Practical knowledge

ABB i-bus® KNX

Lighting
Constant lighting control

This manual describes practical knowledge for constant light control.
Subject to changes and errors excepted.

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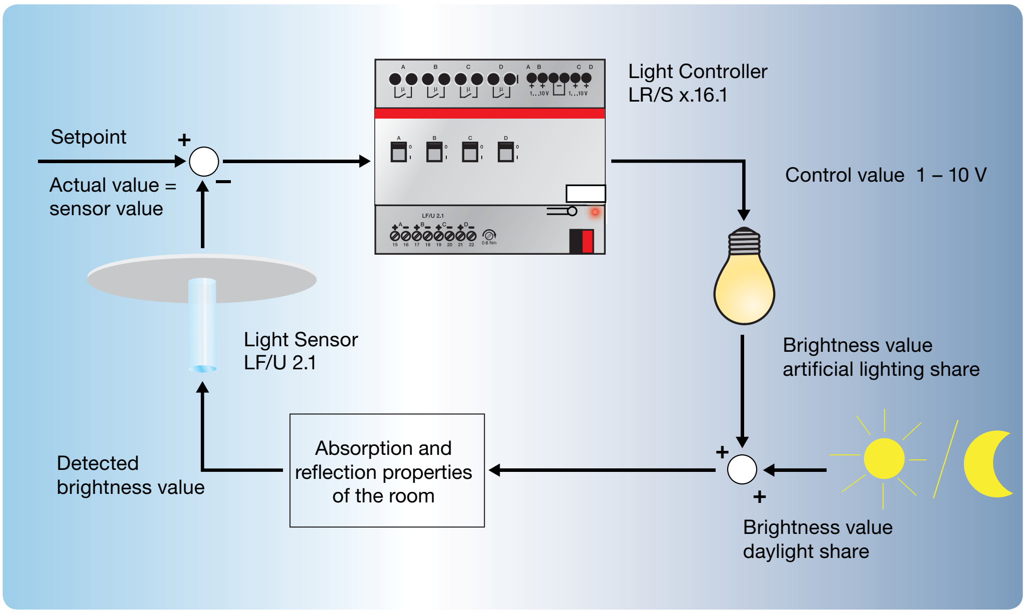
The following elaboration on the topic of constant lighting control should provide adequate background information to

– better understand the method of operation of a constant lighting control,
– ensure optimum placement of the light sensors required to detect the actual value,
– recognise critical ambient conditions which interfere with the function of the constant lighting control, and
– evaluate the physical limitations to which a constant lighting control is subject.

For this purpose it is necessary to understand the most important terms used in the field of lighting technology.

How does constant lighting control function?

In constant lighting control a light sensor installed on the ceiling measures the luminance of the surfaces in its detection range, e.g. the floor or the desks.



This measured value (actual value) is compared with the predefined setpoint value, and the control value is adjusted so that the divergence between the setpoint and actual values is minimal. If it is brighter outside, the share of artificial lighting is reduced. If it is darker outside, the share of artificial lighting is increased. The exact function of the light controller is described in detail in the manual of the Light Controller LR/Sx.16.1.

A Luxmeter placed underneath the light sensor, e.g. on a desk, is used for setting the setpoint. This Luxmeter detects the degree of illumination which illuminates the surfaces underneath the light sensor.

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The objective of a constant lighting control is to retain the set degree of illumination when a setpoint is set. To perfectly implement this objective, the light sensor should be placed exactly on the spot where the Luxmeter was placed to adjust the setpoint value, in order to also determine the degree of illumination. As this is not possible for practical reasons, the light sensor is generally mounted on the ceiling.

This is a compromise. For the reference setting of the setpoint, a Luxmeter is used for measurement of the degree of illumination; however, the light controller primarily detects the luminance underneath the light sensor. In this way the light controller indirectly maintains a constant degree of illumination.
If certain constraints are not observed with indirect measurement, it can mean that the constant lighting control will not function or not function as required.

This is not a specific phenomenon just affecting our constant lighting control, but rather is the case for all constant lighting controls.

