Light plays a central role in the design of a visual environment. The architecture, people and objects are all made visible by the lighting. Light influences our well-being, the aesthetic effect and the mood of a room or area.
It is light that first enables spatial perception. Above and beyond this, our perception of architecture can also be influenced with light: it expands and accentuates rooms, creates links and delineates one area from another.
Lighting interior spaces

Light can alter the appearance of a room or area without physically changing it. Light directs our view, influences perception and draws our attention to specific details. Light can be used to divide and interpret rooms in order to emphasise areas or establish continuity between the interior and exterior. Light distribution and illuminance have a decisive influence on how architecture is perceived.
Forming functional zones

Observation

Light can be used to emphasise individual functional zones in an area, e.g. traffic areas, waiting areas, and exhibition areas. Zonal lighting with delineated beams of light visually separates one area from another. Different illuminance levels establish a perceptual hierarchy and direct the viewer's gaze. The differentiation of light colours creates contrasts and emphasises individual zones.

Conclusion

Differentiated lighting of functional zones divide up an area and improve orientation. Areas of a space can be separated from each other using narrow beams of light and strong contrasts in brightness. Distinct contrasts between individual zones and their surroundings remove them from their spatial context. Large areas that on the whole are evenly illuminated can appear rather monotone if they are not divided up. Low general lighting provides the basis for adding lighting accents. Lighting control systems allow functional zones to be adapted to different uses.

Applications

Projects:
Private home, New South Wales
Heart of Jesus Church, Munich
Teatri Ravintola, Helsinki
ERCO, Lüdenscheid
Defining spatial borders

**Observation**

Floor illumination emphasises objects and pedestrian surfaces. Vertical spatial borders are emphasised by illuminating wall surfaces. Uniform light distribution emphasises the wall as a whole, whereas accentuating, grazing light gives the wall structure by adding patterns of light. Bright walls create a high level of diffuse light in the room.

Vertical illumination is used to shape the visual environment. Room surfaces can be differentiated using different levels of illuminance to indicate their importance. Uniform illumination of the surfaces emphasises them as an architectural feature. A decreasing level of brightness across a wall is not as effective as uniform wallwashing at defining room surfaces. Lighting effects using grazing light emphasise the surface textures and become the dominant feature. Indirect lighting of a ceiling creates diffuse light in the room with the lighting effect being influenced by the reflectance and colour of its surface.

**Conclusion**

Wall bright Wall dark

**Applications**

Projects:
- Fondación Banco Santander Central Hispano, Madrid
- Lamy, Heidelberg
- Ezeiza Airport, Buenos Aires
- Light and Building, Frankfurt
Emphasising architectural features

Observation

The illumination of architectural details draws attention away from the room as a whole towards individual components. Columns appear as silhouettes in front of an illuminated wall. Narrow-beam downlights emphasise the form of the columns. Grazing light accentuates individual elements or areas and brings out their form and surface texture.

Conclusion

Rooms can be given a visual structure by illuminating the architectural features. By using different levels of illuminance, different parts of a room can be placed in a visual hierarchy. Grazing light can cause highly three-dimensional features to cast strong shadows.

Applications

Projects:
Tokyo International Forum
St. Petri church, Stavanger
Palacio de la Aljaferia, Zaragoza
Catedral de Santa Ana, Las Palmas
Combining rooms can create complex architectural patterns. Light interprets these in terms of their structure and orientation. Targeted lighting enables the viewer to look into an area and creates spatial depth. The consideration of material qualities in combination with the correct illuminance, colour of light and light distribution is an important aspect in the design stage.
Observation

The bright rear wall gives the room depth and accentuates the spatial perspective. Illuminated objects in the background achieve a similar effect. If the emphasis of the illuminance level is shifted from the back to the front area of the room, then the focus of attention will also shift from the background to the foreground.

Conclusion

Light makes surfaces or objects visible and allows them to become the focus of attention. Dark spatial zones cause spatial limits to disappear and recede into the background. Differentiated spatial lighting can produce a hierarchy of how spaces are perceived. Illuminating vertical surfaces is of particular creative importance for the design since a better effect is achieved as the result of spatial perspective than when illuminating horizontal surfaces.

Applications

Projects:
Museum Georg Schäfer, Schweinfurt
Catedral de Santa Ana, Las Palmas
DZ Bank, Berlin
Guggenheim Museum, Bilbao
A high illuminance level in the interior combined with a dark exterior creates a strong reflection on the facade plane. The interior visually appears to double in size from the exterior due to the reflection. Objects in the outdoor area are not recognisable. As the illuminance level in the interior decreases and the luminance in the exterior increases, the mirror effect is reduced and objects on the exterior become recognisable.

The reflection on the glass becomes less as the luminance in front of the glass decreases and the luminance behind the glass increases. Well shielded luminaires in front of the glass plane cause less reflection. Lower illuminance in the interior allows better perception of the exterior. When directing luminaries on the exterior, direct glare into the indoor area should be avoided.

Projects:
Nagasaki Prefectural Art Museum, Nagasaki
Restaurant Olio e Pane, Metzingen
Private home, New South Wales
ABN AMRO, Sydney
Guideline: Designing with light | Architectural lighting | Connecting spaces

Outside – looking inside

Observation

The high illuminance level of daylight causes a strong reflection on the glass surface. Objects in the indoor area are not perceptible. As the illuminance level in the outdoor area decreases, the reflection becomes less. This allows illuminated objects or surfaces in the indoor area to become visible. The glass is no longer perceptible.

Conclusion

The reflection on the glass becomes less as the luminance in front of the glass decreases and the luminance behind the glass increases. Luminaires in front of the glass that are well shielded and integrated into architecture cause less reflection of themselves. A low illuminance level in the indoor area produces a deep spatial effect at night. The illumination of objects in indoor areas – such as shop windows – requires very high illuminance to make these objects visible during the day due to the high illuminance level outside. Adjusting the indoor lighting to the changing daylight is recommendable. A higher illuminance level during the day and a low level in the evening reduces the contrast.

Applications

Projects:
Lamy, Heidelberg
Bodegas Portia, Gumiel de Izán
"Dat Backhus" bakery, Hamburg
Leonardo Glass Cube, Bad Driburg
**Observation**

A bright rear wall lends depth to the room and helps delineate the room limits. Illuminated objects in the background achieve a similar effect. If the emphasis of the illuminance level is shifted from the back to the front area of the room, then the focus of attention will also shift from the background to the foreground.

**Conclusion**

Light makes surfaces or objects visible and brings them into the foreground. Dark zones of the room make the room limits disappear and the effect of areas recedes into the background. Due to the low illuminance level at night, the required illuminances are less than for indoor lighting.

**Applications**

Projects:
- Hong Kong Convention and Exhibition Centre
- Grote Markt, Antwerp
- Federal Chancellery, Berlin
- Private home, Milan
Light directs our view and focuses the attention on details. The direction of light, illuminance and the light distribution all determine the effect of an object in its surroundings.

 Illuminate objects

Direction of light  
Vary the light distribution  
Accentuate objects
Directed light from the front produces a strong modelling ability. Light from above Causes the object to cast strong shadows on it. Light from behind creates a silhouette. The steeper the incident light, the more pronounced the shadow effect.

