Openings and Natural Light: Experiences in Full-scale Models

Tobi Stoeckli (stoeckli@lesomail.epfl.ch)

EPFL, Switzerland

Keywords: Light Chimney, Daylighting Research, Anidolic Daylighting System, Computer-controlled Heliodon, Diffuse Light Simulation

Abstract

On the EPFL-campus two experimental laboratories are located just side by side: the LEA (Laboratoire d'Expérimentation Architecturale) and the LESO (Laboratoire d'Energie Solaire et de Physique du Bâtiment). The research work on daylighting performed by the LESO will be presented in the frame-work of this contribution and finished with a personal statement about ope-nings.

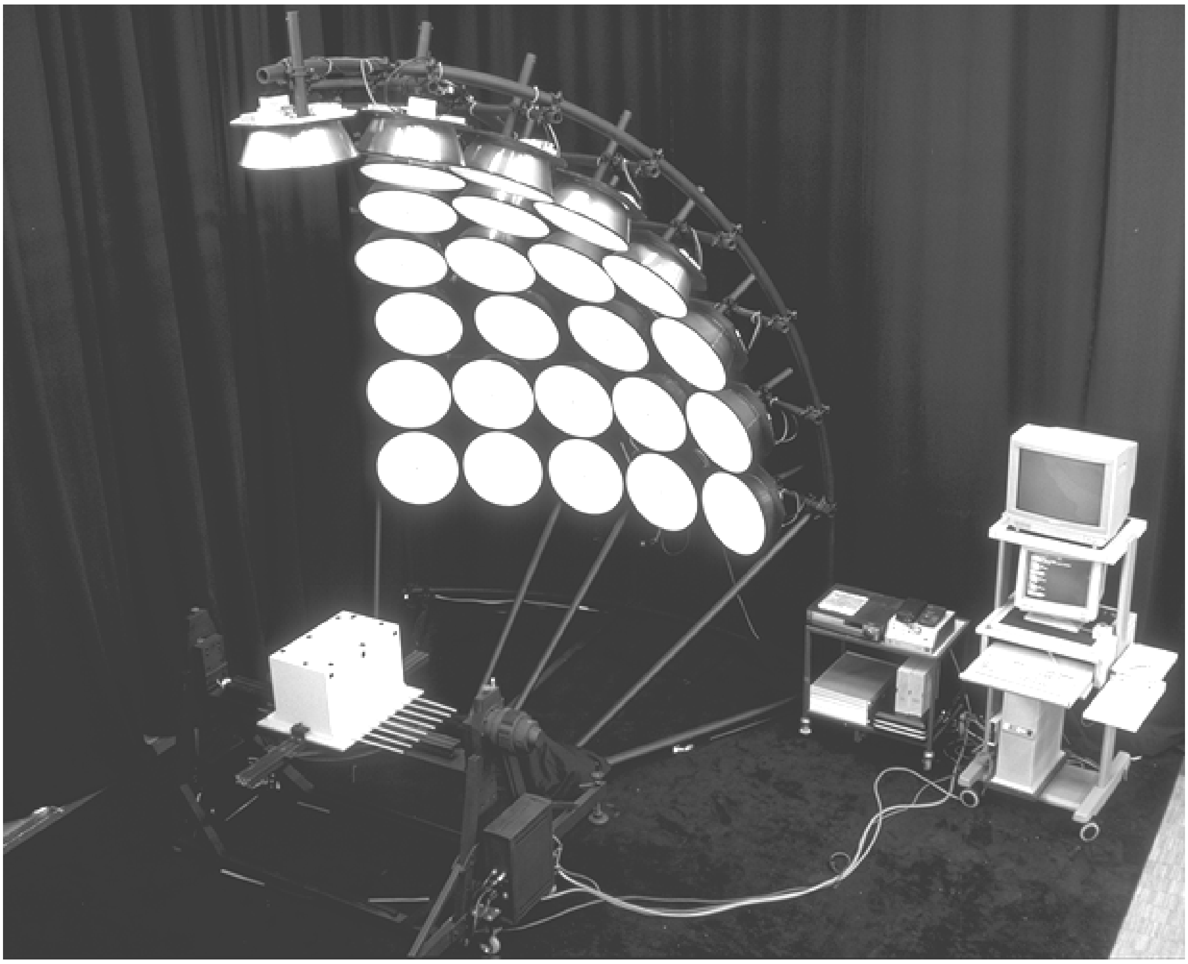


Fig. 1 View of the diffuse light simulator and the equipment.

