LATEST GERMAN DEVELOPMENTS IN ARCHITECTURAL GLASSES AND DAYLIGHT GUIDANCE SYSTEMS

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ABSTRACT

Pleased by new techniques and the industrial production of glass, the architects in the first half of the century realized the dreams of their colleagues throughout the civilization of mankind: being part of nature without being bothered by nature's realities: rain, wind, cold, insects etc., perfectly demonstrated with House Farnsworth, Ill., USA, by Ludwig Mies van der Rohe (1950). Triggered by the oil-crisis of 1973, a new development started in Germany with the aim to reduce the outrageous energy consumption of buildings, mainly caused by the generous use of glass and therefore poor insulation standards. Today new materials and techniques combine the old dream with new efficiency.

INTRODUCTION

Throughout mankind's civilization of planet Earth, (sun-)light was considered a holy element by almost every cultural group. Whereas in ancient times the sun-god was worshipped by the people, in our century we started to demonstrate our affection for the sun even more directly: the beaches all over the world are crowded with sun-worshipping individuals. It comes to no one's surprise, that during the last centuries architects were especially concerned with the aspects of light. One climax in the architectural development was reached with the transition from the heavy, lightless romanesque towards the gothic style. New techniques suddenly allowed the construction of light-flooded cathedrals as well as profane buildings. It took some more centuries to create another light-connected highlight: the famous glass-palaces in England, mainly built in the second half of the last century. At that time, there were still two limitations: the size of glass was limited to 60 x 180 cm and glass was still not produced at an industrial scale and therefore very expensive. Both changed in the first half of our century: new techniques in the glass production cleared the way for an increased use of this material, supported by decreasing prices.

With the beginning of the rationalism in the twenties, „Bauhaus" architects in Germany started to integrate glass as a surface material for facades. Given the intensive use of concrete with all its static and therefore aesthetic potential, an absolutely new architectural style was possible: suddenly a facade could change from material to anti-material, from closed to open, from light to shadow. Some of the „Classics": Fagus-factory,1911, by Walter Gropius and Adolf Meyer, Bauhaus in Dessau, 1925 by Walter Gropius, the German pavilion at the international exhibition in Barcelona, 1929, by Mies van der Rohe, Haus Tugendhat, Brünn, 1930, Mies van der Rohe and the Farnsworth House in Illinois, 1950, by the same architect. Not that known during his life-time, Erik Gunnar Asplund set a remarkable sign for modern, elegant and light-flooded architecture with his restaurant at the Stockholm exhibition 1930.

As one of the leading architects of the „International Style", already in the early twenties, Mies began with visionary (and never realized) studies of totally glassed skyscrapers.

His dreams finally came true, when he got the chance to design the Seagram building in New York, in partnership with Philip Johnson in 1958. The Seagram building, like the Lake Shore Drive Apartments in Chicago (1950) are considered as milestones of the International Style. The aesthetic expression of both projects are emphasized by the use of the curtain wall construction, which consists of a big portion of glass. It served as an example for hundreds of skyscrapers on all continents and in all climatic zones around the world.

In Germany after the end of the second world war, there was a huge demand for new buildings, due to the vastly destroyed cities. Cities like Munich, Cologne, Hamburg and Berlin had lost around 60 to 80% of their prewar buildings. In the beginning, the reconstruction was started with bricks, regained from the ruins and the rubble by the famous „Ladies of the rubble", at a time when the male population was reduced significantly by war.

With the beginning of the German „Wirtschaftswunder", the economic miracle, in the fifties, architects were asked again to demonstrate the well being of their contractors, and, especially in the area of office buildings, to join the International Style again, though skyscrapers never caught on in Germany. The break came in the early seventies, caused by the oil-shock, when energy prizes rocketed sky, oil exploded from DM 0,19/liter to DM 0,90/liter. Therefore almost quintupled. Due to the German climate, which reaches it's summery peak at almost 40°C and it's wintry low at an arctic 20°C below zero, the energy costs for the climatization of office buildings exploded. The owner of the Hypo-Bank building, one of the very few (and modest) skyscrapers in Munich, paid in only five years as much money for the energy consumption (for fighting the chilling cold in the winter and the insupportable heat in summer) as for the whole construction of the buildings. New ways for energy efficiency had to be found at that point. Legislation was changed to urge the planners to reduce the necessary energy input significantly. To accomplish this aim, engineers and architects, in close cooperation with the industry, developed new materials, improved existing ones and formulated a new design concept. The development is still not concluded, though the already realized improvements are quite interesting:

- in the area of residential buildings the zero energy house was realized in 1992. All necessary energy is obtained by the facade.
- The average energy consumption (for climatization) of the existing building stock sank from 440 kWh/m^2 in 1970 to 150 kWh/m^2 in 1996.
- And, basic to all future improvements in energy efficiency, private as well as public investors are learning to consider not only the construction costs but also the energy and maintenance costs over the years.

