

**Lamp measurement report – 28 July 2009**

Line Lite International BV  
MR11 3W 12V AC/DC CW Cree



*Photo courtesy by [www.OliNo.org](http://www.OliNo.org)*




## Lamp measurement report – 28 July 2009

### Summary measurement data

parameter	meas. result	remark
Color temperature	7307 K	Cold white
Luminous intensity $I_v$	493 Cd	
Beam angle	18 deg	
Power P	2.3 W	
Power Factor	0.66	For every 1 kWh net power consumed, there has been 1.1 kVAhr for reactive power..
Luminous flux	81 lm	
Luminous efficacy	36 lm/W	
CRI_Ra	80	Color Rendering Index.
Coordinates chromaticity diagram	x=0.3026 and y=0.3119	
Fitting	MR11	
PAR-value	5.1 $\mu\text{Mol/s/m}^2$	The number of photons seen by an average plant when it is lit by the light of this light bulb. Value valid at 1 m distance from light bulb.
S/P ratio	2.3	This factor indicates the amount of times more efficient the light of this light bulb is perceived under low environmental light levels.
D x H external dimensions	35 x 35 mm	External dimensions of the light bulb.
D luminous area	20 mm	Dimensions of the luminous area (used in Eulumdat file). This is equal to the diameter of the transparent disk at the front side.
General remarks		<p>The ambient temperature during the whole set of measurements was 26-29 deg C.</p> <p>Warm up effect: during the warm up time the illuminance and consumed power decreased with 8 % and 4 % respectively.</p> <p>Voltage dependency: the power consumption depends little on the voltage applied. At the end an extra photo of the light bulb.</p>

## Lamp measurement report – 28 July 2009

### Overview table

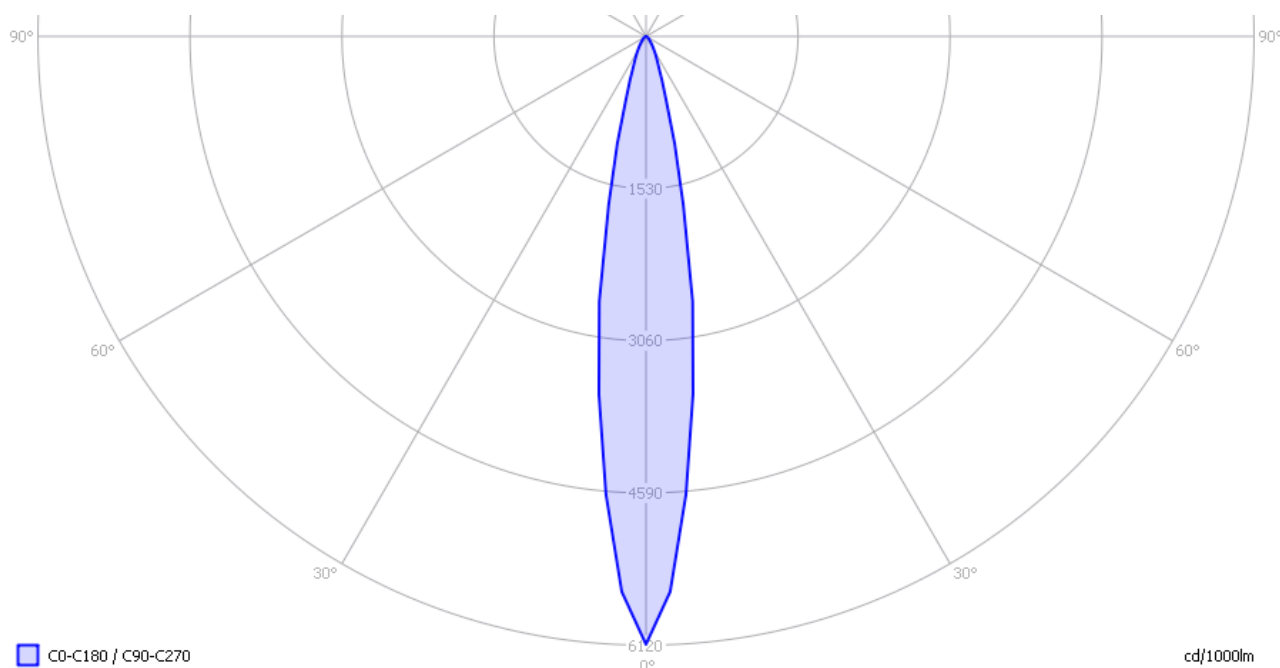
m.	Ø 50%	18°	E (lux)	Efficacy
0.25	0.08		7885	36 (lumens per Watt)
0.5	0.16		1971	Half Peak Diameter
1	0.32		493	0.32 x diameter(m)
1.5	0.48		219	Illuminance
3	0.96		55	493 / distance <sup>2</sup> (lux)
				Total Output
				81 (lumens)

The illuminance values are measured in the far field (i.e. at least 5 times the distance of the largest illumination dimension) such that the light bulb can be seen as a point source. From this distance the values are calculated to values at the given distances. If the light is not anymore a point source at any given distance, then the real measured values (with an actual lux meter) will be lower than indicated in this table.

