Fördergemeinschaft Gutes Licht

Good Lighting for Museums, Galleries and Exhibitions 18

Free Download at www.all-about-light.org

Contents

Cover photograph: Lighting creates visual experiences in any exhibition. Modulating and accentuating the visual landscape, it enhances the impact of a presentation. Lighting is vital for spatial impression and enjoyment of art.

Fig. 1: The graphic above shows a virtual museum: most of the space is occupied by the exhibition area (blue), followed by the general public areas (red) and the rooms which serve as work premises (orange). The outdoor area (green) is surrounded by the building.

Around 100 million people a year visit Germany's museums to view, experience, admire and enjoy their exhibits. There are more than 6,000 such institutions in total, with a wide variety of collections, a broad spectrum of specialisations and presentation concepts that range from hands-on displays for an interactive experience to quiet retreats for silent contemplation. What they all have in common, however, is that they seek to inspire the visitor.

Whether the focus is art or science, technology or history, the presentation needs to be appealing, interesting and varied. And that is where lighting plays an important role: it creates visual experiences in any exhibition, it helps modulate and accentuate the visual landscape, it enhances the impact of the items on display. The visual ambience must not cause fatigue. On the contrary, it should stimulate – but not confuse. In large buildings, differentiated room design is also a requirement.

Light spaces

Lighting is vital for spatial impression and enjoyment of art. Different light colours and beam spreads, different designs and arrangements of luminaires and lamps create different lighting situations – light spaces – designed to meet the relevant needs of the exhibition.

Special attention needs to be paid to conservation requirements. Light protection plays an important role in any exhibition room.

There is more to a museum than just what it displays; it is also a place of research, where collections are stored, preserved and managed. Only in the right lighting can museum staff work effectively. Lighting also draws attention to tripping hazards and reduces the risk of accidents. So although the lighting designer has a great deal of freedom in exhibition rooms, functional lighting must always be provided.

1

Route lighting
In some exhibition rooms, visitors are free to move around in any direction. In many others, however, because of the nature of the exhibition or for organisational reasons, they need to be 'directed'. Luminaires which highlight routes without interfering with the display areas on either side are a practical solution for this task. Also practical – and stylish as well – is (additional) floor-level orientation lighting, e.g. with LED lighting strip.

Photo 1: Ambience and the way we experience a room are shaped by light and shadows and the way they are mixed.

Photo 2: Diffuse lighting is predominantly used for general room lighting.

Photo 3: Illuminating objects – exhibits are set off to dramatic effect by directional lighting

The design and configuration of exhibition room lighting depends on many planning parameters. Foremost among these is the architecture of the building with which the lighting is required to harmonise. Other factors are room proportions, interior design, colour scheme, available daylight and, last but not least, the nature of the exhibition. The way the ambience is shaped by light and shadow is a matter of fundamental importance.

Light protection
Daylight and artificial light contain rays which may fade, dry out, discolour or deform exhibits. Conservation measures can protect against this but only if they are properly applied and observed. For more about light protection, see page 30.

Room lighting
Lighting for exhibition rooms in museums is made up of diffuse and directional light. The relative amounts and resulting mix of the two types of light determines the harshness of the shadows cast by picture frames and the three-dimensional impact of sculptures and spatial objects. The diffuse and directional light mix also defines the overall impression made by the room.

A closely related matter here is the distinction between room and exhibit lighting. The diffuse lighting is almost all generated by the room lighting, which determines the distribution of brightness and sets lighting accents in the horizontal plane.

Room lighting alone is rarely enough to meet all an exhibition's needs. Conversely, the directional lighting used to illuminate exhibits does not provide bright enough room lighting except in a few – mostly small and bright – interiors.

Exhibit lighting
Exhibit lighting uses hard-edged directional light to accentuate individual items on display. As a general rule, it needs to be supplemented by softer room lighting. Exhibit lighting based on spots alone is advisable only where a particularly dramatic effect is required.

Otherwise, a stimulating spatial experience is obtained with a mix of diffuse (room) and directional (exhibit) lighting.

Diffuse lighting
Diffuse lighting illuminates room zones or objects from a surface that radiates light in all directions. At the site of illumination, i.e. in the room zone or at the object illuminated, the direction from which the light comes cannot be clearly determined: the light flowing into the room and over the objects is not directional. Where it comes from very many directions, i.e. where the radiant surface is large, the lighting produces little or no shadowing.

Directional lighting
Directional lighting is generated mostly by punctual light sources – i.e. lamps that are small in relation to the lighting distance – or spots of similar design. The light falls directly onto the object illuminated, striking it, or parts of it, at an angle defined by the geometry of the lighting arrangement. Where the surface of the object is uneven, clearly defined shadows occur. These enhance the visual impact of three-dimensional surfaces but can also be a source of visual interference if they are too dominant or too large.

2

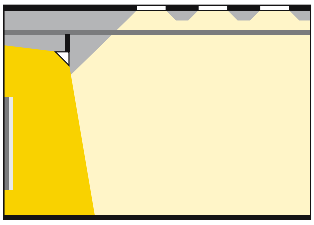


Fig. 2: Directional lighting for the wall, diffuse lighting for the room

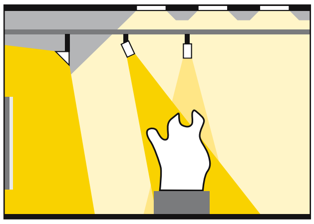


Fig. 3: Supplementary directional lighting for objects in the room

3

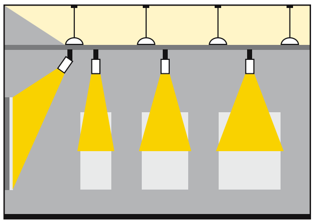


Fig. 4: Indirect and direct components produce diffuse and directional lighting respectively

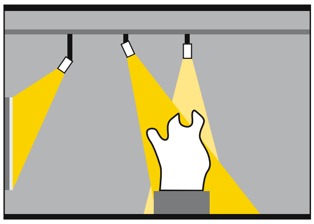


Fig. 5: Solely directional light

Diffuse/directional lighting

In many applications, light cannot be clearly defined as wholly diffuse or wholly directional. This is the case where the surface radiating the light is neither large nor punctual – e.g. a spot with a diffuser disc. Depending on the diameter of the disc and on the lighting distance, shadows are narrower or wider, harsher or softer.

Diffuse/directional lighting also occurs where a surface is illuminated or backlit to produce diffuse lighting and part of the light is made to radiate in a particular direction and is thus partially directional. The direction from which the light comes can be seen on the objects illuminated. However, the shadowing that occurs on exhibits is less clearly defined than if the light were entirely directional. The modelling is rendered more subtle by the brightening effect of the diffuse lighting component.

Diffuse/directional lighting can also be produced, for example, by linear lamps in appropriately designed luminaires. Here, shadowing depends on the position of the luminaire in relation to the picture: wallwashers with tubular fluorescent lamps mounted horizontally or parallel to the upper edge of the wall produce hard-edged shadows beneath horizontal picture frames, whereas the shadows cast by the vertical part of the frame are barely discernible.

Avoiding cast shadows

Directional light produces form shadows. Where it also results in cast shadows on neighbouring objects, the hard contours and obscure origin of such shadows are disturbing. Cast shadows are avoided by ensuring an appropriate mix of diffuse and directional light, correct positioning of the light source producing the directional light or appropriate positioning of the illuminated objects in relation to one another.

4

Photo 4: *Luminous ceilings are particularly suitable for painting galleries. The cove lighting provides additional brightness.*

5

Photo 5: *Indirect lighting has an impact similar to that of a luminous ceiling.*

The most important lighting systems used in exhibition rooms are:

- luminous ceilings with opal glass enclosure (diffuse light) or satinised and textured glass (diffuse/directional),
- indirect luminaires (diffuse),
- cove luminaires (diffuse),
- wallwashers (directional or diffuse/directional),
- spot lamps.

Luminous ceilings
The idea of luminous ceilings stems from a desire to imitate daylight. Luminous ceilings deliver light which is particularly suitable for painting galleries – predominantly diffuse with an opal enclosure, partly directional with enclosures of satinised/textured glass. The heat that is generated in any luminous ceiling needs to be dissipated or extracted.

The light sources of choice are tubular fluorescent lamps arranged according to the structural grid of the luminous ceiling. For good uniformity, they should be spaced no further apart than the distance to the ceiling enclosure. The size of the luminous ceiling, its subdivision and the transitions between ceiling and walls need to suit the proportions of the room and the nature of the objects displayed.

Luminous ceilings imitating natural daylight need to deliver a high level of luminance: 500 to 1,000 cd/m^2, ranging up to 2,000 cd/m^2 for very high-ceilinged rooms. Luminous ceilings are especially suitable for interiors with 6 metre ceilings or higher. Where room heights are lower, their light can dazzle because they occupy a large part of the field of vision. Where the lighting is dimmed for conservation reasons or to reduce glare, the luminous ceiling loses its daylight quality and looks grey and oppressive. All luminous ceilings – including daylighting installations – need to be designed by a specialist.

Indirect luminaires
An impact similar to that of a luminous ceiling is achieved with indirect light bounced off the ceiling and upper wall surfaces into the room. This diffuse, uniform light is predominantly used in rooms where no daylight enters. It is produced by suspended luminaires radiating light upwards.

In exhibition rooms, for example, luminaires for suspended power track systems are an option: they are inserted in the track from above while spots for directional lighting are accommodated in the lower channel.

Cove luminaires
The diffuse light of luminaires installed in the curving transition between wall and ceiling – the cove or coving – is another indirect lighting solution. The cove luminaires most frequently used in modern museum buildings are models with housings which themselves form the coving.

The main direction of light with cove lighting is closer to the horizontal than with a luminous ceiling and corresponds roughly to that of perimeter luminaires mounted in continuous rows. The light is largely shadow-free. Linear lamps – generally tubular fluorescent lamps – are the most widely used light source.

Excessive luminance at the ceiling and on the upper part of walls causes glare and interferes with spatial experience. This can occur in coves where no steps are taken to provide optical control – for example because the existing cove offers no space for prisms or reflectors. Where simple non-overlapping battens are installed, disturbing light-dark transitions are also visible around the lampholders.

Wallwashers
Wallwashers are used as individual luminaires or in continuous rows. Installed flush with the ceiling (or with kick reflector protruding from the ceiling) or mounted close to the ceiling, they should illuminate the walls as uniformly as possible. This task is performed by reflectors with asymmetrical optics. It is important to ensure good shielding in the direction of the observer. Elements on the luminaire for mounting accessories – such as filters or anti-glare flaps – are useful.

Favoured light sources for wallwashers include linear lamps: fluorescent lamps, compact fluorescent lamps in elongated designs, linear high-voltage halogen lamps. The diffuse/directional lighting delivered by the continuous row arrangements that are possible with these light sources produces relatively deep shadows, especially along the horizontal edges of picture frames.

The directional light delivered by individual luminaires with non-linear lamps, on the other hand, gives rise to additional shadows along the horizontal edges of a picture frame.

Spot lamps
Reflectors in reflector lamps (used in luminaires with no reflector) or spots direct most of the light emitted by punctual light sources in a defined beam direction. Spots and downlights with spot characteristics can be fully or partially integrated into a ceiling (or wall) as recessed ceiling spots. Surface-mounted ceiling spots and downlights as well as spots for power track have visible housings. Elements on the luminaire for mounting accessories – such as filters or anti-glare flaps – are useful.

Punctual light sources include high-voltage halogen lamps and low-voltage halogen lamps with and without reflector, incandescent lamps with or without chrome cap as well as metal halide lamps.

Photo 6: Wallwashers distribute their light asymmetrically.

Photo 7: The directional light of spot lamps raises the brightness for exhibits – here with an appropriate beam angle for paintings.

6

7

Medium-scale, large and very large exhibits and the light that falls on them are seen to full effect only from a distance. This must be borne in mind when the exhibits are positioned.

Viewing without interference

To ensure that all exhibits are shown to their best advantage, neither the room nor the exhibit lighting should interfere with the visual task:

- There should be no evocative shadows or patterns of light on walls or ceiling. Such visual interference definitely needs to be ruled out for exhibition walls.
- Reflections and undesirable shadows on pictures and objects should be avoided. With direct lighting, the way to guard against this is to position luminaires so that the distance from the exhibit is around a third of the height of the wall.
- No cast shadows should fall on neighbouring exhibits.
- A greater distance between wallwashers and wall makes for better uniformity but presents a risk of direct glare. The compromise between uniform illumination and visual comfort: the angle between luminaire and wall down to the lower limit of the presentation area should be between 25 and 30 degrees (see Fig. 6 + 7)

Reflectance in the room

The colour, pattern and reflectance of ceiling, walls and floor affect the visual impact of the exhibits and the atmosphere of the room. How bright or dark walls and ceiling can be kept – i.e. how high their reflectance should be – depends crucially on the design intention. It is not possible to make a general recommendation.

What kind of light has what impact?

An "exhibit in the limelight" is (almost) always an exhibit in directional light. What happens when changes are made in direction of light and beam angle? What do objects look like with and without bright surroundings? What difference can luminaire accessories make? Answers are found in the photographs on page 7, where a portrait and a non-figurative painting are presented as examples of two-dimensional pictures and a fragment of an ancient sculpture and a red vase for three-dimensional objects.

8

Photo 8: Higher power lamps or multiple spots are used for illuminating large-scale objects.

Basically speaking, the impact of any change on these relatively small exhibits is the same for large-scale pictures and objects. The only difference is that they need more light: higher power lamps or greater numbers of spots need to be used for illuminating large objects. A very large object, such as a car or a plane, can also be illuminated from several points. This makes for striking visual impact from various viewing angles.

Text panels

Printed information about an exhibit is useful only if it is legible – which is always the case with adequately large black type on a white background. Where different lettering is required, it should be tested for legibility in advance. And always remember: legibility is impaired by reflections.

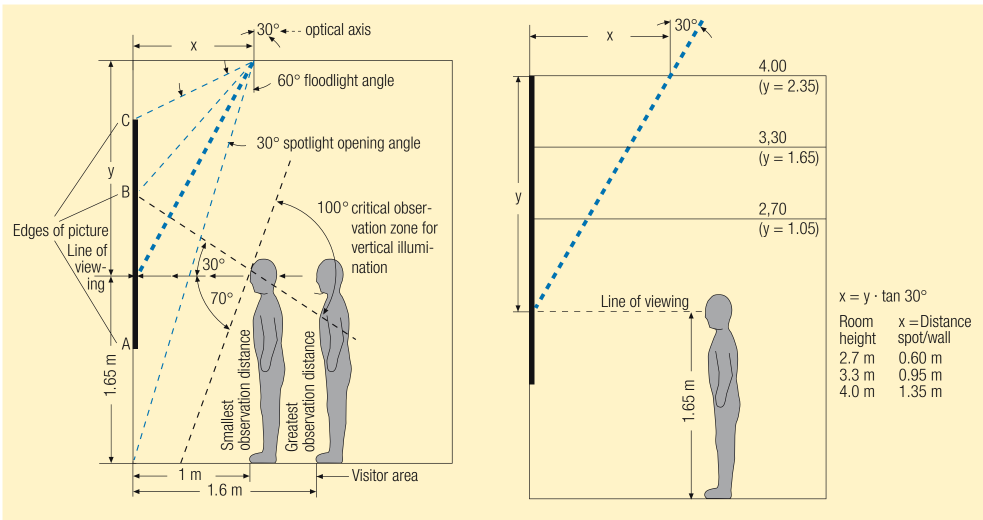
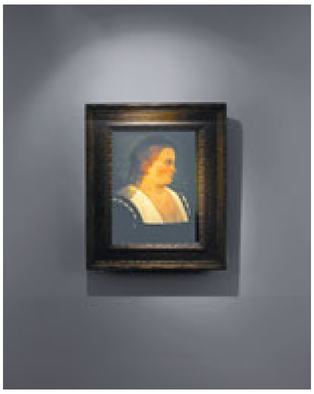


Fig. 6 + 7: Calculation of the optimal positioning of a luminaire for pictures on a wall – room height, observation zone, size of picture and optimal viewing angle (fig. on left) are the parameters defining the optimal position of a wall-lighting luminaire. The upper edge of the picture determines the spotlight opening angle (B: 30°, C: 60°) with a constant angle of inclination of 30°. Angles less than 30° can result in reflections at the upper edge of the picture (critical observation zone). The mathematical formula for calculating the distance "x" between spotlight and wall for illuminating a picture with the height "y" is: $x = y \tan 30°$ (fig. on right).



