SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Office space with light redirecting structures in upper part of the façade

Large-scale micro-optical panels were integrated into the upper part of a façade. The lower part is operated with venetian blinds for sun and glare protection.

At the Fraunhofer IBP in Stuttgart, large scale micro-optical panels were integrated into glazing units and integrated into the upper part of the façade of a lab room. The evaluation of the performance of the lighting conditions and the energy related parameters were compared to a second identical room, with blinds in the upper part of the façade.

The project

The goal of this project, called TaLed, was to improve the energy efficiency, life cycle balances and indoor comfort by employing micro-structured optical components for daylighting and electrical lighting. A micro-optical structure, currently under development, is applied to both sides of transparent substrate layers. The structure have been optimized for redirecting glare-free daylight deeply into the building interior. In the case here reported, large scale micro-optical panels were integrated into glazing units and integrated into the upper part of the façade of a lab room at FHG-IBP (Figure 1). On the lower part of the window a standard venetian blind is being operated for sun and glare protection. The lighting conditions and the energy related parameters are compared to a second identical room, which has standard venetian blinds on the whole window. All blinds are adjusted automatically, and they close when direct sunlight is on the façade. Both test rooms were equipped with six direct-indirect pendant luminaires each (Figure 3), controlled in two groups (window group with four luminaires and door group with two luminaires). The luminaires were coupled to a daylight harvesting system.

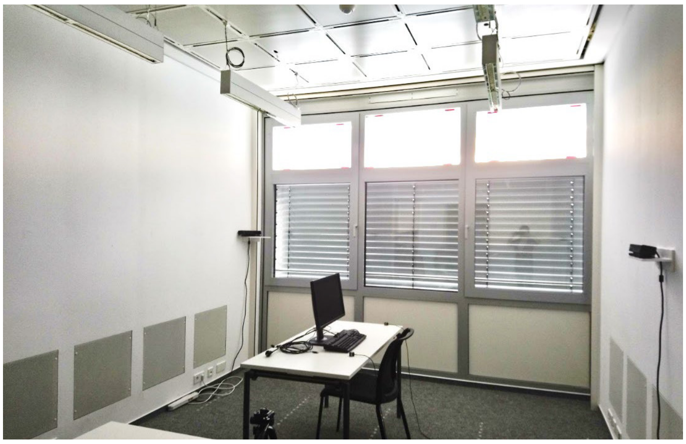
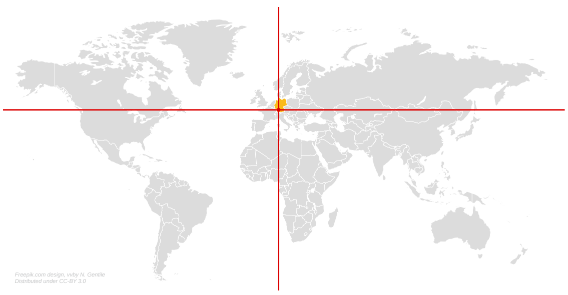
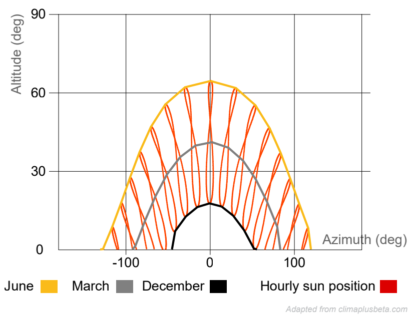


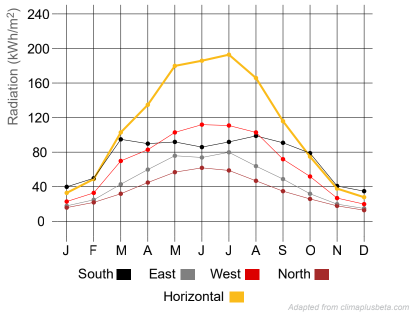
Figure 1. The lab room seen from the inside. The micro-optical panels are placed on the top part of the windows and provide a soft daylight illumination deep in the room.



Location: Stuttgart, Germany
48.74° N, 9.10° E



Sun path for Stuttgart, Germany



Global horizontal and vertical radiation for Stuttgart, Germany

IEA SHC Task 61 Subtask D
Monitored by **Carolin Hubschneider, Yuen Fang and Daniel Neves Pimenta**
More info **Jan de Boer,** IBP Fraunhofer, jan.deboer@ibp.fraunhofer.de

Figure 2. An exterior view of the lab. The facades of both the reference and test room can be seen in the picture.

