The Peculiarities of Light as a Quality in Architecture

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ABSTRACT

This study focuses on the evolution of lighting, both natural and artificial, and its effects on space. The twentieth century is taken as a focal time period, which had witnessed great developments in lighting field that caused inevitable transformations on space and spatial concepts. The evolution of artificial light, the significant innovations in building technology, and the new requirements formed under the desires of a new society are examined in their relation to architectural context with respond to light and lighting in space.

The research includes cases from architectural and artistic world, and tries to investigate the role of light in the built environment. These cases are examined in a comparative way, considering the psychical and experiential characteristics of light in order to define its meaning for space.

The study consists of two parts. In the first part the process of the evolution of lighting in the twentieth century, its position today, and the social, cultural, and technological alterations are examined deterministically. The second part is a classification of cases under the guidance of some concepts, which defines the interaction of light and space.

ÖZ

Bu çalışma doğal ve yapay ışığın gelişim sürecine ve mekan üzerindeki etkilerine odaklanmaktadır. Mekan ve mekansal kavramların dönüşümünü beraberinde getiren, aydınlatma alanında yaşanan önemli gelişmelere tanık olan yirminci yüzyıl çalışmanın yöneldiği zaman dilimini oluşturmaktadır. Yapay aydınlatmanın gelişimi, yapı teknolojisi alanında ortaya çıkan önemli yenilikler, değişen toplumsal yapı sonucunda ortaya çıkan yeni mekansal gereksinimler mimari bir bağlam içerisinde; ışık ve mekan aydınlatması özelinde ele alınmıştır.

Araştırma mimari ve sanat çevrelerinden örnekler içermekte, ve ışığın yapılaşmış çevre üzerindeki rolünü ortaya çıkarmaya çalışmaktadır. Örnekler, ışığın fiziksel ve deneyimsel özelikleri göz önünde bulundurularak karşılaştırmalı bir yöntemle incelenmiş, ve ışığın mekansal deneyimde rolü ve anlamı sorgulanmıştır.

Çalışma iki bölümden oluşmaktadır. Birinci bölüm yirminci yüzyılda aydınlatma kavramının gelişim sürecini ve bugün vardığı noktayı; toplumsal, kültürel ve teknolojik değişmelere koşut olarak deterministik bir yaklaşım içerisinde ele almaktadır. İkinci bölümde, ışık ve mekan etkileşimine açıklık getiren bazı kavramlar ışığında mimari örnekler gruplandırılmış ve incelenmiştir.

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INTRODUCTION

1.1. DEFINITION OF THE PROBLEM

"...Light is the origin of all being...Light grants autonomy to things and, at the same time, prescribes their relationships...Light: the creator of relationships that constitute the world; yet although the origin of all being, it is by no means an immobile source. Light is, rather, tremulous motion - out of its ceaseless transformation, light continually reinvents the world..."

TADAO ANDO (Dalco 1996)

It is clear that "light" is one of the main concepts of architecture. Light and architecture have had close relationship since the beginning of time. For ages light has been used in various ways in order to define and form architecture. It has been mostly used literally to provide vision and to establish perceptual relationships between man and physical background and also as a vehicle for religious mysteries to set up the required rituals, which are necessary for devotion. Light has always been a genius tool for space design.

The invention of electricity at the end of the 19th century initiated a new era for light – space relationship. Electric lighting became an important way to illuminate space and, with the development of technology, new materials and lighting systems, designers had an unlimited recourse from which to choose. And the development of light sources and lighting techniques made great changes in spatial design and in the meaning of the term "space quality". This process of technological development led architecture to a new era of new concepts today. Laser technology, holography, projectors, light as art techniques, illusions, and mediarchitecture are all amazing innovations which force designers to rethink and rewrite the spatial concept and its principles and led to an stunning, surprising and dynamic architecture.

During the 20th century, daylighting in architecture has also entered into a transformation period. The industrial revolution and the modern movement brought with it new spatial requirements and a new understanding of articulating space that caused a shift from symbolic use of light to a more literal use of light in architecture, which means illumination.

The age of industrialization, new building techniques with the new materials for building - glass, the thin steel frame, and so forth - and the philosophy of the society of this modern age changed the way architects used to express their time through architecture. Glass facades within the steel frames allowed as much light as possible to penetrate the interior space. Light was used to express the architectural philosophy of the time of new technologies and materials with a rejection of history. Shadows were disappeared under a belief, came with the modern movement, that modern world must be illuminated.

Figure 1- 1 Chicago at night (Thomsen 1994 p169)

Figure 1- 2 Shanghai (*FOL* **9**)

Today it is possible to see the reflections of the modern dogma and its philosophy, which is supported and became stronger with the increasing technology. The facades turned into filigrant pellicles and the ideal way without barriers into interiors. Technology allows light to reach the very depths of a building without a direct connection to the outside. It is possible to render, texture and color the beam due to the

lots of equipment offered by technological developments. Cities appear at night as pieces of night architecture of light and color. Artificial light has become undeniably one of the basic needs in human life. This was contested by some groups, which claim that light causes visual pollution and disability for some rituals, such as being able to see the sky at night. A living area (called protection area against artificial light) was planned and recently constructed in Toronto by Canadian Government, where no artificial light was used (Bilim Çocuk 2000 p4).

Today other intentions in light use, such as the mystical and poetic use, also exist. An understanding of creating spaces and spatial effects with light and shadow in a sensitive manner, with respect to the basic perceptive and psychological human needs and which has only been seen in religious architecture. The aim seems to define the spatial relations with light in that kind of a manner by enhancing the importance of experiencing architecture.

It is clear that illuminating a space is not the responsibility only of an architect. Lighting has been (or must be) a cooperation of several disciplines since the middle of the first half of the century. Light engineering that made the agenda in the twenties with the development of lighting industry has brought with it its own rules and principles, which stand on quantitative basics and which are not much related to required concepts such as perceptual psychology. It is not possible to define a good illuminated space with only quantitative terms. Since architecture is an art of experiencing, other concepts, which are deeply connected to the human spirit, must also be taken into consideration. Lighting is a subject that requires knowledge in engineering, psychology and design.

1.2. DEFINITION OF THE STUDY

Space and its concepts have been changing. Lighting has also been in a transition process since ages. One of the reasons for this changing in space and light use is the mutual influence between light and space. This study is aimed at revealing that the invention of electricity and the use of artificial light in architecture has made this influence stronger, and has given it an impetus; that light has a dominant character in architectural space design and changing space concepts through the century. It is also

aimed at analyzing of the fragmented use of light in the late 20th century, showing the transitional process with the technological, social and cultural turning points.

As mentioned before, light and space are in a relationship in a way that light defines and sets up the required rituals. What is the role of light in setting up the required rituals? What are the main concepts or the in-between parts in the light and space relationship? The questions here are important, since they form the basis of the body of the thesis. It is aimed at finding answers to these questions.

1.3. METHODOLOGY

This study will focus on the 20th century, which witnessed an important transitional process based mainly on the invention of electricity and the use of artificial light in architecture, and the development in lighting technologies, and other industries. That influence still remains today and it seems it will remain and grow stronger in the future. This limitation does not mean that the historical background of light and lighting is not a part of the research. The historical references have been taken into consideration for some thresholds in the twentieth century, which seem to have an effective role especially in the last decade of it.

Architectural and artistic cases have been considered as important tools in order to show the interaction of light and space. In this respect lots of buildings and artworks, related to light and to technology derived from light, are examined. The results were classified under the guidance of some concepts, which forms the answers to the questions above. The examples are deliberately chosen from the western culture because it is in the West, where artificial light was born, and where the transitional process of space concepts can be best observed. Some of them were visited on site, experienced in the light of the ideas related to light and its effects on space and spatial relations. The rest are examined through books and periodicals. Photographs, and two and three-dimensional drawings were the effective tools used in order to reach an analysis.

The research includes two chapters. The first part deals with the long process of lighting design and its components, which were set up during the 20th century. The

adventure that had begun with the invention of the light bulb, which is a turning point for architecture, and led to laser technology, holography, media architecture, and intelligent architecture today, is examined with its technical ingredients and effects on architectural space. Besides the development of light technology, the social, cultural, and economic transformations in the society, such as the Modern Movement, and World War II, which are connected to or have an effective role on spatial creations, also on light use, have been taken into consideration. Ideology and technology have enjodey a symbiotic and reciprocal relationship. However the use of technology can, and has, often deviated from the original ideology. These are also a part of the content of the first part. The last decade of 20th century has become a fragmented character through the technological developments and the changing understanding of articulating space, as it was mentioned before. On one side there are the experimental works as a result of a new understanding of space, which is called mediarchitecture. On the other side it is possible to see a modernist kind of articulating light, which is made stronger with its technological background. On another side one witnesses the spiritual use of light, which is based on historical references and local traditions. These varying understandings, and the transitional process that led to these kinds of articulating space, are examined in the first part of this research.

The second part seeks answers to the questions above connected to light and spatial relations. Several architectural and artistic works are grouped under the guidance of some concepts derived from the effects of light in space. The second part begins with a sub-part that deals with perceptual psychology, which is really important as a basic knowledge in understanding and explaining the illuminated space and the crucial relation between illuminated spaces. This part focuses on the importance of light in spatial perception. It is well known that a single space can be perceived in varying moods as the lighting conditions change. So it is possible to perceptually create intended situations in a space through light. A change in perception means a restructuring of space that can also affect the way that it is experienced.

CHAPTER 2

A GENERAL OVERVIEW ON THE EVOLUTION OF LIGHTING

2.1. INVENTION OF THE ELECTRICITY

It is obvious that the inventions of the electricity and incandescent light bulb are the most important innovations in lighting design. It is possible to divide the history of lighting in two parts as "before electricity" and "after electricity". Electricity had great impacts on the architectural lighting and on changing space concept, which is still in a transformation period today. It has begun a new era at the end of 19th century, with its own concepts and language; which has led to an illuminated world of technology.

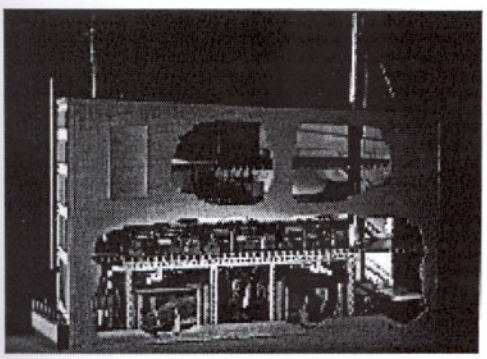


Figure 2- 1 Edison Station (http://www.escape.ca/~williams/history.htm)

Before electricity, the best source for illumination was gas. However it was far from being convenient. It was dirty, unhealthy, uncomfortable and dangerous. Moreover, its main disadvantage was that it could not serve as a source of power for the appliances we use today such as computers, refrigerators, wash machines and so forth. In 1876, at the Philadelphia Centennial Exhibition, a few arc lights were shown. They were very bright and suitable for only large open spaces. Three years later, in 1879, Thomas Edison announced his invention of the incandescent light bulb and a new era of lighting history has begun.[1] However, Thomas Edison is not the inventor of the idea of

[1] For further readings on the complex circumstances behind Edison's invention: Invention of the light bulb, http://www.ushistory.net/toc/electricity.html and J. L. Nuckolls, *Interior Lighting for Environmental Designers*, (John Wiley & Sons, New York, 1983)

the incandescent light bulb. He just was the first to make it practical. The inventor of the idea is Sir Joseph W. Swan from England. In 1882, Thomas Edison had opened a central station on Pearl Street in Manhattan and was supplying electricity to a one-mile square section of New York. It was now possible for designers to use artificial light in buildings. The Auditorium Building in Chicago (1887-90), designed by Louis Sullivan and Dankmar Adler worth mentioning, because its here that electric light was used for the first time as a design feature. Anna Massey, in his book, says:

"...The impressive 'golden arches' which span the theatre-interior are decorated in an eclectic style, with luscious gilded plant forms picked out with electric light bulbs..." (Massey 1990 p49)

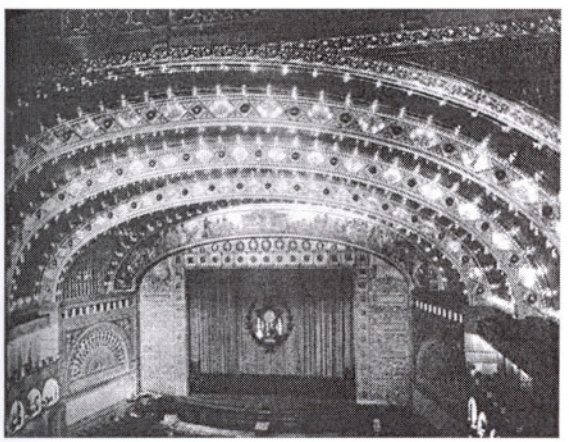
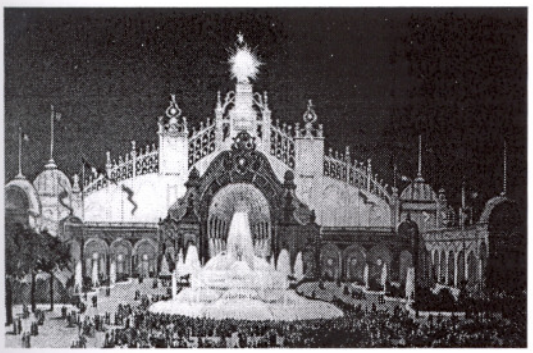


Figure 2- 2 Scene of the Auditorium Building (Massey 1990 p49)

Figure 2- 3 The Edison Tower of Light in the Columbian- Chicago Exposition (http://www.bc.edu/bc_org/avp/cas/fnart/fa267/1893fair.html)

The Expositions were and still are the main places, where the new technologies as well as the lighting industry meet the public. The Columbian- Chicago Exposition in 1893 pointed different ways of using artificial light in buildings. George Westinghouse was the lighting manager of the Exposition. The main building of the Exposition was "The Edison Tower of Light", which was twenty-five meters high and was wrapped with mirrors and incandescent light bulbs, which flashed in changing patterns of color. A replica of an incandescent light bulb was placed to the top, which is constructed from thirty thousand prisms. Outside, all the waterways and buildings were lit with incandescent light bulbs. The bulbs in different colors, activated in the night, were creating a stunning view in an avant-garde manner for that time (Marvin 1998 p171-172).



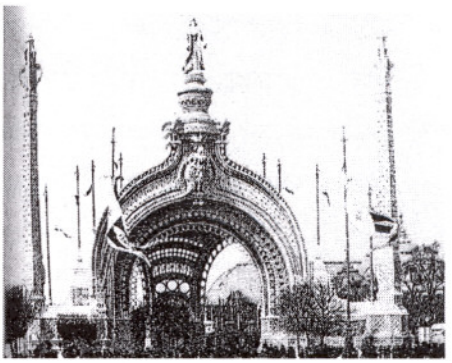


Figure 2- 4 Palace of Electricity (A+U 307)

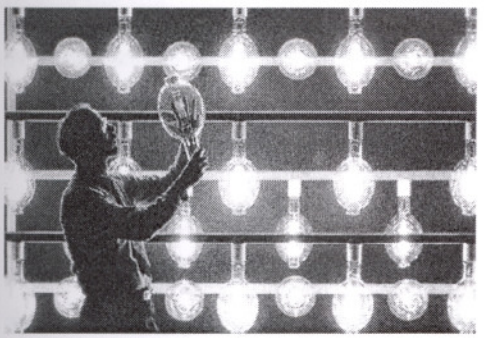
Figure 2- 5 Porticus (A+U 307)

The Porticus (Rene Binet) and Palace of Electricity buildings, built for the Paris World Exposition of 1900, were among the early examples of buildings, that were built to see how artificial light and space can stick together by creating marvelous light effects. Christian W. Thomsen wrote:

" In daylight they both represented that exotic fairy-tale eclecticism this expo became notorious for; in the evening they both revealed their second nature as pieces of light architecture... Rene Binet's Porticus, covered by thousands of blue and green light bulbs... seemed to some journalist visitors like a bizarre ethnological absurdity and monstrosity. As soon as it grew dark and the light bulbs began to shine, Porticus changed into a glimmering body of light as if it were emanating from precious stones or from the colored glaze of exotic lamps. The Palace of Electricity at night, presented itself like a jewel, glowing and radiating like an enchanted castle. Differing from Binet's Porticus, which always shimmered in the same colors, a lively continuously changing, almost breathing light event happened in the Palais... But the real fascination originated from the buildings own interior and exterior lighting. The façade was covered with thousands of light bulbs, which could be activated from a central desk. The light façade could gleam in one single color: red, blue, orange, amber. It could also be dissolved into complementary light-light dots. The buildings immense impact was based upon the fact that, in this case, architecture was not illuminated from the outside but became in itself the source of light and color". (Thomsen 1996a p105-106)

As it was mentioned before a new era for architecture had begun. Cities became a new character through the rising use of light. Architects were excited before the new technology, that made lots of things possible and they were willing to learn and use the wide capabilities of lighting techniques in their experimental architectural works.

2.1.1. THE ELECTRIC LAMP



Through most of human history, activities requiring good light were reserved for daylight hours. This was not only because of the poor quality of the avaible light sources but also because of the expense. Oil lamps and candles, the main sources of light were so expensive that even the rich people did not use more than a couple of hours. During the eighteenth and early nineteenth century, the whaling industry existed mainly for supplying oil and wax for lighting needs. The importance of whaling declined in the middle of the nineteenth century when kerosene, extracted from petroleum, became a source for lighting needs. Coal gas was an important light source in the nineteenth century. It was accepted both at outdoors and indoors. The light that is produced, however, was not much better than from the oil lamps, until the invention of the mineral-impregnated mantle in the 1880's.[2] Since gas lighting, even with the mantle, caused high levels of heat and air pollution, it was easily replaced by electric lighting at the beginning of the twentieth century.

[2] "...The gas mantle converted the gas flame to a spectrum more closely approximating "white" light, and this principle has changed little up to present day, although higher efficiencies have been obtained..." (Philips 1969 p72)

INCANDESCENT LAMPS

The principle depends on an electric current passing through a wire. The wire, becoming hot, produces light. Carbon wire was used first by incandescent lamps. Modern incandescent sources use tungsten wire since 1907, and efficiencies have been greatly increased with this method. The efficiency of the tungsten lamp is limited by the temperature of the tungsten. Both the light output and the life of the lamp are affected by the temperature of the filament. Increases in temperature improve the light output, but reduce the life. The average life of an incandescent lamp is about 1000 hours. The range of incandescent lamps is extensive, and new lamps are being developed for extra needs still today.[3]

DISCHARGE LAMPS

A major improvement in electric lighting came first with the development of fluorescent lamp and then with the development of high-intensity discharge lamps. All of these lamps are based on a principle known as discharge, where an ionized gas rather than a solid filament emits light. Discharge lamps consist of an envelope containing two electrodes, the light producing element and a gas. Electricity flows from one electrode to another through the gas. The element is usually on the walls of the tube. Light is produced along the entire length of the arc. The nature of the element determines the characteristics of the lamp. Mostly used elements are mercury, sodium and neon.[4]

Fluorescent lamp was first introduced at the two world's fairs in 1939 and 1940. This introduction was a great revolution for lighting field, since fluorescent lamp produced more light at a lower cost than the incandescent lamp. The fluorescent lamp has also other important advantages. It has a low surface brightness, its life is longer

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[3] For further readings on the incandescent light sources:
D. Philips, *Lighting in Architectural Design*, (Mc Graw Hill Company, New York, 1969) and
Norbert Lechner, *Heating, Cooling, Lighting- Design Methods for Architects*, (John Wiley & Sons,New York, 1991)

[4] For further readings on the discharge lamps:

D. Philips, *Lighting in Architectural Design*, (Mc Graw Hill Company, New York, 1969)

than the incandescent lamp, it can produce shadowless lighting, and it does not produce much heat as the incandescent lamp does.

Table 2- 1 Discharge Lamps (Philips 1969 p79)

Description	Wattage range	Life, hours	Types and special features
Mercury clear	100–3,000	6,000–9,000	Tubular or bulb shape depending on size; 125-watt size only can have inside frosted
Mercury reflector	100–1,000	6,000–9,000	Aluminium or silvered reflectors
White phosphor-coated mercury	175–1,000	6,000–9,000	
Color-improved phosphor-coated mercury	100–1,000	6,000–9,000	Better color than "white" mercury lamps
Semireflector mercury (½ phosphor-coated)	700–1,000	6,000–9,000	
RS sunlamp	275	1,000	Combines 100-watt mercury tube with 175-watt tungsten filament in one envelope
Caution yellow mercury	400	6,000	
Sodium	45–280	4,000	

Table 2- 2 Color Data on Fluorescent Lamps (Philips 1969 p82)

Color Data on Fluorescent Lamps

Lamp	Average efficiency 4-ft 40-watt T.12, lumens per watt	European or alternative term	Spectral distribution (1) Far violet 0.38–0.42	(2) Violet 0.42–0.44	(3) Blue 0.44–0.46	(4) Blue green 0.46–0.51	(5) Green 0.51–0.56	(6) Yellow 0.56–0.61	(7) Light red 0.61–0.66	(8) Dark red 0.66–0.76	Uses
Daylight	51	Color matching northlight 6500°K	0.17	0.42	0.56	8.1	45.8	39.0	8.0	0.22	Used where color matching is important; equivalent to a north sky; not in general use because of high proportion of blue
Cool white	58	Daylight 4500°K	0.01	0.30	0.30	5.0	41.0	50.0	7.0	0.13	Combines high efficiency with good color rendering; used in factories, offices, schools; rather cold in appearance
Deluxe cool white	42	Natural 4200°K	0.01	0.30	0.30	5.0	39.0	51.0	8.5	0.2	Less efficient than daylight by 20 per cent; has better color rendering properties in the long wavelengths; used in stores and some factories where color is important
White	59	White 3500°K	0.008	0.25	0.20	3.0	36.0	55.5	8.4	0.13	Highest-efficiency lamp; often used in factories and offices
Warm white	59	Warm white 2900°K	0.005	0.22	0.10	1.7	33.0	59.6	8.9	0.15	High-efficiency lamp; only moderate color rendering; poor in reds—emphasizes yellows and yellow greens; used in offices
Deluxe warm white	42	Home-line	0.008	0.27	0.05	2.3	36.7	44.2	16.0	0.48	Least efficient lamp; closest approximation to tungsten filament color rendering; suitable for homes, restaurants, hotels
	5-ft 80-watt initial efficiency										
Red	3½						1.0	20.5	73.1	5.4	Primary colored lamps; red is of very low efficiency, green very high; can be placed in special dimming equipment for color mixture
Blue	19		0.13	1.5	2.3	17.8	57.9	18.6	1.76	0.02	
Green	53		0.005	0.17	0.03	5.2	79.0	13.9	0.65	0.02	
	30	Yellow				0.1	22.1	63.5	14.0	0.43	
Tungsten filament 2800°K	12		0.006	0.06	0.25	5.5	33.5	42.7	16.6	1.54	

SOURCE: *Fluorescent Tube Guide*, Dec. 1957.

NEON AND COLD CATHODE LAMPS

Neon and cold cathode lamps are close to fluorescent lamps in principle. Besides mercury vapor, these lamps use other gases such as neon, which gives off red light, and argon, which gives off blue light. By using different combinations of gases, colored glass, and phosphors, a large variety of colored light sources are possible.

The main advantage of these lamps is that they can be made to almost any desired shape. Neon lamps are wired into place; cold cathode lamps usually fit into sockets. Both lamp types have long lives about 25000 hours. Neon and cold cathode lamps are not the alternative for fluorescent lamps for general lighting because of their lower efficiency and light output. A cold cathode lamp's light output is half and the neon lamp's light output is a sixth of a fluorescent lamp of equal length. Neon and cold cathode lamps are appropriate for applications that require special colors and special shapes. They are most suitable when the shape of the lamp is closely integrated with the form of architecture, when the shape of the lamp is a design element.

HIGH-INTENSITY DISCHARGE LAMPS

The high-intensity discharge lamps are very efficient light sources that are in size and shape more likely incandescent lamps. In all the high-intensity discharge lamps, light is emitted from a small arc tube that is inside a protective outer bulb. When light is desired, phosphors are added to the inside of the outer bulb.[5] There are three types of high-intensity discharge lamps:

. Mercury Lamps[6]

. Metal Halide Lamps[7]

. High-Pressure Sodium Lamps[8]

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5 For further readings on high- intensity discharge lamps:
Norbert Lechner, *Heating, Cooling, Lighting- Design Methods for Architects*, (John Wiley & Sons,New York, 1991)

[6] They have poor color rendition. They produce a very cool light, rich in blue and green, however they are preferred because of their long life (16 to 24 thousand hours) and low first cost.

[7] Metal Halide Lamps are appropriate for stores, offices, schools and outdoors where colour rendition is important. They are one of the best sources of light today because of their high efficacy, long life (10-20 thousand hours), very good color rendition and small size for optical control.

2.2. THE NEW CONCEPTS WITHIN THE MODERN MOVEMENT

The invention of the electricity, the incandescent light bulb and the technological way of artificial lighting are not the only facts, which had brought architecture to a new era. It was the Industrial Revolution also, that brought the rapid changes. Those technological and social changes caused new requirements and solutions for architectural lighting. The technological improvements were exciting. New materials and new construction techniques offered great architectural opportunities to architects and designers. New techniques in glass production made it cheaper also avaible in large sizes in good optical quality. The improvements in structure were greater. The thin steel frames, trusses, columns and also the reinforced concrete made as much light as possible to enter the interior space. A whole new architecture of light was born.

Crystal Palace, built in London in 1851, designed by Joseph Paxton is a good example for the new understanding of design with the new technology. This greenhouse was a sign for the coming building style and space concept, supported with the increasing technology, with its structural innovations and total transparency.

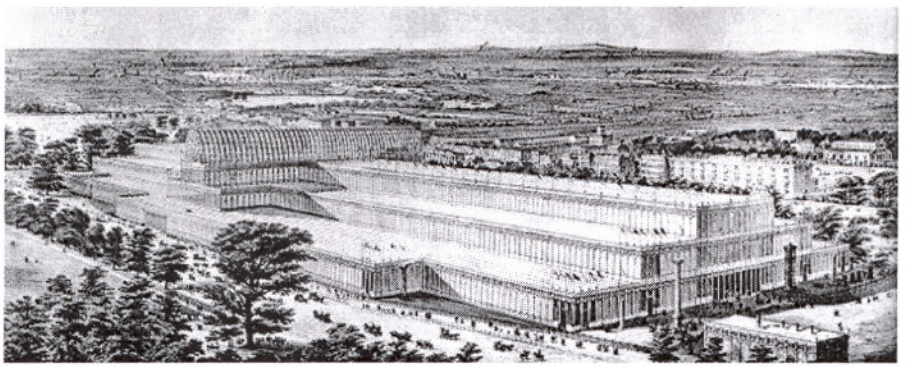

Figure 2- 6 Crystal Palace (http://soa.syr.edu/faculty/bcoleman/ARC523/images/crystalpalace)

The Industrial Revolution had another impact on architecture. It caused a need for large buildings to house both the industry itself and the commerce that grew from it (C.E.C 1993 p10). The rural population flooded into the cities to work in factories, workshops and so forth. That caused a greater need for light, because most of the population was working indoors. The invention of the incandescent light bulb seemed to

[8] They are appropriate for outdoor applications such as street lighting, parking areas,

provide the need for illumination, which was a necessity for indoors, despite of being expensive. A lumen of electric light in 1880 cost six hundred times more than today. That forced designers to create spaces, illuminated by daylight, which enters mostly from the top of the building, with the help of increasing technology and a style of toplighting developed in industrial and commercial buildings. The requirement for daylighting was a formgiver to both plan and section. The Larkin Building in Buffalo-New York, designed by Frank Lloyd Wright in 1904 is an example of the central atrium for office use, illuminated with daylight enters through the transparent opening placed on the roof.

Figure 2- 7 Larkin Building (Massey 1990 p78)

Not only the industrial and commercial workplaces, the whole architecture gained a new character. Architecture became lighter and illuminated; the facades were no longer the barriers for daylight. Tassel House, designed by Victor Horta is another example. The glazed roof over the living room, carried by iron columns, provides a brightly lit interior. At his house in Rue Americaine in Ixelles, Victor Horta designed a skylight, which illuminates a centrally placed staircase of white Carnara marble. The yellow and white skylight has huge mirrors at either side that give an effect of infinite space (Massey 1990 p37). Charles Rennie Mackintosh was another architect who created bright spaces in regard to new technology. Anne Massey said in her book about Mackintosh's house in Mains Street, Glaskow:

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sport areas and floodlighting, where high efficacy is needed.

"...He created an equally dramatic effect with white for the wall and floor-coverings as well as for the majority of the furniture. He created a light and spacious living area, diffusing natural daylight with muslin stretched over the windows. All furniture are white- enamel painted to ensure that no detail of joints on grain of the wood detracted from the sculptural effect. The furniture was also carefully placed revealing Mackintosh's dept to Japanese house- design...". (Massey 1990 p53)

Figure 2- 8 Horta House (Borsi and Portoghesi 1991 p228)

Figure 2- 9 Interior of the House in Mains street (Massey 1990 p54)

Developments in technology, the changing space concepts with the Modern Movement resulted in a literal light use, which means illumination. Lighting had gradually lost its former meanings, its poetic, symbolic, and mythic use, as in Gothic and Baroque periods. The aim was to design buildings, which was mostly illuminated. Shadows were disappeared against large openings arise from structural abilities. The Glass Pavilion of Bruno Taut, built for the Werkbund Exhibition in 1914, and the Bauhaus Building at Dessau, built in 1926 are examples, which define the relationship of modern architecture with light. It is not possible to see the emotional use of natural light till the late modern period.

Figure 2- 10 Bauhaus, Dessau

A spiritual use of light can be seen in the later works of Le Corbusier. These were religious projects, and one can say that there is nothing unusual to take light into consideration in a religious atmosphere, however the Monastery in La Tourette and the Chapel in Ronchamp are examples, in which light plays a role more than in any religious buildings. They seem as they have been built for light and its effects. In addition to this, Le Corbusier deserves special attention for his understanding of light use in his previous projects. For example the brise- soleils in Cite de Refuge in Paris, built in 1933, and in the Assembly Building in Chandigarh are elements, designed for lighting comfort. James Brogan wrote about Le Corbusier's religious masterpiece:

"... His church at La Tourette, with its chapels consisting of immensely powerfull light scoops and light tubes, and made simply of concrete, color and light, transformed a place of worship into an 'other- worldly' environment. In his chapel at Ronchamp, light was used not only as an integral part of the structure, as historical allusion (to the stained glass of the Gothic Cathedrals) but as an uplifting and worshipfull environment witnessed in the individual chapels filled with colored light."
(Brogan 1997 p7)

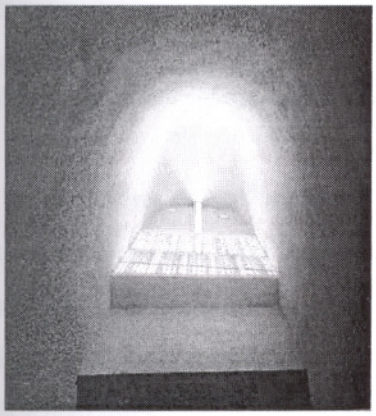


Figure 2- 11 Light shaft in Notre Dame du Haut, Ronchamp (http://www.greatbuildings.com/cgi-bin/glk?http://www.demel.net/fs-ronchamp.html)

Figure 2- 12 La Tourette Monastery (http://www.greatbuildings.com/cgi-bin/gbi.cgi/Convent_of_La_Tourette.html/cid_2463890.gbi)

Louis Kahn was another architect with his poetic light use in the late modern period. Kahn used light as the dominant characteristic in his works. He utilized light in order to illuminate his pure forms and materials. His work was based on light, using it as a tool in order to create spaces, where spirituality and a mystical atmosphere can be experienced.

