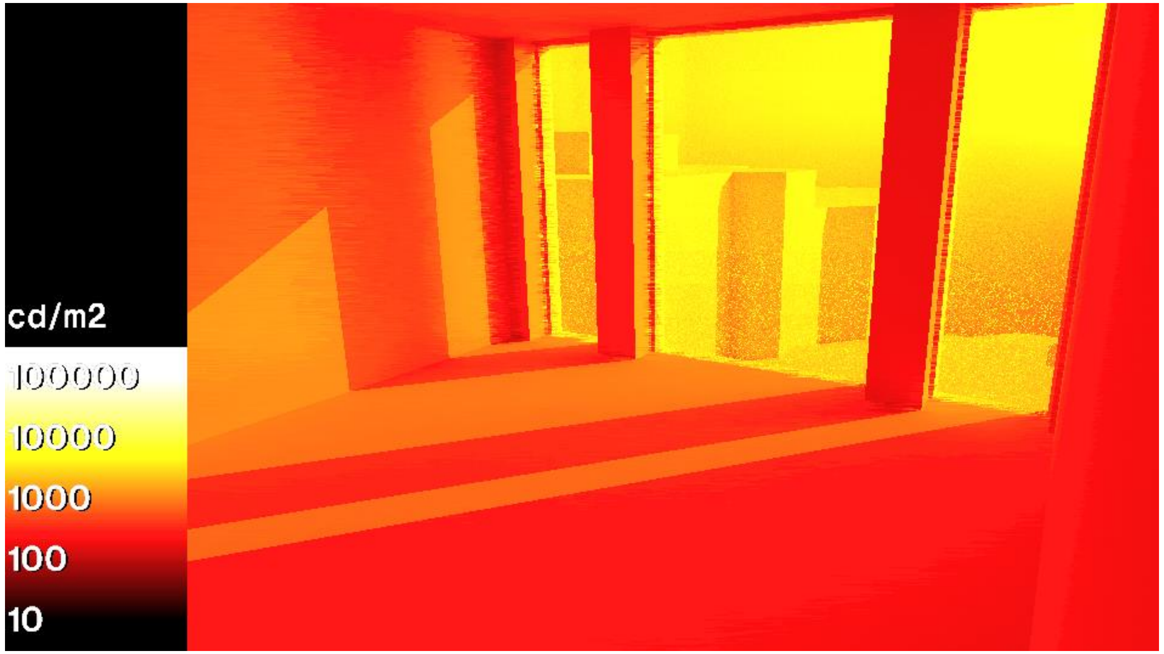
APPLYING SOFTWARE TO EVALUATE THE EFFECT OF SOLAR SHADING ON ENERGY CONSUMPTION, DAYLIGHTING AND GLARE IN BUILDINGS

RESULTS FROM THE ICON PROJECT BETWEEN LBNL AND FRAUNHOFER ISE



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ES-SO Webinar

23.02.2022

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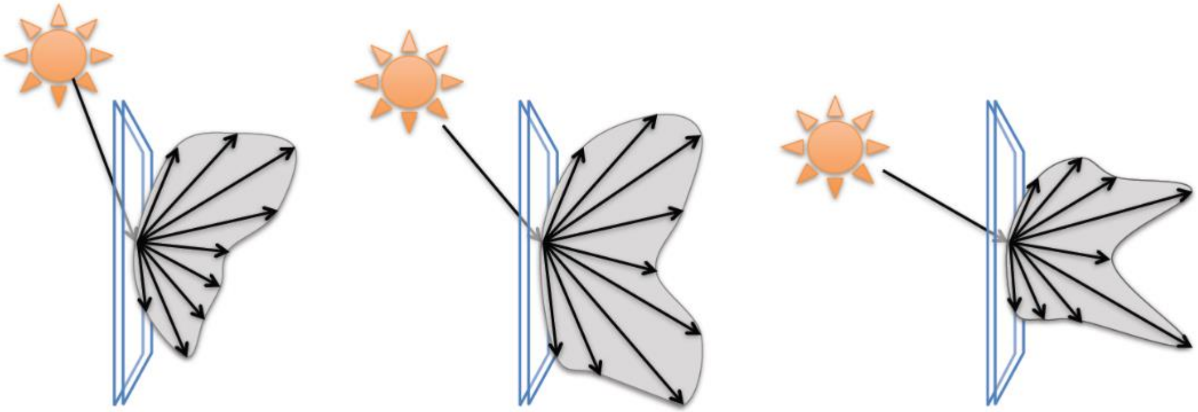
Bi-directional optical properties of solar shading are necessary in order to quantify its dynamic effect on energy consumption, daylighting and glare in buildings

We need to know where radiation is scattered for different sun positions in a year!