### Eulumdat light diagram

An interesting graph is the light diagram, indicating the intensity in the C0-C180 and the C90-C270 plane. This light diagram below comes from the program Qlumedit, that extracts these diagrams from an Eulumdat file.

## Lamp measurement report – 28 July 2009



*The light diagram giving the radiation pattern.*

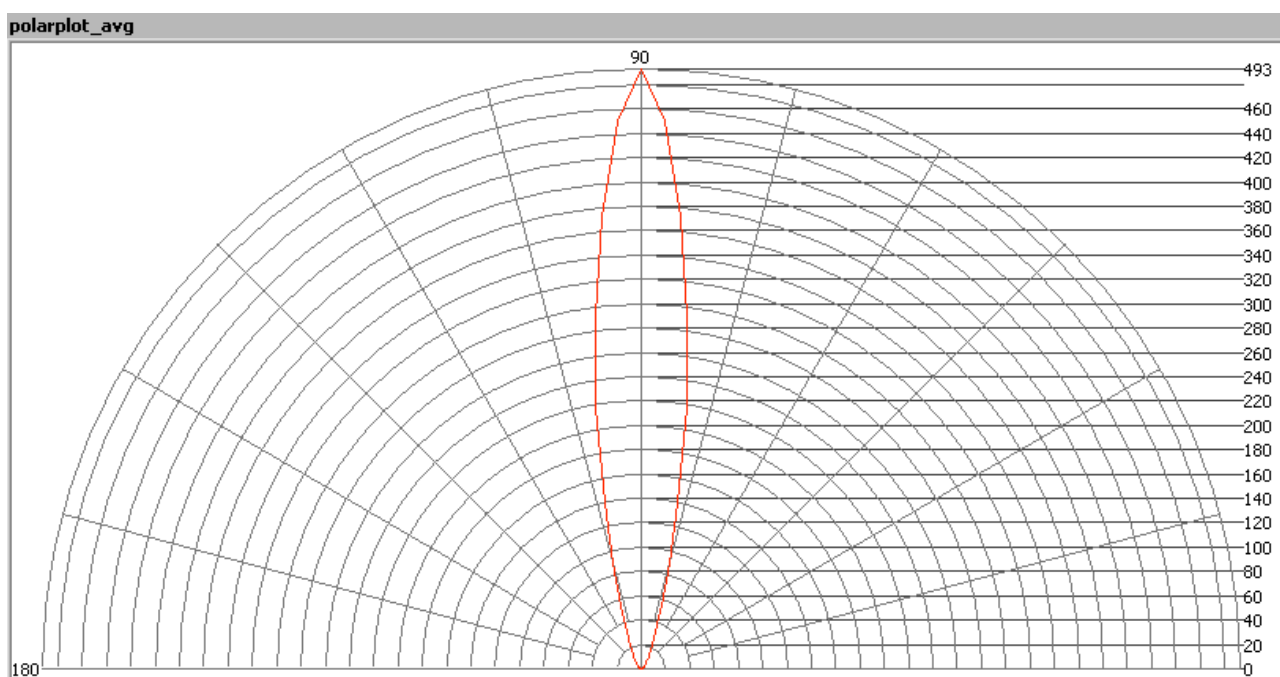
It indicates the luminous intensity around the light bulb. This light bulb has the same light diagram for the C0-C180 as for the C90-C270 plane since it has symmetry over 360 degrees. It produces a very focused beam.

The unit is Cd/1000lm, meaning the intensity in Cd assuming there would be 1000 lumen in the measured light bulb. This enables comparing different types of light bulbs.

### Illuminance $E_v$ at 1 m distance, or luminous intensity $I_v$

Herewith the plot of the *averaged* luminous intensity  $I_v$  as a function of the inclination angle with the light bulb.