Alvar Aalto also should be mentioned here, with his ability in using light as a creative tool in architecture. The dematerializing, defining and differentiating effects of light is present almost in all Aalto's interior. Especially the Viipuri Library in Russia, the Mt. Angel Library in Oregon, and the Church in Vuoksenniska, Imatra, Finland are examples, which were formed for light and its effects.

Figure 2- 13 Mt. Angel Library
(http://www.greatbuildings.com/cgibin/gbi.cgi/Mount_Angel_Library.html)

During the 20th century, a new approach to designing with light was developed, an approach that was related far more intensely to architectural lighting and its requirements. Joachim Teichmüller, founder of the Institute for Lighting Technology in Karlsruhe, is a name that should be mentioned here. Teichmüller defined the term "Lichtarchitektur"[9] as architecture that conceives light as a building material and incorporates it purposefully into the over-all architectural design. He also pointed out – and he was the first to do so – that, with regard to architectural lighting, artificial light can surpass daylight, if it is applied purposefully and in a differentiated way. (Ganslandt and Hoffmann 1992 p23)

[9] This term will be used throughout the thesis in order to define that kind of attitude in architectural design, as described above. It is translated as Lightarchitecture into English.

Lighting engineers still tended to practice a quantitative lighting philosophy, that is not always efficient to define a satisfactory lit space. It was the architects who were now beginning to develop new concepts for architectural lighting. Daylight had always been the defining agent. With the development of more efficient artificial light sources, the knowledge that has been gained of daylight technology was now joined to artificial light. Light was no longer only an effect coming from outside into the building. It could light interior spaces, and now even light from inside outwards. Le Corbusier described architecture as the "correct and magnificent play of masses brought together in light" and today this is no longer applied only to sunlight, but also included the artificially lit spaces.

This new understanding of light had special significance for extensively glazed facades, which were not only openings to let the daylight penetrate into the building, but gave the architecture a new appearance at night through artificial light. The glass skyscrapers such as the Seagram Building of Mies Van der Rohe in New York were are avant-garde examples for the new understanding of light.

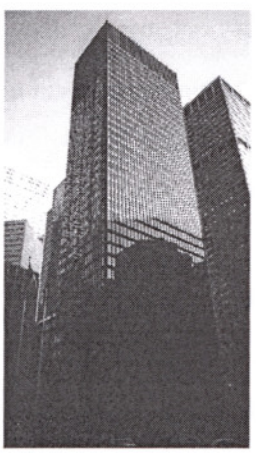


Figure 2- 14 Seagram Building, New York

In order to develop more extensive architectural lighting concepts, designers had to consider the third factor beside architecture and light: Perceptual psychology. In Handbook of Lighting Designed it is mentioned:

"In contrast to physiological research, it was simply a question of the quantitative limiting values for the perception of abstract "visual tasks". Man as a perceiving being was the focus of the research, the question of how reality perceived is

reconstructed in the process of seeing. These investigations soon led to evidence that perception was not purely a process of reproducing images, not a photographing of our environment. Innumerable optical phenomena proved that perception involves a complex interpretation of surrounding stimuli, that eye and brain constructed rather than reproduced an image of the world around us." (Ganslandt and Hoffmann 1992 p24)

Under the light of these theorical developments lighting acquired a totally new meaning. Light was no longer just a physical quantity that provided sufficient illumination; it became a decisive factor in human perception. Lighting was not only there to make things and spaces around us visible, but also in order to determine the priority and the way, objects in our visual environment were seen, to determine the life in space.

2.2.1. CRYSTALLINE ARCHITECTURE

The Modern Movement brought with it new ideals, which based on the technological opportunities. One of its ideals was that modern world must be illuminated. Paul Scheerbart said in his Glassarchitectur, published in 1914:

" ...If we want our culture to rise to a higher level, we are obliged, for better or for worse, to change our architecture. And this only becomes possible if we take away the closed character from the rooms in which we live. We can only do that by introducing glass architecture, which lets in the light of the sun, the moon, and the stars, not merely through a few windows, but through every possible wall, which will be entirely made of glass- of colored glass..." (Conrads 1971 p19). And in der Architecten Kongress he went on: *"...We want no walls that completely exclude the outside world- like the old masonary walls. We want brilliantly colorful, transparent, double glass walls– everywhere, whenever they can conceivably be put- especially in government buildings. We want walls that do not shut us out from the great, infinite universe. Boundlessness is the greatness supreme. Let us never forget it. And boundless is the endless space of the cosmos. Nevermore shall we allow ourselves to be separated from it. This is why we want glass architecture to vanquish all the rest..."* (Thomsen 1994 p82)

Scheerbart was suggesting an architecture formed of weightless colored glass columns, walls, and floors. These radical approaches of Scheerbart were followed by the works of contemporary architects of that time. Bruno Taut dedicated his Glass Pavilion in 1914, designed for Werkbund Exhibition in Cologne to Paul Scheerbart. The large panes of glass of which the pavilion was constructed had effectively introduced a transparency and brightness which was previously unseen.

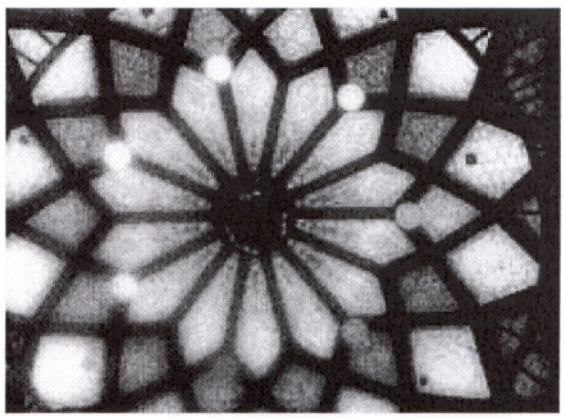


Figure 2- 15 Glass Pavillion, Bruno Taut

Figure 2- 16 Glass panes of the Pavillion

Bruno Taut was in an informal gathering, called "Glaeserne Kette- The Crystal Chain" with other architects and artists such as Wenzel August Hablik, Hans Scharoun, Wassili Luckhardt, Max Taut, Hans Hansen, Wilhelm Brückmann, Paul Gösch, Hermann Finsterlin, Walter Gropius and Carl Krayl. The aim of this informal gathering was to exchange written and graphical ideas in order to define and form the new architecture of the new century, which is in a transformation period since Sir Joseph Paxton's Crystal Palace of 1851. They were bewildered before the architectural potential of glass and designed some projects and sketches that way. They were dreaming of utopic cities of glass. Bruno Taut wrote a book in 1918 with the title "Alpine Architecture", which included thirty drawings, created under his ideals for glass architecture. Christian W. Thomsen discussed the drawings in this book:

" *...Here glass was no longer merely a thin, water- clear skin that helped dematerialize architecture or integrate interior and exterior; it was crystalline, cut like gems, shone with noble brilliance, and was charged with all the symbolism of a*

romantic medievalism... Crystal was thought to have powers of healing and regeneration, and it also stood for innocence, purity, peace of mind, closeness to nature, and the ability to start one's life anew. In this vein, the Expressionists adopted the reflections and refractions of crystal as embodying the optimism and dynamics of a new architecture". (Thomsen 1994 p83)

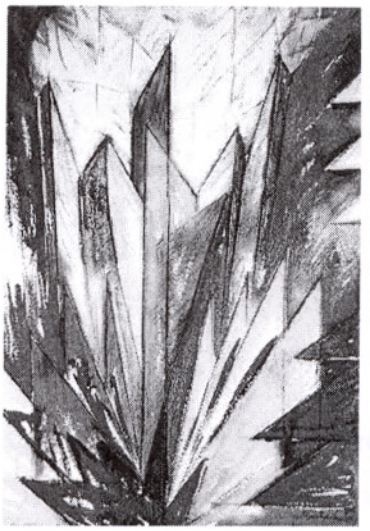
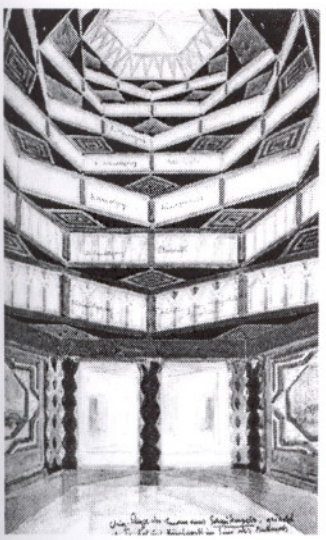


Figure 2- 17 Wenzel August Hablik, Cathedral Interior:Festival Hall (Thomsen 1994 p80)

Figure 2- 18 Hans Scharoun ,Principles of Architecture, ca. 1919 (Thomsen 1994 p81)



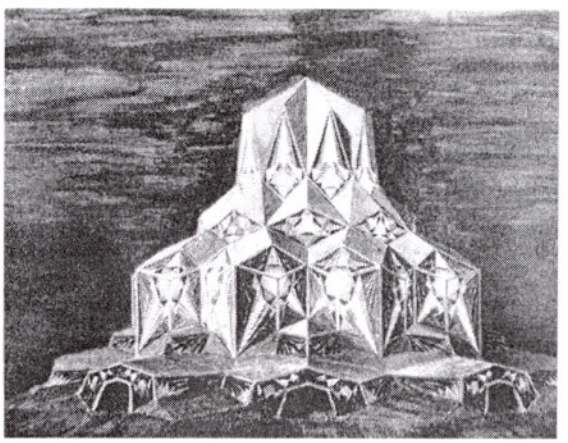


Figure 2- 19 Wenzel August Hablik, original sketch of the interior of an exhibition palace, 1914 (Thomsen 1994 p83)

Figure 2- 20 Wassili Luckhardt, 1919 (Thomsen 1994 p85)

romantic medievalism... Crystal was thought to have powers of healing and regeneration, and it also stood for innocence, purity, peace of mind, closeness to nature, and the ability to start one's life anew. In this vein, the Expressionists adopted the reflections and refractions of crystal as embodying the optimism and dynamics of a new architecture". (Thomsen 1994 p83)

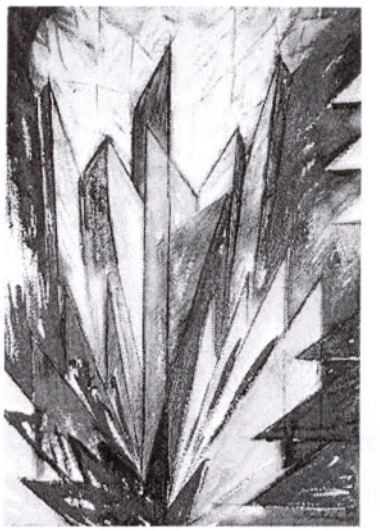


Figure 2- 17 Wenzel August Hablik, Cathedral Interior:Festival Hall (Thomsen 1994 p80)

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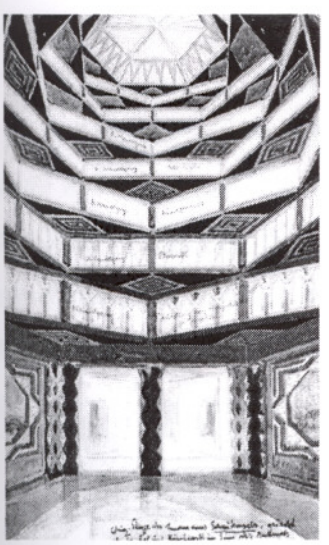

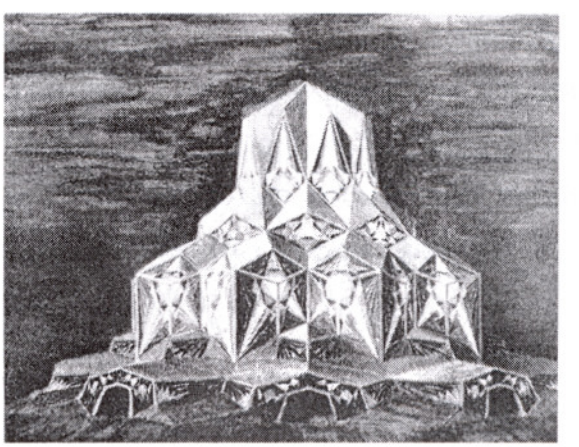

Figure 2- 19 Wenzel August Hablik, original sketch of the interior of an exhibition palace, 1914 (Thomsen 1994 p83)

Figure 2- 20 Wassili Luckhardt, 1919 (Thomsen 1994 p85)

It is interesting to see some effects of Crystalline Architecture in another kind of profession such as cinema. The set designs and the general aura of Metropolis, directed by Fritz Lang in 1926 derive from the principles of Crystalline Architecture.

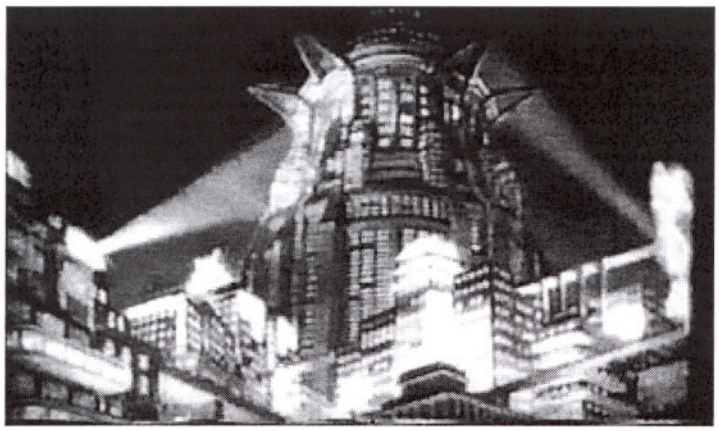

Figure 2- 21 A scene from the movie Metropolis, Fritz Lang, 1926
(http://www.paulist.org/doug/metro/default.ssi)

Meanwhile some rejections to Glaeserne Kette and to glass architecture came from Russia. Some artists in Russia were thinking, that glass architecture with its total transparency had disadvantages. Evgenii Zamiatin, in his book 'We' described how the denizens of the glass buildings of his unified state were deprived of all will- power and healed by destroying the imaginative center of their brains with rays. (Thomsen 1994 p82)

The designs of the Glaeserne Kette have influenced architects through 20th century. It is also possible to see some reflections of this fraction of Crystalline Architecture today. The glass Pyramid in Louvre, designed by Ieoh Ming Pei; The Canadian National Gallery in Ottawa, designed by Mosche Safdie in 1988 are some examples, which are influenced from the basic ideals of the Glaeserne Kette.

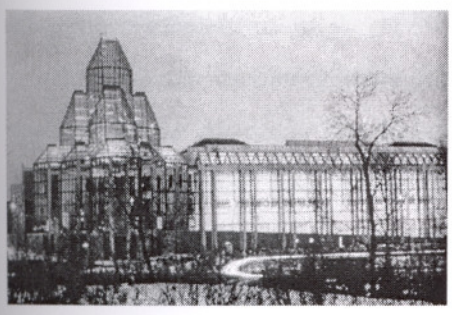

Figure 2- 22 Canadian National Galerie (Thomsen 1994 p90)

Figure 2- 23 Glass Pyramid in Louvre (www.erco.com)

2.2.2. THE 1920'S

The 1920's witnessed important innovations in lighting industry. First of all, artificial lighting became cheaper with the increasing technology. New and powerful lamps, accessories such as prisms, mirrors and lenses that could shape and color the light beam in different ways, and electromechanical switching systems were developed. These developments enabled architects and designers to create extraordinary effects in buildings interiors and exteriors. Lighting became more architectural in character during the twenties. Lighting became a science and new professions came to agenda such as lighting designers and lighting engineers. And these professions became an important part of a cooperation built with architect or designer throughout the 20th century. Light engineering brought with it its own rules and principles, which mostly stand on quantitative basics and that is why it is exposed to strong critics like the lack of the basic concepts such as psychology. It is possible to see radical efforts of architects and designers at this period in integrating the light into the building in order to emphasize structural lines, wall and ceiling panels. Walter Kantack, as a lighting designer discusses this point as follows:

" We are becoming more familiar with the possibilities offered by reflecting surfaces and in designing our lighting equipment are actually thinking of light as a definite element built into our structure, having just as important a place as color, materials, and ornament have commanded in the past..." (Rub 1986 p32)

Another innovation was the development of floodlighting. This technique was not new, it had already been developed and was shown at the Panama- Pacific Exposition of 1915 in San Francisco. In this Exposition, searchlights[10] also became public, which will be used in architecture and art illustrations and also for bad purposes that they are designed for (as anti-aircraft searchlights in Nazi Germany at the second world war).

Floodlighting had great impacts on architecture. Before, building exteriors had been illuminated by outline lighting, with strings of incandescent light bulbs, arranged to emphasize the structural and ornamental features. The disadvantage of this method was the disturbing glare of the incandescent bulbs. And in San Francisco at the Exposition underline lighting was replaced with floodlighting. W. Darcy, director of General Electric Illuminating Engineering explained in the Exposition:

".... Incandescent outlining in the main group of the palaces was avoided, and screened or masked flood or relief lighting to produce the third dimension or depth substituted, and great care was exercised with proper relative intensities. For the first time at an international exposition the illuminating sources, whether areas, incandescents, or gas, lost their identity as such..." (Rub 1986 p32)

Floodlighting gained great popularity during the twenties. It had a wide use area from airports and construction sites, to night- time sporting events and touristic attractions. The scenic wonders such as Washington Monument and Niagara Falls became a new character.

After a while, people realized that floodlighting was one of the advertising mediums. It pointed a structure much more stronger than the street. Soon, skyscrapers were illuminated under the technique of floodlighting. Edward G. Neale, the president of Luminous Structures observed:

".... Light has real sales value and when the commercially wise architect uses light, not merely as an accessory but as an actual architectural element, he has

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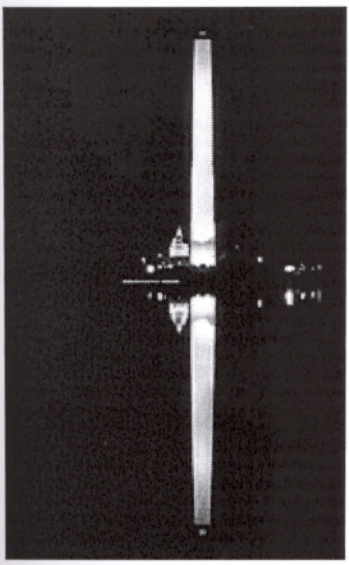
[10] A type of lamp with very strong light output, which can produce linear beams. Searchlights were designed to be able to see the aircrafts at night.

provided his clients with a very distinct advantage in the highly competitive race for business... " (Neale, 1933 p22)



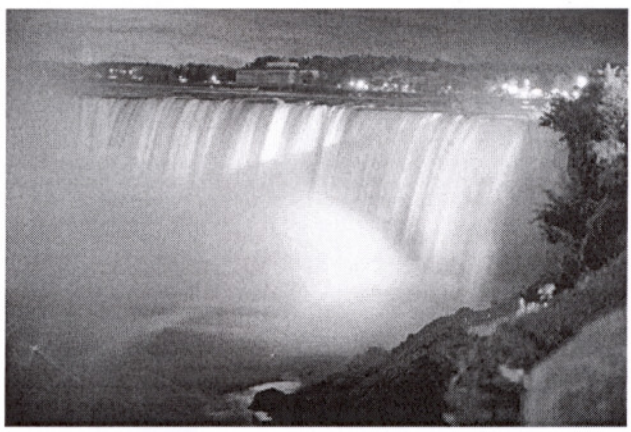


Figure 2- 24 Washington Monument at night (http://www.rgimages.com/images/img03050.html)

Figure 2- 25 Niagara Falls at night (http://photo.net/photo/pcd0738/niagara-canadian-falls-far-66.tcl)

Lighting firms served to this market by expanding their products. Bulbs in varying sizes, mounts, reflectors, and lenses that could both color and texture the beam were all avaible. Another important improvement was, the close relationship between the architect and light engineer. Engineers managed to persuade architects that floodlighting should be studied at the design stage. Most common methods were perspective renderings and models with miniature bulbs. After a while, designers had changed the principles of floodlighting. It should be used in a selective way, producing contrasts of light and shadow in order to emphasize certain parts of a building such as cornice, colonnade or tower, rather than on the whole. The Empire State Building is an example of toplighting applied as an integral part of architectural design.

The twenties and early thirties were also the years of Art- deco period. And this trend played an important role in the interior decoration, forming a new understanding of using light. The cheapness of electricity had encouraged its use in interior design. Streamlining with light bulbs in bars, restaurants, hotels and so forth was the new approach to light in interior design. It was a kind of lighting that directed the viewer's

attention towards the intended image. It was mostly used in cinemas. These were the spaces, where light played a significant role in the interior and exterior.

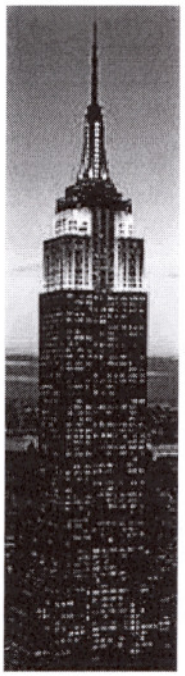


Figure 2- 26 Empire State, New York (http://newyork.citysearch.com/E/V/NYCNY/0009/97/69/)

2.2.3. LIGHT AND MONUMENTALISM

From the late thirties, until the end of the Second World War, light became an instrument of architecture of power. Monumentalism had been a style of architecture in many countries, such as Germany, Italy, Russia, and America. Among many architects, Albert Speer is prominent with his success in using light in a mythic and symbolic quality. For him light was the ideal and creative tool, for representing the power and tyranny. The National Socialist Party Convention Ground in Nuremberg and the Tower of the German Pavilion for the World Exposition of 1935 in Paris are some examples of his ability in using light as a tool of his ideals. Wolfgang Schievelbush emphasizes how perfect Albert Speer understood the treatment of light. He commented:

".... The combination of archaic-mythical forms with the most sophisticated modern technology, which was characteristic for the Nazi system, could be found most perfectly realized not only at the Parisian Pavilion but also in the grandstand of the Reich's-Party-Convention-Ground at Nuremberg and the New Reichskanzlei. Integrated in an architecture which denied every progress in building technology of the 20th century and every stylistic feature of modernity, the powerful reflector lamps of Zeiss-

Ikon radiated a light which in technical perfection and suggestive power was equal to the most modern lighting equipment at the Berlin-Babelsberg or Hollywood film studios...". (Schievelbush 1989 p146

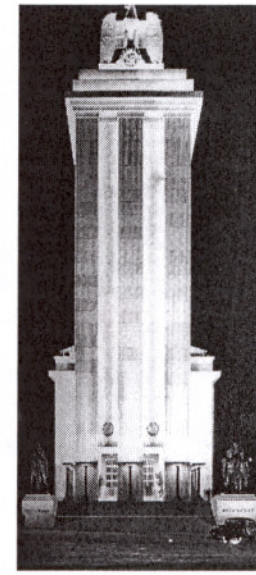


Figure 2- 27 Nazi Via Triumphalis, Unter den Linden, on the occasion of Mussolinis' visit to Berlin. (*A+U* **308** p113)

Figure 2- 28 Tower of German Pavilion in the Paris World Exposition of 1937 (*A+U* **308** p113)

Figure 2- 29 Albert Speer, Light show, on the occasion of Mussolinis' visit to Berlin. (*A+U* **308** p115)

Albert Speer used searchlights, a powerful light source, which can produce linear beams, in some his installations. Light Dome in Nuremberg in 1936 during one of Hitler's rallies in support of the Nazi Party, Berlin Olympic Stadium and Nazi Via Triumphalis are some examples of his amazing works, where light is used as a symbol

of power. In the Second World War, these searchlights were used for exact purposes they are created for, as anti- aircraft searchlights.

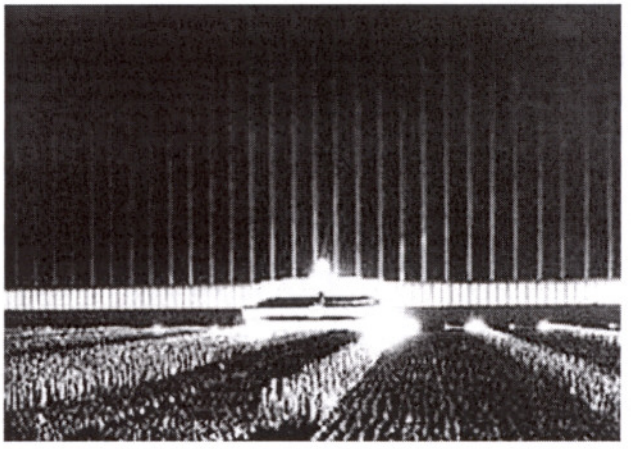


Figure 2- 30 Albert Speer, Nuremberg Statium (http://www.calvin.edu/academic/cas/gpa/pt36p.htm)

Figure 2- 31 Albert Speer, Nuremberg Statium (http://www.calvin.edu/academic/cas/gpa/pt36p.htm)

It is interesting to witness that Albert Speer, with his understanding in using light mostly his belief in Nazism had a recent effect on one of projects for Berlin. A light show was designed by Gert Hoff, a German art director, for the millennium-party, on December 31th 1999, expected to draw half a million people to the famous Victory column at the center of the Tiergarten (Aktan 1999). Organizers of the "Art in Heaven" light show bill it as the largest ever, and there is no doubt it would be a technological wonder.

Figure 2- 32 Millenium Light Project for Victory Column in Tiergarten, Berlin (http://62.96.245.61/english/frame.htm)

As the project web site[11] makes clear, this was meant to be a dramatic show, using 3.8 million watts of electricity and sending light 70 kilometers into the sky, it should be visible as far away as Dresden and Hamburg. The show is cancelled, because of the objections of a group of people, which suggested that such a spectacle of the lights is just like the light shows Albert Speer made for the Nazi party rallies in Nuremberg.

2.3. DEVELOPING LIGHTING INDUSTRY AFTER 1950'S AND THE IMPACTS ON ARCHITECTURAL SPACE

Light and space have always been in a close relationship through human history. In the 20th century, especially in the second decade of it, through increasing technology, artificial light sources, light systems, and new lighting techniques have joined to this relationship as creative tools. In this period we witness some works appear that are based on lighting technologies. Artists, interior and lighting designers, being supported by the new technology, soon realized the potential of light as a design tool in space and began deal with the incredible effects of light. Their aim was to influence viewer's perception by creating unusual light effects in space.

2.3.1. NEW TECHNOLOGIES

Lighting field became an area of abilities where anything is possible with the increasing technology after 1950's. Some of these technologies were previously developed, however did not have a wide use in architectural applications. Fran Kellogg Smith classified these new technologies into three parts as hardware, kinetic effects, and illusions. (Smith and Bertolone 1986 p192)

HARDWARE

The first category of light as art techniques, hardware, contains both light sources and light fixtures. There are neon light, fiber optics, acrylics, light pipes and acrylic panels.

Neon was first introduced to public in Century of Progress Exposition of 1933 in Chicago, where also the structural glass block came to the agenda. The term neon refers

[11] http://62.96.245.61/english/frame.htm

to luminous tubes that light up when the neon gas is ionized by the passing electric arc and produce and orange-red glow. Most gases behave similarly, such as the mercury gas, found in the common fluorescent light. But rare gases like xenon, argon, krypton, and neon are most easily ionized gases. Each of these produces a distinctive color and all are avaible in the type of slim tubing.

A neon sculpture is usually the work of three people: the architect or interior designer, the neon artist, and the craftsman. Under the guidance of neon artist, the hands of the craftsman use neon to create line drawings of light in space (Smith and Bertolone 1986 p192). Although neon provides some illumination, it is not possible to think of it as a source of architectural light.

Fiber optics are thin cylindrical glass or plastic fibers of optical quality that must be so optically clear that light entering one end of it can be transmitted to the other end by a process called 'total internal reflection'. Fiber optics are used for many purposes[12] besides their use in architectural lighting in order to carry light to desired places.[13]

Fiber optics produce intense points of light that can be used for many decorative effects such as creating starlight patterns, underlining the threads of a staircase and so forth. Uses of fiber optics in architectural lighting tends to be decorative, because the light is only a short distance effective when it has left the fiber. It is rare that fiber optics are used in order to light objects or backgrounds.

The same principle of 'total internal reflection' causes light to travel through acrylic pipes and sheets, but there are a few distinctions. Acrylics are cheaper than fiber

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[12] To expand medical diagnosis- Tiny bundles of optic fibers can be inserted in accessible parts of the body for diagnostic examination, in traffic signs- fiber optic bundles can be brighter than traditional neon and incandescent sources and use less energy, to carry light to unreachable places such as in autos or in underwater works, in communications. (Watson 1990)

[13] For further readings on fiberoptics:
http://www.netoptics.com/ also
L. Watson, "On Being a Master Technician: The Building Blocks, *Lighting Design Handbook*, edited by J. E. Stein (Mc Graw Hill, New York, 1990), 62-64

optics. Also, fiber optics attempt to deliver all the light to their endpoints, whereas acrylic pipes and sheets can deliver light more gradually.

A light pipe is an empty acrylic square with ribs of high optical quality on its external surface. The rips are shaped so that 95 percent of the rays are reflected back into the length of pipe. This fixture can be used to deliver light to one end or it can be a continuously glowing fixture with an outer covering that allows emitting light. Fran Kellogg Smith wrote about the uses of light pipes in his book:

The uses for light pipes range from the aesthetic to the practical

1. The same coloring techniques used with fiber optics can also be used with light pipes, but the luminosity can be seen along the length of pipe as well as at its end. Color effects can be visibly mixed inside the pipe by locating light sources of different color at either end.
2. When lighting must be installed in an area with difficult access- like a pool or atrium- the replacement of bulbs becomes harder. Light pipes allow lamp bulbs to be placed in an accessible area and the light itself "piped" up to where it is needed.
3. By placing the light source outside of interior spaces, light pipes eliminate the heat load usually placed on air conditioning thus saving energy. (Smith and Bertolone 1986 p193)

Acrylics are produced also in panels, and almost all techniques used for fibers and light pipes are also used for acrylic panels.[14] Acrylic panels are useful as partitions for small places. When the panel is mostly etched[15], it can serve as an acoustic barrier without blocking the view, so it can enlarge an enclosed space. When the partition is mostly frosted[16], it serves to protect privacy by obscuring the view and also for acoustical purposes.

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[14] For further readings on acrylics:
F. K. Smith and F. J. Bertolone, "Light as Art", *Bringing Interiors to Light: The Principles and Practices f Lighting Design*, (Watson-Guptil, New York, 1986),194

[15] Without light, reflected on their inner flat surfaces

[16] With light, reflected in their inner flat surfaces

KINETIC EFFECTS

This group includes the work, in which light became a moving element in space with the help of some mechanisms. To give light motion is an effort, which exists since the Second World War. Many artists tried to enhance spatial limitations through that way. Especially ZERO, an art movement consist of some German artists, had performed several art works, in which light played an important role as a moving element.

RAINBOWS

Both diffraction and refraction of light can produce moving fragments of a rainbow. Several well- known artists work with rainbows. They create art- works, in which giant prisms are designed to cast bands of rainbow through an interior space. Such prisms must be suitable in geometry to the interior and the sun angles on the site; but the daily, seasonal, and climatic changes provide the variety and motion. When the light source is not sunlight, effects can also be generated with artificial light sources. Joost van Santen is a dutch artist, skilled in rainbows. His art-works will be discussed later.