What is the difference between degree of illumination and luminance?

In order to fully appreciate the problems relating to indirect measurement, it is necessary to examine the most important terms used in lighting technology. Only the basic terms are explained and we will forego a more exact and detailed explanation or mathematical derivation of more complex terms, e.g. luminous intensity = luminous flux/steradian.

A luminary, e.g. a fluorescent tube, converts electrical energy to light. The light rays emitted by a light source (luminous exitance) are referred to as a luminous flux.
The unit is the Lumen [lm]. Luminaries convert the input energy to light at varying degrees of efficiency.

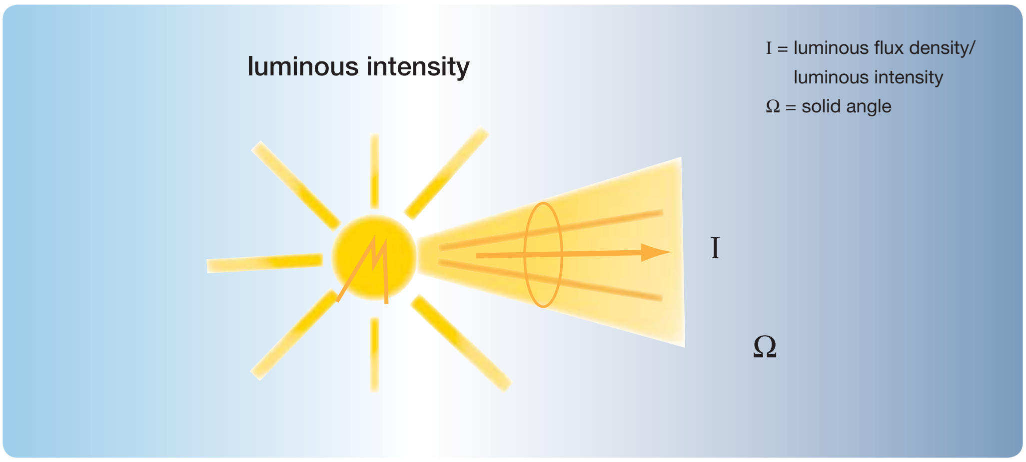
Category	Type	Overall luminous efficiency (lm/W)	Overall luminous efficiency
Incandescent lamp	5 W incandescent lamp	5	0.7 %
	40 W incandescent lamp	12	1.7 %
	100 W incandescent lamp	15	2.1 %
	Glass halogen	16	2.3 %
	Quartz halogen	24	3.5 %
	High temperature incandescent lamp	35	5.1 %
Fluorescent lamp	5 – 26 W energy saving light bulb	45 – 70	6.6 – 10.3 %
	26 – 70 W energy saving light bulb	70 – 75	10.3 – 11.0 %
	Fluorescent tube with inductive ballast	60 – 90	7 %
	Fluorescent tube with electronic ballast	80 – 110	11 – 16 %
Light emitting diode	Most efficient white LEDs on the market	35 – 100	5 – 15 %
	White LED (prototype, in development)	up to 150	up to 22 %
Arc lamp	Xenon arc lamp	typ. 30 – 50; up to 150	4.4 – 7.3 %; up to 22 %
	Mercury Xenon arc lamp	50 – 55	7.3 – 8.0 %
	High pressure mercury vapour lamp	36 (50W HQL) – 60 (400W HQL)	up to 8.8 %

Category	Type	Overall luminous efficiency (lm/W)	Overall luminous efficiency
Gas discharge lamp	Metal halide lamp	93 (70W HCI) – 104 (250W HCI)	up to 15 %
	High pressure sodium lamp	150	22 %
	Low pressure sodium lamp	200	29 %
	1400 W sulphur lamp	95	14 %
Theoretical maximum		683	100 %

Source: Wikipedia

In addition to the luminous flux there is the item luminous intensity, also referred to as the luminous flux density. The luminous intensity is measured in Candelas [cd]. The Candela is a measurement unit for luminous intensity emitted by a light source in a particular direction. An exact definition will lead to a complex mathematical analysis, e.g. the explanation of a steradiant.