9

Spot with 15° beam angle and ambient luminescence

10

Spot with 15° beam angle and diffuse ambient luminescence

11

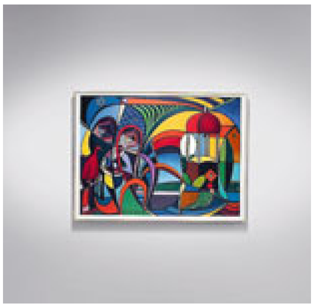
Contour spot with no ambient luminescence

12

Diffuse ambient luminescence

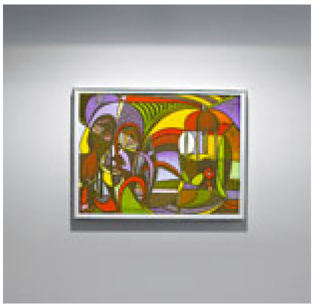
13

Spot with 15° beam angle and soft focus lens



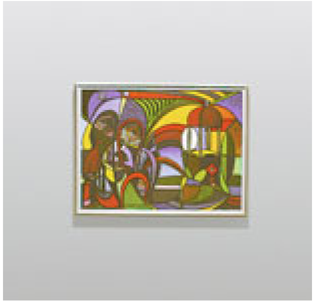
14

Spot with 45° beam angle and oval lens



15

Wallwasher with symmetrical light distribution fitted with R7s halogen lamps (230 V)



16

Wallwasher with asymmetrical light distribution fitted with R7s halogen lamps (230 V)

17

Spot with 15° beam angle, lighting from front, top, middle

18

Spot with 15° beam angle, lighting from front, top, left

19

Spot with 15° beam angle, lighting from front, bottom, left

20

Side lighting from right

21

Lighting from front

22

Lighting from back

23

Lighting from right

24

Lighting from above


25


26

Showcases are miniature exhibition rooms and the exhibits they contain need to be illuminated accordingly – with diffuse or directional light. In some cases, illuminating and accentuating light may also be mixed in glass display cabinets.

The right light for the task
The type of lighting required depends essentially on the characteristics of the exhibits – on three-dimensional form, structure, surface gloss and transparency or colour.

Most metal objects – gold or silver receptacles, for example – acquire a fascinating beauty when they gleam. And that gleam occurs when they are illuminated by punctual light sources. Under diffuse lighting, the receptacles appear matt and lifeless.

For transparent or translucent objects such as glass exhibits, the key to heightening visual impact lies more in modelling than in gleam. The structure of surfaces – cut, etched or painted – also plays an important role here. Depending on the exhibit, the correct solution may be diffuse or directional lighting (through-lighting) or a combination of the two. With directional lighting, visual impact is determined by the angle of light incidence. Diffuse lighting is appropriate for coloured or transparent materials such as glass windows.

Integrated lighting
Small, shallow display cabinets (glass-topped desks) and high or box-shaped showcases mostly have an integrated lighting system. This has advantages:
- Fewer or no reflections occur on the cabinet glass.
- It is easier to avoid direct glare for the observer due to bright unshielded light sources.
- It is easier to engineer special lighting effects for a dramatic presentation.

In small display cabinets, exhibits are normally illuminated from the side. In high showcases, lighting from the cabinet roof is an option. Alternatively, objects can be bathed in light from below from the base of the cabinet.

In addition to the lighting integrated in the showcase, separate ambient lighting is generally essential. Depending on the atmosphere required and the illuminance permitted for conservation, the room lighting should be just below the level of the showcase lighting or even lower. Orientation lighting which relies entirely on stray light from showcases and not on a dedicated orientation lighting system should not be too low.

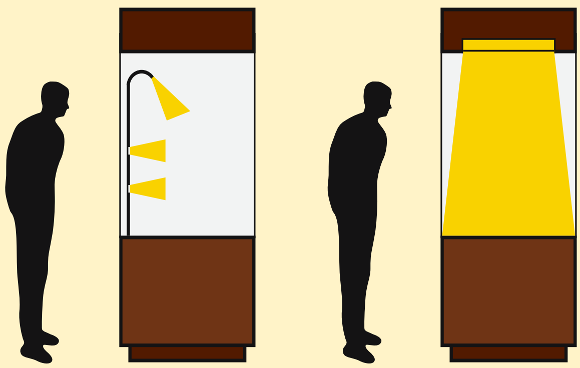
Photo 25: Under the top-down showcase lighting, the suits of armour gleam in fascinating detail

Photo 26: LEDs for light protection – luminous diodes emit neither ultraviolet light nor heat.

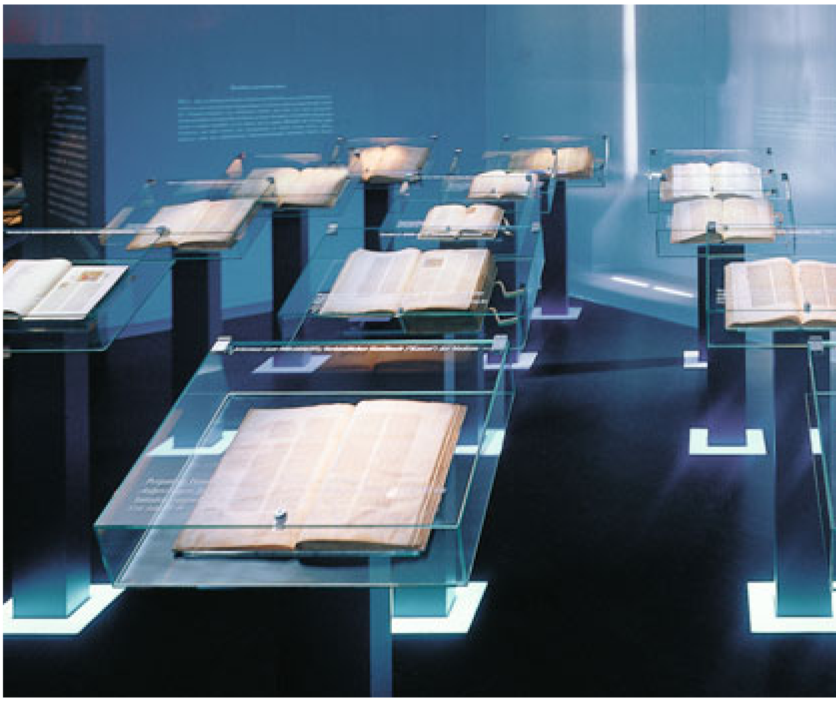
Light protection
Light protection (see page 30) is also an important consideration for showcase lighting – not least because lamps in showcases are often closer to exhibits than in exhibition rooms. It must also be borne in mind that the enclosed space of a showcase has its own microclimate.

For the lighting, there are alternatives to the lamps used in the past: LEDs, for example, which deliver a beam that contains no IV or IR radiation, and fibre-optic lighting systems, which

Fig. 8 + 9 Directional lighting (left) accentuates exhibits, planar lighting (right) makes for uniform illumination.



27



28

have a very low UV/IR content. Incidentally, because of their size, both of these solutions are also suitable for illuminating very small display cabinets.

For fluorescent lamps, compact fluorescent lamps and high-voltage and low-voltage halogen lamps, the same safeguards are required in showcases as in large exhibition rooms.

External lighting
Room and object lighting outside showcases is generally provided by ceiling lights. This type of lighting is particularly suitable for all-glass cabinets and shallow glass-topped desk showcases for viewing from above. Daylight and object-oriented room lighting generally need to be supplemented by accentuating exhibit lighting. Where luminaires are arranged to suit showcases, there is little risk of reflected glare.

Limiting reflections
Limiting reflected glare is an important consideration whatever kind of lighting is installed for showcases with horizontal and vertical glass surfaces. Effective protection against reflected glare is provided by non-reflecting glass.

Reflections on horizontal glass surfaces occur less frequently if the glass is tilted towards the observer. How visible they are depends on the degree of contrast with the surroundings, i.e. the darkness of the showcase. Light-coloured showcases with bright internal lighting thus present a lower risk.

Reflections can also be caused by windows (daylight). Appropriate positioning of showcases or daylight screening – e.g. with vertical blinds – prevents this kind of reflected glare.

Photo 27: The manuscripts in the showcase walls are uniformly illuminated from top to bottom.

Photo 28: Reflection-free external lighting illuminates and highlights the books in the cabinets.

Photo 29: Where luminaires are arranged to suit showcases, ceiling lighting is largely reflection-free.

29

Exhibits which are not on permanent display or which go on tour are presented in rooms for revolving exhibitions. Each new show is an added attraction and draws new visitors to see the permanent exhibition.

To cater for a regular change-over of exhibits, lighting systems need to be adaptable. So very flexible lighting is required. It should be noted, however, that absolute flexibility – enabling the lighting to be as finely tuned for every temporary presentation as for a permanent exhibition – is an unattainable goal.

Flexible lighting
The general – diffuse – lighting takes little account of the positioning of exhibits. The flexibility of the system depends on the directional lighting. Particularly suitable solutions here are furnished by power track systems, in which swivellable, rotatable spots can be snap-mounted at any point. Part of the power track installed should be mounted along the walls to permit gallery-style wall lighting. In the rest of the room, rectangular or square arrangements of power track make for greater flexibility than an arrangement in just one direction.

An alternative to power track are stationary gimbal-mounted spots. These can also be set at any angle and servomotors can be used for re-angling and focusing. Gimbal spotlights are not quite as flexible as spots on power track but they permit a ceiling that makes a much more tranquil design statement than one with power track.

Realigning luminaires
The luminaires of a flexible lighting system need to be realigned for each new revolving exhibition – if necessary by experimenting and repositioning exhibits. This invariable calls for the use of ladders and steps. For inaccessible locations, remote control spots are the right answer.

Taking account of daylight
Where revolving exhibitions are staged in daylit rooms, daylight incidence and the position of showcases in relation to windows (see page 9) must also be taken into account. To maximize the scope for catering to exhibition requirements, it is best to ensure that daylit rooms can be fully darkened. More information about daylight is found on pages 22/23. Facilities for darkening rooms can also be useful for light protection; for information about the light protection requirements of exhibits – which naturally also need to be met in revolving exhibitions – see pages 30–33.

Mobile spots
Where mobile partitions are used for presentations, mobile spots fastened to the partitions by clamps or screw mountings are an alternative to spotlights on power track. So that power cables to spots do not present a tripping hazard, rooms for revolving exhibitions should be provided with power points in the floor.

Photo 30: The light of the gimbal-mounted spots is focusable.

30

31

Photo 32: Power track integrated in the ceiling makes it possible for spots to be positioned in flexible arrangements.

Photo 33: High illuminance where required – each luminaire features four gimbal-mounted spots.

Photo 31: Power track is integrated in the ceiling grid construction to accommodate the spotlights for the exhibit lighting.

Photo 34: The spotlights need to be repositioned for every new revolving exhibition.

32

33

34

Foyers, corridors, staircases

The entrance area is the calling card of the establishment. It shapes visitors' first impressions, its design can overcome fear of crossing the threshold. A harmonious lighting atmosphere sets the scene for a friendly reception. Foyers also serve a functional purpose: they lead into the interior of the building.

Harmonious lighting
To meet these requirements, the lighting needs to incorporate a mixture of direct and indirect light – delivered by a combination of lighting systems designed to cater for every lighting task: the uniform general lighting provides security and facilitates orientation, accentuating light on ceiling and walls makes the visual impact less severe. Direct or direct/indirect luminaires with efficient fluorescent or compact fluorescent lamps are the most widely used light sources for the general lighting; wall luminaires for indirect lighting form part of the accent lighting.

In the entrance zone, people step out of bright daylight into a darker building or out of night-time darkness into a brightly lit interior. To enable their eyes to adjust to the change in brightness level, adaptation zones are recommended. During the day, the immediate entrance area needs to be particularly brightly lit; at night, the illuminance inside the building should decrease towards the exit.

The calling card role of a foyer makes it an interesting place for special architectural features – features which lighting and lighting characteristics should underline. For high ceilings, for example, high-intensity spots with high-pressure discharge lamps are recommended. As pendant luminaires with direct/indirect light distribution, they emphasize the height of the room. Moulded plaster ceilings, columns or galleries can be very effectively stressed by accentuating light.

Guiding light
Corridors, staircases and lifts connect the entrance area with the deeper recesses of the building. If they are significantly darker than the foyer, they can be off-putting. To avoid this tunnel effect, the illuminance realised should either be the same or reduced very gradually in stages. DIN EN 12464-1 stipulates a minimum of 100 lux illuminance for circulating areas such as corridors.

A route guidance system provides an effective additional orientation aid for visitors. To ensure reliable guidance, it should include bright information panels or back-lit signs with a clear message.

Safe light
The risk of tripping on steps and stairs is reduced by good lighting. The illuminance should be at least 150 lux (DIN EN 12464-1). As it is generally more dangerous to fall down stairs than to trip on the way up, it is particularly important that the lighting should ensure that treads are clearly discernible from above. In addition, light falling from the upper landing makes for short soft-edged shadows. The treads can thus be clearly distinguished; each one is readily identifiable.

Floor-level orientation lighting provides added security. Wall lights at the side of the stairs casting direct light onto treads are a solution here. LED technology offers a new alternative, e.g. with luminous diodes set into risers. LEDs are also used for illuminating banisters.

35

Photo 35: Distributor role – foyer and corridors provide both a physical and optical link with the deeper recesses of the building.

Photos 36 and 37: The entrance area shapes first impressions. Harmonious lighting makes for a friendly reception.

36

Photos 39 and 40: Corridor lighting provides guidance for visitors and makes their route safe. Minimum illuminance: 100 lux.

37

39

38

Photo 38: Light in banisters – LEDs make it possible.

40

Audiovisual media

41

An exhibition may include video installations or presentations on large screens or monitors of various sizes. It may also include audio exhibits, i.e. recordings of voices, sounds or music.

Reflected glare is annoying
The lighting needs to cater for the use of audiovisual media. Because reflected glare on screens is very annoying, highly directional lighting should not be installed in the vicinity of monitors. High luminance from neighbouring exhibition areas has the same dazzling effect; stray light from such sources should also be limited.

For audiovisual presentations, lighting should normally not be too bright – neither for visual perception nor for the perception of sounds on which visitors need to concentrate. Where presentations are interactive, however, it is important that controls such as buttons and their labels should be easy to identify. The illuminance of the additional lighting provided for the purpose and its radiance in the direction of the screen (reflected glare) and the operator (direct glare) must nevertheless be limited so that they do not interfere with visitors' perception of the presentation.

Computer room
Where computers and monitor screens are not integrated in the exhibition but installed in a separate computer workstation room, it is advisable to light that room as if it were an office (see page 19). If the time visitors spend in the room is kept short – for example by putting a limit on the maximum length of stay – the lighting concept of the exhibition can also be adopted here even if it means a lower lighting level. Having said that, the risk of direct and reflected glare must always be ruled out.

Photo 41: Audiovisual media can form part of an exhibition. Catering for them calls for lighting incorporating no highly directional light, delivering illuminance tailored to presentations and providing adequate light for the use of controls.

42

Photo 42: In a separate computer room, the rules of office lighting apply.

Photo 43: Feeling, hearing, seeing – all the senses are involved in experiencing the exhibition.

43

Lecture room

Virtually every type of event takes place in a lecture room; certain guided tours also start and end here. The room should therefore be furnished and equipped as a multifunctional facility – with lighting installations designed to create the lighting conditions needed for all the relevant occasions, thus enhancing concentration, raising receptivity and facilitating communication.