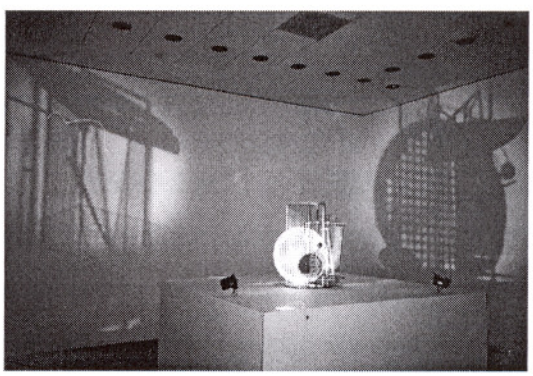

Figure 2- 33 Amersfoort Railway Station, Joost van Santen (http://home.wxs.nl/ ~jvansant)

Figure 2- 34 Laszlo Moholy Nagy, Licht raum modulator, 1922-30 (hgk archive)

LUMIA

"Scientifically speaking, light waves underlie the phenomenon of color just as sound waves underlie the experience of music" (Smith and Bertolone 1986 p195). The similarities between light waves and sound waves have been known for some time.

Lumia is the unpredictable colored response of light to sound waves. It creates mysterious and exciting effects in space. Peter Sedgley is one of the many artists, who works with audiovisual light sculptures, will be discussed later.

LASER ART

The word laser derives from the longer term "light amplification by stimulated emission of radiation". The term laser defines a special type of light beam with its own unique properties. The beam is composed of coherent light, which means it is of one color and wavelength. Neon gas is used to produce red laser beam; argon and krypton gas for blue and green.[17]It is not possible to see the light from a laser, unless smoke or dust or a surface from which it can reflect is present. That means an observer never sees a laser beam- only reflected laser light.

Figure 2- 35 Jean Michel Jarres' Houston concert with several light shows (*A+U* **308**)

Laser history goes back to after-war years. After long studies Dr. Charles Townes announced his invention of laser and made it public with a display in 1960. In early 70s lasers were accepted for entertainmental purposes by rock groups such as Led Zeppelin and The Who. In 1973, Ivan Dryer, a film expert, opened the first Laserium show at the Griffith Observatory in Los Angeles. This is fallowed by another Laserium shows in many countries such as Canada, England, and Japan. After a short while, lasers had appeared in discos and today we see lasers in an amazing range of applications

[17] For further readings on laser:
T. Kallard, *Laser Art and Optical Transforms*, (Optosonic Press, New York, 1979)
L. Watson, "On Being a Master Technician", *Lighting Design Handbook*, (Mc. Graw Hill, New York, 1990), 58-62
S. Coleman, "Lasers", *Lighting Dimensions* **2**, 1983, p 23-39,52

besides its use in outdoor and indoor spaces as a design element, such as in heavy industry, in medical science, in safety and so forth.[18] Laser technology also made emerge another technology, called holography, which has great effects on the new space concept, will be discussed later.

Laser and laser- based technologies used by many artists in order to change the meaning and rituals of space. Tully Weiss, a lighting designer says:

"... Lasers are fascinating in that they can actually restructure some interiors with their colored beams of light. What has been created here are seemingly physical planes or sheets of light in the air..." (Weiss 1984)

Figure 2- 36 Reichstag at night, Berlin (www.erco.com)

Laser is used in concerts, public celebrations, and festivals, in important buildings such as Reichstag in Berlin. Using computer- aided laser installations is the contemporary kind of anticraft searchlights. Christian W. Thomsen wrote about a work of three architects, created by laser:

"... Laser, moreover, can generate immaterial, three- dimensional light sculptures. In 1983/84 a team of three young Frankfurt architects, Norbert Berghoff, Michael Landes, and Wolfgang Rang planned a Frankfurt skyscraper festival, which they called 'Radiant Frankfurt'. Bright, shining pencils of rays were supposed to cut through a warm July night over downtown Frankfurt. Reflected by the walls of glazed

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[18] For further readings on uses of laser:
L. Watson, Lighting Design Handbook, (Mc Graw Hill, New York, 1990), ?

and mirroring skyscrapers, they would cross and intersect, they would from grids and nets and transform the entire backdrop of high-rise buildings into a gigantic monument... " (Thomsen 1996b p113)

In 80s laser technology influenced film directors and scriptwriters as being the highest technology, and that interaction still exists today. In science- fiction laser played an important role. As creating the world of future, scenarists foresighted lots of technology, derived from laser applications. The laser swords, laser protected jails, doors are some examples for the utopias deriving from laser. Some of the basics of architecture were replaced with laser-based technologies. And the increasing technologies make us to think about the general concepts of architecture, which seems to be shaken against the new era.

ILLUSIONS

The third group of light as art techniques consists of illusions created by reflected light. These include holograms, and the disembodied rooms of James Turrell. Recently it has been recognized that these magical lighting effects serves as practical solutions in space applications. To avoid the boredom and discomfort of architecturally failed and small interiors, designers can use several devices and techniques to create spatial illusions. Lighting illusions offer the possibility to enlarge, customize, and change interior spaces. These illusions are the result of the technology, however it is also possible to create illusions without using the highest technology. In fact, the history of illusions in space goes amazingly far back to the first century AC. Heron, in his book 'Catoptrics', deals with problems for the construction of mirrors in order to reflect objects in a particular way, thus created astonishing experiences in space.

"... One of many methods is to arrange mirrors in a given place so that a person who approaches cannot see either himself or any one else but can see image desired. When this configuration is placed in a temple so that when one approached the altar one would see suddenly the apparition of the deity as if emerging through the wall. The statue supplying the reflection would be hidden from sight and lit by a concealed side-window so that the apparition would be made to appear bright and shining while the edges of the mirror were carefully concealed by drapery... " (Potamianos 1997 p102-103)

Ptolemy of Alexandria (second century AC) also wrote about Optics in five books, and in Catoptrics section, he deals with plane, concave and convex mirrors, binocular vision, visual impressions and optical illusions.

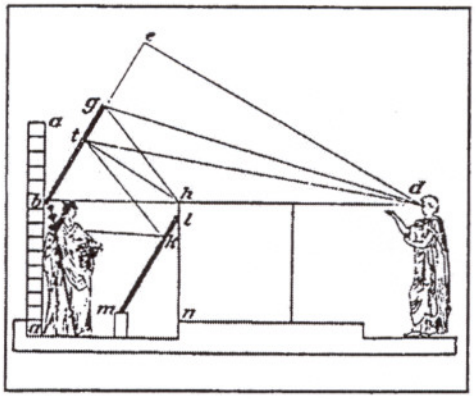


Figure 2- 37 Arrangement of mirrors (Potamianos 1997 p103)

The mirrors and the technique of reflecting light in order to carry it to a desired place are also used in ancient Egypt. The introverted style of architecture because of the heat and the dust of the desert resulted in dim interiors. The scene, where light is reflected through several mirrors in order to illuminate the very dark and large interior space, in motion picture 'Mummy', directed by Stephen Summers in 1999, shows the way how the ancient Egyptians used to utilized the avant-garde technology of that time.

HOLOGRAPHY

Holograms are the pieces of film on which information about light waves has been recorded. From these holograms, holographic projections, or images can be produced. A holographic image seems to be a three- dimensional object, existing in space. It can be viewed from various angles or walked around. A holographic image is created by a complicated optical process in such a manner that the viewer visually accepts the light and shadow image as a three- dimensional object.[19] Two procedures are

[19] For further readings on the creation process of holograms:
F.G. Smith and J.H.Thomson, "Holography", *Optics*, (John Wiley& Sons, New York, 1988), 269-278

needed in holography. The first is the creation of the hologram. The second is a holograph, an assembly of mirrors and lenses that create a three- dimensional object by using laser light to display the information recorded on the hologram. First holographs were reconstructed with laser light of one color, however today it is possible to reconstruct full color holographs. It is also possible to create moving holographs.

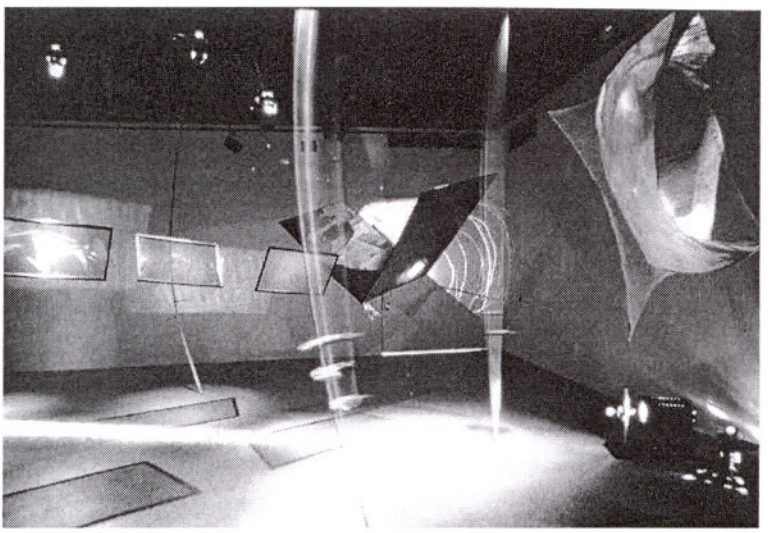


Figure 2- 38 Doris Vila, Heaven, home+weightless, Holographic installation, Boston, 1992

(Thomsen 1994)

Although holography technology exists for a long time, besides some art- works, it does not have a wide use in architectural space. It is for sure that this exciting technology will play an important role in space creations with its large benefits. Thomas Lück and Vito Orazem created two light installations in 1992, Arche- Di- Em and Diffracted Wall. In both applications, the main technology was holography. The installation 'Diffracted Wall' was first shown at the exhibition 'Light and Architecture' in Ingolstadt, Germany in 1992. Vito Orazem wrote about his installation:

"...The idea was to design a light environment with the help of holographic optical elements and video monitors. In Arche-Di-Em *the HOEs are let into the walls and the floor and are illuminated by monitors, which show graphic patterns and very simple computer animations. The installation is constructed so that it conveys the*

R. Guenther, "Holography", *Modern Optics*, (John Wiley& Sons, New York, 1990), 469-520

impression of a shelter, an ark. The visitor via a short staircase the visitor enters a corridor and comes into the main room where two wall openings and one opening in the floor can be seen. These openings contain HOEs that are illuminated by five monitors. On the other side of the room there is another aperture with a ramp behind it over which the visitor leaves the installation ... Here holographic optical elements are illuminated by the simplest computer animation. The light of the TV is manipulated, distorted and multiplied as it passes through the hologram. The video light, the images on the screen are animated and then further manipulated as they are bent through the holographic surface. In the installation 'Diffracted wall' the rough mechanical structure of an ordinary wall was neglected and became an immaterial element with new properties and qualities..." (Orazem)

Diffracted Wall is an example about the changing concepts in architecture through holography. Immaterial effects, achieved with expert light use, are a well-known design attitude since ages. The south wall of Notre Dame du Haut in Ronchamp, for instance, is an example for immaterial effect, however total immateriality is something that has new met architecture with the increasing technology during the last decade of 20th century. It is obvious that holography has many practical applications for architectural space. It has a role as information guide in public spaces and the creation of a new light – architecture. Dwellings could have holographic windows that show a new landscape each season. It is possible to bring desired view on living rooms' wall. One can have a live ocean panorama even in Konya. Fran Kellogg Smith observes:

"... For space colonists, the lack of a view would mean the loss of contact with nature and potentially claustrophobia. Futurists believe holograms will serve a purpose here, too- as porthole vistas..." (Smith and Bertolone 1986 p197)

The architecture of the present time is the field where the technological and aesthetic qualities of holography can be expressed significantly. According to Vito Orazem, it is hopefully to reach the multi-perspective space feeling with these developments.

2.3.2. LIGHT ART

"How old is light? Where does light come from? Who has first seen light? Who has seen light last? Does light come to the eye? Does the eye come to the light? How much is a kilogram of light? To whom does light belong? How transparent is light? How deep does light penetrate into the skin? Is light sharp? Is light shy of light? How does light dress? How often does light take a bath where bathes it? Where does light sleep? With whom does light sleep? By whom is light loved?"

Children of the light ZERO

During the second decade of the twentieth century, lots of artists emerged, who are interested in light and its dynamics in space. In their works, they not only intended to make the beauty of light visible, but also tried to integrate their work with architecture.

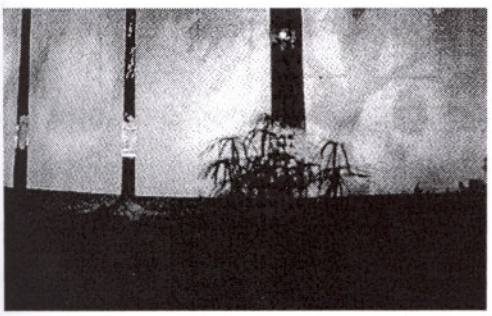
Zero, one of the first post-war art movement, which is formed of three German artists; Heinz Mack, Otto Piene and Günther Uecker, is a notable one among many artists.

"Light is seen by the ZERO members as the most essential power of life, and ZERO's question is to link art, working, and living spaces by aesthetic arrangement in order to reach a re- harmonization in the interrelation of man and nature. This is in particular true for both Heinz Mack and Adolf Luther, the latter calling many of his sculptures made of lenses and concave mirrors. 'Architectural Integrates'" (Thomsen 1996c p120)

ZERO created experimental works between 1958-65 with mobile objects. They used lanterns, spotlights, searchlights, electric motors and such unusual materials in order to form their non-static art. They built variable light mills, light steales, light carousels and developed modern sculpture and light art, and from the point of view of Christian W. Thomsen, they all appear as explicit forerunners of computer arts, of animation, of computer- directed kinetic sculptures, of cyberspace and of new digital forms of art yet to come; media architecture, which will be discussed later, as a theme of this thesis. As it was mentioned before their works was deeply related to architecture. Thomsen mentions:

".... Their shining surfaces tried to do away with materiality: they tried to create spaces of vibration, reflection, and motion. Especially in many of Mack's works, interference, intervals, and superimpositions of different layers played an important role. He used aluminum foils, industrial glass, mirroring glass, acrylic glass, and honeycombed aluminum grids, which have since found frequent use in architectural constructions. Mack mainly intended to create objects which convey spatial images that look immaterial, oscillate by means of interference, force the eye to journey through the sculptures, making discoveries of new spatial experiences, using the existing space as a kind of body of resonance." (Thomsen 1996c p121)

Peter Sedgley is another artist, who built light sculptures, integrating them into architecture as audiovisual elements. His sculptures transform sounds of daily life and natural events such as wind, into colored lights. His first installation was in Place Gambetta in Bordeaux Festival of 1973. He placed microphones at certain places in the square. And at night, the recorded sound of people, noises, wind, moving leaves etc., were transformed into color and projected on the screen, hung up between the trees, next to the footpaths. It seems clear that these works have influenced the works of a Japanese architect Toyo Ito, which will be discussed later.



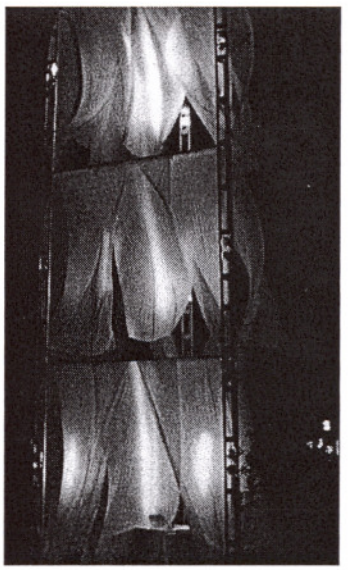
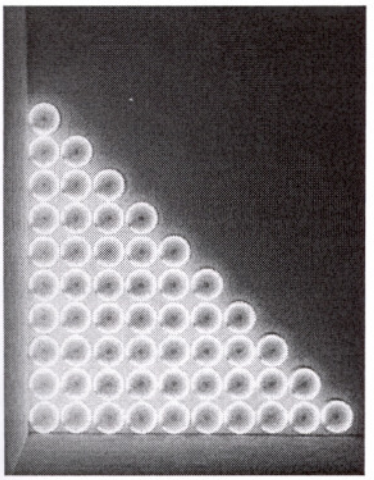


Figure 2- 39 Peter Sedgley, Light Ballet, Bordeaux, 1973 (*A+U* **310** p117)

Figure 2- 40 Peter Sedgley, Wind- Light- Sound Tower, Munich 1978- Stuttgart 1979 (*A+U* **310** p117)

Dan Flavin is an American artist, changes the meaning of spaces and creates strong and complex effects by his work of art, achieved to create eight neon tubes in different colors. He adds different levels to interior spaces as fragmenting them into different parts. His art- works can be explained as color illusions. In 1962, Dan Flavin introduced his first aesthetic experiments with electric light art: square paintings with attached fixtures and bulbs.



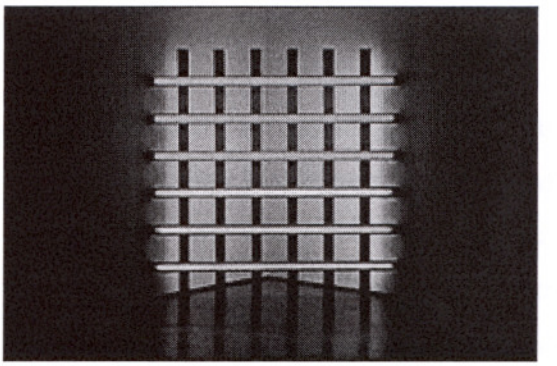


Figure 2- 41 Dan Flavin (http://www.diacenter.org/exhibs/flavin/images.html)

Figure 2- 42 Dan Flavin (http://www.diacenter.org/exhibs/flavin/images.html)

Flavin explains his use of fluorescent tubes in his works of art: *"In time, I came to these conclusions about what I had found in fluorescent light, and about what might be done with it plastically: Now the entire interior spatial container and its parts-wall, floor, and ceiling, could support this strip of light but would not restrict its act of light except to enfold it... Realizing this, I knew that the actual space of a room could be broken down and played with by planting illusions of real light (electric light) at crucial junctures in the room's composition. For example, if you press an eight-foot fluorescent lamp into the vertical climb of a corner, you can destroy that corner by glare and doubled shadow. A piece of wall can be visually disintegrated from the whole into a separate triangle by plunging a diagonal of light from edge to edge on the wall; that is, side to floor, for instance.*

...What has art been for me? In the past, I have known it (basically) as a sequence of implicit decisions to combine traditions of painting and sculpture in architecture with acts of electric light defining space...." (Govan)

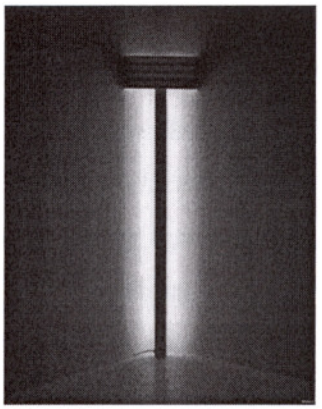
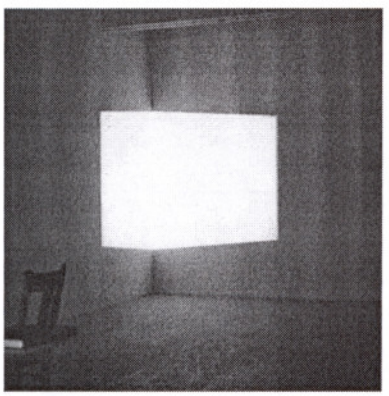


Figure 2- 43 Dan Flavin (http://www.diacenter.org/exhibs/flavin/images.html)

Another contemporary artist utilizing the perception of light and color in space is James Turrell. Like the work of Dan Flavin, Turrell's work is site specific and includes spaces, in which the intensity, quality, and angle of light create the appearance, and disappearance of objects, walls, and even entire rooms. James Turrell knows to control three- dimensional perception towards complete adaptive brightness[20]. Darkness adaptation happens autonomicaly when the visitor passes through darker and darker spaces in Turrell's environments. The key in his illusions lies in controlled brightness and color contrasts. For years, James Turrell's ambition has been to reveal the extraordinary properties of light. Since 1966, all of his works (quartz- halogen projections, fluorescent space constructions, apertures to natural illumination) have been concerned with light as the creator of illusion.



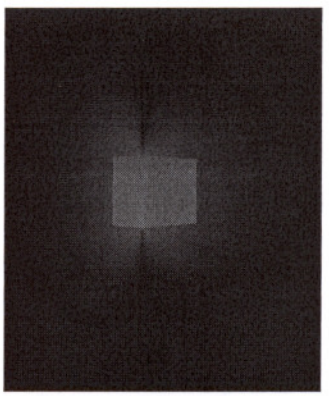


Figure 2- 44 James Turrell (http://www.arc.cmu.edu/portfolio/v/documents/light/)

Figure 2- 45 James Turrell (http://www.arc.cmu.edu/portfolio/v/documents/light/)

[20] The change in brightness of surfaces in a neighboring space, caused by light or dark adaptation of the eye to the space it is in.

Fran Kellogg Smith wrote about an exhibition of his work, first seen in 1983:

"... The visitor, after a short walk along a more and more dimly lighted pathway, enters a large gallery with a high ceiling. On the farthest side of the otherwise empty gallery, an immense black velvet tapestry covers almost the entire wall. The second phase of the visual experience begins when the visitor finally approaches the tapestry to examine it. Depending on the amount of control or decorum of the visitor, it may take some minutes before the viewer finally reaches out to touch the tapestry. But nothing is there! The tapestry is really a hole in the wall. After an additional lapse of time- as the visitor tries to ascertain how she/ he was fooled- the third part of the experience takes place as the viewer starts to suspect the presence of a space or room beyond the hole in the wall. By staring into it, very slowly an entire room becomes visible and is soon clearly present..." (Smith and Bertolone 1986 p199)

In James Turrell's illusions boundaries are important. They are places where illusions occur. Susie Kalil wrote about the boundaries in Turrell's installation 'Night Light':

"*As the boundary between inner and outer worlds vanishes, you confront a dilemma similar to that of philosopher Chuang Tzu: Awakening from a dream, he did not know whether he was a man dreaming that he was a butterfly or a butterfly dreaming that he was a man. For a few minutes, you, too, exist in a state of suspension. It knows neither birth or death; it exists in an everlasting now, it just is.*" (Kalil 1998)

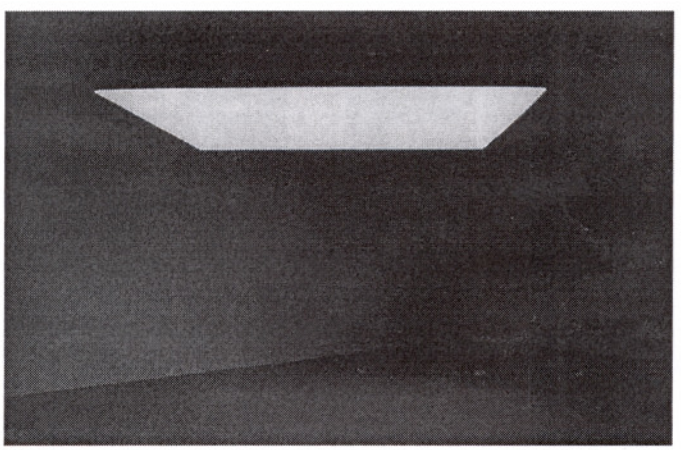


Figure 2- 46 James Turrell (http://www.arc.cmu.edu/portfolio/v/documents/light/)

Maurizio Nannucci is another contemporary artist, who works with light. He devoted himself to explore the relationship between language and visual images. His art is based on linguistic ideas and includes varying media, such as photography, video, and sound installations. In 1967, he began to create his neon writings that added a further dimension to his work. Suzanne Reece observes:

"...Nannucci is interested less in the play of natural light than in the fluidity and flexibility of light in the spatial and architectural structures of the urban world. The content of this illuminated neon texts is not confined to the conceptual analysis of reality; instead it poetically reconciles the conflicting claims of language and the real, with the confident assertion that 'light' and 'beauty' are two unquestionable facts, or provocatively inverts commonplace notions by introducing an opposition between text and reality: 'There's no reason to believe that art exist'..." (Reece 1999 p37)

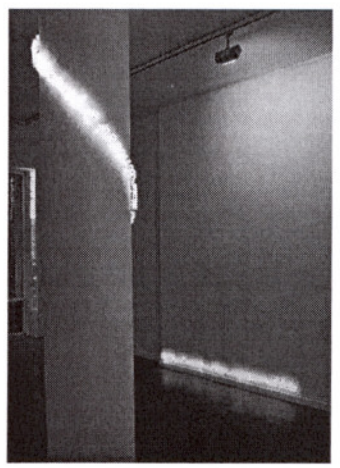


Figure 2- 47 Lets talk about art maybe, 1993, Edinburgh (http://art.dada.it/nannucci/body.html)

Figure 2- 48 Installation, Victorio Miro Gallery, 1983, London (http://art.dada.it/nannucci/body.html)

Figure 2- 49 The missing poem is the poem, 1969, Munich (http://art.dada.it/nannucci/body.html)

Figure 2- 50 My sense of your sense of language, 1994, Aarhus (http://art.dada.it/nannucci/body.html)

Another striking light artist is from Netherlands. Joost van Santen is a visual artist and works with natural light, intertwining it to architecture. He benefits from technological tools related to light and also builds his own instruments. He says that the essence of his work was to experience light as a part of the universe (Santen 1998). In the Ordnance Survey Building in Emmen he placed colored mirror objects on the skylight over the gallery void that reflect sunlight onto the wall and white panels. The reflected images vary with the time and movement of clouds. In the railway station of Amersfoort, the front façade is articulated in varying colors. The sunrays falling down the interior create moving pattern of colored light, which is the spirit of this project (Figure 2-28).

Figure 2- 51 Ordnance Survey Building, Emmen, 14:00 pm (http://home.wxs.nl/ ~jvansant)

Figure 2- 52 Ordnance Survey Building, Emmen, 16:00 pm (http://home.wxs.nl/ ~jvansant)

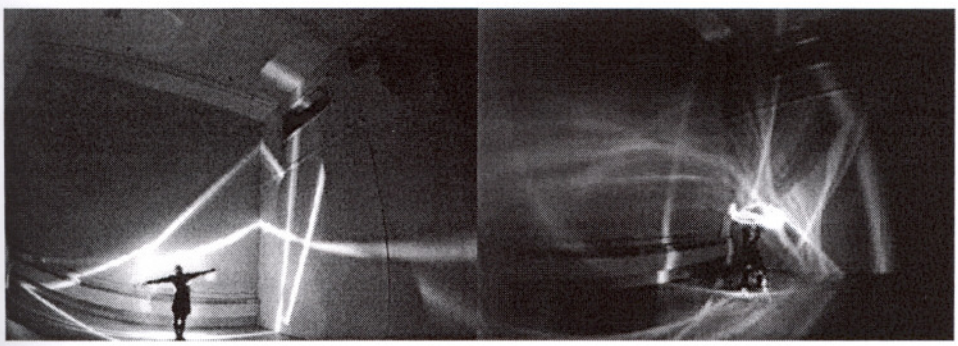


Figure 2- 53 Seth Riskin, Light Dance, he is an artist who tries to define space through light and body language (http://web.mit.edu/mit-cavs/www/Seth.html)

Figure 2- 54 Seth Riskin (http://web.mit.edu/mit-cavs/www/Seth.html)

2.4.THE LAST DECADE OF THE 20TH CENTURY

During the last decade of the 20th century light became a tool that can be controlled by the increasing technology. It is possible to direct, redirect, collect, diffuse, color, and do whatever one can imagine for the spatial needs. And the desired technology in 80s that will lead to a reacting architecture is now avaible. Otl Aicher, a graphic designer who works for ERCO, a lighting firm, realized lighting designs almost whole of the important buildings of leading architects, had commented:

"At the beginning of this century there was a cry for light. A cult of sun-worshipping had arisen. Today we have enlarged the program into a controlled interdependence of light and shade. Such an architecture cannot be realized from a merely static beauty. It needs an architecture able to react and to change. This should be achieved by machines as well as by individual manual control. The result is a building with variable, moveable sails, blinds slats and flaps. The result is a cheerful kind of architecture." (Aicher 1990 p17)

Architecture gained a mediated character today, as a result of the new spatial concepts through increasing technology. Recent architecture is full of examples, their walls formed not by multiplication of windows, which open towards true nature, instead electronic screens, supplying desired view and spatial effects to the viewer. In an interview[21], Paul Virilio states: *"... Architecture of the nineties is loosing exactly those qualities, which is used to be its essentials. Step by step and piece by piece architecture is letting some of its conventional components slip away..."*. The importance given to glass and transparency today, Paul Virilio says is a metaphor for the disappearance of reality:

"... Transparency is a symptom for the loss of matter in architecture and it announces media- buildings proper: the façade will be replaced no longer by glass, but by screens. The screen will advance to the state of the last wall: no longer a wall of stone, but of screens...".

Works of Toyo Ito are examples, showing the new mediated architectural concepts. In Tower of Winds, Egg of Winds, and the 'Visions of Japan' in Exhibition

'Dreams' in London, he created structures that interacts with the visitor and with its context in a mediatic way. The Egg of Winds, built in Tokyo in 1991, is an egg- like structure located in front of the high- rise apartment buildings. The structure is wrapped with aluminum panels. In the daytime it is an object, which reflects the sunlight, but at night, it turns into a colored sculpture, displaying video images live and recorded by means of five projectors, on the internal screens and on its aluminum paneled surface.

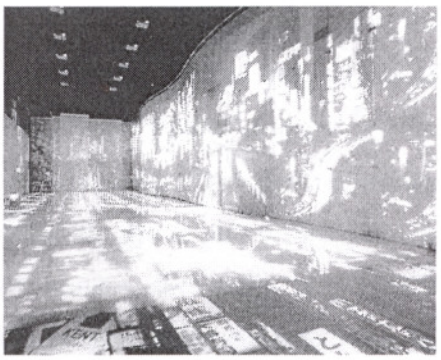


Figure 2- 55 Visions of Japan, London

Figure 2- 56 Egg of Winds, Tokyo, 1991

The tower of Winds, built in Yokohama in 1986, is an empty aluminum tower that has no real architectural function. The tower is surrounded with acrylic mirrors and twelve neon rings and over one thousand bulbs are attached between them. At night sounds of people, natural data's such as sound of wind and rain, actual events on the street are recorded and played back graphically on the façade with help of computer controlled light sources. *"...Toyo Ito creates an interactive architecture reflecting words of an evanescent and abstract kind is the equivalent of a Zen landscape painting featuring mists, mountains and wind..."* (Ito 1995)

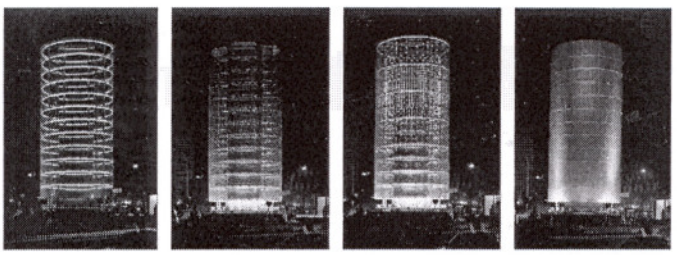


Figure 2- 57 Tower of Winds, Yokohama, 1986 (*AD* **67**)

[21] "Der Bildschirm als Mauer" ("The Screen as Wall"), Deutsche Bauzeitung, June1994 http://www.chez.com/freecyb/virilio/INTERVIEW.HTM

The Galleries La Fayette in Friedrichstrasse, Berlin is another example for the mediatic understanding of design in the late of the 20th century. Jean Nouvel wanted to design a transparent building, so that inside and outside could be connected visually. Friedrichstrasse was one of the main cultural and commercial centers of Berlin before the World War II and before the separation of Berlin. During the postwar period it had lost much of its character. After the destruction of the wall, local administration decided to revive the old Friedrichstrasse again, and for that purpose several competitions were opened. The basic requirement in architectural programs for each competition was that the buildings should respect to the historical references in height, and façade organizations. The Galleries La Fayette could be taken as a conflicted example after that explanation, however it is not. In façade organization, the classic building ornamentations like architraves were replaced here with strips of animated electronic advertisements. The building tries to combine past and present on its transparent animated façade as a screen. Besides its mediatic characteristics, the building also shows respect to daylight in interior design. In order to get light enter into the required places, several voids of cylinder and cones were placed into the building. The two cones in the middle of the building, attached base to base, for example, provide daylight even to the park places in the basement floor.

