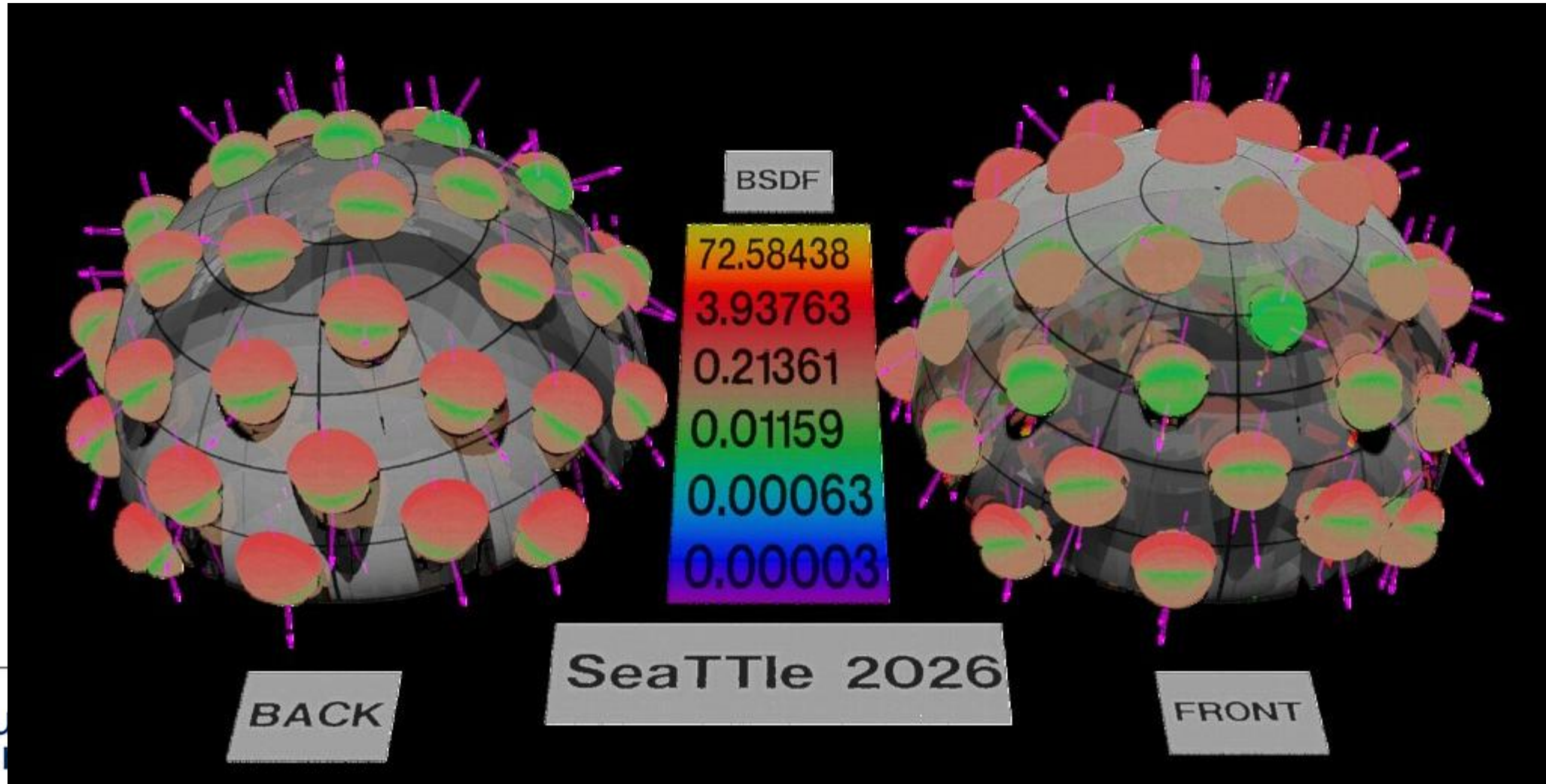
Viewing BSDFs (ii)

VenetianBlinds_Klems_def.hdr



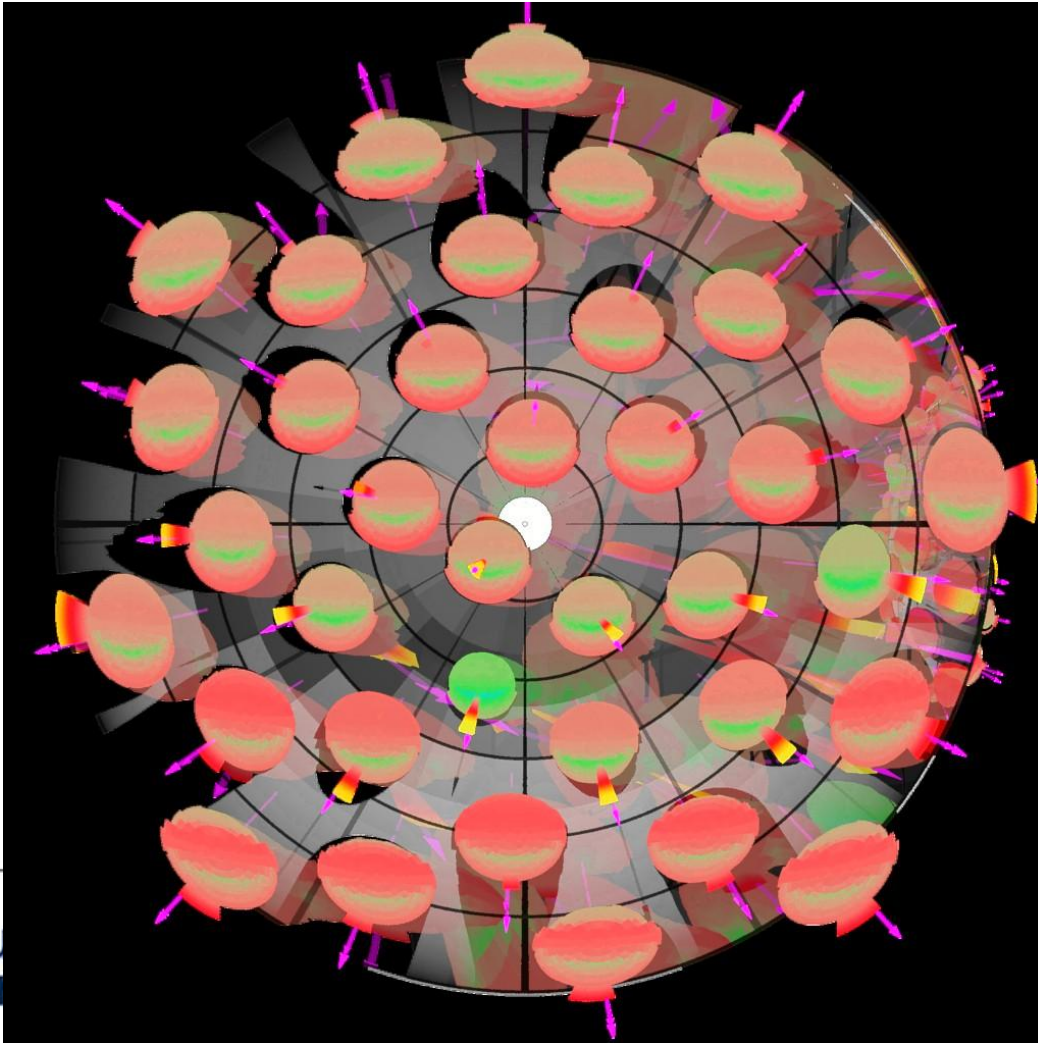
Viewing BSDFs (ii)