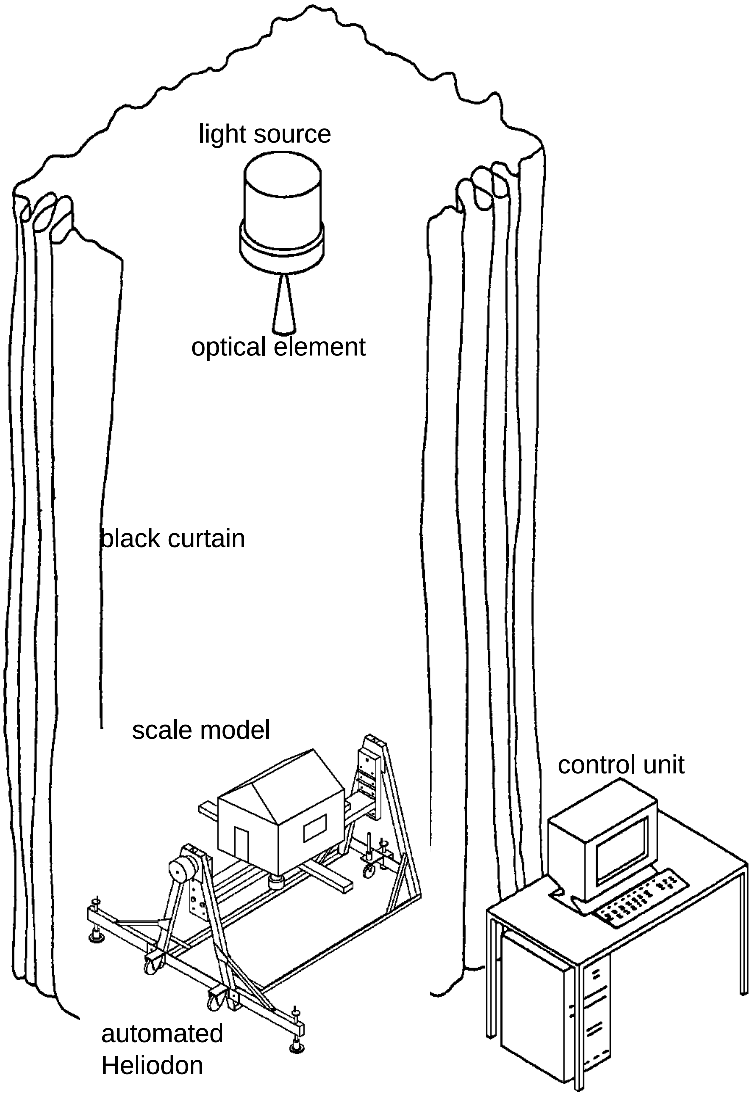


Fig. 2 Principal components of the direct light simulator.

The Daylighting Laboratory

In the main experimentation area of the LEA parts of the daylighting laboratory of the LESO are hosted, which is a result of the available ceiling height and the possibility to install a light source which simulates direct sunlight. Further principal components are:

1. A *heliodon*, which enables to turn the scale model in the exact position (latitude) of the site and to simulate the course of the sun during a specific day (summer/winter);
2. A control unit (computer), which presents the indications to move the model, stores up the measurements and visualizes the luminous conditions perceived within the model;
3. A black curtain, which protects the measurements against other light sources.

As Switzerland has more days with overcast sky and diffuse light than clear days with direct light a *diffuse light simulator* was also built up. For the diffuse light simulator, 1/6 of the whole hemisphere (diameter: 5 m) was built. This surface is big enough for the measurements. A computer program allows the control of the entire light simulation. This basic installation is completed by additional equipment such as:

- photometers to measure the illuminance inside the scale models;
- endoscopic objectives and a high-definition CCD-camera;
- image digitizer;

The installation allows:

- to measure the daylight penetration inside the scale model;
- to evaluate the visual comfort under given, simulated daylighting conditions;
- to visualize the luminous environment perceived inside the scale model.