Observation

Conclusion

If the light from the front is also coming slightly from one side, it gains a strong descriptive power. Light that is solely head-on hardly causes any shadow in the direction of vision and the object loses some of its 3-dimensional appearance. Very steep incident light is suitable for objects having a very shallow texture in order to make them more 3-dimensional.
Arrangement

The steeper the incident light, the more pronounced the shadow effect. Objects can be illuminated well when the direction of light is between 5° and 45° to the vertical. The optimal direction of light for illuminating objects is at 30°. This avoids strong reflected glare or undesirable shadows on people or objects.

Applications

Highlighting is used for modelling objects in:
- museums
- exhibitions
- salesrooms

Preferred luminaire groups
- spotlights
- floodlights

Projects:
Pinacoteca Vaticana, Rome
Guggenheim Museum, Bilbao
Hermitage, St. Petersburg
Hermitage, St. Petersburg
Guide

Designing with light | Architectural lighting | Illuminate objects

Vary the light distribution

Observation

Narrow-beam spotlights accentuate the object and make it stand out against the surroundings. The beam of light is stretched into an oval using a sculpture lens. Flood lenses spread out the narrow beam and create a soft brightness gradient.

Conclusion

The narrower the beam of light cast on the object, the stronger the effect. Sculpture lenses are particularly suitable for projecting light at objects over their entire height. With their wide light beam, flood lenses illuminate the surroundings stronger and represent the object in its spatial relationship.

Applications

Highlighting is used for modelling objects in:
- museums
- exhibitions
- salesrooms

Preferred luminaire groups
- spotlights with accessories

Projects:
Bunkamura Museum of Art, Tokyo
Museo del Prado, Madrid
Vigeland Museum, Norway
Hermitage, St. Petersburg
**Accentuate objects**

The objects and the wall are given general lighting by wallwashers. Beams from individual spotlights add emphasis to the objects. A higher brightness contrast increases the level of accentuation.

**Conclusion**

When the brightness contrast of the ambient surroundings to the object is 1:2, a contrast can hardly be noticed. When the ratio is 1:5, a minimum brightness contrast is established between primary and secondary points of interest. A contrast of 1:10 brings out the difference very well. A brightness contrast of 1:100 detaches the object very strongly from its ambient surroundings but an unintentional dissection of the wall can arise.

**Applications**

Highlighting of objects on walls is a practice used in:
- museums
- exhibitions
- trade-fair stands
- salesrooms

Projects:
- Museo Ruiz de Luna Talavera, Spain
- German Architectural Museum, Frankfurt
- Guggenheim Museum, Bilbao
- Museo Picasso, Barcelona
Colour is a significant component of visual perception. It cannot be perceived without daylight or artificial lighting. The combination of lamps and filters allows a multitude of design possibilities for emphasising or altering the lighting effect of rooms and objects with coloured light. The term "colour of light" covers both white and coloured light. Warm white, neutral white and daylight white are derived from the white colour of light. The coloured light covers the entire visible spectrum.
Light colour

The light colour refers to a colour which is emitted by a light source. The light colour is produced as a result of the emitted spectrum of light. The type of light colour is defined by hue, saturation and brightness. Using filters produces coloured light. This enables the colouration of rooms to be modified without changing the rooms physically. Mixing several light colours is referred to as additive colour mixing.

Body colour

The body colour arises as a result of the incident light and the specific absorption properties of the surface. Therefore, the tri-stimulus value of a body colour can only be determined in combination with the type of light with which it is illuminated. In addition to hue, brightness and saturation, the body colour of an object is also defined by the reflectance. When illuminating coloured walls or objects with coloured light, the reciprocal effect of light colour and body colour is paramount. This interplay is the basis of subtractive colour mixing. The chromatic effects can be intensified or altered.
In the CIE standard colorimetric system, body colours and light colours are represented in a continuous, two-dimensional diagram. The spectral constitution of light colours results from the type of light, while that of body colours results from the type of light and the spectral reflectance or transmittance. The dimension of brightness is left unconsidered here; this means that only the hue and saturation of all colours can be determined in the diagram. The coloured area is enclosed by a curve on which the chromaticity locations of the completely saturated spectral colours lie. At the centre of the area is the point of least saturation, which is designated as a white or uncoloured point. All levels of saturation of one colour can now be found on the straight lines between the uncoloured point and the chromaticity location in question. Similarly, all mixtures of two colours are likewise to be found on a straight line between the two chromaticity locations in question. Complementary colours are located opposite each other in the CIE model and combine to form white.

In the Munsell system, body colours are arranged according to the criteria of brightness, hue and saturation to produce a complete sample catalogue in the form of a three-dimensional matrix. Brightness here refers to the reflectance of a body colour; the hue refers to the actual colour, while the term saturation expresses the degree of coloration, from the pure colour down to the uncoloured greyscale. Whereas a two-dimensional diagram is sufficient for colours of light, a three-dimensional system is required for body colours due to reflectance.
**Observation**

The higher red component in warm white light allows rooms to appear warmer than with neutral white light. The higher blue component in daylight white light creates a cooler atmosphere.

**Conclusion**

Warm colours of light are preferred above all at lower illuminances and with directed light, whereas cold colours of light are accepted at high illuminances and diffuse illumination. White light is described by specifying the colour temperature, colour rendition, chromaticity location and spectrum. The white colour temperature is divided into three main groups: warm white, neutral white and daylight white. A good colour rendition with the lighting will only produce a low colour deviation. The chromaticity location identifies the colour within the CIE diagram.

**Applications**

On presentation lighting, making specific use of colours of light allows luminous colours to be achieved on the objects being illuminated. Daylight white light is often used in office rooms to augment the daylight.

**Projects:**
Sony Center, Berlin
Glass pavilion, Glass technical college, Rheinbach
Hong Kong and Shanghai Bank
ERCO, Lüdenscheid
Observation

Compared to the primary colours yellow, blue and red, the colours amber and magenta appear weaker in their expressiveness. Yellow and red colours of light create a warm atmosphere in a room. Blue colours of light allow a room to give a cooler impression.

Conclusion

In architectural lighting, colours from the daylight spectrum are felt to be natural: magenta (conditions of light at sunset), amber (atmospheric light at sunrise), night blue (clear night sky) and sky blue (light of the sky by day). For coloured light, the data concerning chromaticity location and spectrum are important. The chromaticity location is specified by the co-ordinates in the CIE diagram, whereby a colour of light can be formed by different colour spectra.

Applications

Coloured light is used for
- exhibitions
- trade-fair stands
- salesrooms
- event lighting

Projects:
ERCO P3, Lüdenscheid
Zürich Insurance, Buenos Aires
Teattri Ravintola, Helsinki
Teattri Ravintola, Helsinki
**Observation**

Super imposing several colours of light is an additive mixing process. Mixing two of the primary colours red, green and blue results in magenta, cyan or yellow. By mixing the three primary colours in equal amounts, white light is produced.