VenetianBlinds_tt45_def.hdr

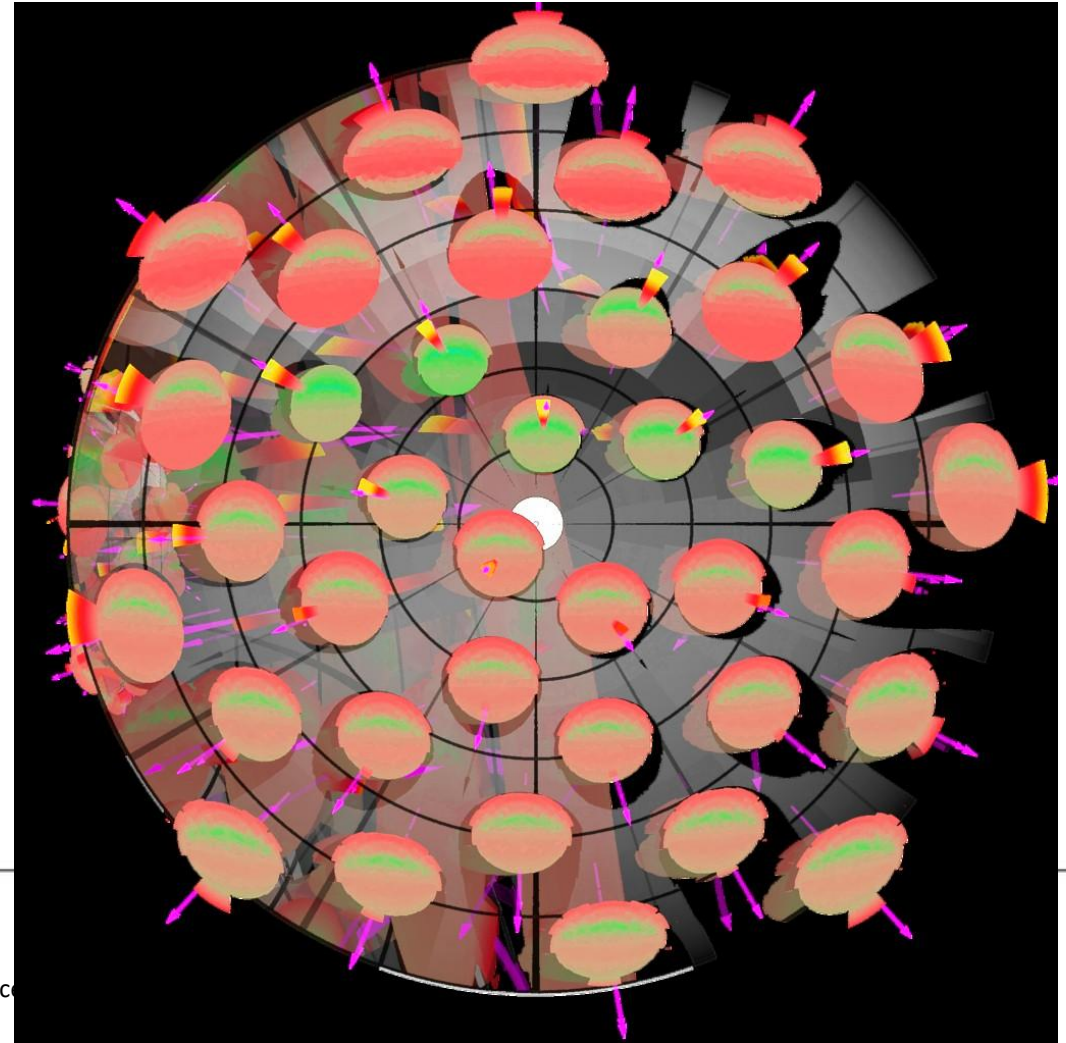


Viewing BSDFs (ii)