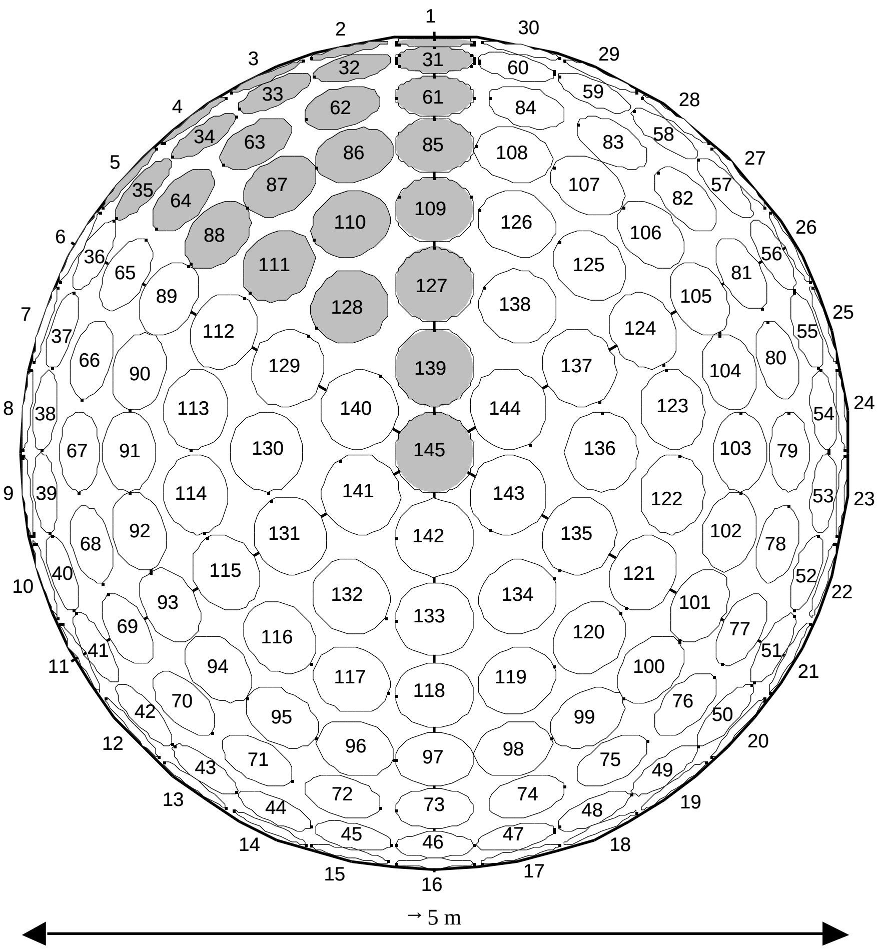


Fig. 3 Top view of the diffuse light simulator. The built lighting zones are 1/6 of the whole diameter.

Research on Light Chimneys

Daylighting chimneys allow bringing natural light in the back-area of deep spaces. This aspect was further studied in the course of a specific research program. On a theoretical basis daylighting chimneys were examined, especially the influence of changing dimensions (width from 60 to 90 cm) and the form of the openings on top (light-catcher) and below (light-diffuser).