Simplification: A luminous intensity of 1 cd corresponds to the measured degree of illumination of 1 lx at a distance of 1 m from the light source.



The luminous flux emitted by the light source illuminates the surfaces that it meets.
The intensity with which the surfaces are illuminated is referred to as the degree of illumination. The degree of illumination depends on the magnitude of the luminous flux and the size of the surfaces.

It is defined as follows:

$$E = \Phi / A \; [lx = lm/m^2]$$

E = degree of illumination
Φ = luminous flux in lm
A = illuminated surface

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In accordance with the above table, a 100 W incandescent lamp with 15 lm/W generates a maximum luminous flux of 1500 lm. If the entire luminous flux of the incandescent lamp is not emitted in a spherical manner into the room, but rather concentrated and distributed evenly on a surface of 1 m^2, then the value for the degree of illumination at every point on the surface would be 1500 lx.

The perceived brightness of an illuminated surface depends on the illuminated surface and the reflectance of the illuminated surfaces. The reflectance is the reflected share of the luminous flux from the illuminated surface. Typical values for the reflectance are:

90 %	highly polished silver
75 %	white paper
65 %	highly polished aluminium
20 – 30 %	wood
< 5 %	black satin

The perceived brightness of an illuminated surface or a self-illuminating surface, e.g. an LCD monitor, is designated as the luminance. The unit of luminance is cd/m^2.

If white paper is subject to a degree of illumination of 500 lx, then the luminance is about 130 – 150 cd/m^2. At the same degree of illumination, environmentally-friendly paper has a luminance of about 90 – 100 cd/m^2.

On what does the luminance measured by the light sensor respectively the measured value of the light sensor depend?

The luminance "primarily" detected by the light sensor depends on different criteria.

It depends on the degree of illumination which the surfaces in the detection range of the light sensor are illuminated. The higher the degree of illumination, the higher the luminance of the illuminated surfaces.

The same applies for the reflectance of the surfaces. The higher the reflectance, the higher the luminance of the surfaces and thus the measured value of the sensor. The measured value of the sensor is the actual value used for lighting control.

The installed height of the sensor also plays a role. If the light sensor was an ideal "luminance measurement device", then the luminance which it measures would be independent of the installation height of the light sensor. As this is not the case, the measured value of the sensor decreases as the installation height increases.

A further criterion for the measured value of the light sensor is its directional characteristic. The light sensor primarily detects the luminance of the surface located below it.

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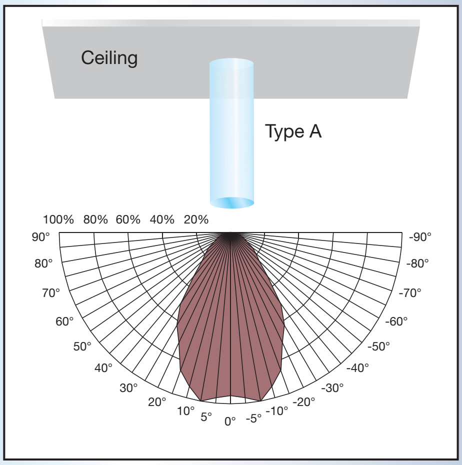

As evident from the above graphic, the 3 dB angle of aperture of the Light Sensor LF/U 1.1 used up to now is about 60°.

An example: At an installed height of about three meters, the diameter of the detection range underneath the light sensor is about five meters. The luminance of all illuminated or self-illuminating surfaces within this circle will be detected by the light sensor.

The prevalent conditions in the room are closely associated with the directional characteristic. In practice highly reflective window sills or walls have exhibited negative influences.

In this image, the highly reflective white window sills in the detection range of the light sensor which is mounted just two meters from the windows, can be seen.

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Reflections from cabinets or plate glass located in the direct vicinity of the light sensor in the following image are also detected by the light sensor.

The reflections can originate both from vertical surfaces (doors) as well as from the upper surfaces.