VenetianBlinds_Klems_ft.hdr



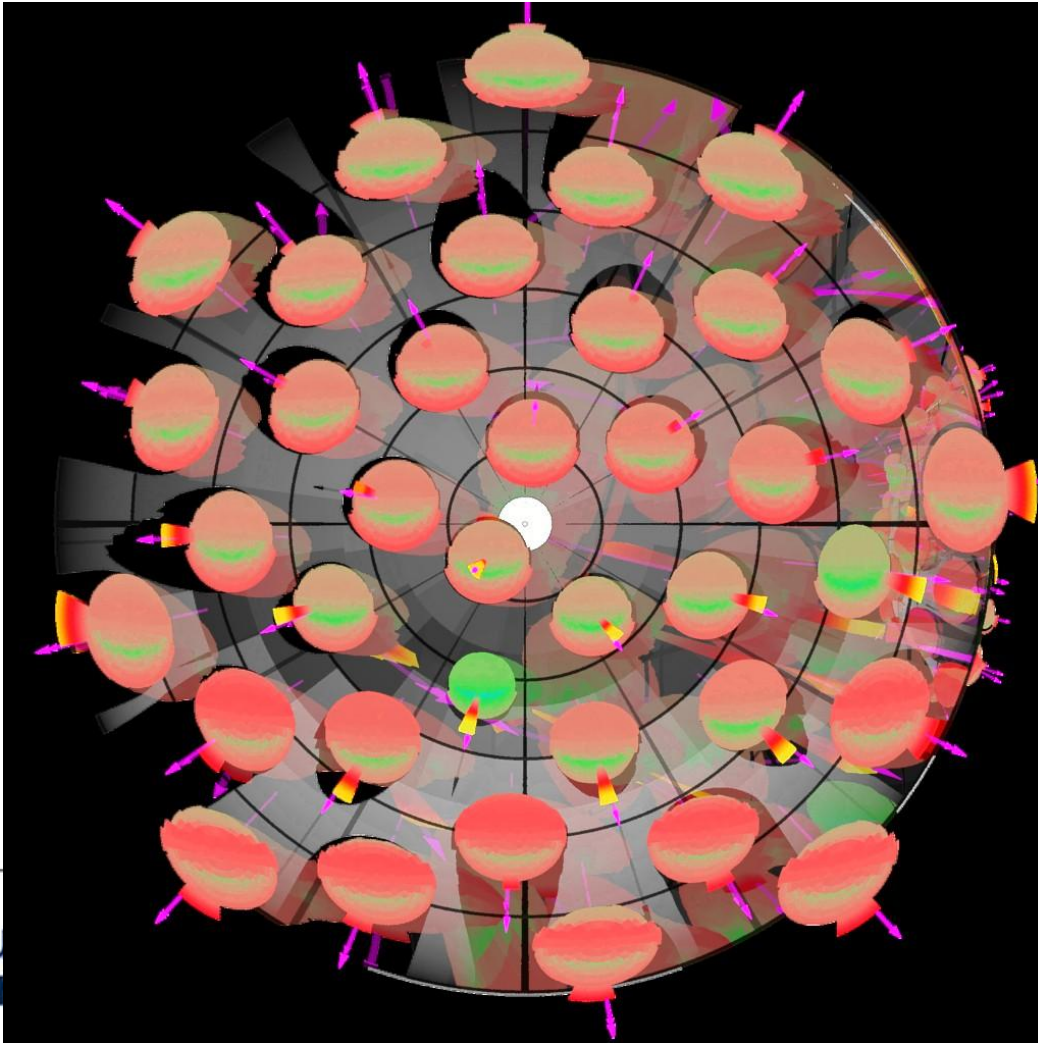
VenetianBlinds_Klems_bt.hdr



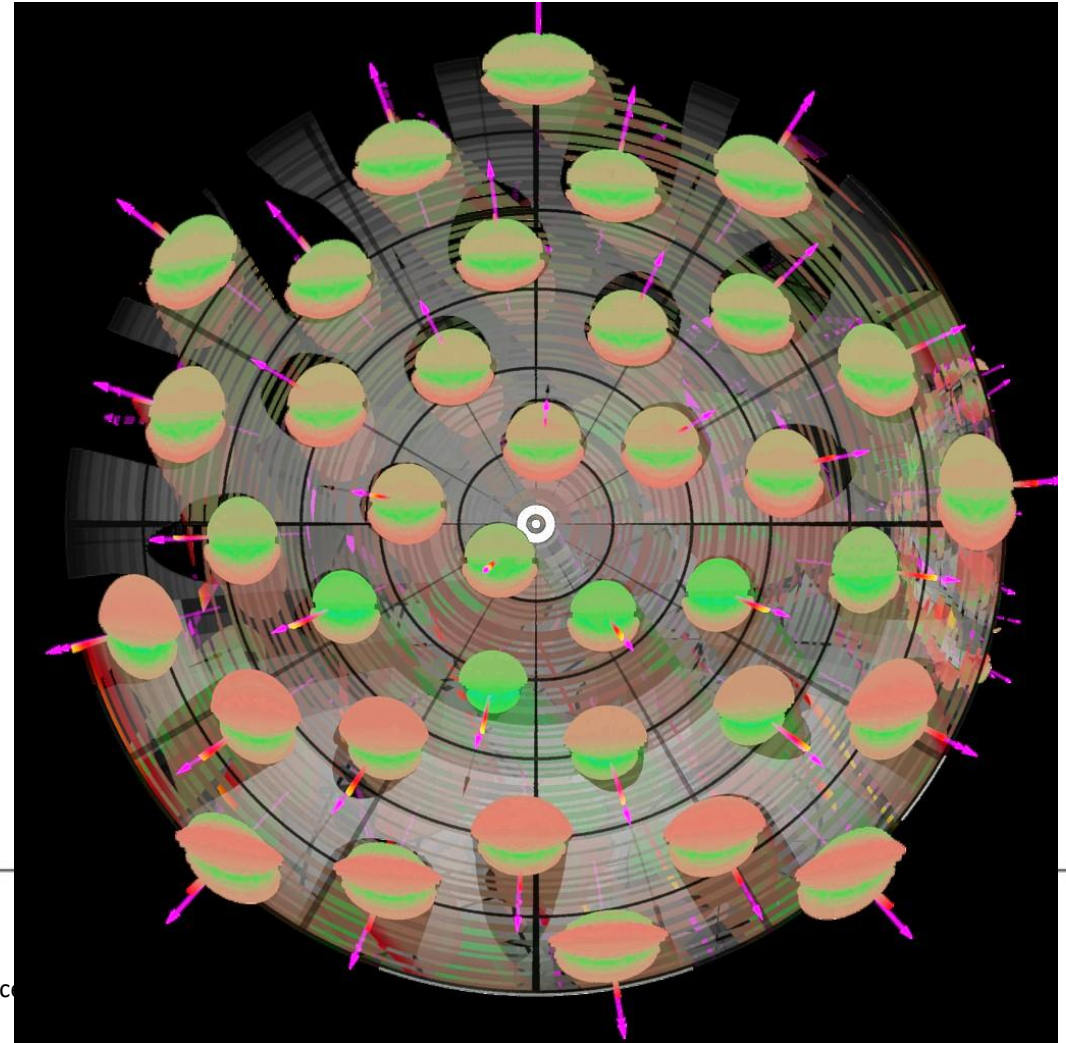
radiance

Viewing BSDFs (ii)

VenetianBlinds_Klems_ft.hdr



VenetianBlinds_tt45_ft.hdr

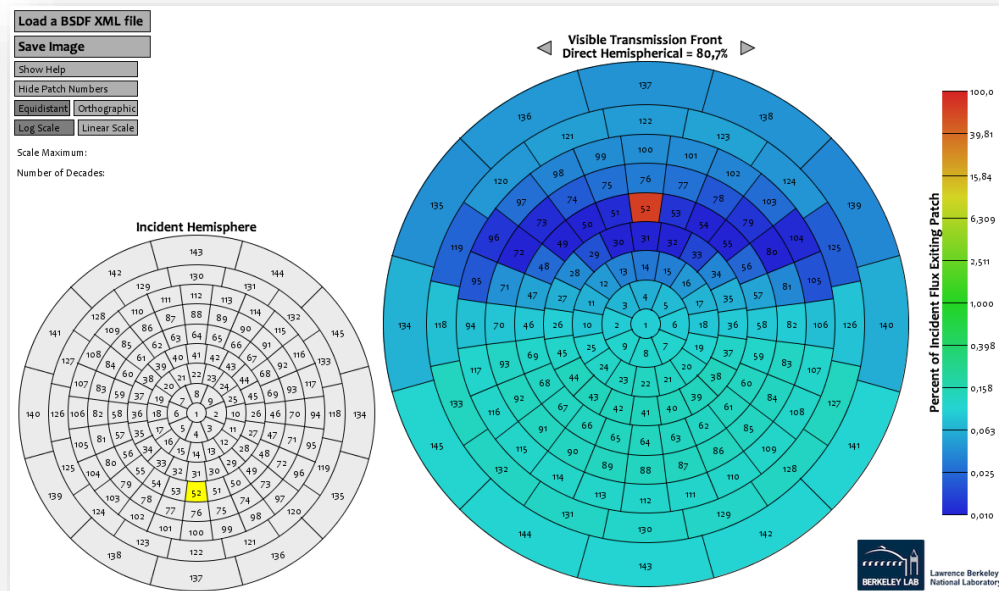


radiance

Viewing BSDFs (iii)

Andy McNeil's BSDFViewer
(Klems, TensorTree) [Windows: Klems Only]

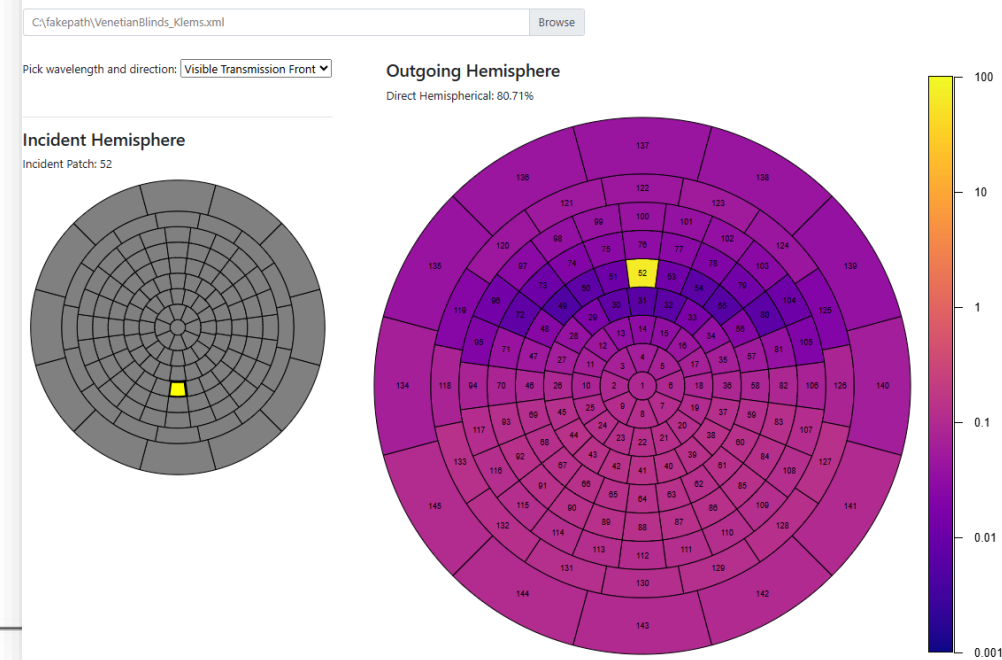
<https://www.radiance-online.org/download-install/third-party-utilities/bsdf-viewer>



Ladybug Tools BSDF Viewer
(Klems)

<https://www.ladybug.tools/bsdf-viewer/>

BSDF Viewer

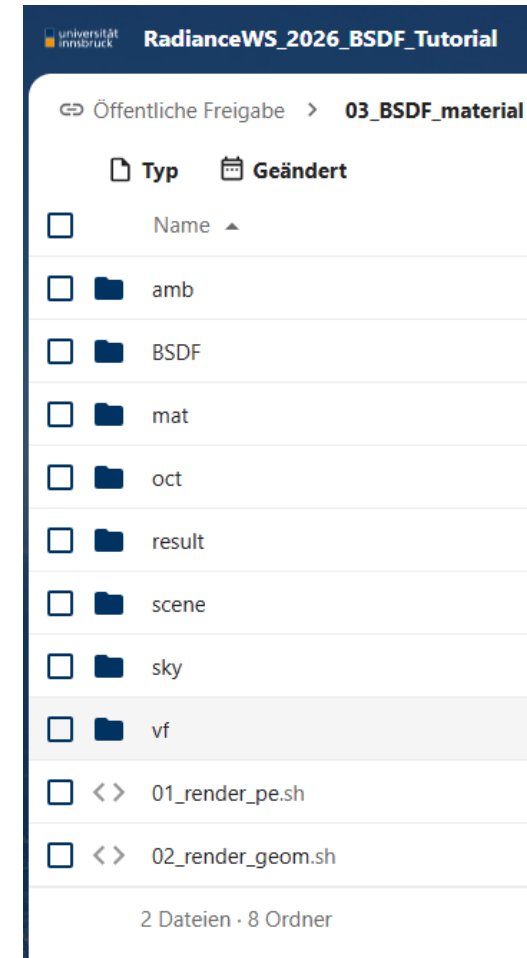


Using BSDFs as material

Get files at:

<https://universe.uibk.ac.at/s/2Waw23CYj8s8Cxz>

➤ 03_BSDF_material



Using BSDFs as material

Render test room with BSDF:

- » Fabric shade with peak extraction (aBSDF) and without (BSDF)
- » Venetian blind as BSDF and with proxy geometry