**Conclusion**

When illuminating objects with differently coloured light sources, the spatial superimposition gives rise to interesting additive colour mixing effects, which may even include coloured shadows.
Guide
Designing with light | Architectural lighting | Design with coloured light

Colour mixing: Light colour and body colour

Observation

Subtractive colour mixing occurs when coloured surfaces are illuminated with coloured light. Mixing two of the subtractive primary colours magenta, cyan and yellow, produces the additive primary colours red, green or blue. Warm body colours are emphasised by a warm white colour of light. Cold body colours appear brighter and more saturated under cold neutral colours of white light, especially daylight white.

Wall: Blue
Light: Warm white

Wall: Blue
Light: Blue

Wall: Blue
Light: Magenta

Wall: Blue
Light: Yellow

Conclusion

The appearance of a body colour can seem more saturated and brighter when the lighting on it is of similar colour. Body colours appear less saturated, or darker, when the coloured lighting is dissimilar. The actual appearance of the results of subtractive colour mixing depends on the spectral constitution of the components being mixed.

Applications

In practice, when illuminating coloured surfaces, it is recommendable to perform lighting tests or calculations. The same applies to the use of colour filters.

Projects:
Indre quay, Haugesund
Apropos Cöln The Concept Store, Cologne
Teatri Ravintola, Helsinki
ERCO Trade Fair, Hanover
The quality of the reproduction of colours is termed colour rendition. Linear spectra have a very good colour rendition. Linear spectra only permit one single colour to be perceived well. Multiline spectra reproduce several colours of the relevant spectrum well, but in the intermediate areas the colour rendition is weaker. Blue and green colours appear comparatively grey and matt under warm white incandescent light despite excellent colour rendition. However, these hues appear clear and bright under daylight white light from fluorescent lamps – despite poorer colour rendition. When rendering yellow and red hues, this phenomenon of respective weakening and intensifying of the chromatic effect is reversed.

**Incandescent lamp**
Continuous spectra lead to good colour rendition. Incandescent lamps or daylight have the colour rendition index Ra 100.

**Daylight**
Continuous spectra lead to good colour rendition. Incandescent lamps or daylight have the colour rendition index Ra 100.
Because the eye is able to adapt to light of the most different colour temperatures, the colour rendition must be determined dependent on the colour temperature. Tungsten halogen lamps feature very good colour rendition. The rendition quality of fluorescent lamps and metal halide lamps ranges from good to average. The degree of colour distortion against a reference light source is indicated using the colour rendition index Ra or the colour rendition grading system. The colour rendition index is only used for white colours of light.

Fluorescent lamp
Discharge lamps such as fluorescent lamps or metal halide lamps feature a multiline spectrum. Their colour rendition is therefore lower than Ra 100.

**Physics**

- Linear spectrum
- Continuous spectrum
- Multiline spectrum

The same colours of light can produce a different rendition of a body colour due to different spectral constitution. Continuous spectra lead to a uniform colour rendition. Linear spectra only correctly render a very small colour range. Multiline spectra are compiled from different linear spectra and thus improve the colour rendition. The more spectra can be bound to one linear progression, the better the colour rendition. Incandescent lamps feature a linear spectrum, while discharge lamps have a multiline spectrum.

**Applications**

Very good colour rendition is important for
- exhibitions
- trade-fair stands
- salesrooms
- offices
- workstations
Guide
Designing with light | Architectural lighting | Design with coloured light

Colour effect

Observation

- Red is the colour of fire and the expression for power, warmth and energy. The colour has a dominant effect. Where pale red is concerned, the aspect of warmth decreases while its lightness increases.
- Yellow is the lightest colour in the colour wheel, but used in the foreground it does not have the same energy as red.
- Blue is the colour of the sky and is one of the cold colours which gives an effect of depth. Dark navy blue has a rather melancholy effect, whereas blue-green emanates peace.
- Green is the colour of vitality. Its nuances range from calming to refreshing.
- White is one of the non-colours and is the polar opposite of black. White stands for purity.
- Black stands for darkness and appears sinister and negative.
- Grey is one of the non-colours and appears indifferent.

Conclusion

The effect of colours is explained from the physiological point-of-view of actually seeing colour and the psychological aspects of sensory perception. The lure of colours triggers associations and is interpreted in the context of the social and cultural environment. The different hues belonging to a colour can, in turn, also have other effects. The effect of individual colours can be increased by way of a colour contrast.

Applications

Projects:
Iittala Flagship Store, Amsterdam
Light and Building 2000, Frankfurt
Restaurant Aioli, Vienna
Teatri Ravintola, Helsinki

Colour effects are particularly important for
- exhibitions
- trade-fair stands
- sales areas
- restaurants
**Guide**

Designing with light | Architectural lighting | Design with coloured light

**Colour contrast**

**Colours themselves**

The seven colour contrasts originated from the colour theory of Johannes Itten. This approach is not based on physical and chemical properties of colours, but on their subjective effects.

The primary colours yellow, red and blue produce the strongest contrast. The colour contrast becomes weaker with secondary or tertiary colours or as the saturation decreases.

**Light-dark**

The “non-colours” black and white produce the strongest contrast. Even with the “proper” colours, their effect is significant. A light colour next to a dark colour has a stronger effect than next to an equally light or lighter colour. The effect of hues can be intensified by greater differences in brightness.

**Cold-warm**

In the colour wheel, the warm colours with red and yellow components are located opposite to the cold blue hues. Green and magenta form the neutral transitions. The effect of a predominant colour can be increased when combined with an accent from the opposite colour.
**Simultaneous**

The effect of the simultaneous contrast has its origin in how the eye processes perception. After staring at a colour for a long time and then looking at a neutral grey, the eye forms a simultaneous contrast colour. Red leads to a green tinged grey shade. Green causes a grey area with a red tinge to appear. Colours change their effect due to the influence of the surrounding colours.

**Complementary**

The pairs of colours lying opposite in the colour wheel form the complementary contrast from a primary colour and the secondary (mixed) colour made of the other two primary colours. Yellow-violet displays the largest light-dark contrast, orange-blue the largest cold-warm contrast. Red-green have the same light intensity. The complementary contrast causes the brilliance of the colours to increase.
Colour contrast

Quality

The quality contrast, or intensity contrast, describes the distinction between pure colours and murky colours. Mixing pure colours with grey shades makes the former murky and dull, and the quality of colour purity is lost. Pure colours have a dominating effect over murky colours.

Quantity

The quantity contrast refers to the relationship of the size of one coloured area with the next. A large coloured area with a small area in a contrast colour increases the chromatic effect of the main colour.
**Observation**

White light that is reflected by a coloured surface takes on the colour of the surface and becomes the predominant colour of light for the whole room. When lighting a coloured wall with coloured light, this effect can be increased, reversed or inverted.

**Conclusion**

The colour of light in a room is influenced by the decoration of the room. In comparison to diffuse light, direct light increases the effect of the light when illuminating a coloured surface. The effect of a body colour can be intensified by using coloured light of a similar colour. Strong colour contrasts appear brighter for the same illuminance than a weaker colour contrast. Lesser colour contrasts can be perceived better under brighter lighting. Within closed rooms the effect is hardly perceptible due to the phenomenon of colour constancy.

**Applications**

In practice, when illuminating coloured surfaces, it is recommended that lighting tests or calculations be carried out.