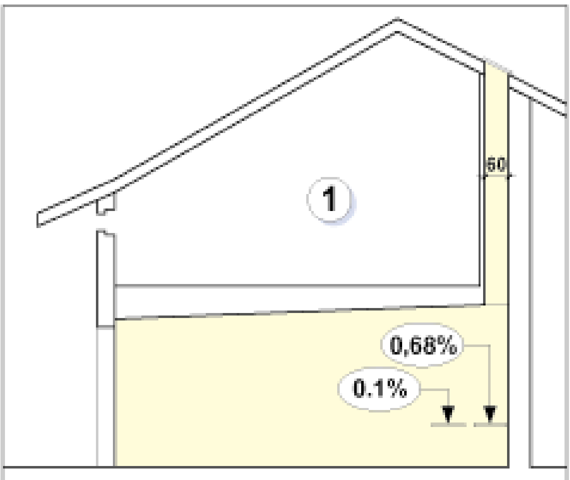


Fig. 4 Basic Project
Width of the chimney: 60 x 80 cm
Surface: white paint

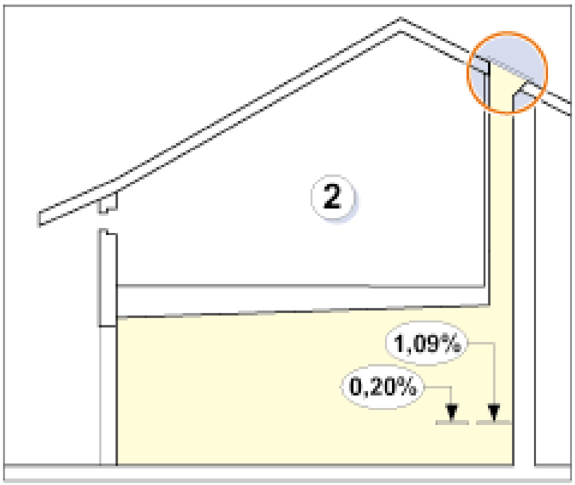


Fig. 5 Variation 1
Enlarged top opening
Surface: reflecting polycarbonate plates

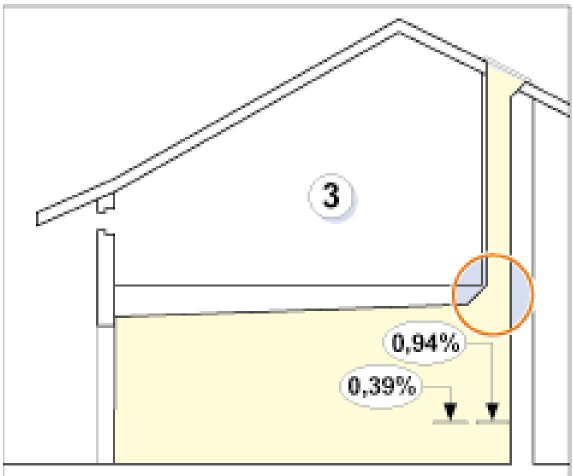


Fig. 6 Variation 2
Enlarged top and bottom opening
Surface: reflecting polycarb. plates

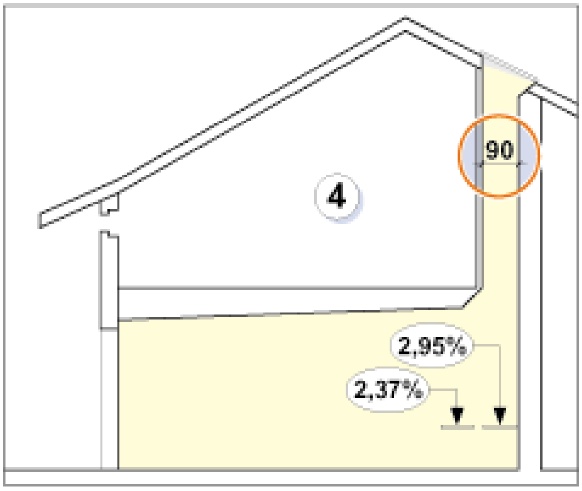


Fig. 7 Variation 3
Width of the chimney 90 x 110 cm
Enlarged top and bottom opening
Surface: reflecting polycarbonate plates

The daylight-factor directly under the chimney increased through this optimization process from 0.7% to 3%, and in a short distance from the chimney from 0.1% to 2.4%. The results were verified through the real construction and were found to be close to the previous values.

Research on Anidolic Daylighting Systems

Based on a theoretical approach, the LESO built three spaces, equal in size and dimension (3x3x6.5m), with the entrance door on one short wall and the windows on the opposite side. The three spaces had the same window surface. In one parameter they were treated differently. They made different alterations and could finally compare four variations:

- grey painting (surfaces);
- white painting (surfaces);
- white painting (surfaces), increasing the window height by 1/4 of the total height and shifting the front part of the ceiling;
- white painting (surfaces), application of anidolic devices in the upper part of the window resp. on the ceiling.