01_render_pe.sh

02_render_geom.sh

Using BSDFs as material

» Define material and assign it to the window geometry

```
void aBSDF mat_window  
5 ./BSDF/02_all_Klems.xml 0 0 1 .  
0  
0
```

mat/02_all_Klems_absdf.mat

```
# obj2rad -m tutorial_window.map tutorial_window.obj  
# Rhino  
mat_window polygon Glazing_DoublePane_LowE_65.1  
0  
0  
12  
4.5005126 -0.05000000075 2.450000048  
4.5005126 -0.05000000075 1.049999952  
0.4994871914 -0.05000000075 1.049999952  
0.4994871914 -0.05000000075 2.450000048  
  
# Done processing file: tutorial_window.obj  
# 9 lines, 8 statements, 0 unrecognized
```

scene/tutorial_window.rad

Using BSDFs as material

» Fabric shade with peak extraction (aBSDF)

```
void aBSDF mat_window  
5 ./BSDF/02_all_Klems.xml 0 0 1 .  
0  
0
```

mat/02_all_Klems_absdf.mat

» Fabric shade without peak extraction (BSDF)

```
void BSDF mat_window  
6 0 ./BSDF/02_all_Klems.xml 0 0 1 .  
0  
0
```

mat/02_all_Klems_bsdf.mat

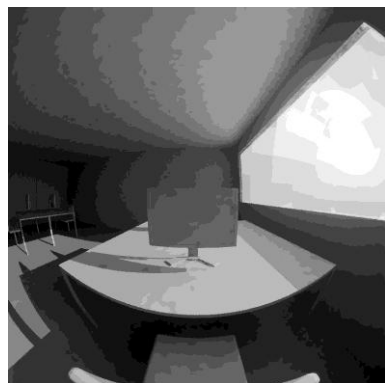
```
void aBSDF mat_window  
5 ./BSDF/02_all_tt_g6_t95.xml 0 0 1 .  
0  
0
```

mat/02_all_tt_g6_t95_absdf.mat

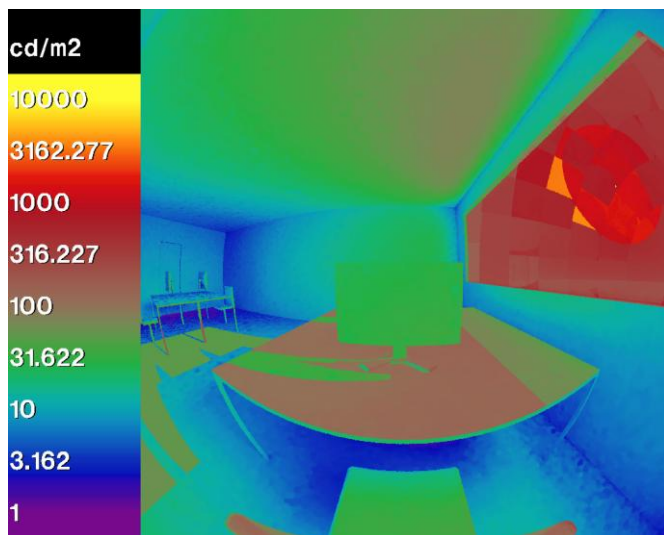
```
void BSDF mat_window  
6 0 ./BSDF/02_all_tt_g6_t95.xml 0 0 1 .  
0  
0
```

mat/02_all_tt_g6_t95_bsdf.mat

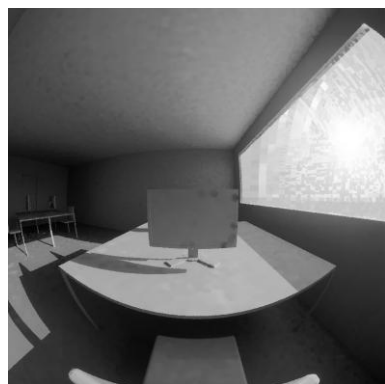
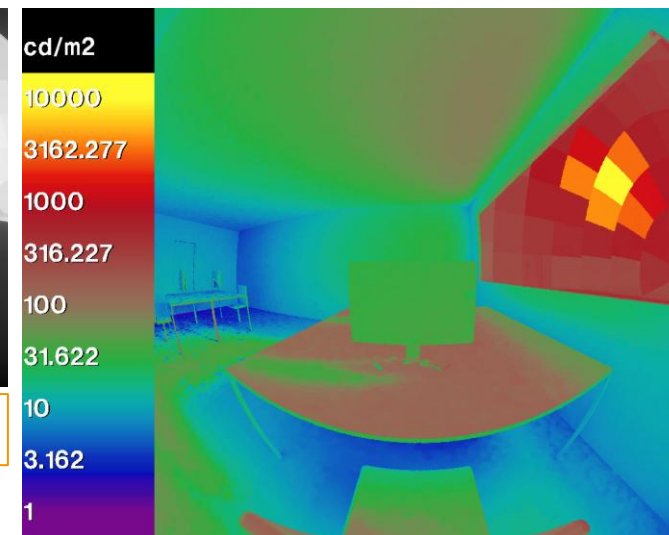
Using BSDFs as material



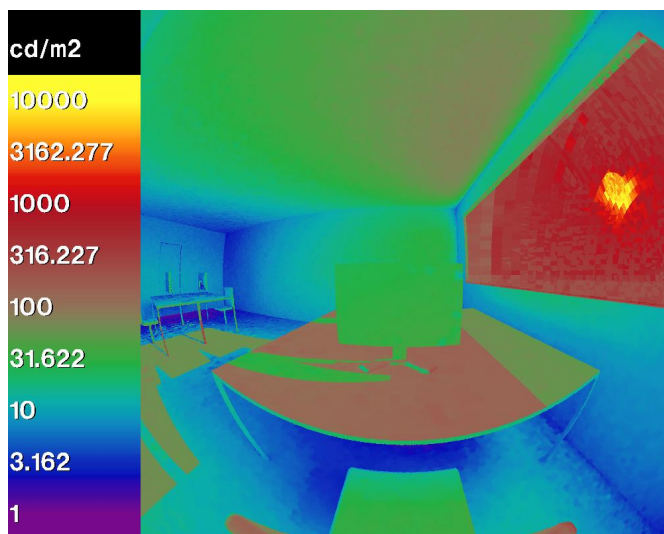
02_all_Klems_absdf



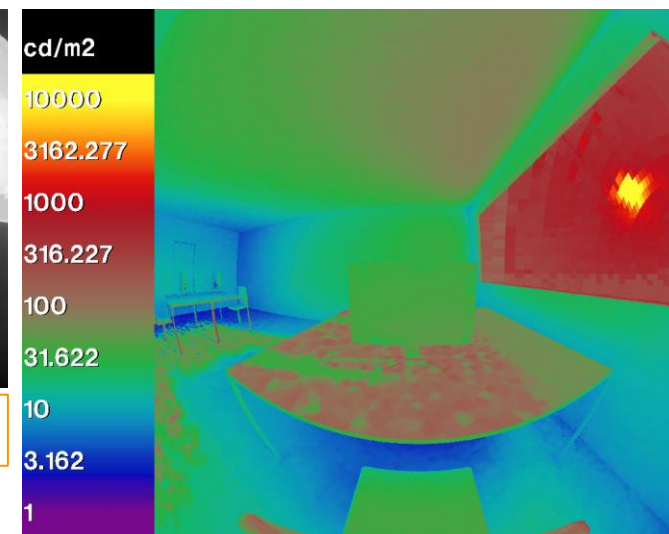
02_all_Klems_bsdf



02_all_tt_g6_t95_absdf



02_all_tt_g6_t95_bsdf



Using BSDFs as material

- » Define material and proxy geometry for window geometry and venetian blinds (use template as generated from pkgBSDF)

```
# Produced by: pkgBSDF VenetianBlinds_Klems.xml
# Material 'Name' by 'Manufacturer'

#void BSDF m_VenetianBlinds_Klems_f
#6 0.0346424 VenetianBlinds_Klems.xml 0 1 0 .
void BSDF m_VenetianBlinds_Klems_f
6 0.0346424 BSDF/VenetianBlinds_Klems.xml 0 0 1 .
0
0

m_VenetianBlinds_Klems_f polygon VenetianBlinds_Klems_f
0
0
12      4.5005126      -0.05000000075      2.450000048
        4.5005126      -0.05000000075      1.049999952
        0.4994871914      -0.05000000075      1.049999952
        0.4994871914      -0.05000000075      2.450000048
#      -2.000000e+00      -1.000000e+00      6.928200e-07
#      2.000000e+00      -1.000000e+00      6.928200e-07
#      2.000000e+00      1.000000e+00      6.928200e-07
#      -2.000000e+00      1.000000e+00      6.928200e-07
```