Lighting tailored for the occasion
How flexible the lighting needs to be depends on the different lighting situations presented by events. The first requirement is that luminaires should be grouped on separate switching circuits because the individual lighting situations – e.g. “reception”, “lecture” or “presentation” – call for different system settings. One luminaire group may be left switched off, for example, while a second is activated and a third is dimmed.

The task of lighting control is performed via a simple control unit or – in larger rooms – by a lighting management system. With lighting management, programmed lighting scenes can be adapted to individual conditions without altering the programming. Cross-fade times can be set as required on a scale from one second to several minutes. Most lighting management systems also offer the option of incorporating window darkening and sunshade settings into programs.

One lighting control system recommended for lecture rooms is the DALI® system (Digital Addressable Lighting Interface) with its standardised digital interface. Its key advantages are that it has few components, requires little wiring and is easy to operate. Information is available at www.dali-ag.org.

44

What is always useful – in some cases also for lecturers – is the opportunity to control the lighting from a remote device.

Accent lighting essential
Apart from having a functional role, lighting is also an element of interior design. Accent lighting, for example, is essential in a prestigious lecture room. Numerous punctual light sources, indirect lighting components emphasizing the architecture of the room and planar or directional illumination of pictures and wall areas produce an agreeable effect. For the lighting situation “reception”, general and accent lighting should be closely coordinated and programmed to be activated together.

Photo 44: “Film presentation” and “lecture” are the two lighting situations most frequently found.

Photo 45: Lecture room lighting is multifunctional lighting designed to create tailored lighting conditions for different situations.

45

Library lighting has several functions: it helps us get our bearings, helps us find the literature we require, facilitates reading and creates a peaceful to subtly stimulating atmosphere. The basis for planning is DIN EN 12464-1. As a general rule, the more demanding the visual task, the higher the lighting requirement. The illuminance required for circulating areas, for example, is 100 lux, for shelving systems 200 lux. Reading areas, however, call for 500 lux.

Fast orientation
The general lighting – with additional route marking and identification of exits – needs to permit fast orientation and provide guidance around the rows of shelves. Direct/indirect lighting produces an agreeably bright ceiling and prevents the so-called "cave effect" that can easily occur in parts of a library. Where direct lighting components are kept small, annoying reflections (reflected glare) on glossy paper are also reduced.

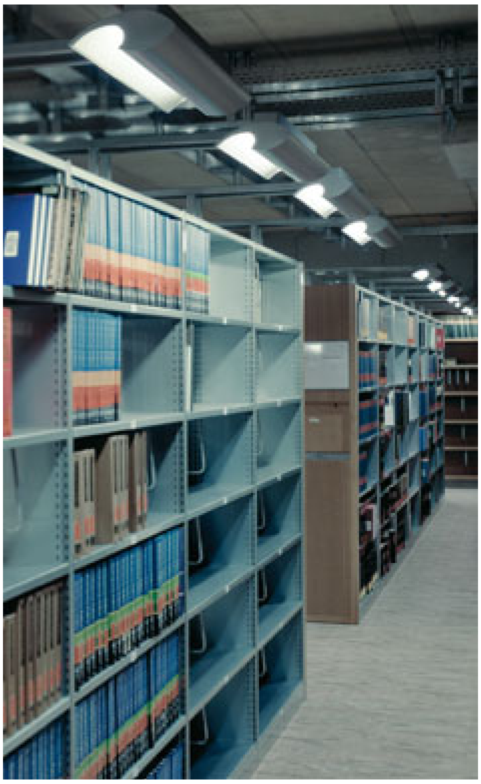
Suspended luminaires for tubular fluorescent lamps are the most widely used here, along with luminaires for metal halide lamps in high-ceilinged rooms.

Vertical lighting components
Bookshelves and bookcases should be well illuminated over their entire area. Vertical components need to reach to the lowest shelf to enable titles on book spines to be read with ease from a reasonable distance. Wallwashers with asymmetrical beams are particularly suitable for this lighting task. Lamps with a good colour rendering index ($R_a \geq 80$) ensure that books can be easily identified by the colour and design of the spine, which are often used as search criteria.

46

Reading desks require brighter lighting. Where desk luminaires are used to supplement the general lighting, visitors can raise the lighting level to suit their personal requirements.

Photo 46: Helping visitors get their bearings, facilitating reading, creating a peaceful to subtly stimulating atmosphere – these are the tasks addressed by library lighting.



47

Photos 47 and 48: Wallwashers with asymmetrical beams illuminate shelves – from the ceiling (47) or as integrated shelf luminaires (48).

48

Study room

Some museums have study rooms, which offer more peace and quiet than reading desks in a library. Here, students and others with special interests can consult not only books but also exhibition and archive documents.

Exacting visual tasks
Even if a study room is not equipped with computers, the lighting should cater for monitors because nearly anyone researching a subject today has a laptop at hand. Working at a computer, reading and writing are demanding visual tasks, for which DIN EN 12464-1 sets out a minimum of 500 lux illuminance. Because glare impairs visual performance and causes visual discomfort, care needs to be taken – as in an office or at any other VDU workplace – to ensure that neither direct nor reflected glare occurs.

Solutions suitable for the direct lighting include pendant luminaires – mounted singly or in continuous rows – with high-grade reflectors and louvers and downlights with similar optical control elements. Alternatively, direct/indirect light can be provided by pendant luminaires or stand-alone luminaires specifically designed for office use.

Adjustable lighting level
A particularly high degree of comfort is offered by lighting systems in which stand-alone luminaires can be dimmed or supplementary desk-top reading lights switched on to tailor the task lighting level to individual requirements. With fluorescent lamps or compact fluorescent lamps operated by (dimmable) electronic ballasts (EBs), study room lighting can also be particularly economical.

49

50

Photo 49: Daylight or artificial light enters the study room as indirect light from the light wells. Downlights along the sides of the room provide supplementary lighting.

Photo 50: The luminaires for fluorescent lamps are mounted on power track to radiate light upwards or downwards. They provide indirect and direct lighting.

Photo 51: These desks are used mainly by students. 500 lux illuminance is provided for reading and writing tasks.

51

Cafeteria, museum shop

52

Photo 52: The general lighting casts a discreet diffuse light.

53

Photo 53: The scene is dominated by the rows of small punctual light sources.

Photo 54: Accentuating light with graduated brightness levels creates a stimulating sales(room) atmosphere.

54

Cafeterias and museum shops are attractive places, especially at the end of a museum visit. The culinary offerings are welcome and many people buy the merchandise on sale as souvenirs or gifts.

Cafeteria lighting

For cafeterias, differentiated lighting with various room-structuring systems is recommended: e.g. pendant luminaires for tables, wall luminaires and downlights for a moderately higher lighting level, downlights and spots for accent lighting. Depending on the size and design of the cafeteria, a single lighting system may be enough.

The range of design options for catering establishment lighting is almost endless. Limits are reached only where visual performance and visual comfort are significantly impaired, which means that glare must always be avoided. Harsh shadows are also bad because they interfere with facial recognition.

In terms of brightness, service areas in a cafeteria can keep a low profile – with one exception: the food counter and any other areas where food and drink are displayed or on sale need to be more brightly lit than the rest of the room. DIN EN 12464-1 stipulates 200 - 300 lux illuminance here. This helps guests get their bearings and facilitates the visual task of choosing food.

Sales lighting

Capturing the attention of today's visually spoilt consumer calls for cleverly designed sales presentations. The spectrum of customised solutions is as wide as the range of modern lamps, luminaires and spots. For a museum shop, the design challenge is to achieve optimal harmony between the structure and furnishings of the room and lighting systems designed to suit the merchandise on sale.

A distinction needs to be made between general lighting – "viewing light" – and accent lighting – "display light" – for shelves, walls or special offer presentations on the sales floor. The rule of thumb for the right mix is: the more upmarket the range, the more stylish the lighting and the greater the importance attached to differentiated accent lighting.

The overall impression made by graduated brightness levels determines how stimulating customers find the sales(room) atmosphere. However, caution is required: excessive differences in brightness place too much strain on the eyes of shoppers and staff. Detailed information is provided in FGL booklet 6 (see page 45) on salesroom and shop window lighting. The relevant standard is DIN EN 123464-1.

Workplace lighting is needed for rooms which are not open to the public and where the lighting caters solely for the visual tasks performed by the people who work there. These rooms are essentially offices, e.g. administration areas, workshops and storage facilities such as warehouses, depots and archives.

Office lighting
The first requirement for visual performance and visual comfort is an adequate level of lighting. For compliance with DIN EN 12464-1, illuminance in the task area must be no lower than 300 lux. The standard makes a distinction between room-related, task area and work surface lighting (more information in FGL booklet 4, see page 45).

The most popular office lighting solution is based on pendant luminaires or standard-alone luminaires for direct/indirect lighting, which most people find agreeable. The alternative – direct general lighting with recessed or surface-mounted ceiling luminaires or pendant luminaires with specular louvers – is appreciated especially for its uniformity.

One of the most important quality criteria, particularly for VDU workplaces in an office, is direct and reflected glare limitation by appropriate positioning of luminaires, desks and monitors. Where accent lighting is provided by wall luminaires or showcase or picture lights, care must be taken to ensure that disturbing reflected glare is avoided.

Workshop lighting
For compliance with DIN EN 12464-1, what applies to offices – see above – basically applies also to workshops. Regardless of the type of work performed, the illuminance in museum workshops, including training workshops, should be 500 lux. The finer and more critical the visual task, the more light is needed. For this, supplementary workplace luminaires can be used to raise the illuminance at the workpiece. A suitable solution for the general lighting is task lighting with luminaires for fluorescent lamps arranged parallel to windows, preferably with light falling on the workbench from the side.

Generally speaking, it is advisable in workshops to install luminaires with a higher degree of protection. A luminaire protected to IP 43, for example, is protected against the ingress of solid particles > 1 mm and against spraywater, while an IP 54 luminaire is dustproof and protected against splashwater.

Storage room lighting
The kind of work done in store rooms, depots or archives requires less light than craft activities. Nevertheless, relatively high illuminance is important for handling small items in storage and for all work involving reading tasks (labelling items for storage, completing forms). If the reading and searching task is focused on shelves – i.e. a vertical plane – as much as 300 lux vertical illuminance may be required.

Higher illuminance than the 100 lux stipulated in DIN EN 12464-1 facilitates reliable visual perception, heightens concentration, helps to avoid mistakes and guards against accidents. Luminaires for fluorescent lamps are the most suitable option for rooms of normal height; luminaires with high-pressure discharge lamps are the solution recommended for interiors with higher ceilings.

Photo 55: In offices, light must cause neither direct glare nor reflected glare on screens.

Photo 56: The finer and more critical the visual task, the more light is required.

Photos 57 and 58: Storage facilities require a minimum of 100 lux to be standard-compliant; higher illuminance levels are better.

55

56

57

58

59

Photo 59: *The interplay of light and shadow casts sculptures in a dramatic light*

Open air museum
Open air museums are a showcase for historical buildings and complexes, either in their original state or reconstructed. They close when it is dark, so artificial lighting is generally installed only inside the buildings – if possible without spoiling the impression of a time before the advent of electricity. Where an open air museum stays open after dark, path lighting is also required.

Whether sculptures or installations, some works of art are intended to be exhibited outdoors while others may become candidates for outdoor display because of their size. For the majority of such objects, an inner courtyard or small patch of garden is normally enough.

Interplay of light and shadow
Outdoor illumination at dusk or at night basically has the same effect as illumination with directional light in an exhibition room (see pages 2, 6). But it also gives exhibits an appearance they do not have in daylight: the artificial lighting creates new structures, reinventing the object in a game of light and shadow.

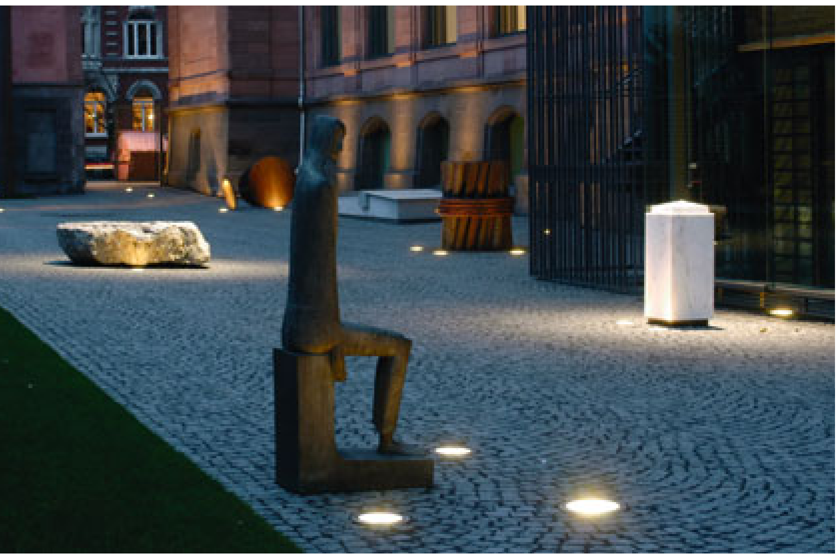
The best way to determine the perfect location for a mobile spotlight or flood is to conduct trials – with light from below, from below and from the side, from the side, from above, from above and from the side, or even bounced off another surface. Every solution has a charm of its own. For lighting from below, recessed ground floods are the alternative to spots. Highly focused beams are by far the first favourite; with illumination from below and some other configurations, the beam spread can be greater.

Avoid glare
If the idea is to illuminate the whole object, lights need to be set at a greater distance than for highlighting details. When positioning spots and floods, it is important to make sure that observers will not be dazzled, at least in the principal viewing direction.

To achieve the same lighting impact with different objects, the general rule is: the darker the object and brighter the surroundings, the more light is needed. Ultimately, however, even illuminance is a matter of taste and design intention.

Photo 60: Light from below – the stationary recessed ground floods are installed in groups.

Photo 61: Facade painting – floodlighting creates a splash of colour at night.



60

61

Night scenes

Buildings bathed in light impact at night because of their architecture. Where facade lighting makes this visible, decorative night images are created. Illuminated advertising signs and frontal floodlighting also help shape a museum building's night-time appearance.

Facade lighting
Light can make any building an eye-catcher. Combined with fascinating architecture, well-planned facade lighting imbues a building with a unique quality – and enhances the area around it at the same time.

Illuminating the entire building has a long-range impact; harnessing light to emphasize only architectural details heightens its presence for passers-by. Where the principal viewing direction and the direction of illumination are not identical, light-dark contrasts create a three-dimensional effect: an angle of around 60 degrees to the viewing direction is right for plain or fairly plain facades; for more detailed or ornate facades, the angle can be smaller.

Ensuring floodlights are not installed too close to the building avoids excessively deep shadows. Beams should not cross or shadows will be too light.

Floods with a long-range impact should be positioned high and mounted as inconspicuously as possible. High-pressure sodium vapour lamps underline the character of warm colours and materials; for cooler-looking surfaces, metal halide lamps are a suitable solution. Illumination is also possible with wall luminaires integrated in the facade and recessed ground floods positioned directly in front of it.

Photos 62 and 63: Light turns facades into eye-catchers, enhances the building and gives it a unique quality.

The illuminance required is determined by the colour and thus reflectance of the illuminated building (building luminance) and by the ambient brightness: the darker the building and brighter the surroundings, the more light is needed. Precise planning avoids light emission into the surrounding area.