Furthermore, sun screening which is directly subjected to the suns rays, e.g. shutters or blinds, affect the light sensor when located in the detection range.

In particular, the ceiling in the direct vicinity of the window is subjected to more daylight than the ceiling further away from the window.

Depending on the distance of the light sensor from the window, the lateral light fall onto the light sensor can heavily distort the actual measured value of the light sensor in its detection range. The light sensor has a defined directional characteristic. However, when the lateral degree of illumination to which it is subject is factors greater than the luminance in its detection range, the directional characteristic is no longer adequate.

On what does the degree of illumination detected by the Luxmeter depend?

Luxmeters detect the degree of illumination at the measurement location and have a so-called horizontal circular characteristic, i.e. they evaluate the incidental luminous flux from all horizontal directions at the measurement location in the same way. On the other hand, the vertical incidence is evaluated in a different way. Light falling vertically on the Luxmeter from above is assigned a greater valuation than a lateral incidence of light. The term used here is cosine correction. At the same time, the spectral distribution in the range from 380 nm to 780 nm is evaluated with the sensitivity of the human eye.

Unfortunately, different measurement results are measured at the same measurement location under the same measurement conditions using different measurement devices.

In the above image, the measurement device on the left indicates 948 lx, the device in the centre (yellow) 765 lx and the device on the right 827 lx. The divergences can be dependent to a lesser or greater extent on whether you are dealing with daylight, artificial light or mixed lighting, or whether the devices are located in the shadows or directly subjected to the suns rays.

At the same measurement location, both the devices on the left exhibit very different values, and on the right of the image they exhibit almost identical values with different lighting conditions due to the incidence of light with slight shadows.

For this reason it is essential to use the same measurement device (Luxmeter) you used for set up for any subsequent checks. Only so can you obtain comparative results.

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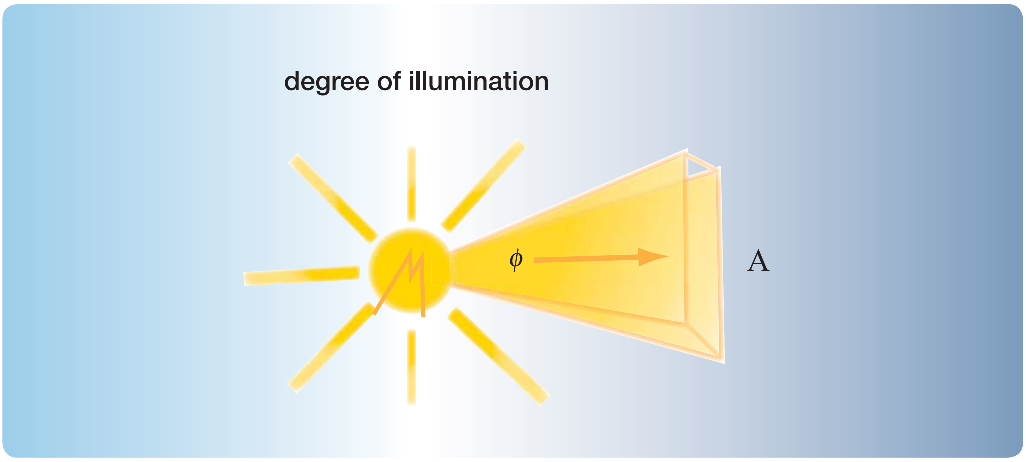
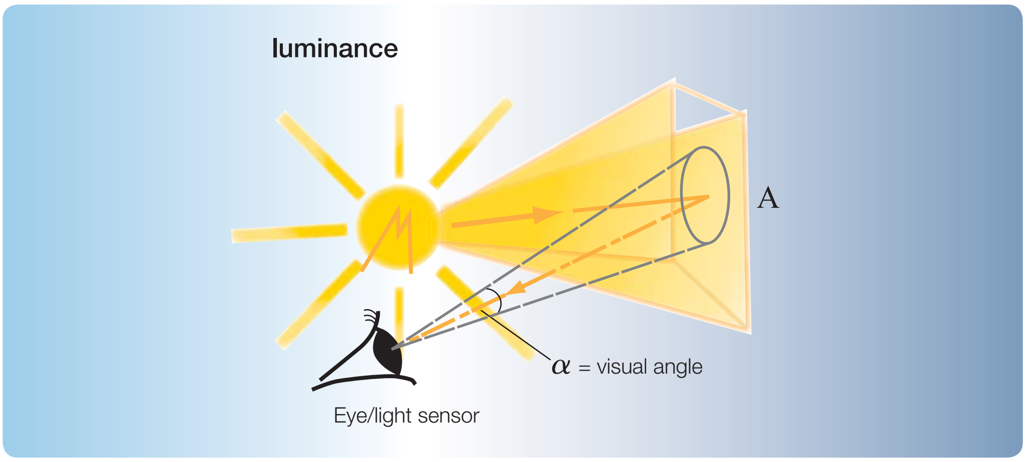
Difference between a light sensor – Luxmeter