mat/VenetianBlinds_Klems_geom.mat

1/3

Using BSDFs as material

- » Define material and proxy geometry for window geometry and venetian blinds (use template as generated from pkgBSDF)

```
#void BSDF m_VenetianBlinds_Klems_b
#6 -0.0346424 VenetianBlinds_Klems.xml 0 0 1 .
void BSDF m_VenetianBlinds_Klems_b
6 -0.0346424 BSDF/VenetianBlinds_Klems.xml 0 0 1 .
0
0

m_VenetianBlinds_Klems_b polygon VenetianBlinds_Klems_b
0
0
12      4.5005126      -0.0846424      2.450000048
        4.5005126      -0.0846424      1.049999952
        0.4994871914      -0.0846424      1.049999952
        0.4994871914      -0.0846424      2.450000048
#      -2.000000e+00      -1.000000e+00      -3.464169e-02
#      2.000000e+00      -1.000000e+00      -3.464169e-02
#      2.000000e+00      1.000000e+00      -3.464169e-02
#      -2.000000e+00      1.000000e+00      -3.464169e-02
```

mat/VenetianBlinds_Klems_geom.mat

2/3

Using BSDFs as material

- » Define material and proxy geometry for window geometry and venetian blinds (use template as generated from pkgBSDF)

```
#####
void plastic lGrey
0
0
5 0.7 0.7 0.7 0 0
!genblinds lGrey venBlinds 0.04 4 1.41 47 -30 | xform -rz 90 -t 4.5 -0.0846424 1.055

## Translated from MGF Version 2.0
## mgf2rad -s
## mgf2rad /tmp/rtbzcWyp #####
# Y-axis points "up", Z-axis into room, right-handed coordinates

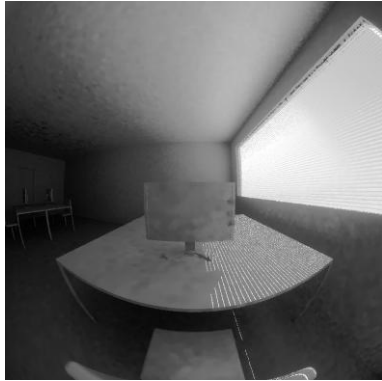
void plastic LightGreyLambert
0
0
5 0.700000 0.700000 0.700000 0.000000 0.000000

LightGreyLambert polygon VenetianBlinds.a0.Slat.f1
0
0
12      -2      -1      -0.0346410161514
      ...
```

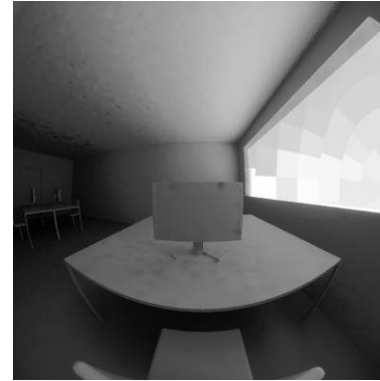
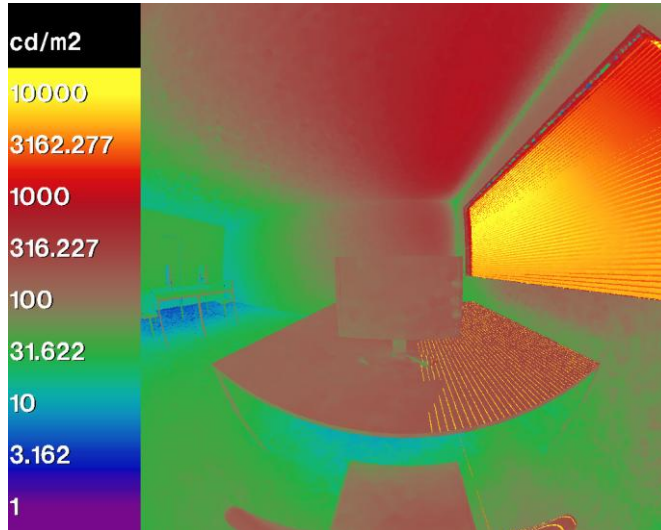
mat/VenetianBlinds_Klems_geom.mat

3/3

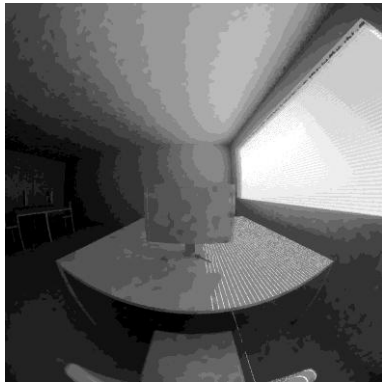
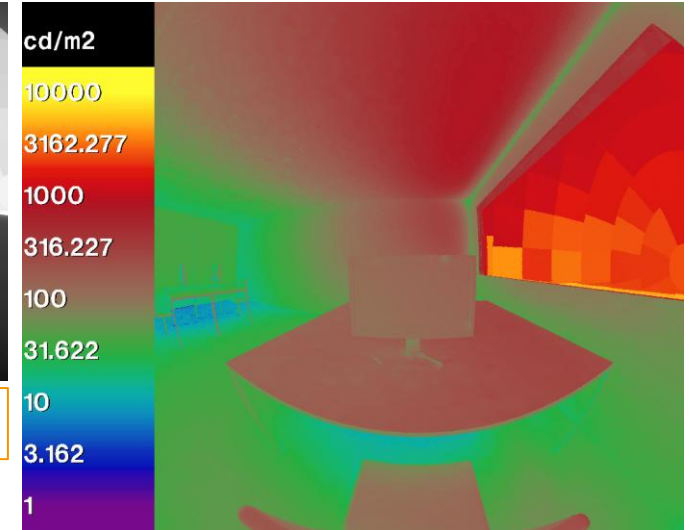
Using BSDFs as material



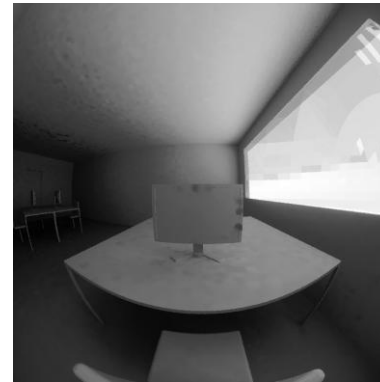
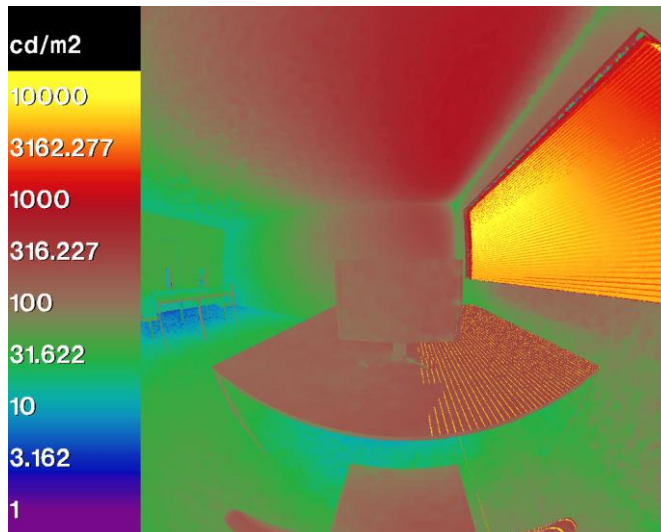
VenetianBlinds_Klems_geom



