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OMS® RIGHTLIGHTHEALTHCARE

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RIGHT LIGHT HEALTHCARE

History of institutions dealing with healthcare, and especially of hospitals, can be traced back to ancient Mesopotamia. Back then, medicine was something magical and mythological, diseases were connected rather with supernatural forces and later on with poverty or dirt. The foundation of modern medicine dates back to ancient Greeks. In that time, more attention was paid to hospitals which started to function as temples and meeting points. As they started to be more and more important for people, also the way they looked started to change.

When it comes to lighting, we have also gained some useful knowledge and skills. Today, we understand that the technical, clinical and human needs play an important role. We are also aware that design and colours have a direct and significant influence not only on health and healing but also on overall feelings of people who work in or visit the health institutions. To make this Smart Light Healthcare more focused, we will be dealing with lighting in hospitals as the best representative of this application. In general, hospitals are not associated with pleasant feelings - most of us visit them only when we or our loved ones get sick. Adding to the naturally unappealing space bad lighting, undesired sounds or any other distressing factor, patients report negative feelings such as anxiety, stress, or even depression. On the other side, natural light has mood-elevating and pain-easing effects. So there is a way how to make the experience in hospitals a bit more bearable. All the scientific facts and research results taken into account, we adopted a holistic approach to lighting of different areas within healthcare institutions and created a set of solutions which can turn them into a more welcoming place.

Keeping the well-being of patients and employees on the top of our priorities, we assess the needs of each space with special care. On the following pages you will read a bit about our theoretical basis to lighting design, you will learn about our approach to environmentally-friendly solutions combined with human centric principles, and we will introduce you to some core ideas for lighting of specific areas which can be applied to similar applications in any healthcare institution.

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CONTENT

LIGHTING AND US

BRINGING ORDER TO THE LIGHTING WORLD

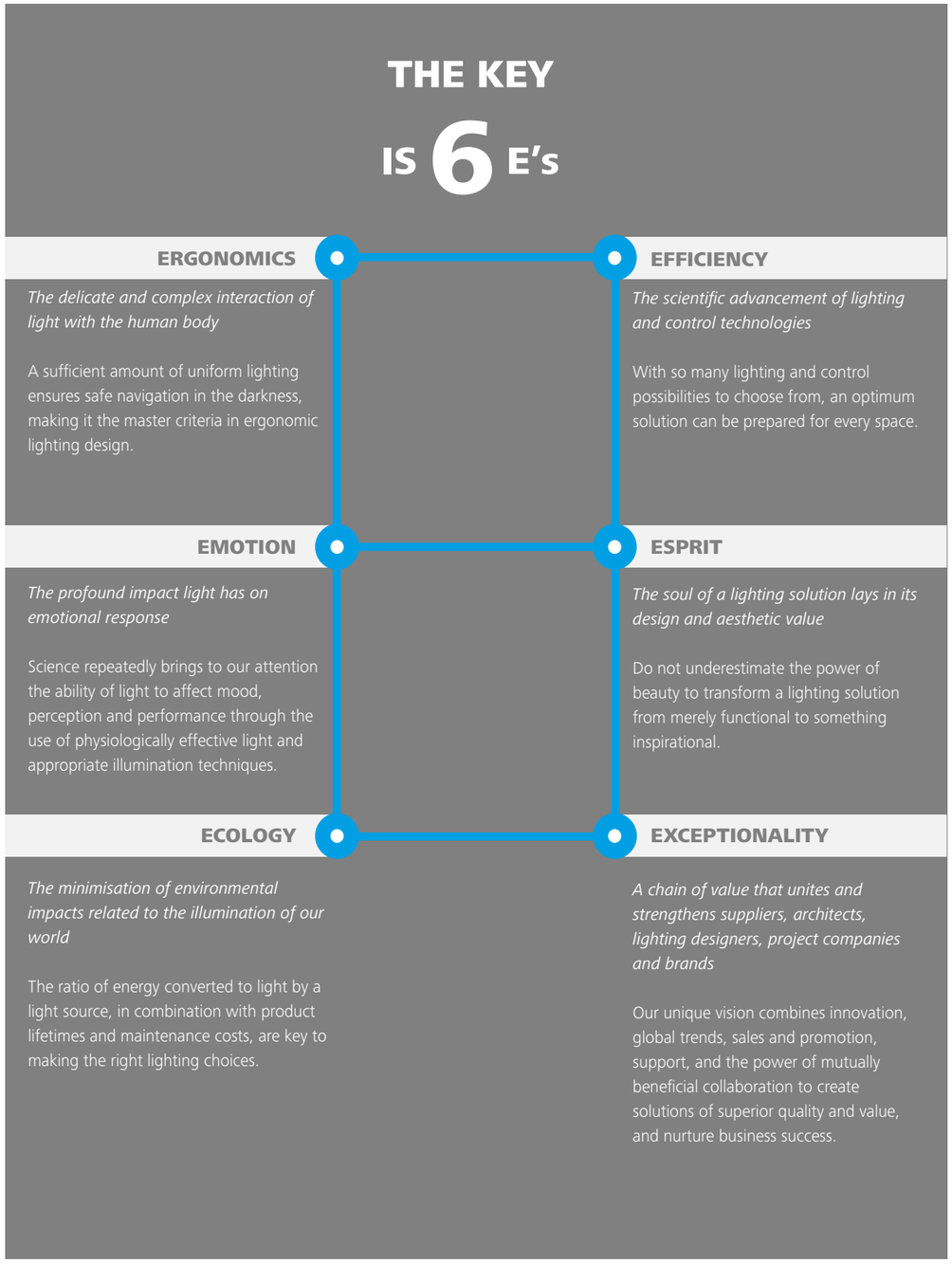
When designing the lighting system, besides the legal standards, also other parameters have to be taken into account. Until recently, the summary of these criteria was not clearly and uniformly stated, however, SLE has come up with the six-point assessment system of the lighting quality which we call Lighting Quality Standard (LQS).

Living by rules is important.

This brand new lighting quality standard helps not only us but also our clients and partners to better understand and evaluate lighting devices and solutions. Behind the acronym LQS, there are six E's: ERGONOMICS, EMOTION, ECOLOGY, EFFICIENCY, ESPRIT, AND EXCEPTIONALITY.

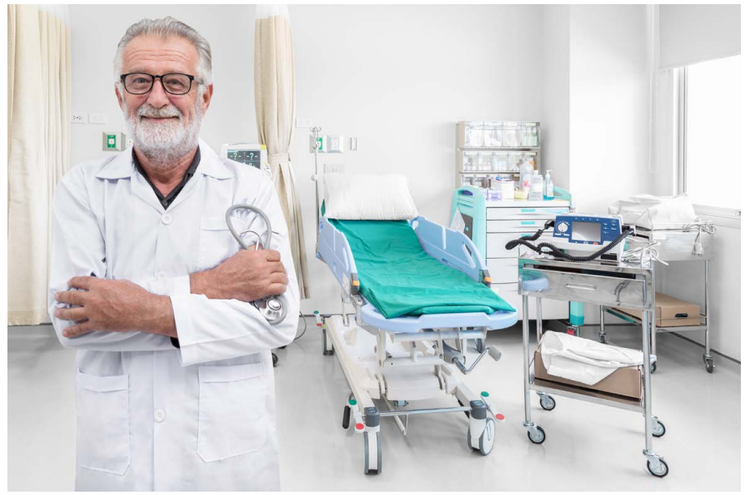
Until now there was no unifying system used in the world of lighting for evaluation of either light fixtures or lighting solutions, and every producer has got its own way for that. Consumers used to get lost in the vast array of criteria which said only a little about the quality of products or solution. SLE brings order to this chaos by introducing a unified LQS available for the whole lighting sector.

If you imagine a house, the first four E's are strong pillars representing criteria that are well-known in the world of lighting. The remaining two are the roof, a powerful superstructure on the top of these pillars. Together, they create an inseparable complex, because the parts of the whole cannot be perceived independently, but only in the context. That is the basic philosophy of the LQS. Immerse in the 6 E's and get to know the lighting with clear rules.



ERGONOMICS

Respecting ergonomic standards in areas which are constantly occupied by a large number of people is a must. Therefore, hospitals and surrounding areas of the hospital call for adequate lighting at all times. Adequate lighting allows for an effective execution of everyday activities for the employees and creates comfortable atmosphere for the patients. All in all, it is stimulating, safe, and pleasant.



In ergonomic spaces, it is easy to identify objects and items. Lighting designers know the tools which help to create such spaces and have the knowledge and experience in applying them to practice.

Basic tools include appropriate colour rendering index, lowering the glare rate to the least value possible, and improving performance, comfort and possibility to concentrate with uniform and sufficient lighting and harmonious distribution of brightness.

COLOUR RENDERING INDEX

One of the most effective ways how to change the quality of light in any space is to change colour rendering index (CRI) of luminaires. CRI is a measure of how well light sources render the colours of objects, materials, and skin tones. Its value varies on a scale from 0 to 100, indicating how truthfully artificial light sources copy the object's colouring compared to daylight.

CRI is extremely important in areas in which the colours need to be recognised without compromise. For instance, lab workers need to test samples of thousand colours and the correct colour recognition can influence a lot of important things, such as correctness of a diagnosis.

Comparison of colour rendering indexes - CRI. Left: CRI 70. Right: CRI 93

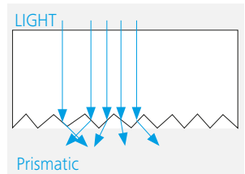
The CRI value of the luminaire is expressed by the average of the first eight factors R1 - R8 out of fifteen colour samples illuminated at first under a reference light source with an ideal value (CRI = 100) and under the light source being tested. The higher the CRI is, the more truthful the colours are. Light sources with CRI of 85 to 90 are considered to be sufficiently good for the most of the applications, however, sources with CRI 90+ are required for certain tasks, too.

The European standard EN 12 464-1 for lighting of indoor workplaces contains recommendations related to hospitals and healthcare buildings, including information about proper colour rendering index.

GLARE PREVENTION

Glare is a negative visual sensation caused by excessive and/or uncontrolled brightness. It can be visually uncomfortable and in many cases even dangerous as it can disable human eye from proper functioning.

Perception of glare is subjective, in general, older people are more sensitive. We distinguish two major kinds of glare - disability glare temporarily reduces or completely prevents human eye from visibility while discomfort glare causes feelings of annoyance and in extreme cases even pain or headache. People exposed to glare for a longer time noticed similar symptoms, such as fatigue, visual impairment, reduced concentration, difficulties with reading, etc.



On the premises of a hospital, glare is especially undesirable. For example, in the waiting rooms, patients face all sorts of stressful situations and troubling light would just support all the unpleasant feelings. Inside the examination rooms, excessive light can decrease the contrast of the image on the visual display units by veiling reflections caused by dazzling of the screen surface, the luminance of the luminaires and bright surfaces which are reflected on the screen. Luminance of light emitting area is in accordance with EN 12464-1: Light and lighting - lighting of indoor workplaces. It cannot exceed the value of 1,500 cd/m^2 in limit angle 65° nor the value of UGR<19.

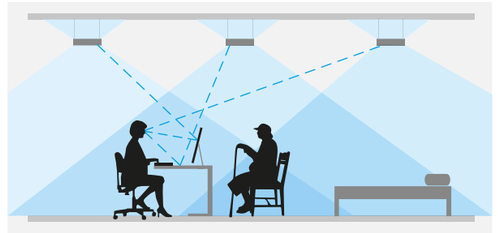
Glare can be caused by different phenomena. Frequently, it is caused by the unprotected exposure to the light source. As LEDs are really powerful, luminaires should always be equipped with appropriate optics. Another reason for glare is the incorrect angle of the light beam entering the human eye. Using microprism and luminaires with louvres, we can modify the angle and direct the light downwards rather than to the sides. Therefore, opal diffusers are not the best option for glare prevention as they direct light to all possible directions which we cannot really control. Reducing the risk of exposing the space users to glare begins with the correct organisation of the workplace. Placing the desks rectangular to the glass window areas for the daylight not to reflect directly to the eye and to fit them out with the blinds are the basic measures of the glare prevention. Another way how to prevent glare is a correct selection of the lighting fixture and its appropriate placement in the space. It is recommended to choose luminaires with low luminance and mat surface and to place them in such a way that the ray of light will not reflect from the objects directly to the eye, e.g. when sitting at the desk while carrying out everyday activities.

Unified Glare Rating

The method of Unified Glare Rating (UGR) is used for uniform qualification of the rate of the psychological glare. It was defined by the Comission Internationale de l´Éclairage which created the following glare formula:

$$UGR = 8\log\left[\frac{0.25}{L_b}\sum\frac{L^2\Omega}{p^2}\right]$$

L stands for luminance of lighting parts of every luminaire in the direction of the eye (in candelas per square metre). Ω is a cut-off angle of a luminaire relative to the eye of an observer (in sr). P is a Guth factor of spatial position of every single luminaire relative to the field of view. L expresses background illuminance (in candelas per square metre).



The correct illumination of the task area creates optimal conditions to perform well. It prevents humans from fatigue, loss of concentration and making errors.

Screen high state luminance	High luminance screen L > 200 cd/m²	Medium luminance screen L ≤ 200 cd/m²
Case A *Values for spaces with common demands on the correct colour rendering and details of the depicted information that is relevant e.g. for all types of hospitals.*	≤ 3,000 cd/m²	≤ 1,500 cd/m²
Case B *Values for spaces with increased demands on the colour rendering, precise work and details of the depicted information, e.g. operation theatres, laboratories, etc.*	≤ 1,500 cd/m²	≤ 1,000 cd/m²

The limit values of the lighting fixtures´ luminance in the angle of 65° and more from the vertical axis.

The UGR values are specified in the European standard EN 12464 for activities and visual tasks:

- **≤ 16** workplaces with high demands on precision and a high rate of visual load (technical drawing)
- **≤ 19** reading, writing, training, meetings, computer-based work
- **≤ 22** craft and light industries, receptions
- **≤ 25** heavy industry, archives
- **≤ 28** railways platforms, foyers

Microprism

Microprism represents one of the most effective methods for the diffuse light distribution as the light breaks at the end of the material, on the so called optical prisms, which results in its uniform distribution. The soft diffuse light is more pleasant for the human eye and it strains less. Microprism in combination with a suspended LED luminaire with direct and indirect distribution of diffuse light is an ideal solution for many spaces, including hospitals.

ILLUMINATION LEVEL

Task area is the most important space in terms of illumination quality. Here the work itself takes place and demands constant and sufficient lighting without any disturbing effects such as glare or flicker. The illumination of the task area should take into account especially the type of work being done and the focus it takes to carry out the task. For example, visually engaging activity, such as checking the colour of samples in test tubes, requires lighting with high-quality colour rendering.

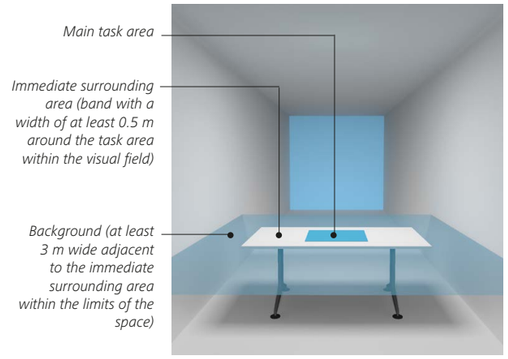
Task Area

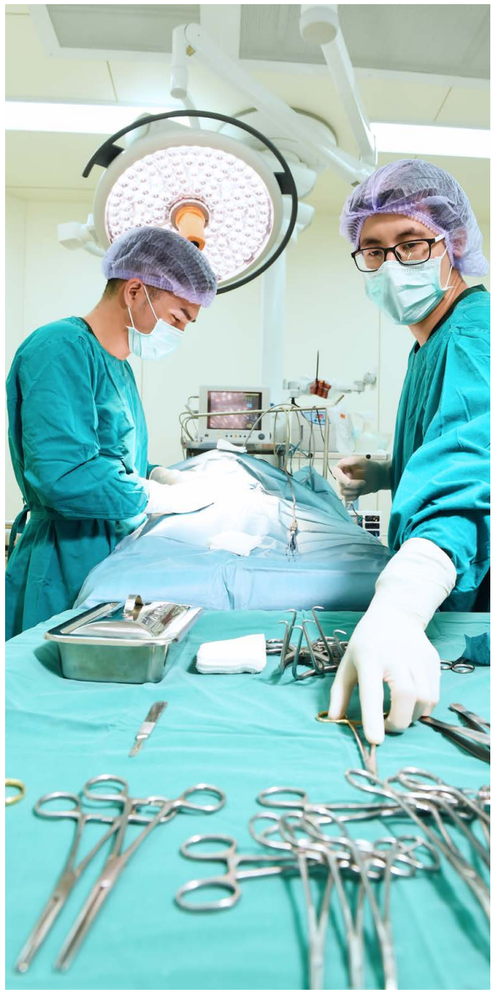
Constant illumination level over task areas is set by the standards. Even though older light sources diminish their illuminance over the course of time, they need to provide the required illumination level or be replaced. Sufficient and uniform lighting of the task area is very important if we want to create comfortable working atmosphere, however, illumination of the immediate surroundings of the task area is important, too. Extreme differences in lighting cause unnecessary strain and discomfort for people facing such lighting for a shorter period of time, such as patients, and ultimately lead to stress and long-term problems of people spending there more time, such as nurses and doctors.

Surrounding areas

The EN 12 464-1 defines the surrounding as radius of half a meter around the whole task area. In this space the illuminance has to be at least 66 to 75 percent of the task area illuminance. For example, if a task area has a minimum illuminance set at 200 lux, the surrounding area has to have at least 150 lux. For the most demanding tasks the standard calls for 750 lux while surrounding must have two thirds of that value, which is only 500 lux.

Quality lighting adds to feelings of comfort and well-being; it influences human psyche, performance, ability to concentrate, and regeneration. Correct illumination of the space makes it easy to perceive visual information and recognise the shapes of objects and faces. Generally speaking, for right-handers it is ideal when a luminaire is placed towards the working surface slightly from the left of the person's view in order to avoid creation of shadows on the task area.



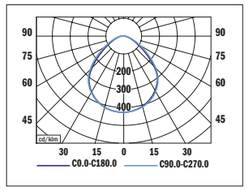


LIGHTING UNIFORMITY

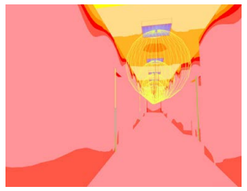
A uniformly illuminated space is perceived as a consistent one. Big differences in the rate of illumination create the impression of a broken space and tire the sight. Uniform illumination affects our ability to perceive the surrounding area and to orient ourselves inside of it. Lighting uniformity can be expressed as a ratio of the minimal and average illuminance of the space assessed. The closer their values are, the more uniform the illuminance of the space is.

An optimal state can be achieved by selecting an appropriate type and number of luminaires and their correct distribution. From the point of view of type of luminaires, the direct and indirect lighting fixtures with a wide luminous intensity curve seem to be the most suitable.

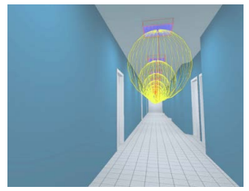
Lighting uniformity index set by the European standard 12464-1 is stricter for workplaces and activities requiring precision.



Luminous intensity curve



A specialised software dialux enables a simulation of the lighting uniformity of the space already during the design phase of the lighting system.



Already the luminous intensity curve gives the designer a hint about the resulting effect.

The customer acquires the visualisation of the room space including the definitions of the material surfaces and parts of the interior as well.

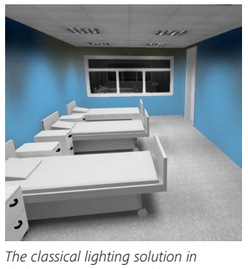
An outstanding lighting uniformity in the space that have to fulfilll demanding requirements of the standard can be achieved by placing a lighting fixture with a cosine luminous intensity curve. These requirements can be fulfillled by a recessed ceiling luminaire with a direct characteristic of the luminous flux distribution.

HARMONIOUS DISTRIBUTION OF BRIGHTNESS

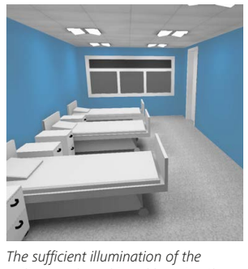
People acquire up to 80 % of information through their sense of vision, therefore lighting is the key factor for correct visual perception. Brightness is the only quantity to which the human eye responds and, therefore, its distribution is the key factor when planning the illumination in any space. Harmonious distribution of brightness affects sharpness of vision and enables the human eye to perceive the contrast. Unequal distribution of brightness places increased demands on the adaptation ability of the human eye, the low contrast reduces the visual stimulation, causes eye fatigue and in this way it affects the performance efficiency. Excessive brightness in the space causes an undesirable glare.

To achieve an optimal distribution of brightness in the space means to begin with a correct organisation of the interior and its design.

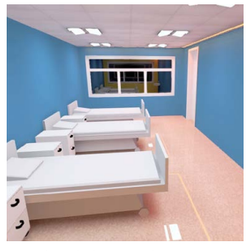
The standards for harmonious distribution of brightness are defined by the norm EN 12464-1 which recommends the value of the reflection factor of the main interior surfaces from 0.7 to 0.9; for the walls from 0.5 to 0.8 and for the floor from 0.2 to 0.4. For the value of the reflection factor of large objects (e.g. furniture) it states the range of 0.2 to 0.7. The standard EN 12464-1 also determines the values for maintained illuminance of the main surfaces.



The classical lighting solution in bedrooms with recessed luminaires with a parabolic louvre ensures sufficient illumination of the rooms but the upper parts of the walls and the ceiling remain dark. Such illumination causes a feeling of a cave effect and makes the room optically smaller.



The sufficient illumination of the ceiling can be achieved by using the luminaire with the direct luminous flux distribution combined with illumination of the ceiling thanks to the specially shaped diffuser. The room then gives an impression of a lighter and larger space.



Even though the second scene is sufficient for bedroom lighting, ideal solution would be to use the recessed luminaires with the special diffuser and complement them with linear RGBW wall washers. This way, we will achieve better contrast on the background, homogeneous lighting, and RGBW will help to create a special atmosphere which has positive effect on human well-being and recovery.

To achieve an optimal distribution of brightness in the space means to begin with a correct organisation of the interior and its design. The types of the material and colour used are decisive.