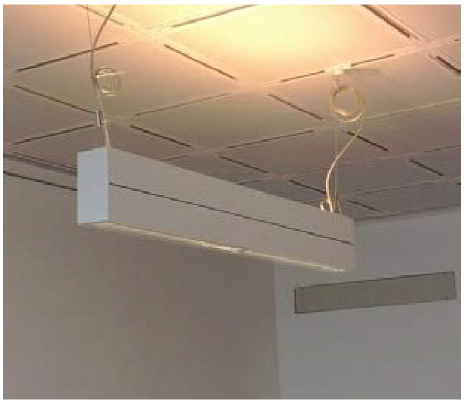


Figure 3. Luminaire with direct and indirect light output.

Extensive documentation on the project and the monitoring is provided in the references at the end of this factsheet.

Monitoring

In Figure 1 the installed sensors and actuators can be appreciated. As actuators, the luminaires and two separate blinds determine the lighting situation in the room. The outdoor illuminance is installed on the roof of the building. Energy consumption is recorded separately for the two groups of luminaires. The following data was recorded in both spaces: outdoor illuminance, illuminance near windows and near doors (via KNX bus), illuminance levels of the illuminance sensors positioned on the working plane, blind position and slat angle for the upper and lower blinds, power and energy consumption for the two luminaire groups, temperature in the room, dimming levels of the luminaire group. The rooms were occupied by test subjects who performed cognitive tests. The measurement data was processed for use in planning and evaluation tools such as DIALux Evo, IEA SHC Task 50: CFS Express and Trnsys.

Energy

The energy use in both test rooms was recorded separately for the two groups of direct-indirect pendant luminaires (window group with four luminaires and door group with two luminaires) with electricity meters. Figure 5 shows the examples of a clear sky day, July 8th 2018, and an overcast day, September 14th.

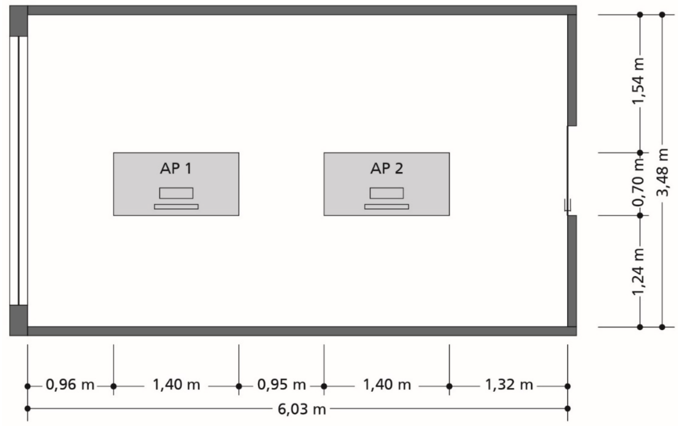


Figure 4. Plan of the lab with the two working spapce (AP 1 and AP 2), where the test subjects performed their tests.

Photometry

The laboratories were equipped with two tables for the subjects to sit and work on their cognitive tests (Figure 4). The Illuminance levels were tracked with five illuminance sensors positioned on the working plane on both tables (distance between façade and sensors 1.0 m, Figure 2), also there were two KNX sensors on the ceiling (calibrated on the basis of the sensors on the working level), which were used to control the artificial lighting.

On the roof of the building the outdoor illuminance is recorded with a weather station, where up to 60 000 Lux were measured (Figure 5).

Circadian potential

The circadian potential was not evaluated. However, considering the high illuminance levels, the significantly higher use of daylight (Figure 5), and the positive feedback from the test subjects, it can be assumed that the circadian potential was significantly increased.

User perspective

The studies for the user perspective were conducted as a within-subjects design, so the test persons experienced both rooms (reference room and test room). They completed various performance tests and questionnaires. The performance tests were not evaluated, but only served to simulate a working atmosphere. The questionnaires examined 50 measures on the following topics: task completion (perceived performance in completing the tasks), fatigue and visual stress, perception, room atmosphere, subjective management atmosphere, light distribution, sunshade or lighting system for the light-directing system.

The data collected was analysed using the SPSS statistical software. For the individual questions of the questionnaires, a t-test was carried out in each case to compare the test room and the reference room.