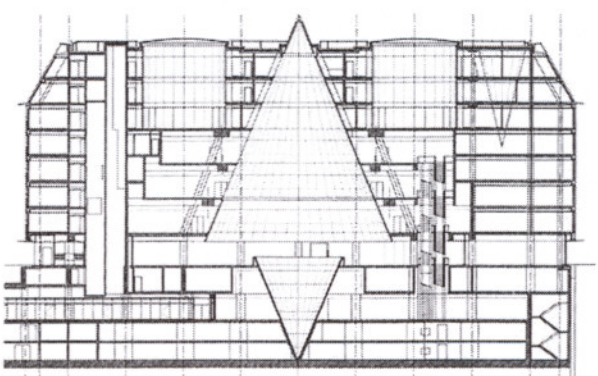


Figure 2- 58 Galeries La Fayette, Berlin (hgk archive)

Figure 2- 59 Section showing the light cones

Technological developments lead architecture to another concept, called intelligent architecture, and lighting systems constitute an important part of it. Norman Foster's buildings in several places of the world appear in examples to intelligent buildings, where light is considered as a fundamental design criterion. Hong Kong Bank is one of the first buildings, where daylight is controlled in a technological way. This project was Norman Foster's first co- operation with the lighting firm ERCO. ERCO designed computer controlled sun scoops, attached to the building exterior and to the top of the atrium, which catches and collects sunlight according to the time of the day and the weather conditions to direct it to the inner mirror in the top of the atrium. From there the sunrays are reflected down the atrium, then to the ground, and as far as to the basement floor. The collectors also contains large lamps, whose color are computer controlled, which came into use, when the amount of daylight is not enough for the desired lighting condition. And it is impossible to differentiate between daylight and artificial light. The same understanding of light and technology relationship can be seen in his other buildings such as Carre Art de Nimmes and Stanstead Airport.

Figure 2- 60 Sun scops over the atrium (www.erco.com)

Figure 2- 61 Hong Kong Bank at night

There is also another kind of articulating light in the last decade of the 20th century, includes the works of architects such as Tadao Ando, Ricardo Legorreta, and Peter Zumthor. These understanding of using light has a spiritual, and emotional

character mainly based on historical references and local traditions. Sure, they benefit from artificial light and related technology, however their work is mostly related to daylight. They created spaces and form their architecture in order to reveal desired effects, related to human psychology, with the help of the daylight.

Figure 2- 62 Peter Zumthor, Thermal Baths in Valls
(http://www.archined.nl/news/9809/zumthor_eng.html)

CHAPTER 3

LIGHTING AS A TOOL FOR CREATING SPACES

3.1. VISUAL PERCEPTION

"The eye sees no shapes; it sees only what is distinguished by light and dark or by colors. Pleasure in colors, singly or conjoined, is experienced by the eye, and communicated by that organ to the organism. Pleasure in form is a part of man's higher nature, and the inner man imparts it to the eye.

Light transmits the visible to the eye;

The eye transmits it to entire man.

The ear is the mute, the mouth is the deaf;

But the eye both understands and speaks."

GOETHE (Eiermann 1997)

Lightarchitecture is based on physiological optics and the general psychology of perception. The eye is the tool, which enables us to contact and interact with the surroundings. Information on the physical world is mostly conceived by means of our eyes.

"The fact that our eyes sit in the same vertical plane makes binocular vision, and so the ability to judge distances, possible. And also it has been argued that the development of color vision was the evolutionary benefit as humankind moved into an upright stance and life as a hunter." (Turner 1994 p25)

The eye however, is not perfect. There are lots of situations that cause discomfort and disability on the eye. Too much light can cause an effect called glare and this can be uncomfortable and dangerous at the same time. Sudden light, for example, can make a driver blind at night. Overloading the eye with a particular color can cause distorting afterimages that mean the eye can retain the same shape and color, although the stimulus is removed. Furthermore, for physiological reasons related to eye, we do not perceive the world as actually it is. [1] In Parthenon the columns are all inclined inward to form the illusion that they are straight. Norbert Lechner wrote in his book:

[1] For further readings on the physiology of the eye:

"... The columns have a slight bulge to counteract the illusion of concavity that characterizes columns with straight sides. The column spacing and thickness vary because of the effect of high brightness ratios. Bright columns on a dark background look sturdier than dark columns on a bright background. This is relevant because the central columns are seen against the dark shaded building wall while the end columns are seen against the bright sky. Thus, the ancient Greeks made the end columns thicker than the central columns..." (Lechner 1991 p259)

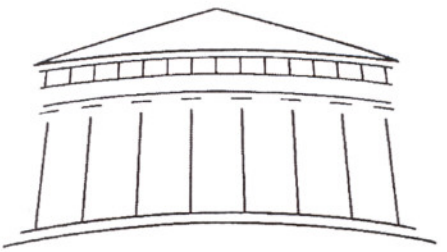


Figure 3- 1 The way that Parthenon was built (Lechner 1991 p259)

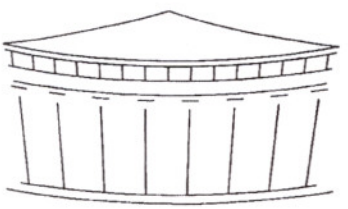


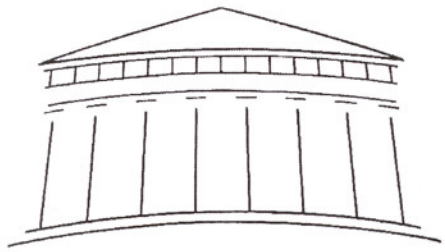
Figure 3- 2 The eye perceives straight lines in a distorted way (Lechner 1991 p259)

Visual perception is a complex process of information selection in which context, prior experience, and expectations are combined with incoming data. As quated from William Lam:

"... Unless distracted, we look at what we want or need to see, as dictated by activity and biological needs for visual information. The visual attention is automatically directed by the focus selector to elements of the visual field, which will provide the needed information. A distracting stimulus may cause the focus selector to redirect the visual attention. Such a stimulus need not be the brightest thing in the view.

L. MICHEL, "Visual Perception for Architecture", *Light: The Shape of the Space-Designing with Space and Light*, edited by J. Griffin (Van Nostrand Reinhold, New York, 1996), 9-11

"... The columns have a slight bulge to counteract the illusion of concavity that characterizes columns with straight sides. The column spacing and thickness vary because of the effect of high brightness ratios. Bright columns on a dark background look sturdier than dark columns on a bright background. This is relevant because the central columns are seen against the dark shaded building wall while the end columns are seen against the bright sky. Thus, the ancient Greeks made the end columns thicker than the central columns..." (Lechner 1991 p259)



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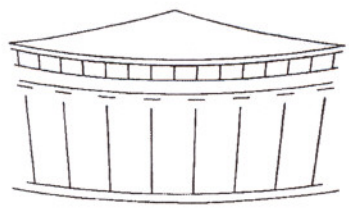

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The information content and context of stimulus also play important roles in determining its perceived relevance and importance..." (Lam 1992 p35)

People feel comfortable when the illumination level allows them to look at what they want to see. Similarly, discomfort arises when the luminous environment reduces ones freedom and ability to do see. The higher the strength, quality, and information content of the stimuli, the better one can see. These factors are affected by surface characteristics of the objects, as well as by the source characteristics, quality, and quantity of the illumination. The experience and attention of the viewer also affect the quality of human vision. All these factors must be considered in the design of luminous environments.

Light is not only an essential requirement and the medium by which the human being is able to see. Through its intensity, the way it is distributed throughout a space and through its properties, light creates specific conditions that can influence perception. Lighting design is, in fact, the planning of the visual environment. Good lighting design aims to create perceptual conditions which promote an effective working ability as well as a feeling of well- being in a particular environment and at the same time enhancing aesthetic qualities. Lighting design can therefore not be restricted to the creation of technical concepts only. Human perception must be a key consideration in the lighting design process.

Several scientists and lighting engineers have pointed out in their research that lighting plays an important role in forming architecture. If carefully studied and successfully applied, lighting can play an integral role in creating architecture (Theodore and Bradshaw 1994). Lighting can enhance and detract from the architecture or the color scheme of an interior (Allpin 1959). IESNA (1987) noted that lighting could play an important role in reinforcing spatial perception, activity and mood setting. Light determines how we perceive space (Cullen 1986). This interaction of light and spatial perception includes several basics from varying disciplines, such as psychology, engineering and design. The effective factors range from the types of the light sources to the color arrangement of the space. The direction of the light sources and the texture could also be factors that influence the viewers' perception.

3.1.1. THE PHYSICAL PECULIARITIES OF LIGHT AS A MEANS OF VISUAL PERCEPTION

The scientific classification of light sources was discussed before (2.1.1). It is also possible to classify light sources according to the physical output that is much more related to visual principles than quantitative values such as point, line, surface, and volume. The visual characteristics of light are deeply related to the spatial perception as well as the mood that is intentionally created in the interior atmosphere. If it is thought in terms of task lighting[2] it may be suggested that the task quality rises from point to volumetric type of illumination. These physical peculiarities of light can be achieved both by daylight and artificial light.

The perception of light as a point in a space means to create an aura where a light source perceived independent of the context, without an intention of focusing on a surface or illuminating volume. The point, the source itself, here attracts attention, not the volume or part of the volume in which the source is mounted. It is obvious that a light source, even with a very low illumination level, creates an illuminated space, or gives some clues about the context where it is located. That, however, is not the first perceived effect by that kind of articulation. An incandescent light bulb in the middle of a ceiling is also a point in a room from which light is distributed through the entire space. There are, however, only little nuances between the point and surface or volumetric kind of illumination. The illumination level and brightness ratio is important. When the illumination level increases, it is possible for that incandescent light bulb to became a source for a surface or a volume that serves for the task needs.

It is interesting to see that a light sources' physical characteristics change perceptually depending on the point of observation. Street lamps provide an illuminated route, a volume, in a part of a city for a passenger at night. However they are perceived as points when they are observed from above or from another part of the city. The street lamps in Karşıyaka, İzmir are perceived as points from Alsancak, however the situation

[2] The required amount of light that is needed for the daily activities. For a brief history of the development of the performance- based standards: C. Cuttle, "The New Photometry", *Developments in Lighting*, edited by J. A. Lynes (Applied Science Publishers, London, 1978)

changes for a viewer, who does the daily trip at night under the street lamps in Karşıyaka.

Figure 3- 3 Points of city lights. An Installation by Diana Löschen and Andrea Prasse in Aegidientorplatz, Hannover (Flagge 1994 p209)

The developing technology of fiberoptics has made possible to creation of artificial light effects such as starlights that are perceived as points in interiors. When the task needs are high, fiberoptics should be used with other kinds of lighting techniques in order to reach the required illumination levels.

In the central hall of Palacio Guell in Barcelona, designed by Antonio Gaudi, it is achieved to create a perception of points with daylight. The daylight penetrating from the openings on the pointed tower is softened with a surface that has little holes on it. The hall is connected to other spaces on each side with gradually increasing brightness levels. The dimness of the main hall makes the effect of holes stronger.

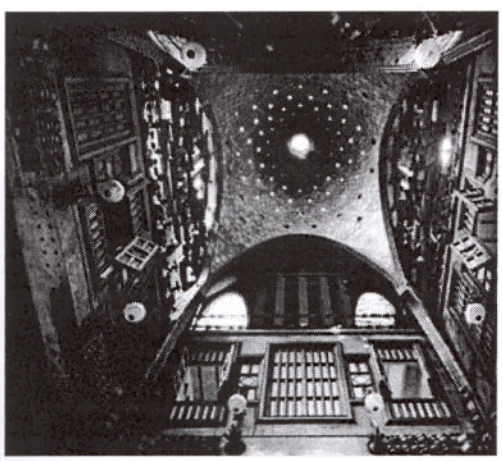

Figure 3- 4 Central Hall of Palacio Güell

The perception of light as a line can be achieved in several ways. The light source itself can be a line like a fluorescent lamp or a neon tube in varying colors.

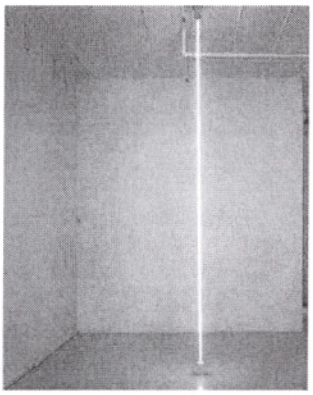

Figure 3- 5 Simon Ungers- Intensity (*AD* **67**)

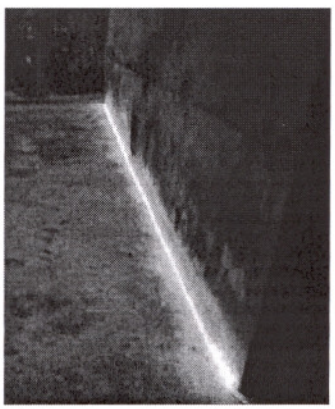

Figure 3- 6 M. Nannucci- The Red Line (http://art.dada.it/nannucci/body.html)

Point light sources can be arranged in a way that they form lines of light. Gestalt psychology clarifies this situation. The second law of proximity says that a number of elements that are spatially close together tend to form a sub group.

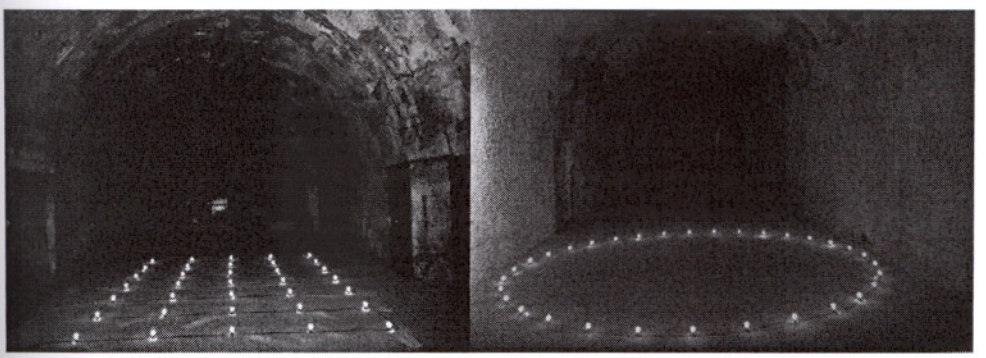

Figure 3- 7 Michael Kahler- Underground (*A+U* **307** p104)

Another kind of creating a perception of lines in a space can arise from the output of the light source. The searchlights of the Second World War, and the more recent laser, are the results of the desires for linear light beams.

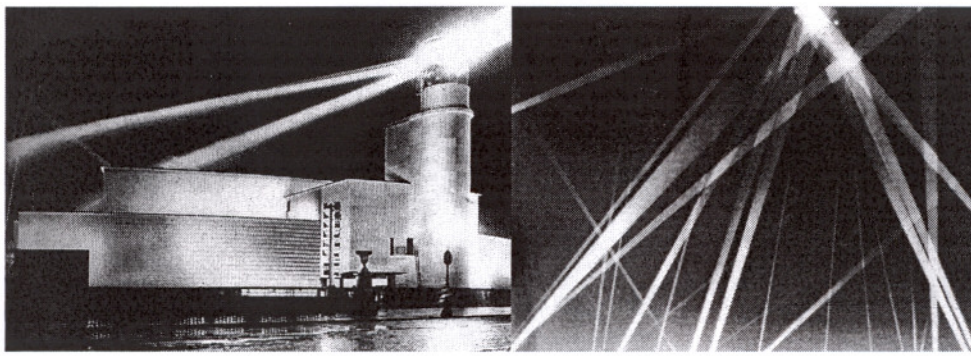

Figure 3- 8 Searchlights (*A+U* **308** p115)

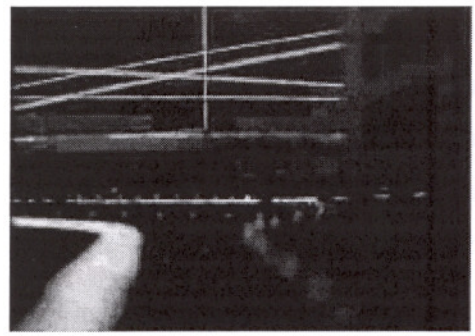

Figure 3- 9 Linear Beams of Laser Light. An Installation by Diana Löschen and Andrea Prasse in Aegidientorplatz, Hannover (Flagge 1994 p209)

Linearity is often used to create movement in space. It psychologically motivates motion. This effect of light will be discussed in detail.

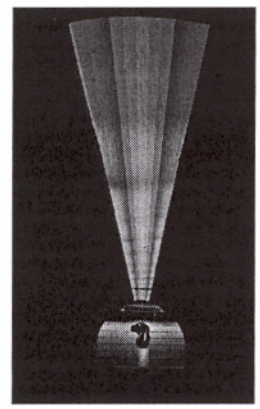

Figure 3- 10 William Kessler- Detroit Institute of Art (Michel 1996)

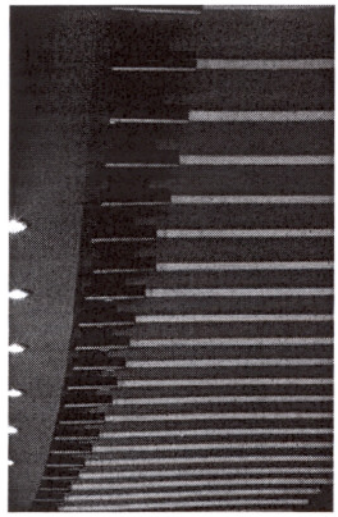

Figure 3- 11 Riphan & Grod- UFO Palast, Köln (Flagge 1994 p111)

Usually it is intended to form a hierarchy in order to arrange the life in space. Architects like to control the dynamics by creating perceptual relations. Light, both natural and artificial, can be used as a tool for achieving this. In order to make an object, a wall or another part of architecture a focal point, it is enough to highlight or wash the surface of it. This would increase its importance relative to the other objects or parts of space.

Surface illumination creates areas of varying brightness. This is the key concept for differentiating space perceptually and can be seen in a variety of examples, such as a wall being lit with a wallwasher, a desk lamp on a table, or a painting under a spotlight.

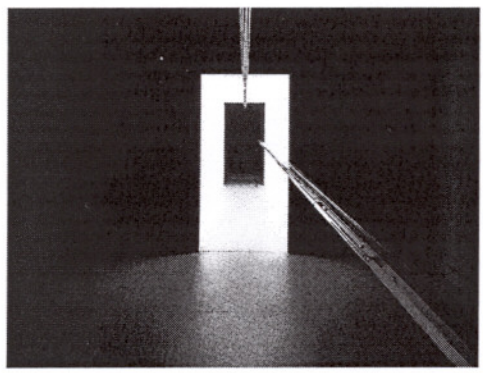

Figure 3- 12 Differences in surface brightness levels. Dan Flavin, Baden- Baden 1989 (*A+U* **308**)

Flood lighting, an invention of the twenties and still popular today, is also a kind of surface illumination, which was once considered the most impressive tool for marking a building in a cityscape.

Volumetric illumination creates uniteral lighting quality in space by eliminating the brightness differences. The whole volume is perceived in a total character and shows the same characteristics in terms of lighting. In a volumetrically illuminated space it is not possible to perceive one object as more dominant than another object. Usually no shadows occur in space. For some specific functions, such as reading rooms and offices, it is an intended articulation. However, it is also a result of planning, which lack of sensitivity in terms of lighting design. Lighting designers need to be sensitive to the variations in human need in order to create psychological comfort. That must be a key concept for lighting designers.

Jutta Kehrer and Petra Mager realized a project in 1994, which is called Harbor Railroad Tunnel. Their aim was to track down a tunnel in the city that was out of use since 1992. Light was the creative tool in this project, and it is possible to see point, line, and surface articulations together.

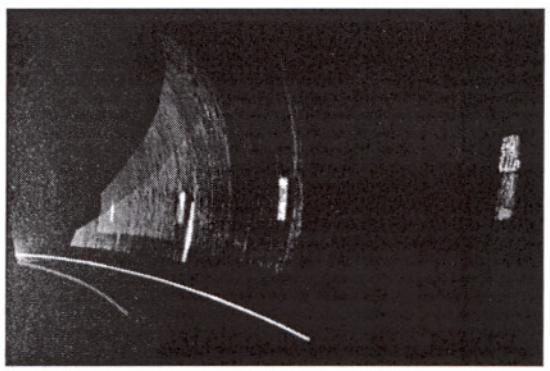

Figure 3- 13 Harbour Railroad Tunnel, Hannover (Flagge 1994 p212)

Figure 3- 14 Harbour Railroad Tunnel, Hannover (Flagge 1994 p213)

3.1.2. DIRECTION OF LIGHT

Direction of illumination is very important for three-dimensional objects in a three-dimensional setting (IESNA 1987). The direction of light falling on an object changes how we see it and the distribution of a light beam also affects the appearance of an object. Birren states that light should neither be too directional (like a beam of sunlight) nor too diffused (like a cloud). As the direction of light affects the perception, the placement of the light sources is important. The right place for a light source is determined by convention, by the surrounding structure and by the object which is to be lit (Holmes 1975 p87).

Shadows and variations in brightness are essential in a space, and only directional light sources can create shadows that are not completely diffused. When a light source is far away from the object, and also small in the quantity of produced light, shadows appears sharply.

Turner states that the direction of a light source, and changes in its intensity, can alter the perceptual mood of a space (Turner 1994 p26). A single downlighter in the center of a space produces a visible cone of light with shadows around it (Figure 3-14). Adding further downlighters creates an ambient light, with less defined shadows (Figure 3-15). Directing the downlighting to wash over the end wall creates a stronger area of light in the background, weaker in the foreground (Figure 3-16). This effect can be emphasized by increasing the amount of light by adding more downlighters (Figure 3-17).

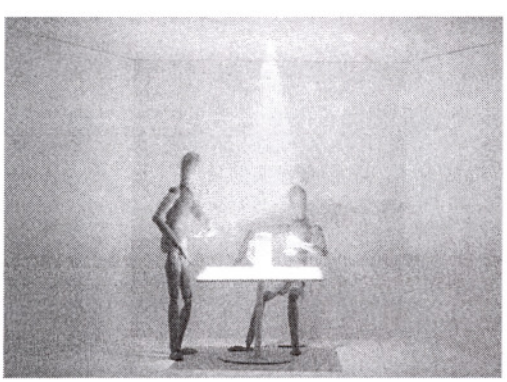

Figure 3- 15 (Turner 1994 p26)

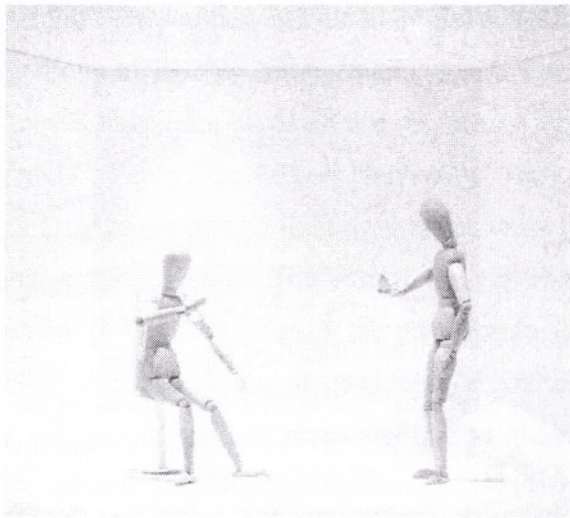

Figure 3- 16 (Turner 1994 p26)

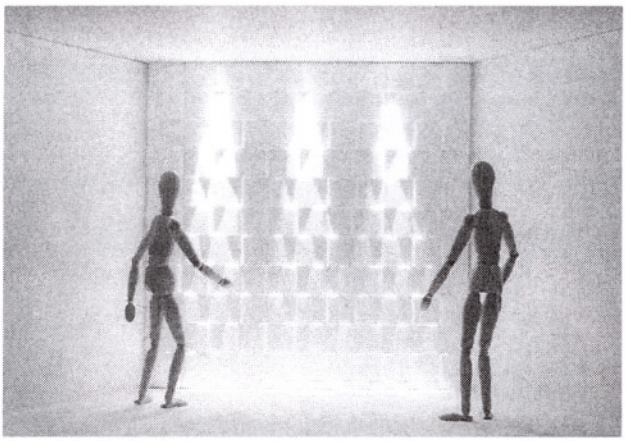

Figure 3- 17 (Turner 1994 p26)

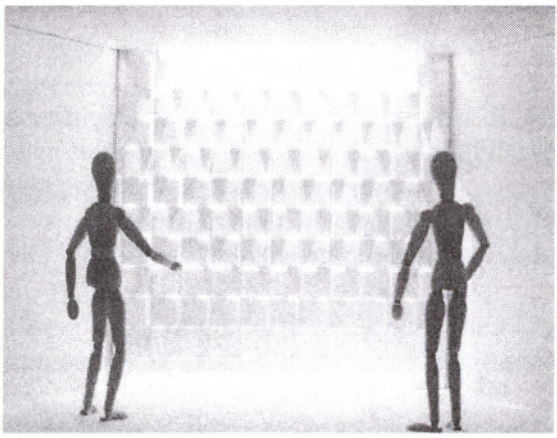

Figure 3- 18 (Turner 1994 p27)

The arrangement of light sources, and the illumination technique, is as important as the quantity. Alterations in lighting arrangements could change the perception of space. Lots of experiments have been made on this subject.[3] A recent one among them belongs to B. Manav and C. Yener from Bilkent University. They prepared a room with four different lighting arrangements. The lighting systems were general lighting, cove lighting, wall washing, and uplighting.[4] The aim of the experiment was to reach an analysis of the perceptual differences between the participants. The participants were asked to fill a questionnaire that included questions on six different impressions: Clarity, spaciousness, relaxation, privacy, pleasantness, and order. The results were as follows: Wallwashers were chosen as the best light source for clarity. Cove lighting was the system that provided spaciousness and order. The system considered as suitable for relaxation, privacy, and pleasantness was uplighting.

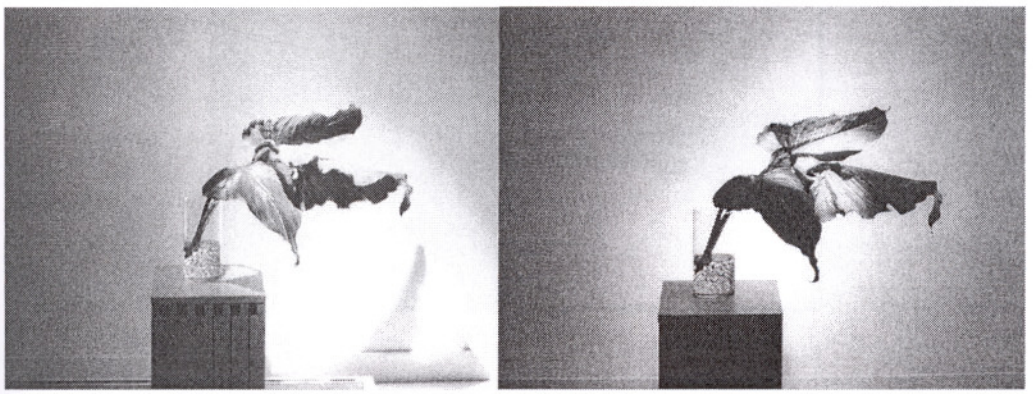

Figure 3- 19 Objects under different lighting systems. The object on the left is lit with a downlighter, and the right one is lit with a uplighter. (Turner 1994 p30)

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[3] The most popular experiments on this subject belongs to J. E. Flynn, F.K. Smith, and P. C. Hughes. For further readings on the experiments about the relation of the arrangements of the light sources and space perception:
J.E. Flynn, "Interim Study of Procedures for Investigating the Effect of Light on Impression and Behavior", *Selected Papers on Architectural Lighting*, edited by M. S. Rea (Spie, Washington, 1992), 435-442
F. K. Smith, "Spaciousness", *Lighting Design and Application* **65**, 1989, 18-23
P. C. Hughes, "An Examination of Visual Clarity as a Function of Color Temperature of Light Sources", *Lighting Design and Application* **21**, 1977, 22

[4] For detailed information on the characteristics of the room and lighting systems used in the experiment:
B. Manav and C. Yener, "Farklı Aydınlatma Düzenlemelerinin Mekanın Algılanmasındaki Etkisi", *II. Ulusal Aydınlatma Kongresi- Bildiriler*, (Bileşim Matbaacılık, İstanbul, 1998), 35-38

3.1.3. BRIGHTNESS AND CONTRAST

Brightness is a basic component of visual perception. The absolute value of brightness as measured by a photometer is called luminance. However, a human being perceives the brightness of an object relative to the brightness of its surroundings. This means that brightness requires two or more surfaces or objects to consider one as brighter than the other. That kind of articulating of light has been in use since the Renaissance. The painters of the Renaissance discovered that it is possible to highlight objects by creating dark settings rather than by high illumination levels. The gray triangles can be given as an example. They are identical in brightness. Their luminance as measured by a photometer will be the same but their perceived brightness will depend on the brightness of the surrounding area.

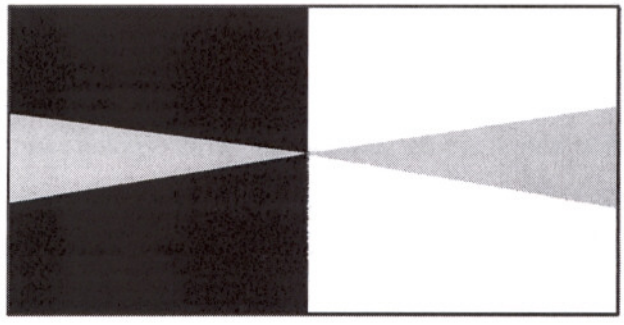

Figure 3- 20 Gray Triangles (Lechner 1990 p260)

An interesting aspect of perception of brightness is gamma movement[5], which influences the way we see a surface in spatial depth. When all physical features are equal, a bright object will appear closer and larger than a darker one, although they are equal in distance and size.

When the appearance of a surface differs significantly from its background, it is said to have brightness-contrast. Placing two surfaces or objects of high contrast in adjacent positions changes the appearance of both. The perceived brightness of a surface changes according to an adjacent surface that is much brighter or darker.

[5] This term belongs to F. Kengel (1931), and stresses brightness advances.

Brightness-contrast is often used in exhibition designs. Sometimes high contrast is used intentionally in order to dramatize the display. In the Kimbell Art Museum, designed by Louis Kahn, brightness-contrast is used between paintings and panels according to the general brightness levels of the paintings.

Figure 3- 21 The Kimbell Art Museum (Millet 1996 p172)

3.1.4.COLOR

Studies in psychology have shown that colors could affect the mood and emotion of participants in space. The reasons are still not clear. Red and orange, for example, are believed to induce hunger and stimulate appetite. That is why these colors are widely used in restaurants, cafés and food shops. It is also possible to make a room perceptually larger or smaller than it actually is with the expert use of color. Brighter colors make a room appear larger, and darker colors make it appear smaller. Certain places can be emphasized by painting them in a color that contrasts with the other colors in the room. It's also possible to change the proportions of the space perceptually with color- use.

Designers use colors in order to modify the shape of a room. Use of color does not merely imply or suggest that the walls are painted in a desired color. Using colored light and washes in the desired place also creates the same effect. It is difficult to repaint a room every time a change in spatial effect is desired, however lights can easily be turned on and off.