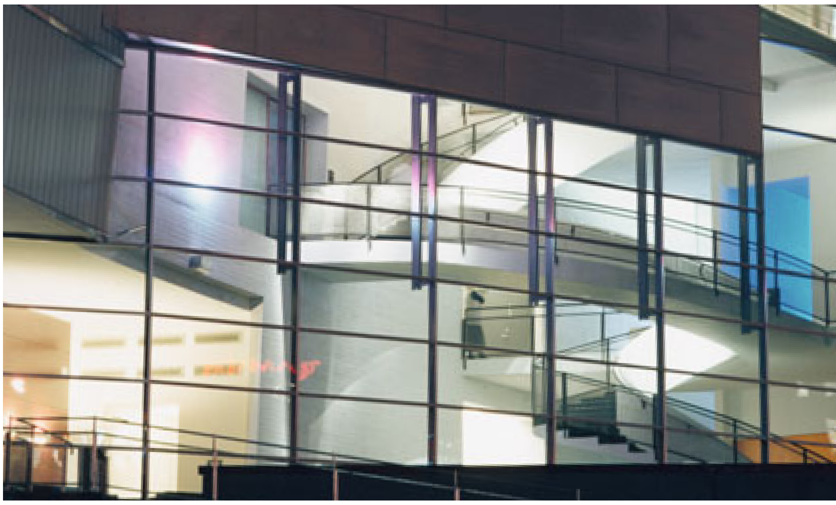
Alternatives to classical illumination are presented by fibre-optic lighting systems and LEDs, with which facades or parts of facades can be bathed in dynamic changing coloured light. Another possibility is facade design based on activated (and controlled) interior lighting.

Other forms of illumination
Facade lighting is normally a discrete design element. However, illuminated signage – e.g. the name of the museum in luminous letters – needs to be planned to suit it. To achieve the desired effect, any additional signal lighting, such as floodlighting for flags or banners, needs to be coordinated with the facade lighting.

In other outdoor areas, attractive scenes are also created by illuminating trees or other vegetation. The rules to be followed here are the same as for outdoor feature lighting (see page 20). If the facade is also illuminated, lights should only be trained on plants well away from the building.

Photo 64: The LED semicircle on the facade of the Buhlsche Mühle event centre in Ettlingen symbolises the millwheels that turned here in the past.

62



63

64

Interior lighting with daylight is an architectural challenge that absolutely must be addressed and resolved at the early design stage of a new building. Conditions for harnessing daylight can rarely be created later and system modification is difficult. Daylight planning is a matter for experienced professionals.

65

Photo 65: The camera looks behind the luminous ceiling of an exhibition room where daylight and artificial light are mixed as required.

Daylight museum
Public museums built in the first half of the 19th century had to rely on daylight. From early times, architects incorporated skylights to harness it: in 1789, the side windows of the Salon Carée at the Louvre in Paris were bricked up to enable all the wall to be used for exhibits.

For a long time, despite the availability of artificial lighting, every new museum was built as a daylit facility. But that changed in the 1950s and '60s when it was realised how much damage daylight can do, especially to paint and other organic materials. For some time after that, all new museums were built with rooms without windows.

Today, our knowledge of lighting engineering coupled with modern control and regulation technology makes it possible for daylight to be precisely directed and dosed. So once again daylight plays a major role in museum construction and design.

Skylights
Skylights are classic daylighting elements for picture galleries. They provide uniform, diffuse lighting. Because the light is admitted over a large area, the shadows produced are soft. The incident daylight that passes through a skylight reaches nearly every part of the room, including free-standing display cabinets, sculptures and partitions.

Because no windows are present, more wall space is available for paintings. There is also no problem with reflections on exhibition walls due to incident daylight from the side.

With large skylights, unwelcome interference may occur and needs to be tackled by positioning the skylights appropriately and providing for precise optical control. There is a risk, for example, of light being unevenly distributed over the walls. In rooms with dark furnishings, in particular, the vertical illuminance at eye level is often too low. The contrast between wall and ceiling brightness can cause glare. And even with light incidence from above, reflections can sometimes occur on pictures on the wall.

Direct sunlight must always be "locked out". But light protection is not alone in presenting high requirements: what all modern skylight solutions have in common is that they are expensive to design and construct for daylight direction, control and filtering. The use of skylights to harness daylight is confined to the upper storeys of a building or calls for single-storey design. Skylights are no substitute for the visual contact with the outside world provided by windows.

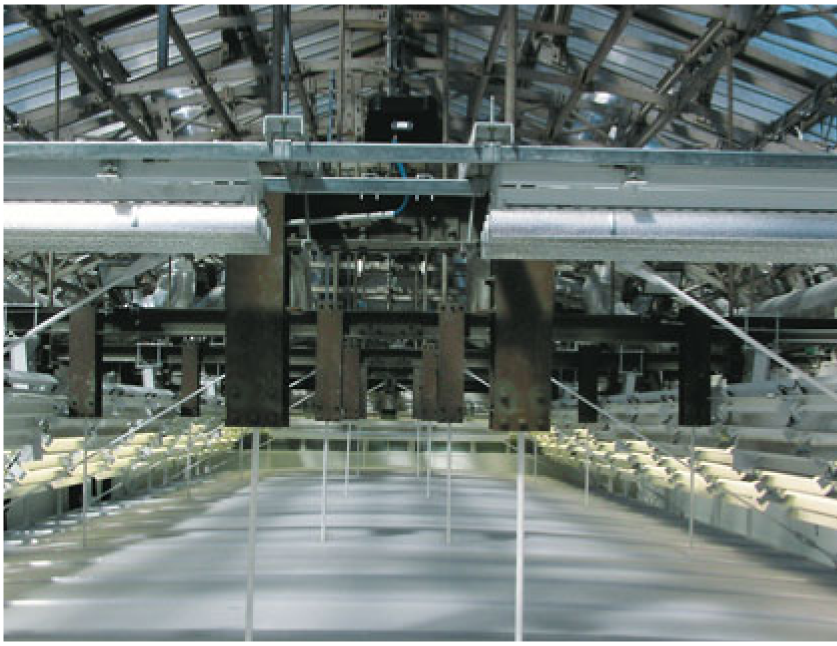
Daylight has considerable damage potential
Both daylight and artificial light contain rays which may cause exhibits to fade, dry out or become discoloured or deformed if exposed to the light for long periods. But daylight is certainly the more dangerous. This is confirmed in the art history publication "Über das Licht in der Malerei" (Wolfgang Schöne, Berlin 1993), which, when considering light sources, focuses almost exclusively on daylight. Few pages are devoted to artificial lighting.
Information on light protection is found in this booklet on pages 30 ff.

Windows
Outsized windows are not necessarily a suitable alternative to skylights and not actually the right tool for making maximum use of daylight. On the other hand, there are many ways today to direct daylight and "lock out" direct sunlight even in rooms with lateral windows. Having said that, these non-transparent systems do not fulfil the requirement met by daylight museum windows in making diurnal and seasonal change – as well as the vicissitudes of the weather – a visual experience.

Windows reduce the amount of wall space for exhibits. Undirected and unfiltered incident daylight can give rise to reflections on exhibition walls.

Daylight and artificial light
If daylight and artificial light are mixed, their rays should be fully blended before they fall on an exhibit. This also means that the spatial distribution of the two types of light needs to be coordinated. The rea-

66



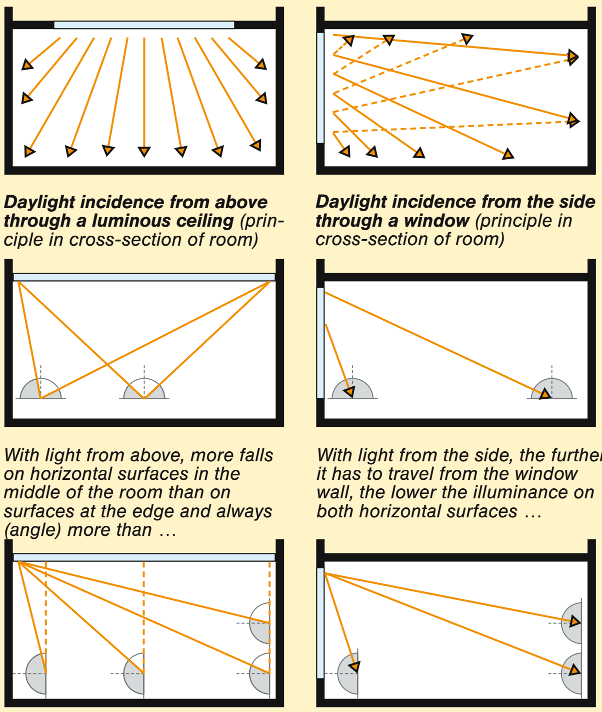
67

sons: the lamps used for artificial lighting radiate light of particular colours, while the spectral composition of daylight changes all the time. In addition, the two have different angles of incidence and different beam angles. This gives rise to conflict; the appearance of exhibits is distorted if the two light forms are not fully blended. The only alternative to blending is “segregation”. This means keeping the daylit zone and the zone illuminated by artificial light far enough apart to ensure that the two types of light do not interfere with one another – unless the twilight is deliberately used to create a particular atmosphere in the room.

Photos 66 + 67: The luminous ceiling of the 800 m² “Salle des Etats” of the Louvre in Paris has an area of 300 square metres. It directs the incident daylight that passes through a glass roof into the exhibition room. Supplementary artificial lighting is activated when the monitoring system reports there is no longer enough daylight. 360 luminaires, each fitted with two 80 W fluorescent lamps, are installed, some with wide-angle and some with narrow-angle reflectors. Illuminance is 250 lux on the floor of the museum, 100 lux at the walls. Photo 67 shows the inside of the ceiling construction.

68

Photo 68: The daylight entering through the skylights falls mainly on the exhibits on the upper floor; the corridor needs supplementary lighting.



***Daylight incidence from above through a luminous ceiling** (principle in cross-section of room)*

***Daylight incidence from the side through a window** (principle in cross-section of room)*

With light from above, more falls on horizontal surfaces in the middle of the room than on surfaces at the edge and always (angle) more than …

With light from the side, the further it has to travel from the window wall, the lower the illuminance on both horizontal surfaces …

… on vertical surfaces in the same place, on walls more than on free-standing partitions.

… and vertical ones, although vertical surfaces are better illuminated because of the more favourable angle of incidence.

Abb. 10-15

Lighting management

At its most sophisticated, lighting management means automation of lighting systems. Lighting management encompasses all systems which go beyond mere "on/off" control – systems which control and regulate lighting by responding to variance from setpoint values.

Degrees of automation
Lighting management system components, which can be used alone or in combination with others for different degrees of automation, include:

- retrievable pre-programmed lighting scenes
- motion detectors primed to activate lighting in response to movement (presence-dependent lighting control)
- daylight-dependent lighting level regulation by dimming and/or
- partial deactivation in response to signals from
  - light sensors in the room or
  - exterior light sensors.

The control and regulation components of a lighting management system are integrated in luminaires and operator interfaces. They may be programmed to govern individual luminaires, individual rooms or groups of rooms or they can be wired into the building management system (BMS).

Lighting management systems can be realised with the standardised digital interface DALI (Digital Addressable Lighting Interface). This also permits integration in building management systems such as BUS systems. Information: www.dali-ag.org.

Lighting management in museums
There are numerous ways in which lighting management can be used in a museum:

- Lighting management systems can activate and deactivate or dim the artificial lighting in response to changes in available daylight.
- They can be used to provide daylight-dependent control for sun-screens and anti-glare shielding on skylights or windows.
- Lighting management systems facilitate lighting productions: stage lighting or dynamic effects can easily be programmed.
- Lighting management can be used to set different illuminance levels in different zones: individual luminaires are simply dimmed. This is useful for casting an exhibition in a dramatic light or as a light protection measure for individual exhibits.
- Lighting management facilitates simple multifunctional use of individual interiors.
- Lighting management enables installed luminaires to be assigned to dedicated exhibition luminaires without de-installing the existing luminaires and without the need for re-wiring.
- A lighting management system can monitor luminaires and report their functional status or failure.
- Lighting management systems can log the operating status of the lighting installation and thus record the radiant exposure of the exhibits for the light pass (see page 32).
- Emergency lighting can easily be integrated into a lighting management system.
- A lighting installation controlled by a lighting management system consumes less energy than a non-managed installation.

69

71

72

Photos 69 and 70: A lighting management system enables the separately switched luminaires and luminaire groups to be easily controlled. The 3D presentation in photo 69 shows the lighting situation "fully activated", photo 70 shows the "spot lighting" situation.

Photos 71 and 72: The lighting in this exhibition and event hall permits a variety of room uses. The lighting situations shown here – controlled by a lighting management system – are "bright daylight-white lighting" (71), which is normally used during the day , and "less bright warm-white lighting" (72), intended mainly for evenings.

70

Photo 73: Digitally controlled daylight ceiling – the steplessly variable artificial lighting is added as required.

73

Fig. 16

74

Over 80 percent of all the information we receive is picked up by our eyes. Anyone who studies the conditions needed for seeing well, i.e. anyone who knows the basic visual requirements, understands more easily how light makes visual performance possible and what can interfere with that performance. More detailed information about the basics of lighting is contained in booklet 1 “Lighting with artificial light” (see page 45).

Illuminance
Illuminance (symbol: E) has a major bearing on the speed, reliability and ease with which we perceive and perform a visual task. Measured in lux (lx), it indicates the amount of luminous flux from a light source that falls on a given surface: where an area of 1 square metre is uniformly illuminated by 1 lumen of luminous flux, the illuminance is 1 lux. Example: the flame of an ordinary candle generates approx 1 lux at a distance of 1 metre.

Illuminance is measured on horizontal and vertical surfaces. Uniform distribution of brightness facilitates the visual task.

In exhibition rooms, the level of illuminance is often determined first and foremost by the sensitivity of the exhibits. For endangered artworks, for example, the illuminance should be as low as possible (light protection, see page 30).

The second criterion is design intention. And in third place – exceptionally – is the question of how much light is needed to enable the visual task to be performed. Applying all three criteria produces a consensus on the illuminance level required, although it needs to be realised that the level must not be too low.

The average illuminance normally provided in exhibition rooms ranges from 150 to 250 lux, depending on whether the lighting caters for wall-mounted exhibits or exhibits throughout the room, with higher vertical components or more horizontal ones. Sometimes it needs to be darker for conservation reasons; brighter lighting is often only required to offset daylight incidence.

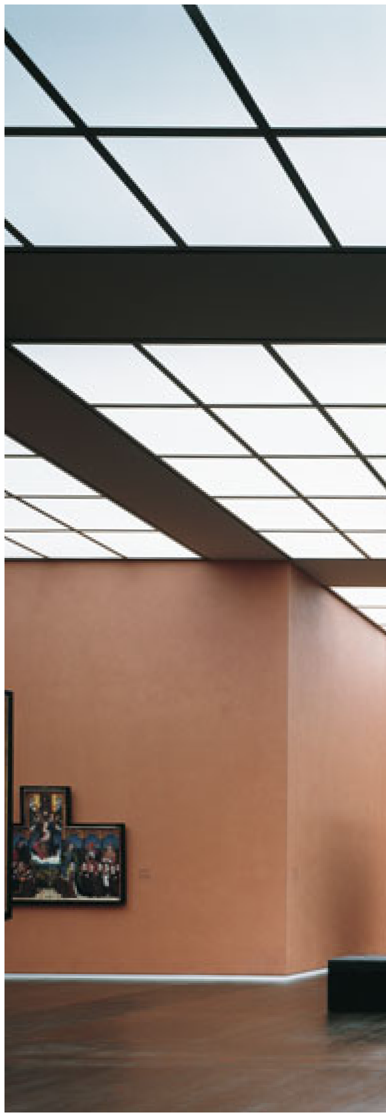
Where lots of diffuse and not much directional lighting is used, the exhibition room is illuminated more uniformly. Light directed exclusively onto exhibits results in a largely uneven pattern of illuminance in the room.

Luminance distribution
Luminance (symbol: L) is the brightness of a luminous or illuminated surface as perceived by the human eye and is measured in candelas per unit area (cd/m). Luminance distribution in the visual field has a crucial bearing on visual performance because it defines the state of adaptation of the eye. The higher the luminance, the better the visual acuity, contrast sensitivity and performance of ocular functions.

For visual tasks at a desk, concentration is promoted by brighter areas in the centre of the visual field. In the context of an exhibition, this means that exhibits should always have a higher luminance than their surroundings. One way to achieve this is with graduated brightness levels.

Visual comfort is impaired where luminance is too low or differences in luminance are too slight (disagreeable lighting atmosphere), where differences in luminance are too marked (eyes become fatigued because of the constant need to re-adapt) and where points of luminance are too high (glare).