In the user study, the acceptance of the light-directing element was tested on three days in the period from 20 June

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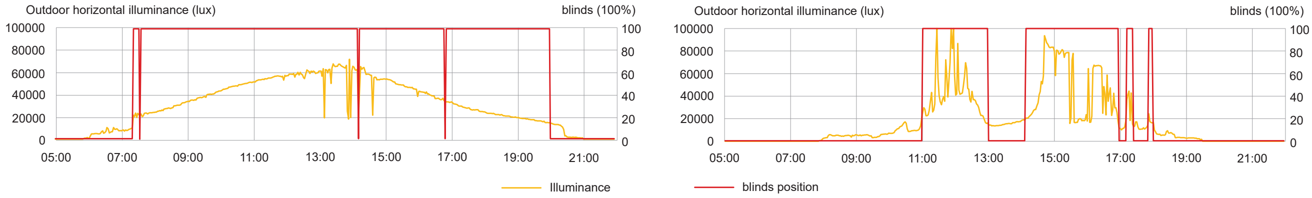
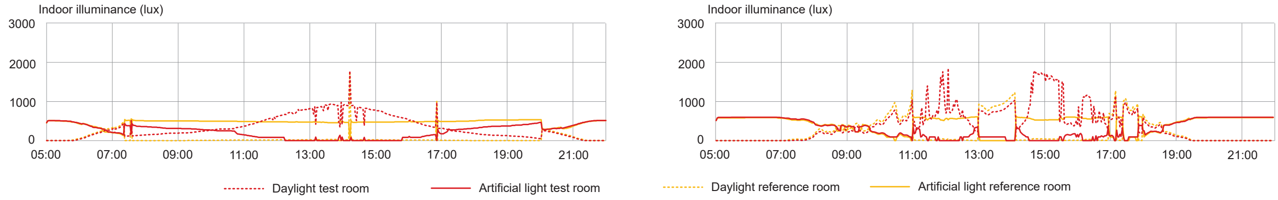
Clear sky day
8 July 2018

Overcast sky day
14 September 2018

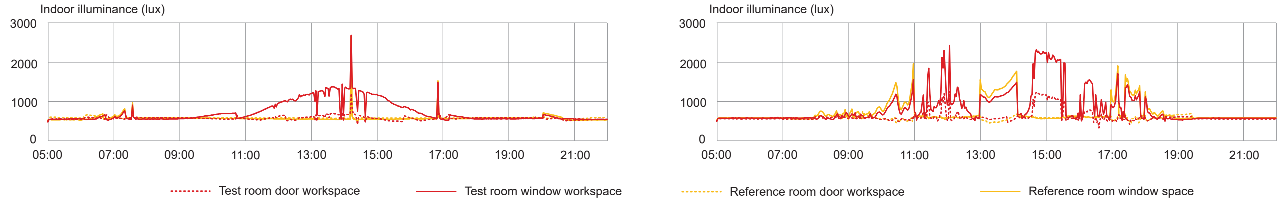
Outdoor horizontal illuminance and blinds adjustment during two monitored days



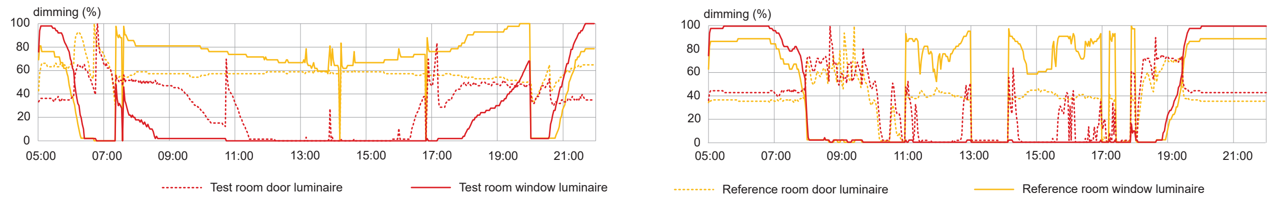
Proportion of average horizontal illuminance for artificial and daylight in the two rooms during two monitored days



Mean values of indoor horizontal illuminance on the two working spaces, close to the door and close to the window