Color also adds spatial dynamism to space by keeping the human responses active and avoiding visual adaptation and monotony. The Palace of Justice in the

Hague, Netherlands has achieved that understanding of space with the work of Joost van Santen. He placed varying lenses that color the beam, to the skylights over the three light wells, which are in relation to all the floors in the building. Light being reflected and colored enters the building interior and creates dazzling effects that show the importance of color in architecture.

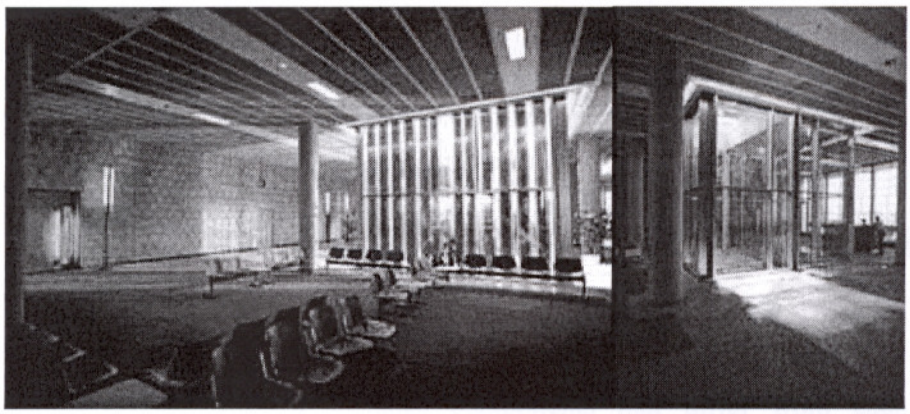

Figure 3- 22 The Palace of Justice (http://home.wxs.nl/ ~jvansant)

According to Lou Michel the color of building material also affects the spatial perception of exterior surfaces. He mentions that the color of material influences spaciousness in a distinctive way (Michel 1996 p120). The Bema Nantes in France, designed by Manuelle Gautrand & Associates in 1994 is an example of material that creates a spatial tectonic through color. The building is enclosed with a translucent material in order to let the daylight enter the interior space. Artificial light sources of different colors are placed in the interior next to the translucent surfaces. They are randomly operated in different colors and the outside view of building changes all the time. It is like a glimmering living creature.

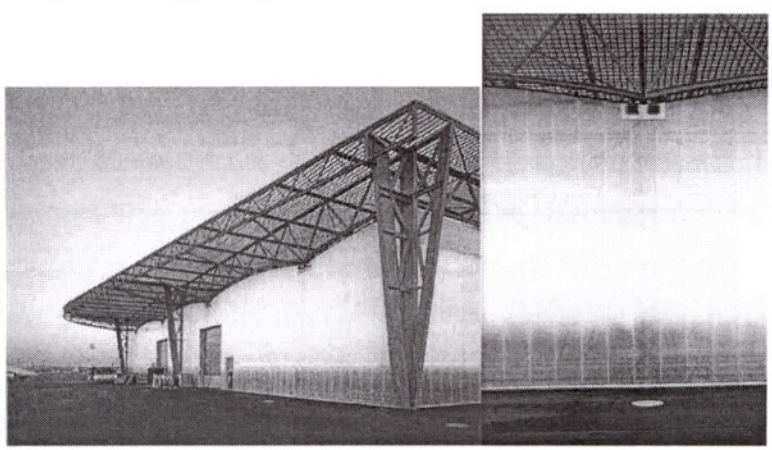

Figure 3- 23 Bema Nantes (*L'architecture d'aujourd'hui* Sep.98 p38)

The bedroom of St. Martins Hotel, London in the figures below show the changing character of a room through changes in color.

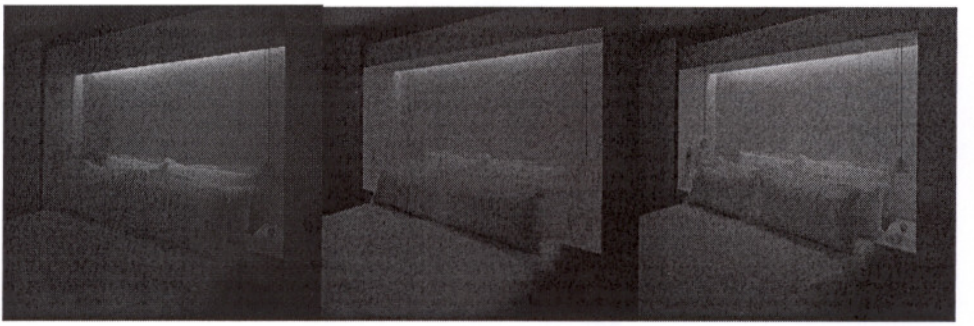

Figure 3- 24 St. Martins Hotel, Philip Starck (*Abitare* **391** p162)

Homogeneous sunlight includes components that differ from each other physically. They differ in frequency and wavelength. The color of daylight appears as white, because it is made up of different color components which together perceptually result in the color of white. Similarly, an object appears white because its surface is in white light and the other wavelengths are all reflected. When one sees a colored object, it is not a result of colored light but reflected light. The object absorbs the light of other wavelengths and reflects back the colored ones.

R. Ünver mentions that the color perception under artificial light is dependent on three factors (Ünver 1998 p27):

. The color of the light source

. The color of the object or surface

. The color perception system of the eye

If the color characteristics of a light source change, the characteristics of color that is reflected back from the object also changes. The object is perceived in a different color that it actually is. Objects are perceived in their original colors only under daylight or a light source that is physically similar to daylight. Ünver mentions that a light source that is similar to daylight contains all the colored light homogeneously. Figures in the next page show the changes in color perception under different light sources.

Figure 3- 25 (Turner 1994 p39)

Figure 3- 26 (Turner 1994 p39)

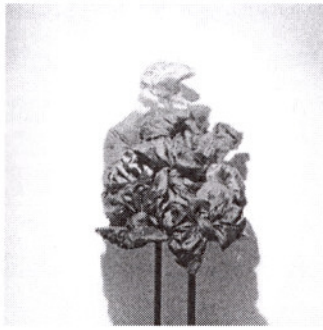

Figure 3- 27 (Turner 1994 p39)

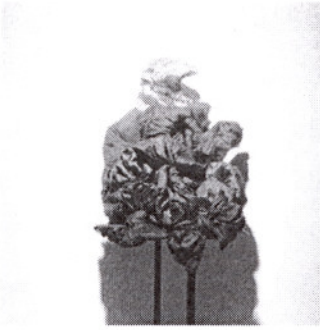

Figure 3- 28 (Turner 1994 p39)

3.2. THE EFFECTS OF LIGHT ON SPACE

3.2.1. THE INTERACTION OF LIGHT AND STRUCTURE

"...Structure is the maker of light. When you decide on the structure, you're deciding on light. In the old buildings, the columns were an expression of light. Light, no light, light, no light, you see. The module is also light, no light. The vault stems from it. The dome stems from it. And the same realization that you are releasing light..."

Louis Kahn (Brownlee and Long 1991 p212)

Structure has an important role on the spatial configurations achieved with light in a construction. Most of all, structure determines locations of openings for incoming daylight. Besides, it dictates the places where supporting artificial lighting will be located.

The Roman Pantheon, with its central oculus, is an example from the ancient world, showing how the Romans used light to articulate space. Light is utilized literally rather than in an abstract and metaphorical way, so that as sunlight moved through the space, it would highlight the figures and statues presented in the interior space. The intended characteristic of moving light in space is provided by the structural abilities of that time.

Another example is Hagia Sophia in Istanbul, where the structure is formed according to intended light effects, which was and still is an important part of the liturgy. Hagia Sophia in its original shape had a totaly different space quality achieved with light effects. The interior was totally different than it is today. The dome consisted of many more openings and was brighter. Besides the openings, the main dome played an active part in luminosity of the church. The original dome had an unusually flat curvature, which was the reason for its downfall. This is criticized as a lack of structural knowledge, however it seems that the choice of the architects derives from the intended light effects in the church's interior. Iakovos Potamianos says:

" ... *If they had simply aimed at structural ability they would have followed time-honored antecedents, but, instead, they chose to defy technological limitations in order to achieve a highly desired effect...* " (Potamianos 1997 p161)

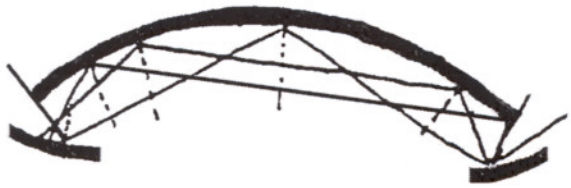

Figure 3- 29 Profile of the original dome with Anthemius' reflectors on the window sills. (Potamianos 1997 p163)

The main dome in Byzantine churches, where the image of the deity is placed, is bright, stemming from the belief that the deity is the distributor of light. Besides, in order to make this effect stronger, Anthemius designed optical reflectors which were placed at the windowsills of the dome of Hagia Sophia. The aim was to direct the rays of sunlight to a given point (onto the image of the deity) independent from the movement of sun during the day. It is also known that the mosaics in the church are not straight, instead angled in order to direct the rays of light to intended locations. This was reported by Thomas Wittemore, an American scientist in charge of the 1950 restoration (Rıfat 1998 p39). Under the direction of ERCO, a lighting company, the dome underwent recent restorations again. The lighting firm ERCO was charged to constitute the lighting design. After this restoration the church is now really far away from its original state.

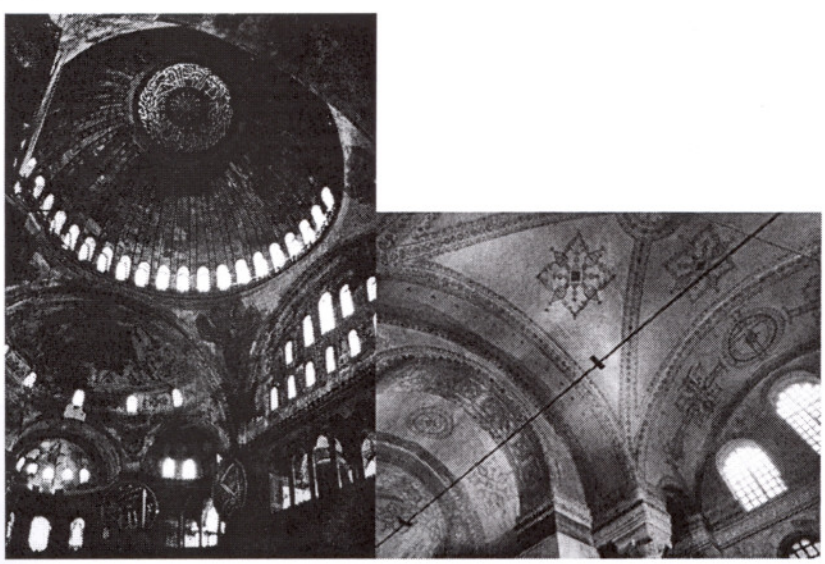

Figure 3- 30 Hagia Sophia (*FOL* **9** p38)

Figure 3- 31 Hagia Sophia after the lighting design of ERCO (www.erco.com)

The relationship between light and structure has been solidified with the advent of new technologies. The use of iron and glass in buildings revolutionized the building interiors, allowing as much light as possible to penetrate to the space. The Crystal Palace and The Bibliothèque Nationale are examples of the new daylighting possibilities; derived from the structural abilities of that time.

Figure 3- 32Bibliotheque Nationale, Henri Labrouste, Paris
(http://arch.ou.edu/a/end/2423/Chapter%2023/slide3.htm)

In modern architecture it is possible to see structure in a leading role in shaping form and space. The Kresge Auditorium, designed by Eero Saarinen, built in 1954, is an example of a building form derived from its structural design. The interior spaces of the Kresge Auditorium are a result of its structural design, which also directs the entry of daylight. A similar work of Eero Saarinen, the TWA Terminal at Kennedy Airport in New York, also shows the structure, form and light relations.

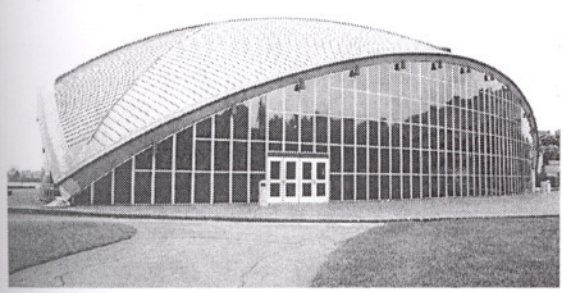

Figure 3- 33 The Kresge Auditorium

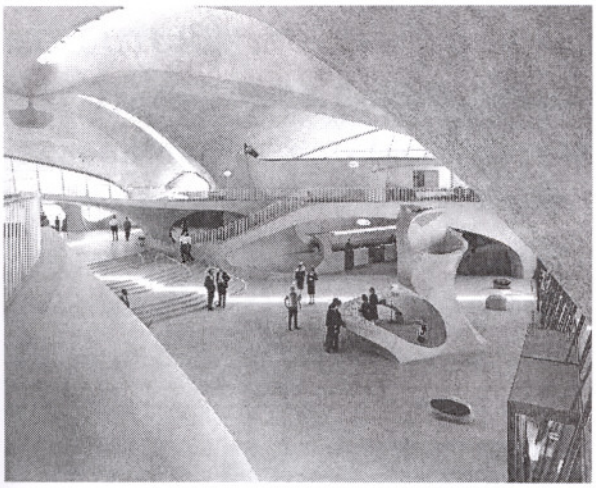

Figure 3- 34 TWA Terminal, New York

The Palazzo Dello Sport in Rome, designed by Pier Luigi Nervi is an important example showing the importance of light on architectural space and light-structure interrelations. The building's interior is covered with a dome, measuring 328 feet in diameter, which has a patterned surface. The dome is coated with opaque materials, and does not have any transparent surface. Light enters the building from triangular openings, which are placed at the intersecting points, where the dome structure meets the ground behind the bleachers and a stunning brightness-contrast occurs. Light, as reflected from the supporting walls, reaches the dome's patterned surface and exposes it by creating light and shadow effects.

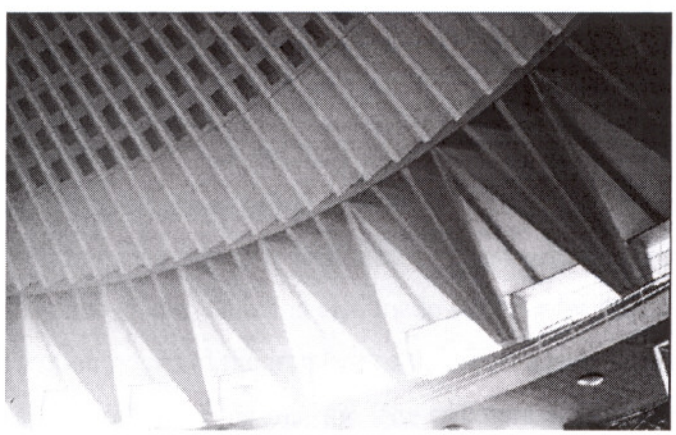

Figure 3- 35 Palazzo Dello Sport, Pierre Luigi Nervi, Rome
(http://www.structurae.de/DataGerman/str00052.html)

3.2.1.1. USE OF LIGHT AS A STRESSING ELEMENT ON STRUCTURE

The Finca Güell in Barcelona, designed by Antonio Gaudi, consists a simple but effective relationship between light and structure. Gaudi designed parabolic arches and between them windows are set on both sides. Here structure defines the places where light enters. Light entering from the windows between the arches creates bright and semi-bright textures on the parabolic arches of Finca Güell, making them perceptually stronger. A spatial rhythm occurs in the interior, which also has a role on the perceptual strength of structure.

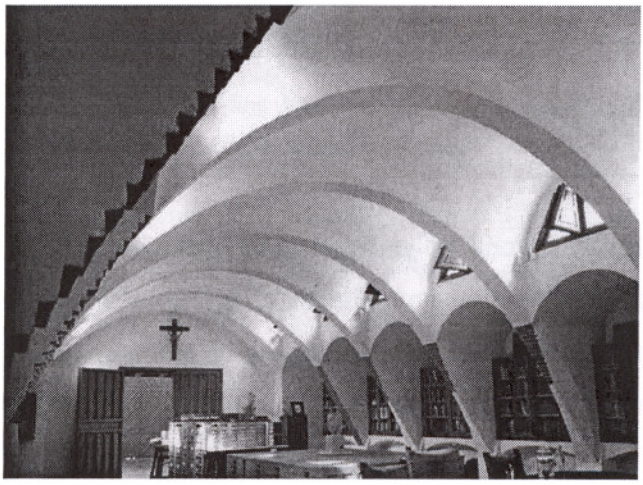

Figure 3- 36 Finca Güell, Gaudi, Barcelona

Frank Lloyd Wright is an important name for the use of light in architecture, since he investigated the integration of structure and light throughout his career. Light provided an important data for him in his architectural creations. He used light as an integral part of the structure and building interior. The light court in the Rookery Building in Chicago, Illinois is one of his early works. Wright was charged to design the interior of this building. He added a light court, constructed of iron and glass and created a highly lit atmosphere, which is also made stronger by the twelve chandeliers, hung on the intersection points of the iron beams that form a square. Wright also created a contrast between the colors of the interior. The structure is white and almost all the other components of the building interior are black. Here the effectiveness of light is made possible by the structure, by the spans allowable by the cast iron system, and the effects of that light, with the help of the artificial light sources, make the structural system perceptually powerful.

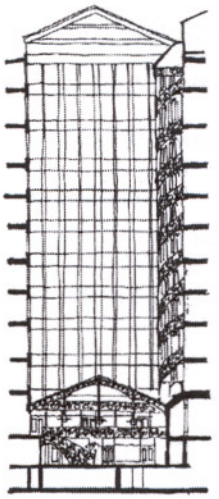

Figure 3- 37 The light court in Rookery Building (http://www.geocities.com/SoHo/1469/flw.html)
Figure 3- 38 Section showing the light court of the Rookery Building

The Johnson Wax Administration Building in Racine, Wisconsin, built from 1936-39 is another example of Wright's intention to combine light and structure. Here, Wright used special columns that do not need a physical connection to the outer walls for their support. Consequently, a gap between the outer wall and roof construction could be left blank, where the daylight could enter the interior space. Wright said for this building:

"*Glass tubing laid up bricks in a wall compose all the lighting surfaces. Light enters the building where the cornice used to be.*"(Lipman 1986 p41)

Figure 3- 39 The main workroom of the Johnson Wax Administration Building, Racine
(http://www.greatbuildings.com/cgi-bin/gbi.cgi/Johnson_Wax_Building.html/cid_johnson_wax_002.gbi

The gaps between the mushroom structures are filled with pyrex glass, which forms a second way for daylight to enter. The innovative structural concept allows light to penetrate to every part of the building. The overall quality of light in the interior (work room) is soft and free of shadows. The specially designed pyrex glass diffuses light, avoiding a feeling that illumination is framed by the roof construction. Light here was involved as a part of the inspiration of the structural innovations. This building is also an example of a specific building type; formed with the intention of allowing greater amounts of daylight to enter and to minimize the energy costs.

Another excellent example is the Guggenheim Museum in New York that is built in 1955-59. Wright designed a skylight on the upper floor, which brings natural light deep into the building. The skylight has a circular form and is an integral part of the structure. In order to achieve this, Wright continued the concrete structure on the upper floor. As the structure begins to turn according to the form of the skylight, it suddenly becomes a part of it with steel and glass. Artificial light sources were also placed on the edge of the circular form, where the concrete and glass structure intertwine.

Figure 3- 40 Guggenheim Museum, New York (http://www.thais.it/Guggenheim/image/006_it.htm)

Louis Kahn is another important name in the creation of an interrelated whole of structure and light. He used light as a dominant characteristic in much of his work. *"...His work was based on the spiritual and mystical aspects of experiencing a space and the use of light as the central element of these spaces..."* (Brogan 1997 p7)

For Kahn, mass was always analyzed rationally as a question of structure, while space was defined more mystically in terms of natural light, the energy that brought space to life. The manipulation of both structure and light was essential in making 'the room', and he believed that they could be made to work together (Brownlee, Long 1991 p212). In 1971 in an article he wrote:

"*The room is the beginning of architecture. It is the place of mind. You in the room with its dimensions, its structure, its light respond to its character, its spiritual aura, recognizing that whatever the human proposes and makes becomes a life. The structure of the room must be evident in the room itself. Structure, I believe, is the giver of light*" (Kahn 1971 p33)

Kahn experimented with systems that could work in buildings for achieving the integration of structure and light, such as perforated screen walls. The Kimbell Art Museum in Forth Worth, Texas and Yale Center for British Art are two of his latest works that are the result of Kahn's proficiency in integrating light to architecture. Kahn said:

"Artificial light is only a single moment in light...I can not define a space really as a space unless I have natural light. And that because the moods which are created by the time of day and seasons of the year are constantly helping you in evoking that which a space can be if it has natural light and can not be if does not. And artificial light- be it in a gallery or be it even in an auditorium- loses one a great deal." (Kahn 1961 p14)

Kahn's intentions in using daylight, his concepts of an architecture of sky lit rooms, was the main reason for getting the job for designing the Kimbell Art Museum (Brownlee- Long, 1991). Richard Brown, the director of the museum, developed the architectural program:

"...Natural light should play a vital part in illumination...The visitor must be able to relate to nature momentarily...to actually see at least a small slice of foliage, sky, sun, water. And the effect of changes in weather, position of the sun, seasons must penetrate the building and participate in illuminating both art and observer...We are after a psychological effect through which the museum visitor feels that both he and the art he came to see are still part of the real, rotating, changeable world..." (Meyers 1979 p61)

The museum forms a multiplication of vaulted units stuck together by defining enclosed courtyards, and vaulted gallery spaces developed by Kahn in the very early design sketches. The freehand sketch of Kahn in 1967 shows his ideas on the interaction of form, structure and light in the Kimbell Art Museum.

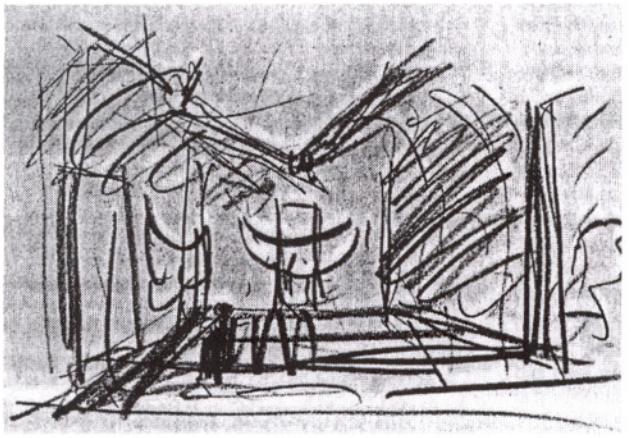

Figure 3- 41 An early sketch of the gallery of the Kimbell Art Museum (Millet 1996 p166)

The vaults are oriented on the north-south axis, and each has a slit in middle for daylight to enter. The aim was to stress the structure in daylight and reflect the light from the ceiling in order to control the quality and level of the light for the exhibited art pieces. After long studies Kahn and his staff developed two reflectors.[6]One is made of perforated aluminum for the lobby, bookstore, dining area, library and auditorium, where protection from daylight was not a problem; another is opaque for the galleries in order to block direct sunlight. The lighting concept for the museum is not only the vault and the reflector. Kahn described the lighting concept in a speech he gave in 1967:

"...Added to the skylight from the slit over the exhibit rooms, I cut across the vaults, at a right angle, a counterpoint of courts, open to the sky of calculated dimensions and character, marking them Green Court, Yellow Court, Blue Court, named for the kind of light that I anticipate their proportions, their foliation, or their sky reflections on surfaces, or on water, will give...Reflector is shaped to spread natural light on the sides of the vault. This light will give a touch of silver to the room without touching the objects directly, yet give the comforting feeling of knowing the time of the day..."(Kahn 1969 p15)

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[6] For further readings on the process of the development of the reflector:
M. Meyers, "Masters of Light: Louis Kahn", *AIA Journal* **68**, 1979

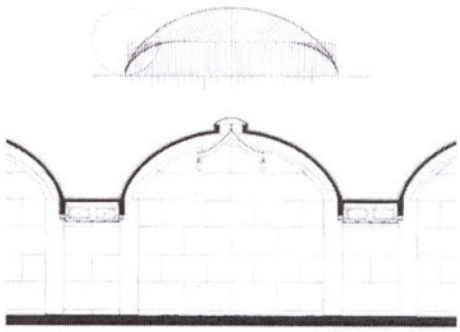


Figure 3- 42 The reflector in the gallery interior (*AD* **67**)

Figure 3- 43 Section showing the reflector of the gallery in the Kimbell Art Museum

Daylight that was not diffused was also used in order to define the structure. Kahn created thin slits, just two or four inches wide, so as not to cause a sensation of glare, at the end of the vaults, where continuous wall support is not needed (Jordy 1974 p43). Kahn called this thin plexiglass light bands 'lunettes'. Kahn's creation of the skylight system in the Kimbell Art Museum is unique in architectural history. He parted the structure and interconnected support and illumination altogether. In the Kimbell Art Museum the vault and the light are one, composing a whole together.

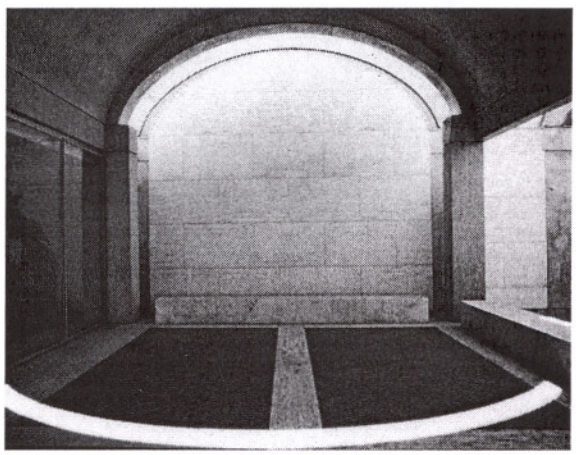


Figure 3- 44 Kimbell Art Museum (Brownlee and Long 1991)

3.2.1.2. LIGHT THAT CONCEALS THE STRUCTURE

That light conceals the structure may seem rather odd, since light makes things visible and reveals them. Sometimes, however, structure is purposefully or thoughtlessly hidden through the use of light or through the dynamics created by light. Sometimes the way the structure looks and the way it really works may not match each

other. When light conceals structure, the laws of physics come into play and determine the rules for structural support exist. Such illusions of light may be contrary to our expectation of structure, giving them unexpected appearances.

The Notre Dame du Haut in Ronchamp, France, designed by Le Corbusier is a good example of the intention of hiding the structure that creates a spatial quality. In Notre Dame de Haut light was used as an integral part of the structure, also as an uplifting element. The ceiling on the small chapel, bulging in the middle, seems to be heavy. And the south wall with the openings seems to be the supporter of the ceiling. However, there is a slit between the wall and ceiling, which is ten centimeters wide and allows daylight to enter. There is no connection between them. Here it is possible to see that light conceals the structure. In fact, the roof is supported by the reinforced concrete columns located inside the thick walls. The ceiling seems to be heavy, but in fact it is a light-weight structure, constructed like a wing of an airplane.

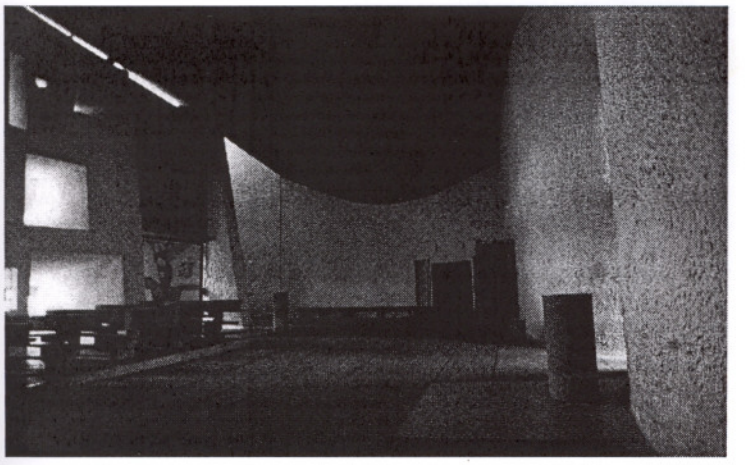


Figure 3- 45 Notre Dame du Haut, Ronchamp
(http://www.tulane.edu/lester/text/1890-Present/Modern/Modern.html)

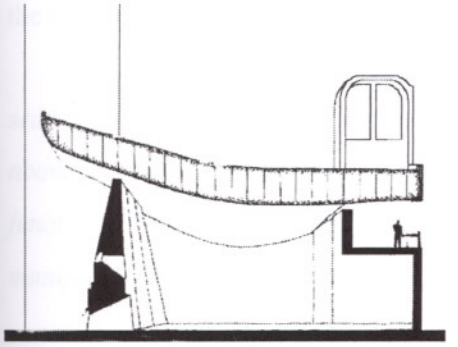


Figure 3- 46 Section showing the roof structure of Notre Dame du Haut (Millet 1996 p65)

Tadao Ando utilized light in The Light Church in Osaka in a similar way. Behind the desk in the lecture room is a cut-out that forms a cross, where light enters and creates a stunning brightness-contrast in the dim interior. It is quite surprising to perceive the upper walls that form the cross seems to be unsupported. There is no clue for the visitor about the structure by which they are carried.

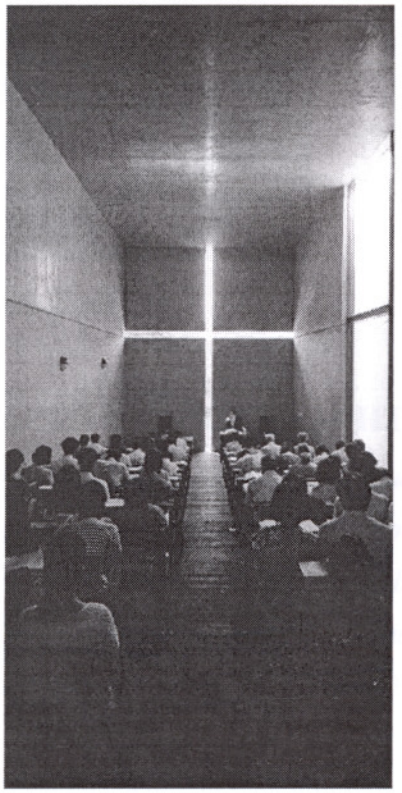


Figure 3- 47 Light Church, Tadao Ando

That kind of utilization of light can also be seen in classic architecture. In Bavarian churches, light is manipulated with the help of the form and color to conceal the structure. Millet wrote about the Zwiefalten church in Germany:

"...Columns and plaster are richly colored and textured in a technique called scagliola,[7] *and thus visually separated from the white pedestals below and entablatures above...They begin to float, exchanging their tectonic for a more purely ornamental function...The reality of the structure is not sacrificed for an illusion, rather structure is manipulated by means of light and color to a complete art form, the Bavarian rococo*

[7] Plastic work imitating marble, granite and etc.

church, in which painting, sculpture and architecture were pictorially fused into illusions of heaven descending right into its churches..." (Millet 1996 p66)

Figure 3- 48 Zwiefalten Church (Millet 1996 p57)

3.2.2. RELATING SPACES THROUGH LIGHT

"Space remains in oblivion without light. Light's shadow and shade, its different sources, its opacity, transparency, translucency, and conditions of reflection and refraction intertwine to define or redefine space. Light subjects space to uncertainty, forming a kind of tentative bridge through fields of experience..."