Photo 74: The diffuse light provided by the luminous ceiling is combined here with directional spotlighting.



75

76

LEXICON

Adaptation
Adaptation to differences in brightness is performed in the human eye by receptors on the retina and changes in the size of the pupil. Adaptation from dark to light takes only seconds; full adaptation to darkness takes minutes.

The state of adaptation affects visual performance at any moment: the more light is available, the faster efficient visual performance can be restored. Visual impairment occurs where the eye cannot adapt to differences in brightness fast enough.

Lamp
No lamp, no light: the term ‚lamp' refers to an engineered artificial light source such as an incandescent lamp, fluorescent lamp, etc..

Luminaire
The term "luminaire" refers to the entire electric light fitting, including all the components needed to mount and operate the lamp. Luminaires protect lamps, distribute their light and prevent them causing glare.

Photo 75: The room is relatively dark, the higher illuminance at the artworks makes the visual task possible. Low illuminance is sometimes necessary in this context to protect exhibits from light.

Photo 76: The diffuse light from a luminous ceiling works only if it is bright. The illuminance here is close to 250 lux.

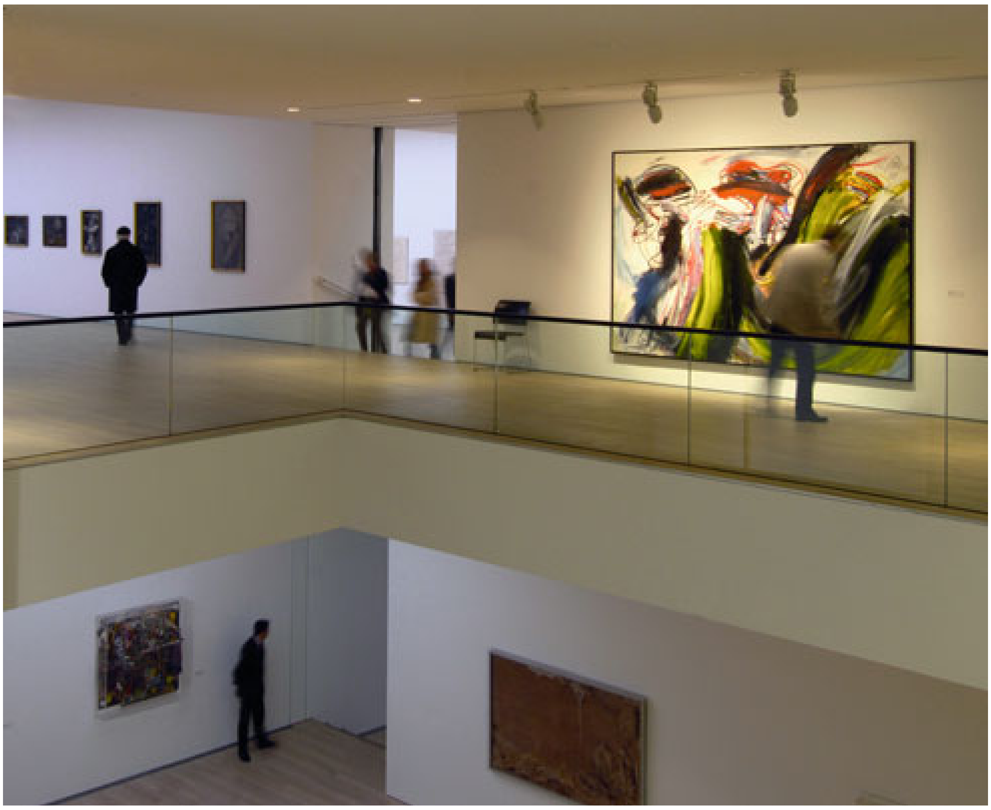
Direct glare, reflected glare
Direct glare is caused by luminaires, general-diffuse lamps or other excessively luminous surfaces – including windows. Reflected glare is caused by reflections on shiny surfaces.

Glare can interfere with visual performance to such an extent that reliable perception and identification become impossible. Physiological glare is a measurable loss of visual functions such as visual acuity. Psychological glare causes discomfort and loss of concentration. Glare cannot be eliminated altogether but it can be significantly reduced. There are recognised methods for assessing both types of glare.

In exhibition rooms, reflected glare can be used to a limited extent as a design tool – for example where shiny exhibits with brilliantly reflective surfaces are bathed in dramatic directional light to maximise their impact.

Direction of light and modelling
Shapes and surfaces in the room need to be clearly (visual performance) and comfortably (visual comfort) identifiable. This calls for balanced, soft-edged shadowing. Shadow formation depends on the direction of light, which is itself determined by the distribution and arrangement of luminaires in the room. Use of light and shadow in exhibition rooms is described in this booklet on pages 2 ff.

Visual performance and visual comfort are also affected by the light colour and colour rendering properties of the lamps used. These two qualities are explained on page 35.



77

78

Photos 77–79: Museum lighting has to meet special standards. At 150 to 250 lux, it does not need to be very bright – but every effort should be made to ensure it does not cause glare because both direct and reflected glare interfere unacceptably with the visual task.

LEXICON

Luminous intensity
Luminous intensity (symbol: I) is the amount of luminous flux a reflector lamp or luminaire radiates. It is measured in candelas (cd). Plotting the luminous intensity values at the different emission angles on a graph produces an intensity distribution curve (IDC).

Reflectance
Reflectance indicates the percentage of luminous flux reflected by a surface. The reflectance of light-coloured surfaces is high, that of dark surfaces low. This means that the darker the room furnishings, the more light is needed to create the same brightness.

Visual task
Visual tasks are defined by light/dark and colour contrasts as well as by the size of details. The more difficult the visual task, the higher the lighting level needs to be to permit the visual performance required.

Visual performance
Visual performance is determined by the visual acuity of the eye and its sensitivity to differences in brightness and darkness as well as by speed of perception.

Fading, yellowing, darkening, discolouring, twisting, bending, splintering, tearing, swelling, shrivelling, shrinking, dissolving – it sounds like a dire list of consequences. In actual fact, exhibits displayed in daylight or under artificial lighting are not normally exposed to more than one of these hazards.

Optical radiation
Even so, the hazard potential should not be underestimated. It exists because some materials cannot tolerate optical radiation, which includes short-wave ultraviolet (UV) radiation (100–380 nm = nanometres), light in the visible range (wavelengths of 380–780 nm) and long-wave infrared (IR) radiation (780 nm to 1 millimetre). It triggers photochemical or thermodynamic (physical) processes. Daylight, with its high UV content and the thermal radiation of the sun, is always critical.

Lighting technologists and other scientists have studied these phenomena. As well as empirical evidence and tips on light protection for conservation, that research has furnished a set of formulas that make the harmful effects calculable but no more comprehensible for the non-engineer. So formulas, mathematical relationships and computations will not be looked at here.

The important thing to know is that the damage is done not by the radiation that strikes the object but by the rays it absorbs. UV radiation and short-wave light are generally more harmful than long-wave light and IR radiation. Which means radiation in the visible spectrum – i.e. light – can do damage.

80

81

Photochemical reactions
Organic materials in particular are susceptible to photochemical change. Inorganic material is much less often affected. In museums, the greatest fear is of changes in colour, i.e. fading, yellowing or darkening of paper, fabrics, wood or the colour pigments, binders or varnishes used in watercolour and oil painting.

Photochemical change is a slow process. But light damage is cumulative and irreversible: no material ever forgets radiation or the length and intensity of exposure to it.

The most important parameters contributing to photochemical processes are:

■ **Irradiance**
of the object. Irradiance is indicated by the symbol E_e and is measured in W/m
■ **Irradiation time**
is the length of time an object is exposed to **irradiation**. Irradiation (H_e) is the product of irradiance and the length of exposure to it. The higher the irradiance and longer the exposure, the greater the potential risk.

■ **Spectral radiation distribution of the light source (daylight or lamps)**
Light of a particular wavelength has a particular spectral colour. White light is made up of a large number of spectral colours of different intensity. This spectral radiation distribution is characteristic of each lamp type as well as daylight. Incandescent lamps, for example, produce a light dominated by the reds of the long-wave spectral region; daylight, on the other hand, is dominated by the short-wave blues.
■ **Relative spectral sensitivity**
indicates the dependence of an object's light sensitivity on the wavelengths of the reference radiation.
■ **Effective threshold irradiation**
is the measure of the absolute sensitivity of an object. Change starts to occur in light-sensitive materials on first exposure to radiation - at first invisibly, then with visible signs. The threshold at which visible damage starts to be done is the yardstick used for assessing light sensitivity.

The threshold irradiation time (i.e. the time till the threshold is reached) is shown for individual materials under daylight or the light of different lamps.

Effective irradiation
is ascertained mathematically from the values for optical radiation (spectral distribution), irradiation and relative sensitivity of the object.

The following characteristics and conditions also play a role in photochemical processes:
■ spectral absorption characteristics of the material and its specific disposition for secondary reactions,
■ ambient and object temperature,
■ moisture content of the object and its surroundings,
■ pollutants or dust deposited on the object,
■ characteristics of the colouring agents and pigments used.

Damage potential
The damaging irradiance and the illuminance at the exhibit stand in a fixed ratio to one another. That ratio indicates the damage potential. It is the crucial quantity used to describe the damage that can be done in a lighting situation where particular light sources and filters are trained on particular exhibits and materials.

Photos 80 and 81: The two samples were taken from the same bolt of fabric. The piece in photo 80 was stored out of the light and thus screened from ultraviolet rays. The piece in photo 81 was exposed during the day to sunlight and thus also UV radiation.

Photo 82: Testing colour fastness. An experimental set-up by lighting technologists at Berlin's Technical University: the irradiated samples 1 and 3 are textiles, the rest watercolours.

82

Light protection in 1905
To protect exhibits from the impact of light, a zoological museum took the "radical step of opening its exhibition rooms on two days a week for 2 hours. During that time the interiors are flooded with light; at all other times, however, curtains admitting no light whatsoever are drawn across the windows, producing the total blackness found in a photo grapher's dark room."

An ethnological exhibition went even further: "… particularly light-sensitive objects like the extremely precious coats of feathers […] are protected by keeping them in containers furnished with curtains which visitors can draw back to view the exhibits inside."

Pre-exposure to light
Studies show that pre-exposure to light can also play a role in the selection of lighting for an exhibit. Even small doses of an effective irradiation damage objects which have never been exhibited or pre-exposed to light, whereas it takes much higher doses to cause the same damage to older, pre-exposed material that has already undergone change.

Many molecular degradation processes gradually slow down and finally even come to a halt. In these cases, it is possible to take account of the pre-exposure time and reduce the light protection measures accordingly. Pre-exposure to light is best established if all irradiation times (and types) are documented. To establish pre-exposure by comparison measurements, parts of the object must be unexposed.

Measures guarding against photochemical change
Where photochemical processes need to be prevented from occurring in the first place, or at least slowed down, light protection means reducing the effective irradiation. In particular, exposure to highly damaging radiation in the short-wave region – especially UV radiation – needs to be reduced or ruled out altogether.

There are a number of effective ways to do this:
- Choosing a suitable light source: very sensitive materials should be illuminated with light that has less damage potential.
- Filtering out harmful radiation: if other lamps are to be used or radiation excluded altogether, short-wave radiation can be blocked by filters.

Halogen lamps for line and low voltage are available with integrated UV blockers but this is not enough to meet conservation requirements. The only tools of choice here are special filters.
- Limiting exposure: in darkness, the risk of photochemical change is reduced to zero.

Filtering to 420 nm
Glass filters, absorption filters, dichroitic filters, plastic lenses or foils – the range is wide, appropriate filters are available for every application. They can be used to cut off short-wave radiation up to 380 nm. Where filters also eliminate light in the short-wave region the cut-off wavelength is 420 nm. If other wavelengths are filtered out, the spectral transmittance shifts so far that the colour rendering index sharply deteriorates. An alternative to light exit filters is showcase glass or picture glass that filters out UV light. Using it in addition to other light protection measures, however, does not make for better conservation conditions.

Limited irradiation time
Where possible, exhibits and exhibition rooms should only be illuminated for a short time. Outside opening hours, darkness is best. For cleaning operations or for setting-up, dismantling and repair work, separate, non-damaging lighting is recommended; presentation lighting, at least, should not be switched on for such operations and the general lighting should be dimmed.

In many cases, presence sensors are a useful tool for limiting irradiation during opening hours. Timely dimming makes for visually agreeable dark/light transitions. Care should be taken to ensure a long-enough delay before programmed deactivation.

Daylight
Light protection also means limiting daylight illuminance. For sensitive exhibits, UV radiation and short-wave light also need to be filtered out. Assessment of the conservation-relevant characteristics of daylight is normally based on the average sky condition with a colour temperature of 6,500 K and its specific spectral radiation distribution. Referencing this standard light type (D65) also makes it possible to establish degrees of damage potential.

Thermodynamic processes
Thermodynamic processes are almost entirely confined to organic materials: wood, textile fibres, parchment and leather are common examples. The thermal load on the exhibit occurs as a result of light and IR radiation being absorbed and mostly gives rise to drying processes. These reduce tensile strength, elasticity and volume – inducing mechanical stresses which cause first the surface, then often the entire object to become deformed.

The physical changes induced by heat radiation are more serious when photochemical processes occur at the same time. These are accelerated by the heat and interact with thermodynamic processes. Physical change is also accelerated by fluctuations in temperature and humidity – e.g. due to the activation and deactivation of lamps.

Unlike the molecular change that takes place in photochemical processes, which can come to a halt, the thermal load on an object during irradiation is always harmful.

The thermodynamic impact of radiation is determined by the thermal load on the object and the spectral irradiance, the radiation absorbed playing a particularly key role. For the thermal load on an exhibition room, the key determinant is the product of the luminous efficacy of the lamps and the coefficient of utilisation of the lighting installation.

Protective measures against thermodynamic processes
The protective measures taken against heat loading correspond to those against photochemical processes. The most effective are:

- Choosing appropriate light sources: for heat-sensitive materials, the only suitable lamps are ones that emit light with a low IR content. Where low-voltage halogen lamps are used, cool-beam reflector lamps are the right choice. No IR radiation is contained in the beams of fibre-optic lighting systems or LEDs.
- Using IR filters to cut off harmful radiation
- Limiting exposure
- Dissipating the heat. Even with lamps that produce a luminous flux with a low heat content, luminaires and their immediate surroundings can heat up. This is possible in a display cabinet, for example. To ensure this secondary IR radiation does no damage, it needs to be dissipated. If necessary, fans can be installed to increase air circulation.
- The IR radiation of daylight is just as damaging as that of lamps. So direct sunlight always needs to be “locked out”.

Light pass
The only way to build up an accurate picture of the exposure history of an object is to record exposures in a light pass. Data that needs to be noted includes details of periods on display as well as the type of light source used, the illuminance and the irradiation time.

Relative spectral sensitivity

Group	Material samples	in %
sensitive	oil paints on canvas	100
very sensitive	textile samples	300
	watercolour paints on hand-made paper	485

The relative spectral sensitivity of the materials shown here is based on the impact on oil paintings (reference value: 100 percent). So watercolours, at 485 percent, are nearly five times more at risk than an oil painting. The illuminance on the object is 200 lux – a compromise between the brightness needed for the visual task and the conditions required for conservation; the illuminance on very sensitive objects should not exceed 50 lux.

Relative damage potential of light sources

Light source	without	edge filter, filter edge at λ (nm)			window glass	
		380	400	420	simple	double
	in %					
Daylight	235	155	130	110	205	190
General service tungsten filament lamp	85	75	70	65	80	75
LV halogen lamp	100	80	75	70	90	90
High pressure metal halide lamp	220	175	145	110	210	210
Fluorescent lamp, neutral white	100	85	80	70	95	90
Fluorescent lamp, warm white	90	75	70	60	85	85
LED, cold white	80	80	80	75	80	80

The relative damage potential of daylight and the lamps listed here is based on the impact of unfiltered light from low-voltage halogen lamps (reference value: 100 percent). An object exposed to the light of a metal halide lamp with a 380 nm edge filter for 1,000 hours at 200 lux illuminance, for example, sustains nearly twice as much damage (180 %) as a similar object exposed to an unfiltered low-voltage halogen lamp.