Whereas the light sensor detects the light reflected from the surfaces in its detection range, the Luxmeter detects the artificial light and/or the direct sunlight shining through the windows, or the diffused daylight when the sky is overcast. This is shown again in the drawing below for clarification.





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What problems result due to direct measurement of the degree of illumination for setpoint adjustment and the indirect measurement of the luminance for lighting control?

Under the prerequisite that
– the spectral distribution of the light does not change,
– the angle of incidence of the light on the light sensors and Luxmeter does not change
– the reflection properties of the room in the detection range of the light sensor and the Luxmeter do not change
there is almost a linear relationship between the measured value of the light sensor and the degree of illumination, i.e. the measured value of the light sensor changes proportional to the change of the degree of illumination.

Thus it is possible in principle, to determine the degree of illumination for the light control as an actual value by indirectly detecting the luminance.

The influence of spectral distribution

As the ratio of the levels of artificial and natural lighting sources, and accordingly the spectral distribution of the light change during the course of the day using constant lighting control, different measured values can result at the measurement location of the light sensor at a degree of illumination which is kept constant. Inversely, the logical consequence dictates that when there are constant measured values on the light sensor (achieved using lighting control), different degrees of illumination are the result.

In order to avoid this effect it is necessary to compensate for the different levels of daylight and artificial light on the light sensor. This is implemented on the new Light Controllers LR/S x.16.1 by a calibration with artificial light and daylight.

For this purpose the setpoint is set using pure artificial light. The light controller stores the respective actual value of the sensor as a setpoint and the corresponding control value for control of the artificial lighting. Subsequently the light controller then passes through the entire control value range from 0…100 % and also stores the corresponding actual values. Accordingly, the light controller is aware of the actual value required for a control value using purely artificial lighting.

Then a daylight calibration is undertaken. For this purpose the setpoint is set during daylight and without artificial lighting. Accordingly, the light controller is then aware of the actual value required for the setpoint using daylight only.

Using the values determined from both calibrations, the controller calculates the correction factors required for the different ratios of daylight and artificial lighting that are required to keep the degree of illumination constant irrespective of the indirect detection of the luminance.

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The angle of incidence of the light on light sensors and Luxmeter

If the daylight calibration is performed with diffused daylight, e.g. overcast conditions, a determined value is set for the degree of illumination on the light sensor at a predefined lux value.

If the daylight calibration is undertaken in bright sunshine – it is possible that at the same predefined lux value for the degree of illumination – a significantly different divergent lux value is set with the light sensor.

Reasons for example include that by different incidence angles of the light the light sensor and the Luxmeter are subject to different influences, or reflections occur on bright or mirrored surfaces which affect the light sensor but do not affect the Luxmeter.

The best solution in such cases is to offset the light sensor so that it will react to different lighting conditions in the same way as the Luxmeter. Generally this is undertaken by observing the surfaces underneath the light sensor and on the light sensor with different lighting conditions.

One of the methods generally not used in practice because of the time involved is determination of the optimum position of the light sensor by experimentation.