The actual R&D measures taken in Germany are concentrated in the area of CO2-reduction and therefore concentrated in cutting the energy consumption for cooling and lighting. [1]

TYPES OF GLASS

In the last 20 years different development directions for window improvements were taken:

- improvements via better (e. g. iron free, structured surfaces) glass or with more layers (from 2 to 4)
- selective coatings for higher IR-reflection; started with single coatings e. g. Zn_2O, In_2O_3, now with multi-layer coatings utmost with Ag
- special gas fillings to depress the convection between the panes (in former time SF_6, now Ar, Kr, Xe or gas mixtures)
- and an other way to depress the convection through high transparent and light material (TIM) with more than 90 % porosity

1. capillaries
2. honeycombs
3. aerogels (granular or monolithic)

Now on the market we have windows in wide ranges of U-Value (5,4 to 0,4 W/m^2K) and of g-Value (0,9 to 0,2). In the field of g-Value from 0.7 down to 0,2 and U-Value from 2 down to 0,4 W/m^2K many different glazings are available. field of g-Value from 0.7 down 0,4 special glazings are given, small and large glazings filled with highly transparent, light material (capillars, honeycombs, and the best material: monolithic aerogel).The thermal performance of these TIM-glazings is much better than the best selective glazing with Xenon or Krypton filling. But theses types of glazing, filled with capillaries or honeycombs, give an „other" view through, so that such glazing are better used only in fanlight. Monolithic aerogel fillings are too expensive at the moment, but they give a normal view through, as a normal window. Between both types of glazings granular aerogel filled glazings are given with a g-Value lower than the other TIMs.The light will be scattered by the particles, so that this filling can only be used for fanlight as well. A special window solution is given by Swiss window HIT (U-Value 0,7 to 0,6 W/m^2K, g-Value 0,2 to 0,3; two outer glazing and two selective foils, produced by the American company South Wall, with a total air gap of more than 30 mm in between, open to the atmosphere). A special, innovative glazing is given too, a vacuum glazing with coated inner surfaces. The U-Value 0,4 W/m^2K is perfect, the g-Value 0,47 is reasonable, but the vacuum tightness is a problem not yet solved.

Looking to cooling savings in warm or hot climates, special window design can reduce the solar load. Performance differences are given through the type of selective foils. One can see, that the triple glazing with Heat Mirror 55 reduce the solar load to the room to only 40 % and reduce for glazing system the U-Value from 5,4 to 1,9 W/m^2K (down to only 35 %), so that the thermal coupling to the outside is depressed too.

1 IBP-Mitteilung 301: H.Erhorn, H.Kluttig: CO2 Reduktionspotential im Verwaltungsbau, Stuttgart 1995 (Germany)

DAYLIGHT GUIDANCE SYSTEMS

Daylight guidance systems are developed to improve the distribution of light. Whereas daylight causes glare close to the facade, the intensity drops sharply just a few feet away from it. 3 meters away from a window 1 m high, the intensity falls to only 1% (at workplace level).

DAYLIGHT INTENSITY [1]

a) window to the sun, clear sky

b) overcast sky, all directions

c) window opposite to the sun, clear sky

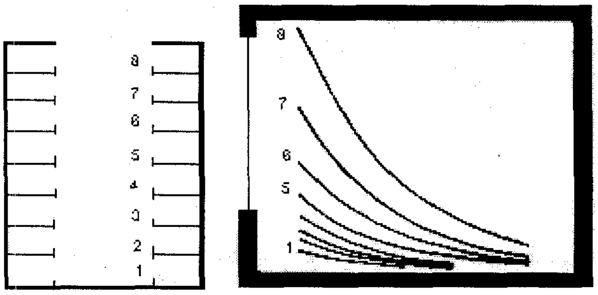


Figure 1. Daylight distribution [2]

A similar problem is found in atrium-houses. Whereas in the upper floor plenty of daylight is found at least close to the facade, the intensity drops sharply with each floor.

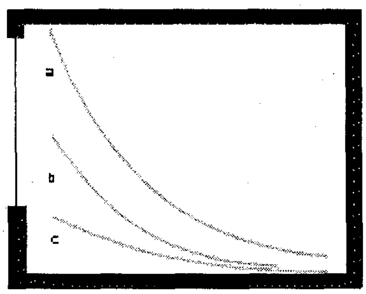


Figure 2. Daylight distribution in atrium-buildings[3]

Due to the glare close to the window, venetian blinds are often closed completely, therefore aggravating the lack of (day-) light. Artificial light is necessary, increasing the energy needed for air-conditioning.