MINIMUM LIGHTING REQUIREMENTS RECOMMENDED BY EN 12464-1

Type of area, task or activity	Em [lx]	UGR	U0	CRI	Specific requirements
Priestory na všeobecné účely					
Rooms for general use					
Waiting rooms	200	22	0.4	80	
Čakárne	200	22	0,40	80	Osvetlenosť na úrovni podlahy.
Corridors during the day	100	22	0.40	80	Illuminance at floor level
Chodby počas dňa	100	22	0.40	80	Osvetlenosť na úrovni podlahy.
Corridors at night	50	22	0.40	80	Illuminance at floor level
Chodby v noci	50	22	0.40	80	Osvetlenosť na úrovni podlahy.
Corridors, during the night use	200	22	0.60	80	Illuminance according to visual task/activity
Chodby s nočným využitím	200	22	0,60	80	Osvetlenosť zrakovej úlohy/aktivity.
Rooms for multi-purpose use	200	22	0.60	80	Illuminance at floor level
Priestory na viacúčelové využitie	200	22	0,60	80	Osvetlenosť na úrovni podlahy.
Waiting rooms	100	22	0.60	80	Illuminance at floor level
Čakárne	100	22	0,60	80	Osvetlenosť na úrovni podlahy.
Elevators, lifts for persons and visitors	100	22	0.60	80	illuminance at floor level
Výťahy pre osoby a návštevníkov	200	22	0,60	80	Osvetlenosť na úrovni podlahy.
Service lifts	200	22	0.60	80	illuminance at floor level
Obslužné výťahy	200	22	0,60	80	Osvetlenosť na úrovni podlahy.
Staff rooms					
Služobná miestnosť	500	19	0,60	80	
Miestnosti pre zamestnancov					
Staff office	300	19	0.60	80	
Miestnosti pre zamestnancov	500	19	0,60	80	
Nemocničné izby, oddelenia šestonedelia					
Staff rooms	300	19	0.60	80	
Celkové osvetlenie	100	19	0.40	80	Osvetlenosť na úrovni podlahy.
Wards, maternity wards					
Osvetlenie na čítanie	300	19	0,70	80	
General lighting	100	19	0.40	80	illuminance at floor level
Jednoduché vyšetrenia	300	19	0.60	80	
Reading lighting	300	19	0.70	80	
Vyšetrenie a ošetrenie	1 000	19	0,70	90	
Simple examinations	300	19	0.60	80	
Nočné osvetlenie, osvetlenie na pozorovanie	5	-	-	80	
Examination and treatment	1,000	19	0.70	90	
Kúpeľne a toalety pre pacientov	200	22	0,40	80	Osvetlenosť na úrovni podlahy.
Night lighting, observation lighting	5	-	-	80	
Vyšetrovne (všeobecné)					
Bathrooms and toilets for patients	200	22	0.40	80	illuminance at floor level
Celkové osvetlenie	500	19	0,60	90	4 000 K ≤ *T*cp ≤ 5 000 K
Examination rooms (general)					
Vyšetrenie a ošetrenie	1 000	19	0,70	90	
General lighting	500	19	0.60	90	4,000 K ≤ *T*cp ≤ 5,000 K
Vyšetrovne zraku					
Examination and treatment	1,000	19	0.70	90	
Celkové osvetlenie	500	19	0,60	90	4 000 K ≤ *T*cp ≤ 5 000 K
Eye Examination rooms					
Vyšetrenie hornej časti oka	1 000	-	-	90	
General lighting	500	19	0,60	90	4,000 K ≤ *T*cp ≤ 5,000 K
Testy ostrosti a farebného videnia	500	19	0,60	90	
Examination of the anterieye	1,000	-	-	90	
Vyšetrenie predného oka					
Vyšetrovne sluchu					
Examination tests with vision charts	500	16	0.70	80	
Ear Examination rooms					
Vyšetrenie sluchu	500	19	0,60	90	
General lighting	500	19	0.60	90	
Pôrodné sály					
Celkové osvetlenie	1,000	-	-	90	
Delivery rooms					
Vyšetrenie a ošetrenie	300	19	0,60	80	
General lighting	1,000	19	0.70	80	
Examination and treatment					
Dialýza	**500**	**19**	**0,60**	**80**	**Osvetlenie má byť regulovateľné.**
Treatment rooms (general)					
Dermatológia	**500**	**19**	**0,60**	**90**	
Dialysis	500	19	0.60	80	Lighting should be controllable.
Miestnosti na endoskopiu	**300**	**19**	**0,60**	**80**	
Dermatology	500	19	0.60	90	
Sádrovne	**500**	**19**	**0,60**	**80**	
Endoscopy rooms	300	19	0.60	80	
Vodoliečba	**300**	**19**	**0,60**	**80**	
Plaster rooms	500	19	0.60	80	
Masáže a rádioterapia	**300**	**19**	**0,60**	**80**	
Medical baths	300	19	0.60	80	
Operačné priestory					
Massage and radiotherapy	300	19	0.60	80	
Predoperačné a pooperačné miestnosti	500	19	0,60	90	
Operating areas					
Operačné sály	1 000	19	0,60	90	
Pre-op and recovery rooms	500	19	0.60	90	
Operačné pole	-	-	-	-	*Em*: 10 000 lx až 100 000 lx
Operating theatre	1,000	19	0.60	90	
Jednotky intenzívnej starostlivosti					
Operating cavity	-	-	-	-	*Em*: 10 000 lx to100 000 lx
Celkové osvetlenie	100	19	0,60	90	Osvetlenosť na úrovni podlahy.
Intensive care unit					
Jednoduché vyšetrenia	300	19	0,60	90	Osvetlenosť na úrovni postele.
General lighting	100	19	0.60	90	illuminance at floor level
Vyšetrenia a ošetrenie	1 000	19	0,70	90	Osvetlenosť na úrovni postele.
Simple examinations	300	19	0.60	90	illuminance at bed level
Ošetrenie a liečba	1,000	19	0,70	90	
Examination and treatment	1,000	19	0.70	90	illuminance at bed level
Zubné ordinácie					
Celkové osvetlenie	500	19	0,60	90	Osvetlenie mé byť bez oslnenia pre pacienta.
Dentists					
Všeobecné osvetlenie	1 000	-	0,70	90	
General lighting	500	19	0.60	90	Lighting should be glare free for the patient.
Ošetrenie zubov	1 000	19	0,70	90	Osobitné požiadavky sú v EN ISO 9680.
Dental treatment	1,000	19	0.70	90	Osobitné požiadavky sú v EN ISO 9680.

MINIMUM LIGHTING REQUIREMENTS RECOMMENDED BY EN 12464-1

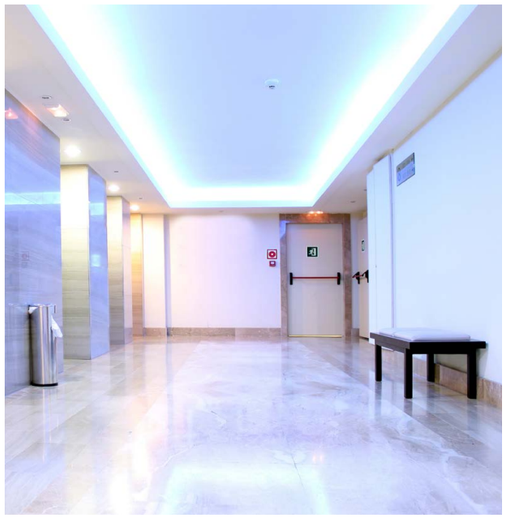
EMOTION

Light is able to substantially affect perception of people, their mood, feelings of visual and psychological well-being, and human circadian rhythm, too. This knowledge has enlarged the role of artificial illumination by a new dimension - today we know that it can be biologically effective, too.

AVAILABILITY OF DAYLIGHT

Hospitals consist mainly of closed, artificially illuminated spaces which serve the most varied purposes. As the scientific research has unambiguously confirmed the positive impact of the natural light on the feeling of people's visual and psychological well-being, their performance efficiency, ability to concentrate and also regenerate, it is a must to provide for a sufficient amount of daylight in hospitals. The task of the artificial lighting is to supplement daylight and replace it only where and when it is fully absent, including the emergencies such both expected and unexpected electrical power cuts. When applying human centric principles to hospitals, properties of artificial lighting are very important, too. Suppose that the walls, ceiling and task areas are lit correctly, human eye does not have to respond to any changes as there is only little contrast which does not require the constriction and dilation of the pupil. Hence the eye is not getting tired too much or too quickly and provides the person perfect visual comfort. Combined with large lighting curves and low UGR we cannot only simulate the properties of natural light in an effective way but we can also apply RGBW to ambient lighting sources illuminating the walls and play with the atmosphere of the whole space, which brings an added value to the whole solution. Moreover, technological progress allows us to control the system in a user-friendly way.

Biologically effective lighting is tightly connected with the opportunities brought by the exploration of the power of human centric lighting. Besides human centric lighting in spaces occupied by people throughout the whole day, also influence of light on emotions is extremely important. By adding the correct mixture of various colours of light and lighting spectrum and by utilising ambient and accent lighting with perfect lighting curves, we can achieve visual and psychological well-being without any negative influence on human regeneration capabilities. All with LMS (Lighting Management System) installed according to the needs and wishes of our customers.



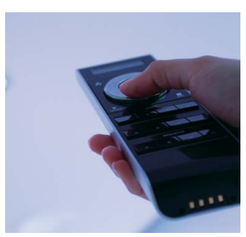
Accent lighting directs the attention to the selected object and emphasises its exceptionality whereas ambient illumination completes the overall atmosphere of the space.

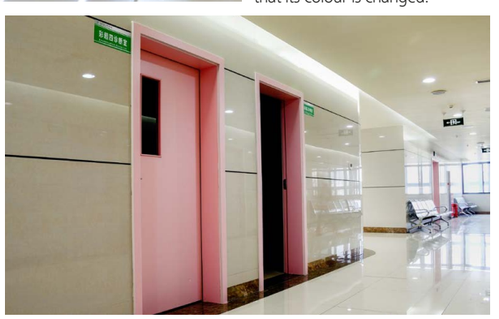
EMOTIONAL LIGHTING

This category includes two different types of illumination. On one side, it is the accent lighting which is able to emphasise or to draw attention to detail. On the other side, the ambient lighting gives the space overall mood and tone. Their task in the interior design is to induce the atmosphere and to emphasise the desirable detail.

The emotional lighting provides, from the point of view of its utilisation, many options in various types of interior and more and more frequently it plays an important role also in the framework of the lighting solution. It gives attractiveness to waiting rooms, cosiness to examination rooms, it supports functionality of the conference halls and meeting rooms, etc. From the technological point of view, it provides a wide space for the utilisation of the RGB LED technology enabling the light colour to mix from red to violet. With RGBW, through adding the white colour, it is possible to achieve a more intensive saturation of the colour along the whole colour spectrum. The colour solution is thus strengthened by the potential to create various lighting scenes that are able to induce a relaxing, motivating or intimate atmosphere. Variable accent luminaires are able to attract attention to unusual details. Their conception is based on people's tendency to respond to various intensities of brightness. So, if we want to emphasise the importance of an object and to achieve the human eye detecting it and saving it as well in its memory as an exceptional one, we have to reach the contrast of luminance between the given objects and the background minimally in the ratio of 3:1.

Lighting of surfaces depends on lighting curves of general lighting. Poorly illuminated walls and the ceiling could make an impression of too much darkness and arouse negative feelings. On the contrary, when we use luminaires with sufficient lumen output and ideally also with an indirect flux distribution, we achieve optical enlargement of the space and artificially simulate the sky, which evokes positive feelings. When lighting the surfaces at workplaces, we tend to follow the recommendations which determine the ratio between illuminance of the ceiling and working area while making use of both direct/indirect luminaires and reflected light. Through the ambient luminaire it is possible to make the overall mood and space atmosphere complete. It is used for illumination of vertical surfaces, especially walls. It is often placed in such a way that it is not visible, e.g. to the soffits (e.g. the so called cove lighting). In this solution the light falls directly to the wall and creates an impression that its colour is changed.





INTRODUCTION TO HUMAN CENTRIC LIGHTING

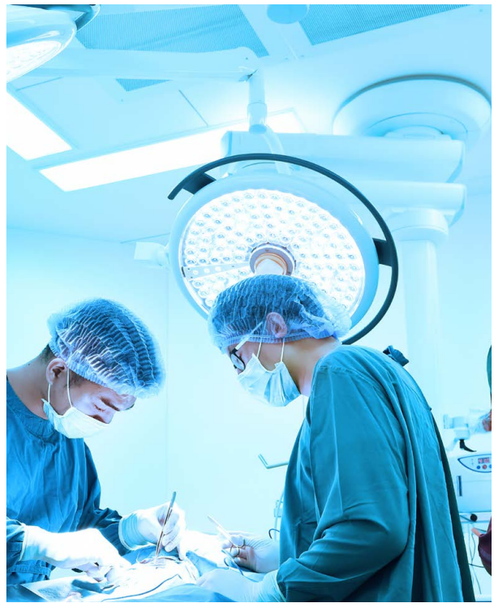
In healthcare facilities light and lighting can be viewed from two distinct angles: from the point of view of employee and patient wellbeing, and from the point of view of treatment. However, even though different, the two areas diverge at times due to the fact that light is fundamental to human existence on every level, having a direct influence over physiological and psychological health. Furthermore, light has many therapeutic effects, especially red and blue light have shown their influence on various biological processes.

Blue Light Content

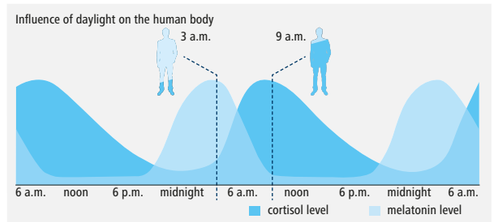
Revealing the function of the third type of receptors in the human eye belongs among the biggest discoveries of the modern science. They are able to affect the production of melatonin, a hormone controlling the circadian rhythm of people. These receptors are sensitive to that part of the light spectrum which has the wavelength of 464 nanometres, i.e. the blue light. This knowledge became the basis for the luminaire producers - the lighting fixtures with a proper proportion of the blue part of the artificial lighting spectrum are able to affect the human activity effectively. From the point of view of evolution, the blue light signals if it is day or night to the human organism. In the spaces with a limited access of daylight, its presence is a key factor that influences the feelings of human well-being. Its shortage stimulates the production of melatonin and signals to the human organism that it is time for some rest and induces an increased need for sleep.

The absence of the blue light in the spectrum can lead to reduced performance and disruption of the circadian rhythm of the human organism. On the contrary, its correct ratio in the light spectrum from an artificial light source can stimulate the performance efficiency and positively affect the feelings of well-being. From this point of view, especially hospital employees working on shifts represent a challenge where a sufficient amount of the blue light is able to adjust biorhythm of those employees who are working at night.

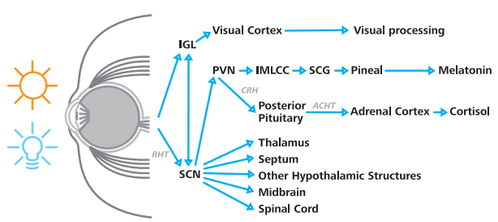
The proportion of the blue light in the light spectrum is subject to changes during the day. A correctly planned light solution can respond to this fact through simulation of the daylight. The latest examination of the standard for the illumination of internal workplaces recommends a combination of direct and diffused lighting, which is in certain areas, such as offices, not only recommended but even required. The suspended lighting fixtures fulfilll these specific requirements in full extent.



A correct ratio of the blue light in the light spectrum from an artificial light source is able to stimulate the performance efficiency and affect positively the feeling of psychological well-being.



During morning hours the human organism produces the hormone cortisol which stimulates metabolism. Its concentration in blood reaches its maximum at about 9 a.m., then during the rest of the day its content continually decreases. Melatonin, also called the hormone of sleep, is produced by the human organism also during the night and its concentration in the human organism culminates at 3 a.m.



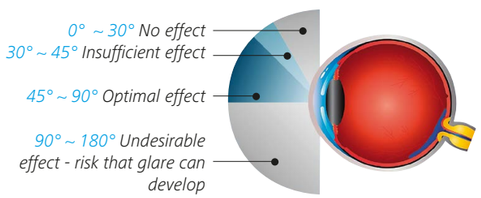
Melatonin
Melatonin makes us feel drowsy, slows down bodily functions and lowers activity levels to facilitate a good night's sleep. It also ensures that a large number of metabolic processes are wound down. Body temperature falls; the organism, as it were, is put on the back burner. In this phase, the body secretes growth hormones that repair cells at night.

Cortisol
Cortisol is a stress hormone, produced from around 3 a.m. onwards in the adrenal cortex. It stimulates metabolism again and programmes the body for day-time operation. The first light of the day then stimulates the third receptor in the eye and suppresses the production of melatonin in the pineal gland. At the same time, the pituitary gland makes sure the body secretes more serotonin.

Serotonin
Serotonin acts as a mood-enhancing, motivating messenger. While the level of cortisol in the blood falls during the day in a counter-cycle to melatonin, serotonin helps us achieve a number of performance peaks. When daylight fades, the internal clock switches to night.

However, if our body does not get enough light during the day, it produces only a low level of melatonin. As a result, we sleep badly, we wake feeling unrested, we are tired during the day and lack energy and motivation. Insufficient exposure to stimulating light during autumn and winter can turn the process into a downward spiral. At that time of year, some people develop seasonal affective disorder (SAD). Their internal clock misses its cues because the hormonal balance in the brain is upset.

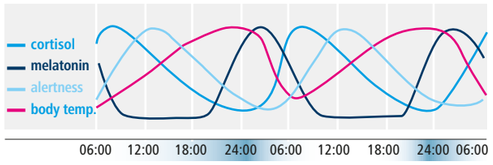
An interesting luminaire design in terms of its ability directs the light in a biologically effective way. The direct light directed from the LED sources located in the bottom part of the construction is completed by a microprismatic diffusor that alters the direct light into soft, diffused light. The side optics are designed in such a way that it directs the blue spectrum of the light directly to the human eye under the optimal angle and affects the third photoreceptor responsible for correct operation of the human circadian rhythm. The positive biological effect of the luminaire would be especially effective with a very cold light with correlated colour temperature 6,500 K.



The third type of the photoreceptors in the human eye is sensitive to that part of the light spectrum which has the wavelength of 464 nanometres, i.e. the blue light. These receptors have influence on creating melatonin, a hormone controlling the circadian rhythm of people.

The circadian rhythm is a fundamental cycle of biological events such as digestion, sleep and body temperature, that repeat on a roughly 24 hour cycle. It can be classified in three parts. First, the internal 'clock' which is located within the suprachiasmatic nucleus or the hypothalamus. Second, a number of external zeitgebers (cues) which entrain the body's clock to the 24 hour environmental cycle. Third, the hormone melatonin secreted by the pineal gland to regulate the body according to the entrained circadian rhythm, the production and levels of which are determined by physiological reactions to illumination level and colour temperature. Melatonin works in partnership with the hormones cortisol, serotonin, and dopamine. During the day, if we consider a natural circadian rhythm, appropriate amounts of these three supplementary hormones are secreted. Cortisol has a balancing effect on melatonin and ensures a stress response, serotonin controls impulses and food cravings, and dopamine ensures healthy mood, alertness, and muscle coordination.

Figure 1
The circadian rhythm

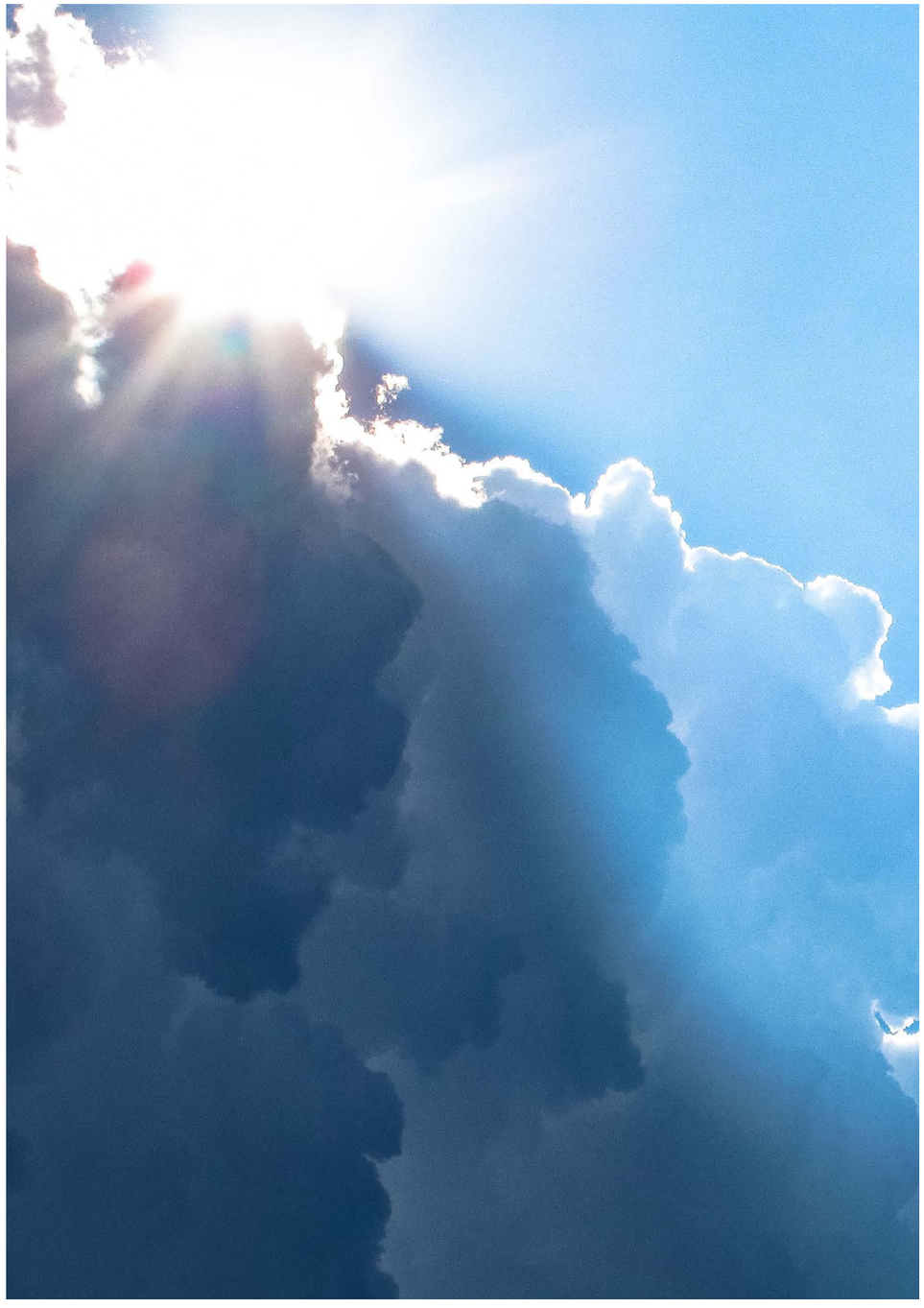


Melatonin, however, is the primary hormone involved in the control of the circadian rhythm by determining energy and activity levels. High levels cause drowsiness and low levels are related to the state of alertness. If there is an insufficient amount of daylight or suitable replacement artificial light during the day, the natural suppression of melatonin does not happen resulting in sleepiness, a lack of concentration and low mood during waking hours.

Red Light Content

Visible red light, at wavelengths ranging from 630 to 700 nm can penetrate tissue to a depth of about 10 mm and is beneficial for treating surface problems such as wounds and scars, as well as stimulating acupuncture points, and can be particularly effective in the treatment of infections.

According to the findings of research conducted by NASA into plant growth in space, deep photon infrared LEDs increase energy within cells, accelerating growth in both plants and aiding in the regeneration of human cells. Infrared light at wavelengths ranging from 800 to 1,000 nm can penetrate tissue to a depth of about 40 mm and is useful for the treatment of internal organs and deep wounds, and can provide relief for bone, joint and deep muscle tissue problems. Although both red and infrared wavelengths penetrate to different depths, they have similar therapeutic properties.



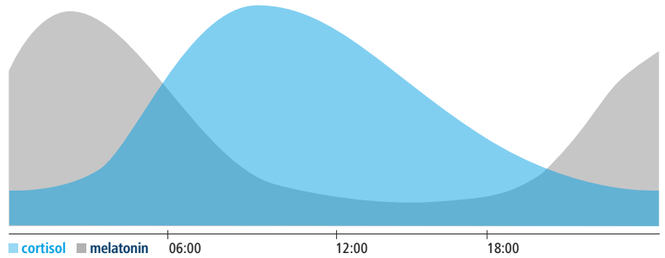


Figure 2
The daytime cortisol and melatonin cycle

NIGHT	DAWN	DAY	DUSK
Have a good sleep at night	**A good start to the morning**	**Have a break and refresh**	**Relax and unwind**
• Lowest light levels	• Cooler increasing light levels	• Warmer decreased light levels	• Warmer decreasing light levels
• Undisturbed sleep	• Increased energy		• Melatonin production starts

Dopamine pathways

Functions
- **reward (motivation)**
- **pleasure, euphoria**
- **motor function (fine tuning)**
- **compulsion**
- **perseveration**

Serotonin pathways

Functions
- **mood**
- **memory processing**
- **sleep**
- **cognition**

Figure 3
Dopamine and serotonin pathways

DAYLIGHT SIMULATION

According to many scientific researches, the daylight is the most typical type of light for people. The effort to adapt the artificial lighting to its properties results from this knowledge. That is the reason why, when designing the light system in the hospital spaces, we utilise the function of daylight simulation. The natural daylight is not monotonous. It changes its properties not only in dependence on the season of the year but it is also dependent on the cloudiness during the day. Its intensity and colour change during the day. All these factors affect our perception of the space and objects inside of it.

The daylight simulation can be achieved by various methods, but the goal is always the same - to achieve such an intensity and light colour that copies the properties of the daylight as truthfully as possible. At the beginning of the working hours higher illuminance with a high proportion of the cold light that will energise to a higher performance is desirable. On the contrary, during the lunchtime it is suitable to increase the colour temperature and to support relaxation. The afternoon decline can be avoided by increasing the proportion of the cold light which is replaced by warmer tones preparing the human organism for the rest time, which would follow at the end of regular working hours to which human bodies are naturally adapted.