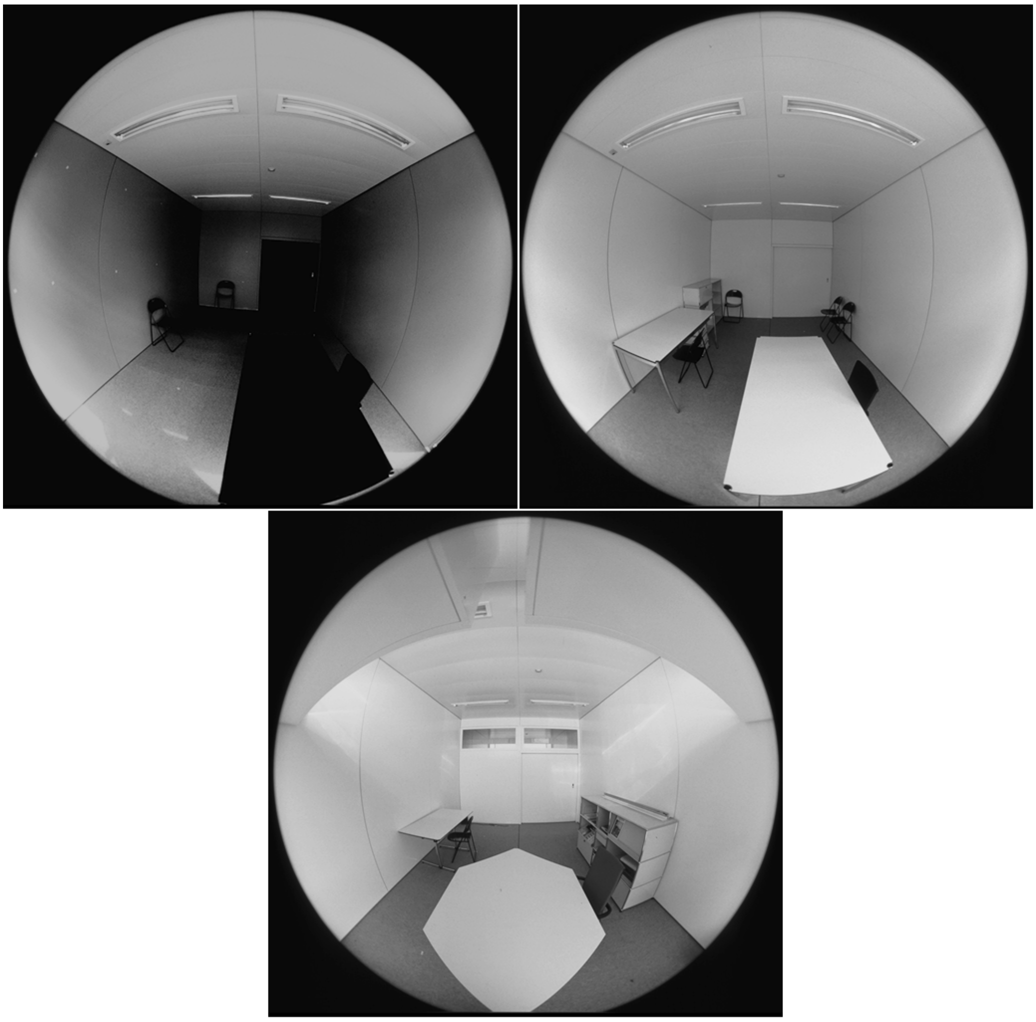


Fig. 8 Interior view seen from the same point near the window into the back of the room [Top left: Daylighting conditions in the room painted grey. - Top right: Daylighting conditions in the room painted white. - Bottom: Daylighting conditions in the room painted white with anidolic daylighting system.].