An example: In a non-representative room in the basement of a building, the degree of illumination and the ratio of degree of illumination floor/ceiling has been determined at different positions in the room (in ceiling width division units at distances from the window) in the morning and afternoon using a Luxmeter on the ceiling (red) and at desk level (blue).

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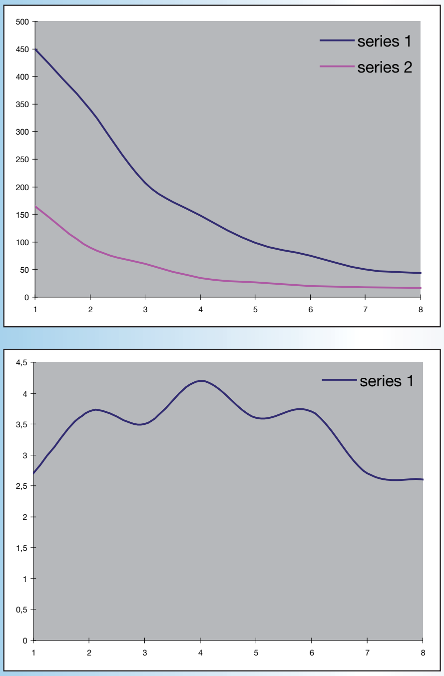
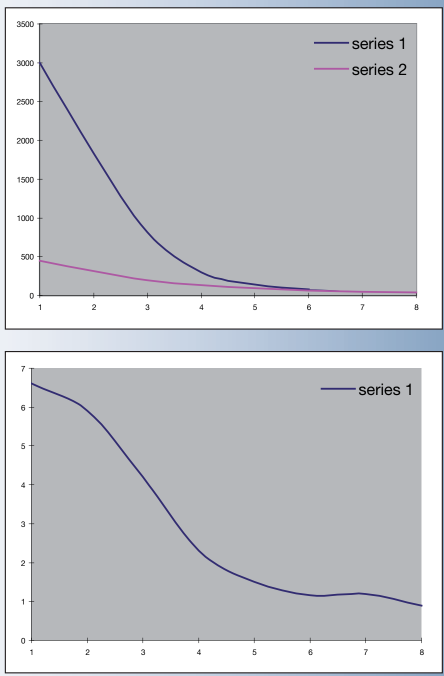


Measurements in the morning



Measurements in the afternoon

As evident in the diagrams, in the morning (no direct sunshine in the room) the ratio is in the range between 2.7 and 4.2; in the afternoon on the other hand (direct sunshine into the room) it is between 0.9 and 6.6.

This means that at a distance of 3.5 ceiling width division units from the window, the Luxmeter on the ceiling always indicates a level which is 3.75 times higher on the ceiling than on the floor, irrespective of the type of lighting. At other locations both Luxmeters indicate values which differ by one or more factors of magnitude depending on the type of lighting.

For ease of handling the measurements have been carried out using two Luxmeters. If you wanted to determine the optimum position of the light sensor using this method, it would be necessary to perform the measurements with a Luxmeter at desk level and a light sensor on the ceiling.

Through the simplified measurement with two Luxmeters, it becomes evident what is of importance with the positioning of the light sensor. It is necessary to determine the position where the Luxmeter and light sensor are influenced in the same way when subjected to different lighting conditions.

In practice the optimum position for the light sensor in most cases has generally proven to be the area from the middle of the room to the rear third of the room furthest from the windows.

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The reflection properties of the room in the detection range

As stated at the outset, the luminance of a surface depends on the degree of illumination and the reflection properties of this surface.

On a dark carpet the reflection factor is in the range of 5 – 10 %, whereas a wooden floor is about 20 – 30 %. If a light gray desk is located below the light sensor, its reflection factor is about 50 %.