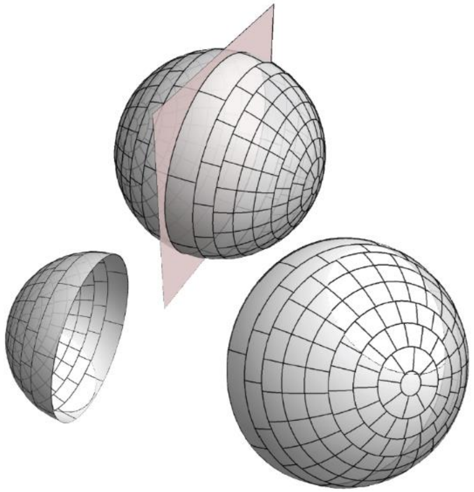


McNeil, Radiance Workshop 2014

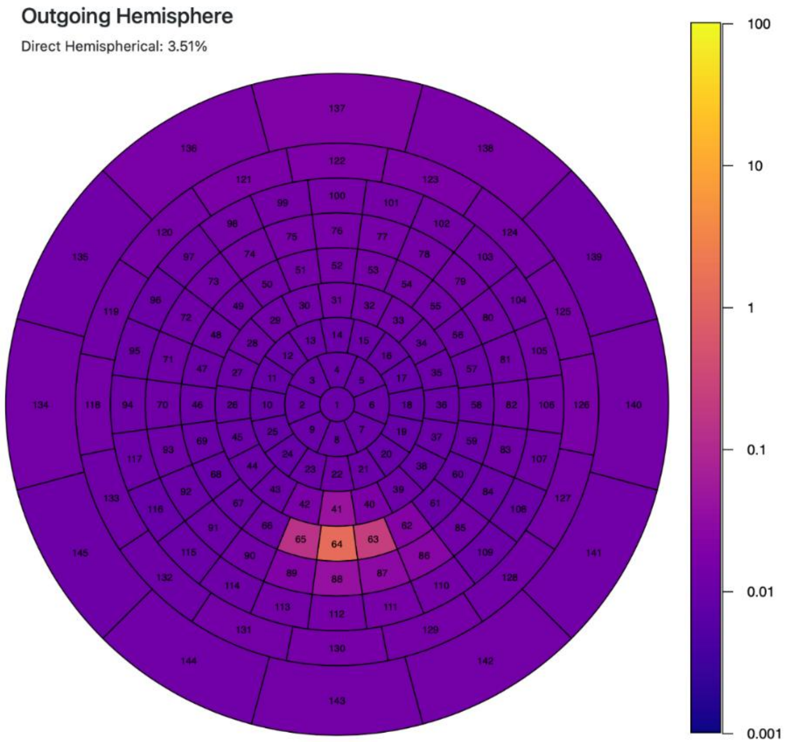
Characterization of solar shading

Bi-directional optical properties

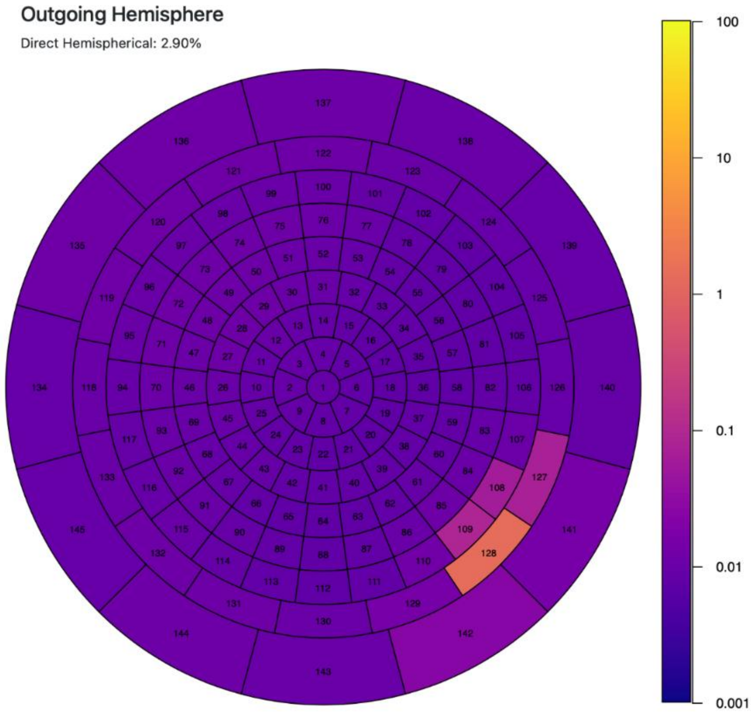
- Bi-directional scattering distribution functions (BSDF) describe the spatial distribution of light scattered by a sample in transmission and reflection for different incidence angles.



McNeil, Radiance Workshop 2014



theta = 40°, phi = 90°

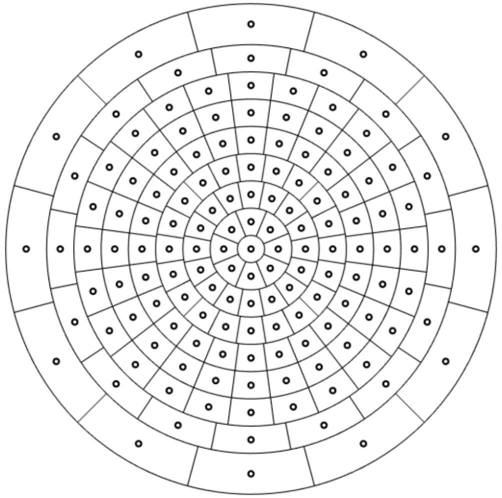


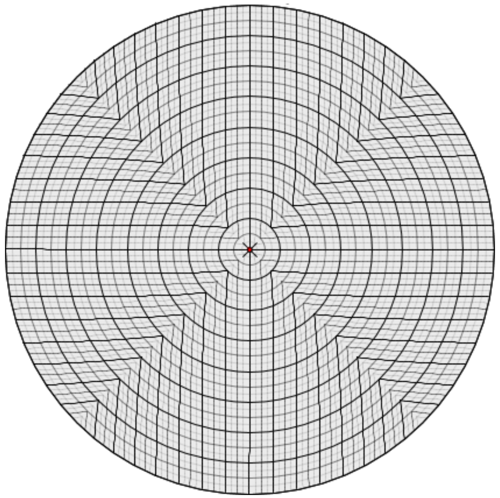
theta = 72°, phi = 45°

