

INCORPORATION OF NUMERICAL GONIOPHOTOMETRY INTO DAYLIGHTING DESIGN

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RÉSUMÉ

Aside measurements in real measurement facilities, numerical methods nowadays allow to obtain photometric descriptions for specific complex fenestration systems (CFS). For using the detailed data sets in the daily design practice a database concept with intuitive graphical user interfaces has been developed and is being currently implemented. Prototypical algorithms allowing to include CFS in daylight calculation have been implemented and will be available in the near future.

1. INTRODUCTION

Aside standard façade systems, more complex fenestration systems (CFS) have evolved over the last decades and are being frequently incorporated into the building construction process nowadays. These systems often require a more detailed description of the angular dependent light transmittance properties than standard glazing systems. Goniophotometric measurement facilities allow to record the bi-directional transmission behaviour for a number of different systems. Nevertheless these measurements are often time consuming and are in many test facilities limited to samples of certain geometric extensions. Using computer simulation instead, seems to be an appropriate alternative.

The bi-directional transmission data obtained only have limited practical meaning. They need to be presented in the context of their real application, i.e. under certain illumination conditions of the façade by the outside sky. In the scope of a joint German national research project [3] a façade system database, which among other can show system behaviour under diverse illumination situations is therefore developed. Links to calculation software for daylight distribution in interior spaces will be provided.

2. NUMERICAL GONIOPHOTOMETRY

Complex facade system require detailed photometric descriptions of angular dependent light transmission. Light transmittance

$$\tau_d = \frac{\phi_{\tau_d}}{\phi} [\%] \quad (1)$$

describes the transmitted flux ϕ_{td} in relation to the incoming flux ϕ for a specific incident direction. In order to describe the exact light distribution on the observer (room) side, the spatial distribution of the luminance coefficient

$$q(\theta_e, \phi_e, \theta_r, \phi_r) = \frac{L(\theta_e, \phi_e, \theta_r, \phi_r)}{E} \left[\frac{\text{cd}}{\text{m}^2 \cdot \text{lx}} \right] \quad (2)$$

can be used. It describes the visible luminance L under the angles θ_r, ϕ_r in relation to the illuminance E caused by a light source illuminating the façade system under the angles θ_e, ϕ_e . These properties can either be determined analytically (e.g. for standard glazing), by measurements (in Ulbricht-spheres and goniophotometers) or alternatively with the aid of optical forward ray-tracing programs.

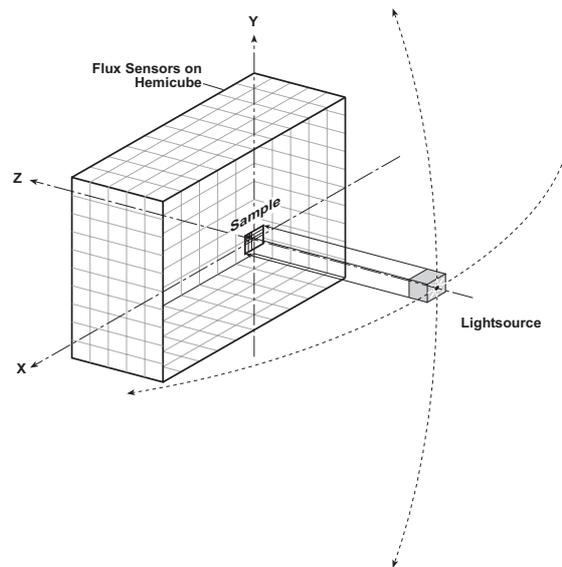
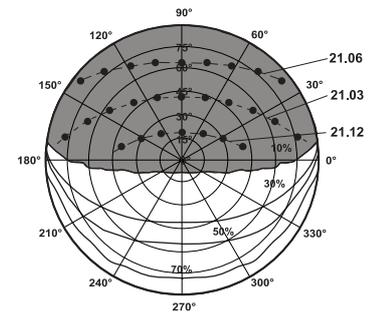
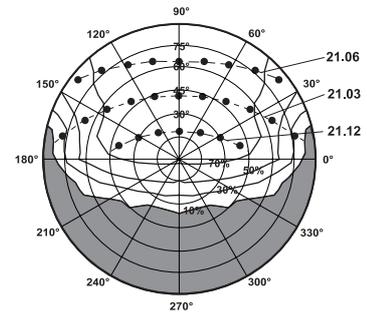
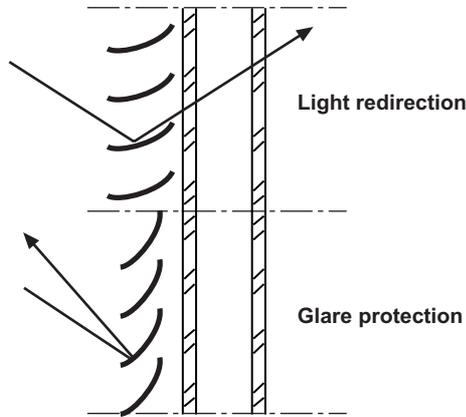


Figure 1: Principle geometrical set-up of the numerical goniophotometer developed at the Fraunhofer-Institute of Building Physics.