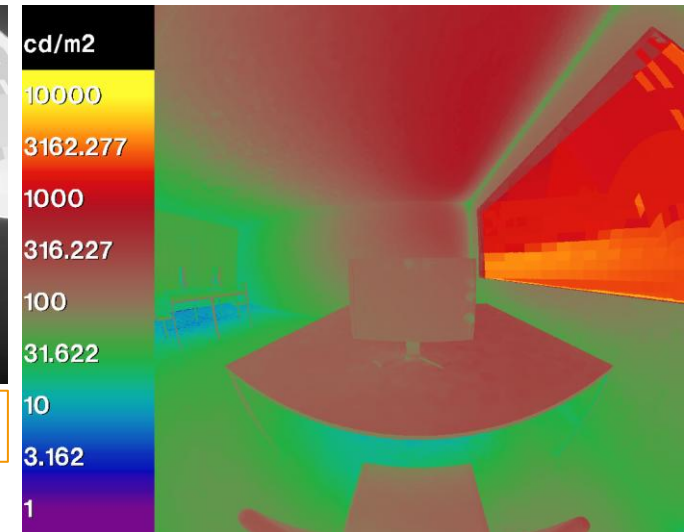
VenetianBlinds_Klems_bsdf



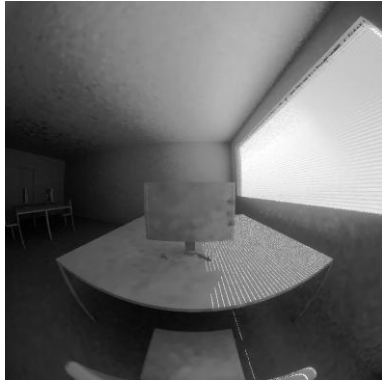
VenetianBlinds_tt45_geom



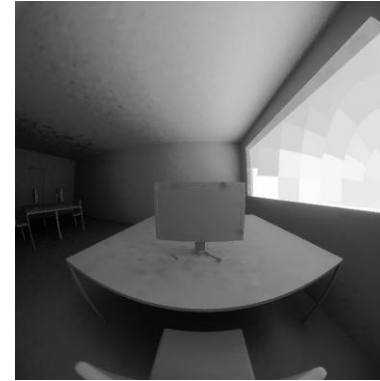
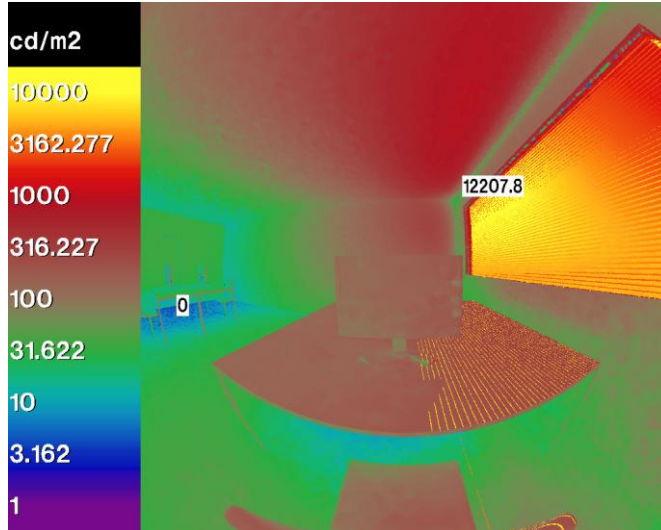
VenetianBlinds_tt45_bsdf



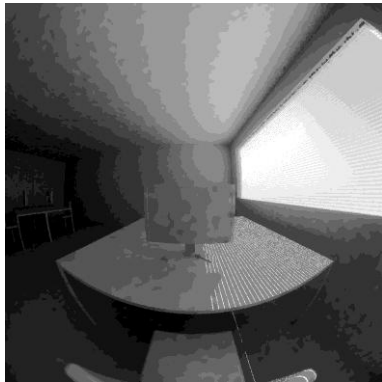
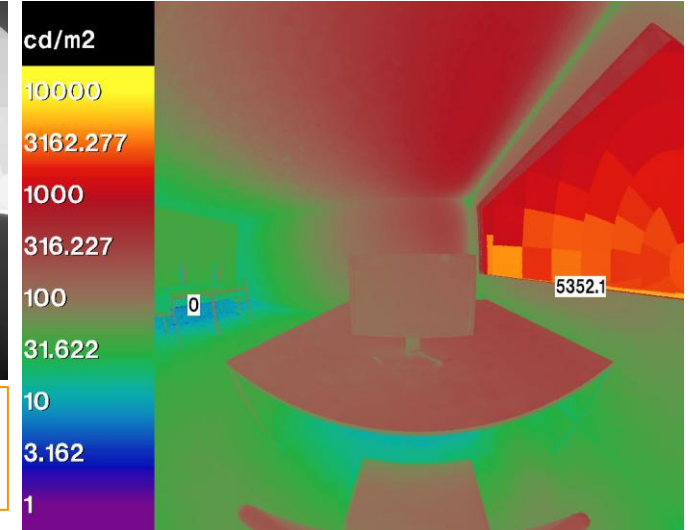
Using BSDFs as material



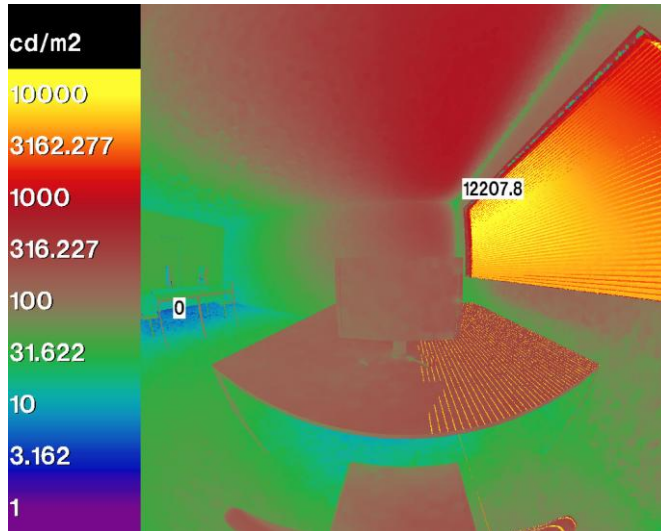
VenetianBlinds_Klems_geom
Ev = 3097 lx



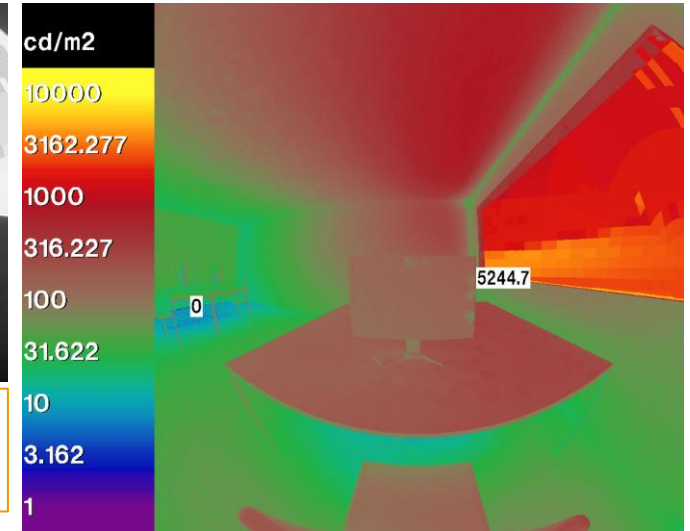
VenetianBlinds_Klems_bsdf
Ev = 1303 lx



VenetianBlinds_tt45_geom
Ev = 3096 lx



VenetianBlinds_tt45_bsdf
Ev = 1323 lx



BSDFs in Matrix-based Methods

- » Sarith Subramaniam's Tutorial

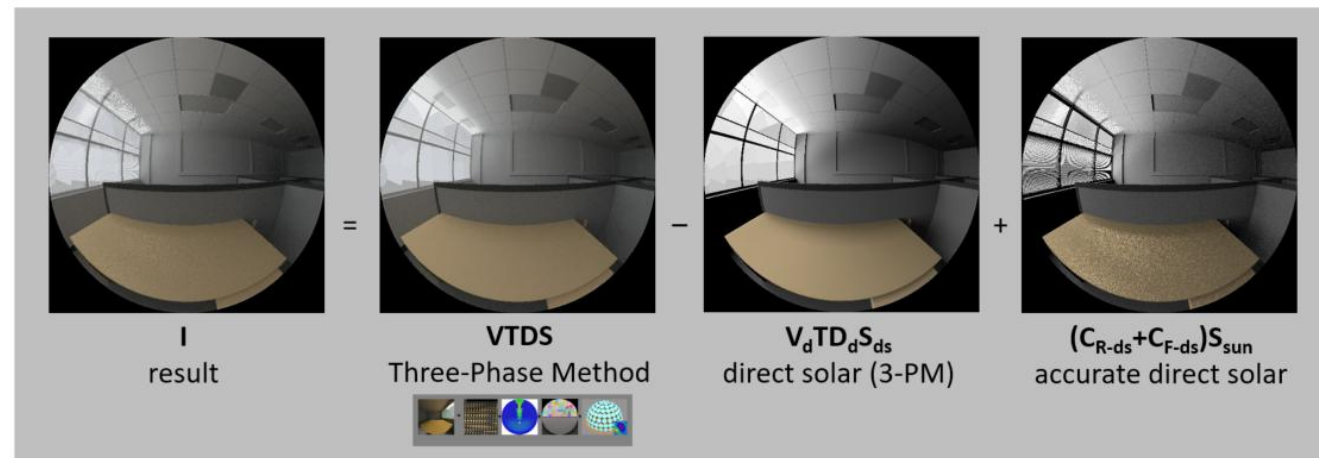
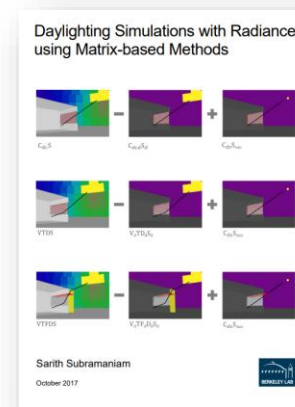
Daylighting Simulations with Radiance using Matrix-based Methods