Source: Wang, LBNL

Characterization of solar shading
Bi-directional optical properties

- Bi-directional scattering distribution functions (BSDF) describe the spatial distribution of light scattered by a sample in transmission and reflection for different incidence angles.
- Tabulated BSDF for a defined number of light directions: 1) low resolution, 2) high resolution.


Low-resolution BSDF (Klems)


High-resolution BSDF (tensor-trees)

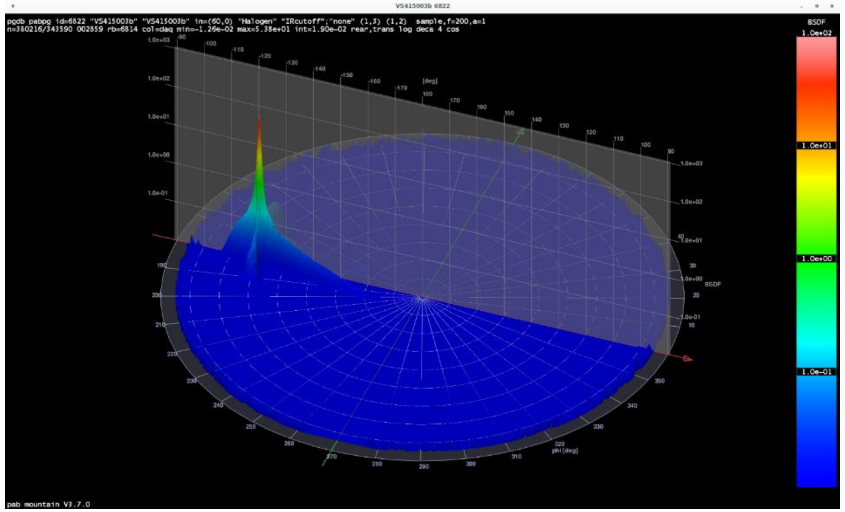
Characterization of solar shading
Bi-directional optical properties - summary