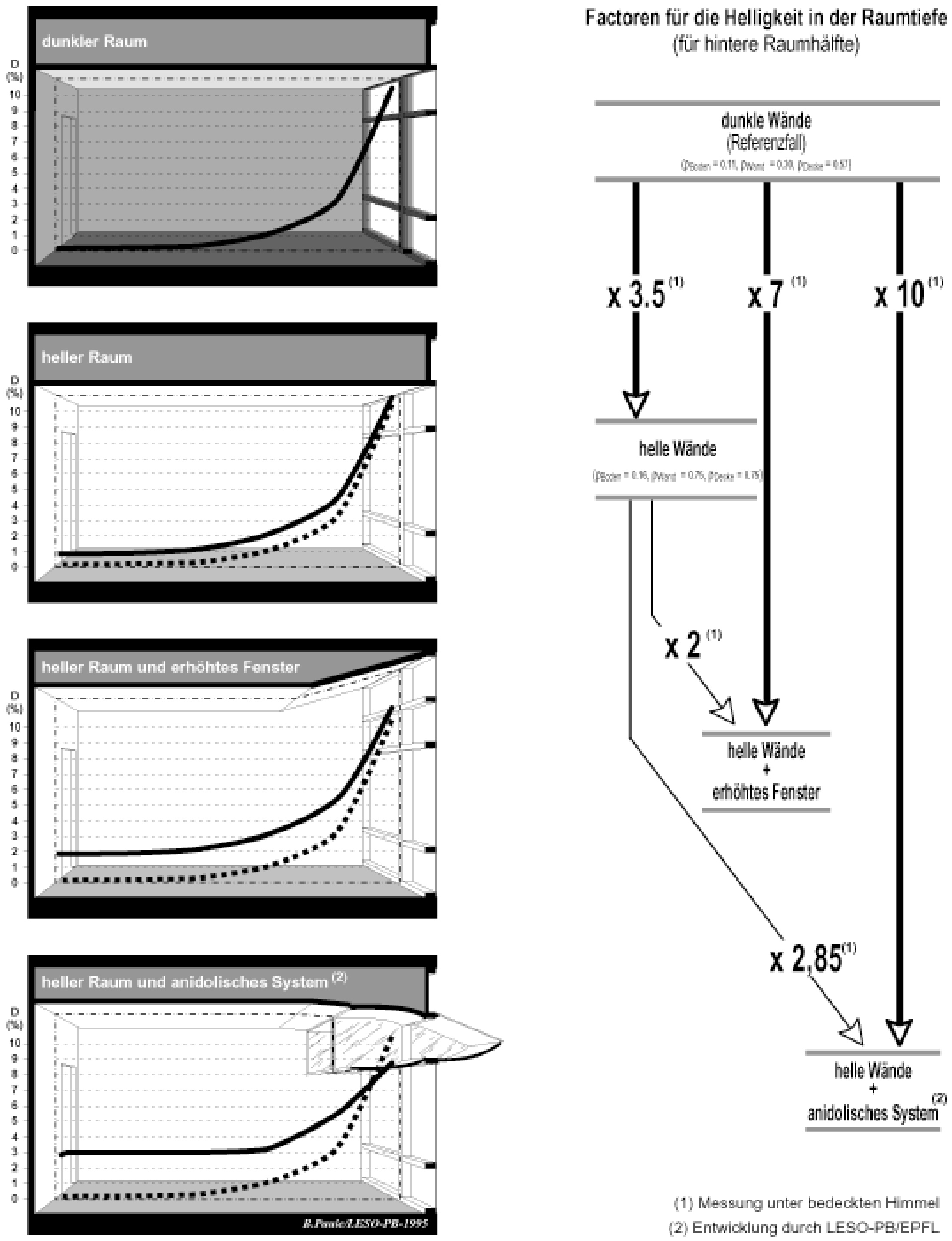


Fig. 9 Configurations and results of the full-scale model.

The measurements were performed during a day with overcast sky. Compared with the grey room, the daylight illuminance in the back half increased:

- for the white room by a factor of 3.5;
- for the room with the enlarged window front by a factor of 7;
- for the room with the anidolic reflectors by a factor of 10 and reached a daylight factor value of 3%.

The anidolic daylighting system proved to be an effective device in re-directing daylight in the back of a deep room. At the same time it changes consequently the appearance of the window area from the inside of the room, as well as the appearance of the façade.