The daylight simulation is often implemented with the daylight sensor that assesses the lighting intensity in the room during the day and according to this it increases or reduces the luminaire output in the light system. In this way constant illuminance of the space in compliance with the standard is ensured during the whole day. Daylight can be simulated with luminaires with adaptable lighting intensity and tunable white function, which allows for altering of the correlated colour temperature in the room. This dynamic lighting is provided by the DALI driver which is able to switch on or dim the light source from the value 0 % to 100 %. The function of the tunable white is ensured by two light sources radiating the light with different correlated colour temperature (cool white 6,500K and warm white 3,000 K). Through changing the output of individual light sources we can achieve various levels of the white colour temperature. For example, at a 50 % performance of both light sources the luminaire radiates neutral light with correlated colour temperature 4,000 K. This solution enables creating illumination in the space that corresponds to its task and emotional state we want to evoke in people who are present.

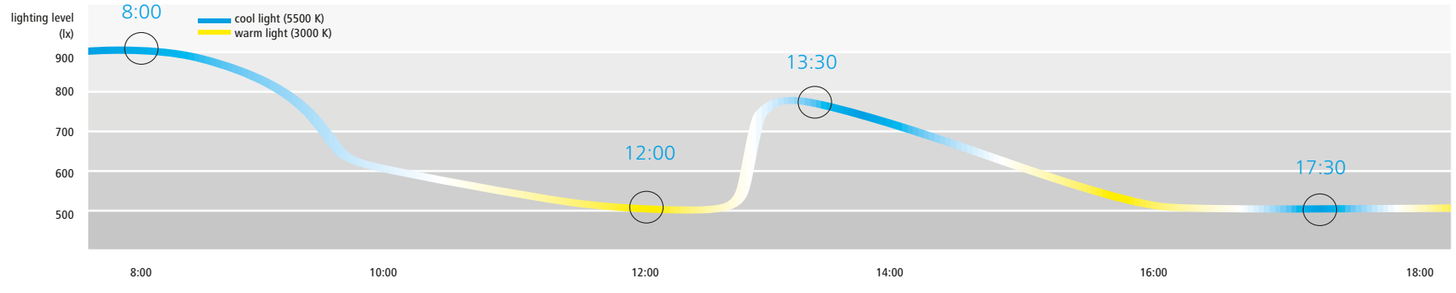
The goal of the daylight simulation is to achieve such a light intensity and colour that copies the properties of the daylight as truthfully as possible.

Good morning
Cool, fresh light raises the energy level of people coming to the hospital and provides a good start to the day.

Lunch time
A short rest helps us to recharge our batteries. The light level decreases and the warm light facilitates relaxation.

Post-lunch dip
After lunch, we usually feel sleepy. The light level rises again and changes to cool white to counter the "post-lunch dip".

Happy hour
Just before the end of what our body identifies as a regular working day, a change to cooler white light provides an alertness boost for afternoon activities. On the other hand, people who stay in the space after this time, can benefit from the pleasant "homely" atmosphere created by the warm white light.



TUNABLE WHITE AND PI-LED TECHNOLOGY

Possibility to select which shoes we want to wear to work or change the height of our office chair is natural. Why should choosing the properties of light in rooms where we spend a considerable amount of time be different? With new technologies and control systems, adapting light to personal preferences is within arm's reach.

With tunable white (TW) technology, not only the intensity, but also the colour temperature of white light can be reset as many times during the day as needed. Be it the cold, activating light, or warm light evoking pleasant and cosy feelings, TW allows the users to be the masters of their lighting. TW technology is integrated in the LMS, running through a DALI bus, and it is controllable via a touch panel or a smart device, be it a smartphone or a tablet. It made it possible for the human centric lighting philosophy to be created and introduced into practice.

It is proven that low light levels cause drowsiness, doctors find it hard to manipulate with instruments and they have to fight with glare, reflection and flickering on daily basis. However, medical staff working in rooms with TW have reported that their ability to see anatomical details has improved, their alertness has increased, their stress level has reduced, and it has many other benefits, such as lesser occurrence of migraines.

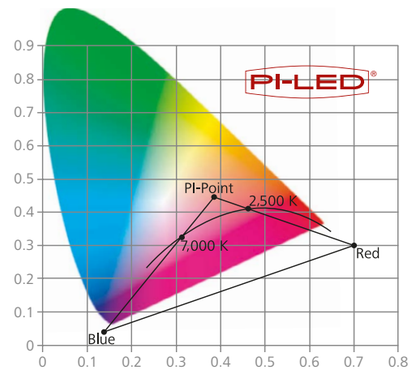
Pi-LED technology is yet another modern buzzword which allows the users adjust the lighting easily and simply. It works on RGBW colour mixing which turns illuminated areas into a realm of the most varied colour tones, creating a special ambience in any space. Adjustable intensity and changeable CCT provides for biological effectiveness that adds the very important health factor to modern lighting solutions. In comparison with TW, luminaires with Pi-LED technology reach higher CRIs and they give the users more freedom to use colours to alter emotions as needed and increase well-being. RGB colour mixing makes the technology perfect for any hospital area, be it a corridor, reception, or the waiting room.

With TW and Pi-LED technologies medical staff can adjust the colour and colour levels of lighting to create different lighting areas. For example, green light emitted from behind the doctor reduces reflection and enhances the depth and contrast on the monitors which are used during each operation, red light from behind the doctors reduces screen glare, white light is useful in areas in which the staff need to find the correct equipment, such as needles, purple behind-screen lighting shows a better picture of X-rays and ultrasound screens, etc. As you can see, this zone-creation is extremely helpful.

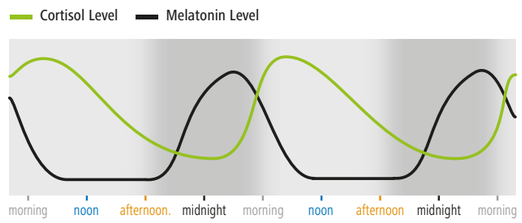
Sunlight spectrum
Cloudy sky, 10 am

PI-LED at 2,700 K
higher intensity in the red area

PI-LED at 6,500 K
higher intensity in the blue area



The circadian rhythm

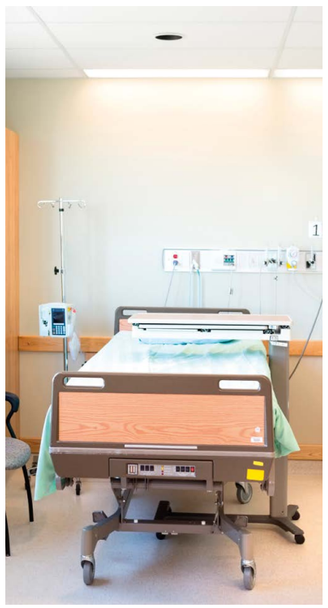


LIGHT FOR EMPLOYEES AND PATIENT WELLBEING

As previously mentioned, the primary hormone involved in the setting and regulation of the circadian rhythm is melatonin. When daylight or appropriate artificial light are absent, the natural suppression of melatonin fails to occur and is accompanied by feelings of depression and sleepiness. For those working night shifts and patients who have little or no access to daylight, it is often the case that their circadian rhythm does not match their actual sleep/wake cycle, resulting in physiological and psychological fatigue, which is detrimental to both work performance as well as recovery times. To overcome this, suitable lighting must be provided for all employees and patients, lighting that can adapt to the needs of particular times and circumstances.

Night shift work is necessary in healthcare facilities because the clock never stops. For those working shifts it is important to ensure high enough illumination levels as brightness acts as an artificial suppressor of sleep-inducing melatonin. A level of 1,000 lx is considered sufficient in this regard based on various studies in which different illumination levels were used during night shifts. Those who worked under the standard 500 lx struggled with fatigue and low mood and made more mistakes, whereas those who worked under high levels were astonishingly alert throughout the shift, felt less fatigued and had a better mood. Measurements of melatonin levels showed that those who worked under higher illumination levels had successfully had their circadian rhythm entrained to the current sleep/wake cycle.

Bright light is not only for staff working night shifts, it is also very useful for those working during the day. Studies show that increased illumination levels are preferred by staff during the performance of critical tasks such as dispensing of medication. It is also the case that fewer prescription dispensing errors were reported under high illumination levels, with a rate of 2.6 % under 1,500 lx compared to 3.8 % under 450 lx.



Depression is a common psychiatric disorder, effecting approximately 20 per cent of people. Seasonal Affective Disorder (SAD) is a sub-type of major depression with a significant number of sufferers. It is often identified by the relationship between the onset and the time of year.

Winter SAD is the most common form, effecting about 5 per cent of the population with 10 to 20 of those having sub-syndrome symptoms, the percentages increasing in a northerly direction. Winter SAD is far more common for women than men, with prevalence increasing with age until about 60 when it decreases drastically. Symptoms include low mood, reduced interest in activity, increased sleep, irritability and increased appetite, especially for carbohydrates, leading to weight gain. These symptoms disappear in summer.

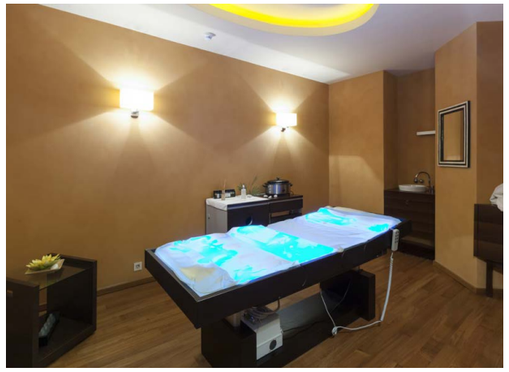
Bright light is an effective treatment for those suffering from SAD, also for those with bipolar disorder. The light intensity usually ranges between 2,500 and 10,000 lx, because it is believed that it suppresses the onset of melatonin secretion. Many studies have been done to assess the effectiveness of bright light therapy in reducing depressive symptoms. In one study, bipolar in-patients in east-facing rooms stayed, on average, 3.67 days less compared to patients in west-facing rooms. Further to this, there is strong evidence suggesting that exposure to bright light in the morning is more beneficial for reducing depressive symptoms.

Many patients spend days, weeks and sometimes months indoors in rooms with limited access to the circadian rhythm regulating cues of daylight. Good lighting can have a positive effect on mood, sleep/wake cycles, rest/activity patterns and recovery times. Studies into this aspect of patient care have had rewarding results, with patients in sunnier rooms recovering statistically faster than those in poorly lit rooms. It is also suggested that exposure to bright light in the morning is more effective than exposure later in the day. It is possible to induce the benefits of daylight exposure using artificial light by providing higher illumination levels and suitable colour temperatures in rooms that do not have access to suitable amounts of daylight. Furthermore, in some cases light is actually used as an out-patient treatment for depressed patients, especially those with Seasonal Affective Disorder (SAD).

THE THERAPEUTIC USES OF LIGHT

Another interesting use of light in healthcare facilities is based on the theory of distraction, where interesting lighting effects are used to divert patient attention during stressful, painful or unpleasant procedures. This is especially useful for children, as their attention can be easily drawn away by bright, colourful, and dynamic lighting.

Light is commonly used for treating various health problems, however, the range of physiological processes which can influence is far wider than we may imagine. Below is a list of just a few of the effects light can have on our bodies.



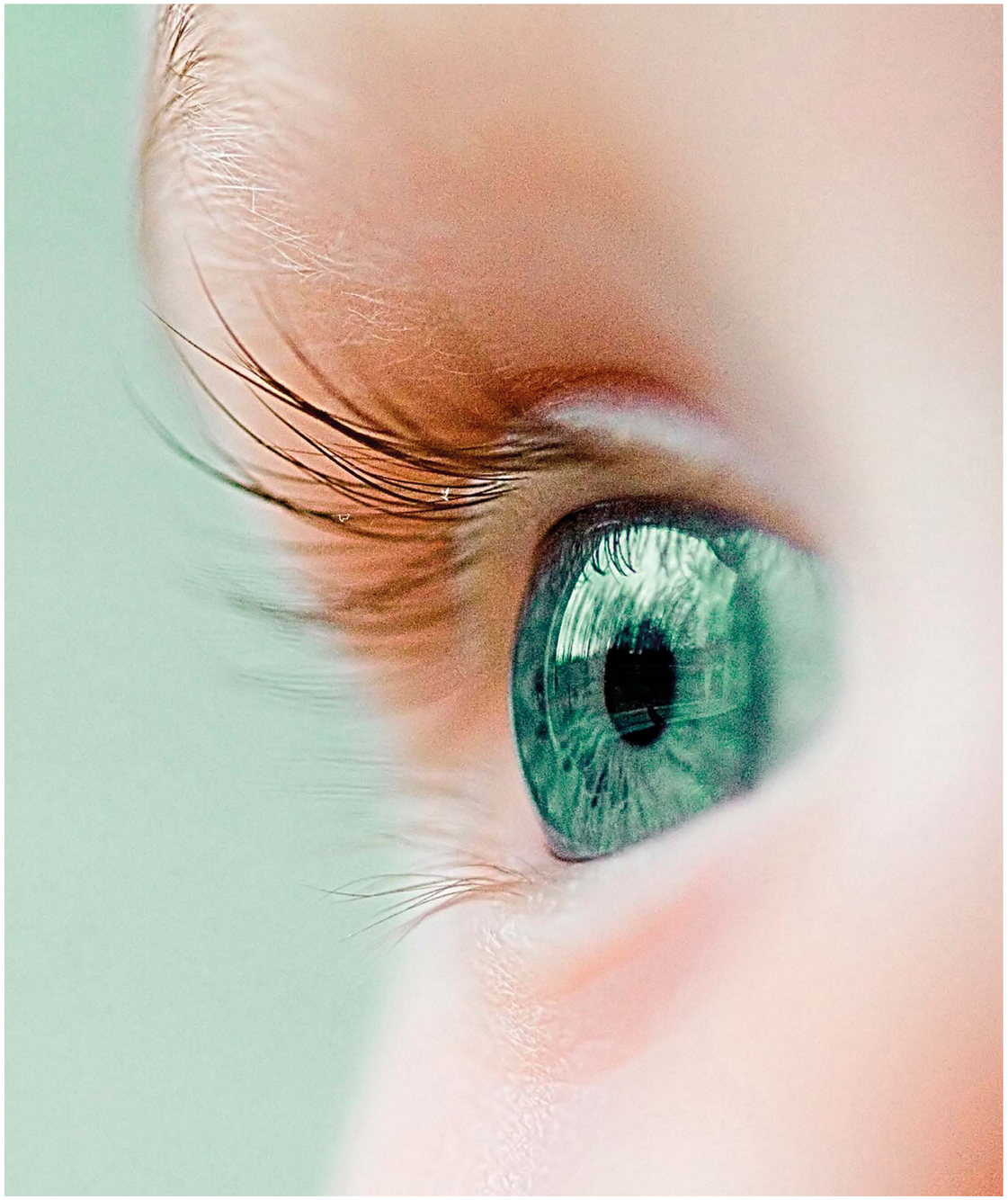
- It increases blood capillary circulation and vascular activity by improving the metabolism of nitric oxide, which in turn provides additional oxygen and nutrients to tissues, accelerating the healing process and causing a cascade of beneficial biochemical processes.
- It reduces scar tissue and stimulates the healing process, including the production of collagen, one of the most important components in the healing of wounds.
- It stimulates fibroblastic activity and tissue granulation, aiding the repair of connective tissues and the formation of collagen fibres, important in the healing of wounds, ulcers, and inflamed tissues.
- It reduces the inflammation and swelling associated with chronic conditions such as arthritis, bursitis, and tendonitis.
- It increases lymphatic system activity and relieves oedema and the discomfort associated with swelling.
- It activates the immune system, especially increasing phagocytosis, the body's natural process of disposing of dead and degenerated cells, and important for infection control and healing.
- It increases RNA/DNA synthesis, which stimulates cellular reproduction and the replacement of damaged cells.
- It stimulates the synthesis of adenosine triphosphate, an immediate energy source for muscle contraction and essential element to cell metabolism.
- It has a relaxing influence on muscle tissue.
- It stimulates nerve transmission and reduces nerve excitability.
- It stimulates acupuncture points and immune response.
- It increases the production of endorphins and encephalin, which can elevate mood and reduce pain responses.
- It stimulates adrenaline production, facilitating long-term pain relief and resilience to stress.

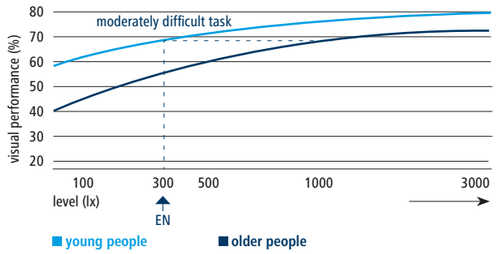
LIGHT IN HEALTHCARE FACILITIES

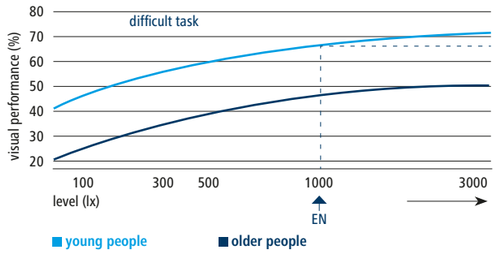
Light's impact on us as we age is not limited to visual acuity, but also involves its ability to aid healthy sleep/wake and rest/activity cycles, improve mood and cognition as well as being able to help those with Alzheimer's and dementia better navigate their world. Good lighting makes life more comfortable, less stressful and safer for the ageing, and its power should not be underestimated.

Visual acuity and safety

Age-related changes to our eyes restrict the amount of useful light able to enter. This makes it important to increase overall illumination levels and contrasts in order to facilitate the same level of visual perception. It is also important that the light be uniform in and between rooms and glare-free as ageing eyes cannot adapt to changes in brightness easily and are more sensitive to both direct and indirect glare, which reduces visual acuity and the perception of detail, especially in combination with insufficient illumination levels. Another factor to take into account is the yellowing of the lens with time, something that can also be compensated for with the light with a cooler colour temperature.







Maintenance and repair of the circadian rhythm

Older people often have problems sleeping and their rest/activity cycles do not match natural daytime routines. This is mainly due to lack of exposure to daylight or suitable artificial light as most spend their time indoors in poorly lit rooms. In order to improve sleep/wake and rest/activity cycles it is appropriate to use a high illumination level of 1,000 lx with a cool colour temperature of 4,000 K or 5,000 K between the hours of 9 am and 6 pm. This mimics some of the natural properties of daylight and in turn stimulates the healthy functioning for the circadian rhythm.

Light and patients with Alzheimer's and dementia

Alzheimer's disease is a degenerative condition affecting the brain, and the most common cause of dementia. Light can have an influence on the behaviour and abilities of those suffering from the disease, both in terms of visual and non-visual functions. Studies have shown that Alzheimer's patients have reduced visual acuity and contrast sensitivity when compared to those of the same age without the disease. This is consistent with reports of both retinal and cortical cell loss in those with the disease. It seems that the reduced visual capability of Alzheimer's sufferers, who are already struggling to make sense of the world around them, intensifies the effects of other cognitive losses, increasing confusion and social isolation. One suggestion is that an increased illumination level and heightened visual stimulation could improve the day-to-day functioning of those with the disease.

Degeneration is also apparent in the suprachiasmatic nucleus of those with Alzheimer's diseases. Such patients are likely to have limited exposure to daylight and its circadian regulating properties. By exposing sufferers to a 24-hour lighting scheme that provides bright high-stimulation artificial light during the day, low-stimulation levels in the evening and a night light that is not disturbing but enough to aid safe orientation, natural visual cues are maintained or even enhanced, helping to reinforce and stabilise healthy sleep-wake and rest-activity cycles. For light to have a high-stimulating effect it must be at a minimum level of 400 lx and with a colour temperature of 6,500 K or higher. Light with a low-stimulating effect must be no more than 100 lx and with a warmer colour temperature. The night light should be max. 5 lx with a warm colour temperature and it should be used in combination with perceptual information such as coloured walls and rails to aid orientation relative to vertical and horizontal surfaces. Such provisions have been shown to improve safety and stability during night activity.

Patients with autism

Another group who have above standard sensitivity to light fluctuation are those with autism. Autism is a neurological disorder that affects a sufferer's ability to communicate and relate to others, and is often characterised by stereotyped behaviour. Symptoms are repetitive activities and movements, resistance to changes in daily routines and surroundings, and unusual responses to sensory experiences. The level of arousal in children with autism is chronically high and it is thought that repetitive behaviours are a way to regulate it. This implies that increased environmental stimulation, such as fluctuations in light level, could cause a higher level of repetitive behaviour. Therefore, care should be taken to avoid lighting controls that change light levels suddenly.

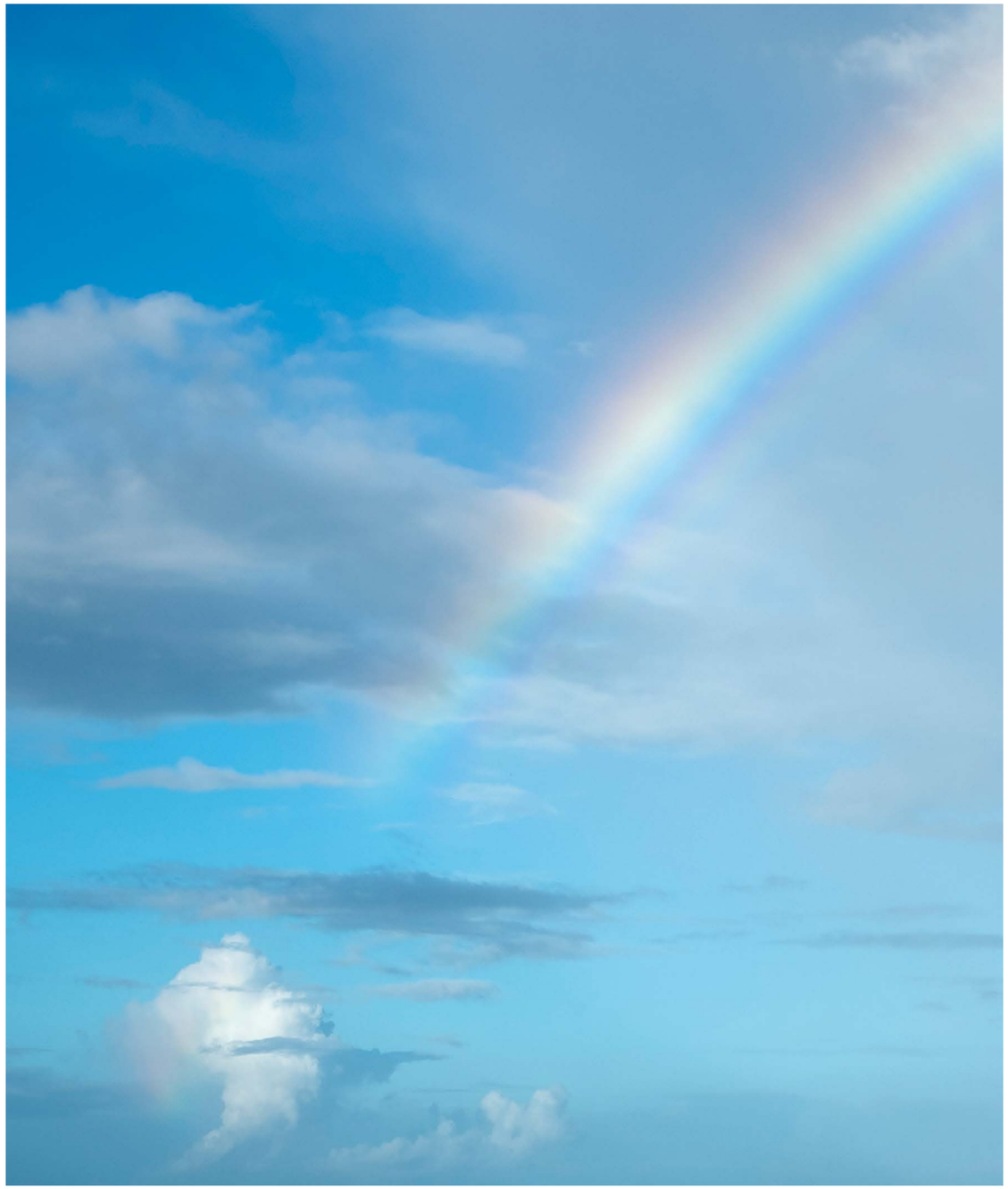
Patients with cancer

There are concerns that night time exposure to light is involved in the incidence and development of breast cancer, which has become increasingly common in industrialised societies over the last 100 years. It has been suggested that this could be in part caused by the suppression of melatonin due to excessive exposure to light during the night. There are two bodies of information supporting this theory. First, a series of studies have been performed into the subject with results supporting the theory. Second, the finding that melatonin-depleted blood increases the growth-rate of cancerous breast tumours. Night time exposure to light has also been tentatively linked to other diseases including diabetes, heart disease, and obesity.