Pros

- BSDF are well-defined optical representations of fenestration systems and can be experimentally determined with a photogoniometer.
- BSDF are necessary to quantify the dynamic performance of complex fenestration systems.

Cons

- BSDF are difficult to interpret and visualize. Typical BSDF datasets weigh between 100 and 1700 MB.
- A product comparison on the basis of these datasets becomes impracticable.
- Slow rate of assimilation of BSDF by the industry of shading devices, software developers and building façade planers, despite their potential.



BTDF plotted for incident direction θi = 60°, φi = 0°. The transmission distribution is generated from goniophotometer data for a woven fabric shade. The sample was mounted such that the warp yarns were parallel to φi = 0°.

The ICON project between LBNL and Fraunhofer ISE

Key findings from WP1 - Simulation

- The optical and thermal methods implemented in current standards, building simulation engines and interfaces have been reviewed.
- Gaps in well-known building simulation tools have been identified. These gaps are mainly related to the use of BSDF and assessment of glare risk.
- The simulation engines Radiance, WinCalc and Fener, as well as the simulation interface WINDOW, have been further developed.
- Several scientific contributions have aimed to improve the understanding of BSDF.
- Standardized formats and representations of BSDF have been proposed.
- Methods and workflows for the use of BSDF in energy, daylighting and glare simulation have been developed.

BSDF-workflows to be implemented in simulation software

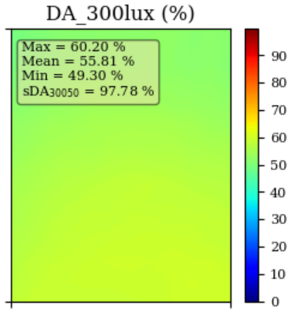
Solar heat gain calculations

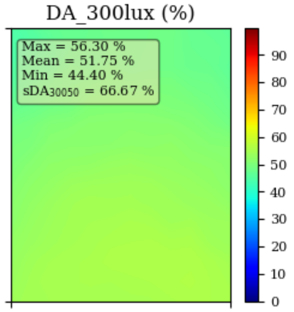
- The g-value has two components: 1) the optically transmitted solar irradiance, and 2) the fraction of solar radiation which is absorbed in the system and then released by convection and radiation to the indoor environment.
- The solar irradiance that is optically transmitted through a scattering fenestration system can be effectively represented by a broadband BSDF covering the entire solar spectral range.
- The spatial resolution of BSDF datasets for building energy analysis can be kept low (Klems)
- BSDF of the shading devices can combined with glazing units by applying the LBNL's WINDOW software.

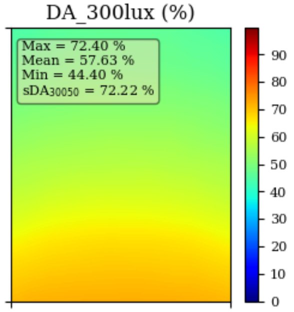
BSDF-workflows to be implemented in simulation software

Daylighting calculations

- BSDF can be used in daylighting simulations in two ways:
  - For point-in-time simulations, directly in the ray-tracing process as a material description, or
  - For annual daylighting calculations, in matrix form.
- In both applications, low resolution BSDF data (Klems) provide fast, approximate results.
- With matrix algebraic methods, the light flux from the sky to indoor points of interest can be divided into several contribution coefficient matrices. For example, for the three-phase method:
  - Sky to the outer window surface
  - The outer window surface to the inner window surface (BSDF)
  - Inner window surface to indoor points.