Steven HOLL (Holl 1989 p11)

Architectural space is an enclosure, in which light plays an important role. Such light has many characteristics. It is especially evident on an exterior wall, where inside and outside meet. Light can be used here to emphasize the connection or separation between the two. Light can also connect or separate interior spaces. These physical effects of light are related with the human perceptual system. When light is manipulated it also changes the perception of architectural space. When the lighting conditions of a room change, the perception of that room changes automatically.

To provide human comfort, most of the natural elements, such as rain, heat, cold, dust and so forth need to be excluded from the interior. However, light is a desired element. At this point peripheral or boundary elements become important. The regional climate factor is also an important criterion for the boundary element. It can be the reason for introverted or extroverted designs that result in open illuminated interiors or closed dim interiors. The window is the major linking tool between the inside and

outside. With its size, it creates the feeling of connection to, or separation from, the outside. Window placement determines the relationship to the landscape, while the amount of light that enters the space depends on the actual window features.

The function of a building also determines the nature of connection or separation in design. church interiors are usually dim since they require a dark atmosphere, separated from the outside world in order to inspire devotion. The success of design in a mosques, on the other hand, is connected to illumination. The three mosques of Mimar Sinan (Şehzade, Süleymaniye and Selimiye) have different lighting qualities. Each of them is mure illuminated than the one built before. Selimiye Mosque in Edirne, which is considered by Mimar Sinan as a work of his master period, has the most naturally illuminated interior derived from the constructive innovations.[8] Though both mosques and churches serve as structures for religious devotion, it is clear that the lighting needs and designs are determined by cultural or ritualistic beliefs.

Figure 3- 49 Süleymaniye, Mimar Sinan (*FOL* **9** p45)

[8] For further readings on the lighting conditions of mosques:
O. Bolak, "Camilerin Aydınlatılması Üzerine Bir Araştırma", (İstanbul Teknik Üniversitesi Yayınları, İstanbul, 1969)

3.2.2.1. CONNECTING SPACES THROUGH LIGHT

The difference between inside and outside is defined by the different amounts of light. The key to connecting spaces lies in creating the approximately equal lighting conditions. That is not only related to the sizes and locations of the openings. It is a design problem, including other factors as well, such as construction details, flora, and formal architectural typologies.

The Eames House in Pacific Palisades, designed by Charles Eames in 1949 is a good example of the connection between inside and outside, achieved by light. The house has almost a total transparency. The transition from inside to outside or from outside to inside, is carefully designed. The level of illumination is almost equal between inside and outside, so a smooth passing could be achieved. The flora plays an important role in reducing the level of the light outside. Also the shadows created by the flora on the inside and outside breaks the materiality of the elements at the boundaries.

Figure 3- 50 Interior of the Eames House (Massey 1990 p157)

Figure 3- 51 Eames House (Millet 1996 p97)

The Glass House of Philip Johnson, Built in 1949 in New Canaan, Connecticut reached an extreme in connecting inside and outside. Johnson used plate glass from floor to ceiling. The transparency of the house is enhanced by its placement directly to the ground. This is only interrupted by the solid brick stack containing the bathroom. The surrounding dense flora also helps by softening the daylight. Millet attached importance to the technique of lighting at night as the most striking effect in this house. The house is illuminated at night from outside by the spotlights that are mounted under the surrounding extension of the roof plate. Light reaches the interior by being reflected

by the pavement surfaces. While this may be an expensive choise, the visual effect is one of the maximum connection of inside and outside (Millet 1996 p98).

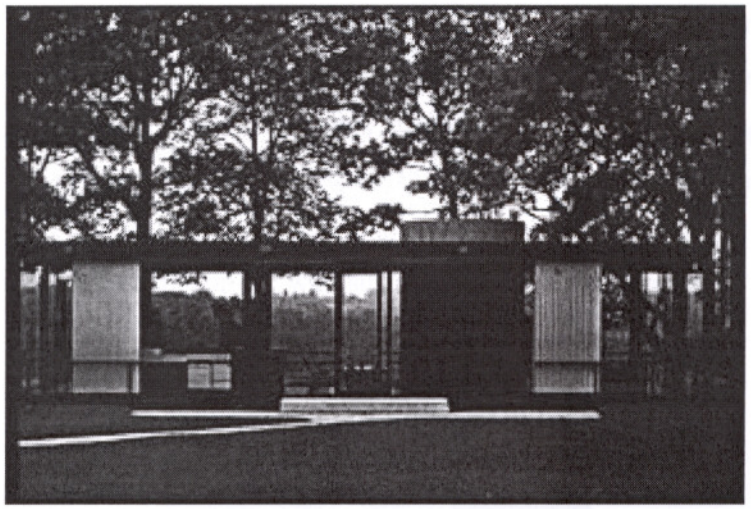
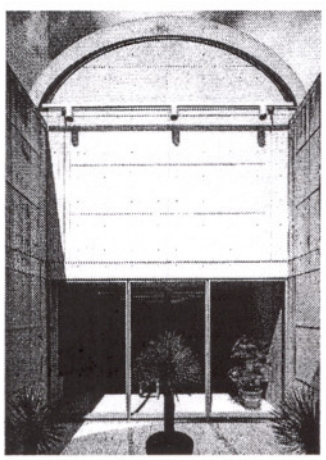


Figure 3- 52 Glass House, Philip Johnson

Another way of connecting inside and outside is to use courtyards. This tradition, especially in the hot regions, goes back to ancient times. That is a kind of extending the interior space to include the exterior. Use of courtyards help to modify light before it enters the building. Louis Kahn had used that old tradition in order to build a connection through light between inside and outside. In the Kimbell Art Museum, the lighting concept included that kind of articulation of light. He designed three courtyards, differentiating each other with their foliage, scale, and surfaces. The reflections through the interior spaces vary according to their characteristics. That was a vital part of the architectural program.



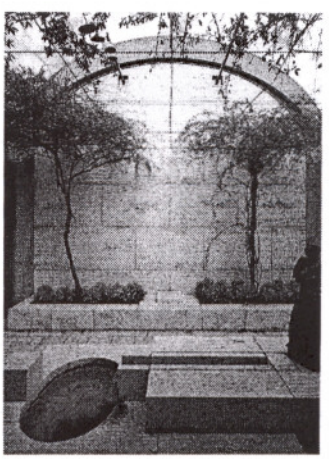


Figure 3- 53 Courtyard in the Kimbell Art Museum (Brownlee and Long 1991)

Figure 3- 54 Courtyard in the Kimbell Art Museum (Brownlee and Long 1991)

In the Yale Center for British Art Kahn achieved a connection between inside and outside in a different way. Daylight can reach the building through skylights. The distribution of light in the galleries is controlled (filtered through several layers), in order to provide the needed illumination levels for the art pieces. But in the lobby, light is allowed to penetrate through skylights directly, bringing the moving patterns of sunlight and changing levels that indicate the changing weather conditions outside (Brownlee and Long 1991 p212). It is possible to see the sky through the skylight. The light creates moving patterns on the wall surfaces, materials and forms.

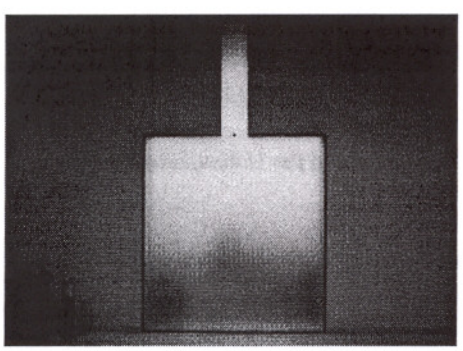
Figure 3- 55 Lobby of the Yale Center for British Art, Louis Kahn (Millet 1996 p98)

A similar approach of connection to the Kimbell Art Museum can be seen in the Neue Nationale Gallerie, designed by Mies van der Rohe in Berlin. The building is constructed from steel and glass and has a total transparency. The four facades of the building catch a connection between inside and outside, which derives from the construction techniques that provide a transparency. These seem somewhat uncomplicated to deserve much attention. However, the courtyard located behind the building, and related to the basement floor galleries, offers a magnificent aura, where light creates a smooth connection to interior through the flora, water, and sculptures.

Figure 3- 56 Neue Nationale Galerie, Mies Van der Rohe (hgk archive)

Figure 3- 57 Courtyard of the Neue Nationale Galerie (hgk archive)

Inside spaces can also be connected through the use of light. Here comes the term 'borrowed light' that defines the connection between inside spaces. Light is often borrowed from a space with direct access to light and delivered to an interior room. The Banco Popolare in Verona, Italy, designed by Carlo Scarpa uses this technique in order to illuminate the corridor spaces that do not have a direct access to daylight. He created openings between the corridor and office spaces and used a kind of glass that let light penetrate through yet also provided visual privacy.



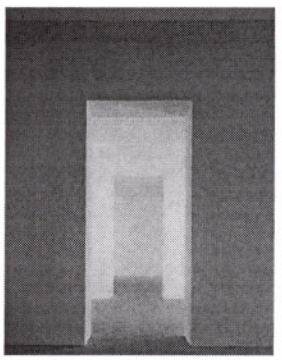


Figure 3- 58 The openings between the corridor and office spaces in the Banco Popolare, Carlo Scarpa (Millet 1996 p112)

Figure 3- 59 The smooth uses of color and lighting conditions creates a visual connection between framed spaces, Dan Flavin (http://www.diacenter.org/exhibs/flavin/images.html)

3.2.2.2. SEPARATING SPACES THROUGH LIGHT

Artificial light is the most obvious separator of inside and outside. Electric lighting produces brightly lit interiors and creates big differences in illumination levels between inside and outside. Certainly that is not an intended creation. There are also

situations where a separation between inside and outside, or inside spaces aimed in order to avoid the disturbing light of hot climates, to create illusions, to enhance the spatial qualities, or to create an aura of an introverted space. The element of this separation can either be artificial light or daylight.

Louis Kahn, who always considered light and its effect in space, developed an architectural language of separation between inside and outside through light. Light quality and comfort were the important criteria for him. As mentioned before he used perforated screen walls in order to control the quantity of light that enters the space. He said:

"...I came to the realization that every window should have a free wall to face. This wall receiving the light of the day would have a bold opening to the sky. The glare is modified by the lighted wall, and the view is not shut off. In this way the contrast made by separated patterns of glare which skylight grills close to the window make is avoided..." (Ronner and Jhaveri 1987 p322)

Kahn planned the buildings in Dhaka for the government of Bangladesh. These buildings show his intentions in controlling light. The Suhrawardy Central Hospital in Dhaka has an entrance verandah that is used as an absorber for the strong sunlight. Views from the lobby are controlled by the outer walls that receive reflected light from the concrete floor and ceiling. Kahn's development of a free wall outside was a unique approach to the problem of controlling light.

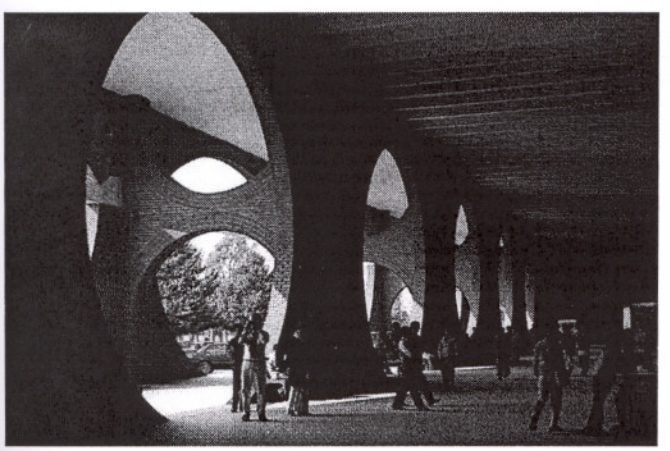
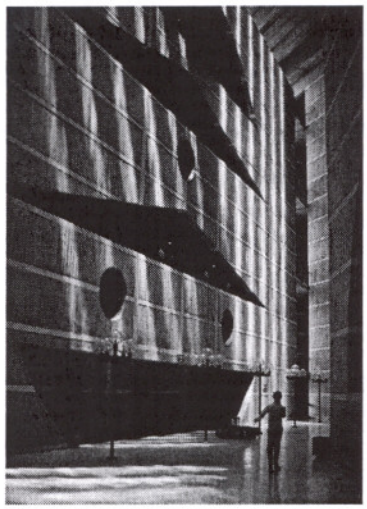


Figure 3- 60 The entrance verandah of the Suhrawardy Central Hospital, Louis Kahn, Dhaka (Brownlee and Long 1991)



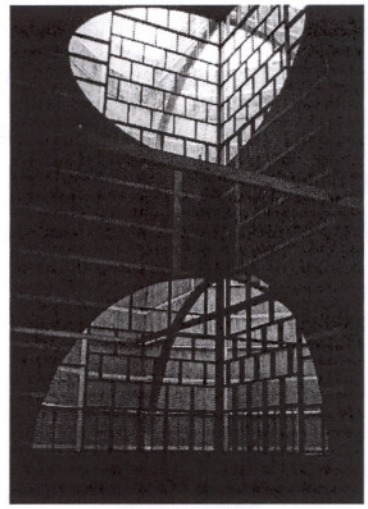
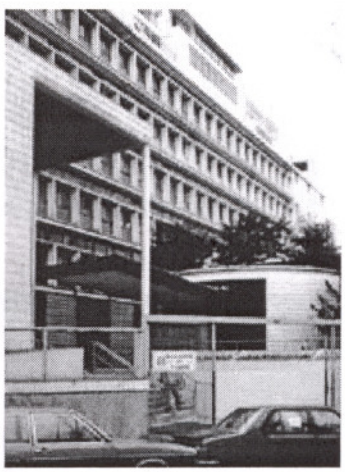


Figure 3- 61 National Assembly Building ambulatory, Louis Kahn, Dhaka (Brownlee and Long 1991)

Figure 3- 62 North entrance staircase

Le Corbusier also developed several ways of controlling light and separating inside from the outside. The brise-soleils[9] in Cite de Refuge in Paris (1929- 33) and the ondulatories[10] in La Tourette Monastery show his ability in realizing this.



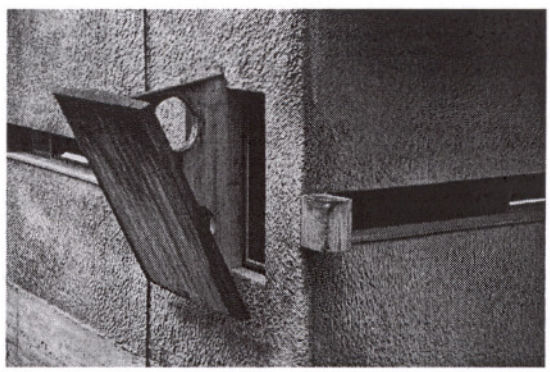


Figure 3- 63 Cite de Refuge, Le Corbusier

Figure 3- 64 La Tourette Monastery, Le Corbusier

Jean Nouvel showed the technological way of separating inside and outside in the Institut du Monde Arabe in Paris. The huge south-facing wall has been designed as a 60m screen. Its appearance seems to be Islamic in decorative terms. It is, however, an

[9] Large screens placed in front of the fenestration in order to block direct sunbeams.
[10] Vertical division panels placed at varying intervals according to the modulor.

ocular device, made up of numerous and variously dimensioned metallic diaphragms set in pierced metal borders. These diaphragms operate like a camera lens to control the sun's penetration into the interior of the building. The changes to the irises are computer controlled according to the time of the day and the seasons. The changes on the diaphragms can be observed on the facade outside and that creates a feeling of a lively building. The main concept of this building seems to be a "play of light".

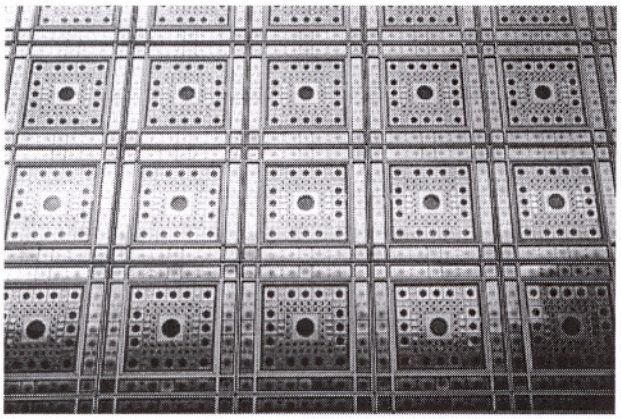


Figure 3- 65 The façade of the Institut du Monde Arabe

Another striking example is from Netherlands. Joost van Santen is a visual artist and works with natural light, intertwining it to architecture. He benefits from technological tools related to light and also builds his own instruments. He realized an artwork in his studio with the help of a tool that he calls a light module[11].

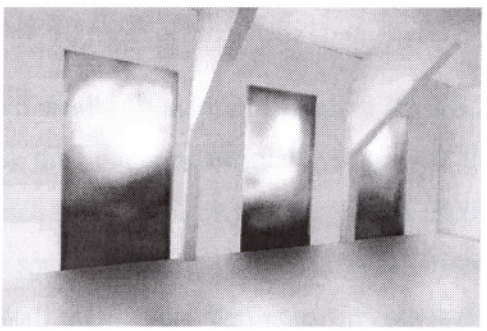


Figure 3- 66 Studio, Joost van Santen

Figure 3- 67 Studio, Joost van Santen

[11] Light modules are tools in which images appear under the daylight. These images can be projected onto a translucent screen. They can be put together to form 'walls of light'. (Santen 1998)

The light modules are placed on to the three windows and daylight casts images from color filters and reflectors on to translucent screens, hung inside the three windows. The projected images change continuously, depending on the season and the time of day. At the same time they present the technological and amazing ability of separating inside and outside.

In the Rio Grande Nature Center and preserve in Albuquerque, New Mexico, designed by Antoine Predock in 1982, the windows are designed so that they are perceived as framed pictures of the surrounding landscape that were hung on the walls. One only realizes that illusion when something begins to move in the view. Windows in the building are placed at different heights to frame specific views for the visitors of different height. The windows create separateness. It is achieved through carefully designed lighting in the interior and at the boundaries between inside and outside.

Figure 3- 68 A window to the outside in the Rio Grande Nature Center (Millet 1996 p103)

Figure 3- 69 The interior of the Rio Grande Nature Center (Millet 1996 p102)

Similar illusions define the art of James Turrell. As mentioned before (in 2.3.2) Turrell, in his art works, tries to deceive or trick the human perceptual system with the help of light. He created many installations which seem to be pictures or planes on the wall, but which in fact are three- dimensional spaces. Iltar is one of his installations, which appears as a flat gray panel hung on a wall that is very luminous. In fact it is a hole on the wall or a gate to the room behind the wall. Here light materializes something that does not exist. To achieve this effect the light levels of the two rooms are balanced according to their sizes and proportions. Illumination levels must be very low for achieving that kind of effect. Color is also a tool, used to realize these kinds of illusions.

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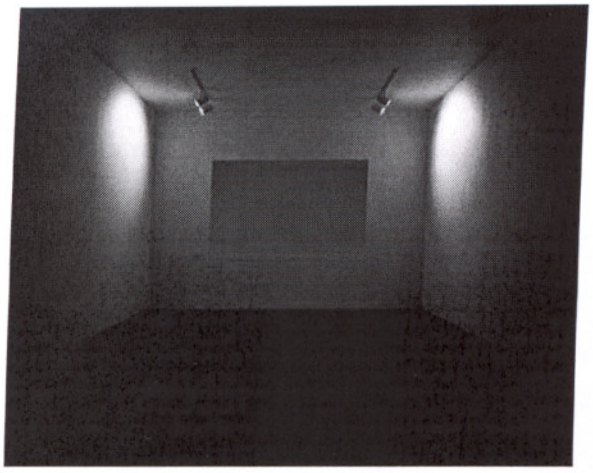


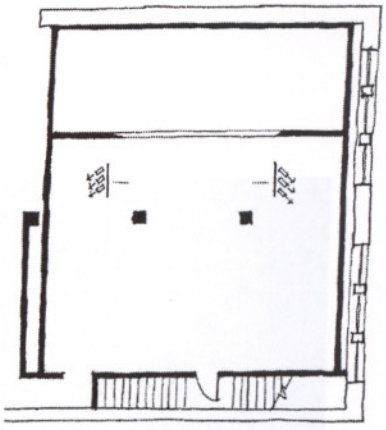


Figure 3- 70 Iltar, James Turrell (http://www.arc.cmu.edu/portfolio/v/documents/light/)

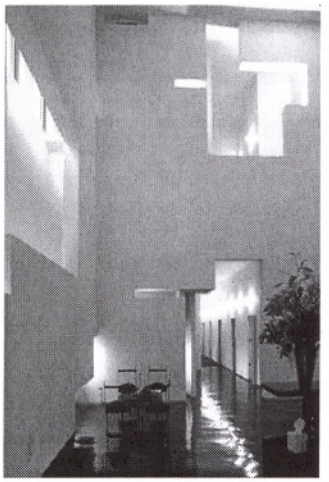
Figure 3- 71 Iltar, James Turrell (http://www.arc.cmu.edu/portfolio/v/documents/light/)

The D.E. Shaw Company in New York, designed by Steven Holl in 1992 consists of spaces where inside and outside are separated. The reception area of the building shows Holl's way of perceiving architecture. In his book Anchoring he says:

"...If we consider the order (the idea) to be the outer perception and the phenomena (the experience) to be the inner perception, then in a physical construction, outer perception and inner perception are intertwined. From this position experiential phenomena are the material for a kind of reasoning and that joins concept and sensation. Outer perception and the inner perception are synthesized in an ordering of space, light and material..." (Holl 1989 p11)

The reception room has no visual connection to the outside. Light also does not enter directly into the room. Holl set interior walls parallel to the exterior walls. Light being reflected and colored enters from the slits between two parallel walls.

Figure 3- 72 Chapel of St. Ignatius, Steven Holl, Seattle (http://www.walrus.com/~sha/)



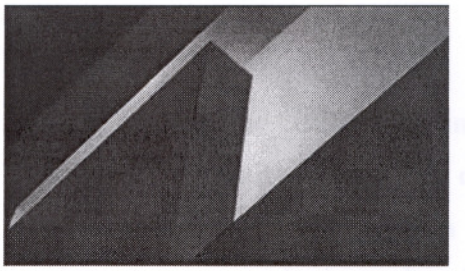


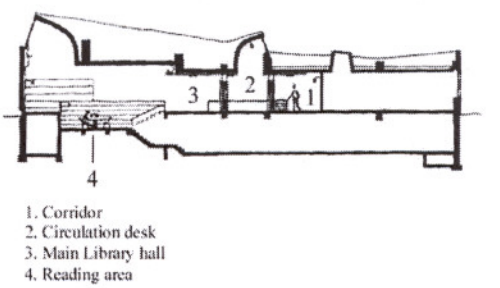
Figure 3- 73 D. E. Shaw& Co Offices, New York (http://www.walrus.com/~sha/)

Figure 3- 74 D. E. Shaw& Co Offices, New York (http://www.walrus.com/~sha/)

3.2.2.3. DIFFERENTIATING SPACES THROUGH LIGHT

It is possible to characterize different places through light in a total space. It is a kind of classification derived from the functional differences. Light here again is a tool that establishes the spatial relations and the dynamics that are needed to experience the space.

That is achieved in the Rovaniemi Library in Finland, designed by Alvar Aalto in 1963. The library consist of several different areas with distinct functions, such as circulation corridor, information desk, library hall, and reading area, which are in a total space, where no separating walls exists. The differences in functions is stressed with the lighting designs of both natural and artificial light. The circulation corridor is defined by a line of artificial light sources.



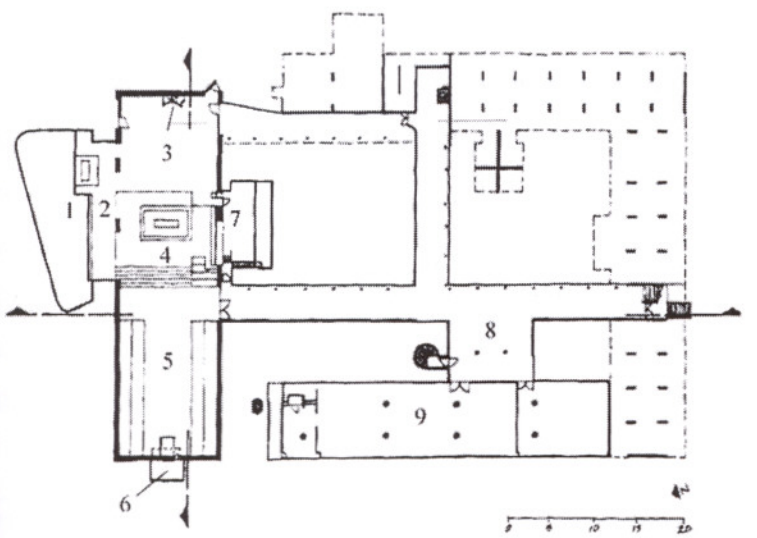
1. Corridor
2. Circulation desk
3. Main Library hall
4. Reading area

Figure 3- 75 Rovainami Library, Alvar Aalto (http://www.iit.edu/libraries/grc/architects/aaalto.html)

Figure 3- 76 Section showing the skylights (http://www.iit.edu/libraries/grc/architects/aaalto.html)

The information desk and the reading area have their own skylights that are orientated in the opposite directions so they could have different amounts of light that create the brightness differences. The rest place is the library hall, illuminated by artificial light sources that are placed randomly and differ from the light sources in the corridor.

The La Tourette Monastery in Lyon, France, designed by Le Corbusier in 1952, owes much to light. A similar effect of light that differentiates the space can be observed in the sanctuary. The sanctuary is rectangular, with an addition of a piano-shaped room that consists of the Chapel of the Holy Sacrament and private altars behind it, on the north wall. Nearly half of the sanctuary on the west side is reserved for the choir of monks. The dimness is broken by a light cannon above and behind the seating places of the monks are slits, where daylight enters softly in several colors in order to provide light for reading. The Chapel of the Holy Sacrament has a totally different lighting quality as being the brightest part of the sanctuary. This is achieved by three light circular cannons, which are painted in three different colors. The east wall of sanctuary also differs from the general dim atmosphere with a slit from floor to ceiling that marks the public entrance.



1. Private Altars
2. Chapel of Holy Sacrament
3. Confessional
4. Main Altar
5. Choir pews for monks
6. Organ
7. Sacristy
8. Atrium
9. Refectory

Figure 3- 77 Church level plan of the La Tourette Monastery

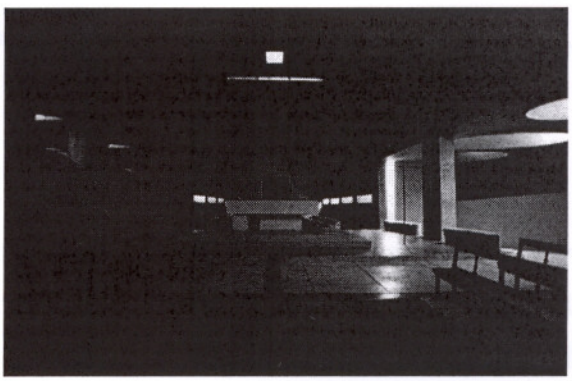


Figure 3- 78 The west wall of the chapel of La Tourette (http://arch.eu.edu/a/end/2423/slides.htm)

Figure 3- 79 Interior of the chapel (http://arch.eu.edu/a/end/2423/slides.htm)

3.2.3. USE OF LIGHT AS A MEANS OF DIRECTION

Human, as phototropic[12] beings react to light. Brightness is the key for creating movement with light. The brightest view in a space catches ones attention first. In architecture the effect of phototropism influences the movement of people from one place to another. Experiments show that light is the strongest stimulus for movement among the alternative choices[13].

According to William Lam orientation is a need for human beings. Continuous visual information is required for all physical activities, such as walking, running or working. In a space the human mind searches for clues that give orientation for experiencing the inner atmosphere. When these clues are distorted or absent (disorientation), the effect can be very disturbing like it is in the Guggenheim Museum of New York (Lam 1992 p21-22). Light can fulfill that need with an expert use, when the knowledge of perceptual psychology is regarded during the design stage.

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[12] The term comes from the ancient Greek. It means 'to seek light'. Scientists use the term 'phototropism' to designate the movement of plants and animals toward light. (Michel 1996)

[13] Lots of experiments have been made on this subject. One of them is the Taylor and Socov Experiment. For further readings: P. Sengbush, 'Phototropism', http://www.rrz.uni-hamburg.de/biologie/b_online/e32/32b.htm

Although the ability of light to attract attention is often used to indicate movement, there are many other cases in which its pointing-out ability is utilized: *"...An obvious example is an auditorium where the combination of dim house lights and bright stage lights virtually compels attention to the doings on the stage while the stage lighting itself leads the eye through the action of play or dance..."* (Rea and Thompson, 1992 p502)

3.2.3.1. LIGHT THAT CREATES A FOCUS

In general, high-brightness lighting that produces sharp contrasts and sharply defined outlines is more forceful than softly graded lighting; even graded light increased to the same brightness. Contrast can be useful in picking out objects or areas for special attention, however it can also be disturbing when the attention is paid to the wrong places. In the city, brightly lit monuments are focal points, such as the Clock Tower and the Municipality Building in İzmir, and the Bosphorus Bridge in İstanbul. Floodlighting (2.2.2) was developed for the same reason in the 1920's in America. Because light draws attention, each of the commercial buildings became highly lit, in order to be a focal point in the city. Smaller structures can also serve as focal points for a region of the city. The vaulted form, constructed of steel in Hisarönü Bazaar in İzmir, creates a bright passage at night that draws attention and encourages a movement along the street.

It is not only artificial light, but also daylight which can create a focus through orientation and careful use of materials. Again, brightness and contrast play a major role here.

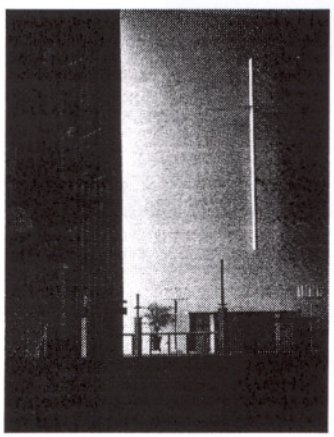
In the Church of Vuoksenniska, designed by Alvar Aalto in 1956, the altar and three crosses behind it are the focal points. In Lutheran churches three things are important: the pulpit, the altar table, and the cross. In this church these were aimed to be focused. In order to achieve this Aalto designed a light cannon, forms of three openings in different sizes, over the pulpit and two light niches on the north wall in the right of the altar. The wall, the ceiling, the altar and the crosses are white in color. Expression is realized through the shadows, cast by the light of the light of the cannon and niches. Electric light also helps to that effect with two incandescent lamps, mounted above the

altar table. Other parts of the church have a dim character, creating a stronger effect on the altar.

Figure 3- 80 Church of Vuoksenniska, Alvar Aalto

Figure 3- 81 Light niches on the north wall

Another Lutheran church in Minneapolis, Minnesota, designed by Eliel Saarinen in 1949 utilized daylight in order to achieve a similar effect. Again the cross is a focal point in this church. Light comes from the vertical opening from floor to ceiling on the left of the altar and washes the white cross and the dark brick wall behind it. The cross is made of glazing bars that are combined diagonally so that it could reflect the light to the worshippers (Millet 1996). Incandescent reflector lamps are mounted in front of the side window in order to provide the same effect at night.