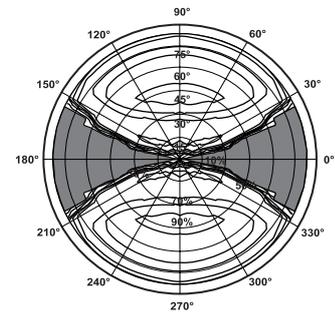
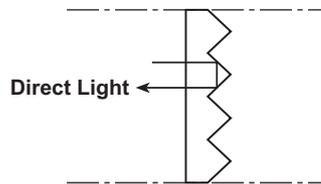
Based on a commercially available ray-tracing program a virtual measurement set up of a numerical goniophotometer as depicted in figure 1 has been developed [2]. Among others it allows to calculate datasets of system properties according to equations (1) and (2) in the format as defined within IEA Task 21 [1]. Geometry and material descriptions of diverse systems can be automatically generated. The method has been validated against a set of physically measured systems, indicating good agreement in the majority of investigated cases, but also showing limitations for systems with small random geometric structures and material properties.

Figure 2 exemplarily represents transmittances as function of the incident angle for two calculated (upper two) and in addition one measured angular selective façade components. The recorded system behaviour matches the known general perception [4]. Areas where light (and therefore radiation) admittance is strongly reduced can be recognized. Based on the principle of total reflection, prismatic systems reject light around the surface normal back to the outside. As known and used in diverse building projects, movable prisms can block direct sunlight, while diffuse light can still enter the room helping to provide higher illumination levels compared to standard shading devices. The distribution of light transmittances of the light redirecting, high reflective venetian blinds and the light guiding glass is rather smooth in big angular areas. These systems function by light redirection. The incoming flux is mainly redistributed into the upper half of the hemisphere for illuminating deep areas of the room.

Lightguiding venetian blinds



Prisms



Lightguiding glass

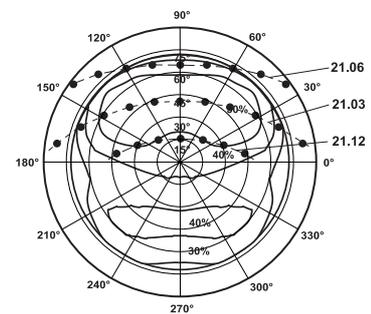
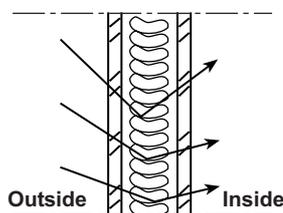


Figure 2: Different light-guiding systems [5] and corresponding light transmittance distributions in polar coordinates. Where meaningful sun paths for winter and summer solstice and equinox are superimposed.

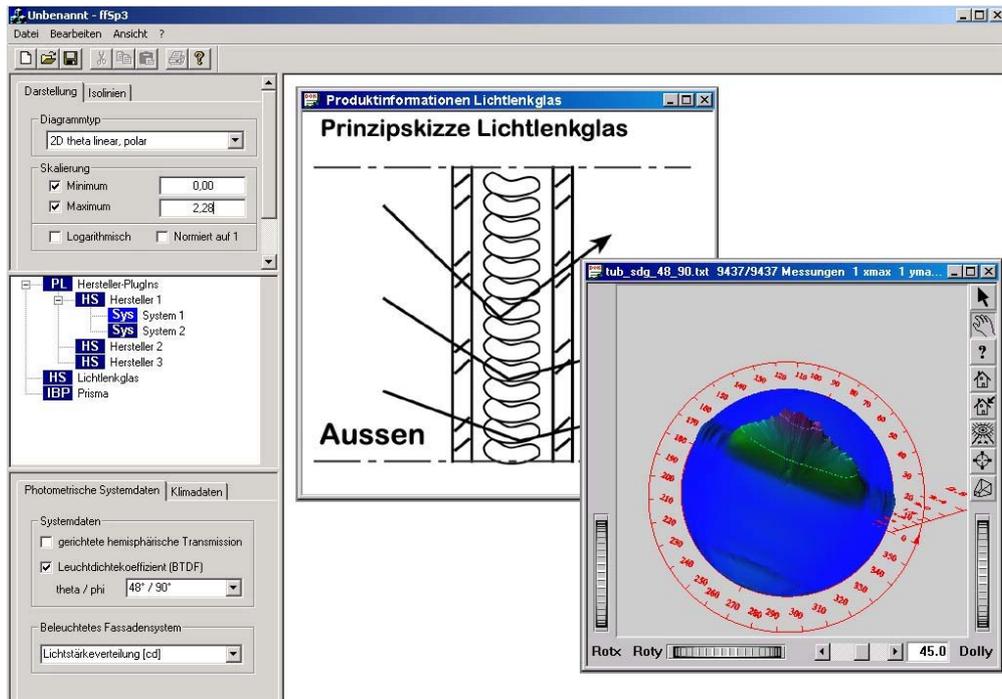


Figure 3: Screenshot of system database under development.