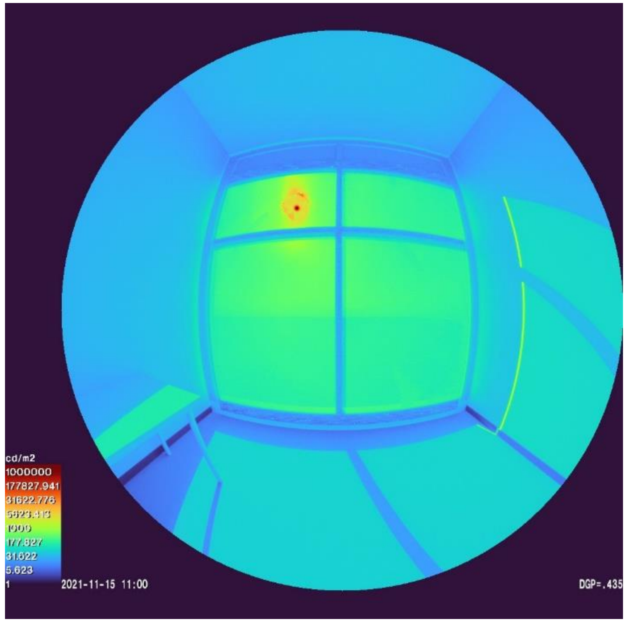




BSDF-workflows to be implemented in simulation software

Glare risk assessment

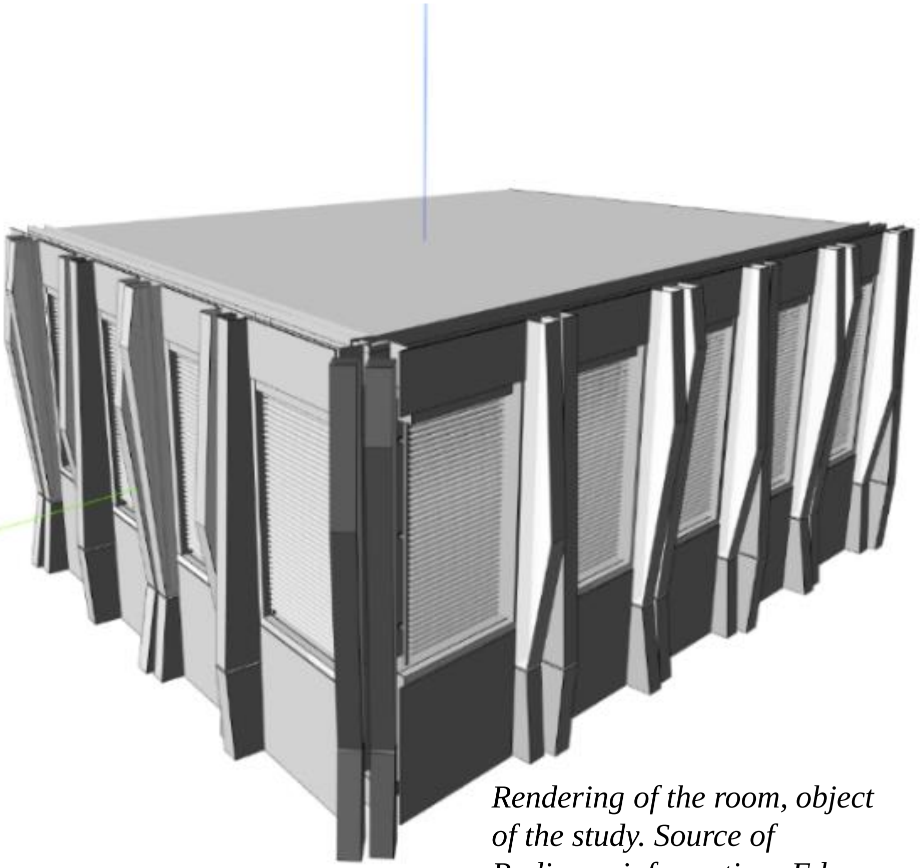
- For systems that allow specular transmission or reflection, sunlight needs to be predicted with highest accuracy.
- Proxy geometries should be used when available.
- Low-resolution BSDF are unsuitable for glare metrics including contrast terms, i.e., luminance-based evaluations, such as DGP or DGI.
- High-resolution BSDF and the five-phase method can be applied in some cases. Impractical high resolutions are however required in some other cases.
- Low-resolution BSDF combined with a peak extraction algorithm is appropriate in view-through type of systems.
  - A peak extraction algorithm separates the transmission peaks from the rest of the BSDF dataset.