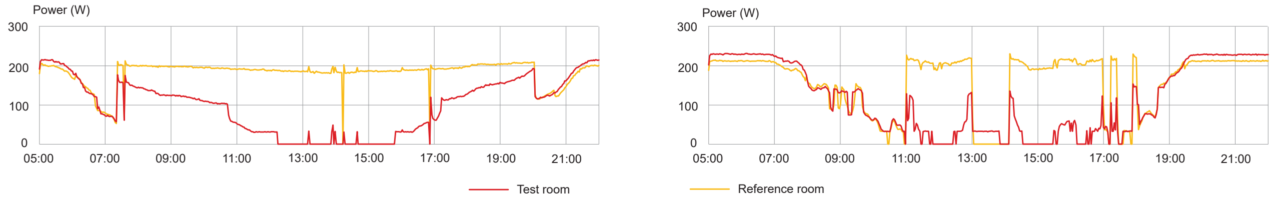


Dimming steps for the luminaires



Mean values of indoor horizontal illuminance on the two working spaces, close to the door and close to the window

Mean values of indoor horizontal illuminance on the two working spaces, close to the door and close to the window



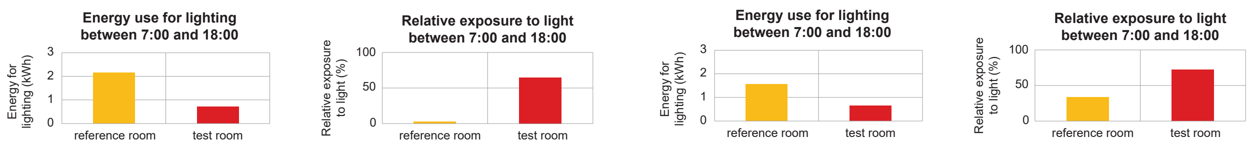


Figure 5. Logged information on outdoor and indoor illuminances, as well as power and energy figures for the installed luminaires. The data refers to both the test and the reference rooms. See DIN V 18599 for the definition of relative exposure to light.

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2018 to 3 August 2018. 22 subjects (students, 10 female, 12 male) aged between 22 and 31 years were invited.

16 out of a total of 50 measures show there was a statistically significant difference between the two rooms ($p \leq 0.05$). General and visual fatigue was perceived as lower in the test room. The lighting environment was also assessed differently by the test persons. In the test room, daylight was described as more pleasant, sufficient and natural. The redirection of daylight into the depth of the room was perceived as more pronounced in the test room. However, the façade system in the test room was perceived as more dazzling.

Lessons learned

The development and future use of micro-structured optical components for daylight utilisation is intended to improve energy efficiency, life cycle balance and the quality of interior usage in buildings. In the project, the structure was optimised, scaled to practical building sizes with newly developed manufacturing processes and the system integration was implemented in glazing units. Lighting and energy parameters were determined and prepared for use in planning tools. Life cycle balance and influence on the energetic building behaviour were estimated. Furthermore, the structures were tested in real installation situations in test rooms in terms of energy and user acceptance. Future architectural application concepts were developed. The main lessons learned are summarised below.

Compared to the reference room, the light-directing façade reduced the lighting energy demand in an office situation by about 55 % with increased evaluations by the users.

The real-life use of the developed solutions was tested in comparison to reference solutions in test rooms. The light-directing components in the façade reduced the lighting energy demand in an office situation by 58 % during the measurement period (May to September 2018). The user evaluations were significantly improved for the test room.

The light-directing structure was integrated into the space between the panes of a standard thermal insulation glazing. In order to avoid cast shadows on the room side, the glazing units were supplemented with linear structured cast glass as a linear diffuser. In order to ensure a generally sufficient supply of daylight to normally deep office rooms, approx. 0.4 - 0.6 m high light-diverting elements are required in the upper window area.

The required material use of plexiglass (PMMA) could be reduced by over 75 % compared to comparable structures.

In a life cycle perspective, the solutions achieved great performance, both in terms of reduced use of raw materials and recycling possibilities. The production process used, "hot embossing" with structures in the order of 500 μm has been further developed so that components can be produced in sizes for building applications (windows) on the one hand and in high quality at low cost on the other. The processes allow the structuring of rigid PMMA sheets. In the project, dimensions of 1,200 mm x 600 mm were realised for testing in the test rooms. Larger dimensions can be produced. The costs of the ready-to-install PMMA micro-optics for light deflection are 30 - 35 €/m² compared to approx. 250 €/m² for the light-deflecting, encapsulated PMMA rods of a functionally comparable product. Recycling possibilities of the glass laminates were evaluated as uncritical.

"Why wasting energy, if we can use daylight?"

Further information

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A Construction Kit for Façade Integration and Integrated Use With Electric Lighting; Francesco Sasso, Green Building R&D GmbH, Düsseldorf, Germany.

Architectural Integration Concepts, Francesco Sasso for Matthias Kraemer, SSP AG, Bochum, Germany.

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