Coloured accent lighting is used for:
- exhibitions
- trade-fair stands
- sales areas

**Projects:**
- Tennispalatsi Cultural Museum, Helsinki
- Kvadrat Sanden, Stockholm
- Tennispalatsi Cultural Museum, Helsinki
- Apropos Cöln Concept Store, Cologne
**Observation**

Coloured accent lighting and coloured background lighting changes the effect of objects in the room. The colour saturation of the object increases in the foreground when the background brightness is decreased. Blue colours seem to recede into the background, while the chromatic effect makes magenta come to the fore.

Wall: White  
Stele: Night blue

Wall: Magenta  
Stele: White

Wall: Amber  
Stele: Magenta

Wall: Sky blue  
Stele: Amber

**Conclusion**

Lighting effects can be intensified using coloured light. Strong colour contrasts increase the brightness contrasts. High brightness contrasts likewise increase the colour contrasts. Natural overall effects arise due to warm colours of light and filter colours such as "Skintone", magenta and amber, or due to cold colours of light such as sky blue and night blue.

**Applications**

Coloured accent lighting is used for
- exhibitions
- trade-fair stands
- sales areas

Projects:
Museo de Bellas Artes, Bilbao  
Zürich Insurance, Buenos Aires  
Teatrit Ravintoa, Helsinki  
Light and Building 2002, Frankfurt
The planning process provides an overview of the sequence of the individual tasks in lighting design. This process is closely linked with the planning procedure for an architectural design. The findings of the analysis are firstly channelled into the concept planning and are then finalised for implementation in the design. In addition, maintenance schedules are a prerequisite for maintaining the quality of light on site.
The basis for every lighting design concept is an analysis of the project; the tasks the lighting is expected to fulfil, the conditions and special features. A quantitative design concept can to a large extent follow the standards laid down for a specific task. Standards dictate the illuminance level, the degree of glare limitation, the luminous colour and colour rendering. When it comes to qualitative planning, it is necessary to gain as much information as possible about the environment to be illuminated, how it is used, who will use it and the style of the architecture.

A central aspect of project analysis is the question of how the spaces that are to be illuminated are used; it is important to establish what activity or activities take place in the environment, how often and how important they are. This comprehensive analysis of the task gives rise to a series of individual visual tasks, the characteristics of which must in turn also be analysed. Two criteria relating to a visual task are the size and contrast of the details that have to be recorded or handled; there then follows the question of whether colour or surface structure of the visual task are significant, whether movement and spatial arrangement have to be recognized or whether reflected glare is likely to be a problem. The position of the visual task within the space and the predominant direction of view may also become central issues.
From the point of view of architecture and ambience, a building or space should be made visible, its characteristics accentuated and its ambience underlined. This requires detailed information on the architecture and on the overall architectural concept complete with the intended indoor and outdoor effect by day and night, the use of daylight and the permissible energy consumption. This also includes information on materials, reflectance and the colour scheme. In Architectural lighting it’s not primarily about the lighting which emphasises the building structures and characteristic features for a particular perspective, but rather how to create the required aesthetic effect in a space. The question of the building shape, of spatial shape, modules and rhythmical patterns, which can be identified and expressed by light and luminaires – constitutes the central issue.

The psychological requirements include perception of the wider surroundings to establish the time of day, the weather and to facilitate spatial orientation. In large buildings frequented by different users, the need for visual guidance can become an important issue. An orderly and clearly structured environment contributes to the general feeling of wellbeing. Differentiated lighting can provide spatial delineation for areas with separate functions. Where there are conversational zones within larger areas, it may make sense to create private areas by using suitable lighting.

Psychological requirements

From the point of view of architecture and ambience, a building or space should be made visible, its characteristics accentuated and its ambience underlined. This requires detailed information on the architecture and on the overall architectural concept complete with the intended indoor and outdoor effect by day and night, the use of daylight and the permissible energy consumption. This also includes information on materials, reflectance and the colour scheme. In Architectural lighting it’s not primarily about the lighting which emphasises the building structures and characteristic features for a particular perspective, but rather how to create the required aesthetic effect in a space. The question of the building shape, of spatial shape, modules and rhythmical patterns, which can be identified and expressed by light and luminaires – constitutes the central issue.

Architecture and ambience
Lighting concepts list the properties that lighting should possess. They give no exact information about the choice of lamps or luminaires or about their arrangement. Project analysis provides lighting quality guidelines giving information about the individual forms of lighting. These relate to the quantity and various quality features of light, and also gives the degree of spatial and temporal differentiation. A practical design concept requires consultation with the other trades involved. It must meet the specifications of the relevant standards and take both investment costs and running costs into consideration. The challenge of a qualitative lighting design is to develop a design concept that combines the technical and aesthetic requirements of complex guidelines. A concept that delivers the required performance with a commensurate level of technical expertise and the highest level of artistic clarity will produce the most convincing solution.

In the design phase, decisions are made regarding the lamps and luminaires to be used, the arrangement and installation of the luminaires and any required control gear and control devices. This also allows a reliable calculation of illuminance and costs. No strict process can be set out, nor even one describing generally routine design stages. The decision regarding lamp type can be made at the beginning of a project or left until an advanced planning stage; luminaire arrangement can be determined by the choice of a certain luminaire or could be the criteria for luminaire selection. Lighting design should be seen as a cyclical process in which developed solutions are repeatedly compared to the stated requirements.
A wide range of luminaire types – e.g. spotlights and light structures – are exclusively designed to be installed as additive elements. They may be mounted on track or lighting structures, suspended from the ceiling (pendant luminaires) or surface mounted onto the wall or ceiling. The range of downlights and louvered luminaires available is so vast and their designs differ substantially, which means that numerous modes of installation are required. In the case of wall or floor mounting the luminaires may be surface-mounted or recessed into the fabric of the building. Ceiling mounting allows a variety of possibilities: recessed mounting, surfaced mounting or pendant mounting. The Installation Instructions for the luminaires explain the installation and maintenance of the luminaires in detail.

The maintenance of a lighting installation generally comprises lamp replacement and the cleaning of the luminaires, and possibly also re-adjustment or realignment of spotlights and movable luminaires. The main objective of maintenance is to ensure that the planned illumination is maintained, i.e. to limit the unavoidable reduction of luminous flux of a lighting installation. The reasons for the reduction in luminous flux may be defective lamps and the gradual loss of luminous flux by the lamps or a decrease in light output due to soiling of the reflectors or attachments. In order to avoid a reduction in luminous flux all lamps must be replaced and luminaires cleaned at regular intervals. Qualitative aspects may also be decisive for maintenance. When one lamp in a geometrical arrangement of luminaires fails it may have a detrimental effect on the overall illumination in the space. The task of the lighting designer is to draw up a maintenance plan that meets the requirements of the given situation and includes the necessary informative literature.
Having completed the project analysis and developed a lighting concept, the next phase entails practical planning: decisions regarding the lamps and luminaires to be used, the arrangement and installation of the luminaires. A detailed design can be developed from a concept based primarily on lighting qualities.
Selecting the right lamp for the luminaire depends on the actual lighting requirements. For the successful implementation of a lighting concept the physical aspects, such as colour rendition, and the functional criteria are decisive.
Modelling and brilliance are effects produced by directed light. Compact light sources such as low-voltage halogen lamps or metal halide lamps are a prerequisite for this. When illuminating sculptures, presenting merchandise or lighting interestingly textured surfaces, the modelling ability and brilliance are of central importance.