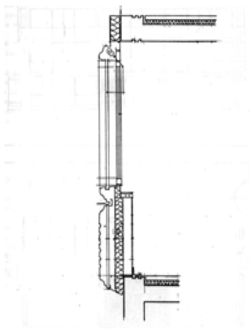
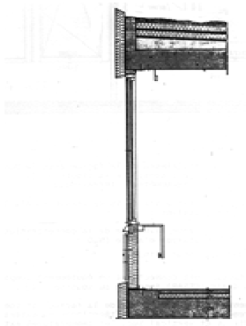
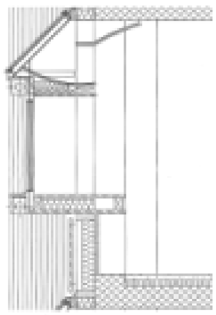
	EPFL - 1	ISAL	LESO - 1999
			
Glazed area (%)	39%	52%	48%
Average U-value (W/m2 K)	2,16	1,19	0.84
Heat requirements (MJ/m2 floor area)	239	154	(93) 86
Mass (kg/m2)	123	29	(42.5) 122,5
Embodied energy (MJ/m2)	1933	1476	(675)

Fig. 10 Measurements of energy savings.

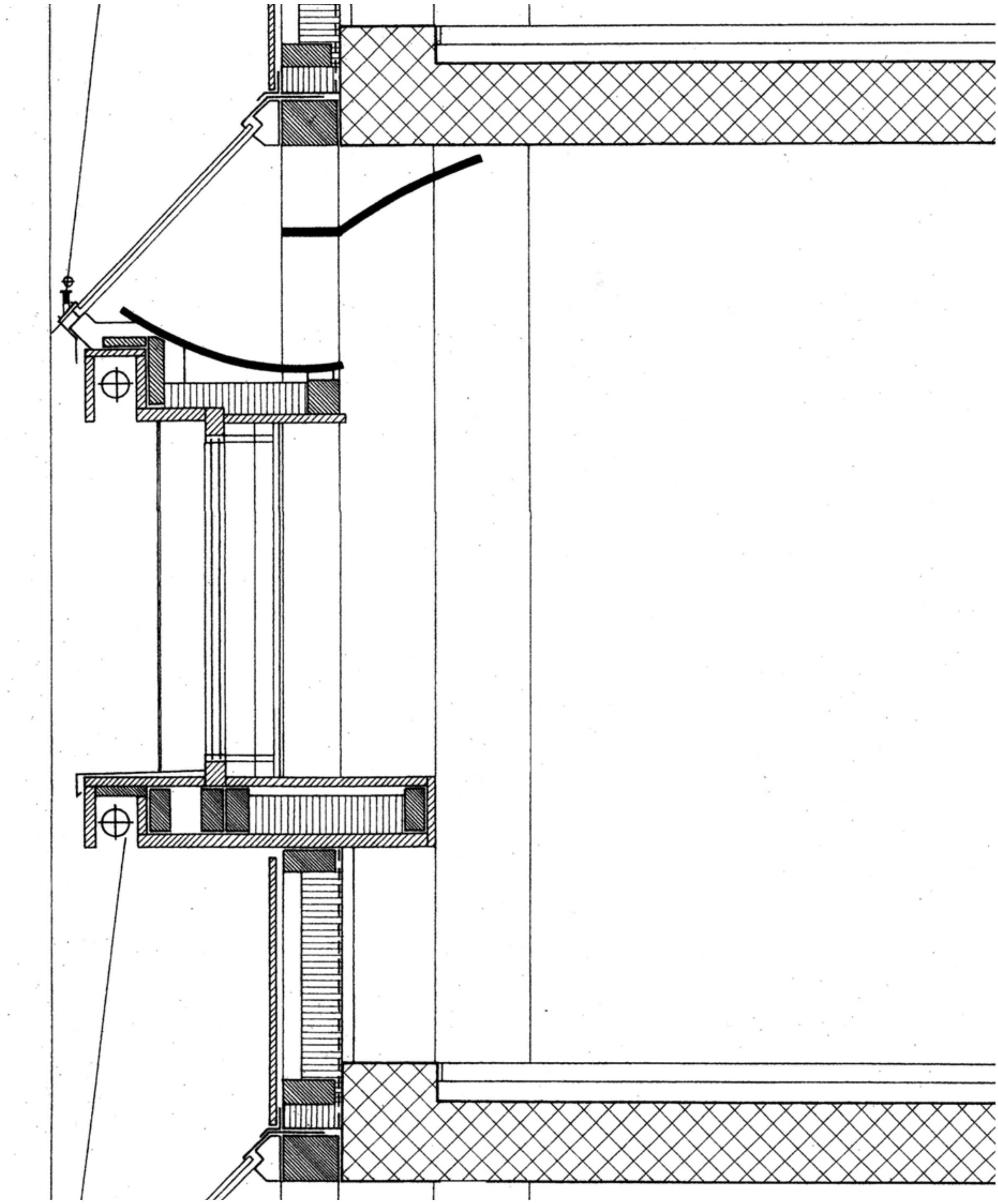


Fig. 11 Section of one floor of the façade.

In the beginning of 1999 the LESO-building got a new façade with anidolic reflectors, which are much better integrated in the overall appearance. This new façade was compared to the existing façade of the EPFL-campus resp. to a conventional metal-facade-system approved to be superior in saving energy (heat requirements and embodied energy). The façade will now be tested and evaluated by the researchers of the LESO themselves.

As these works show, the researchers of the LESO apply simultaneously different tools to these topics. They have developed a number of computer simulation tools. These results are continuously compared with studies on reduced scale models and within full-scale models. All the three levels of research are necessary to be able to compare and to take advantage of the potency and the effectiveness of each tool. Furthermore, confidence is reached about the computer simulation, which finally approves to be the quickest and the fastest tool to compare different solutions for a given problem.

Research on Computer Simulation

For architectural projects it is necessary to control the different aspects as early as possible. For daylighting problems LESO developed sophisticated software with fuzzy logic techniques, which allows the user to get comprehensive results when the first draft of a building is made and many parameters are yet not fixed. Moreover, the software can be used by architects without help of a lighting specialist. It allows to work with “unprecise” data and gives recommendations for improvements to be made in order to realize an improved daylighting strategy. Furthermore, comparisons with reference cases are suggested. In this respect architects have the opportunity to control the effect of daylight within the space at an early stage of the project, when necessary corrections and modifications can be made easily.

The Architects Point of View