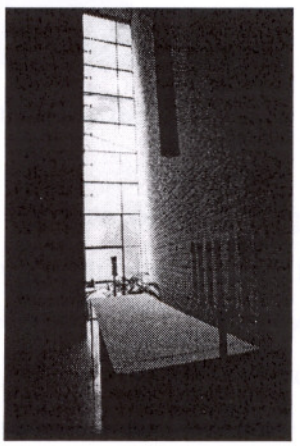


Figure 3- 82 The altar of the Christ Church Lutheran, Eliel Saarinen

Figure 3- 83 Side window which illuminates the cross behind the altar

The Jewish Museum in Berlin, designed by Daniel Libeskind and opened recently consists of several metaphors, which tries to describe the holocaust years and the pains of the Jewish culture. The building includes a tower, called Holocaust Tower, which is thirty meters in height and begins underground from a small door. The interior is absolutely dark, so that one needs some time to see clearly while the eye adapts to the darkness. The only opening is a slit that is located above, near the end of the tower on the south façade. If you look above to the slit, you get disturbed against the glare, caused by the total contrast of interior and exterior. Actually that kind of effect is criticized, because glare is something that is not wanted, since it threatens the human comfort. However discomfort is something that is intended in this space, in order to make people realize the wildness of the holocaust.

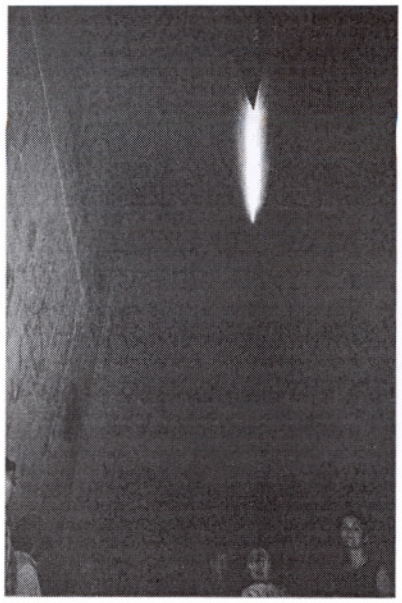


Figure 3- 84 Holocoust Tower, Jewish Museum (hgk archive)

In the Kresge Chapel in Massachusetts Institute of Technology Campus in Cambridge, designed by Eero Saarinen, the altar was again designed as a focal element. An opening above the altar let light penetrate interior space in a spotlight effect, illuminating meanwhile the sculpture, formed of glazing particles hung down the edges of the circular opening. The effect can be seen from the entrance and is so lively that the altar serves also as a visual invitation element.

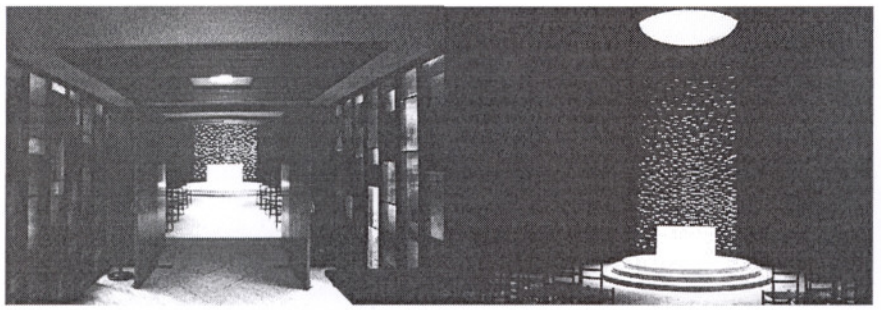


Figure 3- 85 Kresge Chapel (http://www.bluffton.edu/~sullivanm/kresgec/kresgec.html)

The Metropolitan Cathedral in Managua, Nicaragua, designed by Ricardo Legorreta is another example where the use of light that creates a focus. The dome structure in the memorial hall has small circular openings on its surface. Light penetrating through them turns into a linear spot effect in the interior. Arising from the form of the dome each linear spotlight runs into same thing, the sculpture of Christ in a glass lantern located in the middle of the hall.

Figure 3- 86 Metropolitan Cathedral (*AD* **67**)

Evry Cathedral in France, designed by Mario Botta is also a place where light plays a major role in spatial relationships. Light penetrating from the skylight above, creates light, and semi- light areas by carrying the structural references of the skylight to the brick walls. The effects on the walls are so adjusted that it points out something in the interior: the altar. The interior has a general level of brightness, except the light figures on the walls and the altar. The brightness of the altar is heightened with the diffused light entering behind it. Besides the brightness of the altar, the directions of the

figures on the walls make it a focal point. That is an indirect relation, like the information signs in a building.

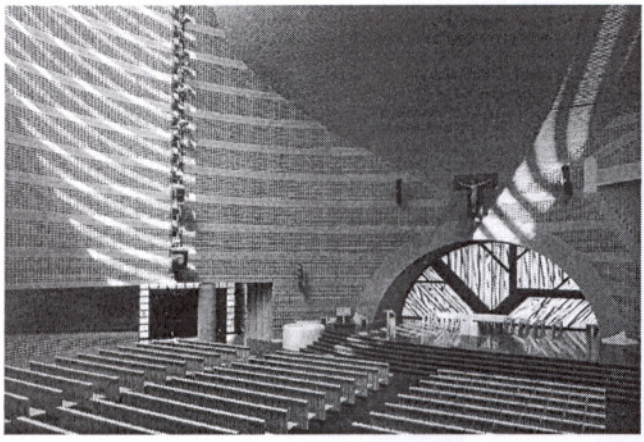


Figure 3- 87 Evry Cathedral (*AD* **67**)

The installation of Maurizio Nannucci 'Mehr als das Auge sehen kann- More than meets the eye' tries to create a relationship between the passenger and structures of urban world. This installation has been held several times. Last time it was in Munich in 1999 at the European Patent Office.

Figure 3- 88 Mehr als das Auge sehen kann, Munich (hgk archive)

Figure 3- 89 More than meets the eye, Wien (http://art.dada.it/nannucci/body.html)

3.2.3.2. LIGHT THAT ENCOURAGES MOVEMENT

There are varying reasons for the feeling of movement, encouraged by light. Brightness can be a reason. As mentioned before, people prefer to move to the brightest view in a scene. Brightness is a design component. Designers must decide the brightest areas in a space, according to the intended dynamics of space. High contrast can be another reason. That contrast can be in color, size or brightness. Pattern also acts as a

focal stimulus. Architectural environments are full of patterns. Windows, walls, sidewalks, and so forth are part of the patterned architectural environment. A dominant pattern can create a different identity and draw attention.

Figure 3- 90 Freie Kirche, Frankfurt, rich pattern attracts attention (hgk archive)
Figure 3- 91 Scala Regia (http://www.tulane.edu/lester/text/)

The architectural form or the form of the surrounding can also heighten the feeling of movement. For example, to put a frame between the viewer and visual object makes the object appear more effective. Lou Michel gives an example of framing in creating a focal point. He describes the Scala Regia in the Vatikan:

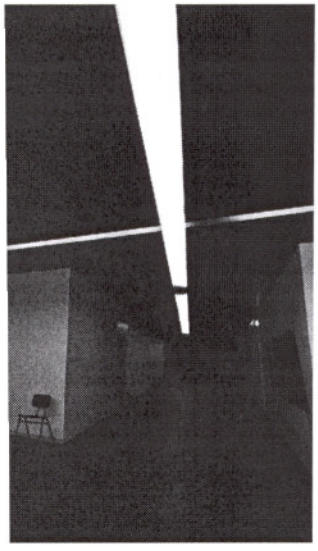
"...Arriving at its base, the observer then discovers another visual objective, which in turn attracts attention up the stairs of the Scala Regia. To achieve this, Bernini covered (and darkened) the entire stair with a barrel vault, but broke the excessive length of the ascent by inserting a window and landing at midpoint where light interrupts the darkness. Under the vault of the second stage, the stair dims again. At the end of the space, a stained glass window breaks the darkness like a beacon of colored light. The Constantine sculpture, the midlanding, and the window are each dominated by light. They forcefully rhythmically draw the eye to those pivotal locations in space..." (Michel 1996 p210)

The motivating factor of movement can also be the arrangement of the artificial light sources, like in the Neue Staatsgallerie in Stuttgart, designed by James Stirling.

ıe information desk is a rotunda located on the left of the axis between the entrance d staircases. In order to draw attention to the information desk artificial light sources ɛ used on the ceiling. The interior of the rotunda is also bright to influence movement.

ure 3- 92 Neue Staatsgalerie, Stuttgart (hgk archive)

The Jewish Museum in Berlin can be given as another example. The linear light ırces on the ceiling form the route for the visitor in the museum. In certain locations, h as at the holes on the turning points of the zigzag form, the linear light sources rease in size according to the size of the paths around the holes.



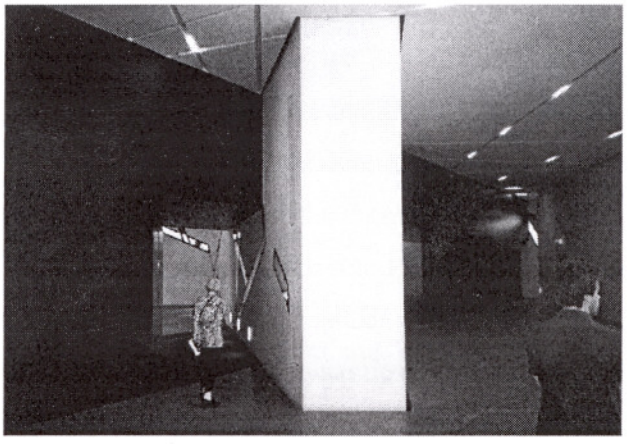


Figure 3- 93 Jewish Museum, Daniel Libeskind (hgk archive)
Figure 3- 94 Jewish Museum, Daniel Libeskind (hgk archive)

In the Jewish Museum the main staircase to the galleries from the basement floor n important part of the building, where the designer tried to create a metaphor. ɛskind describes the staircase as 'a path to the illuminated future, where no pain

exists'. He benefited from daylight here, in order to realize this metaphor and created a feeling of movement in the staircase. Light enters from a slit above and washes over parts of the staircase void. That causes a great brightness, which is the reason for the feeling of movement. Returning from the galleries, the viewer is confronted by darkness, creating fear and hesitation. However, this is the only way to get out of the building, which seems an intended part of design, like all the other disturbing experiences in the building.

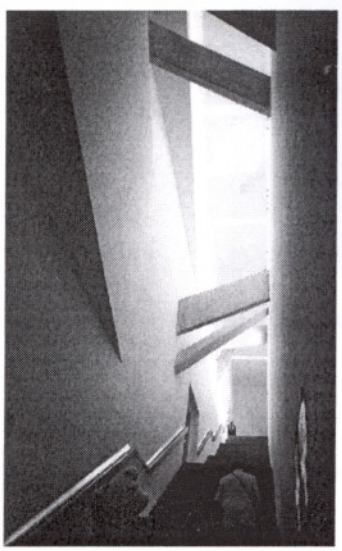


Figure 3- 95 Staircase to the galleries, Jewish Museum (hgk archive)

Figure 3- 96 Staircase, Jewish Museum (hgk archive)

The Camino Real Hotel in Ixtapa, Mexico, designed by Ricardo Legorreta in 1981 provides an atmosphere of light and color. In the corridor he framed the light sources in boxes so that they create a pattern of light on the floor and ceiling. That creates a rhythm of brightness and encourages movement. Ricardo Legorreta is famous for his creations of architecture, where light and color are essential parts of design. He believes that light is a fundamental tool in achieving spatial dynamics. A poem of him is quoted below in order to discuss his opinions on light and space:

"Light and spirituality go together
Light and architecture go together
Light gives value to walls, windows, materials, textures, and colors.
During hours, days, and seasons
It changes space

And is a fundamental tool for shaping our emotional response.
Light, both natural and artificial, cannot be ignored
Nor used with a technical mind.
Light belongs to the heart and to the spirit..." (Legorreta 1990 p43)

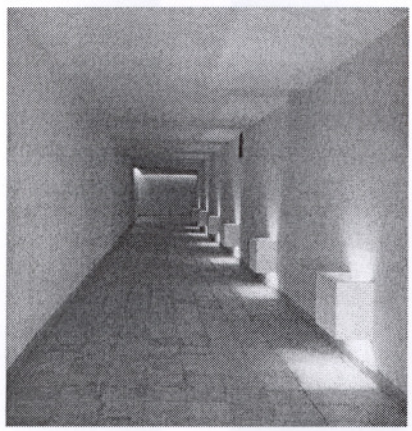


Figure 3- 97 Camino Real Hotel (Legorreta 1990)

The installation of Maurizio Nannucci held in Munich in 1995 explains how brightness can influence movement. The long corridor, blue in color, with a dim atmosphere is lit by recessed linear fluorescent sources on the left side. The capitals of light on the floor cause curiosity. However, the most effective component of the installation, that creates movement, is the very bright light at the end of the corridor.

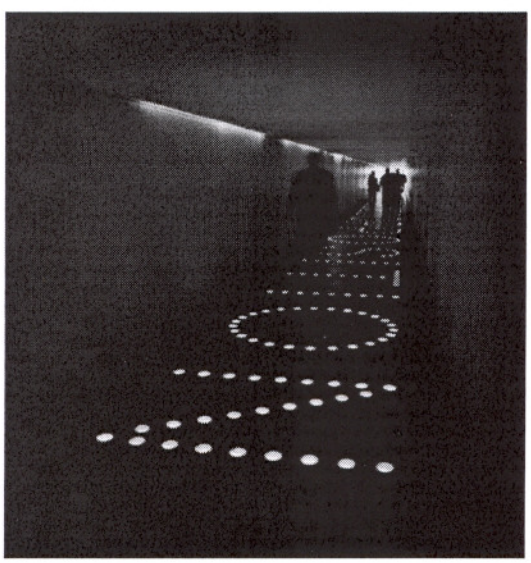


Figure 3- 98 Noits opposed art sees trades opposition, M. Nannucci, Munich (http://art.dada.it/nannucci/body.html)

A very similar use of light is in the staircase of the Pawson House in London, designed by John Pawson.

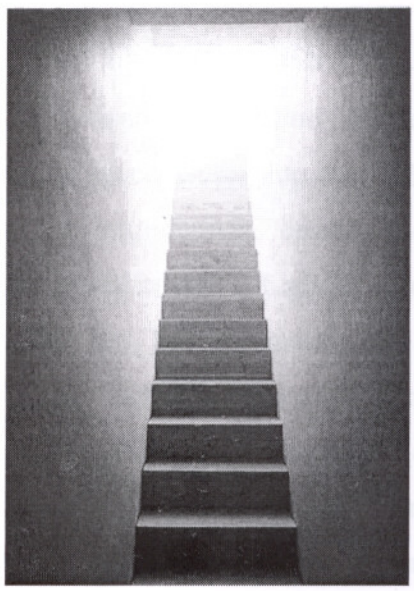


Figure 3- 99 Pawson House (*AD* **67**)

Figure 3- 100 Bergama (*FOL* **9**)

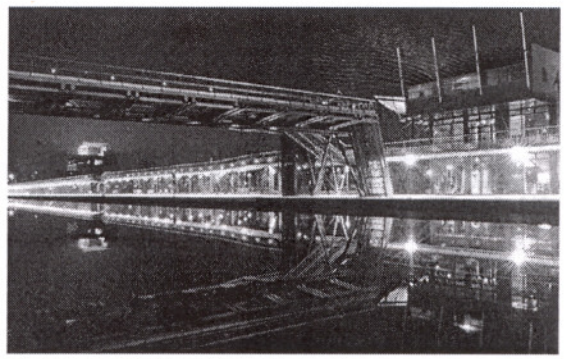


Figure 3- 101 Alte Pinakothek, Munich (hgk archive)

Figure 3- 102 La Villette at night, Bernard Tschumi, Light defines the way (Thomsen 1994 p170)

3.3. A GRAPHICAL ANALYSIS ON EFFECTS OF LIGHT IN SPACE

CONNECTING SPACES THROUGH LIGHT

The visual connection between spaces is an important requirement for experiencing space. Supplying the ability of seeing, which is a must for perception, is not the only requirement, besides the fluidity and smoothness are needed between spaces for visual comfort. Light is a powerful tool for that kind of connection between spaces. The key lies in creating the equal lighting levels between spaces which is wanted to be connected each other. Exterior spaces are always brighter than the interior spaces, since the exterior is under the effect of direct sun light. This great difference in the lighting levels of interior and exterior can be reduced through a sensitive design process. It is possible to soften the transition between inside and outside by controlling the penetration of light into space.

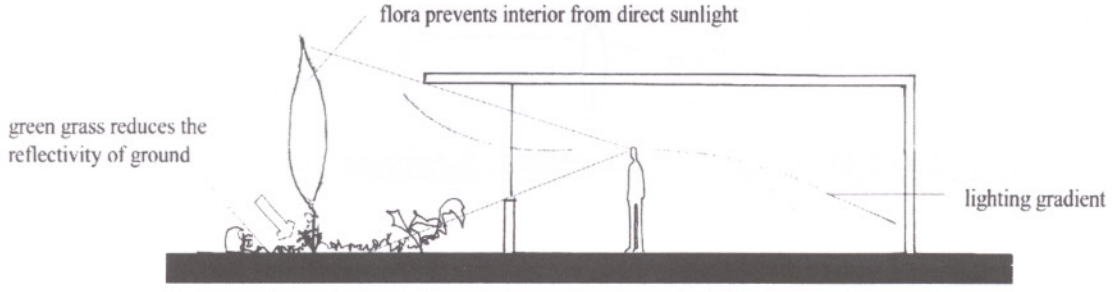


Figure 3- 103 Use of flora for lighting comfort

The most effective ways are to use shades, louvers, baffles and light shelves. Light to the interior comes not only from he sun above. The reflected light from the ground could be account for more than the half of the total amount of light in the interior. The reflected light could cause glare in some conditions, which is the main reason of visual disability in space. The reflectivity of the ground around the space could be reduced through green grass or water element.

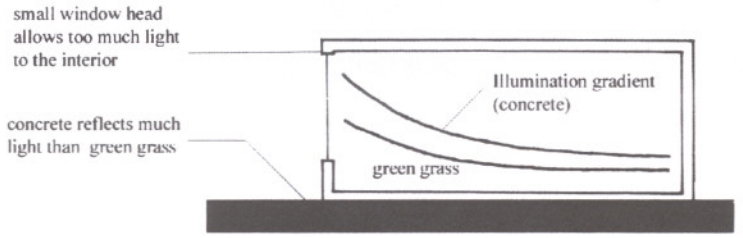


Figure 3- 104 Illumination gradient differences according to the material of the surrounding

Color also is important, since it determines the reflectivity of the boundaries of space. Lighter colors have a high level of reflectance than darker colors. Color could help by making the illumination gradient stable that means the lighting level could be constant in the interior.

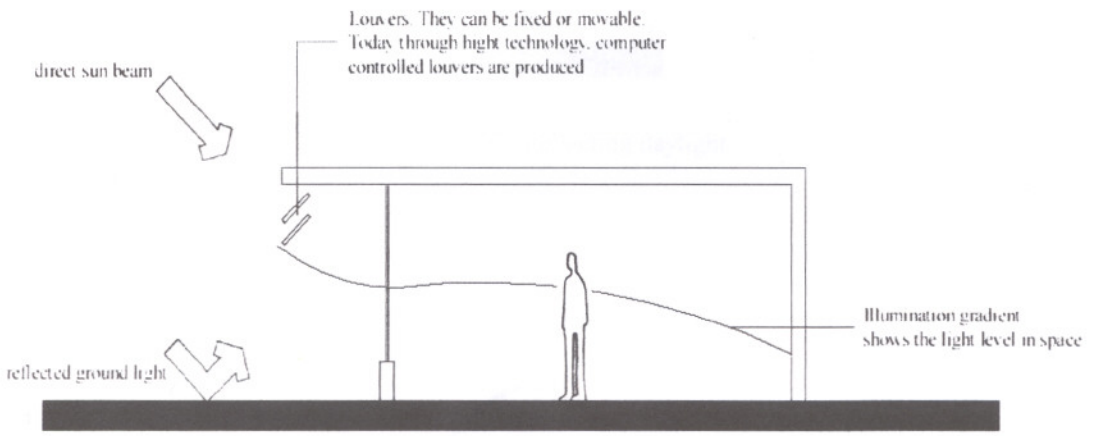


Figure 3- 105 Controlling daylight

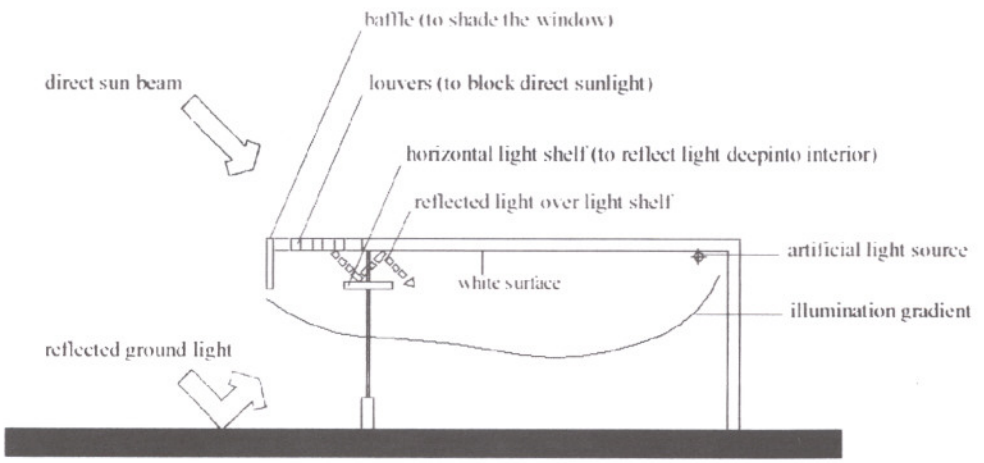


Figure 3- 106 Controlling daylight

It is also possible to reflect daylight in another way. The openings can be formed in a shape that they reflect light toward interior. Openings for that purpose can be covered with materials of high- reflectance and this would increase the amount of reflection.

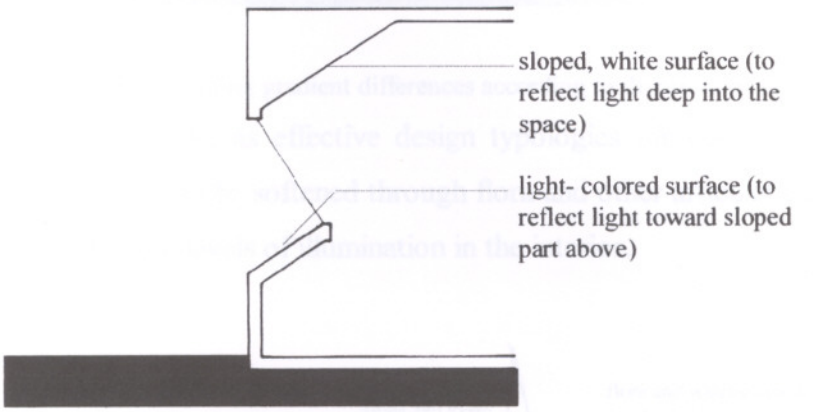


Figure 3- 107 Reflecting daylight

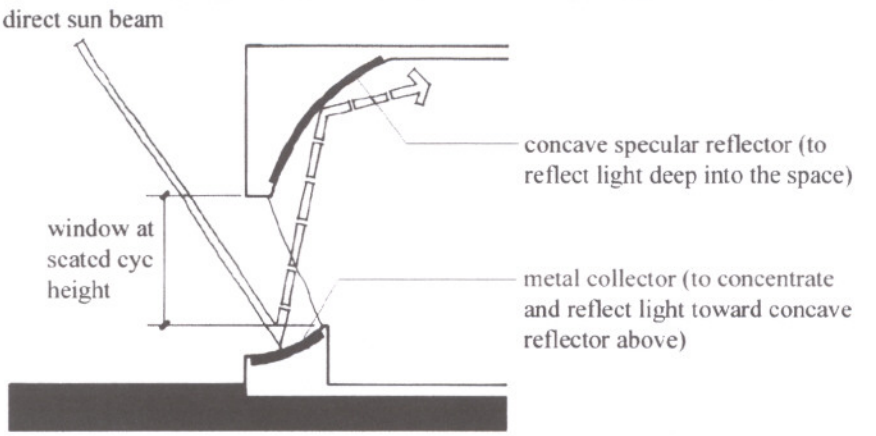


Figure 3- 108 Reflecting daylight

Artificial light also could help by making the illumination gradient stable. The amount of light decreases at parts of space that is far from the openings. Artificial light fixtures can be used in addition to daylight in order to increase the level of illumination at these parts.

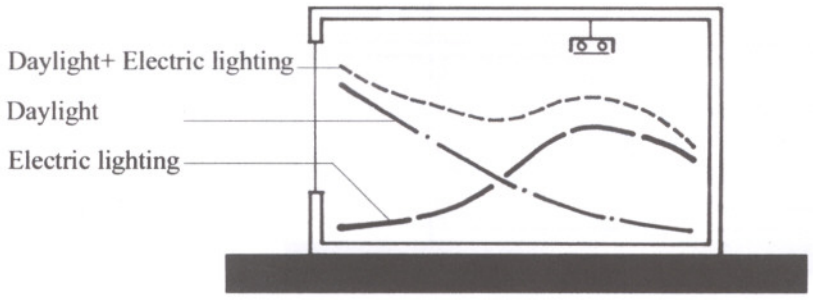


Figure 3- 109 Lighting gradient differences according to illumination type

Courtyards can serve as effective design typologies for connecting inside and outside. The bright light can be softened through flora and other articulations in order to reach approximately equal levels of illumination in the interior.

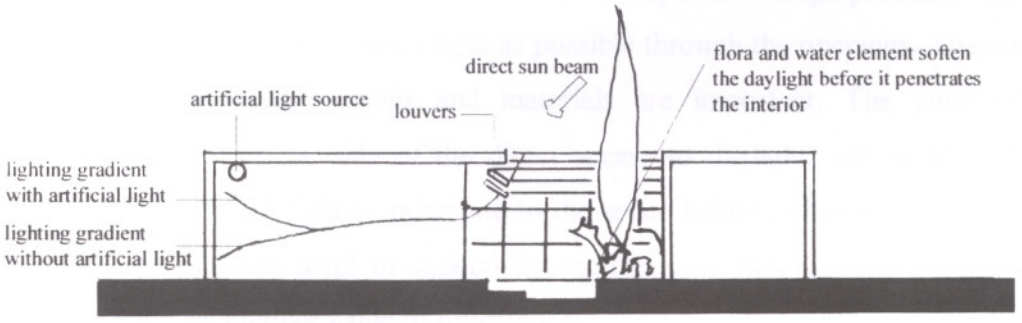


Figure 3- 110 Connecting spaces through use of courtyards

The size of the overhangs plays a crucial role by connection and visual comfort of space.

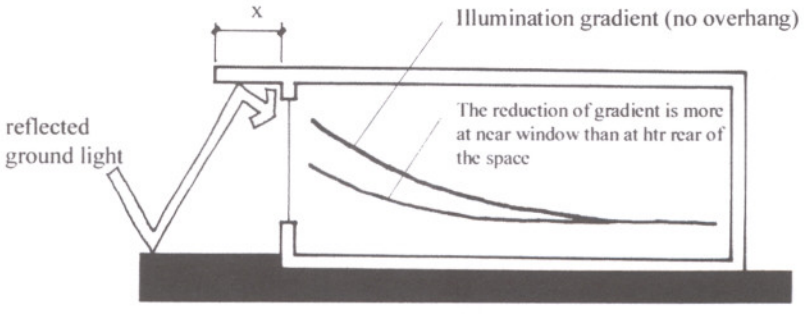


Figure 3- 111 Short overhang

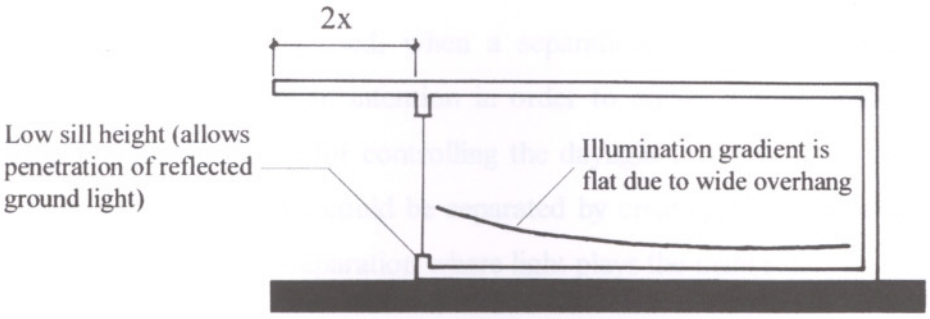


Figure 3- 112 Wide overhang

Inside spaces also can be connected through light. A space with no openings can be illuminated with connections to a space with direct access to daylight. Light can be barrowed from a space in order to illuminate another one. In that kind of articulation the openings at the boundaries can be constituted as an important design problem. Here the aim must be to let penetrate as much light as possible through the openings. The sizes of the openings, construction details and materials are important. The parts of the openings, which are on the side of the direct access to daylight, can be shaped in a manner that allows much light to penetrate to the space behind. The openings can be in lighter color so that the level of reflectivity increases or they can be covered with materials, which has a higher value of reflectance.

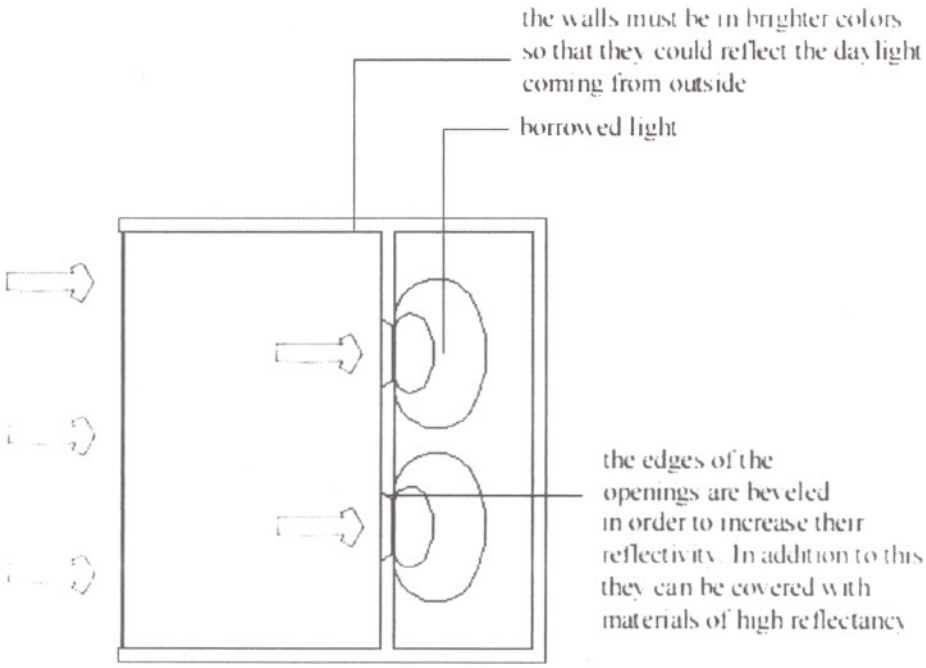


Figure 3- 113 Borrowing Light

SEPARATING SPACES THROUGH LIGHT

Light again can be used, when a separation needed in a space. Sometimes separation could be the main intention in order to create desired spatial effects or it could be a result of a need for controlling the daylight to create the spatial comfort. It easy to say that two spaces could be separated by creating the unequal lighting levels. There are varying ways of separation where light plays the main role:

. Controlling the daylight

. Outer walls

. Brise- soleils

. Ondulatories

. Diaphragms (the technological way of controlling daylight)

. Spatial effects

. Illusions (an intension of faking the human perceptual system)

. Light modules (technological equipment that creates images on transparent surfaces)

Color plays an important role in all these kinds of separation, especially in the ways that are used for spatial effects.