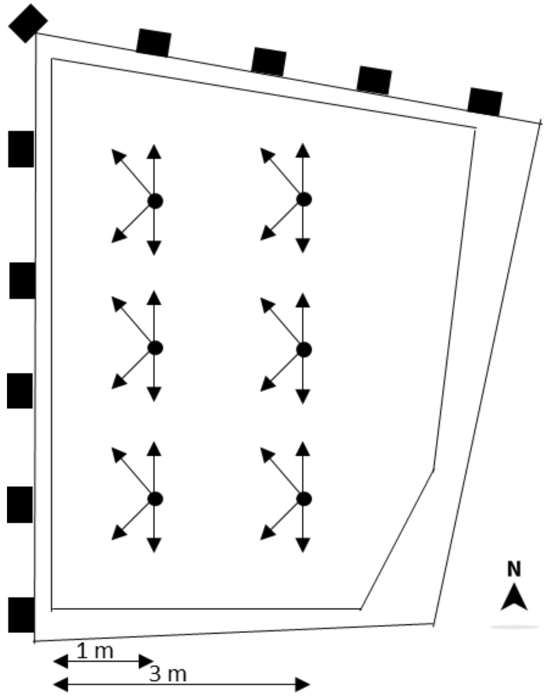
Source: Wang, LBNL

Case study to illustrate some of findings of the ICON project

- Meeting room in Stuttgart.
- The façade is composed of a multi-layer wood structure.
- The room has two main facades facing west and north.
- Window elements are equipped with triple-pane glazing units and internal glare-protection roller blinds.
- A façade designer wants to choose a glare-protection fabric for this building.



Rendering of the room, object of the study. Source of Radiance information: Ed Züblin AG



Plan view of the room, indicating view positions and directions.

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Case study - Choosing a glare protection device according to the standard

- Look-up-tables of recommended glare protection classes of fabrics for a predefined set of building locations, façade orientations, room geometries, view positions and directions.
- The standard recommends glare protection classes of fabrics between 1 and 3 for a Sunshine Zone L (Germany), a west orientation and a large opening

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 17037

December 2018

ICS 91.160.01

English Version

Daylight in buildings

L'éclairage naturel des bâtiments
Tageslicht in Gebäuden

Distance to the façade	Parallel view direction	45° view direction
1 m	2	3
2 m	1	3
3 m	1	2

Case study - Choosing a glare protection device according to the standard

- Two fabrics are optically measured at the TestLab Solar Facades at Fraunhofer ISE.
- Both fabrics are classified as glare protection class 3.
- The designer can choose any of the two fabrics for its room and finalize here the design.
- **HOWEVER**, our case study inevitably differs from the cases considered in the standard, which could result in an inaccurate glare risk assessment.

Integrating sphere (3D Scanning photogoniom.)	Fabric A 	Fabric B 
Normal-normal visible transmittance	1.8 % (2.0 %)	1.6 % (1.5 %)
Normal-diffuse visible transmittance	1.2 % (1.3 %)	0.4 % (0.4 %)
Glare protection class	3	3

Case study - Choosing a glare protection device beyond the standard

- A façade designer, who has to make a decision taking into account conflicting functions of fenestration systems, may want to use a building simulation program.
- Most existing building simulation programs do not include state-of-the-art glare evaluation methods.