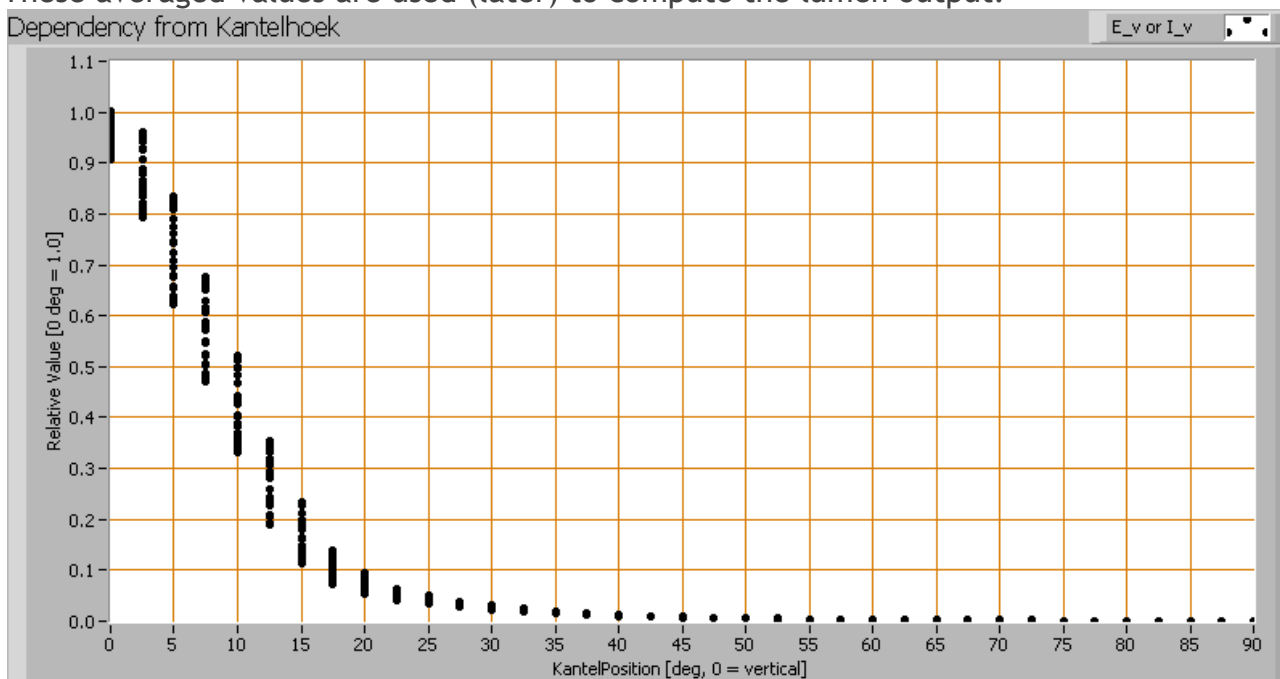
## Lamp measurement report – 28 July 2009



*The radiation pattern of the light bulb.*

This radiation pattern is the average of the light output of the light diagram given earlier. Also, in this graph the luminous intensity is given in Cd.

These averaged values are used (later) to compute the lumen output.



*Intensity data of every measured turn angle at each inclination angle.*



## Lamp measurement report – 28 July 2009

This plot shows per inclination angle the intensity measurement results for each turn angle at that inclination angle. There normally are differences in illuminance values for different turn angles. However for further calculations the averaged values will be used. When using the average values per inclination angle, the beam angle can be computed, being 18 degrees. This is the average value but as the light bulb has a symmetry over 360 degrees, this angle is valid for all turn-angles the light bulb is looked at.

### Luminous flux

With the averaged illuminance data at 1 m distance, taken from the graph showing the averaged radiation pattern, it is possible to compute the luminous flux. The result of this computation for this light spot is a luminous flux of 81 lm.