<https://www.radiance-online.org/learning/tutorials/matrix-based-methods>

- » Tutorial Radiance Workshop 2019

https://www.radiance-online.org/community/workshops/2019-new-york-ny/presentations/day1/20190821_BSDF_and_Matrix_Tutorial_final.pdf

https://www.radiance-online.org/community/workshops/2019-new-york-ny/presentations/day1/02_3and5phase.zip



$$I = VTDS - V_dTD_dS_{ds} + (C_{R-ds} + C_{F-ds})S_{sun}$$

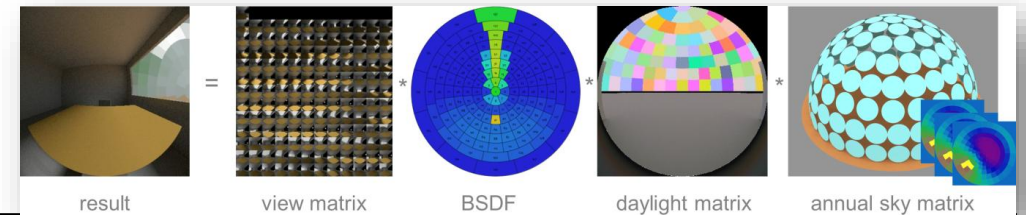
<https://doi.org/10.26868/25222708.2017.401>

BSDFs in Matrix-based Methods

- » Tutorial Radiance Workshop 2019

https://www.radiance-online.org/community/workshops/2019-new-york-ny/presentations/day1/02_3and5phase.zip

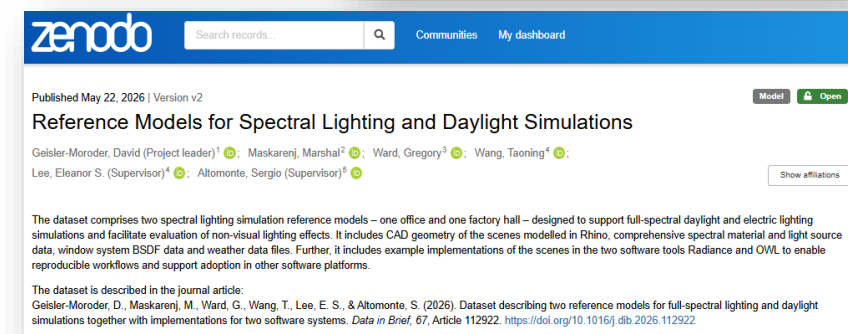
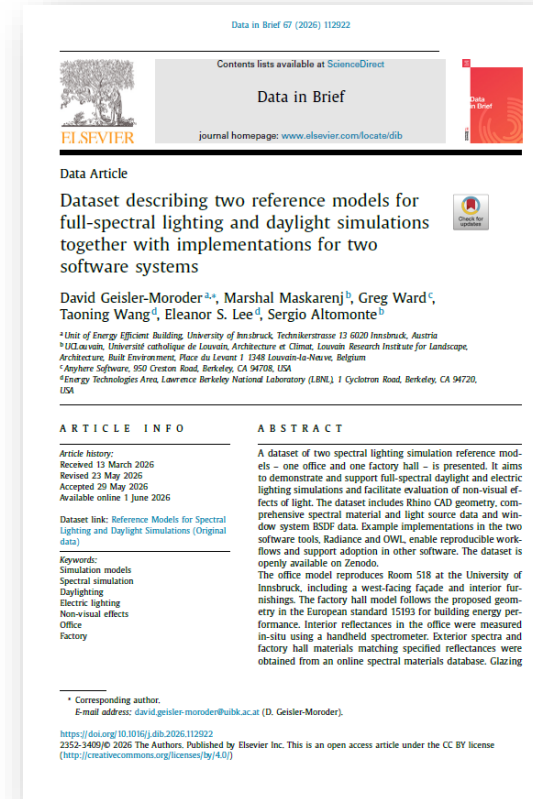
- » E.g. in scripts/3PM_sensor_04_matrix_calc.sh



```
dctimestep matrices/tutorial_room_3pm_sensors.vmx \  
    BSDF/blinds_20deg_Klems.xml \  
    matrices/tutorial_room_3pm_rein1.dmx \  
    weather/NY_sky_day01.smx \  
    > result/blinds_20deg_NY_sky_day01_3pm.dat  
  
rmtxop -fa -c 47.448 119.951 11.601 -t result/blinds_20deg_NY_sky_day01_3pm.dat \  
    > result/blinds_20deg_NY_sky_day01_3pm.ill
```

Combining BSDFs with spectral data

- » Reference Models for Spectral Lighting and Daylight Simulations
<https://doi.org/10.5281/zenodo.18836176>
- » `_office_step01.sh`



Combining BSDFs with spectral data

Get files at:

<https://universe.uibk.ac.at/s/2Waw23CYj8s8Cxz>

➤ 04_BSDF_spectral

universität innsbruck		RadianceWS_2026_BSDF_Tutorial	
		Öffentliche Freigabe	> 04_BSDF_spectral
	Typ	Geändert	
☐	Name	▲	
☐	< >		01_BSDF_spectral.sh
☐			Baulng_518.cal
☐			Baulng_518_factor.cal
☐			Baulng_518_smult_780-380.txt
☐			Baulng_518_Window_t_vis.csv
☐	< >		Bauing_ILM_Lamelle_+75.xml
☐			Bauing_ILM_Lamelle_+75_winSpec.mtx
☐			CIE_xyz_1931_2deg.csv
☐			cie31_2deg.cal
9 Dateien			