**Colour rendition**

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Ranges of the colour rendition index Ra for different lamp types.

The colour rendition of the light source is determined by the actual lamp spectrum. A continuous spectrum ensures the optimal colour rendition. Linear or band spectra generally worsen the colour rendition. A very good colour rendition quality is produced by incandescent lamps including tungsten halogen lamps.

**Light colour**

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<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>QT (12V)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>QT</td>
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</tr>
<tr>
<td>HST</td>
<td>HST</td>
<td>HST</td>
<td>HST</td>
<td>HST</td>
<td>HST</td>
<td>HST</td>
</tr>
</tbody>
</table>

Ranges of colour temperature TF for different lamp types.

The light colour of a lamp depends on the spectral distribution of the emitted light. In practice, the light colours are categorised into warm white, neutral white and daylight white. Warm white lamps emphasise the red and yellow spectral range, whereas blue and green, i.e. cool colours, are accentuated under daylight white light.
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### Choice of lamps

#### Luminous flux

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>LED A</th>
<th>QT (12V)</th>
<th>QT</th>
<th>TC</th>
<th>T</th>
<th>HST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (lm)</td>
<td>10</td>
<td>50</td>
<td>100</td>
<td>500</td>
<td>1000</td>
<td>10000</td>
</tr>
</tbody>
</table>

Ranges of luminous flux $\Phi$ for different lamp types

#### Economy

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>LED A</th>
<th>QT (12V)</th>
<th>QT</th>
<th>TC</th>
<th>T</th>
<th>HST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (W)</td>
<td>10</td>
<td>50</td>
<td>100</td>
<td>500</td>
<td>1000</td>
<td>10000</td>
</tr>
</tbody>
</table>

Ranges of power $P$ for different lamp types

#### Radiant emission

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>UV (W/m²)</th>
<th>Visible Light (W/m²)</th>
<th>IR (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, PW</td>
<td>0.25-0.10</td>
<td>5-7</td>
<td>35-80</td>
</tr>
<tr>
<td>DT</td>
<td>0.10-0.15</td>
<td>5-6</td>
<td>25-30</td>
</tr>
<tr>
<td>T, TC</td>
<td>0.20-0.15</td>
<td>2-5</td>
<td>6-10</td>
</tr>
<tr>
<td>HST</td>
<td>0.20-1.00</td>
<td>2-3</td>
<td>18-15</td>
</tr>
</tbody>
</table>

Relative radiated power $\phi$ of different lamp types, with respect to a luminous flux of 1000 lm, subdivided into the wavelength ranges: UV [280 nm–380 nm], visible light [380 nm–780 nm], IR [780 nm–10000 nm].

Example: $\phi = \text{UV} \cdot \text{lm} / 1000$

An A60 lamp with 100W and 1380 lm results in a UV radiated power of 0.069–0.138 W.

The economy of a lamp depends on the luminous efficacy, the lamp life and the cost of the lamp. Incandescent lamps and tungsten halogen lamps have the lowest luminous efficacies. Clearly larger values are attained by fluorescent lamps, high-pressure mercury vapour lamps and metal halide lamps. Incandescent lamps and tungsten halogen lamps have the lowest lamp life. The life of fluorescent lamps and high-pressure lamps is considerably higher.

Aspects of radiation are important in the field of exhibition and display. Infrared and ultraviolet radiation can cause damage on paintings. High proportions of infrared radiation and convection heat are emitted above all by light sources with low luminous efficacy, such as incandescent lamps or tungsten halogen lamps. With conventional and compact fluorescent lamps the infrared radiation is noticeably lower. The damaging infrared and ultraviolet components can be reduced considerably by using filters.
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Luminaire selection

The choice of light sources outlines the technical qualities of the lighting design concept and the limits to the lighting qualities that can be achieved. The lighting effects that can be obtained within this range depend on the choice of luminaires in which the lamps are to be used. The choice of lamp and luminaire is therefore closely related. Opting for a particular light source will reduce the choice of luminaire, and vice versa, the choice of luminaire will restrict the choice of lamp.
Uniform general lighting is a standard lighting concept. For general lighting, wide-beam luminaires such as downlights and light structures are suitable. Uniform lighting can also be achieved by indirect illumination. However, a lighting concept that aims solely to create isolated lighting accents is the exception. Often, accent lighting will contain general lighting components to allow the viewer to perceive the spatial arrangement of the illuminated objects. Spill light from the accentuated areas is frequently sufficient to provide adequate ambient lighting. Luminaires that emit a directed, narrow beam can be used for accent lighting. Adjustable spotlights and directional luminaires are ideal.
Direct lighting allows diffuse and oriented light, and both general lighting and accent lighting. A lighting plan can be used with direct lighting that allows differentiated distribution of light. This greatly enhances the three-dimensionality of illuminated objects as the result of high contrasts.

With indirect lighting, lighting is designed to give diffuse general lighting. Indirect lighting produces a highly uniform, soft light and creates an open appearance due to the bright room surfaces. Problems caused by direct and reflected glare are avoided. Indirect lighting alone can give a flat and monotonous environment.
The decision for narrow or wide light distribution is closely connected with the concept of general or differentiated lighting. Luminaires with a beam angle of less than 20° are known as spotlights and above 20° as floodlights. With downlights, the cut-off angle also gives an indication of the width of the light distribution. Wide light distribution creates a higher proportion of vertical illuminance.
Symmetrical light distribution is used for providing even lighting. The light distribution can be wide for downlights used for the general lighting of horizontal surfaces. With spotlights, the light distribution is narrow beamed to provide highlighting. Luminaires with asymmetric light distribution are designed to give uniform light distribution for surfaces located to one side. Typical luminaires with this characteristic are wallwashers and ceiling washlights.

For luminaires with axially symmetrical beam emission, such as light structures, two light intensity distribution curves are given.

Symmetrical light distribution for general lighting

Asymmetrical light distribution of wallwashers for uniform wall illumination
Focusing on horizontal lighting is frequently in line with the decision to plan functional, user-orientated light. This applies to the case of lighting for workplaces for instance, where the lighting design is primarily aimed at giving uniform lighting for horizontal visual tasks. In such cases, vertical lighting components are predominantly produced by the diffuse light that is reflected by the illuminated, horizontal surfaces.

The decision to plan vertical lighting may also be related to the task of fulfilling functional requirements when illuminating vertical visual tasks, e.g. for shelves, blackboards or paintings. However, vertical lighting frequently aims to create a visual environment. Vertical lighting is intended to emphasise the characteristic features and dominant elements in the visual environment. This applies not only to the architecture itself, whose structures can be clearly portrayed by illuminating the walls, but also to the accentuation and modelling of the objects in the space.