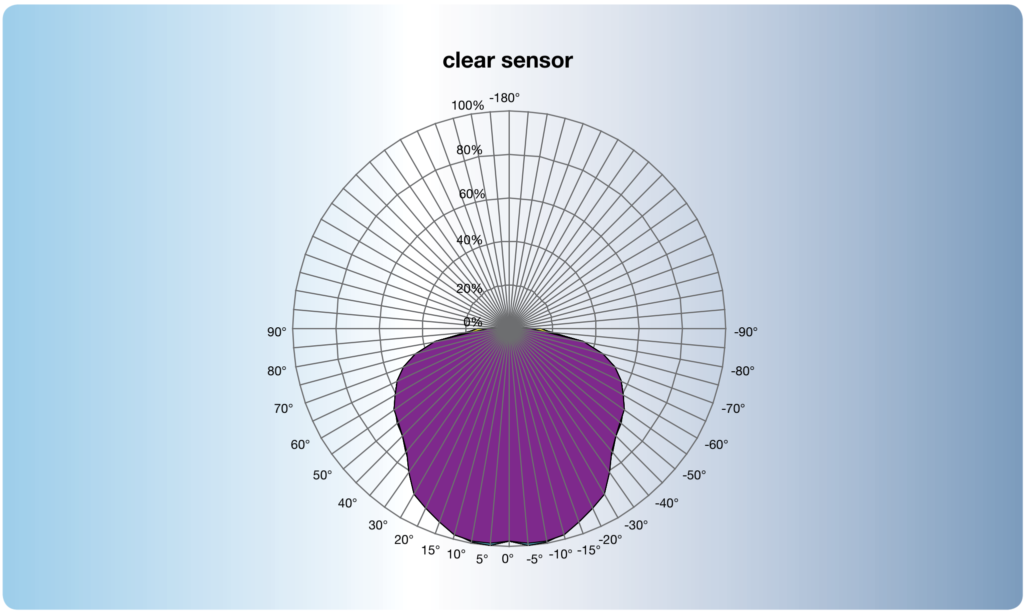
It is therefore evident that it is not very useful to set-up a constant lighting control before the room is fully furnished.

If for example a setpoint is set when no furniture and just a dark carpet is located in the room, then the value to be set will be significantly higher after than the setpoint originally set after the room has been furnished with bright furniture.

Changes/modifications to the furniture made during operations, movement of partitions, changes of wall colours etc., may require a renewed setting of the setpoint and may even necessitate displacement of the light sensor.

Selection of the light sensor rod

The Light Sensor LF/U2.1 in conjunction with the clear sensor rod introduced in mid-2008 features a 3 dB angle of aperture of about 120°, i.e. it detects the luminance of a relatively large area underneath the installation location.



Below an angle of about 70° the incidence of lateral light on the light sensor is practically not attenuated. Light which falls on it at an angle of 85 – 90° is however very strongly attenuated (total reflection on the clear rod).