Combining BSDFs with spectral data

```
#!/bin/sh

echo "Step 1a: Normalize spectra to V(lambda) to be used as multiplier."

## generate cal files
tabfunc xbar2 ybar2 zbar2 < CIE_xyz_1931_2deg.csv > cie31_2deg.cal
tabfunc glaz < BauIng_518_Window_t_vis.csv > BauIng_518.cal

## get glazing factors
echo "g_fact(x):select(x," > BauIng_518_factor.cal
cnt 20 | rcalc -f cie31_2deg.cal -f BauIng_518.cal \
-e 'l=780+(380-780)/20*($1+.5)' \
-e '$1=ybar2(l);$2=ybar2(l)*glaz(l)' -t"," | total -t"," >> BauIng_518_factor.cal
echo ");" >> BauIng_518_factor.cal

## get scaled spectrum glazing
cnt 20 | rcalc -f BauIng_518.cal -f BauIng_518_factor.cal \
-e 'l=780+(380-780)/20*($1+.5);f_ybar=g_fact(1);f_glaz=g_fact(2)' \
-e '$1=f_ybar/f_glaz*glaz(l)' > BauIng_518_smult_780-380.txt

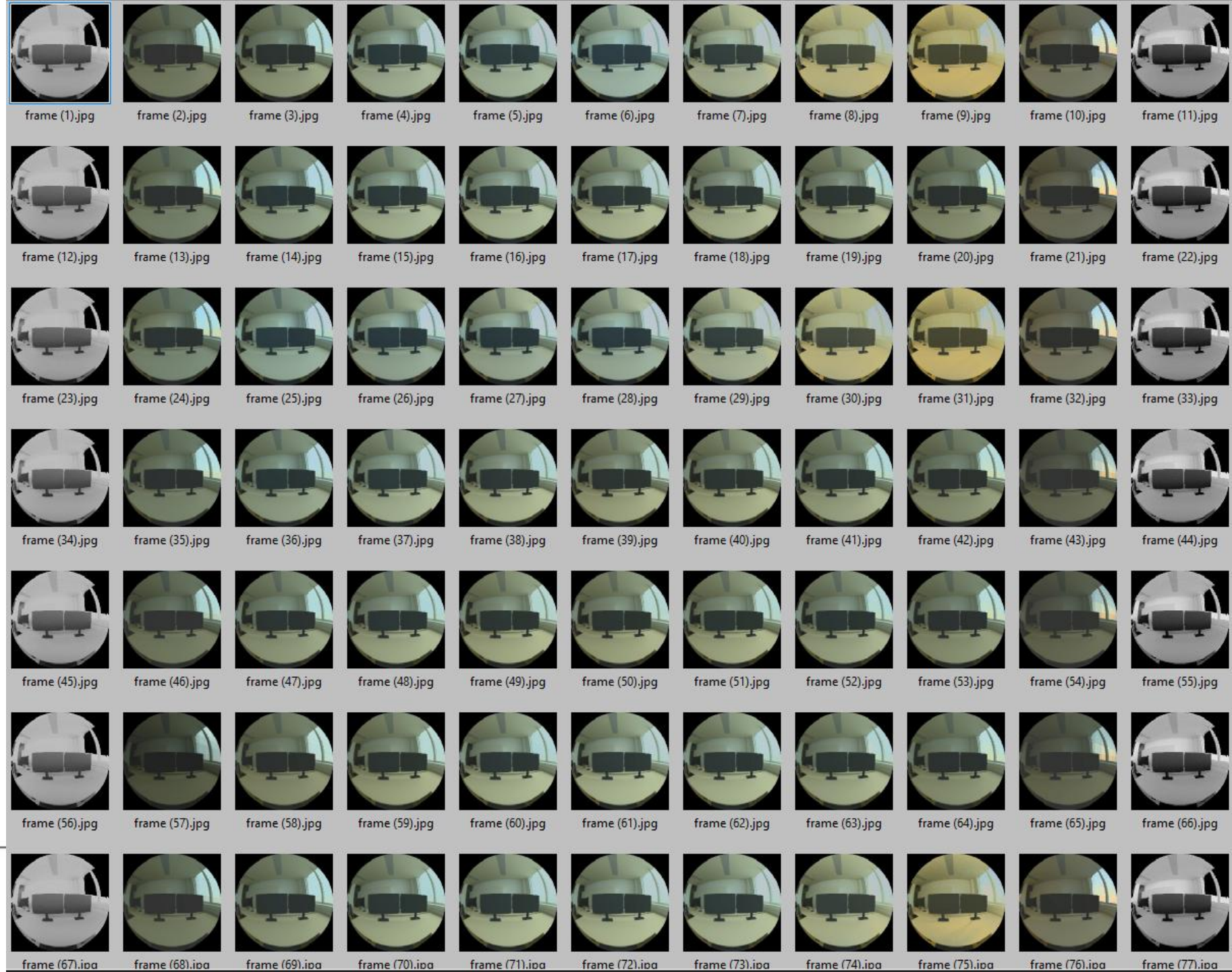
echo "Step 1b: multiply spectrum against BSDF files"
rmtxop -ff -c 'rcalc -e '$1=0:$2=$1:$3=0' BauIng_518_smult_780-380.txt' \
BauIng_ILM_Lamelle_+75.xml > BauIng_ILM_Lamelle_+75_winSpec.mtx
```

Use in matrix multiplication with **rmtxop** together with

- spectral view matrix,
- spectral daylight matrix, and
- spectral sky matrix.

01_BSDF_spectral.sh

Example result with BSDF and spectral data

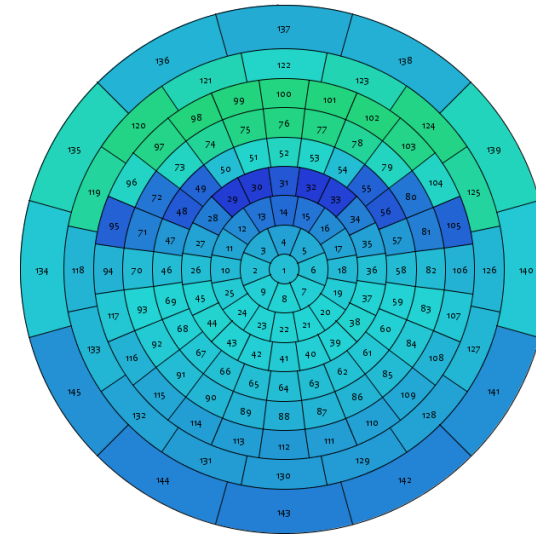


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Greg, who has developed this wonderful software over the past nearly 40 years, thereby laying the foundation that makes it possible for all of us to be here today, and who has never stopped seeking new challenges, solutions, and perspectives.



Acknowledgements

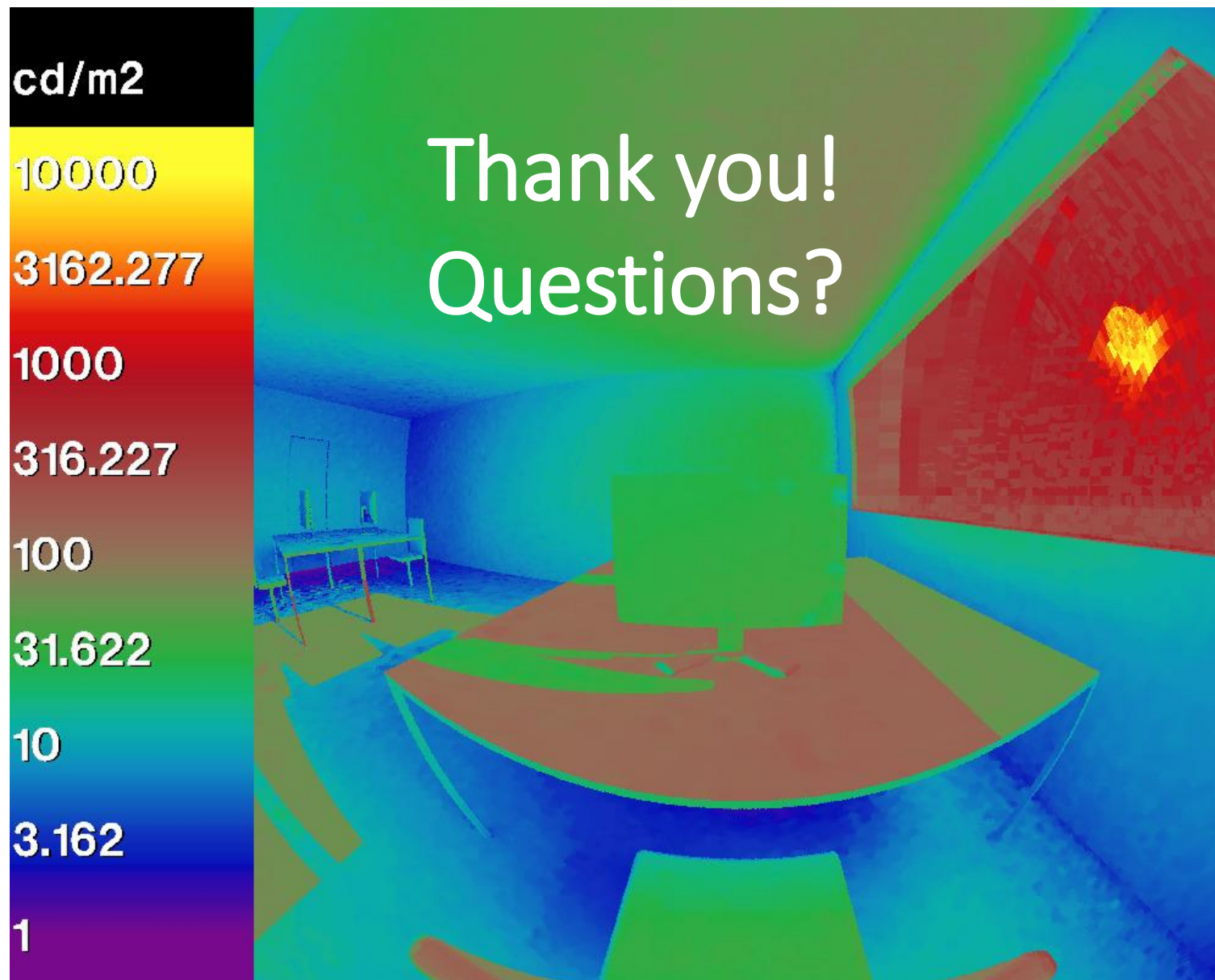
Funded by

 Federal Ministry
Innovation, Mobility
and Infrastructure
Republic of Austria



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