In most cases the choice of luminaires will be confined to the standard products available, because they can be supplied at reasonably short notice, have clearly defined performance characteristics and have been tested for safety. Standard luminaires can also be used in special constructions, such as lighting installations that are integrated into the architecture [e.g. cove lighting or luminous ceilings]. In the case of large-scale, prestigious projects consideration may also be given to developing a custom designed solution or even a new luminaire. This allows the aesthetic arrangement of luminaires in architecture or in a characteristically designed interior and the solution of specific lighting tasks to be effected in closer relation to the project than if only standard products are chosen. Additional costs for development and time considerations must be included in the calculation of overall costs for the project.
The colour of light from a luminaire depends on the lamp. The range of white light colours is divided into warm white, neutral white and daylight white. Coloured light can be produced from these lamps by using colour filters. The use of a coloured light source such as an LED or fluorescent lamp creates coloured light directly and avoids the reduced transmission of colour filters. With luminaires having RGB technology, red, blue and green primary colour light sources can be mixed to give a multitude of colours. An electronic control allows the light colour to be changed dynamically.
There are two basic contrasting concepts for the arrangement of luminaires in an architectural space, which can allocate different aesthetic functions to the lighting installation and provide a range of lighting possibilities. On the one hand, there is the attempt to integrate the luminaires into the architecture as far as possible, and on the other hand, the idea of adding the luminaires to the existing architecture as an element in their own right. These two concepts should not be regarded as two completely separate ideas, however. They are the two extremes at either end of a scale of design and technical possibilities, which also allows mixed concepts and solutions. The decision to opt for a stationary or variable lighting installation overlaps the decision to go for an integral or additive solution; it is determined by the lighting requirements the installation has to meet rather than by design criteria.

In the case of integral lighting, the luminaires are concealed within the architecture. The luminaires are only visible through the pattern of their apertures. Planning focuses on the lighting effects produced by the luminaires. Integral lighting can therefore be easily applied in a variety of environments and makes it possible to co-ordinate luminaires entirely with the design of the space. Integral lighting generally presents a comparatively static solution. The lighting can only be changed by using a lighting control system or by applying adjustable luminaires. Typical luminaires here are recessed wall or ceiling luminaires.
Additive lighting

In the case of additive lighting, the luminaires appear as elements in their own right. Besides planning the lighting effects which are to be produced by these luminaires, the lighting designer also has to specify the luminaire design and plan a lighting layout in tune with the architectural design. The range extends from harmonising luminaires with available structural systems to selecting luminaires that will have an active influence on the overall visual appearance. What is gained in flexibility is offset by the task of harmonising the visual appearance of the lighting installation with its surroundings and of avoiding the visual unrest through the mixing of different luminaire types or by a confusing arrangement of light structures. Typical luminaires here are spotlights and light structures, as well as pendant luminaires.

Stationary lighting

With stationary, mounted luminaires, different light distributions are available, e.g. adjustable luminaires such as directional luminaires. The luminaire layout should be thoroughly checked in the design phase because any subsequent alterations to recessed luminaires are very costly.
Movable lighting

There are different ways of making a lighting installation flexible. The highest degree of flexibility, as required for lighting temporary exhibitions and for display lighting, is provided by movable spotlights mounted on track systems or support structures. These allow the luminaires to be realigned, or even rearranged or replaced.
Glare

With regard to glare a distinction is made between direct glare, caused primarily by luminaires (1), reflected glare in the case of horizontal visual tasks (2) and reflected glare in the case of vertical visual tasks, e.g., at VDT workstations (3).

Glare limitation at VDT workstations: for areas with VDT workstations a cut-off angle $\alpha$ of at least 30° is recommended.

Standards

By projecting the field of vision onto the ceiling surface it is possible to define the area in which the luminaires may have a negative influence on contrast rendering.

Standards exist for the lighting of workplaces, which stipulate minimum cut-off angles or highest permissible luminances in the cut-off range. For workstations with VDTs there are specific requirements. The critical area can be defined as that portion of the ceiling which is seen by the user in a mirror covering the working area. In the case of luminaires with mirror reflectors direct glare control improves the greater the cut-off angle. The standard cut-off angles are 30° and 40°.

The UGR (Unified Glare Rating) process is used to evaluate and limit the direct discomfort glare in indoor areas. The UGR value is influenced by the light source’s luminance, its visible size (solid angle) and its position (position index), as well as the luminance of the background. It is usually between 10 and 30. The smaller the UGR value, the less the glare.
Visual performance generally improves sharply as the illuminance level is increased. Above 1000 lux, however, it increases more slowly, and at extremely high illuminance levels it even starts to decrease due to glare effects. However, following a set of fixed rules for illuminance levels gives little consideration to actual perception. It is not the luminous flux falling on a given surface – illuminance – that produces an image in the eye, but the light that is emitted, transmitted or reflected by the surfaces. The image on the retina is created entirely by the luminance pattern of the perceived objects, in the combination of light and object.

<table>
<thead>
<tr>
<th>E (lx)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-50</td>
<td>Paths and working areas outdoors</td>
</tr>
<tr>
<td>50-100</td>
<td>Orientation in short-stay spaces</td>
</tr>
<tr>
<td>100-200</td>
<td>Workrooms that are not in continuous use</td>
</tr>
<tr>
<td>200-500</td>
<td>Simple visual tasks</td>
</tr>
<tr>
<td>500-750</td>
<td>Visual tasks of average degree of difficulty</td>
</tr>
<tr>
<td>750-1000</td>
<td>Difficult visual tasks, e.g. office work</td>
</tr>
<tr>
<td>1500-2000</td>
<td>Complicated visual tasks, e.g. precision assembly work</td>
</tr>
<tr>
<td>3000-5000</td>
<td>Extremely complicated visual tasks, e.g. inspection and control</td>
</tr>
<tr>
<td>&gt; 2000</td>
<td>Additional lighting for difficult and complicated tasks</td>
</tr>
</tbody>
</table>

Recommended illuminance level E according to CIE for various activities
Safety requirements

Luminaires are required to meet the safety requirements in all cases; in Germany this is usually guaranteed by the presence of a test symbol. In some cases there are other requirements that have to be met and the luminaires marked accordingly. Special requirements have to be fulfilled by luminaires that are to be operated in damp or dusty atmospheres, or in rooms where there is a danger of explosion. Luminaires are classified according to their mode of protection and protection class, whereby the protection class indicates the type of protection provided against electric shock, and the mode of protection its degree of protection against contact, dust and moisture.