### Luminous efficacy

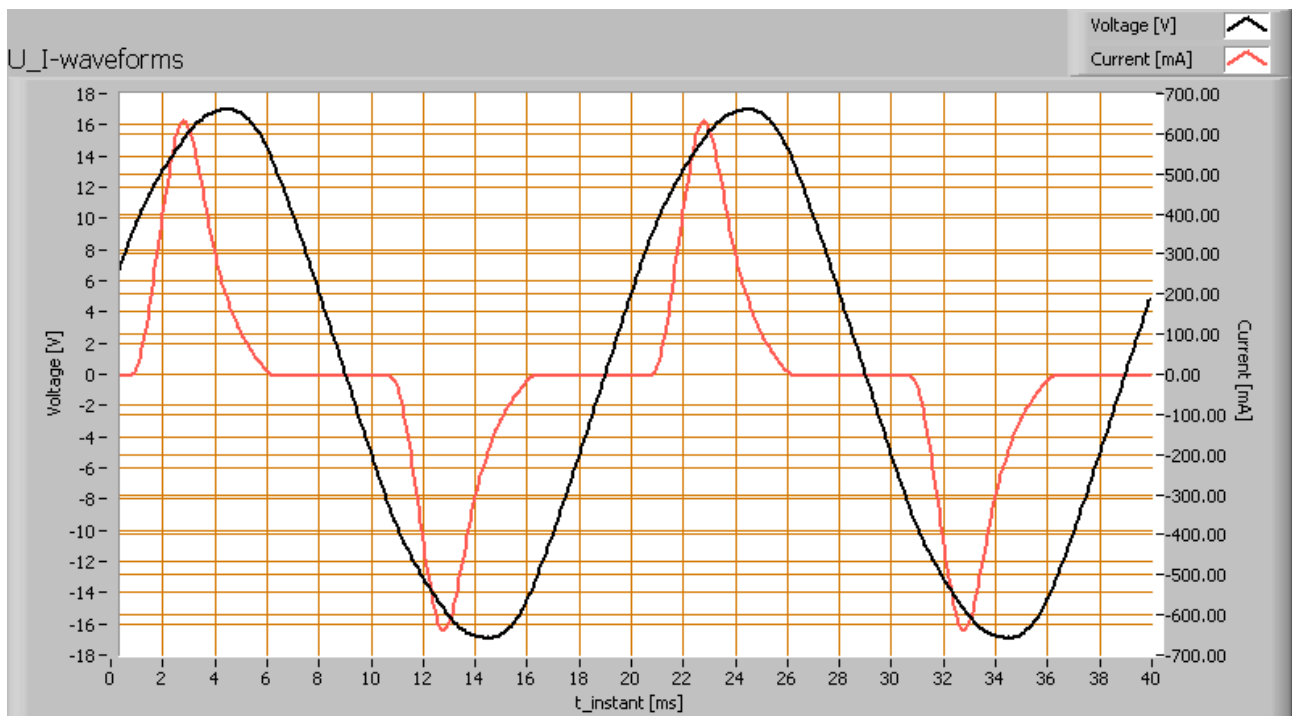
The luminous flux being 81 lm, and the power of the light bulb being 2.3 W, yields a luminous efficacy of 36 lm/W.

A power factor of 0.66 means that for every 1 kWh net power consumed, a reactive component of 1.1 kVAr was needed.

Light bulb voltage	12 VAC
Light bulb current	29 mA
Power P	2.3 W
Apparent power S	3.5 VA
Power factor	0.66

Of this light bulb the voltage across and the resulting current through it+its constant current driver power supply are measured and graphed.

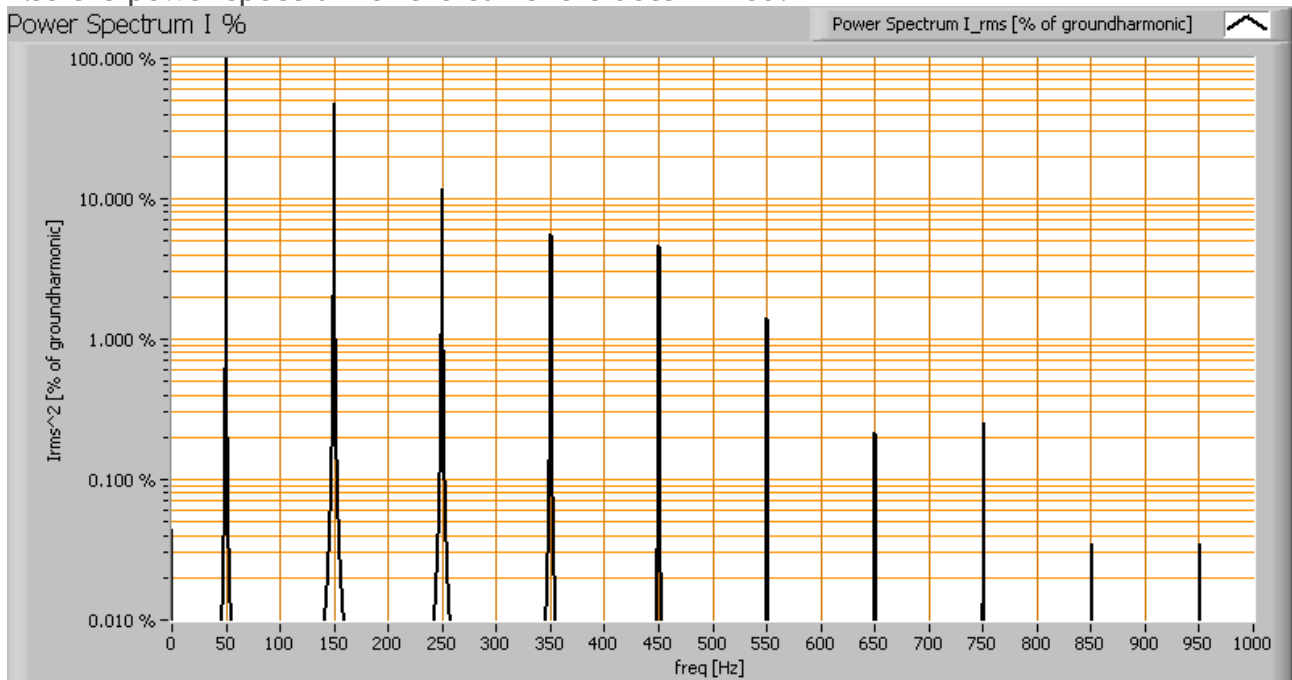
## Lamp measurement report – 28 July 2009