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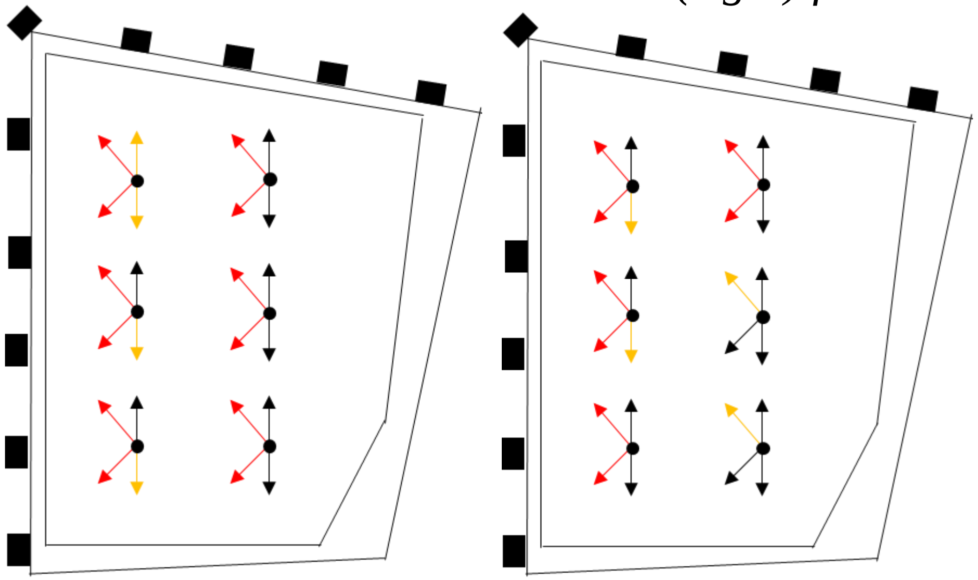
Case study - Choosing a glare protection device beyond the standard

- A workflow to perform annual glare risk assessments has been implemented in a OSS-script and can be integrated in building simulation programs https://github.com/bbuenoun/trace-glare
- The script contains commands for the OSS Radiance.
  - Optimized Radiance parameters for glare calculations are included.
  - A computationally efficient sampling strategy is also provided.
  - The Radiance primitive aBSDF is used to represent fenestration systems with a Klems BSDF dataset combined with a peak extraction algorithm.

fDGPt greater than 5%.
(red) DGP_e = 0.45
(orange) DGP_e = 0.40
(left) fabric A
(right) fabric B



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Contributions related to the application of BSDF to fenestration systems

- Recommendations for adequate BSDF resolutions for different classes of systems: transparent systems, homogeneous or small pattern diffusing systems, diffuse or specular blinds and grids, macroscopic prismatic systems, and micro- or nano-structured systems.

Geisler-Moroder, D., Lee, E.S., Ward, G., Bueno, B., Grobe, L.O., Wang, T., Deroisy, B., Wilson, H.R. (2021). BSDF generation procedures for daylighting systems. White paper. T61.C.2.1 - A Technical Report of Subtask C, IEA SHC Task 61 / EBC Annex 77. https://task61.iea-shc.org/publications. DOI: 10.18777/ieashc-task61-2021-0001

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- Benchmark of state-of-the-art methods for annual glare analysis in terms of computational time (CPU time) and accuracy.
- Strategies to reduce the computational time of glare calculations without compromising the accuracy.

Sepúlveda, A., Bueno B., Wang T., Wilson H.R.. Benchmark of methods for annual glare risk assessment. Building and environment 201 (2021), ISSN: 0360-1323. DOI: 10.1016/j.buildenv.2021.108006

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Bueno B., Sepúlveda A., Maurer C., Wacker S., Wang T., Kuhn T.E., Wilson H.R.. Easy-to-Implement Simulation Strategies for Annual Glare Risk Assessments based on the European Daylighting Standard EN 17037. Proceedings of Building Simulation 2021, International Building Performance Simulation Association, Bruges, September 1-3, 2021.

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Geisler-Moroder, D., Ward, G.J., Wang, T., Lee, E.S., 2021. Peak extraction in daylight simulations using BSDF data. Proceedings of Building Simulation 2021, International Building Performance Simulation Association, Bruges, September 1-3, 2021.

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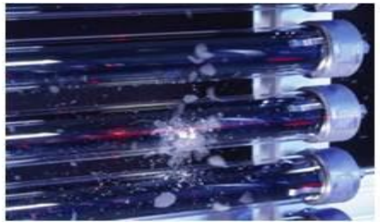
- Review of simulation workflows for energy, daylighting and glare analysis based on data-driven BSDF.

Ward G.J., Bueno B., Geisler-Moroder D., Grobe L.O., Jonsson J.C., Lee E.S., Wang T., Wilson H.R. Daylight Simulation Workflows Incorporating Measured Bidirectional Scattering Distribution Functions. Energy and Buildings, 2022 https://doi.org/10.1016/j.enbuild.2022.111890

Thank you for your attention!

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