### Protection mode

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No protection</td>
</tr>
<tr>
<td>1</td>
<td>Drip-proof: water spray from above</td>
</tr>
<tr>
<td>2</td>
<td>Protected against spray (up to 15° to the vertical)</td>
</tr>
<tr>
<td>3</td>
<td>Protected against spray from all directions</td>
</tr>
<tr>
<td>4</td>
<td>Protected against jets of water from all directions</td>
</tr>
<tr>
<td>5</td>
<td>Water-proof: flooding</td>
</tr>
<tr>
<td>6</td>
<td>Waterproof: immersible</td>
</tr>
<tr>
<td>7</td>
<td>Water-proof: may be submerged</td>
</tr>
</tbody>
</table>

Identification of protection mode (IP): code X, foreign body protection
Identification of protection mode (IP): code Y, water protection

### Protection classes

<table>
<thead>
<tr>
<th>Protection class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>The luminaire has a connection point for an earthed conductor to which all metal parts with which users may come into contact must be connected. Connection to the mains earth conductor is imperative</td>
</tr>
<tr>
<td>II</td>
<td>The luminaire is insulated such that there are no metal parts which users can touch that may be live if a fault occurs. There is no earth conductor</td>
</tr>
<tr>
<td>III</td>
<td>The luminaire is operated on low-voltage up to 42 V, supplied via safety transformers or batteries</td>
</tr>
</tbody>
</table>

Protection classes for the electrical safety of luminaires

Luminaire suitable for mounting on parts of buildings comprising materials with an ignition point of >200°C |
Luminaire with a limited surface temperature, suitable for installation in areas exposed to dust or containing inflammable materials or in danger of explosion |
Luminaire suitable for installation in or surface mounting on furniture made of standard inflammable material |
Luminaire suitable for installation in or surface mounting on furniture with unknown inflammable properties |
Safety distance (d) in the direction of beam

Identification of special luminaire properties and safety requirements

Special requirements to fire safety have to be fulfilled when luminaires are installed in or on furniture or other inflammable materials.
Designing the lighting layout should not be seen as a solely technical or functional process. In quantitative lighting design, it has become preferred practice to plan the lighting layout of ceiling-mounted luminaires to produce a completely uniform grid, with the aim of providing uniformly distributed lighting. Consequently, there is no direct link between lighting layout and lighting effect; by exploiting the wide range of luminaires available it is possible to achieve a designed pattern of lighting effects using a variety of lighting layouts. The lighting design should make use of this scope, producing ceiling designs that combine functional lighting with an aesthetic lighting layout that relates to the architecture.
Floor

The recommended offset from the wall (a) is half the luminaire spacing (d). The luminaire spacing (d) between two adjacent structures should correspond to the height (h) above the floor or work surface.

Cut-off angle

The greater the cut-off angle, the greater the visual comfort provided by the luminaire due to improved glare control. The same lighting layout of downlights produces different distributions on the wall. A cut-off angle of 40° gives the best possible compromise between the necessary horizontal illuminance on the floor and vertical illuminance. Vertical illuminance is important in places such as salesrooms where products should be well illuminated. On downlights with a 30° cut-off angle, the maximum luminous flux is emitted at a high lateral angle. Due to their narrow light distribution, downlights with a 50° cut-off angle achieve very high visual comfort for high rooms.

No light is emitted beyond the cut-off angle.

30° cut-off angle

40° cut-off angle

50° cut-off angle
Wall

The distance from the wall for wallwashers should be at least one third of the room height. Alternatively, the wall offset is given by a 20 degree line extending from the base of the wall up to the ceiling. Whereas for normal room heights the luminaire spacing is the same as the wall offset, in high rooms this spacing must be reduced to compensate for the illuminance which is generally reduced. Wallwashers do not give optimum uniformity until at least three luminaires are used. A wallwasher in a room corner should be positioned on the 45° line.

Room corner

The recommended distance of downlights to the wall is generally half the distance between the downlights. Corner-mounted luminaires should be mounted on the 45° line to produce identical scallops on both walls.

Mirrored walls

For mirrored walls, the lighting layout should be chosen such that the pattern continues uniformly in the reflection.
Wall element

In spaces with dominant architectural features, the lighting layout should harmonise with the architectural elements.

Ceiling

Ceiling lighting requires sufficient room height to achieve even light distribution. Ceiling washlights should be mounted above eye-level to avoid direct glare. The ceiling offset depends on the degree of evenness required and should generally be 0.8m.

Object

Objects can be illuminated with light directed from between 30° to 45° to the vertical. The steeper the incident light, the more pronounced the three-dimensionality of the illuminated object. If the angle of incidence of the light is approximately 30°, the so-called "museum angle", this produces maximum vertical lighting and avoids reflected glare that may disturb the observer. In the case of reflecting surfaces, e.g. oil paintings or pictures framed behind glass, attention must be paid to the angle of incidence of the light to avoid disturbing reflections that may arise in the observer's field of vision. This will also avoid any heavy shadow, e.g. picture frame shadows on the picture.
Horizontal surfaces

High luminance values reflected by surfaces or objects cause secondary glare. The luminaires should not be positioned in critical areas. Indirect illumination with diffuse light reduces the secondary glare. The beam should be aimed such that shadows on the work surface are avoided.

Vertical surfaces

If a reflective surface is arranged transversely, luminaires can be mounted in front of the excluded ceiling zone. If a reflective surface is arranged vertically, they can be mounted next to the excluded ceiling zone.
Point source

The simplest layout of these points is a regular grid, in a parallel or staggered arrangement. A regular pattern of identical luminaires can easily result in a monotonous ceiling appearance, plus the fact that differentiated lighting is practically out of the question.

Point source combinations

An alternating grid of different individual luminaires or luminaire combinations can produce more interesting arrangements; in this case luminaires of the same or different types can then be purposefully combined.

The point sources may be luminaires of different shapes and sizes, or compact groups of luminaires.
A further step towards more complex design forms is the linear arrangement of point sources. In contrast to simple lighting layouts in grid patterns, the ceiling design in this case relates more closely to the architecture of the space. The ceiling is designed along the lines dictated by the architectural form of the space. This may involve following existing lines or purposefully arranging the luminaires in contrast to the existing formal language.

Point sources: linear arrangements

Since the linear arrangement of the luminaires does not necessarily relate to an actual line such as the course of a wall, ceiling projections or joists, the luminaire arrangement can only be created on the basis of the perception of gestalt. These laws of gestalt must receive special attention during the planning phase. The crucial criteria are the equidistance and proximity of luminaires to each other.

Luminaire arrangements can follow existing architectural structures or create patterns of their own.
Whereas linear arrangements consisting of a series of points are only produced indirectly by our perception of the gestalt, they can also be directly formed of linear elements. These linear elements can be particular types of luminaires, or even trunking systems. Light structures and track arrangements or other trunking systems belong to this design category. The formal language of linear arrangements is identical to that of rows of points. As the visual forms produced when linear luminaires are used are real and not just implied, more complex arrangements can be planned with no danger of distortion through perception.

Creative design allows both the alternating application of different luminaire forms and the use of spotlights on lighting structures or trunking systems. This allows differentiated lighting without the individual luminaires disturbing the intrinsic appearance of the structure.
Decorative solutions

The combination of different elements gives rise to a broad range of design possibilities, including decorative solutions.

Linear structures

The rectangular arrangement of tracks corresponds to the shape of the room. This allows flexible lighting of all wall surfaces and accentuating of objects in the space.
Both technical and design aspects are important when mounting. If the arrangement of the luminaires is already fixed, then the focus shifts to the mounting detail. Various mounting versions are available for downlights, e.g. surface-mounting, recessed-mounting or pendant suspension.
Suspended ceilings

In the case of flat suspended ceilings, e.g. plasterboard ceilings, the luminaires can almost always be arranged irrespective of the suspended ceiling grid. The luminaires are fixed firmly in the ceiling apertures provided; if necessary, the weight of the luminaire must be carried by additional suspensions fixed onto or in close proximity to the luminaire. If the ceiling is to be plastered, plaster rings are required for the luminaire apertures.