Conversely, this means: for the same degree of damage, the object can be illuminated by the unfiltered light of a low-voltage halogen lamp for nearly twice as long or nearly twice as intensely as by the filtered light of a metal halide lamp.

As lamps, luminaires and room surfaces age and become soiled, illuminance decreases. So every lighting installation requires regular maintenance. The values set out in European lighting standards such as DIN EN 12464-1 – e.g. for illuminance – are maintained values, i.e. values below which the relevant lighting quantity must not fall at any time.

Installed values should be higher
To ensure the required lighting level over an appropriate period of time and to enable the lighting system to be operated longer without additional maintenance work, installed values need to be higher. How much higher is determined by applying a maintenance factor.

Maintenance factors depend on operating conditions as well as on the type of lamps, electrical gear and luminaires used. They need to be defined and recorded by designers (and operators) and form the basis of maintenance schedules. Installed values are calculated as follows: installed value = maintained value / maintenance factor.

More maintenance for exhibition rooms
The standards do not stipulate a particular maintenance factor for exhibition rooms. This needs to be established individually and used as the basis for the maintenance schedule. On the whole, maintenance in exhibition rooms is a somewhat more complex task than elsewhere because it involves more than just regular cleaning:

- Maintenance is complicated by the number of different types of luminaire used, the different lamps fitted, the possibilities for angling and adjusting light sources and the extent to which accessories (filters, lenses, etc.) are used.
- User-friendly luminaires, easy to mount and with a controlled surface temperature, minimise the additional maintenance required.
- After cleaning or when exhibits are replaced, luminaires need to be re-set at the correct angles.
- Wherever possible, luminaires should not be obstructed, not even by structures on the floor, because inaccessibility makes maintenance operations a great deal more difficult
- When a luminaire needs to be replaced, the fitting used to replace it should, if possible, be from the same luminaire family.
- When individual lamps fail, they need to be replaced immediately. Here, care should be taken to ensure that the new lamps have the same light colour as the other lamps in the relevant luminaire group. From time to time, it may make sense to replace whole groups of lamps together.
- Electrical gear that extends lamp life reduces maintenance requirements. So where fluorescent and compact fluorescent lamps are fitted, electronic ballasts (EBs) should be used.

83

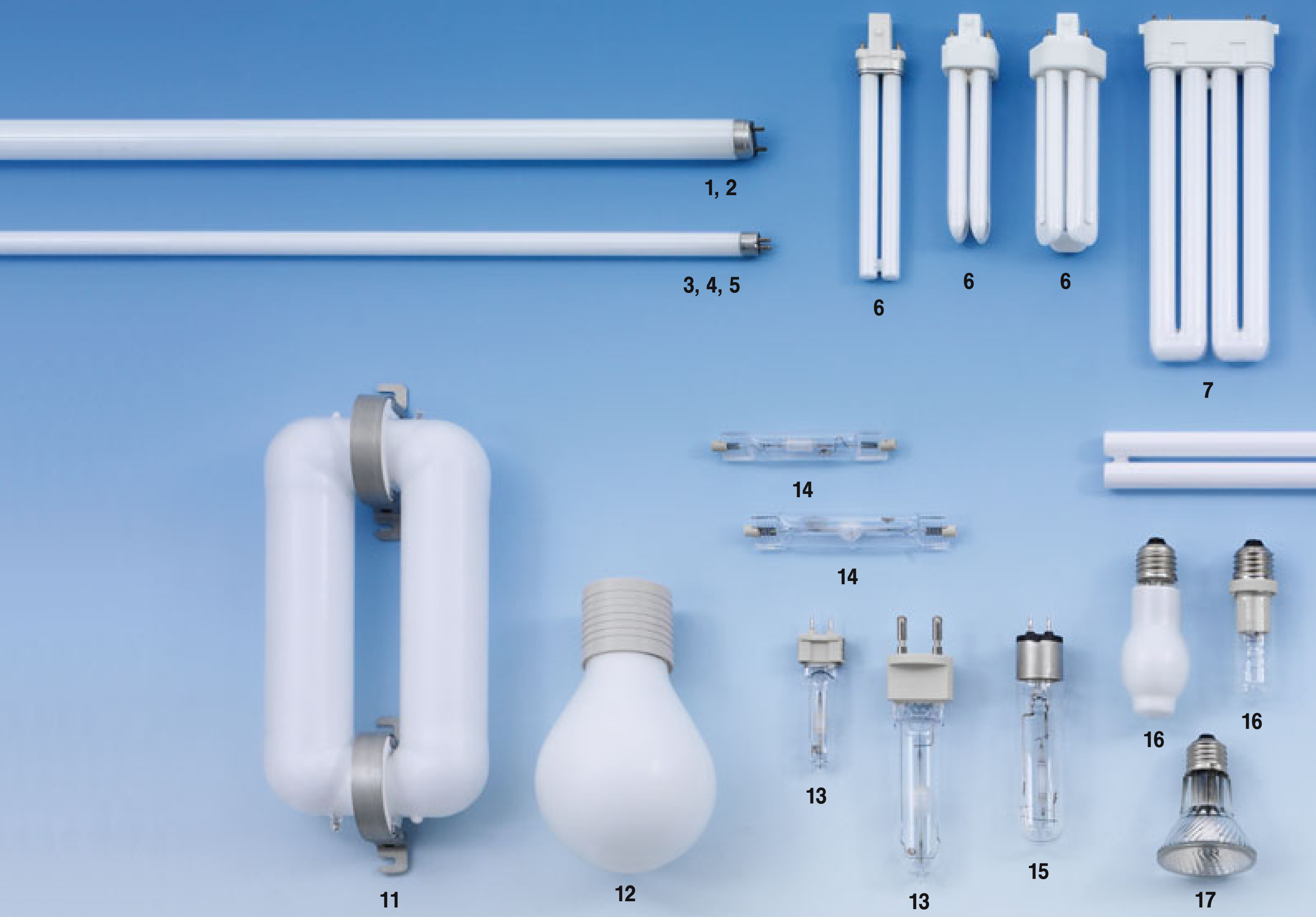
Photo 83: All lighting installations require regular maintenance because, as time goes by, ageing and soiling cause illuminance to decline.

Cost-effective lighting
Lighting accounts for a relatively small amount of total energy consumption. Nevertheless, every economy helps. Energy-efficient lighting for the cost-conscious means
- long-life lamps with high luminous efficacy (lumens/Watt rating),
- efficient electrical gear such as electronic ballasts (EBs) for fluorescent lamps,
- efficient luminaires with good optical characteristics and
- luminous intensity distribution curves tailored for the application.

The kind of light should also be right for the task. It would be wrong, for example, not to use directional light just because most of the lamps suitable for it have a lower luminous efficacy rating than fluorescent lamps. Information on how and where economies can be made is contained in FGL booklet 12 “Lighting quality with electronics” (see page 45).

Emergency lighting
For most rooms in museums, mains-independent emergency lighting is required by law to enable visitors and staff to vacate the building safely in the event of a power failure. To permit this, security lighting is needed for escape routes and escape route signs.

Rules governing the installation, operation and maintenance of emergency lighting are set out in DIN EN 1838 and DIN 4844 (lighting requirements) and in DIN VDE 0108 (electrical requirements). Detailed information on the subject is contained in FGL booklet 10 “Notbeleuchtung, Sicherheitsbeleuchtung” (currently available in German only, see page 45).



ww = warm white
colour temperature below 3,300 K

nw = neutral white
colour temperature 3,300 to 5,300 K

dw = daylight white
colour temperature over 5,300 K

Features / Lamp type	1 three-band Ø 26 mm	2 "de luxe" Ø 26 mm	3 three-band lamp, Ø 16 mm, high luminous efficacy[4]	4 three-band lamp, Ø 16 mm, high luminous flux[4]	5 "de luxe" Ø 16 mm	6 1-, 2- or 3-tube lamp	7 4-tube lamp and square design	8 elongated design	9 "de luxe" elongated design	10 3- or 4-tube lamp[4]	11 ring-shaped	12
	Tubular fluorescent lamps					**Compact fluorescent lamps**					**Induction lamps**	
Power rating classes (Watt) from to	18 58	18 58	14 35	24 80	24 54	5 70	16 38	18 80[5]	18 55	60 120	70 150	55[6] 165[6]
Luminous flux (Lumen) from ***luminous intensity (Candela)*** to	1.350 5.200	870 4.600	1.100 3.300	1.650 6.150	1.300 3.550	250 5.200	1.050 2.800	1.200 6.000	750 3.650	4.000 9.000	6.500 12.000	3.650 12.000
Luminous efficacy (Lumen/Watt) from to	75[1] 89[1]	61[2] 79[2]	79 (93[3]) 93 (104[3])	69 (84[3]) 88 (99[3])	58 (67[3]) 76 (79[3])	50 82	61 78	67 87	42 66	67 75	75[6] 79[6]	66[6] 73[6]
Light colour	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw	ww, nw	ww, nw
Colour rendering index R_a (in some cases as range)	85	> 90	85	85	> 90	80–85	80–85	80–85	90	80–85	80–85	80–85
Base	G13	G13	G5	G5	G5	G23, G24 2G7 GX24	2G10 GR8 GR10q	2G11	2G11	2G8-1	special	special

The table below shows the most important lamp types and their technical specifications, which are expressed in ranges. More precise values for individual lamps and other specifications, such as lamp life, can be found in manufacturers' catalogues.

Power rating class indicates how much power is consumed by the lamp in Watts (W). The operation of discharge lamps (lamps 1 – 5) requires ballasts, which consume additional electricity. This power loss in ballasts is not taken into account in the table (exceptions: lamps 11 and 12).

Luminous flux in lumens (lm) is the rate at which light is emitted by a lamp in all directions. For reflector lamps, **luminous intensity** (see page 29) in candela (cd) is shown instead of luminous flux. The efficiency with which a lamp (without reflector) generates light from electricity is indicated by its **luminous efficacy** in lumens/Watt. The higher the lm/W ratio, the more light a lamp produces from the energy it consumes.

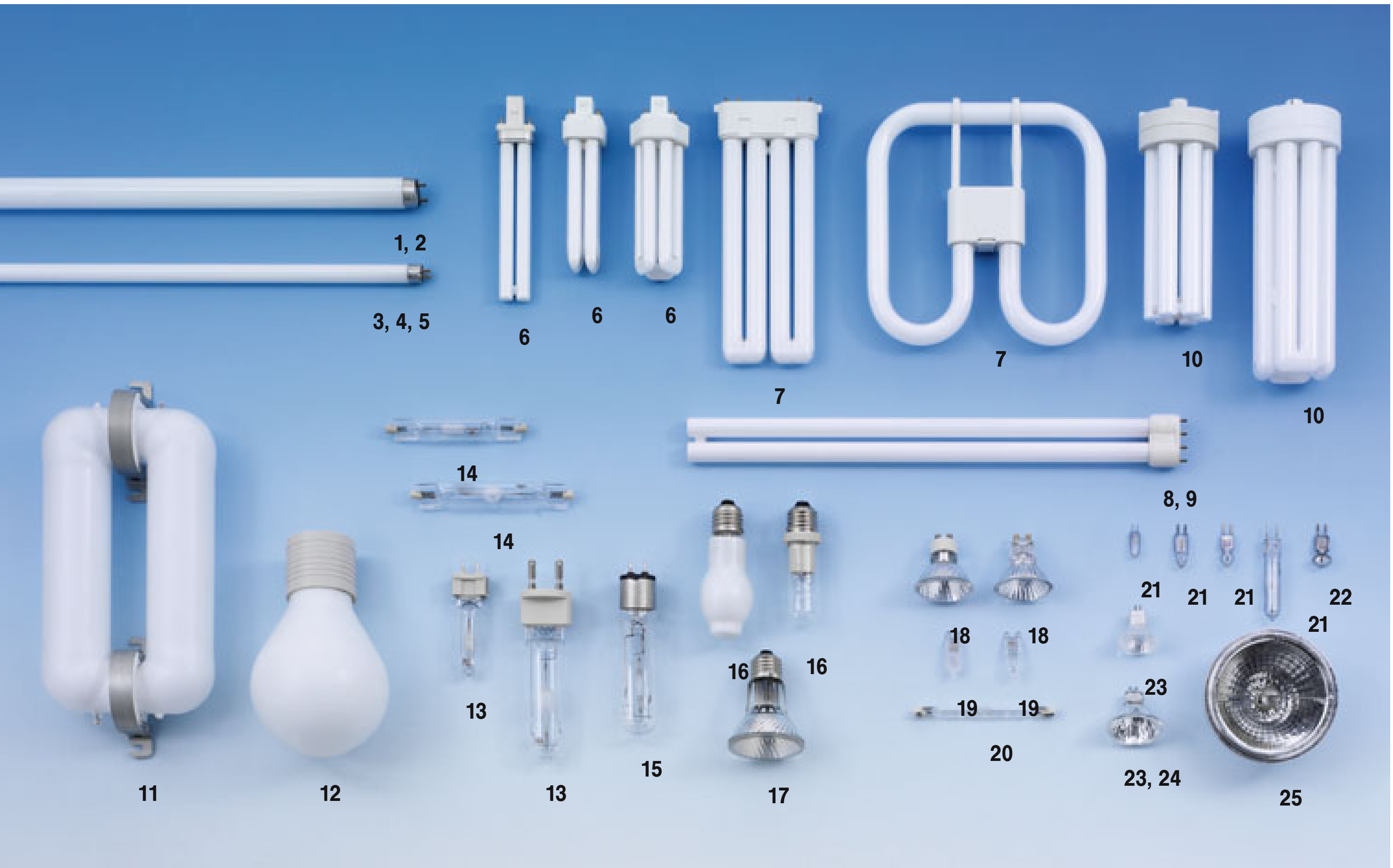
Lamps have different **light colours**, depending on their colour temperature (in kelvins K): warm white (ww), neutral white (nw) or daylight white (dw). The colour rendering properties of a lamp are defined by the general **colour rendering index R_a**. The highest value possible is 100. The lower a lamp's R_a value, the poorer its colour rendering properties.

The **base** provides the mechanical connection with the luminaire and supplies power to the lamp. Basically, there are two kinds of lamp base: screw bases, e.g. all E bases, and plug-in bases.

bulb-shaped

with base at one end (ceramic technology)	with base at both ends (ceramic technology)	plug-in base, highly colour-corrected	with jacket	with alu reflector	with alu or cool-beam reflector	without jacket	with base at both ends	pin base with/without IR coating	pin base, with reflector	with alu or cool-beam reflector	with alu or cool-beam reflector. IR coating	with alu reflector, Ø 111 mm, with/without IR coating
13	14	15	16	17	18	19	20	21	22	23	24	25
Metal halide lamps		HP sodium	Halogen lamps (230 V)					Low-voltage halogen lamps (12 V)				
20 250	70 250	35 100	25 230	40 100	20 75	25 75	60 2.000	5 100	10 50	10 50	20 50	35 100
1.600 25.000	5.100 25.000	1.300 5.000	260 4.350	*850* *8.500*	*160* *3.000*	260 1.100	840 44.000	60 2.200	*250* *1.400*	*300* *13.000*	*450* *16.000*	*1.400* *48.000*
80 100	73 100	39 52	10 19	–	–	10 15	14 22	12 27	–	–	–	–
ww, nw	ww, nw	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww	ww
80–85	75–95	80–85	100	100	100	100	100	100	100	100	100	100
G12, G22 GU6,5/G8,5 PGJ5	Fc2 RX7s	PG12-1	E14 E27	E14 E27	GU10 GZ10	G9	R7s	G4 GY6,35 G8,5	G4 GY6,35	G4 GU5,3	GU5,3	G53

1) Where lamps are EB-operated, luminous efficacy increases to 81–100 lm/W.
2) Where lamps are EB-operated, luminous efficacy increases to 66–88 lm/W.
zu 1+2) Power consumption decreases from 18 W to 16 W, from 36 W to 32 W and from 58 W to 50 W.
3) High value realisable only at 35°C ambient temperature
4) EB operation only
5) 40 W, 55 W and 80 W only with EB
6) System (lamp + EB)



84

Photo 84: These are the most important types of lamp for museum, gallery and exhibition lighting. Their technical specifications are summarised in the table on pages 34/35.