At this point the daylight guidance systems come into play. They are distinguished between passive and active systems. Due to the exorbitant pricing of active systems this article concentrates on passive systems.

1. Venetian blinds are generally used as sun protection in front of or behind windows. With an especially coated surface and the proper angle towards the sun the venetian blind reflects the daylight into the depth of the room. To reduce glare these should be used only above eye-level. An even better result is achieved with flipped around blinds, the concave side to the top. A further development are the especially designed venetian blinds „okasolar“ integrated between the panes. This design determines the extent and in which direction the sunbeams are allowed to enter the room. Problems here are the heat between the panes because of multiple reflection and the individual design which is necessary to optimize the effects due to the latitudes which causes high production costs.

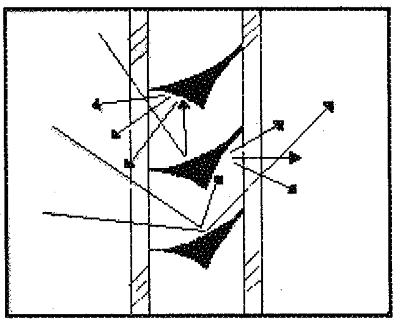


Figure 3. "Okasolar"

Inspired by "Okasolar" scientists tried to eliminate the negative aspects while retaining the positive ones. The result were semi-transparent plastic blinds (see Figure 10.3), also to be located between panes. The advantages are obvious. Due to its special design the beam-catching range is far wider than with „Okasolar"so it has not to be redesigned with changing the orientation of the facade or the latitude. Therefore the production quantity is much higher and the price significantly lower.

2. Perhaps the oldest existing system for passive light guidance is the light shelf, already realized 1812 at the Soane's museum in London. Limited by the technical means of his time, he used a flat mirror under the fanlight to guide the zenith-light into the room. In the meantime the system was improved by introducing the anadolic light shelf[4], marked by the concave form of the shelf.

It uses the technology of the diffuse light concentrator.

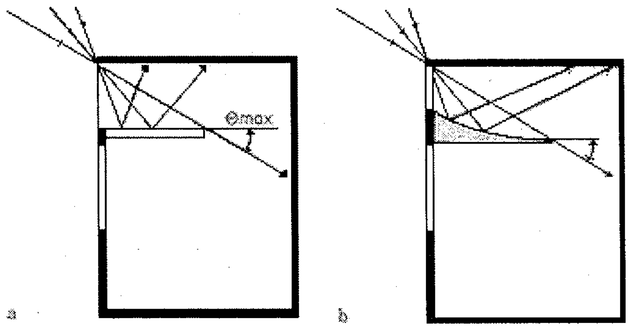
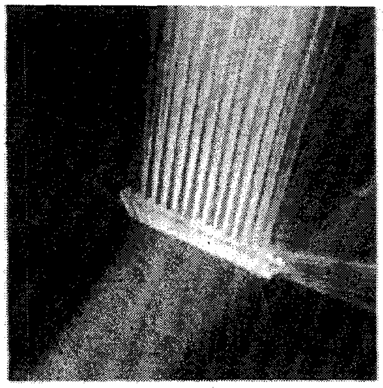


Figure 4.A. light shelf
Figure 4.B. Anadolic light shelf

3. Prism systems reflect direct daylight in individually adjustable angles, but allow diffuse light to penetrate the room. This technique was applied e.g. in the „Deutscher Bundestag" (German Parlament), Bonn.

4. Developed in cooperation between the architect Herzog and the light-engineer Bartenbach an other type of reflecting system was integrated at large scale in the „skin" of the design center in Linz, Austria[5]. With the help of very potent computers each „mirror system" panel is individually designed and produced. All of the very small „light channels" are multiply curved to achieve the demanded retro-reflection of the direct light. Produced by Siemens, they consist of a raster 15 mm high, wafer-thin coated with unalloyed aluminum. The „mirror system" is located between panes, for protection against pollution and as part of the insulation system. Therefore a solution for the problems of „glass-palaces" of the last century was finally realized.