Melatonin suppression happens with exposure to light of 30 lx or more for at least 30 minutes, which is not more than people are exposed to during the night when sleeping including trips to the bathroom. However, the amount of light people are exposed to during night shift work far exceeds the threshold. Therefore, it is vital for those who work night shifts to have fully adapted circadian rhythms, which is not always possible. One solution could be to provide sufficient light for the performance of visual tasks whilst avoiding melatonin suppression. The mechanism by which melatonin is suppressed is particularly sensitive to short wavelength light, especially blue light; by using long wavelength light the mechanism could be partly side-stepped, minimising the negative effects of exposure to light during the night.

PSYCHOLOGICALLY BENEFICIAL LIGHT

The lighting used in a room and the creation of a suitable ambience can change the way we experience and perceive our surroundings. It can calm a stressed mind, help the tired to sleep better and generally improves feelings of wellbeing. Changes to the colour and brightness of light in a room can have an immediate effect on mood, so it is a powerful tool by which we can promote psychological health and balanced behaviours. Below are explained different types of lighting and their effects that will promote the psychological health of older people.



- Daylighting is ideal to enliven and brighten space with vibrant beams of light entering the room. This is natural, stimulating, and lifts the mood.

- Warm lighting strong in red and golden tones creates an inviting, relaxing and cosy ambience and is ideal for calming, and preparing people for sleep.

- Neutral lighting feels natural and comfortable and is balancing, it also has the correct spectrum to supplement daylighting. It is ideal for use in the middle of the day or when you want to focus attention.

- Dynamic lighting that incorporates changes in illumination level and light colour is especially beneficial when provided with a wide direct and indirect distribution, and can be used to stimulate the human body. This is useful at any time of the day and is highly adaptable, be it to entertain, stimulate, calm, or sooth.

ECOLOGY

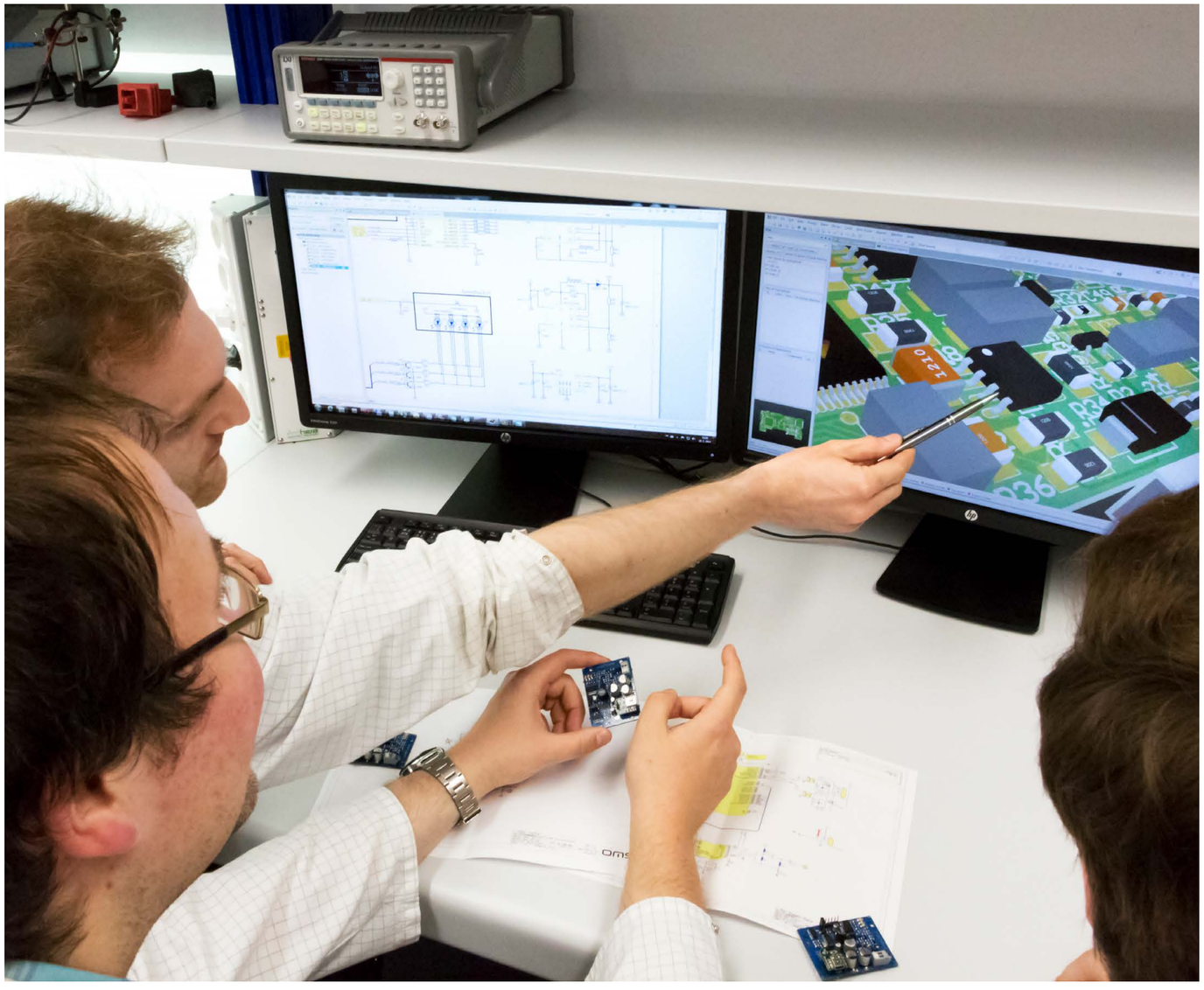
ECO
FRIENDLY

The ecology and ecological solutions respecting the fragile equilibrium of the environment are important topics which have become key values across the whole industrial spectrum during the last decades. The manufacturers of the luminaires and light sources are no exception in this area.

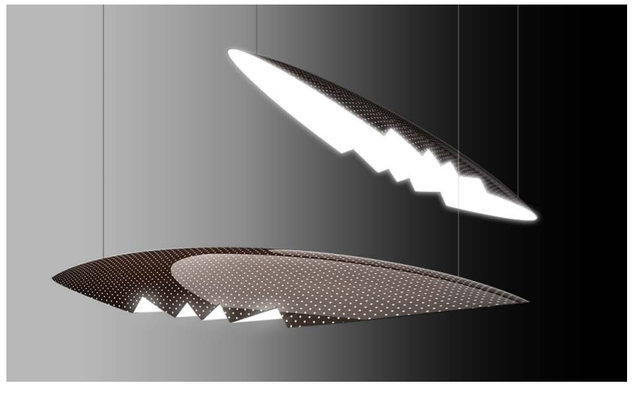
Also in this line of business the demands on efficient utilisation of energy, the recyclability, and long life of the products constantly rise. Achieving effectiveness in luminaire and light source manufacturing, we need to keep an eye also on their impact on the environment. These are categories which, besides the ecological approach, contain a substantial potential for energy savings and in this way also reducing the operating costs. Another important number we are constantly trying to reduce is production of CO^2. For the developers and architects of the hospital buildings just this factor is the source of the strongest motivation when designing the light systems.

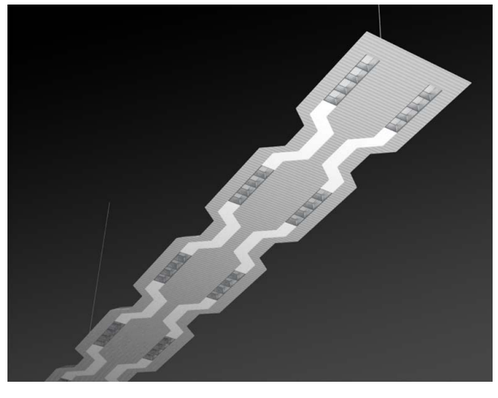
THE LATEST LAMP TECHNOLOGY

The times when the whole world applauded Thomas Alva Edison for the discovery of the light bulb are irrecoverably over. Although he made his mark on history forever as the inventor of artificial light, other scientists and inventors came after him and they shifted and are still shifting the development by leaps and bounds ahead.



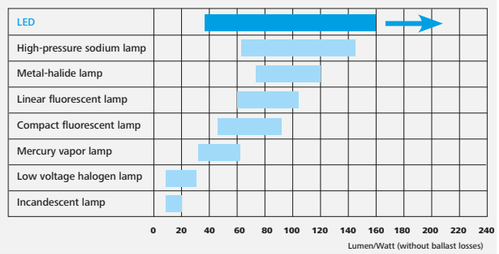
With the knowledge about the limitedness of the energy sources which causes permanent increase of their prices, the trend taking into account the ratio of effectiveness of the luminaire or the light source and the consumed energy is coming to the foreground. As late as a few years ago, the metal-halide lamps especially met these requirements but even they are retreating in favour of the light emitting diodes - LED. Compared to the conventional sources the LEDs achieve better parameters in each respect: they are more effective, they emit a negligible amount of heat, they place lower demands on the consumption of electrical energy, they do not contain mercury and so they are more ecological. In the area of manufacturing the light sources, just LEDs represent a category which currently progresses most quickly. Up to 90 % of all innovations today take place in the category of the LED light sources. Of course, the development and production of the conventional light sources has not been stopped but they progress more slowly. However, also here it is valid that the trend heads especially to manufacturing more effective and economical types of the existing light sources. The original types are replaced by the eco and long-life fluorescent lamps or metal-halide lamps with ceramic burner of the second generation, etc.

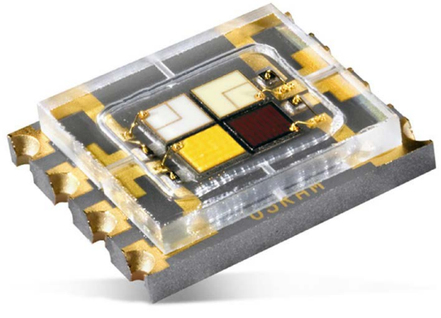




The main indicator for selecting an optimal light source, which a designer of the light system in hospitals has to follow, is the efficacy of the light source. Its value shows with what effectiveness electric power is changed into light, i.e. how much of luminous flux (lm) is produced from input power (W) delivered to the light source. The unit is lumen per watt (lm/W). The LED light sources achieve the best parameters also in this category. Currently the LED chips with efficiency of 160 lm/W at cool white CCT are commercially available; however, in the lab conditions the value of 254 lm/W has already been achieved.
The higher price of LED luminaires is the reason why they have not replaced lighting fixtures with conventional light sources in spite of the fact that they offer so many benefits. But also this factor is to be viewed in a wider context. Although the initial costs for purchasing of LED luminaires will always be higher, the return on investment in the form of energy savings during the whole luminaire lifetime and practically no maintenance costs make the LED luminaires extraordinarily commercially interesting. From this point of view the retrofits where we only change the conventional light source for a more modern type prove to be only temporary and from a long-term point of view it is also a loss-making solution.

EFFICACY OF LIGHT SOURCE





SYSTEM EFFICACY OF LUMINAIRE

The luminaire efficiency factor determines how effectively the lighting fixture itself is able to direct the light from the light sources with the smallest possible losses on the surfaces of the optical system. The light output ratio (LOR) expresses the ratio of the luminous flux flowing from the luminaire and the sum of the luminous fluxes of all light sources in the system.

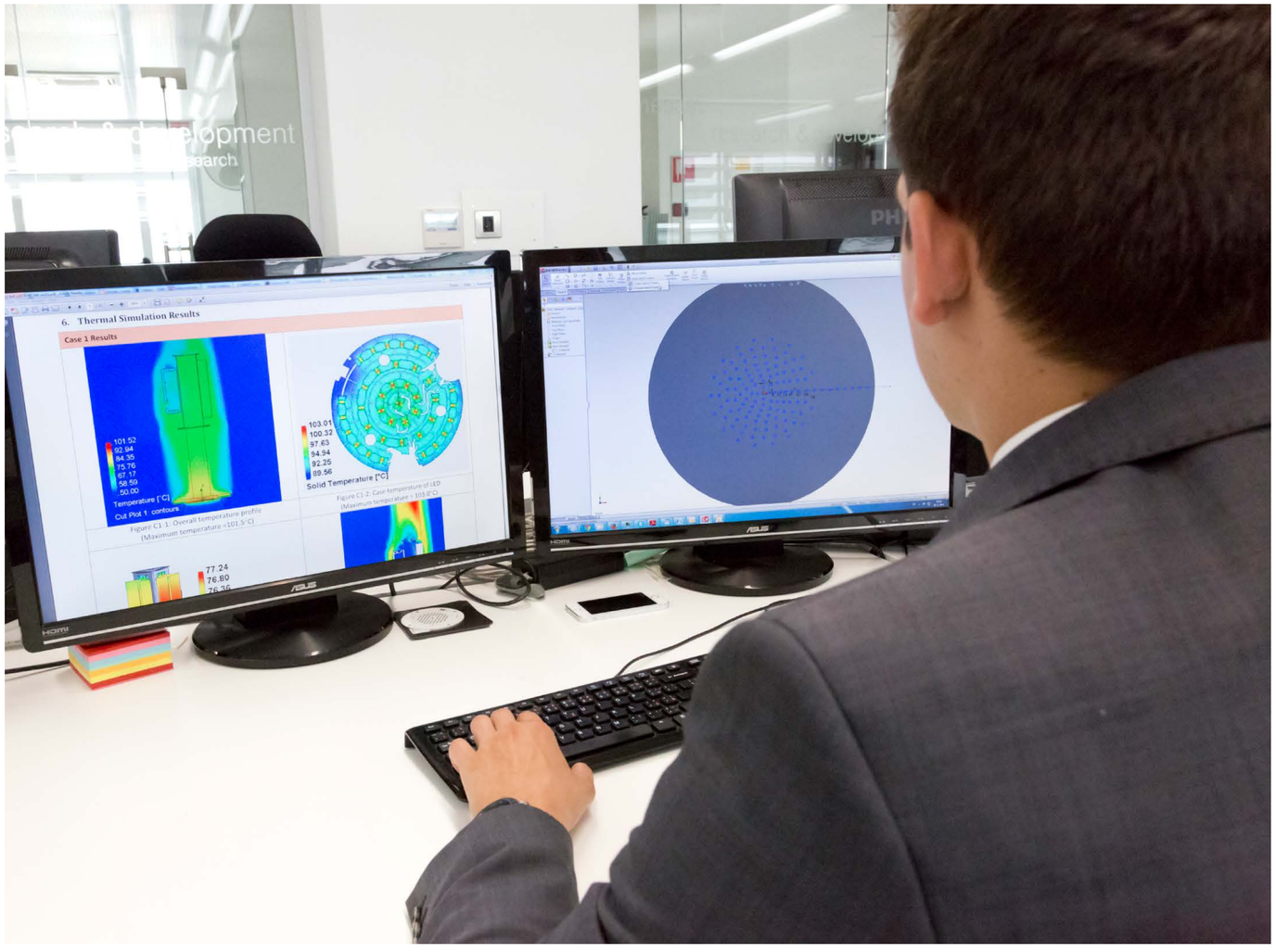
$$LOR = \frac{\text{Lumen output of luminaire}}{\text{Lumen output of lamp}} \%$$

This value can be divided into the upward and downward ratio that expresses how many percent of the luminous flux from the luminaires heads to the upward and downward space (i.e. over and under the luminaire). This is of special importance for those spaces which place high demands on the illumination of the ceiling.

The materials used for luminaire production have the biggest influence on its efficiency. The optical materials enable changing the distribution of the luminous flux of sources, diffusing the light or changing the spectral composition. They are divided into reflective and transparent ones. Using various surface finishes, aluminium is the one that creates the predominant part of the reflective materials. The most often used transparent materials are glass and plastics. Aluminium, glass, plastics, and steel have all different reflectance and capability to absorb light. However, in general, it is valid that the more effective the materials used in the optical system are, the lower the losses on these surfaces and the higher the luminaire efficiency.

$$\text{System efficacy of luminaire} = \frac{\text{Lumen output of luminaire}}{\text{Installed power of luminaire}} \left[\frac{\text{lm}}{\text{W}}\right]$$

Besides the used material themselves the luminaire efficacy is also affected by the design or the shape of the optical system. A correctly designed luminaire reflects the largest amount of light to the surroundings at minimal losses. The optimal mathematical and physical geometrical shapes of the lighting fixture can be calculated by modern computer software.



THERMAL OUTPUT OF LAMP

The light spectrum visible for the human eyes is between the ultraviolet (UV) and infrared (IR) spectrum. In spite of the fact that the human eye is not able to catch the infrared light, it perceives it as radiant heat. Every object that is exposed to such radiation is constantly strained. The lower the value of the radiated IR is, the more effective the light source is. From this point of view, on the bottom of the scale as the least efficient, there are the usual incandescent lamps which change up to 95 % of energy into heat and only remaining 5 % into visible light.

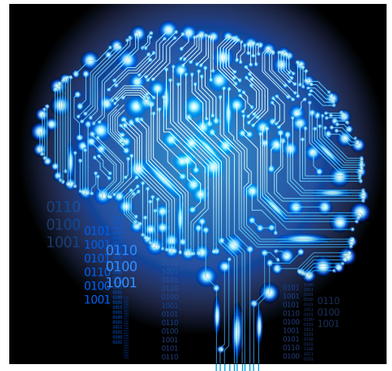
On the hospital premises, especially in spaces with air-conditioning, the light sources with a high IR radiation percentage are a sufficiently big load for the electric power consumption. The heat from the non-effective sources heats the air continually in the closed space cooled by the air-conditioning - this fact is connected with the need for a higher performance of the air conditioning. For 2.5 W of the luminaire energy, we need approximately 1 W of the air-conditioning energy, i.e. if the energy consumption of the lighting system increases, the energy consumption for the air-conditioning operation grows in direct proportion, too. The user of the hospital spaces illuminated by outdated light sources is burdened by increased costs not only for the energy needed for the operation of the light system but also for the air-conditioning.

From this point of view the installation of luminaires with light sources creating the minimal percentage of the IR radiation is considered the most economical. These requirements are currently reliably fulfillled by the latest LED light sources that radiate only a negligible amount of the IR radiation.

EFFICIENCY

Nowadays, modern technologies allow us to equip lighting with a control system. The automatic control saves time, it enables selecting the adjusted lighting scenes by simple control through buttons and at the same time it creates potential for energy savings up to 80 %.

To change the lighting intensity and the light colour in the room in order to create varied atmospheres or emotions can be achieved by a simple control of the button or a touch on the smart-phone display. Today, the technological progress enables the managers of the hospital buildings to take benefits of the quality illumination of the space and at the same time to save time, energy, and costs for maintenance. Thanks to the intelligent forms of the lighting management system the operation of an hospital building can be more effective today than any time before.



LIGHTING
MANAGEMENT
SYSTEM

DAYLIGHT SENSOR

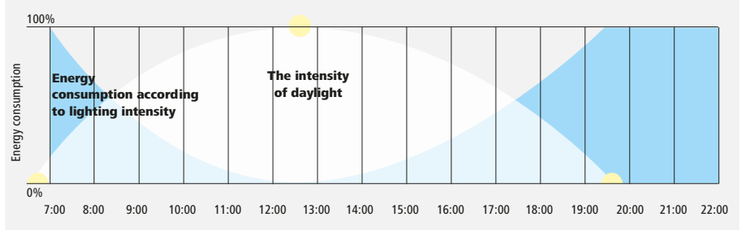
The daylight has a decisive importance on the health and psychological well-being of people. Its shortage affects not only the quality of vision but also the performance efficiency and the ability to concentrate and can even disrupt the circadian rhythm.

Environment which will be able to imitate the properties of daylight as truthfully as possible is extremely important. Although the majority of rooms have minimally one wall with windows, the availability of the daylight is never that optimal to be able to do without a high quality lighting system. The light conditions change during the day in dependence of the time of the day, weather and the season of the year. The task of the artificial lighting is to balance the differences and to complete or to replace in full extent the natural light when its availability is limited.

The core of the system is the luminance sensor which reads the light conditions on the scanning level. The advantage is that the daylight and the artificial light complete each other, i.e. when the day lighting decreases, the artificial one increases and vice versa. This property ensures that in the given space there is always as much light as we really need. Such a regulation method can be carried out continuously or in steps and the luminaires dim down to the value of 0 %. In the case of larger spaces several sensors are used. They assess the mutual resulting values by averaging.
The control of the luminaires is carried out on the basis of the lighting intensity fully automatically and besides the energy savings also the user comfort is improved. Its efficiency is higher the more daylight falls to the given space. When installing the daylight sensors it is necessary to pay attention to the fact that the scanned zones must not overlap. Similarly it is unsuitable to place them in the reflection zone and the radiation sources which negatively affect the scanning process. An ideal case is to position the scanner over the task area which places the highest demands on the constant lighting.

The light conditions change during the day in dependence of the time on the day, weather and the season of the year. The task of the artificial lighting is to balance the differences and to complete or to replace in full extent the natural light when its availability is limited.

The energy consumption of the lighting system in dependence on the daylight availability achieves the maximum values early in the morning and during evening hours.

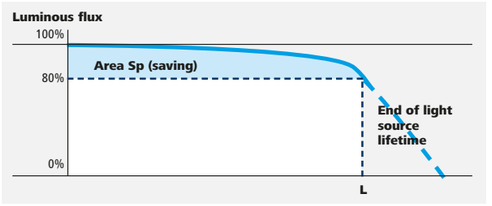


CONSTANT ILLUMINANCE SENSOR

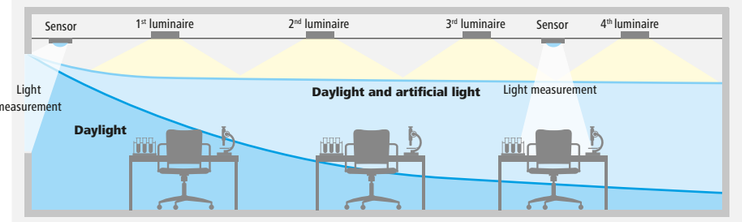
The task of this sensor in the hospital spaces is to ensure constant illuminance independently of the state of the luminaires in the lighting system. The essence of this type of control results from the fact that the light qualities of the luminaires deteriorate during their installed lifetime, the optical parts are polluted or some lighting fixtures in the lighting system fail.

The constant illuminance sensor behaves in the space as the sensor of the light intensity and so it artificially adapts (decreases or increases) the luminaire luminous flux. For the sensor to be able to fulfilll its function it is necessary to count on its installation already during the design phase of the lighting system which has to be over-dimensioned from the very beginning of the design. The economy of this solution can look contradictory at first sight. However, the reality is that it really occurs because during the first years of operation of the over-dimensioned lighting system the individual light sources do not run at full power. The system is adjusted to 100 % performance only when it starts to show signs of wear. In this way the constant lighting intensity of the whole scanned space is guaranteed.

From the point of view of the economy improvement, it is suitable to combine the constant illuminance sensor with the daylight sensor. In this combination, both types of sensors are able to fully utilise the potential of the natural light falling to the space through the windows and to adapt the intensity of the artificial light to this situation. Combining several types of the lighting management system enables to make use of the natural light potential in full extent in the hospital spaces and to adapt the performance efficiency of the lighting system to it - this will prolong the lifetime and maximises the energy savings.



Every lighting system is over-dimensioned, minimally by 20 %. At the end of the lifetime it still achieves the required illuminance intensity. Using the constant illuminance sensor we can achieve 20 % energy savings during the first years of the lifetime.



When installing the sensors it is important to pay attention so that the scanned zones do not overlap and are placed in sufficient distance from radiation sources, which negatively affects their detection ability.