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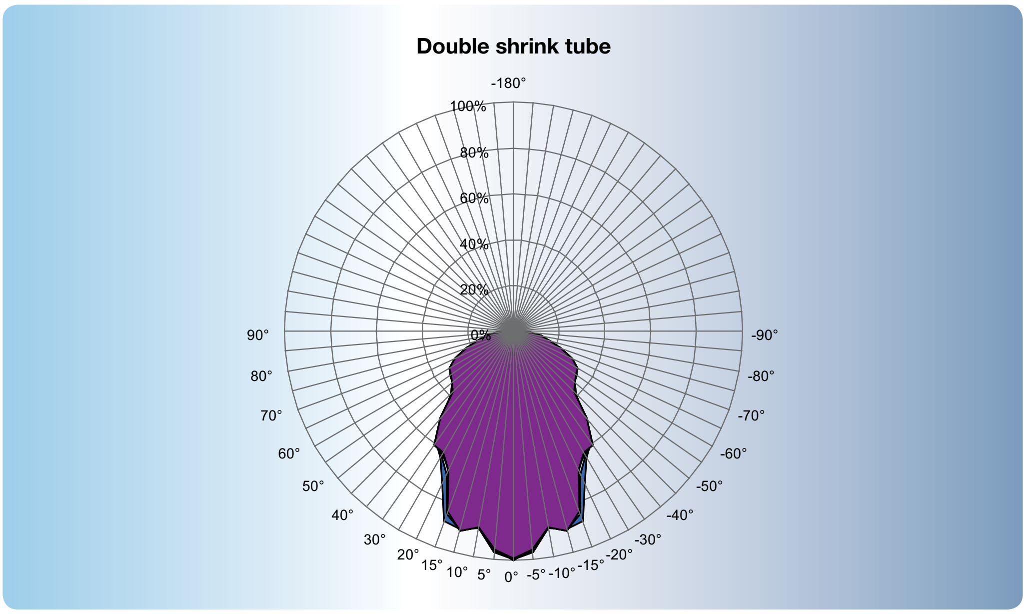
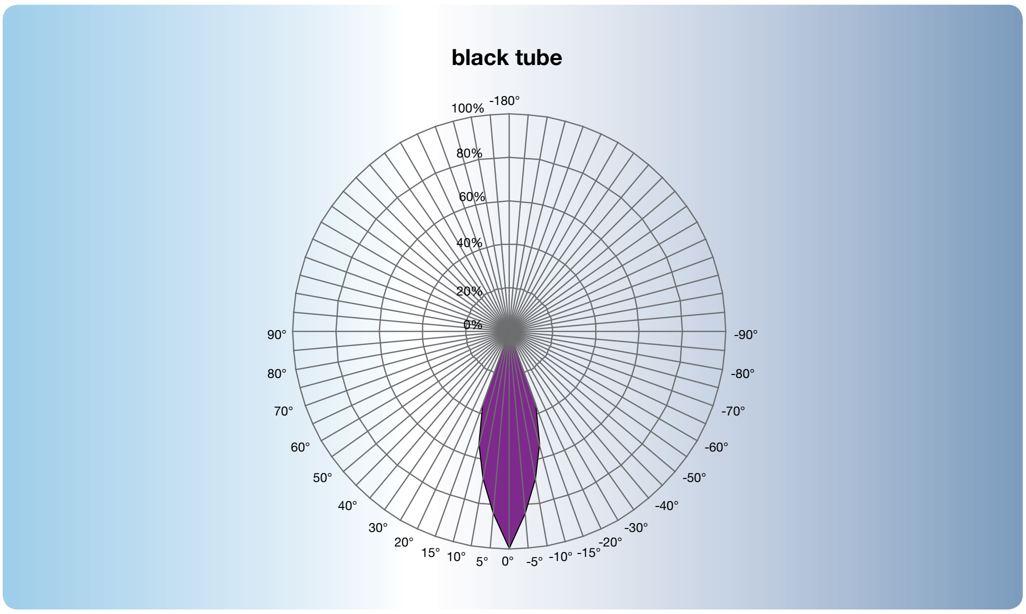
Practical application has shown that in critical ambient conditions a covering of the rod may be necessary, in order to suppress the influence of the lateral incidence of light as much as possible.

For this reason a rod painted gray or with a shrinkable tubing covered rod has been available since mid-2008 which features a significantly smaller angle of aperture of about 40°.



When this rod is used, influences through the lateral incidence of light are reduced significantly. Furthermore, the control is more sensitive to changes in the detection range of the light sensor, e.g. the exchange of a dark desk pad by a brighter desk pad.

If in extreme cases the use of a covered rod may not be possible, then you can – as was previously the solution in such cases – cover the rod with the jacket of a NYM cable. Thus it produces similar conditions as with the use of a black tube as shown here..



Positioning of the light sensor

The following should be observed when positioning the light sensor as indicated in the instructions in this manual:

The optimum positioning of the light sensor is only possible in a room which is fully furnished/ in its intended state.

As this is generally not possible to determine the position of the light sensor on the basis of drawings in the planning phase, it is necessary to proceed as follows:

As the installation location for the light sensor, the area from the middle of the room to the rear third of the room furthest from the windows is preferred.

If this is already shown on the drawings, it is necessary to ensure that the light sensor is not directly illuminated by the lamps, e.g. from uplights or lamps in the direct vicinity.

The lateral distance from lights to the light sensor should be as great as possible.

The information in this leaflet is subject to change without further notice.

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