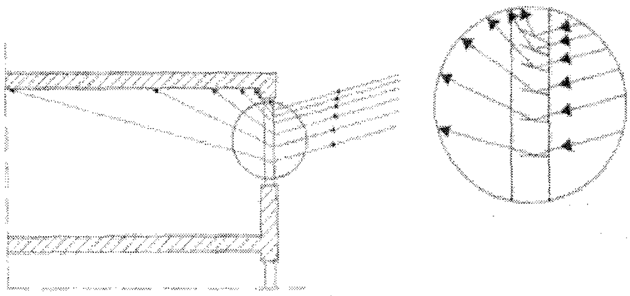


Figure 5. A. Prism for sun protection and zenith-light guidance
Figure 5.B. Individually Laser-cut panels

6. Laser-cut panels are Plexiglas panels with thin parallel laser cuts. They guide light through direct reflection without obstructing the sight. Due to a flexible production they allow design of an individual and optimized light guidance medium.

7. The Transparent Insulation Material (TIM) combines high light transmissivity with a very good insulation standard. Compared with conventional insulation glazing the transmission loss is reduced up to 70%, depending on material thickness. The typical honeycomb structure achieves direct transmission of 72%, compared with double glass direct transmission of 75%, which is still plenty of daylight for the building. Another positive effect is daylight guidance. This system is already integrated in various buildings with very positive results, but there is still plenty of R&D necessary to optimize the system. Due to the high production costs there are new production technologies necessary, also enabling the producer to adjust the angle of the tubes and therefore to perfect the light guidance abilities.

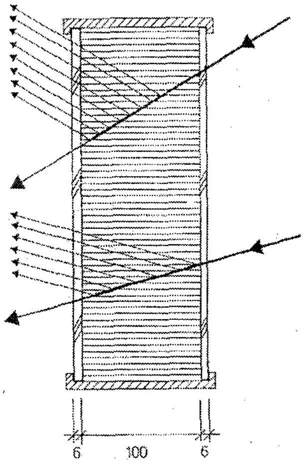


Figure 6. Special Light Opening improved with Transparent Insulation Material (TIM), Structure Vertical to the Glazing

6. The most interesting recent developments in the area of daylighting are the Holographic Optical Elements (HOE). Holograms are thin films between panes, using the physical effect of bending light, for example mirrors, prism, lenses etc. Due to its production technology an exactly calculated light distribution is possible.

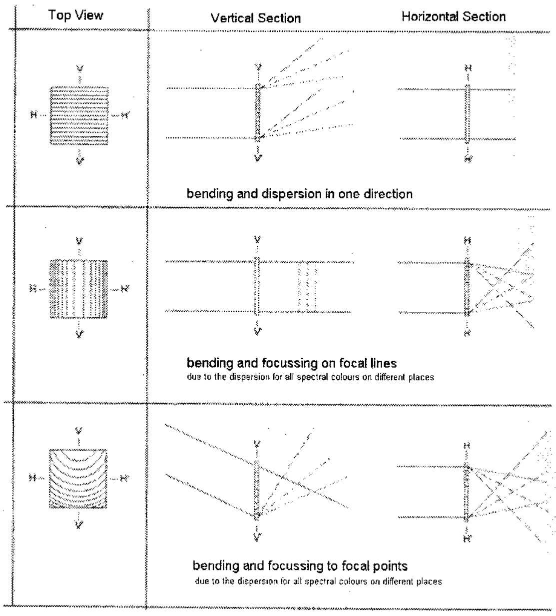
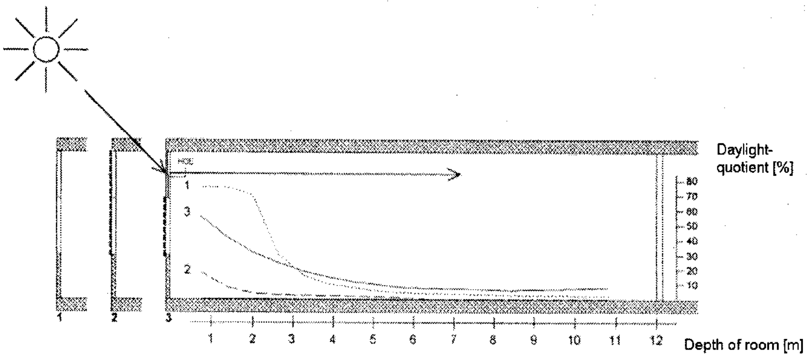


Figure 7. Holographic Optical Elements (HOE) - different possibilities[6]