PRESENCE DETECTOR

In the framework of the hospital building there are spaces that do not require constant lighting. They are rooms, communication zones or underground parking lots without permanent occurrence of people and from the point of view of energy saving they represent a big potential.

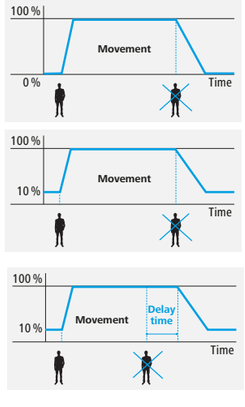
The presence detector represents a suitable type of control of these spaces. Its usage allows the luminaires to be switched on only when somebody appears in the space, i.e. only when the lighting is really needed. It is automatically controlled via sensor responding to the heat of the moving persons in the detection area. Scanning the space is ensured by passive infrared technology with built-in infrared scanners in the sensor which respond to the heat radiation emitted by the human body and transform them to an electrical signal. This sensor subsequently assesses the situation and switches on the illumination. The scanner itself does not emit any radiation and therefore we can speak about passive infrared sensors (PIR).

The presence detector switches on the luminaires in the selected spaces when somebody occurs there and thus when the illumination is really necessary.

The presence detector can be used both in the indoor and outdoor applications with different sensitivity and mounting height. For an ideal coverage of the space, it is suitable for the sensors to be placed in positions where their scanning areas partially overlap. It is important to avoid installing the sensors close to street lamps, air-conditioning or heating units and other sources of intensive infrared radiation which could affect their functionality. When installed properly, the sensor responds immediately after somebody enters the scanned zone.

When using control based on movement we can utilise the function of delay of dim down which means that the luminous flux of the luminaire does not change immediately after the movement detection dies down, but after passing the adjusted time without movement. This time is determined according to the type of the space and the frequency of the movement. The dim down can be transferred either to a certain level (e.g. 10 %) of the luminaire luminous flux or the process of dim down up to the value of 0 %. The level of the luminous flux amounting 10 % is used especially for safety reasons so that there is not full darkness even in case no movement is detected. It results in a better picture shown on security cameras and prolonging the lifetime of the light sources.

Sophisticated systems enable to adjust the presence detector in such a way that it will switch on the luminaires in that part of the room where the presence of people requires it.

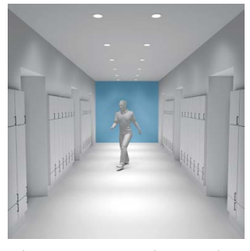


The movement sensor can be an independent action element (which controls the light system) or serves only as an input element that delivers information for assessment to the higher control unit or system.

Comprehensive lighting management system of a whole building

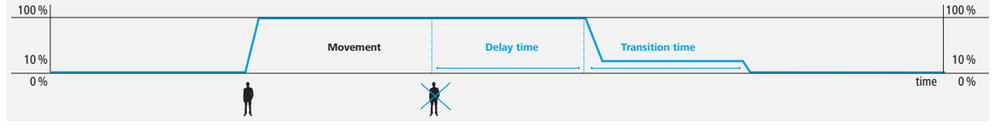
As a comprehensive lighting management system for a whole building must control many luminaires and peripheral devices and operations, it is necessary to incorporate several systems, because DALI and DMX have limited capacity. Their joining together can be achieved by standard LAN (Ethernet) connection without limiting sensor integration or control optionality. One big advantage is that it is possible to create a single control location or several with the same functionality, meaning that the user or building administrator can have an overview of the whole building, not only from a particular location, but even remotely through the internet from anywhere in the world. Combining several control methods such as analog, digital, and switch phase allows the control of several separate systems within one interface. The system also allows local control in individual rooms or areas. Peripheral devices can be controlled, too, through a device such as a smartphone or tablet. It is necessary to programme the system functionality before its launch. Such a comprehensive system offers the highest level of saving potential due to its intelligent, specific and all-encompassing control.

If there is nobody in the space, the presence detector switches off the lighting.



When someone enters the room, the presence detector responds to the infrared radiation the human body emits and switches on the lighting.

The presence detector can be adjusted in such a way that the lighting in an abandoned space will not switch off immediately after departure of the last person but gradually.



LIGHT IN THE HOSPITAL

WAITING AREAS

INTENSIVE CARE UNITS

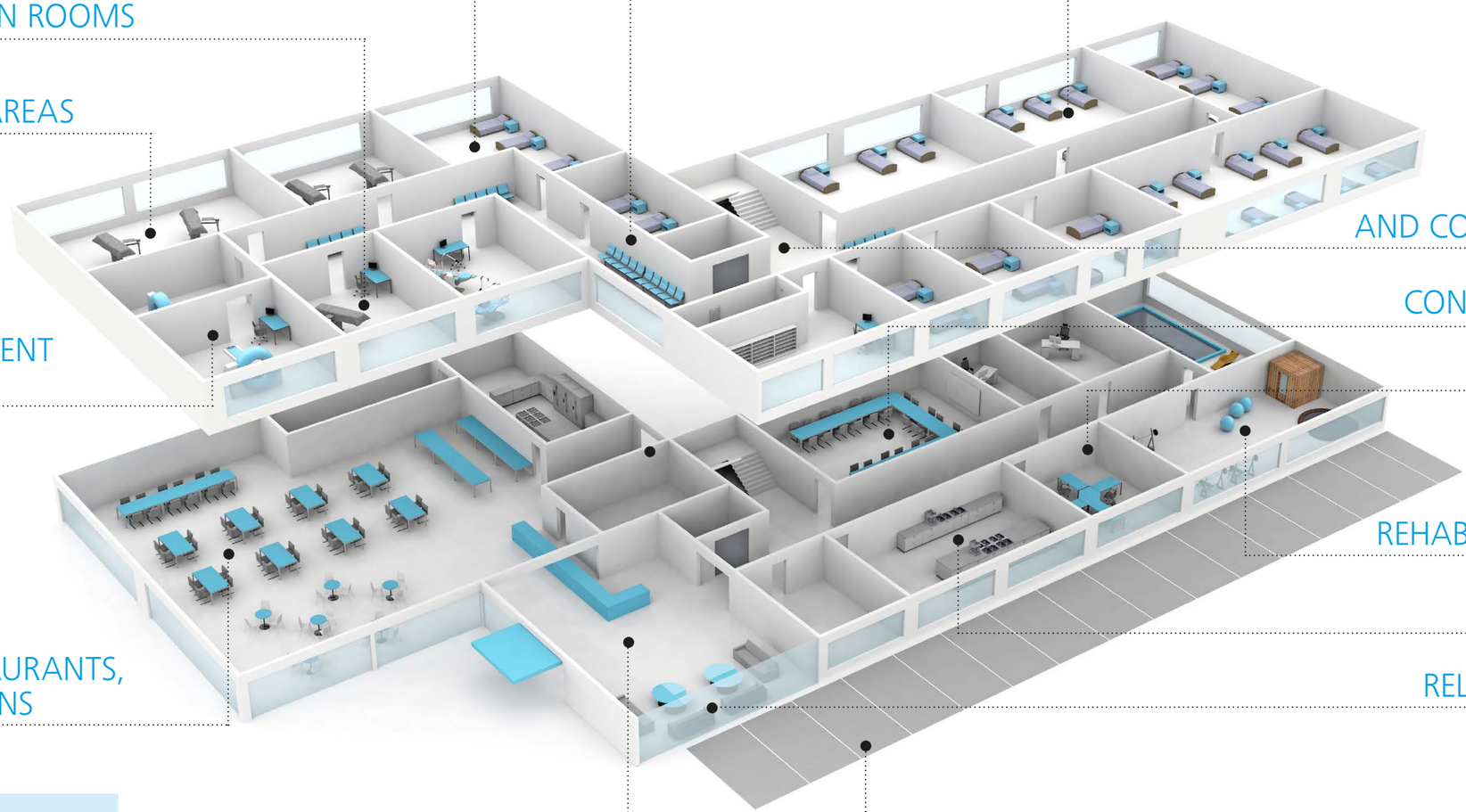
EXAMINATION ROOMS

OPERATING AREAS

SURGERY
AND TREATMENT
ROOMS

CAFÉS, RESTAURANTS,
AND CANTEENS

ENTRANCE AREA,
RECEPTION, AND FOYER



WARDS AND
PATIENT ROOMS

CORRIDORS
AND COMMUNICATIONS

CONFERENCE ROOMS

OFFICES

REHABILITATION AREAS

LABORATORIES

RELAXATION ZONES

EXTERIOR ILLUMINATION
AND PARKING AREAS

ENTRANCE AREA, RECEPTION, AND FOYER

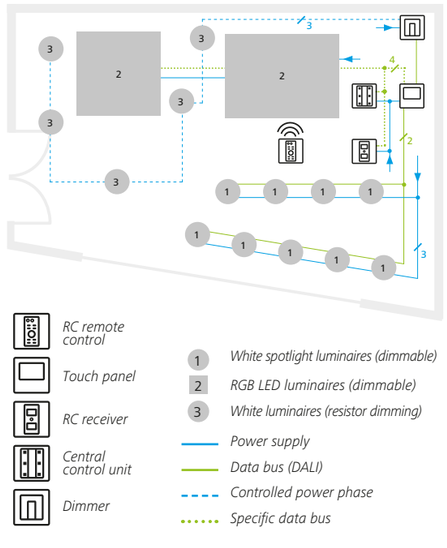
The entrance space is an advert for any building. It is the place of first contact based on which we create an impression about the character of space.

The basic level of illumination determined for these types of spaces by the technical standards is not by far the only criterion that is to be taken into account when planning the illumination today. The emphasis is placed not only on the functionality but also the representative character and creativity of the lighting solution.

The correctly chosen vertical and horizontal lighting of the entrance spaces increases the visibility and makes orientation in the space easier.

The space of the hospital reception can be illuminated by recessed luminaires and from the design point of view, it is nice and practical to have suspended luminaires installed above the reception desk. Moreover, suspended luminaires provide visually effective direct-indirect lighting. Alternatively, any other luminaire providing sufficient illumination for work with a computer can replace the suspended luminaires. The ambient light of the reception desk by the LED modules in combination with a transparent material contributes to increasing the space attractiveness and creates a positive communication atmosphere.

For the main lighting of the reception area we can use recessed luminaires with a direct characteristics of luminous flux distribution and luminaires with a narrow beam angle (spotlights). The accent lighting or luminaires with an asymmetric radiation curve can be used for the illuminance of the logo. When designing the lighting system for the entrance spaces and receptions, we not only emphasise the requirements of the standard but also the representative character and creativity of the light solution.



This type of the reception, with a permanent duty, places specific demands on the illumination. From the point of view of selecting a correct type of the luminaire which copies the needs of the hospital and the workplace. For example, the ambient and wall luminaires or luminaires with a narrow beam angle of radiation are able to create interesting light effects in the entrance space and to contribute to its flexibility.

The recessed floor LED luminaires help people to orient themselves in the space, they copy the communication paths, and make the entrances and doors to other communication zones visible.

By building-in the intelligent lighting management system we can correct the intensity and diversity of the lighting scenes in the reception area, to adapt various time intervals to needs and achieve in this way not only an effective illumination in this part of the hospital space but also the optimal energy consumption.

LMS for receptions

Receptions offer a huge potential for the use of atmospheric ambient lighting. For the lighting to be effective is it necessary to use intelligent controls which allow the lighting to be changed according to the needs and desires of the user. Trends in commercial lighting have become more apparent as the relationship between architecture and light has moved from a functional partnership to one where light plays a vital role in the appearance of a space and is viewed as a central element of any design. RGB control systems can be integrated into superior management systems that can also control, for example, air conditioning and multi-media devices. The whole system is controlled by touching the buttons on a built-in touch panel or remote control. Communication between the touch panel and RGB luminaires is done via a specific data bus. This type of lighting system is not focused on energy saving but on the comfortable control of a dynamic system which affects the emotions.

WAITING AREAS

The lighting system in waiting rooms has to be adapted to the layout of the space. In general, it is valid that the illumination in an open space should be uniformly distributed without any places with a distinct light exposure or shadow.

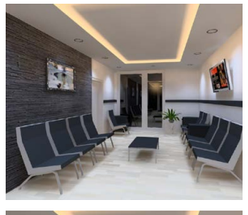
Waiting rooms are not a place people would enjoy to spend time at. Many times, they spend there several hours in a row without much activities to do and with no distraction. Subsequently, they get nervous, anxious, annoyed, occasionally even irritated and bad-tempered. Paired with the threat of an illness, these are very stressful situations for human organism. Selecting the correct luminaires and light sources can help to reduce the tension.

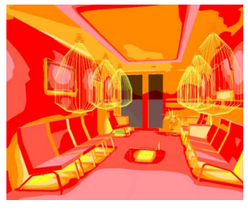
Even though the open disposition of waiting rooms in hospitals seems to offer a lot of space for distribution of furniture and possibility to apply creativity when designing the layout of the space, the opposite is the truth. Paradoxically, there is usually only a limited number of ways how chairs could be organised so that there is enough space for patients waiting to all examination rooms and clear entrance for a nursing bed or a wheelchair to all of them.

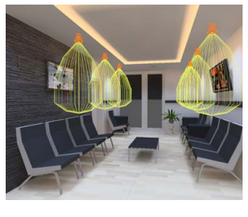
Atmosphere in the waiting rooms can be boosted by costant visual conditions, luminaires with correctly selected correlated colour temperature and Pi-LED technology. As a minimum favour for the patients, we recommend to use neutral white light with correlated colour temperature of 3,000 K or a possibility to change it up to 4,000 K, which creates a warmer and more welcoming ambiance, and pay appropriate attention to vertical illumination of surfaces by wall-washers, which fulfilll their task when people orient themselves in the space. Vertical illumination enlarges the space, people feel better, more relaxed and safer. Additionally, opportunities offered by the new Pi-LED technology would come in handy. Not only will it distract the thoughts of the patients, but their mood will improve and their feelings will subconsciously shift towards more positive ones.

If the waiting rooms have windows, especially directed southwards, they will be exposed to the permanent influence of the daylight. Therefore, to bring efficiency to lighting management, the daylight sensors would be a good energy saving idea. Optimal combination of daylight and artificial lighting can achieve savings up to 70 %. Another solution for waiting rooms without permanent use would be a presence detector. It would scan the space and automatically turn the lighting on or off depending on whether the space is occupied or not. Both sensors and the lighting can be part of the building management system, which is an integrated management system of all electric installations in the building enabling the hospital management to remote control the lighting system, shutters and blinds, security cameras, alarm, heating, and all the other systems within the infrastructure.

The lighting system has to be adaptable to the structure of the space. Increased demands are placed on the lighting uniformity that should prevent eye tiredness and increase overall visual comfort.







OPERATING AREAS AND SURGERY ROOMS

Physically and mentally most demanding tasks are performed in operating theatres so reliability and functionality in all respects, lighting included, have top priority.

Light output of the luminaires used in these areas needs to be spectacular, optics need to distract reflections and meet rather strict standards, such as IP 65. As the staff spend hours and hours by hard work which requires a lot of concentration, lighting can never fail them. All luminaires have a back-up power supply in case of an unexpected electricity cut.

The operating field is the brightest zone with illuminance from 40,000 to 160,000 lux. Surrounding areas need to be bright enough not to tire the eyes and/or cause fatigue. Immediate vicinity of the operating table should have at least 2,000 lux, but lighting in the rest of the room should not go below 1,000 lux.

Colour rendering index 90 or higher is a must as the doctors need to distinguish between different types of tissue. In the room, there cannot be glare, shadows, nor reflections.

Operating areas are also the cleanest rooms which meet the strictest hygienic requirements. Doctors and medical staff follow extremely demanding requirements on their visual appearance in order to enter the operating theatres. Luminaires used in the area need to be perfectly cleanable and maintainable, too.

What we see as an added value in some spaces is an absolutely basic requirement in others. In surgery and other treatment rooms, flexibility is a great example. These rooms could not work without easily customisable lighting. Intensity of general lighting needs to be adjustable and complemented by special fixtures in order to carry out special examinations.

As the examination rooms, surgery and treatment rooms function also as an office, basic requirements for office lighting cannot be disregarded. It means that all luminaires need to have UGR below 19, flickering and shadows are not allowed, sufficient CRI and adjustable CCT are welcome.

It is also important that the luminaires are resistant against chemicals because the rooms need to stay clean and free from bacteria.

Other areas with extremely high demands on quality lighting

In a hospital, there are many areas that require extremely high quality lighting. Autopsy rooms and mortuaries are just two examples. In these rooms, doctors need to identify the tiniest details which can play an important role, so perfect lighting is a must. Another example is a laboratory in which medical staff detects the correct colour and content of the most varied samples which might end up in the test tubes. Depending on the specific space, we always choose the right lighting solution.

INTENSIVE CARE UNITS

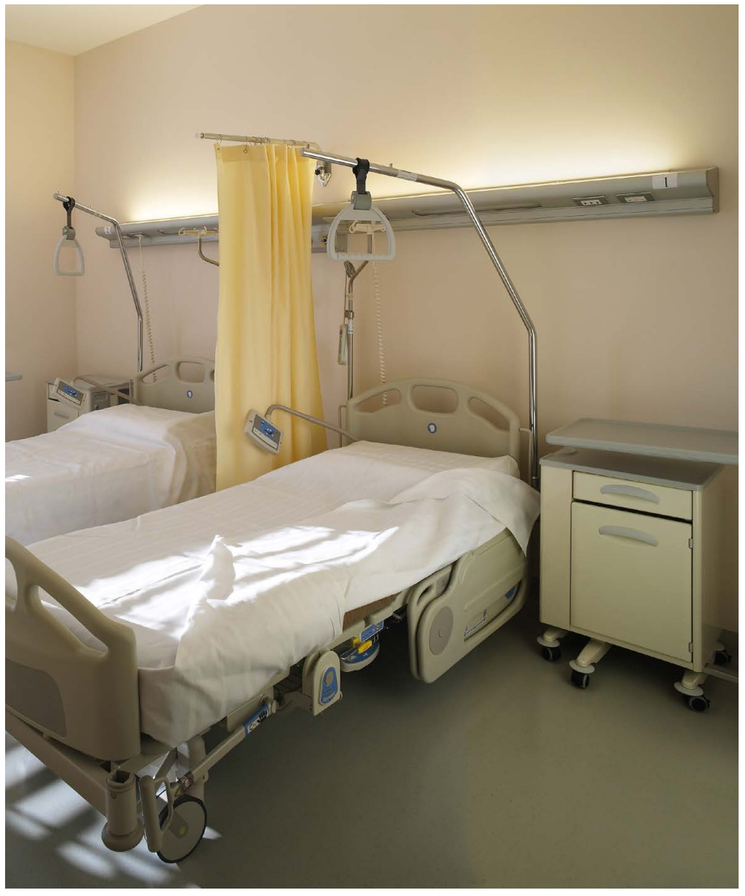
ICUs must be equipped with highly developed medical devices. The healthcare staff makes a good use of lighting as it allows them to set up, check, and monitor all the devices, give the patients a due care, and, on the other side, it gives them the opportunity to adapt to the needs of the patients - lighting cannot disturb patients while sleeping so its adjustability is extremely important.

General lighting needs to be set to minimum 100 lux illuminance. Lighting in the immediate proximity of the patient plays a more important role. It needs to reach at least 1,000 lux and colour rendering index 90. Usually, lighting is connected with the complex system of functionalities such as supply of electricity, vacuum and medical gas and all the medical devices and machines which monitor and support the health functions of the patient. The whole system needs to have a back-up power supply all the time.

WARDS AND PATIENT ROOMS

As for many patients, hospitals become temporarily their new home, their rooms should be equipped accordingly. Appropriate lighting in patient rooms facilitates nursing, simplifies the examinations, and quickens the wound-healing and recovery process.

There are many tips for lighting of patient bedrooms. As we mentioned before, human centric lighting, which follows natural rhythm of the human body via tunable white technology, or ambient lighting, which is achieved via wall washers with Pi-LED technology based on RGBW colour mixing, can add to the overall atmosphere of the room and accelerate regeneration of the patients.

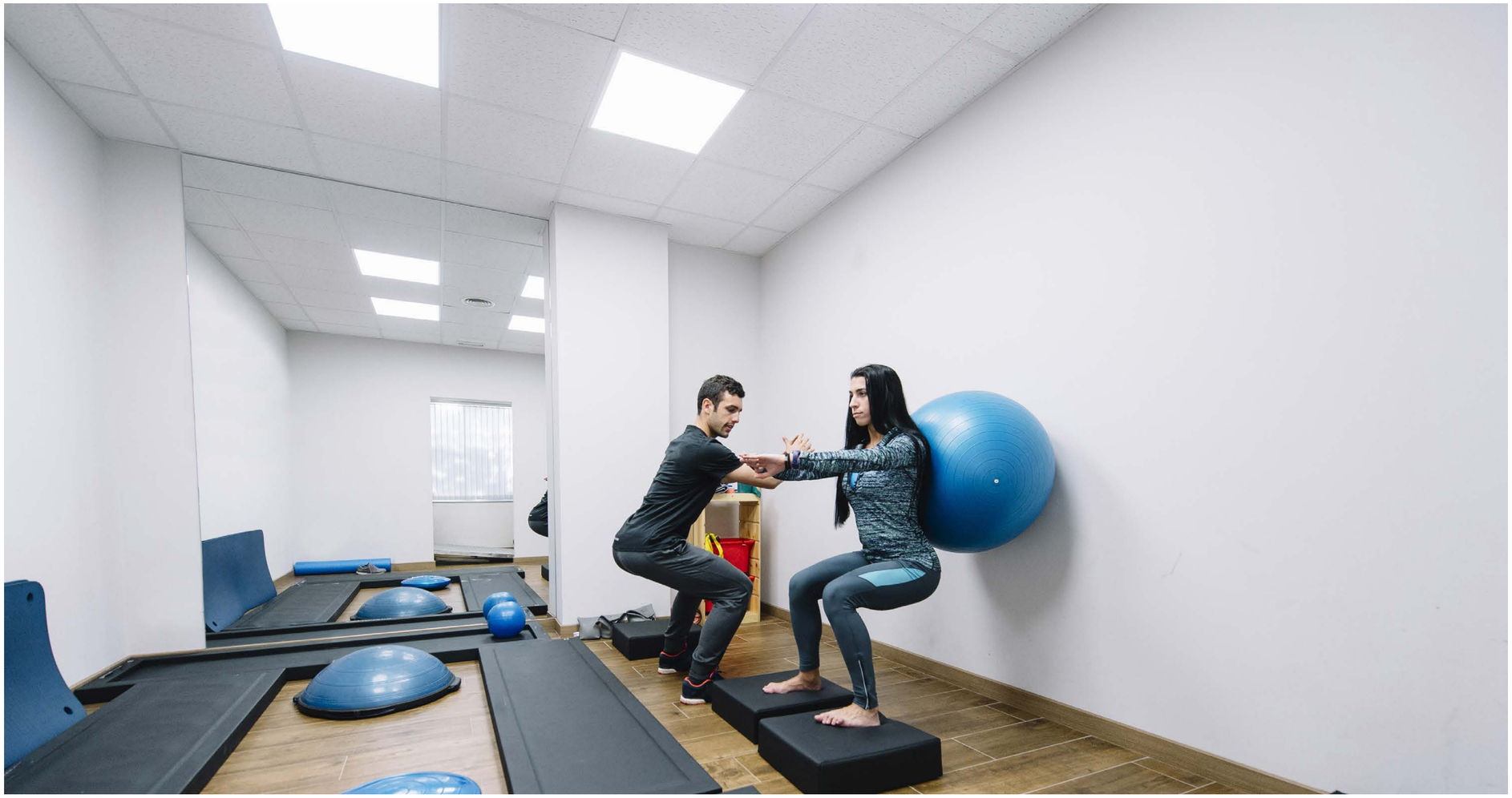


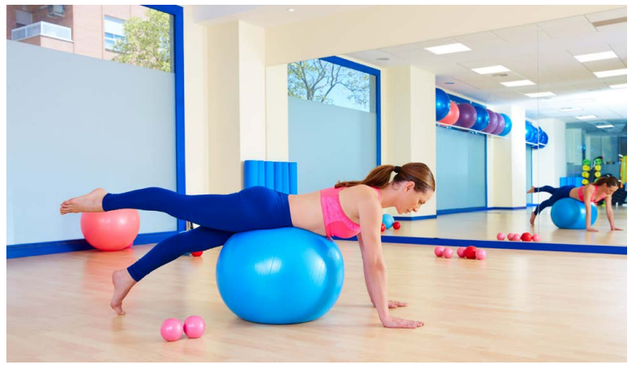
All in all, lighting in patient rooms should give a feeling of an open and stimulating space in which patients can perform all sorts of activities, be it reading, getting a proper check, relaxing, napping, or deep sleeping even during the daytime if needed. Reading lights next to each bed should deliver at least 300 lux and they should be possible to turn on and off individually. Examination lighting should be at least 300 lux, however, proper treatments and emergencies require a minimum of 1,000 lux. At night, staff should be able to get around the sleeping patients safely and monitor them without disturbing. Proper conditions will be created by 5 lux illuminance in a line approximately 0.5 - 1 m above the floor. The ratio of maximum to average illuminance should be no less than 1:2. Lighting which meets all the above mentioned criteria will create a home-like atmosphere, but keep the benefits of professional care.