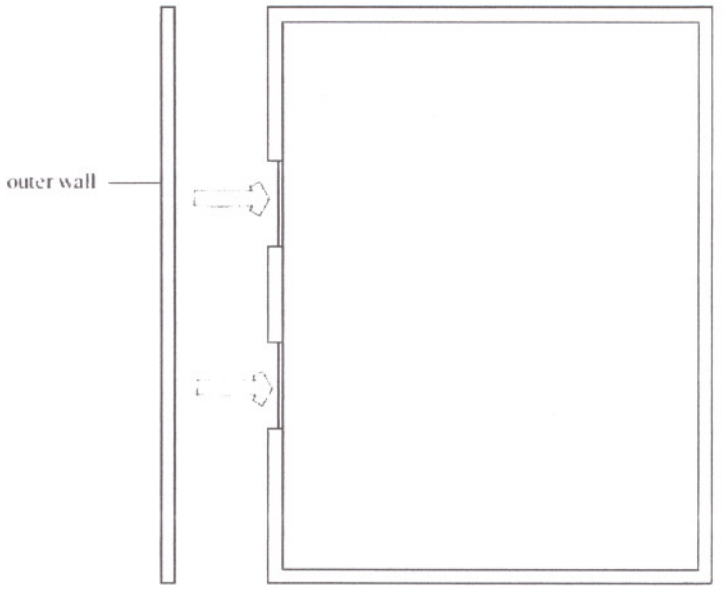


Figure 3- 114 Separation with outer walls

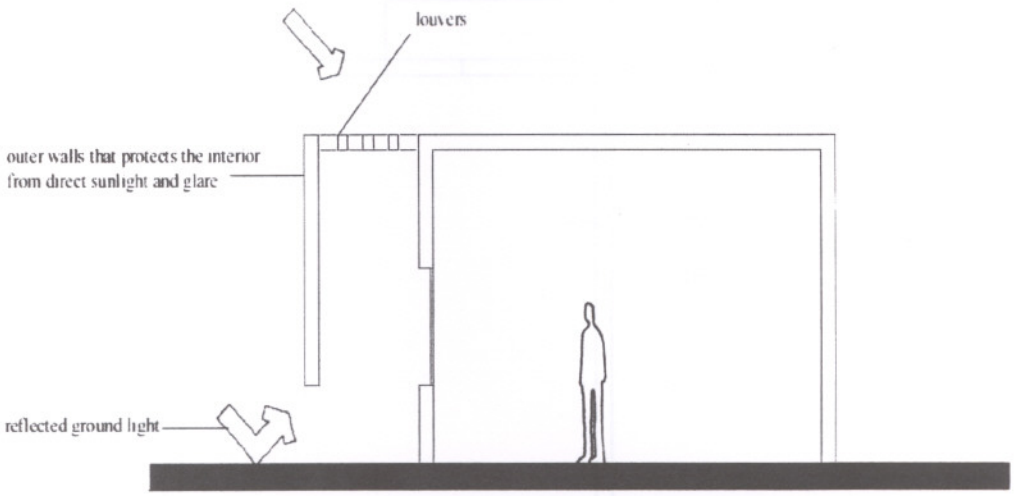


Figure 3- 115 Separation with outer walls

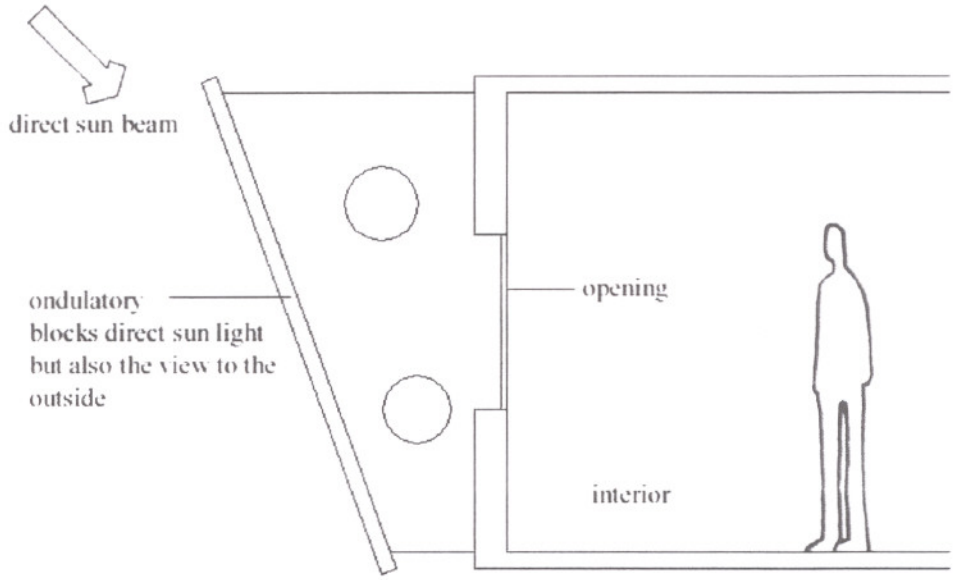


Figure 3- 116 Ondulatory

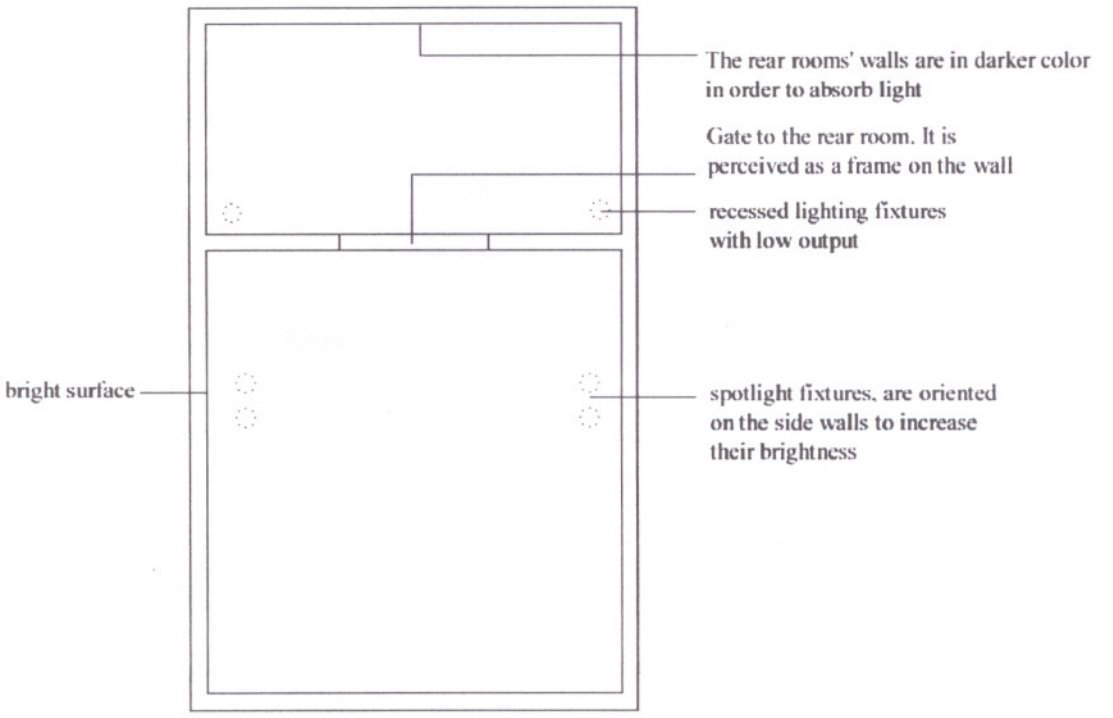


Figure 3- 117 Illusion. The gate appears as a frame on the wall

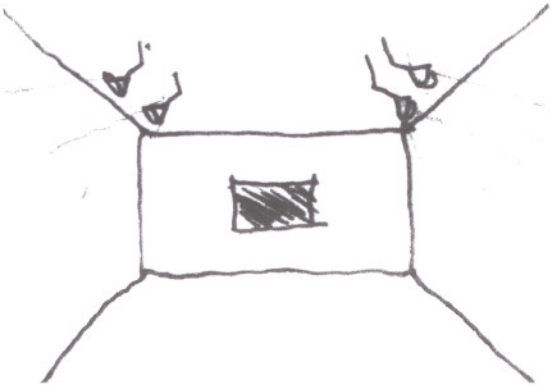


Figure 3- 118 Sketch

DIFFERENTIATING SPACES THROUGH LIGHT

It's possible to characterize different places through light in a total space. It is a kind of classification derives from the functional differences. Light here again is a tool that establishes the spatial relations and the dynamics that are needed to experience the space. In order to create different auras in a total space through light, different lighting qualities need to be generated. The functional relations and the body of space is the basis for the lighting design. The union of daylight and artificial light could lead to pleasant solutions in that kind of an intention in space. Distinction could be created by changing the:

. Illumination type

. Daylighting

. Artificial lighting

. Illumination system

. Direct lighting

. Indirect Lighting

. Perceived illumination form

. Point

. Line

. Surface

. Volume

. Lamp types

. Brightness ratio

. Color

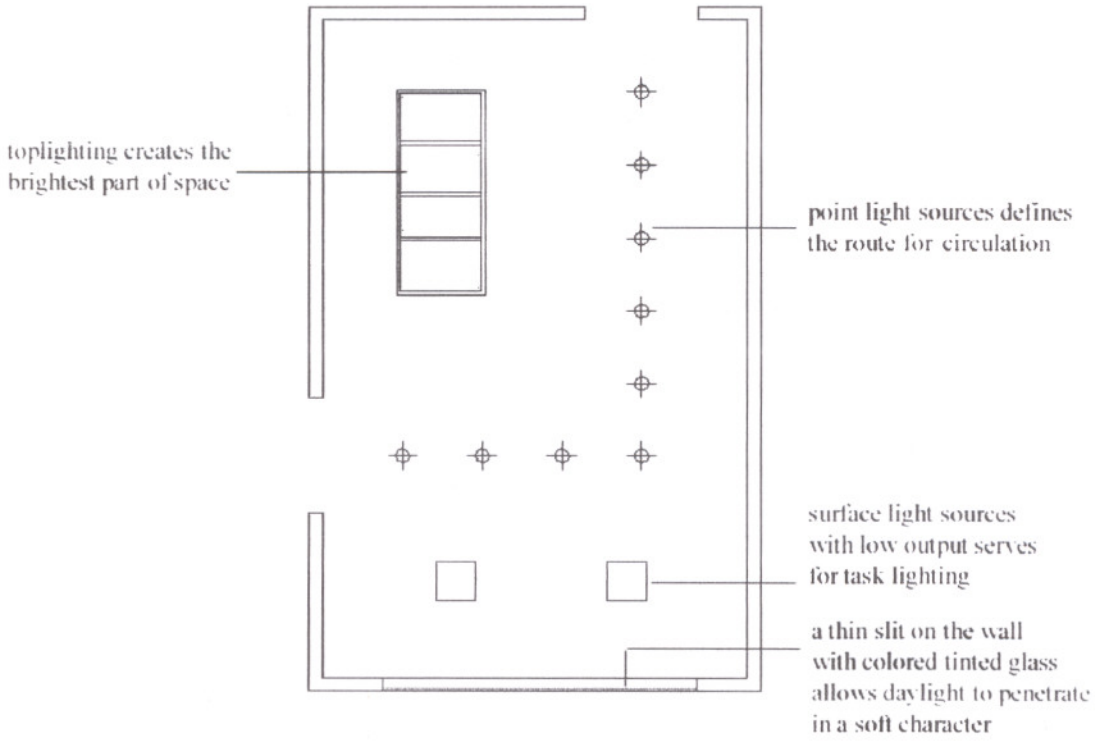


Figure 3- 119 Differentiating space through light

USE OF LIGHT AS A MEANS OF DIRECTION

Orientation is an important factor by experiencing space. This requirement can be achieved by means of light in several ways. The hierarchical order in a space can be stressed with the help of light, continuous visual information, which is also a necessity for human activities, can be created. In point of fact, the feeling of direction is in lights' basis. Human as a phototropic being, react to light and follow it. This is an important clue for illuminating a space, when a focal point or movement is desired. There are several ways of creating the feeling of direction through light, both natural and artificial.

. Brightness

People prefer to move to the brightest view in a scene.

. High Contrast

Contrast can be in size, color or brightness. For example washing a wall with a warm colored light in a soft illuminated space could attract attention.

. Arrangement of the light sources

Artificial light sources can be arranged in a way that they form an order or they create a focus on an object or a part of space, which influences movement.

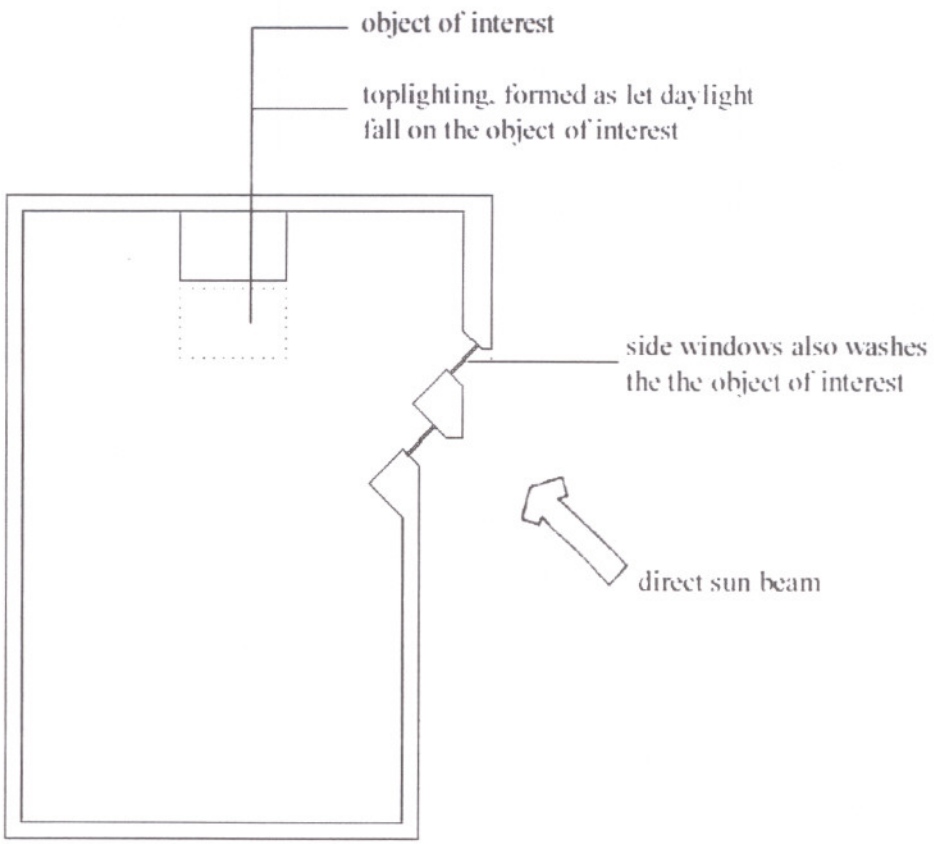


Figure 3- 120 Creating a focus on an object in space through light

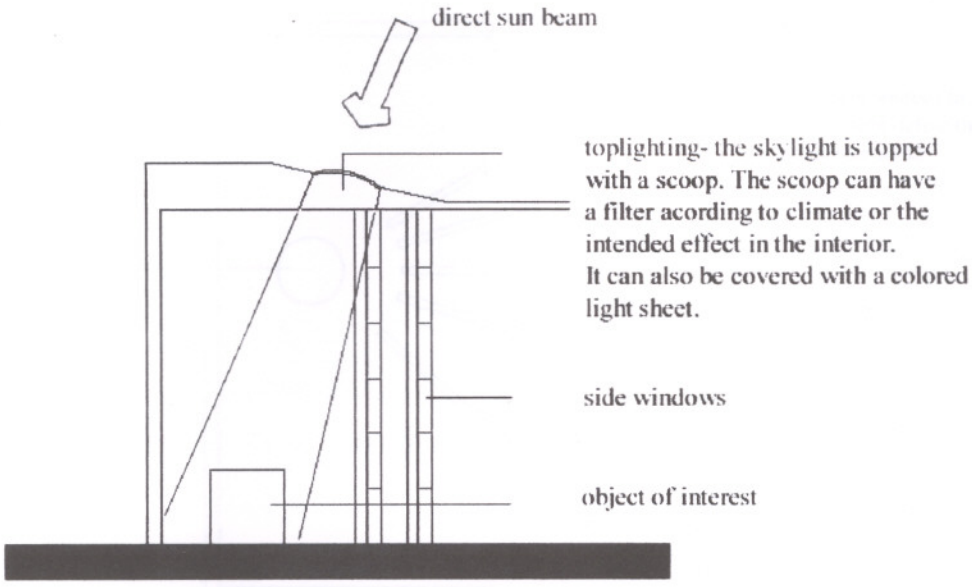


Figure 3- 121 Creating a focus on an object in space through light

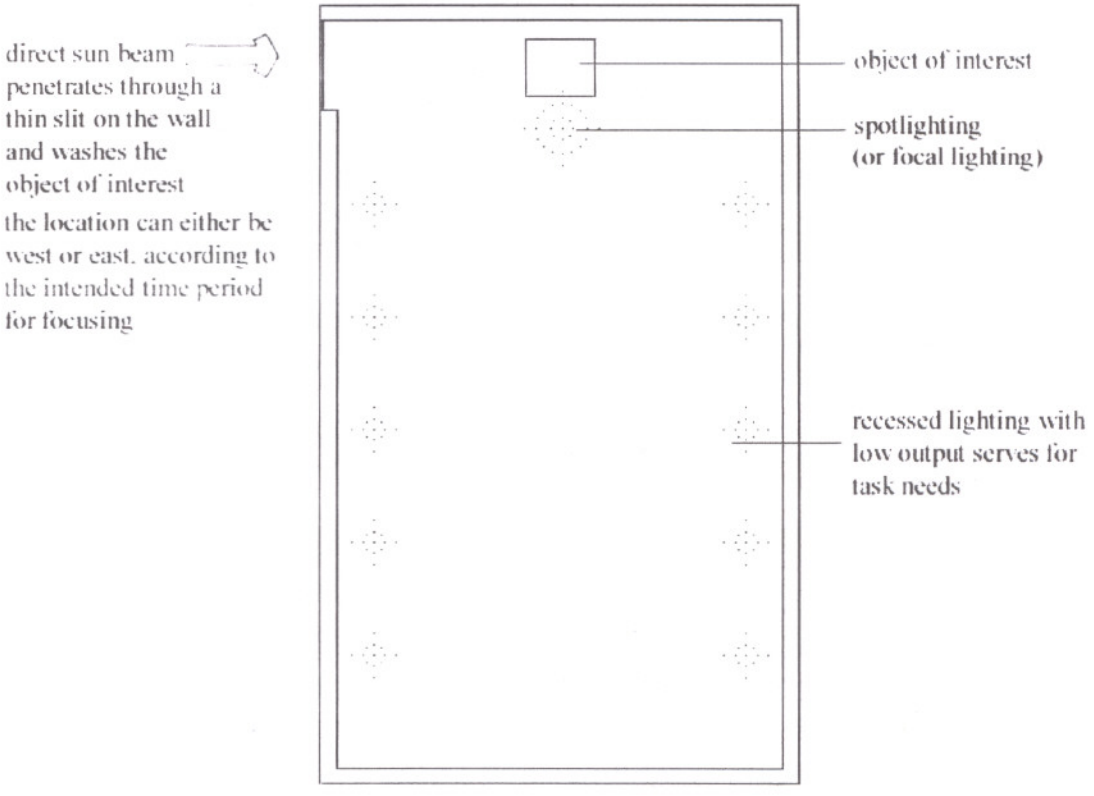


Figure 3- 122 Creating a focus on an object in space through light

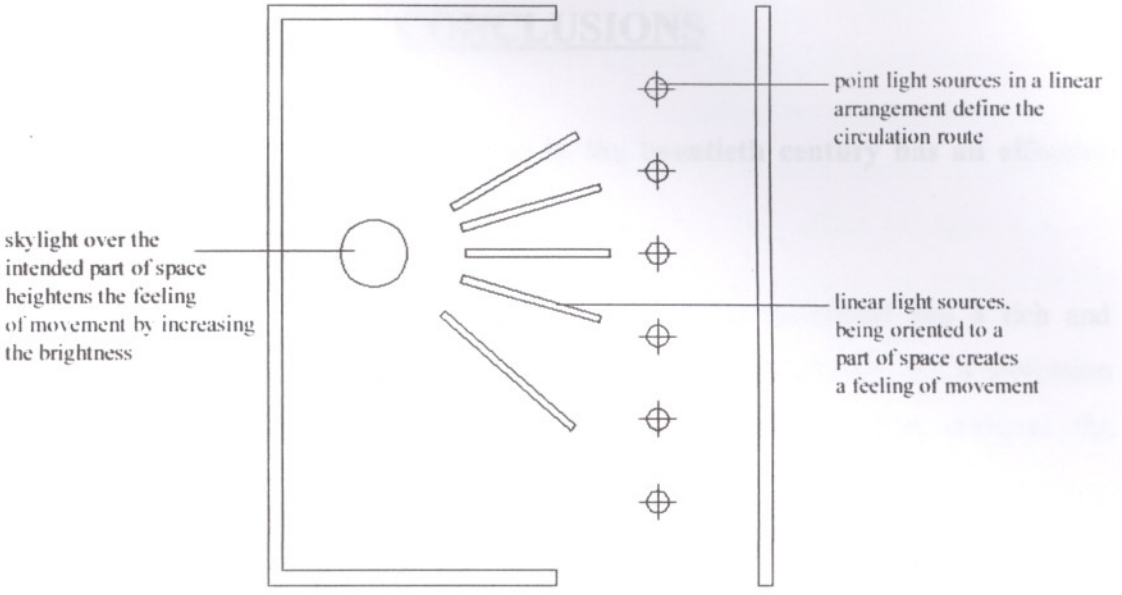


Figure 3- 123 Creating movement through light

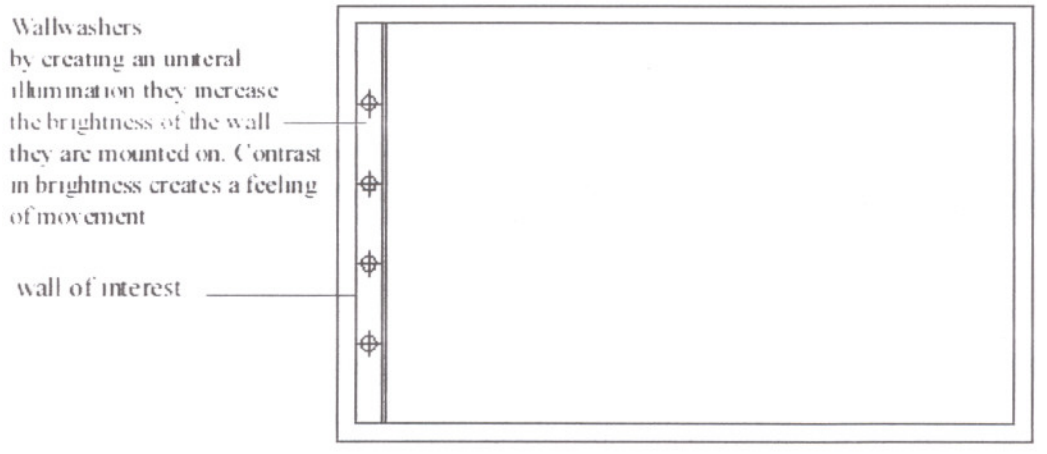


Figure 3- 124 Creating movement through light

CHAPTER 4

CONCLUSIONS

Artificial light that is developed in the twentieth century has an effective role on the transition process of space.

Light sources and lighting techniques have today developed into a rich and complex world where the manipulation of artificial light has evolved into a profession of its own. This evolution, caused by technological advances, has enhanced the illuminated world of architecture by creating surprising and sensitive interiors.

The adventure had begun with the invention of the light bulb, and it stands today on a vast platform of abilities, where anything is possible. Through the century, artificial light has been used as an effective tool in order to change the rituals of space. It has been an inspiring tool for the futurists who tried to foresight the spatial concepts of the future. The present situation of lighting field and light-based technologies seems to verify and support these ideas created in the past. It would not be an exaggeration even to mention that these ideas were been passed over by the present technologies. Terms such as holography and mediarchitecture are deferentially involved to the new understandings of articulating space. It is hard to prudence the future of space from now, but it is for sure that light and light- based technologies will continue to be a part of it as inspiring tools.

Light could determine the relations between spaces, individual and objects as an influential tool for architecture

It is possible to create spatial relations through light, when it is manipulated consciously. As an essential part of space, light both natural and artificial could create intended dynamics in space. It is not meant to state that conscious design is the reason that results at this point. This ability is in light's basis. It is also possible to see that kind of effects of light in nature, which is not a human-designed part of the world. However, this potential of light is usually disregarded, which seem as a lack of sensitivity.

Knowing the peculiarities of light will help in controlling the aura of the built environment and in creating intended dynamics in space. Light is actively involved in every part of architecture. It is the undeniable ingredient, and the basic component for the spatial creation, since it determines the visual relations by making things visible. More importantly, it acts as a design element and renders spatial articulations. Technology has always been an influensive and improving effect on light, and the cooperation of light and technology seems to have involved among the impacts of the creation of new architectural concepts today.

As mentioned before, light is an impressive tool for the creation of intended dynamics in space. It has a reciprocal relation with form, structure, and other basic components of space. Light illustrates form and structure, and these spatial components define its physical limits and quality in space. They dialectically render each other.

It is easier to realize of the importance of lights' characteristics, and the interplay of it with space through experiencing architecture. It is possible to connect or separate spaces both interior and exterior through use of light. Light could also create directional relations in space. One can attract attention to a desired part or an object in a space. It is even possible to create movement through use of light. Today one can color or texture the beam due to the advances of technology and it is possible to change a space perceptually to an intended character. All of these effective characteristics of light show that it is an important data that must be involved in the design stage of architecture.

Lighting has an interdisciplinary character, which is defined by design, engineering, and psychology. In order to achieve good lighting design and enhance the space in terms of quality, these disciplines must work in cooperation.

Light engineering that made the agenda in the twenties with the development of lighting industry has brought with it its own rules and principles, which stand on quantitative basics and which are not much related to required concepts such as perceptual psychology. Lighting was considered only as a problem in quantity, and not as a problem of quality that must be integrated with architecture. A good illuminated environment cannot be defined only with quantitative terms. Quality should have more importance over quality.

Since architecture is an art of experiencing, defined by a union of concepts of several disciplines, other concepts, which are deeply connected to the human spirit, must also be taken into consideration. Lighting is a subject that requires knowledge in engineering, psychology and design.

GLOSSARY

Afterimage visual effect that occurs after stimulus is removed

Baffle opaque element used to block direct sun beams and create shade on transparent surfaces

Binocular vision vision by both eyes

Borrow light illuminating a space without any access to daylight by means of openings to a space with direct access to daylight

Brightness subjective impression of light reaching the eye. Subjective brightness does not vary directly with measured brightness

Brightness ratio ratio between two measured brightnesses of two elements in a visual field

Brise-soleil panel used for blocking direct light.

Bulb outer envelope of light source, usually quartz or glass

Candela quantity of light reflected from or transmitted through an object

Chroma purity or saturation of color

Color contrast relationship between the color of an object or area of interest and that of its immediate surround

Contrast relationship between brightness or color of an object and its surrounding

Cornice lighting lighting from sources behind panel, parallel two wall, and attached to ceiling. Light is distributed over walls

Cove lighting lighting from sources shielded by molding, ledge, or horizontal recess. Light is distributed over upper walls and ceiling

Crystalline Architecture the works of an informal gathering, which respect to the ideas of Paul Scheerbart about light and architecture

Dark adaptation process by which retina adapts to luminance less than about 0.01 candela. Complete dark adaptation can take up to one hour

Diaphragm a device used to control the interior light level according to the seasons and time of the day.

Direct glare glare caused by bright source directly in field of vision

Discomfort glare glare which is distracting, annoying, or uncomfortable but does not significantly reduce the ability to perform visual tasks

Downlighting lighting with a small lighting fixture which directs light downwards

Fiberoptic a way of transmitting light through long flexible glass or plastic fibers, using the principle of total internal reflection

Flood lighting washing the facades of a building from outside with powerful light sources

Fluorescent lamp discharge lamp that emits electron arc stream from cathodes at ends. Fluorescent phosphor coating inside of bulb transforms ultraviolet energy into visible light

Gamma movement perceive a brighter object closer among others, although all the physical features are equal

Glare harch, uncomfortably bright light source or reflection which interferes with visual perception. Light from the wrong place at greater brightness than that to which eyes are adapted

Ground light light from sun and sky reflected by ground cover

High-intensity discharge lamp (HID) discharge lamp which passes a high-pressure electron arc stream through a gas vapor. Examples are mercury, metal halide, and high-pressure sodium lamps

Hologram a piece of film on which information about light waves has been recorded

Holograph an assembly of mirrors and lenses with laser light used for displaying the information recorded on hologram

Hue classification of color. Red, yellow, green, blue, and purple are the primary hues in the Munsell color system

Illumination gradient graphic representation of variation in illumination levels along an axis of measurement

Illumination level quantity of light which reaches a surface (lux)

Illusions some techniques for light use, which aims to fake viewers perception

Incandescent lamp lamp in which light is produced by heating filament by means of an electric current

Incandescent outlining a way of illuminating a building at night by means of incandescent light bulbs, used at the beginning of the 20th century

Incident light light which falls onto a surface or object

Indirect light lighting achieved by reflection, usually from wall and ceiling surfaces.

Laser a light source that produces coherent light, which means it is of one color and wavelenght

Lens shielding or diffusing portion of fixture which controls luminance and directs light.

Light architecture architecture thar conceives light as a building material and incorporates it purposefully in overall architectural design

Light as art techniques techniques used for spatial effects. These can be classified into three categories as hardware, kinetic effects, and illusions

Light module device that causes a separation between inside and outside by producing images on transparent surfaces according to the time of the day.

Light pipe hollow acrylic square with optical rips on its external surface. It can carry light to a desired place or can be a glowing fixture.

Linear illumination to create an aura where the illumination is perceived as a line. The reason can the arrangement of the light sources, the light source itself, or the output of the light source.

Louver series of baffles used to shield light sources from view at certain angles

Lumia the colored response of light to sound waves

Lunette thin slit on the wall that lets daylight penetrate into space

Mirror a device used for redirecting light

Neon light source in a tubular form that lights up when the neon gas is ionized by the passing electric current. The color that it produces is red. Other gases such as xenon, argon, and krypton can be used

Night architecture term used for the result of illuminating architecture at night, came to the agenda in the 1920's, after cities gained a new character through artificial light use

Ondulatory a panel used for blocking direct light, also visual access to outside

Phototropism attraction toward light

Point illumination to create an aura where a light source perceived independent of the context, without an intention of focusing on a surface or illuminating volume

Projector a lighting unit which, by means of lenses and mirrors, concentrates light in a limited angle and intensifies it.

Rainbow an effect of light that it is divided into prismatic colors.

Reflectance percentage of incident light on surface which is reradiated . It depends on angle of incidence

Reflector a device used to redirect light from a source

Searchlight powerful light source that can produce linear beams, designed as a anti-aircraft lights in II. World War.

Skylight opening in roof, glazed with transparent or translucent material, for daylighting

Specular having the reflective properties of a mirror where angle of incidence is equal to angle of reflection

Stimuli object of interest

Streamlining a way of using light in interior design in 1930's, in the years of Art Deco period. Framing object with light bulbs in order to make it the object of interest

Texture pattern of highlight and shadow

Toplighting lighting from skylights, clerestories, and light wells

Uplighting lighting with a small lighting fixture which directs light upwards

Value lightness or darkness of color, measured by scale from perfect white (10) to perfect black (0)

Volumetric illumination to create uniteral illumination in space by eliminating brightness differences

Wall washer light source, located close to wall plane, which distributes light on wall

Wavelength distance between two similar points of given wave. Unit of measure for wavelengths of light is the nanometer

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