Tubular **three-band fluorescent lamps** with 26 mm **(1)** or 16 mm **(3, 4)** diameter have a very long service life and generally high luminous efficacy. Operated by electronic ballasts (EBs), they are even more energy-efficient; 16 mm ∅ lamps are designed for EB operation only. Hot-start EBs increase the life of these lamps.

Three-band fluorescent lamps are available in all light colours. Colour rendering is good (R_a index 85): lamps with the suffix “de luxe” **(2, 5)** have very good colour rendering properties (R_a index > 90), special daylight white models achieve an R_a index of 98. However, the luminous efficacy of “de luxe” lamps is somewhat lower. With appropriate EBs, fluorescent lamps can be dimmed.

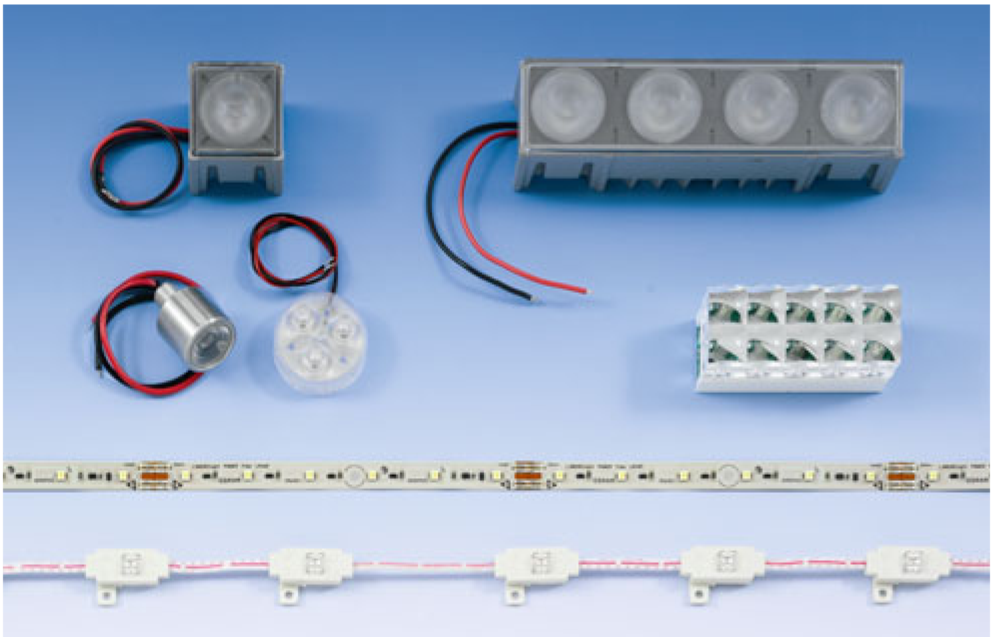
Tubular fluorescent lamps require an elongated luminaire, **compact fluorescent lamps** are also suitable for smaller rectangular or round luminaires. The smaller designs **(6)** include 4-tube lamps and square models **(7)**, elongated lamps **(8, 9)** and the newly developed lamps with high luminous flux **(10)**.

Compact fluorescent lamps have the same positive characteristics as tubular three-band fluorescent lamps: (very) long life, high luminous efficacy, colour rendering properties that range from good to very good (“de luxe” models) and a full choice of light colours. Lamps for energy-efficient EB operation have a 4-pin base; nearly all can be operated by dimmable EBs.

Because they have no components subject to wear, such as incandescent filaments or electrodes, **induction lamps (11, 12)** have an extremely long service life (up to 60,000 operating hours) and thus require less frequent replacement. They are therefore a particularly attractive option for high-ceilinged rooms and ceilings which are not easily accessible, such as those above escalators. Light is generated in these high-output fluorescent lamps by electromagnetic induction and gas discharge.

Metal halide lamps (13, 14) are powerful, cost-efficient light sources combining a very compact design for optimal optical control with high luminous efficacy, very good colour rendering and a long service life. Models with bases at one or both ends are available in warm white or neutral white light colours. Nearly all metal halide lamps have UV absorbing bulbs.

High-pressure sodium vapour lamps (15) emit a particularly warm white light with no UV content and have a very high luminous efficacy rating. The only HP sodium lamps suitable for interior lighting are “highly colour-corrected” models with a colour rendering index of R_a 80–85, which have a lower luminous efficacy than other HP sodium lamps.



85

Photo 85: In light-emitting diodes (LEDs), the production of light takes place in a semiconductor crystal which is electrically excited to emit light (electroluminescence). A housing protects the semiconductor from environmental conditions.
There are single LEDs and – as shown here – LED modules. The basic element of a module is a conductor plate, which carries the semiconductor crystals or single LEDs and all the other components, including those for controlling the LEDs.

Halogen lamps (16–25) are characterised by an agreeably fresh, warm white light with exceptional brilliance. They have luminous efficacy ratings which are substantially higher than those of general service tungsten filament lamps and a longer service life. Their luminous flux also remains constant throughout – a fact due to the halogen cycle. In this, tungsten atoms evaporate from the filament and combine with halogen atoms; the gaseous compound then returns to the hot filament, re-depositing tungsten atoms and releasing halogens, after which the cycle starts again. There is thus no "lamp blackening" due to tungsten deposits on the bulb, so the luminous flux is not reduced.

Halogen lamps with bases at one or both ends are available in a wide range of shapes and power ratings. A basic distinction is made between halogen lamps for 230 Volt line voltage **(16–20)** – also known as high-voltage halogen lamps – and low-voltage halogen lamps **(21–25)** – mostly designed for 12 Volt operation but also available for 6 or 24 Volt systems – which require conventional or electronic transformers. 230 Volt lamps are fully dimmable; dimming low-voltage lamps calls for special dimmer/transformer combinations.

A special infrared bulb coating can reduce the energy consumption of a halogen lamp by as much as 45 percent. Used in 230 Volt lamps **(20)** with a base at both ends und in low-voltage lamps **(21, 24, 25)**, the coating reflects much of the radiant heat dissipated by the incandescent filament back onto the filament.

230 Volt and low-voltage lamps are available in designs with cool-beam reflector. These have a faceted reflector (cool-beam specular reflector) which reduces the radiant heat of the beam by two thirds; the retained radiant heat is conducted backwards by the reflector.

Light-emitting diodes (LEDs), shown in photo 85, have not been used for lighting for long. Very small light sources, they generate light very efficiently. They also have an extremely long life (up to 50,000 operating hours). In LEDs (light-emitting diodes), the production of light takes place in a semiconductor crystal which is electrically excited to emit light (electroluminescence). A housing protects the semiconductor from environmental conditions. LEDs are available as individual diodes and as LED modules.

In contrast to conventional light fittings, LEDs emit monochromatic radiation. White light is produced by luminescence conversion, which involves directing the light of a monochrome blue LED through a converter such as phosphor.

The light produced by LEDs contains no ultraviolet (UV) or infrared (IR) radiation. So LEDs can be a good choice where lighting is needed for light- and heat-sensitive exhibits.

LEDs started out as status and signal indicators in electrical equipment and automobiles. Then, with the development of new coloured LEDs, they quickly found applications in special effect and display lighting and also became an established solution for orientation lighting. Now, used in desk and standard luminaires, white LEDs are addressing their first "viewing light" applications.

The brightness of LED light can be adjusted: varying the operating current causes the radiant luminous flux to fluctuate in direct proportion to the changes. This basically amounts to dimming and is used primarily for lighting effects.

Further information is contained in FGL booklet 17 "LED – Light from the Light Emitting Diode" (see page 45).

Luminaires

The term “luminaire” refers to the entire electric light fitting, including all the components needed to mount and operate the lamp. Luminaires protect lamps, distribute their light and prevent them causing glare.

The stylized images on this double page, which are not to scale, show a selection of typical interior (Figs. 17–40) and exterior luminaires (Figs. 41–44). The next double page shows the basic range of spotlights and accessories available for them.

Selection criteria
Lighting quality, cost-efficiency, dependability, ease of installation and user-friendliness are important aspects of luminaire design. And with luminaires which are made to high technical standards, functional features are matched by aesthetic ones, such as shape of housing, finish and colour.

Operational reliability and conformity to standards are documented for luminaires by the VDE symbol and the equivalent European mark of conformity ENEC. Both are awarded in Germany by the Offenbach Institute of the Verband der Elektrotechnik Elektronik Informationstechnik (formerly Verband Deutscher Elektrotechniker), the ENEC symbol with the identification number 10.

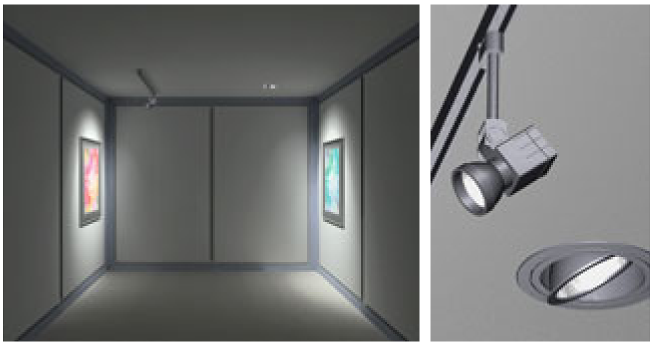
Luminaire selection is also dependent on the choice of lamps. Furthermore, the decision is crucially influenced by the architecture of the room, its furnishings and the design concept.

Figs. 21 + 22

Recessed wallwashers with asymmetrical beam spread, the one on the right with a specular “kick reflector” for also directing light onto the edge of the ceiling.

Figs. 23 + 24

Luminous ceiling



Figs. 17 + 18

Spots for power track (left) and swivel-mounted recessed downlight with spotlighting characteristics (right); power track is also suitable for recessed ceiling mounting.

Figs. 25 + 26

Cove luminaire with a housing that forms the coving (left), and light from a coving formed by architectural elements (right).

Figs. 19 + 20

Downlights with symmetrical beam spread (left) and asymmetrical beam spread (right)

Figs. 27 + 28

Lighting channels with clear (left) and opal (right) enclosure

Figs. 29 + 30

Indirect luminaire with fluorescent lamps for power track, operated by a power track phase in the ceiling guide

Figs. 37 + 38

Light for working: pendant luminaire for tubular fluorescent lamp with direct/indirect light distribution

Figs. 31 + 32

Gimbal-mounted spot as recessed downlight with spotlighting characteristics (left) and as power track spot (right); power track is also suitable for recessed ceiling mounting.

Figs. 39 + 40

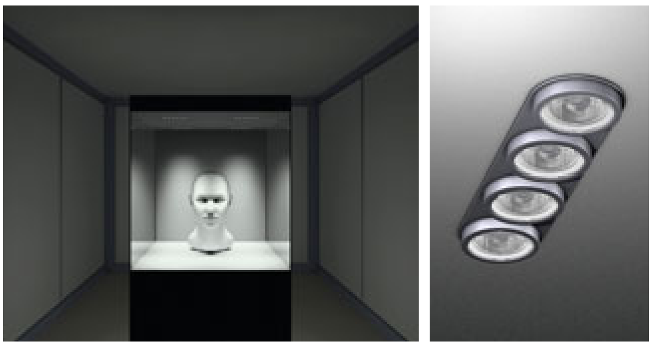
Escape sign luminaire

Figs. 33 + 34

Fibre-optic lighting system for display cabinets: the light guides are inside curved tubes. An optical connector at the end of the fibre/tube distributes the light.

Figs. 41 + 42

Recessed floor floods (left) for illumination and accentuating light, and orientation luminaires for recessed wall mounting (right)



Figs. 35 + 36

Miniature LED luminaire, installed here in the ceiling of a display cabinet for showcase lighting

Figs. 43 + 44

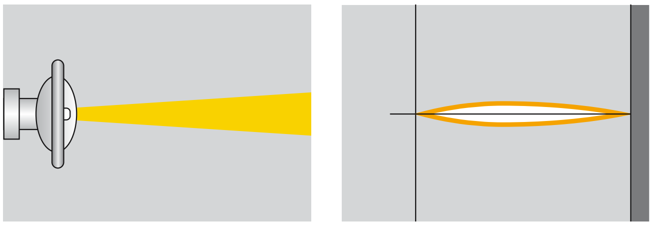
Projectors for illumination, with reflectors for spotlighting (left) and floodlighting (right) beam spread

Luminaires

Spots and luminaires with spotlighting characteristics are crucially important for exhibit lighting in museums galleries and exhibitions. The simplest spotlight models do not require a reflector because there is one integrated in the lamp. In all others, a reflector in the spotlight housing directs the main beam. The lighting quality of a spot or luminaire with spotlighting characteristics depends crucially on the minimisation of stray light, which can cause annoying patches of brightness or even glare at a distance.

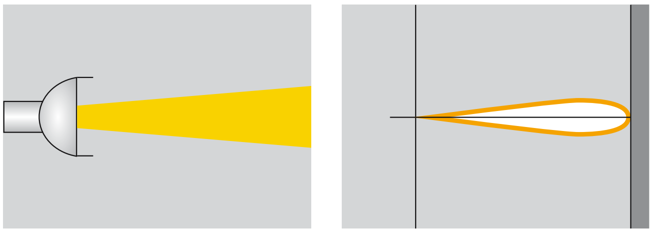
Types of spots

Figures 45, 47, 49 and 51 show the five main types of spots and their beam characteristics, figures 46, 48, 50 and 52 the corresponding intensity distribution curves. The boundaries between these generic groups are fluid, however, because of overlaps due to the reflectors and lamps used.



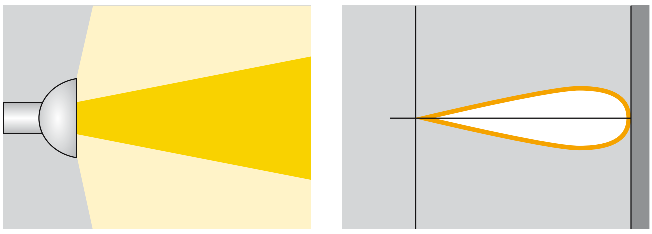
Figs. 45 + 46

8° spot *with filament shield, which prevents the filament being visible beyond the spotlight opening angle: symmetrical, extremely narrow-angle spot up to max. 8° with very high luminous intensity; lamps: low-voltage halogen lamp Ø111 mm*



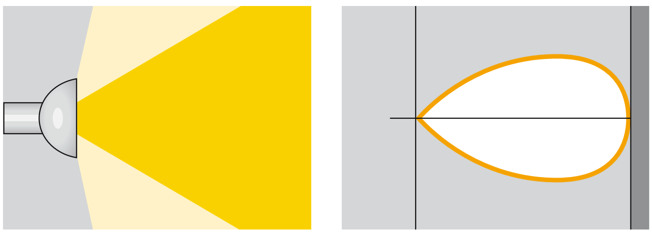
Figs. 47 + 48

12° to 24° spot *with lamp shield, which prevents stray light and glare beyond the spotlight opening angle: symmetrical, narrow-angle spot with half the luminous intensity of the 8° spot; lamps: low-voltage halogen lamp Ø111 mm or other low-voltage lamps, incl. models with cool-beam reflector*



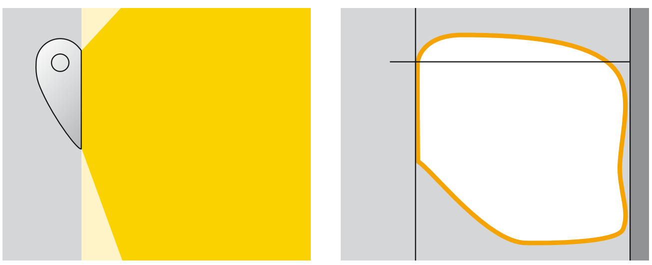
Figs. 49 + 50

24° to 38° accent spot: *symmetrical spot with less clearly defined beam than the narrower-angle spots, with increasingly soft contours due to the stray light content but the beam itself with a tendency to have a hard centre; lamps: various low-voltage halogen lamps*



Figs. 51 + 52

60° wide-angle spot: *symmetrical, very wide-angle beam with very soft contours and soft centre, almost floodlighting characteristics; lamps: various low-voltage halogen lamps*



Figs. 53 + 54

Flood with wide rectangular beam: *rectangular housing with scoop reflectors for linear lamps, very wide-angled beam for uniform vertical illuminance; lamps: tubular fluorescent lamps*

Accessories for spots

Numerous accessories are available for spot lights. Attachments, lenses and filters are often borrowed from the world of theatrical lighting for use in not just exhibition rooms but also shop windows and salesrooms. The accessories are positioned directly in front of the light emission aperture of the spot with the help of mounting devices.