REHABILITATION AREAS

Rehabilitation areas can be for many patients the sacred place where miracles happen, for others they are just a necessary part of the recovery process and for some, they represent a place where they must carry out an activity which they do not enjoy at all. Lighting, thanks to its variability, can either push or suppress extreme feelings, depending on the needs of the patients.

When planning the illumination of rehabilitation area, the most important criteria are adjustable intensity, uniformity of the lighting, and low glare. The individual types of rehabilitation activities require different lighting. In general, we could compare the lighting requirements of rehabilitation procedures to the demands of a sports lesson or training, values for which are stated by the European standard EN 12193 to 200 lux.





For similar areas, recessed or ceiling surfaced luminaires with shielding (e.g. with a louvre or micro-prismatic diffuser) are ideal as they avoid undesirable glare. In the rooms with higher ceilings, it is possible to use linear suspended luminaires. White neutral light with 4,000 K is ideal, however, as it is mentioned above, every patients has a different approach to rehabilitation. Some might require a bit more push by the colder temperatures, especially when they want to excel themselves or for activities which call for more motivation, on the other side, lie-down stretching or warm-ups can be perceived as more enjoyable in warmer temperatures.

EXAMINATION ROOMS

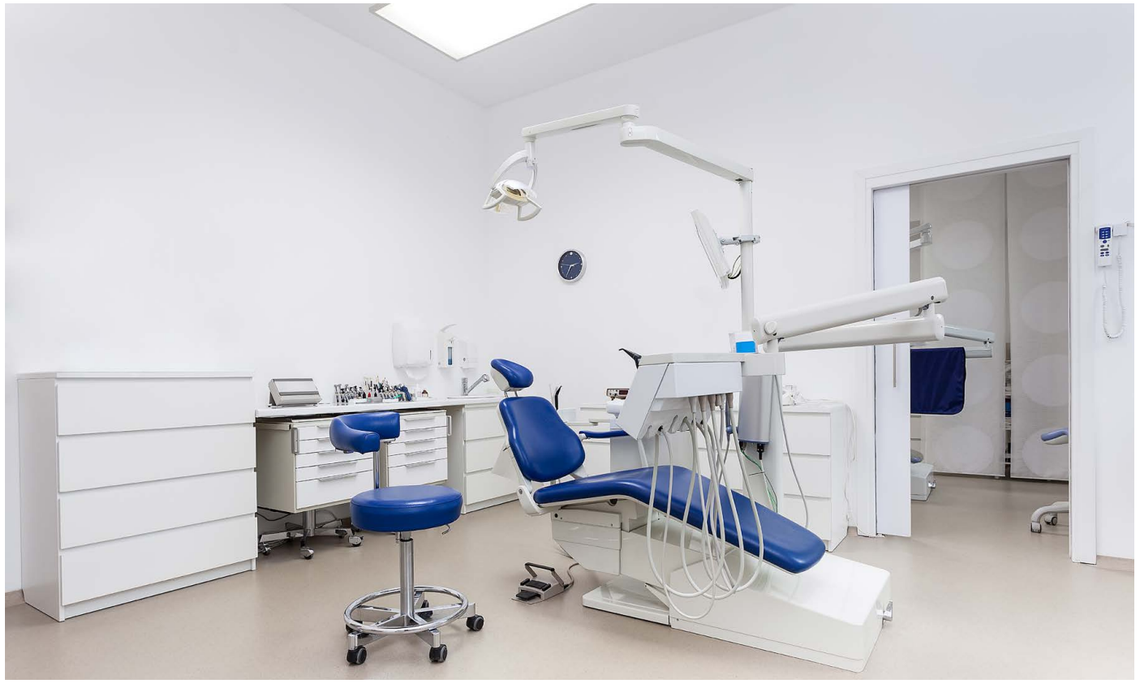
A well-designed examination room is a pleasant place for both the doctor and nurses and also for the patients. Many times, patients get a feeling that it gets too crowded and that there is not space to escape. On the other hand, examination rooms fulfilll a variety of other functions such as an office, treatment room or patient interview room. Examination rooms should give the patients enough comfort to talk about their health issues, be it a regular check or the most complex examination. Lighting can add to this comfort significantly.

Thanks to lighting, often rather small rooms with too much equipment can get optically larger by providing for a uniform lighting distribution on all surfaces, including the walls and ceiling, not just the task areas. Presence of windows and availability of the daylight helps, too. Obviously, options in this respect depend on the orientation of the building and the room itself. Also, daylight should not interrupt the staff in their work duties, so if the sharp daylight causes reflection on the computers or creates undesired shadows on the patients' body while the doctor is trying to do a proper check, blinds need to be applied and artificial light turned on. Adding to ways how to optimise the working atmosphere for doctors and nurses, it is appropriate to mention a correctly selected correlated colour temperature. The light with a neutral colour and CCT of 4,000K can create optimal conditions for stimulating and concentrated work. However, the maximal visual well-being of the employees working eight hours in the same space can be fully achieved by the system of the daylight simulation. In general, illuminance levels depend on the purpose of specific rooms but we can say that it varies between 300 to 500 lux. Static and mobile examination lights need to guarantee a minimum of 1,000 lux with minimum colour rendering index 90 and colour temperature from 3,000 K to 6,700 K.

Regarding the specific luminaires, recessed fixtures are considered the most economical lighting solution. The suspended luminaires over the tables nicely complement the general lighting and with the direct or indirect luminous flux distribution are considered a more comfortable and attractive solution which optically induces an impression of a larger space even in really small rooms and in this way helps to create a homely atmosphere. Also the wall-washers creating ambient lighting will enlarge the room optically and will create an impression of a more open space.

Lighting zones in a dental room treatment room

Special activities call for special lighting. It is easy to demonstrate it at the dentist's office. Around the examination chair, it is required to have lighting of minimum 500 lux, there needs to be at least 1,000 lux above the patient's head and during the check/treatment, this minimum requirement increases to 5,000 lux. When working on the colour of the teeth, lighting needs to reach temperature of 6,000 K, CRI 90 and at least 1,000 lux. General lighting at the dentist's should be neutral white or daylight white. To avoid glare, ideally asymmetrical luminaires cannot be positioned within 2.5 x 2.5 m distance from the patient's field of vision.



CONFERENCE ROOM

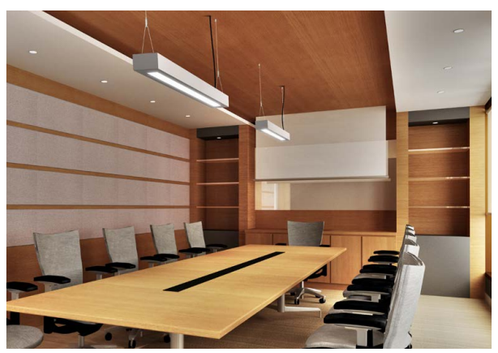
A recessed ceiling luminaire with a direct characteristic of the luminous flux distribution is equipped with a diffuser and emits a soft and non-glare light. The high colour rendering index CRI 80 and the UGR value under 19 makes it an ideal luminaire for the hospital spaces.

Conference rooms function as multimedia communication centres. Flexible, effective and at the same time pleasant lighting is important for these places which do not serve only as information sharing points but also as the dens for creative ideas and innovation.

General lighting needs to be composed of various recessed ceiling luminaire with a direct, soft, and non-glare light distribution. We recommend to use homogenous non-glare luminaires with neutral white light with the correlated colour temperature of 4,000 K, high colour rendering index CRI 80, and the UGR value under 19. It supports the impression that the space is larger and allows for effective work. It is suitable for video-conferences, too, as it guarantees visually safe experience and at the same time enables the meeting participants to take notes.

For the illumination of the conference desk and the task area the determined values are maximally 500 lx, the lighting of the surrounding of the task area is to achieve the value of maximally 300 lx. For this purpose it is suitable to use suspended luminaires with a direct and indirect distribution of the luminous flux. The boards, white-boards, flipcharts and projection screens currently belong among the standard outfit of the meeting rooms. Based on its location, the best idea is to place the lighting fixtures with asymmetrical characteristics from 0.85 to 1.3 metres from the presentation surface.

For the eye not to be strained permanently by the forced adaptation to the changed luminance level, it is necessary to ensure correct vertical lighting and uniform distribution of brightness on vertical surfaces, such as walls, presentation surface and its surrounding (maps, flipcharts). The high-quality vertical lighting also helps the orientation in the space.



The conference, meeting and workshop rooms frequently fulfilll a representative mission in the hospital building and are the place of meetings with the clients. By the accent lighting, we can highlight important objects, referring for example to the hospital name and logo.

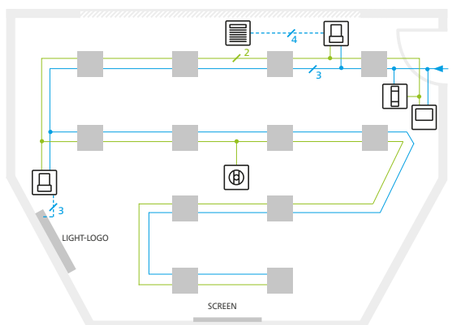
It is a space which people do not permanently occupy, therefore, installing the presence detector can lead to savings on electricity consumption. In the spaces with availability of the daylight from the point of view of savings it is suitable to consider the usage of the daylight sensor, too.

LMS in doctors' offices and conference rooms

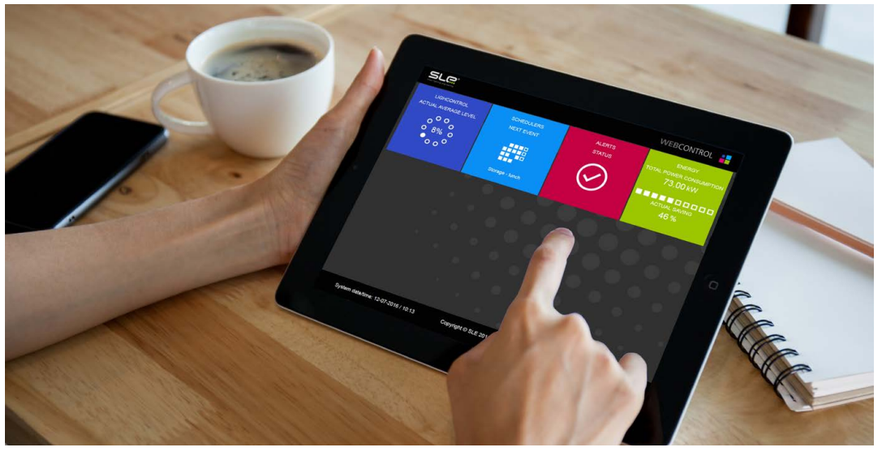
Optimal control systems for offices ensure the basic needs, such as illuminance level, but there is also a huge saving potential. The most basic control requirement is the manual or automatic change of illumination according to need. When this is combined with motion and lighting intensity sensors, we will have achieved an automatic system which offers the greatest possible saving potential. Simple and intuitive controls, which could be as little as a single wall switch, will minimise inconvenience and its application will bring maximum efficiency.

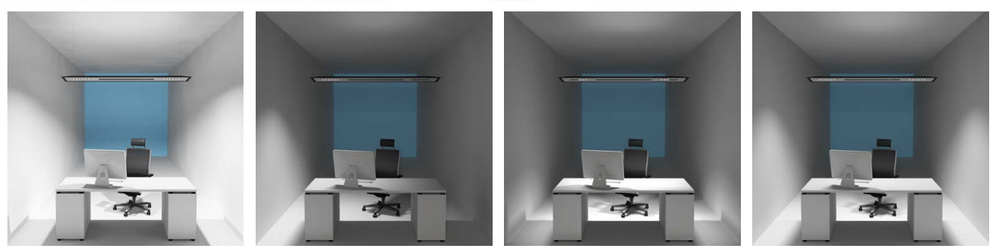
Combined control of luminaires and peripheral devices

Using this type of control system we can change from a lighting scene set for a meeting to one set for a presentation or a coffee break. In this sample application the touch panel is only the control device. One sensor situated in the centre of the room scans the lighting intensity. The system also manages the blinds and backlighting of the company logo. The switch control defined for managing the blinds receives commands via the DALI bus from the touch panel. The company logo is also controlled via the DALI bus which switches the power phase. By a single touch on the touch panel the room is prepared for a presentation. The backlighting of the company logo is turned off, the luminaires near the projection screen are turned off and the remaining luminaires are set at a level of, for example, 30 % luminous flux. Once the presentation is concluded, another touch of the same button on the touch panel returns the room to its previous state. Through an individually designed graphical interface on the touch panel device we can create intuitive control for any user, enabling control of the entire system within the room. Before operation the system and control device must be computer programmed.



Main lighting (dimmable))
Power supply
Switched power phase
Data bus (DALI)
Touch panel
Multi-sensor
DALI power source
Multi-channel DALI relay
Motor-driven blind control





The LED sources with various luminous intensity which reflect the light from the built-in reflectors under different angles enable changing the width of the luminous intensity curve within one luminaire.

Web Control

Web Control is a modern solution for easy controlling and monitoring of the lighting system in many areas, not just offices. The lighting management system is controlled through a graphical user interface that is customised according to the specific office solution. This advanced platform is designed to manage and monitor the system. Its key modules make it possible to automatically collect, store and process data; schedule switching; generate reports about the system status and savings; and send notifications about failures and system errors.

Other benefits of the system include keypad control which enables turning the lights manually ON or OFF when needed. As a whole, web control system can be implemented into any building management system.

RELAXATION ZONES

Long are the days when hospitals were cold, sterile places where one went only occasionally and with fear and disgust. Nowadays, hospitals respond to the natural needs of patients, visitors, and staff and create pleasant conditions for them to relax and regenerate in between examinations and duties.

Relaxation zone with comfortable places for sitting is a common part of every modern hospital. They provide space for exchanging information in an informal environment and copy the natural biological needs of the human organism. The equipment and functional lighting of the relaxation zones contributes to the feeling of comfort, creates a space for having rest and increases positive feelings. In the zones determined for relaxation, equipped with comfortable furniture especially the indirect lighting will find its place. It will enable flexible changes in the room without any need to change the lighting solution.

Currently there is a common trend heading to the creation of a home atmosphere for all spaces defined as the relaxation zones. The furniture in warm colours becomes the dominant feature of the space as well as the pleasant illumination with the correlated colour temperature of 3,000 K or 4,000 K. For a lighting designer such a space provides inexhaustible creative opportunities. The task of the relaxation zones is to affect the people's emotions and therefore especially the ambient lighting will find its place in such spaces. The task of the relaxation zones is to affect the people's emotions and therefore especially the ambient lighting and RGB colour mixing will find its place in such spaces. We can play with wall-washers, spot luminaires, ambient lighting and even multimedia to affect people's feelings and moods, because this space really allows us to let our creativity speak.

CAFÉS, RESTAURANTS, AND CANTEENS

Cafés and restaurants serve as a space for quick refreshment and socialising so it is necessary that customers feel comfortable and relaxed. We achieve the perfect ambiance by luminaires with both direct and indirect lighting, which help to avoid visually distracting phenomena such as glare, stark contrasts and dark corners. Also tunable white technology offers great opportunities for making the dining space more friendly and homelike.

The illumination in the catering establishments should be designed to create a positive communication atmosphere (besides meeting the normative requirements). The time people spend in these spaces is mostly limited therefore the recovery effect of the illumination on the human well-being should come in the shortest possible time. Through the combination of the natural light, daylight and artificial light in the buffet and canteen areas we can create an impression as if they were literally filled by light and in this way contribute to the welcoming atmosphere. It is suitable to use the suspended linear luminaires with the direct and indirect component of radiation or the ceiling luminaires with the direct and indirect component of radiation which will sufficiently illuminate also the vertical surfaces and ceiling.

When there is a stable layout of the tables, it is suitable to deploy the luminaires in such a way that they will copy the communication paths in the canteen, café, or restaurant, and will make the orientation in the space easier. The main lighting can be completed by suspended luminaires placed over individual tables. If they were to affect the space in a disruptive way, a suitable alternative can be the luminaires with a narrow luminous intensity curve directed straight over the table. For improving the vertical space illuminance it is possible to place the wall-washers directly on the walls which will take care of pleasant colour accents on the coloured walls.

Research results show that a good lighting in the canteens and restaurants which are displaying the food is able to increase sales as it creates a pleasant shopping environment that stimulates purchase behaviours. For food applications, we developed luminaires with 3 different beam angles, exceptional reflector and efficiency, and Tridonic LED driver and COB-LED module. They come with modules which we adapt to the type of products which are being illuminated:

BAKERY products: The brownish shades of GOLD CCT add a crispy look, while with the golden shades of GOLD+ we can achieve the “fresh out of the oven“ appearance.

FRUITS AND VEGETABLES: Green produce looks more attractive and appealing with enhanced colours under FRUIT CCT.

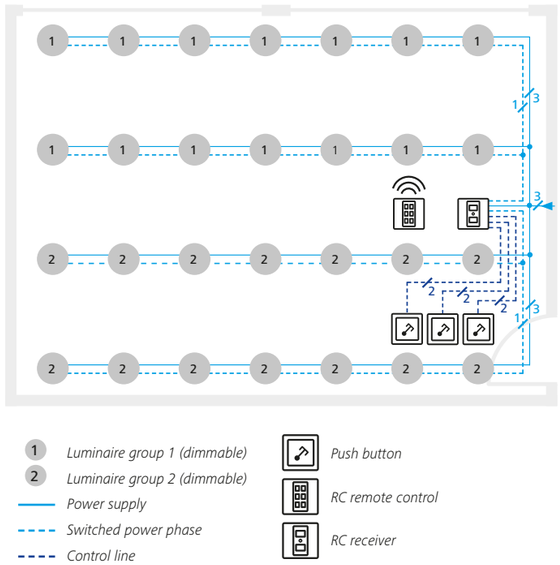
MEAT products: Make displayed meat products look fresh while white elements remain naturally white with MEAT module, and add MEAT+ for highlighting red colour tones.

FISH and SEAFOOD: Underline the freshness of fish and seafood with colder light colour tones of FISH module luminaires.

Our food lighting solutions are designed to achieve high energy saving potential. The luminaires are A++ certified so that our lighting has a really small environmental footprint. To further enhance efficiency, control management system adjusts the light level to the available amount of the natural light available. This way the new solution will combine optimal comfort for the eyes with minimal energy consumption.

Manual and group control for canteens

This sample application uses an RC receiver which allows for the independent control of two separate groups of luminaires. The push button control device is located by the door, via this control it is possible to turn the luminaires on and off and to set the luminous output level. To make this system more comfortable we use an RC remote control. This allows for the control of a maximum of four groups of luminaires via two RC receivers. It is not necessary to use remote control, but it is a comfortable and practical option. Manual dimming allows the light to be adapted to the use of the space, a lunch break which requires a high level of illumination, or cleaning and servicing where a lower level of luminous output is sufficient.

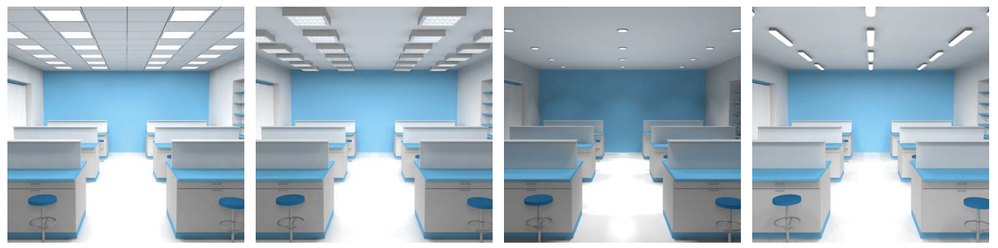


LABORATORIES

The labs place extraordinary high demands on the solution of the lighting system. The correctly designed lighting system has to comply with the illuminance parameters stated by the standard and simultaneously has to create such light conditions which contribute to the safety of these spaces.

The European standard EN 12464-1 determines the minimal illuminance 500 lux for the labs and workshops and the more demanding the visual tasks to be realised in the specialised room are, the higher its value has to be. It is important to prevent the rise of undesirable glare and reflections from the glossy surfaces and to avoid sharp shadows. The optimal light conditions can be achieved by luminaires with asymmetric curve for vertical illumination. For better concentration of the employees it is suitable to use the light sources emitting cold white light.

The experiments and tests carried out in the labs place increased demands on the correct identification of colours of chemicals, wires or connectors, therefore, from the point of view of safety it is inevitable to use the luminaires with a high colour rendering index - CRI >90. It is suitable to use luminaires with a housing made of unbreakable material which does not change its photometric properties. When the artificial lighting is on, it is also important to avoid the stroboscopic effect, flickering, headaches and other health issues, such as lacrimation. These phenomena can be prevented by installing the appropriate LED luminaires with correctly set-up control.



When selecting the luminaires for the labs it is necessary to take into account several factors at the same time. It is suitable to use luminaires with the protection level IP 54 or IP 65 in these spaces.

CORRIDORS AND COMMUNICATIONS

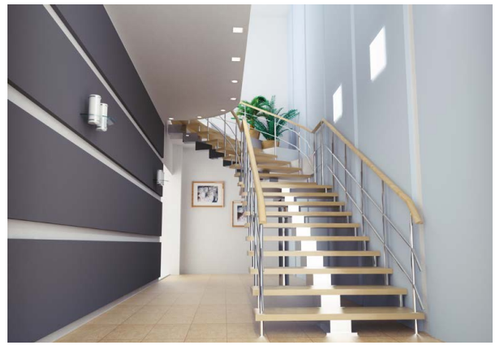
The corridors, staircases and elevators represent the communication paths connecting the key points inside the building in the framework of the hospital space. Their appropriate illumination brings easier orientation even in an unknown space, increases the feeling of comfort and safety. They are used by a large number of people, however, their presence is not consistent and constant and many times they stay unoccupied. Therefore, it is wise to take appropriate measures for energy saving.

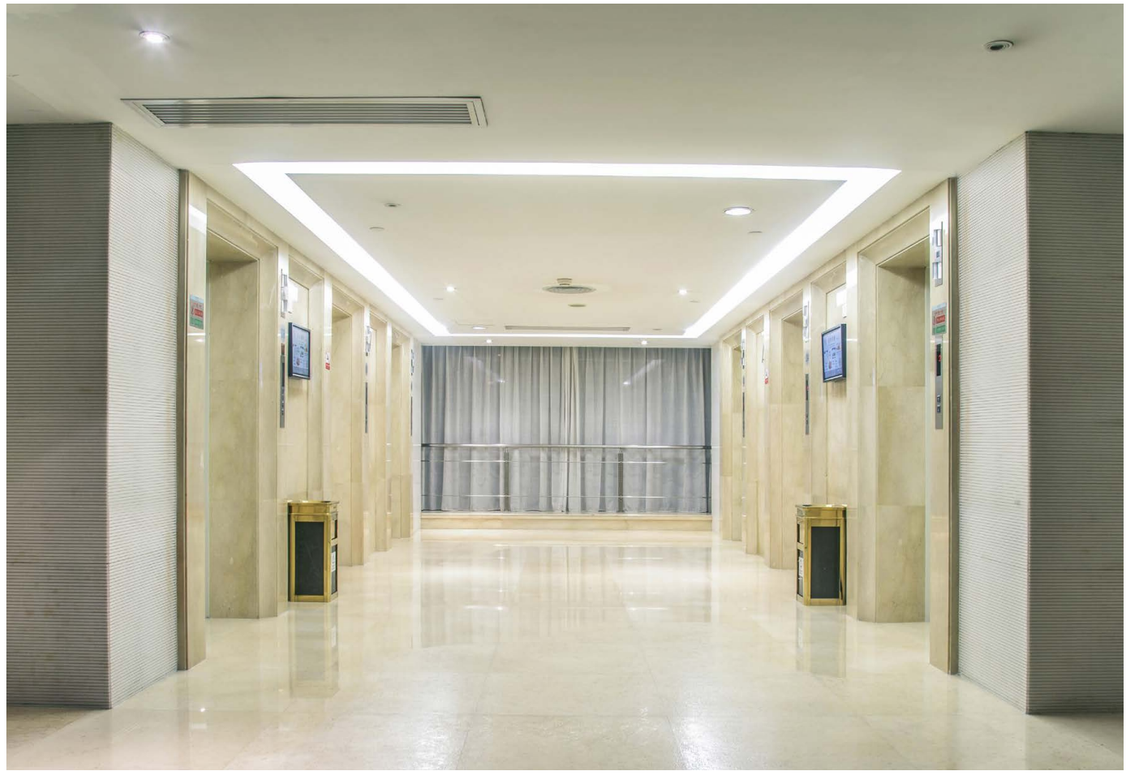
With control based on movement sensing the waste of lighting can be eliminated easily. It turns the lighting on automatically when movement is detected and off when the space stays unoccupied for a preset period of time. Clients can create zones, time schedule or set up delay for dimming, too.