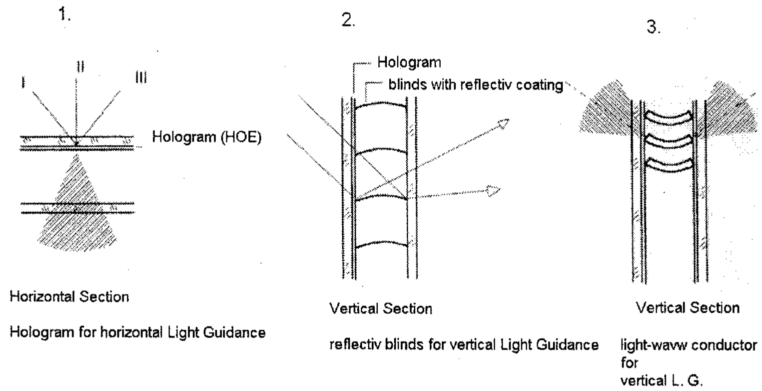


Facade 1: without sun-protection

Facade 2: conventional sun-protection

Facade 3: HOE in the fanlight, combined with conventional sun-protection

Figure 8. HOE - effects on daylight distribution[7]



1. HOE only
2. combination between HOE for horizontal Light Guidance and reflectiv adjustable blinds for vertical Light Guidance
3. combination between HOE (horizontal L.G.) and light-wave conductor (vertical L.G.)

Figure 9. HOE - Horizontal Light Guidance in combination with vertical „Light Guides“[8]

CONCLUSION

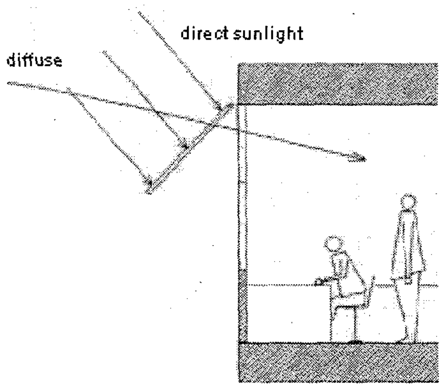


Figure 10. Innovative sun-protection [9]

New technologies offer new architectural options. While in many areas scientists developed mind-blowing improvements and innovations in very short cycles, e.g. in computer technology, architecture seemed to be grid-locked by tradition.

Today many options seem revolutionary: Zero-energy houses are possible even in poor climate conditions. Even energy-gains are obtained with active and passive solar-facades. The visual comfort can be increased significantly by Daylight Guidance Systems. Also architectural concepts might be affected, e.g. the division of windows into fanlight, especially equipped with 3-D Daylight Guidance Systems for an optimized light distribution without glare and a sun-protected window at eye-level for visual contact with the outside world.

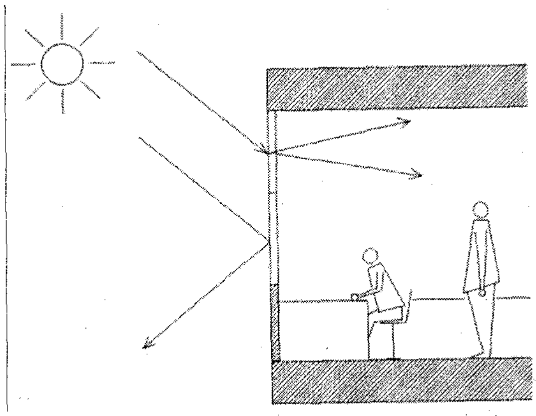


Figure 11. Combination between 3-D Light Guidance Systems and conventional sun-protection. [10]

While many of the innovations shown above were developed in the first half of the nineties, only today the first results of the technical conduct are available. The results are promising.

Now its up to architects and engineers to put the new options into practice.

1 Robbins, C., *Daylighting: Design and Analysis, Van Nostrand Reinhold Company, New York 1986*

2 Robbins, C., *Daylighting: Design and Analysis, Van Nostrand Reinhold Company, New York 1986*

3 Robbins, C., *Daylighting: Design and Analysis, Van Nostrand Reinhold Company, New York 1986*

4 *J.-O. Dalenbäck, Solar Heating with Seasonal Storage, Chalmers University of technology, Göteborg/Sweden, 1993*

5 *Herzog, Prof. Dr., „Glaspalast" mit neuartigem Paneel-System, DBZ p.1303 ff., München 1992*

6 *ILB, Fassaden der Zukunft-Mit der Sonne leben, p.181, Köln/Germany 1992*

7 *ILB, Fassaden der Zukunft-Mit der Sonne leben, p.183, Köln/Germany 1992*

8 *ILB, Fassaden der Zukunft-Mit der Sonne leben, p.183, Köln/Germany 1992*

9 *ILB, Fassaden der Zukunft-Mit der Sonne leben, p.183, Köln/Germany 1992*

10 *ILB, Fassaden der Zukunft - Mit der Sonne leben, p.183, Köln/Germany 1992*