Attachments

The most important attachments are for anti-glare shielding. These prevent stray light and shield the face of the luminaire: anti-glare cylinders or barn doors. Honeycomb screens also guard against glare. Other attachments include cross-baffles, framing attachments, gobo holders and other projection accessories. Attachment rings – e.g. with filters – for screw or plug attachment are also included in this group.

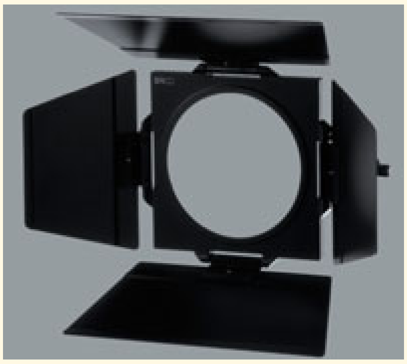
Lenses

The most widely used lenses are diffusers, flood lenses and sculpting lenses. They are used to change beam characteristics. Stepped Fresnel lenses enable beam spread to be adjusted and focusing aids are available to facilitate alignment with the lamp.

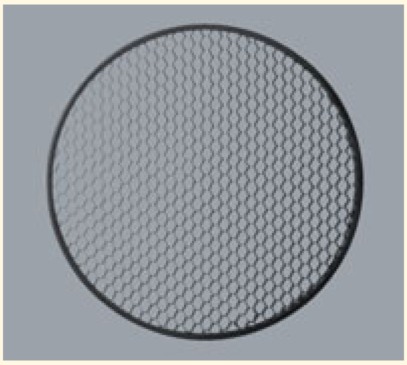
Filters

The most important filters for exhibitions are safelight filters (“Light protection”, see page 30) such as UV barrier filters, IR absorbers or combinations of the two. Colour filters are also available; where filters are used in exhibitions at all, they are used for subtle colour changes. Filter holders or filter cartridges enable several filters to be kept ready for use.

86
anti-glare cylinder



87
barn doors



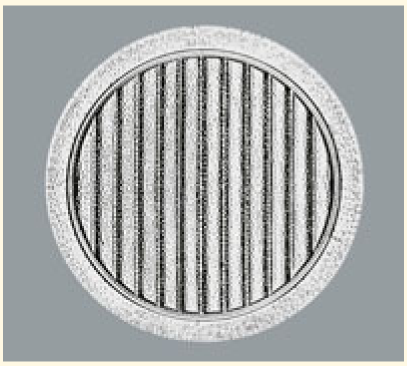
88
honeycomb screen

89
cross-baffle

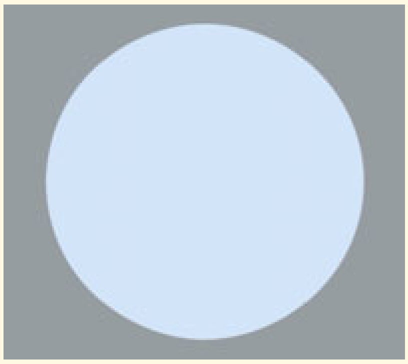
90
gobo holder

91
projection attachment

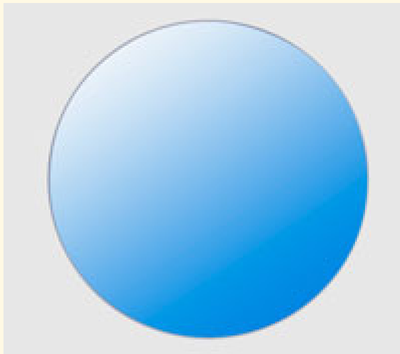
92
flood lens



93
sculpting lens



94
UV/IR filter



95
daylight conversion filter

96
skin-tone filter

97
filter cassette

Standards and literature

DIN EN 12464-1 Light and lighting – Lighting of work places, Part 1: Indoor work places

DIN EN 1838 Lighting applications – Emergency lighting

DIN 4844 Graphical symbols - Safety colours and safety signs - Parts 1-3

DIN VDE 0108-100 Emergency escape lighting systems

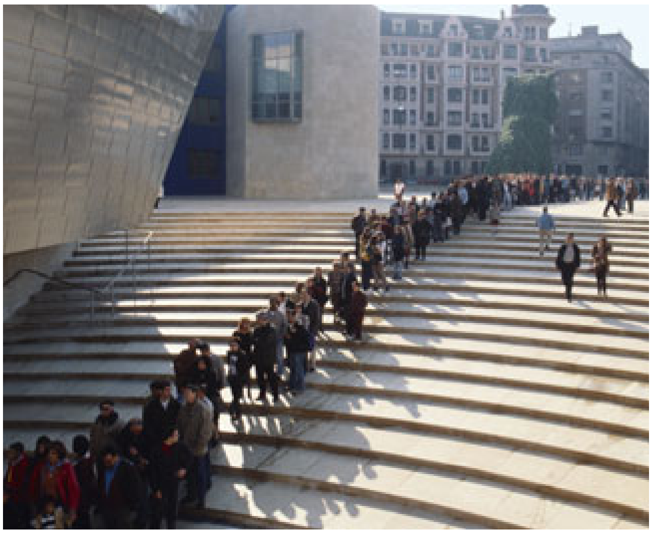
Handbuch der Lichtplanung, Rüdiger Ganslandt and Harald Hofmann, Lüdenscheid and Braunschweig/Wiesbaden 1992 (download at www.erco.de)

Museumsbeleuchtung: Strahlung und ihr Schädigungspotenzial – Konservatorische Maßnahmen, Grundlagen zur Berechnung, special publication by Fördergemeinschaft Gutes Licht (FGL), Frankfurt am Main 2006 (download at www.licht.de)

Control of damage to museum objects by optical radiation, CIE publication 157, Vienna 2004 (www.cie.co.at/cie)

Sammlungsgut in Sicherheit, Günter S. Hilbert (ed.), Berlin 2002 (3rd edition)

Zur Beleuchtung musealer Exponate, Günter S. Hilbert, Sirri Aydinli and Jürgen Krochmann, Fachzeitschrift für Kunsttechniken, Restaurierung und Museumsfragen "Restauro", Munich 1991 (5), pages 313–321



98

99

100

Photos 98–100: There are more than 6,000 museums in Germany. Hosting exhibitions from the worlds of art, science, technology and history, they attract over 100 million visitors a year.
They all present different exhibits and thus differ in the type of exhibitions they stage. What they all have in common, however, is a desire to enthral their audience. And that is where lighting plays an important role. Creating visual experiences and modulating and accentuating the visual landscape, it makes a key contribution to the success of any exhibition.

Acknowledgements for photographs

Photographs
Cover, 1–79, 83, 86 to 109 – all made available by members of Fördergemeinschaft Gutes Licht (FGL)

Additional information about photographs
26 Chris Korner, Marbach
38 Jürgen Tauchert, Wuppertal
44 JARO Medien, Mönchengladbach
80, 81 Andreas Kelm, Darmstadt
82 Fachgebiet Lichttechnik an der TU Berlin
84, 85 Blitzwerk, Mühltal

Illustrations
Fig. 1 Designergruppe Schloss+Hof, Ute Marquardt, Wiesbaden
Figs. 2–5, 8–15, 45–54 Kugelstadt MedienDesign, Darmstadt
Figs. 6, 7 FGL members
Figs. 16–44 JARO Medien, Mönchengladbach

Numbering of photos on back page:

101	102	103
104	105	106
107	108	109

Postage stamp

Postcard

Fördergemeinschaft
Gutes Licht
Postfach 70 12 61
60591 Frankfurt am Main
Germany

From

Name, Company, Office

Department

c/o

Address or P.O. Box

City, Postal Code

03/07/00/18E

The listed booklets are available in English only as pdf files, download free of charge at www.all-about-lighting.org:

1 Lighting with Artificial Light (7/04)
2 Good Lighting for Schools and Educational Establishments (7/03)
3 Good Lighting for Safety on Roads, Paths and Squares (3/00)
4 Good Lighting for Offices and Office Buildings (1/03)
6 Good Lighting for Sales and Presentation (2/02)
7 Good Lighting for Health Care Premises (4/04)
8 Good Lighting for Sports and Leisure Facilities (9/01)
11 Good Lighting for Hotels and Restaurants (2/05)
12 Lighting Quality with Electronics (5/03)
16 Urban image lighting (4/02)–
17 LED – Light from the Light Emitting Diode (05/06)
18 Good Lighting for Museums, Galleries and Exhibitions (03/07)

Imprint

18

This booklet is No. 18 in the series **Information on Lighting Applications** published by Fördergemeinschaft Gutes Licht (FGL) to provide information on good artificial lighting.

The postcards on this page can be detached and used for ordering the booklets. Alternatively, orders can be placed by e-mail (fgl@zvei.org) or via the Internet (www.licht.de). An invoice will be sent with the booklet(s) ordered. The pdf files of the booklets available for download at www.all-about-light.org are free of charge.

Publisher: Fördergemeinschaft Gutes Licht (FGL)
Stresemannallee 19
60596 Frankfurt am Main
Germany
phone: 069 6302-0
fax: 069 6302-317
e-mail: fgl@zvei.org

Technical consultants: Deutsche Lichttechnische Gesellschaft (LiTG) e.V. and Fördergemeinschaft Gutes Licht

Editing and realisation: rfw. redaktion für wirtschaftskommunikation Darmstadt

Design: Kugelstadt MedienDesign Darmstadt

Lith film: Layout Service Darmstadt

Printed by: available only as pdf file, download at www.all-about-light.org

Acknowledgements: The booklets in this series contain references to current DIN standards and VDE stipulations.
DIN standards:
Beuth-Verlag GmbH
10787 Berlin
DIN-VDE standards:
VDE-Verlag
10625 Berlin

ISBN: 3-926 193-35-2

Reprints: With the permission of the publishers.
03/07/00/18E

Printed on chlorine-free bleached paper.

Bestellung

Bitte liefern Sie ohne weitere Nebenkosten die bezeichneten Hefte (**e** = available in English, **E** = available only as pdf-file, download at www.licht.de):

Heft-Nr./Titel			Stück
1 Die Beleuchtung mit künstlichem Licht (7/04)	E	€ 9,–	
2 Gutes Licht für Schulen und Bildungsstätten (7/03)	E	€ 9,–	
3 Gutes Licht für Sicherheit auf Straßen, Wegen, Plätzen (3/00)	E	€ 9,–	
4 Gutes Licht für Büros und Verwaltungsgebäude (1/03)	E	€ 9,–	
5 Gutes Licht für Handwerk und Industrie (4/99)		€ 9,–	
6 Gutes Licht für Verkauf und Präsentation (2/02)	E	€ 9,–	
7 Gutes Licht im Gesundheitswesen (4/04)	E	€ 9,–	
8 Gutes Licht für Sport und Freizeit (9/01)	E	€ 9,–	
9 Repräsentative Lichtgestaltung (8/97)		€ 9,–	
10 Notbeleuchtung, Sicherheitsbeleuchtung (4/00)		€ 9,–	
11 Gutes Licht für Hotellerie und Gastronomie (12/04)	E	€ 9,–	
12 Beleuchtungsqualität mit Elektronik (5/03)	E	€ 9,–	
14 Ideen für Gutes Licht zum Wohnen (9/99)		€ 9,–	
16 Stadtmarketing mit Licht (4/02)	E	€ 9,–	
17 LED – Licht aus der Leuchtdiode (10/05)		€ 9,–	
18 Gutes Licht für Museen, Galerien und Ausstellungen (12/06)		€ 9,–	
Lichtforum		kostenlos	

Hefte 13 und 15 sind vergriffen

Ort Datum Stempel/Unterschrift

Bitte den Absender auf der Rückseite der Postkarte nicht vergessen.

The listed booklets are available in English only as pdf files, download free of charge at www.all-about-lighting.org:

1 Lighting with Artificial Light (7/04)
2 Good Lighting for Schools and Educational Establishments (7/03)
3 Good Lighting for Safety on Roads, Paths and Squares (3/00)
4 Good Lighting for Offices and Office Buildings (1/03)
6 Good Lighting for Sales and Presentation (2/02)
7 Good Lighting for Health Care Premises (4/04)
8 Good Lighting for Sports and Leisure Facilities (9/01)
11 Good Lighting for Hotels and Restaurants (2/05)
12 Lighting Quality with Electronics (5/03)
16 Urban image lighting (4/02)–
17 LED – Light from the Light Emitting Diode (05/06)
18 Good Lighting for Museums, Galleries and Exhibitions (03/07)

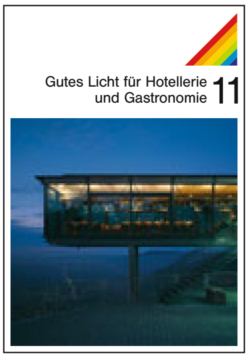
Fördergemeinschaft Gutes Licht publications

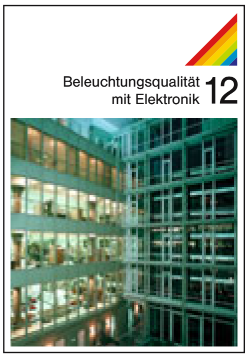
Fördergemeinschaft Gutes Licht (FGL) provides information on the advantages of good lighting and offers extensive material on every aspect of artificial lighting and its correct usage. FGL information is impartial and based on current DIN standards and VDE stipulations.

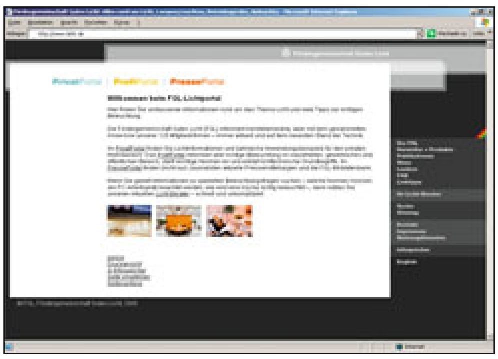
Information on lighting applications
The booklets 1 to 18 in this series of publications are designed to help anyone who becomes involved with lighting – planners, decision-makers, investors – to acquire a basic knowledge of the subject. This facilitates cooperation with lighting and electrical specialists. The lighting information contained in all these booklets is of a general nature.

Lichtforum
Lichtforum is a specialist periodical focusing on topical lighting issues and trends. It is published at irregular intervals. Lichtforum is available only in German.

www.all-about-light.org
On the Internet, FGL offers tips on correct lighting for a variety of domestic and commercial "Lighting Applications". In a Private Portal and a Pro Portal at www.all-about-light.org, numerous examples of applications are presented. Explanations of technical terms are also available at the click of a mouse on the buttons "About Light" and "Lighting Technology". Databases containing a wealth of product data, a product/supplier matrix and the addresses of FGL members provide a direct route to manufacturers. "Publications" in an online shop and "Links" for further information round off the broad spectrum of the FGL light portal.







Booklets 13 and 15 are out of print.

Information
on lighting applications
Booklet **18**

Good Lighting for Museums, Galleries and Exhibitions

Fördergemeinschaft Gutes Licht