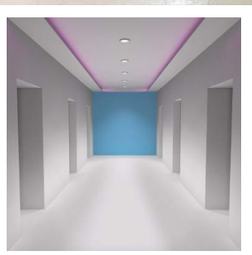
In areas which include windows, we always advise to install a daylight sensor which can easily adjust lighting according to the amount of available daylight and illumination rate of the given space. The illumination rate depends on the geographical position, windows, skylight size, and overall orientation of the space.

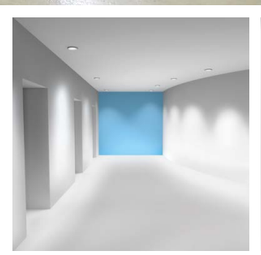
Input type transducers or sensors produce a voltage or signal output response which is proportional to the change in the quantity that they are measuring (the stimulus). The type or amount of the output signal depends upon the type of sensor being used (temperature, pressure, sound, speed, position, etc.). To apply control with RF system, a small antenna is implemented in each luminaire through which data is transmitted in a mesh network topology. Data can be transmitted from different luminaires simultaneously. No additional cabeling for control is needed. For controlling switched loads such as blinds, non-dimmable luminaires and various non-lighting devices, we use relay units.

All in all, both above mentioned tools are a safe and comfortable way of lighting management. Ideally, we recommend to combine both motion detection and light intensity control. This combined control will provide higher savings than one alone.









For the general lighting of the corridors, we use the lighting fixtures with a very wide radiation curve. They are also able to effectively illuminate the wall edges and this brings an optical enlargement and brightening of the whole space. The ceiling surfaced luminaires with the direct or indirect luminous flux distribution, the ceiling surfaced luminaires with a wide radiation curve or suspended lighting fixtures with direct or indirect luminous flux distribution belong to this category.

The illumination of the vertical surfaces is the most important from the point of view of the correct lighting of the corridor and the communication zones. The illumination of the ceiling is also important, especially due to the feeling of orientation. The long corridors can add interest by works of art or paintings referring to the corporate culture. The accent luminaires with a narrow beam angle are able to improve the attractiveness of this space. By placing a line of luminaires to the upper ceiling corners of the corridor, the so called cove lighting, we can achieve its optical enlargement. This type of illumination belongs to the group of the ambient lighting and it is often completed by the RGB function for mixing colours. The technology RGBW is used for reaching better pastel colours.

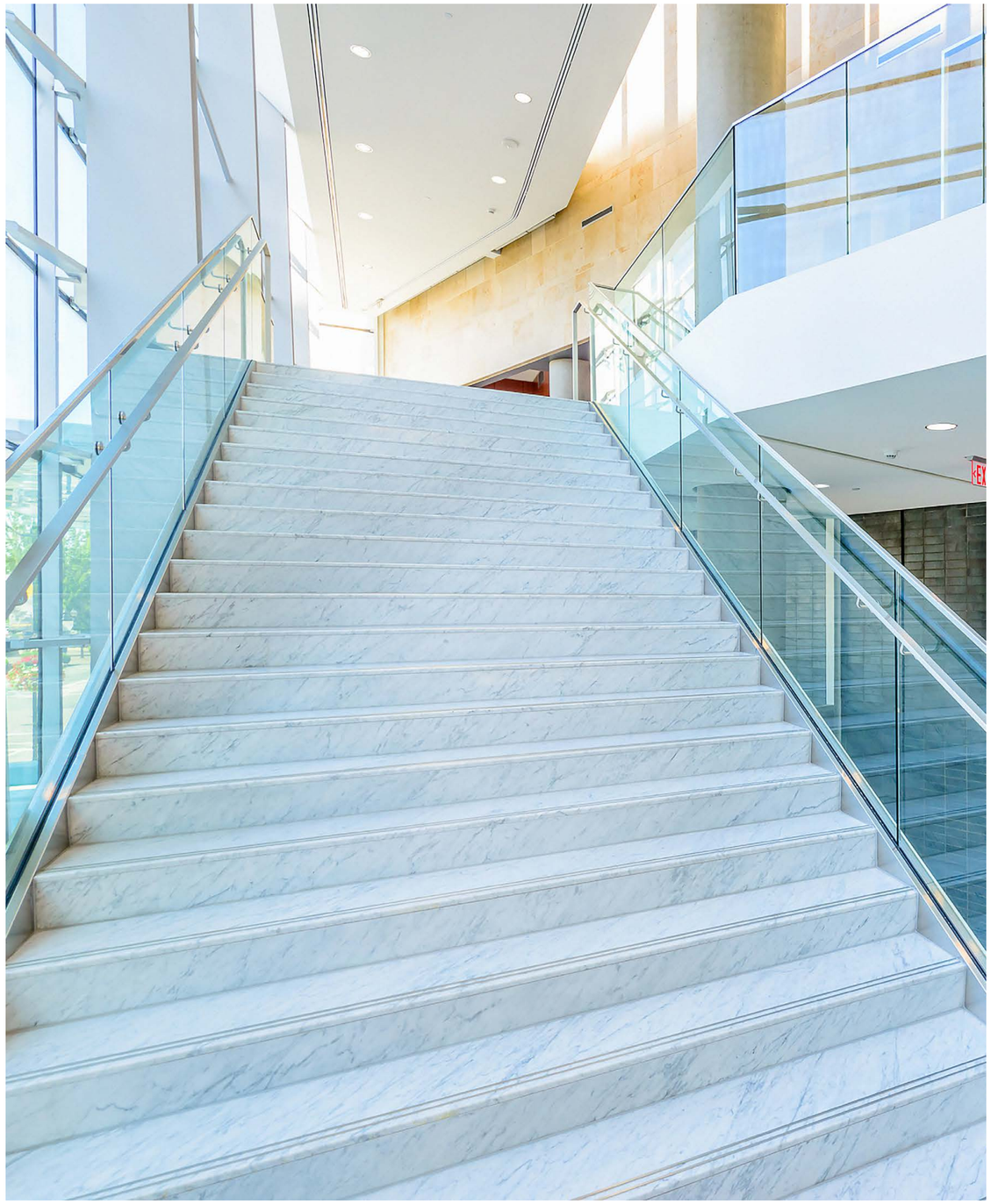
The additional orientation luminaires recessed in the floor or the corridor wall give direction to the strategic points in the hospital space and especially fulfill the orientation and safety function. They fulfilll the same functions on the staircases which represent not only another communication but currently also a representative zone in the hospital space. When selecting the correct type of illumination we especially emphasise the minimisation of shadows and visibility of individual steps. Recessing the LED luminaires to each third step we achieve improvement of safety and comfort for movement on the staircase. Due to the fact that the corridors and staircases fulfilll the task of escape routes, during the designing process it is inevitable to schedule for installing the safety and emergency luminaires in compliance with the legal standards (see the chapter Safety and Emergency Lighting).

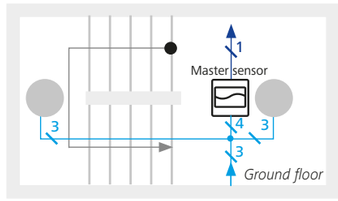
LMS for corridors, staircases and toilets

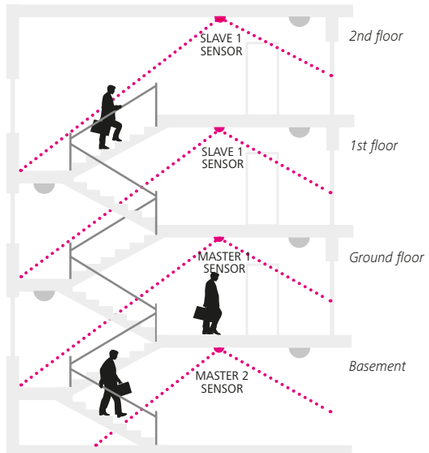
Corridors are one of the spaces within a building where there is great saving potential as they are not in continuous use. These spaces require a specific kind of lighting solution that can take full advantage of their inherent characteristics. When designing the illumination it is vital to place enough emphasis on safety, and to focus on the functionality and mood of the lighting rather than placing undue significance on aesthetics. In this way we can ensure the best possible saving potential. The use of motion sensors is the most effective method of regulation for such applications; when a corridor is effectively covered by the sensors the lighting will switch on only when necessary. From a safety point of view, and in order to minimise the risk of injury during busy times, it is useful to have a delay in switching off the luminaires, and that the switching off is not complete but to a 'safety level' (this is called the corridor function). In such cases the luminous flux is reduced to 10 % which ensures sufficient visibility, even when there is no movement detected. This type of solution reduces the need for a large number of switches and control devices.

Cascade scanning of movement for staircases

As with corridors, staircases in public places have a high rate of occupancy. Controlling the lighting via a standard wall switch is not user-friendly, whilst having continuous full illumination is not economically advantageous. This problem is easily resolved by the use of cascade scanning of movement. The lighting on each floor can be independently managed, or all groups on above-ground floors can be controlled as one group and below-ground floors as another group. By connecting one master and two slave sensors for above-ground application all above-ground lights can be controlled as one. The functionality of these sensors is as in the previous section 'Zone scanning of movement'. If it is a space with no available daylight required levels of luminous flux and timing can be set remotely or manually directly in the sensor. Controlling each floor independently will provide higher saving potential. I t is possible to use PIR sensors in corridors as well as high-frequency sensors.







Scanning plane of sensor
Luminaire (non-dimmable)
Switch phase
Control line from SLAVE sensor
Movement switching sensor

SAFETY AND EMERGENCY LIGHTING

Emergency lighting is the essential life safety system that allows people to find their way out of the hospital building quickly and safely in case of a crisis, along with the guidance of EXIT signs. Regulations describe the specific locations for emergency lighting, minimum lighting levels, installation and testing requirements, and product quality.

Sufficient emergency lighting (of adequate intensity) must be provided along escape routes, near changes of direction, at emergency exit doors, at stairs, near each fire fighting equipment and first aid point. The requirements for high risk task areas are more strict because a disruption may be critical and endanger life.

The main directives are defined in European standard EN1838. The standard ensures products are safe to use, and have been designed and manufactured for correct performance under emergency conditions. There are country-specific deviations which should be considered in each project, however, the minimum requirements are the same:

Emergency lighting must be at least twice as bright as the moon in a cloudless sky. There must be an adequate number of signs to clearly indicate the escape route.

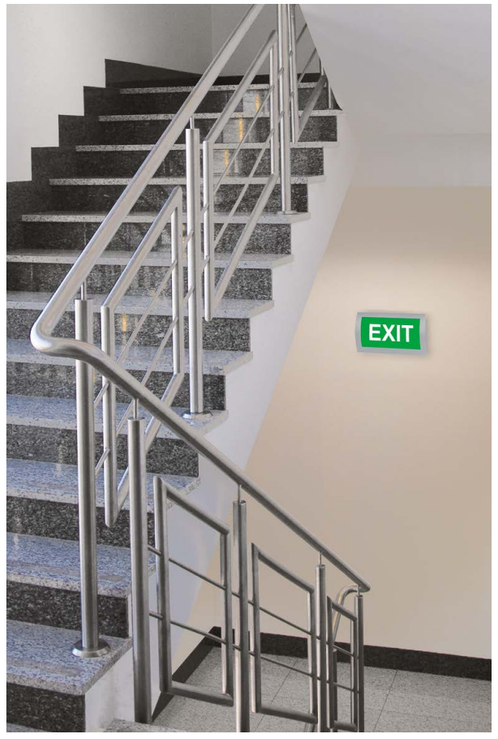
Cloudless night sky: 0.01 lux
Full moon: 0.25 lux
Anti-panic lighting: 0.5 lux
Safety lighting: 1 lux

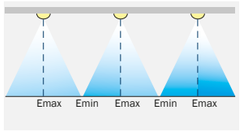
There are several options that may be used as replacement power supplies: single battery system, group battery system, central batteries, generating sets (high-speed and instant standby generating set) or a specially protected mains power supply, so-called safety power unit.

Emergency lighting covers safety lighting and standby lighting. Safety lighting stands for the following:

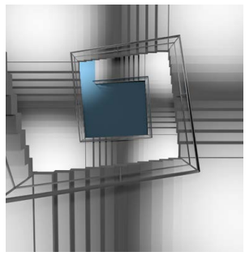
Safety lighting for escape routes
Anti-panic lighting
Safety lighting for hazardous workplaces

Standby lighting is the part of emergency lighting that takes over the task of general lighting for a limited period of time on a substitution basis so that normal operation can continue. Emergency lighting comes into operation in case of the failure of power supply systems that can occur because of severe weather, fire, maintenance works or electrical overloads. As the system can save lives it is very important to apply modern, reliable solutions to every building.





REQUIREMENTS ON EMERGENCY LIGHTING
Illuminace Emin = 1 lx
Uniformity Emax:Emin ≤ 40: 1 lx
Colour Rendering Index CRI ≥ 40
Operating time 1 h
Activation of lighting 50 %, or for required illuminance within 5 seconds, 100 % within 60 seconds



FAÇADE

The task of building illumination is not only to make it visible during night hours. The light as the fourth architectonical dimension is able to accent the construction character, to emphasise interesting details and at the same time to communicate a message.

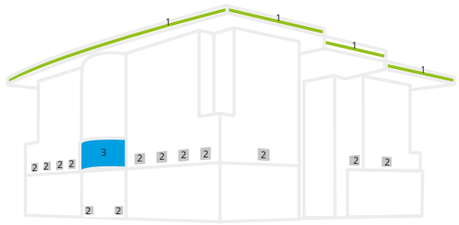
The correct façade illumination is able to breathe style and elegance to the modern glass-walled buildings; it helps to accent the not interchangeable character of the historical ones. The play of light and shadow is able to conjure dramatic sceneries in dependence on the type of lighting and installation of luminaires and to breathe the hospital life.

The illumination of large façade surfaces can be achieved by installing luminaires with a wide luminous intensity curve placed e.g. on the columns in front of the building. When we place an accent luminaire directly on the façade wall, it can emphasise interesting architectonical as well as artistic elements, e.g. the sculptures, to emphasise the materials used on the surface building or to illuminate a cornice in an interesting way. The luminaires recessed to the ground with an asymmetric radiation curve placed in an optimal distance form the vertical contours of the walls, their lighting by spotlights from the bottom emphasises the architectonic details of the building (balconies, cornices, sculptures, etc.). The used LED luminaires can be enriched by the RGB function of mixing the colours and to strengthen the emotional effect of the illumination. When planning the light solution of the Façadethe selection of the light colour is one of the decisive factors. The modern architecture with clean lines is flattered by a white neutral light and vice versa, the historical buildings become apparent after dark in the light of warmer colours. The dynamic illumination is able to increase the attractiveness of the light solution by gradual switching on and off of the selected scenes or the name of the hospital.

From the point of view of selecting a light source also in the case of the façade illumination, it is valid that effectiveness, functionality and economy of the LED luminaires highly exceed the parameters of the standard metal-halide lamps. The LED RGB modules are able to interpret up to 16.7 million colour tones, they work more reliably also at low external temperatures and thanks to their long lifetime they reduce the demands on the service and maintenance. The exterior illumination of the hospital building requires sophisticated light solution also because of the orientation and safety. Beside representation its task is to enhance the fast orientation in the space (e.g. to lead to the main gate or entrance to the parking lot) and to improve the safety of the moving persons during the night hours.

However, during solving the façade illumination, we should not forget about the lighting of the adjacent green areas. The coniferous and broad-leaved trees become apparent in the light of the sodium discharge lamps, while the dark-green trees in the light of the metal-halide light sources. By their suitable placement we can achieve an attractive multi-colour effect.

The modern architecture with clean lines is flattered by white neutral light and vice versa, the historical buildings become apparent after dark in the light of warmer colours.



1 *RGB linear luminaire 'highlighting the building outline' (DMX)*
2 *RGB projector luminaire 'wall' washing effect (DMX/Wi-Fi)*
3 *LED RGB panels 'video effect' (DMX)*

LMS for façades and architecture

Just as light can be used to complete the design of an interior space, it can also be used to highlight the external façades of buildings, drawing attention to important or historically valuable places. Cool white or RGB illumination that changes dynamically is suitable for modern glass-walled buildings. On the other hand historical buildings benefit from warmer white lighting. By implementing control elements into external lighting solutions we can increase the functionality of the system and consequently the appeal of selected buildings, especially during evening hours. Smart programing of management systems enables the dynamic lighting of façades using many colours, or highlighting of the company logo. Such systems do not offer much saving potential, however if LED luminaires are used in combination with effective programing and the use of sensors (such as twilight sensors), it will increase the saving potential to its maximum.

Architectural lighting

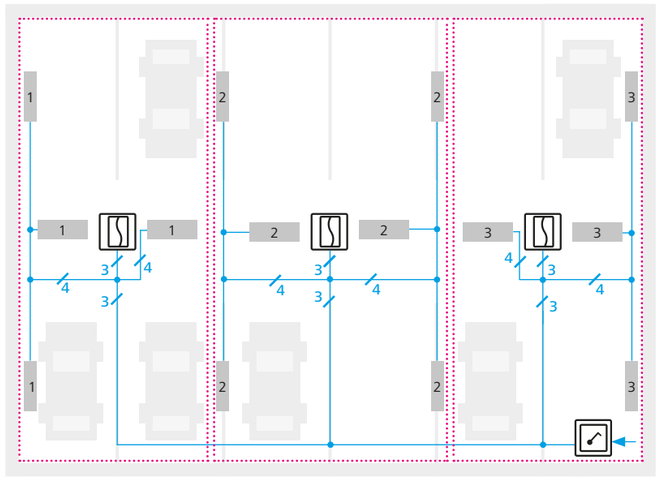
When designing architectural lighting it is vital to consider the type of building being dealt with, whether it is historical, culturally important or modern, as each requires a very different lighting solution. The purpose of lighting the façades and frontages of buildings is to draw attention to their architecture, not only at night but also during the day, to highlight their value, importance and/or advertising function. Illumination can be either direct or indirect. The required effect can be achieved by use of various and appropriate types of luminaire. Projector luminaires can create a so called 'wall washing' effect or be used to highlight the size of a building, while linear luminaires accentuate the outline of a building. LED panels can show videos of various qualities and resolutions, or they can be used to create lighting effects. This type of lighting is a hugely variable and adaptable tool in the hands of designers and architects-they have at their disposal a large number of luminaires suitable for accentuating the building façade. If it is not possible to build in a separate control line, control can be facilitated via the current power line using PowerLine AC.

RGB control can be done wirelessly-see the control of the projector luminaire in the sample application. In this application the façade illumination is provided by LED line luminaires controlled through a DMX bus. Overall control is provided by one central touch panel and video converter (for video visualisation). It is necessary to program system functionality prior to start-up. Saving potential can be offered by the switching on of the system (manually or automatically or based on time) only when necessary. The primary focus of such a system is not energy saving but comfort of use and the effect created by the lighting used. The whole system must adhere to the required IP (Ingress Protection) level corresponding to its location and use.

EXTERIOR ILLUMINATION AND PARKING AREAS

Besides the aesthetic task, the exterior lighting especially fulfills the security function. It makes the orientation in the external spaces easier, it refers to the entrances and the entry ways to the building, it increases the feeling of safety and comfort.

The increased demand on the illumination of the external spaces is especially where the pedestrians, bikers and car drivers meet. The correctly illuminated vertical as well as horizontal areas minimise the risk of collision and provide enough information about the orientation in the space. The access roads and external parking lots are made visible by the pole luminaires; decent in the ground recessed lighting fixtures separate the parking areas from the traffic lanes and the pedestrian zones. For all types of luminaires for external usage there are strict criteria as to the resistance against humidity, the temperature fluctuations and pollution. Also the underground parking lot places special demands on the intensity and type of illumination, beginning with the luminaire marking the entrance and way out, through the guidance lighting up to general lighting of the functional area.



One of the most important tasks of the lighting system designers when they solve the illumination of an underground parking lot is the entrance and exit zone from the parking area in the framework of which the light scenery is distinctively changed. Such an environment places extraordinary demands on the adaptation phase of the human eye during transition from various light environments. It is inevitable to reduce this phase to minimum. The optimal solution includes a higher density of the luminaires installed in these zones (similarly as in the tunnels) which means a softer transition.

The task of the general lighting in the underground parking lot is not only to ensure the basic visibility but to provide the person in the parking area a feeling of comfort and security. For the road users in the parking lot environment to be able to assess and solve the situation sufficiently quickly, it is inevitable to choose the luminaires with the lighting intensity of minimally 75 lx. In general it is recommended to use the luminaires in anti-vandal version and a long lifetime placed on both sides of the traffic lanes. A sufficient illumination especially in the areas with irregular occurrence of people is inevitable also from the security point of view. It enables the persons to recognise faces and to respond in time to the first signs of aggression.

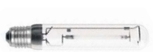
When designing the light solution it is to also take into account the lifetime of the light sources. From the point of view of the lifetime and demandingness on the maintenance the LED luminaires are especially suitable. As they are areas without any access of daylight and at the same time without permanent occurrence of persons, it is suitable from the point of view of energy saving to consider the installation of the constant illuminance sensor and presence detector that scans the movement of the vehicles in the garage, manages the illumination in the zones where it is necessary and creates the guidance lines in the area of the underground parking lot.

Zone switching based on movement for underground parking areas

Similar to corridor lighting, the illumination of garages is focused on meeting the requirements stipulated for such a space. Many garages have no access to daylight so motion sensors are the obvious control methods to use. Luminaires are divided into groups, each with an independent PIR switching sensor or one which uses high-frequency radio waves. These sensors only switch the power phase of the luminaires - turning them on or off. The delay before the luminaires are switched off after movement is no longer detected can be set manually or by remote control (depending on the type of sensor). When using a more sophisticated lighting management system, as in the sample application, it is possible to use the corridor function- here the luminaires do not switch off fully but to a reduced luminous output, a safety level of maybe 10 %. This function uses a switching sensor and two phase control where the level of luminous output depends on whether one or both phases are switched. In order to implement the corridor function all luminaires must be dimmable. An additional functionality is when the system is set in such a way as to lead drivers to vacant parking spaces. The overall switching off of the luminaires is done by switching the power phase and disconnecting the system from the power supply.

SELECTION OF THE RIGHT SOURCE

Different areas within hospital premises have different demands on the illumination. When designing a lighting system, the task of the lighting designer is to choose the light sources with the most suitable parameters where, besides the procurement price, the categories of effectiveness, lifespan and safety are also included.