3. INCORPORATION INTO DAYLIGHT DESIGN

The angular dependent light transmittance through CFS and the interaction with outside illuminance conditions delivers spatial and time variant indoor light penetration of generally much higher complexity compared to standard glazing systems. These dependencies have to be made transparent to the designer in an easy to handle fashion, such that for specific problems the best solution can be found at low expenses. Therefore a database with an intuitive graphical user-interface is under development aiming at comparable software support for CFS as for luminaire selection in artificial lighting design. For predicting the impact of different systems on natural room illumination, incorporation of calculation methods into daylight calculation tools is under way.

3.1 DATABASE

The database system being currently set up is based on the raw data sets of the CFS. Content viewers will allow to visualize system functionality. This will include:

- Display of the raw data files.
- Display of daylight distribution (e.g. luminances and incoming flux) as function of façade orientation and incline under different climatic conditions.
- Calculation and display of light entering the room through façade systems (alike candlepower distribution curves in artificial lighting).
- Simple room interface illustrating the direct light incident onto surfaces of a shoebox type room.
- Calculation and illumination of direct sun interaction with the deliberately positioned façade component for static and dynamic systems.

- (Manufacturer) Information on systems like figures, pictures, and texts.
- Plugin specifications, such that different manufactures can plug in own dialogs into the database and can provide automatic updates and product information.
- Plugin specifications for linking into daylight calculation programs like ADELINe but also allowing to link to artificial lighting calculation engines, extending their capabilities.

As depicted in figure 3, the system is developed with MS VC++ using the Open Inventor graphical library, which allows for powerful graphical representation. The database is developed in the framework of a joint project with the Fraunhofer-Institute of Solar Energy Systems, system developers, and consultant offices [3]. The database will be available for free.

3.2 INCORPORATION INTO DESIGN TOOLS

Figure 4 shows a photo-realistic visualization of a daylit room using an light redirecting glass in the upper area of the façade. The calculation is based on a prototypical algorithm developed at the Fraunhofer-Institute of Building Physics. The size of system data sets can reach up to 15 Megabyte for one system state (for movable systems multiples hereof). For an effective integration into daylight design tools the use of data compression techniques is therefore necessary. From the outside luminance distribution and the systems' luminance coefficients the systems' candlepower distribution curves are calculated and can be integrated into Radiosity or Ray-tracing based lighting calculation engines like normal luminaries. A broad inclusion into the software for lighting engineers is therefore possible. Figure 5 exemplarily shows for the specific outside luminance conditions of figure 4 the normalized candlepower distribution curve. Integration into the lighting calculation engines allows the calculation of illuminance conditions due to complex facade systems on arbitrary work surfaces as depicted in figure 6.



Figure 4: Photorealistic visualization of room illuminated by standard venetian blinds in the lower facade area and a light redirecting glass in the upper facade area.

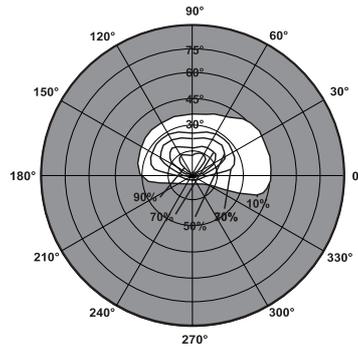


Figure 5: Calculated normalized candlepower distribution curve for a light redirecting glass under outside illumination with direct sun.

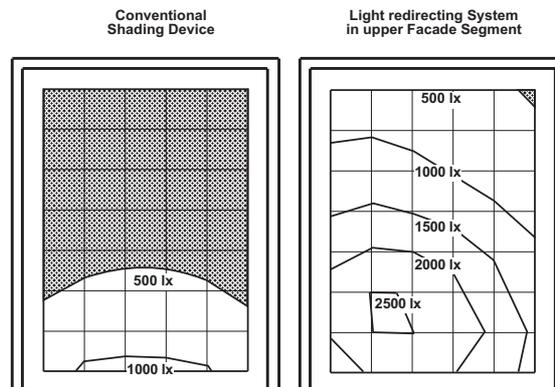


Figure 6: Comparison of room illumination by a conventional shading system (left figure) and a system with light redirection properties in the upper window area (right figure).

ACKNOWLEDGEMENTS

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