Panel ceilings

For open grid ceilings and honeycomb-grid ceilings there are recessed cassettes available complete with suitable apertures for the recessed mounting of downlights. The cassettes are dimensioned to suit the respective ceiling grids. They can replace a ceiling panel or allow the installation of luminaires between ceiling panels which would otherwise not be suitable to take the static load.

Ceiling channel

Light sources can be mounted in a track ceiling channel in order to integrate them invisibly into the ceiling.
Pendant luminaires

Pendant mounting can be effected in a variety of ways. Light-weight luminaires are usually suspended by the connecting cable. Heavier luminaires require a separate suspension device. This may take the form of a stranded wire cable or a pendant tube, which generally contains the connecting cable.

Concrete ceilings

For recessed mounting into concrete ceilings the luminaire apertures are created when the ceiling is cast. Another possibility is to install prefabricated housings, which are also attached onto the concrete shuttering and remain in the ceiling. It is essential to check that the planned lighting layout is compatible with the structure of the ceiling, whether specific installation locations must be avoided, for example, due to concealed joists or whether the reinforcement of the ceiling should be co-ordinated with the lighting layout.
Wall

Luminaires can be mounted onto wall surfaces or recessed into the wall. The latter can be in either concrete or hollow walls. Luminaires can be mounted on wall brackets or cantilever arms for indoor partitions or outdoor facades.

Floor

Luminaires for floor or ground installation can be surface-mounted or recessed-mounted. When recess-mounted in the floor or ground, the luminaire cover must be robust and provide protection against the ingress of moisture. Bollard luminaires and mast luminaires may also be used outdoors.
By stipulating a light loss factor when planning the lighting, the intervals at which maintenance is to be carried out can be controlled. By keeping light loss factors low, the lighting level will initially be higher and the period during which luminous flux is gradually reduced to below the critical value will be extended. Using a suitable maintenance factor, lamp replacement and the cleaning of luminaires can be timed to take place simultaneously. The adjustment of luminaires is also classified as maintenance in the interest of the qualitative aspects of the lighting installation. In the area of display lighting in particular, luminaires have to be realigned to accommodate the layout of a new arrangement. A maintenance plan should enable the operator to service the installation at regular intervals, checking whether the technical requirements are being met and the lighting is performing as planned.
Representing lighting installations and their lighting effects in architecture plays a key role in lighting design. The range of representations includes the whole gamut from technically oriented ceiling plans to graphic illustrations of varying complexity to computer-calculated room representations and three-dimensional models of architecture or lighting installations. Skilled lighting designers use ceiling plans and diagrams to derive a realistic idea of the lighting effects achieved. Others in the planning process with less expertise have to rely on visual representations and technical specifications.
The graphic methods employed extend from simple sketches to detailed and elaborate processes. The more elaborate the method used, the more accurate is the representation of the illuminated environment and the lighting effects. Perspective room representations include the positioning of the lighting equipment in the room.
In the simplest case, lighting effects can be shown in a graphic format by light beams designed either as contours, as coloured surfaces or in grey tones contrasting with the background. Drawings that show light beams using light, coloured pencils or chalk on a dark background achieve an intense luminosity and are particularly useful for representing outdoor lighting at night. When visualising an overall concept, a deliberately simplified sketch can demonstrate the lighting effects produced more effectively than an allegedly realistic representation with artificially scaled brightness ratios.
Using rough sketches for visualisation, the story board acts as a creative script detailing the spatial and temporal progression of the lighting effects. It is an effective tool in scenographic lighting design to look at the dynamic processes in the building. These processes result from aspects such as the spatial progression encountered as you walk through the building, but also from the time dimension experienced in a room throughout the course of a day.
The mood board is a collection of pictures, sketches, materials, colours, and terms to describe emotions. Where different moods are required as special effects in a room, parallel collages with diverse themes can be used to underline the statements on contrasts and colours for the different light scenes. While the mood board initially focuses on a broad collection of pictures, the process of evaluation and concentration is more analytical.
Technical drawings provide exact information on the type and positioning of the luminaires used in the ceiling plan and the sectional drawing. For spotlights, for example, the drawing can also specify the alignment of the luminaires. For a better overview, a table can be used to list all the luminaires with their symbols and features. The electrical designers also require details on circuits, switches, push-buttons and protection modes.

Diagrams can be used to document aspects such as the illuminance or luminance distribution in a room. In the Isolux diagrams, contours indicate the same illuminances, while the contours in Iso-candela diagrams specify the luminances.
While the spatial representations of simulation programs reproduce the illuminance levels in a room by way of diagrams, they also provide a visual impression of the lighting concept. In contrast to the drawing, the computer graphic furnishes objective information, as it is based on precise calculations.
Qualitative simulation

The light simulation for qualitative representations focuses on portraying atmosphere. The spatial perspective provides an accurate impression useful for the presentation of the lighting design. The degree of detailing can include photorealistic illustrations.

Quantitative simulation

The quantitative simulation is used for the analysis of a lighting design. It determines the physically correct numerical values for specific visual tasks. The simulation also helps to check compliance with requirements specified in standards, such as uniformity of illuminance. A further effective visualisation method is false-colour diagrams which allow levels to be represented through a colour scale.

Animation

Animation combines individual images generated through simulation to produce a film. It is ideal to demonstrate dynamic lighting effects. Animations where either the camera angle remains the same but the lighting changes or the lighting stays the same but the camera is moved are comparatively simple. Animations where both the lighting and the camera position change are far more complex since each individual image of the film has to be recalculated. The alternative is to use special video post-editing processes.
One of the significant advantages resulting from the use of models is that light is not just represented but becomes effective. Lighting effects are visualised in all their complexity, not merely schematised. A further advantage of models is the aspect of interaction in that the observer can accurately check every angle. A distinction has to be made here between a working model and a presentation model.
Model making

Size and accuracy limit the informative value of the simulation and should be determined accordingly. The scale ranges from 1:100 or 1:200 for the daylight effect of whole buildings to scales of 1:20 to 1:10 for differentiated lighting effects in individual areas. The most critical factor, specifically when using very small-scale models, is usually the size of the luminaires themselves. Variations in the light intensity distribution are clearly reflected in the result. The accuracy of luminaire reproductions is limited on account of the dimensions of the light sources available. The result is that designers often use light guide systems from an external light source to simulate the output from several luminaires.

Mock-up

A mock-up is a reproduction of a room situation at a scale of 1:1. A mock-up of the luminaire or the architectural space concerned is ideal as a basis for decisions specifically when assessing customised luminaires or luminaires which are to be integrated into the architecture. To limit the effort involved, a mock-up is based on an architectural section for maximum benefit.
In the simplest case, both the sun and the daylight can be used directly in outdoor scenes or else be reproduced exactly using a solar simulator or an artificial sky. When simulating sunlight outdoors, a sundial-type display instrument is used to position the model at precisely the angle of incidence of the light that corresponds to a specific season and time of day. In the solar simulator, this is performed by a movable, artificial sun. Both methods allow reliable studies of the lighting effects in and around a building and of engineering designs for daylight control or sun protection even for small-scale models. Cameras are used to capture these observations and to document the lighting changes throughout the day or year. The artificial sky is used to simulate the lighting conditions on a cloudy day and to take measurements of the daylight ratio.