	Lamp type	power rating from-to [W]	luminous flux from-to [lm]	efficacy [lm/W]	light colour	colour rendering index (CRI) from-to	lifespan from-to	lampholder
	**Incandescent**	30-100	300-1,000	10-12	ww	> 90	1,000	E27, E14
	Tungsten halogen	5-116	60-2,135	12-22	ww	> 90	2,000	E27, E14, G9, GU10, GZ10
	Tube-shaped fluorescent FD (T8) Ø 26 mm	18-70	860-6,200	61-93	ww/nw/dw	80-96	16,000-80,000	G13
	**Tube-shaped fluorescent FDH (T5) Ø 16 mm**	14-80	1,100-7,000	67-106	ww/nw/dw	80-93	24,000-45,000	G5
	**Compact fluorescent lamp**	5-80	250-6,500	46-95	ww/nw/dw	80-90	5,000-32,000	2G11, 2G7, 2G8-1
	**High-pressure metal halide lamp MT/ME (HIT/HIE)**	35-2,000	3,200-240,000	67-120	ww/nw/dw	65-96	6,000-15,000	E 27, E 40, PG12-2
	**High-pressure sodium lamp ST/STH (HST)**	35-1,000	3,500-150,000	74-150	ww	20-25	12,000-32,000	E 27, E 40, PG12-1
	Double ended metal-halide lamp MD/MN (HID)	70-2,000	5,500-230,000	73-117	ww/nw/dw	65-95	4,500-15,000	RX7s, K12s
	**Double ended high-pressure sodium lamp SD (HSD)**	70-150	6,800-15,000	97-100	ww	20-25	12,000-32,000	RX7s
	**LED retrofit**	3-7	90-800	37-70	ww/nw/dw	80-90	5000 -20,000	GU10, E27
	**LED module**	1-140	100-17,200	90-200	ww/nw/dw	70-98	50,000-100,000	-

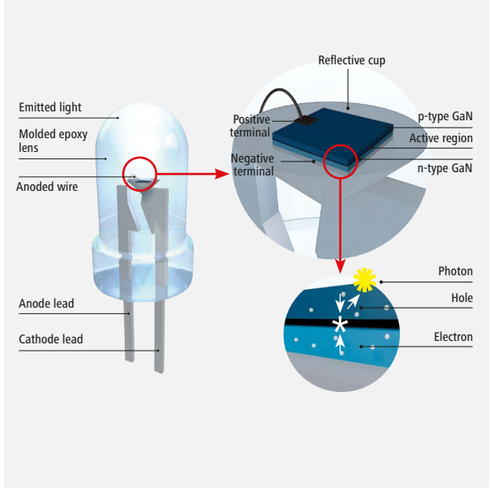
ww = warm white correlated colour temperature (CCT) below 3300 K
nw = neutral white correlated colour temperature (CCT) 3300 K to 5300 K
dw = daylight white correlated colour temperature (CCT) over 5300 K

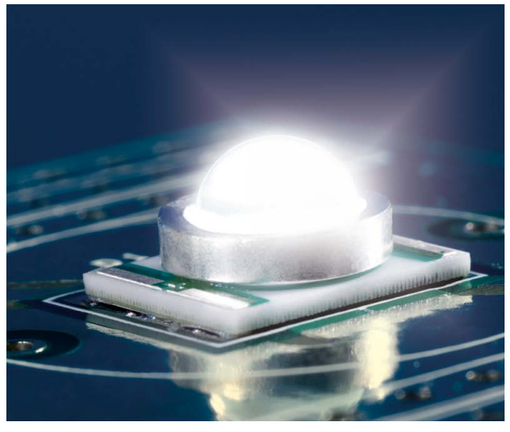
LED FOR HEALTHCARE

When in 1962 the American professor Nick Holonyak created the prototype of the first "light emitting diode" - LED, his invention remained almost unnoticed. The only one who anticipated its revolutionary future on the pages of the magazine Reader´s Digest was the inventor himself. It lasted almost forty years until the industry revealed all the exceptional properties of the LED and learned how to utilise them. In the lighting industry the LED sources currently represent an area that is developing in the most dynamic way.

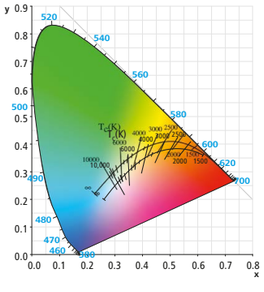
In what respect are the LED light sources so exceptional and exceed the properties and parameters of the conventional sources? Why do the architects, developers and users of industrial buildings concentrate more and more frequently on the LED sources when designing the lighting systems?
It would be possible to answer in a very simple way: The LED sources are highly effective, they have a long lifespan and an excellent colour rendering, they are cost-effective and environment-friendly. But let us have a look at the individual categories more thoroughly and we will explain why the LED sources represent also for your industrial spaces the best solution.

The LEDs are light sources based on the semi-conductor basis. A very small amount of energy is necessary for emitting the light. The diodes emitting light consist of two types of semi-conductors - the N-type with surplus of electrons and the P-type which has lack of electrons (the so called holes). After connecting the power the excessive electrodes and holes begin to migrate to the PN junction. When they meet the recombination develops and the diode starts emitting photons. By its size that is not larger than a dot made by a pencil the LED ranks among the smallest light sources. The package which is at the same time a lens serves as protection. It enables distributing the luminous flux directly under the angle 15° to 180°. While a common light bulb is able to change into visible light only 5 % and the fluorescent lamp 30 % of the electric power, the LED with its ability to change up to 40 % of the total energy reaches incomparably better parameters in this category. The efficiency of the light source or its efficacy says with what efficiency the electric energy is changed into the light, i.e. how much of luminous flux it produces from the electric input power (W) delivered to the light source. The unit is lumen per watt (lm/W). While the first white LEDs in 1996 had an efficacy of 0.1 lm/W, today there are commercially available LED chips with an efficacy of 200 lm/W for cool white CCT LED and in the labs there has been achieved an efficacy of up to 303 lm/W.

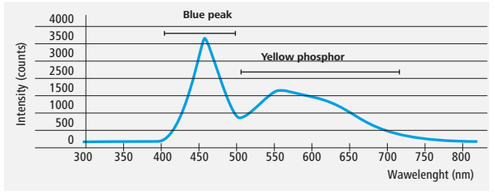




If the LED sources after binning are on the Planck curve, they emit "pure white", i.e. pure white light.

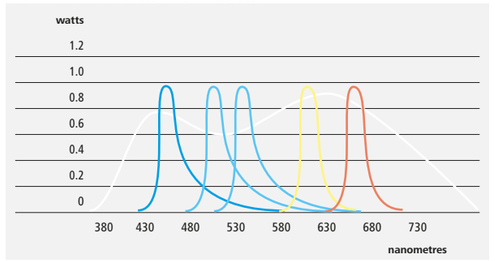


The LED luminaires used in the industrial and production spaces have to fulfill high ergonomic and economic requirements. In the industrial areas they are required to deliver high-quality lighting without glare for the optimal visual comfort also for the Visual Display Units (VDU) and at the same time they have to fulfill the requirements of the European standards. The LED diodes are primarily the source of the white colour radiation. The white LED light can be acquired by various methods; however, the principle of luminescence is most frequently used for its production. In this method a thin phosphorus layer is applied to the blue LED which, after the switching the source on changes part of the blue light which passes it into the white one. This technology of the LED production enables achieving the emission of the white light with various correlated colour temperature from 2,700 K to 10,000 K.
Another method making it possible to acquire the white LED light consists of mixing the coloured light of various wavelengths. Through additive mixing the red, green and blue colours (RGB) the white light can arise. The advantage of this method is that besides the white light by targeted mixing we can also acquire coloured light. The disadvantage when acquiring the white light by the RGB technology consists in its demandingness. It requires a lot of know-how because the management of the coloured LED with various values of luminance is demanding and the white light produced often achieves lower values of the colour rendering index CRI 70 - 98. If we consider changes of the correlated colour temperature of the white light when solving the illumination in the industrial spaces, it is suitable to combine the coloured chips with white LEDs. In this way optimal CRI values are obtained. From the point of view of the lifespan the LED light sources achieve above-average parameters. Their lifespan moves in the values of up to 100,000 hours which represents 22 years for 12-hour-operation daily, 365 days a year. The drop of the light source performance to 70 %, in some cases to 5 % is introduced as the LED lifespan end. It means that the LED failure rate is substantially lower compared to the conventional sources. However, appropriate cooling of the light source is a necessary condition for maintaining the lifespan parameters.



White light can be produced by combining blue and yellow light only. Sir Isaac Newton discovered this effect when performing colour-matching experiments in early 1,700 s.

SPECTRA OF WHITE AND COLOURED LEDS



LEDs do not require colour filters. The colour tone of the light is determined by the semiconductor material used and the dominant wavelength.

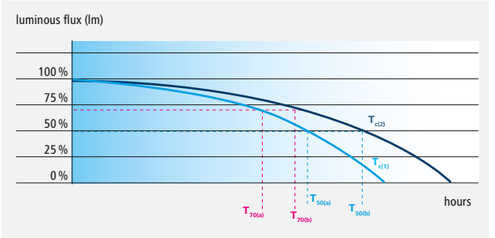
COLOURS STRAIGHT FROM THE SEMICONDUCTOR

Colours straight from the semiconductor

LEDs do not require colour filters: their light comes in different colours produced directly by different semiconductor materials. Secondary colours are also possible. The major semiconductors are:

Semiconductor material	Abbreviation	Colour(s)
Indium gallium nitride	(InGaN)	Blue, Violet
Gallium(III) nitride	(GaN)	Blue, Violet, Ultraviolet
Aluminium gallium indium phosphide	(AlGaInP)	Red, Orange, Yellow, Green
Gallium(III) phosphide	(GaP)	Red, Orange, Yellow, Green
Aluminium gallium phosphide	(AlGaP)	Green
Indium gallium nitride/Gallium(III) nitride	(InGaN)/(GaN)	Green

DEFINITION OF LIFESPAN



LEDs do not fail but the intensity of the light they produce diminishes over time. The lifespan (L) of LEDs thus need to be defined for different applications. For emergency lighting, for example, rating up to L80 are required, this means that the LED reaches the end of its service life when the luminous flux falls to 80 percent of the original flux measured. For general lighting, values of L50 or L70 are defined. The lifespan of LEDs depend to a large extent on ambient and operating temperature. Where an LED is operated at a high temperature (Tc1) or with poor thermal management, its life is shortened.

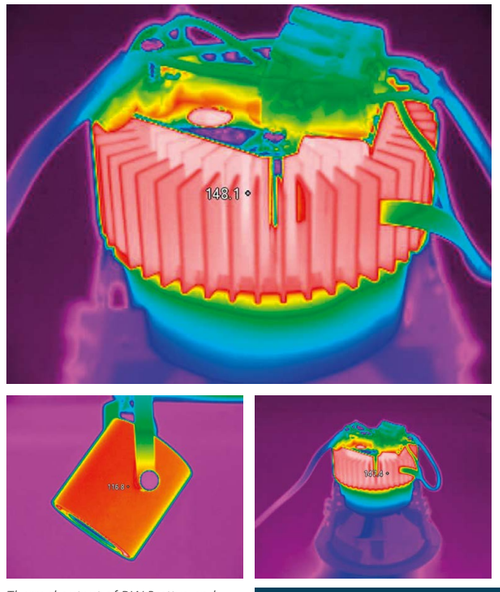
In spite of higher purchase costs the LED sources represent in a longer-term horizon the most effective and economical light solution. The experts estimate that if we replaced all existing light sources for the LED ones today, the energy savings worldwide could reach the amount of 30 %. If we realise that the artificial lighting consumes up to one fifth of the energy produced, this amount is not negligible at all. When we take into account a smaller area illuminated by obsolete conventional sources, we would be able to save up to 75 % of lighting system input power by the controlled LED illumination. All light sources also produce the IR radiation during the change of the electric power into the light which the human organism perceives as heat. However, the LED light sources produce it in a negligible amount compared to the conventional sources and thus they do not increase the inadequate costs for the air-conditioning power consumption. The lifespan and failure rate of the LED sources reduces the lighting system maintenance costs as it does not require any regular interventions of service staff and purchasing new light sources.

The LED source saving potential can be maximised by installing the intelligent lighting management which enables adjusting the radiation intensity of every luminaire in the lighting system automatically in dependence on the availability or intensity of the daylight.

The environment-friendly approach is a topic also for the producer of the light sources today. The reality is that the majority of the conventional light sources cannot be produced without using the toxic heavy metals - lead and mercury. The users of the premises equipped with this type of light sources have an additional burden when they replace them as they are compulsory to remove the used or damaged sources in compliance with the law about disposal of the toxic waste and on the other hand they are exposed to the risk of breathing the toxic vapours when the light source is damaged. In this respect the LED sources represent an incomparably lower risk. Though they contain a small amount of heavy metals, they are in solid state and so there is no danger of breathing in the toxic vapours when the LED source is damaged.

Thermal management

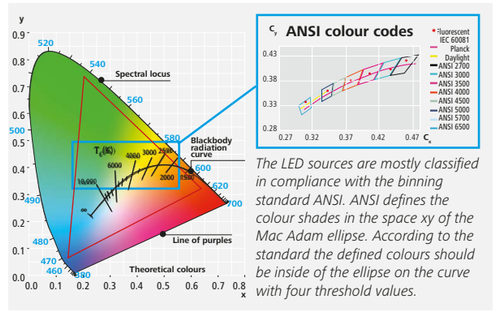
Similarly as in the case of other light sources, the temperature significantly affects the performance of the LED light source. Without any adequate thermal management overheating of the LED source can develop and it reduces its lifespan and the risk of its damage is also increased. Implementing a suitable cooling system we achieve maintaining the declared lifespan of the LED light source and its high efficacy. From this point of view the thermal management represents the most critical factor for the luminaires with the LED source.



Thermal output of DW Prettus and Avior

Binning

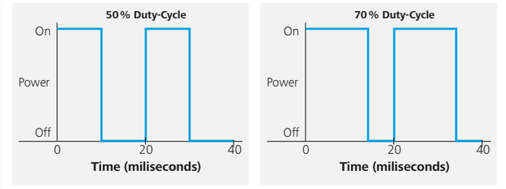
During the industrial production of LEDs deviations of the key parameters arise in the individual batches. In the framework of one batch the parameters are generally the same, but when we compare two various batches, the LEDs differentiate e.g. in colour or the luminous flux.
To ensure the constant quality of light with the same level of luminance and colour of the light, it is inevitable to sort out every batch according to the value of individual parameters. This sorting is called binning. The main criteria taken into account when binning are as follows: the luminous flux measured in lumens (lm), the correlated colour temperature measured in Kelvins (K), the forward voltage measured in volts (V). The LED sources are nowadays classified according to the binning standard ANSI. This standard defines the colour shades of LED by the MacAdam ellipses which depicts the colour deviation on the axis X and Y. The MacAdam ellipses shows how the colour of the individual LED modules can differ. The binning standard ANSI recommends for the resulting colours to be inside of the ellipse on the curve with four threshold values. The binning groups of the LED sources which show minimal differences of the values measured will produce the light of the same colour.



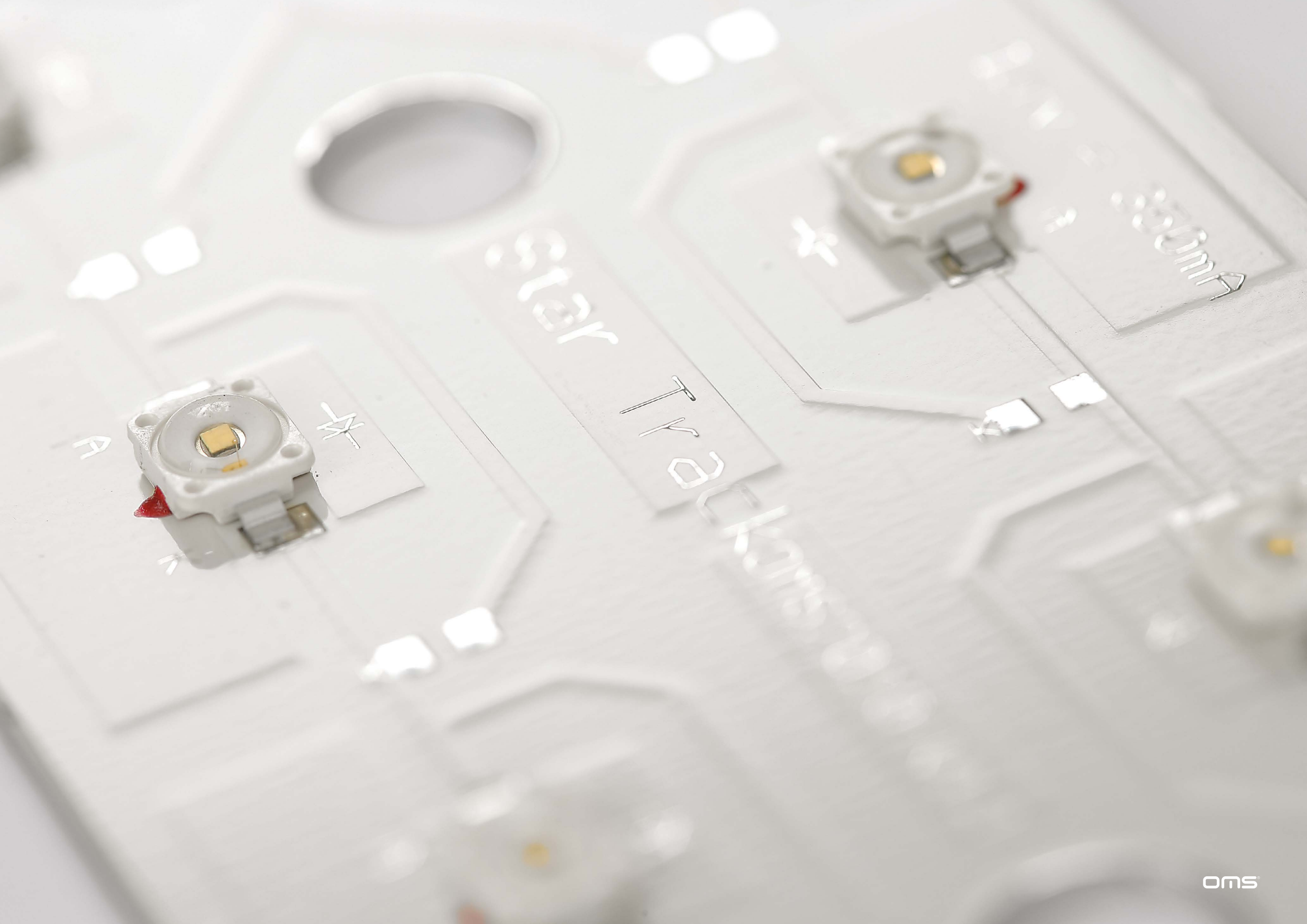
The LED sources are mostly classified in compliance with the binning standard ANSI. ANSI defines the colour shades in the space xy of the Mac Adam ellipse. According to the standard the defined colours should be inside of the ellipse on the curve with four threshold values.

PWM control

The Pulse Width Modulation (PWM) represents the most effective method how to check the intensity of the LED light source. The PWM principle is based on periodical switching on and off of the constant current directed to the LED. The resulting intensity of the LED light source is characterised by the ratio between the state of switching on and off. The frequency of switching on and off is adjusted for the human eye to perceive the emitted light as a continuous luminous flux. Its intensity depends on the adjustment of the PWM cycle (0 % to 100 %). The advantage of the impulse width modulation is the maintaining of the constant correlated colour temperature in the whole range of dimming.



Compared with the conventional light sources the LED light sources reach the full luminance immediately. The immediate start of the LED source is a benefit from the point of view of safety and comfort. At the same time compared to the conventional sources, frequent switching on and off does not make any damage to the LED source and does not reduce its lifespan as well.


Star Tracker
Beacon

BASIC TERMS

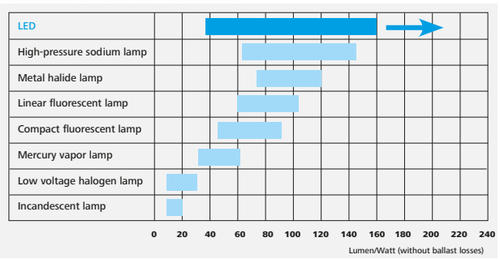
LUMINOUS FLUX Φ

The luminous flux is a physical quantity which states how much light in total a light source emits to all directions. It is the radiant power of the light source assessed from the point of view of the human eye sensitivity. The luminous flux expresses the ability of the radiant flux to cause a visual perception. The unit of the luminous flux is lumen (lm).

EFFICACY η

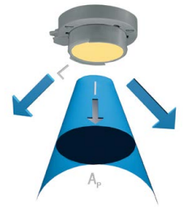
The luminous efficacy states with what efficiency the electric power is changed into the light, i.e. what proportion of the luminous flux is produced from the input power (W) delivered to the light source. The unit is lumen per watt (lm/W).

LUMINOUS EFFICACY OF THE SOURCE



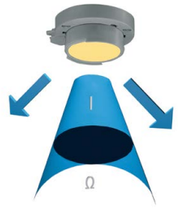
LUMINANCE L

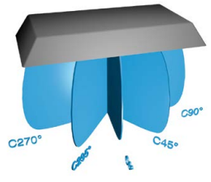
The luminance is the gloss of the shining or illuminated surface as the human eye perceives it. The unit is candela per square metre (cd/m²). This quantity gives the level of the luminous intensity over the specified surface area. The luminance of the illuminated surface depends in a great extent on its reflectance.



LUMINOUS INTENSITY I

The luminous intensity is a physical quantity which states what volume of the luminous flux the light source (or luminaire) emits to the elementary solid angle in the direction evaluated. The unit of the luminous intensity is candela (cd).

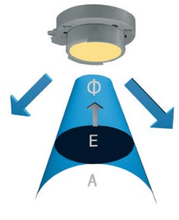




Intensity distribution curve

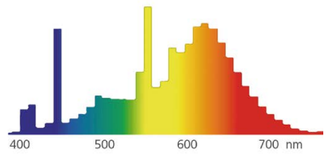
ILLUMINANCE E

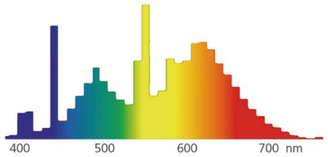
Illuminance is a vector quantity which states what amount of the luminous flux falls to the illuminated surface. The unit of the illuminance is lux (lx).

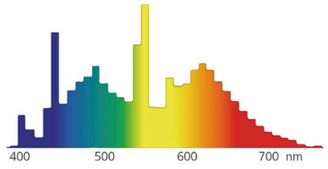


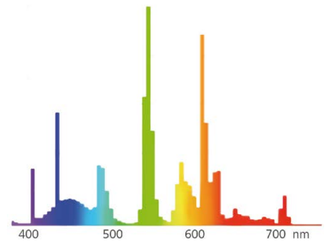
GLARE

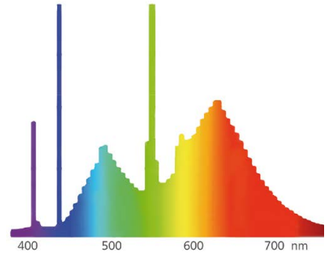
If too great luminance occurs in the field of vision of the eye, its differences or the spatial or time contrasts which exceed the vision adaptability and the glare arises. During the glare the activity of the visual system is deteriorated.











2,700 K

4,200 K

6,500 K

CORRELATED COLOUR TEMPERATURE (CCT)

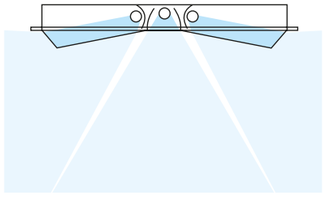
The correlated colour temperature of the light source determines the atmosphere in the room. It is defined by the correlated colour temperature of the light source expressed in Kelvins (K). Low temperatures create a warm light, the high ones the cooler ones. The most used light colours are the warm white (below 3,300 K), the neutral white (3,300 to 5,300 K) and the day white colour (over 5,300 K). The warm white colour is predominantly used for emphasising the red and yellow colour. The blue and green colours become apparent at higher temperatures.

CRI 70

CRI 95

COLOUR RENDERING INDEX (CRI)

The properties of light source colour rendering are given in the levels of the general index of colour rendering - Ra. The CRI gives the rate of the congruence of the object surface's real colour illuminated by the considered light source under stated conditions of comparison. The smaller this difference is, the better the property of the colour rendering of the given source is. The light source with Ra = 100 renders all colours completely equally as a standard light source. The lower the index Ra is, the worse the colour rendering is.



LIGHT OUTPUT RATIO (LOR)

The Light Output Ratio is the ratio of the luminous flux coming out of the luminaire and the sum of the luminous fluxes from all light sources.