Although this research work is useful and significant, as architect one has to combine this convincing knowledge with many other aspects of an architectural case and to integrate this in the basic concept of the architectural project. Considering this task one may raise several questions:

1. Remaining within the topic of light, the question remains: "what is the appropriate quality of light in a room?" It is evident, that insufficient light or dazzling light is embarrassing. It is also evident, that *light and shadow* create the atmosphere within a space. What is, in consequence, the convenient contrast of shadow and light to feel comfortable?

2. The quality of light is only one aspect of a window. Apart from the light, an opening has to serve for both viewing through and ventilation. For the user the view might be the most important aspect. It shapes the relation between the world outside and the interior. It shapes the connection to others and gives the inhabitants the feeling of belonging to a place and to be at home (even in an office space). The necessary technical devices of the anidolic daylighting system like reflectors and sun protections are influen-

cing the view and have to be integrated in the shaping of the relation to the outside and to the others. This integration increases the complexity of the architect's task considerably and it is unfortunately very often under-estimated or even neglected.

3. The opening itself is only one element of the building, but a decisive one. It is a constituent part of the façade, which itself is a fundamental element of the architectural concept. The integration of technical devices influences or even determines the architectural expression. It can be regarded as a basic question, whether it is appropriate to let a technical device - like a light catcher - dominate the composition of the façade. This can be observed f.i. at the back side of the Shanghai Bank in Hongkong (Norman Foster). What are the gains and what the losses?

Conclusion

Technical devices should not have the power to dominate resp. to determine the architectural concept. Many other aspects are even of more importance and responsible for the “building quality”. An architectural concept should reflect profoundly on daylighting requirements and energy savings problems being able to integrate them in an overall view of a sustainable development. This is doubtlessly an extensive task and waiting to be taken up.