*Voltage across and current through the lightbulb*

The current is not in phase with the voltage and has not a sinusoidal form. Hence the power factor is low.

Also the power spectrum of the current is determined.

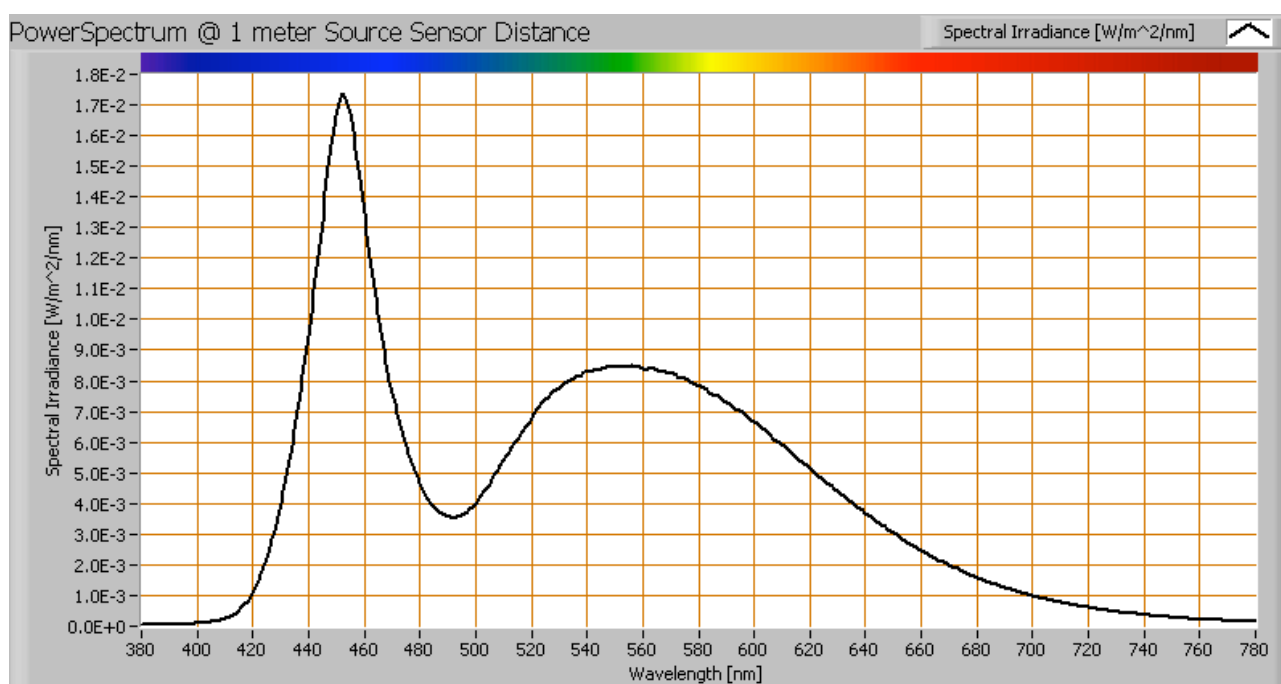


## Lamp measurement report – 28 July 2009

*Current power spectrum in % of the first harmonic (50 Hz).*

Due to the peaks in current a lot of higher harmonics are in the current.

## Color temperature and Spectral power distribution

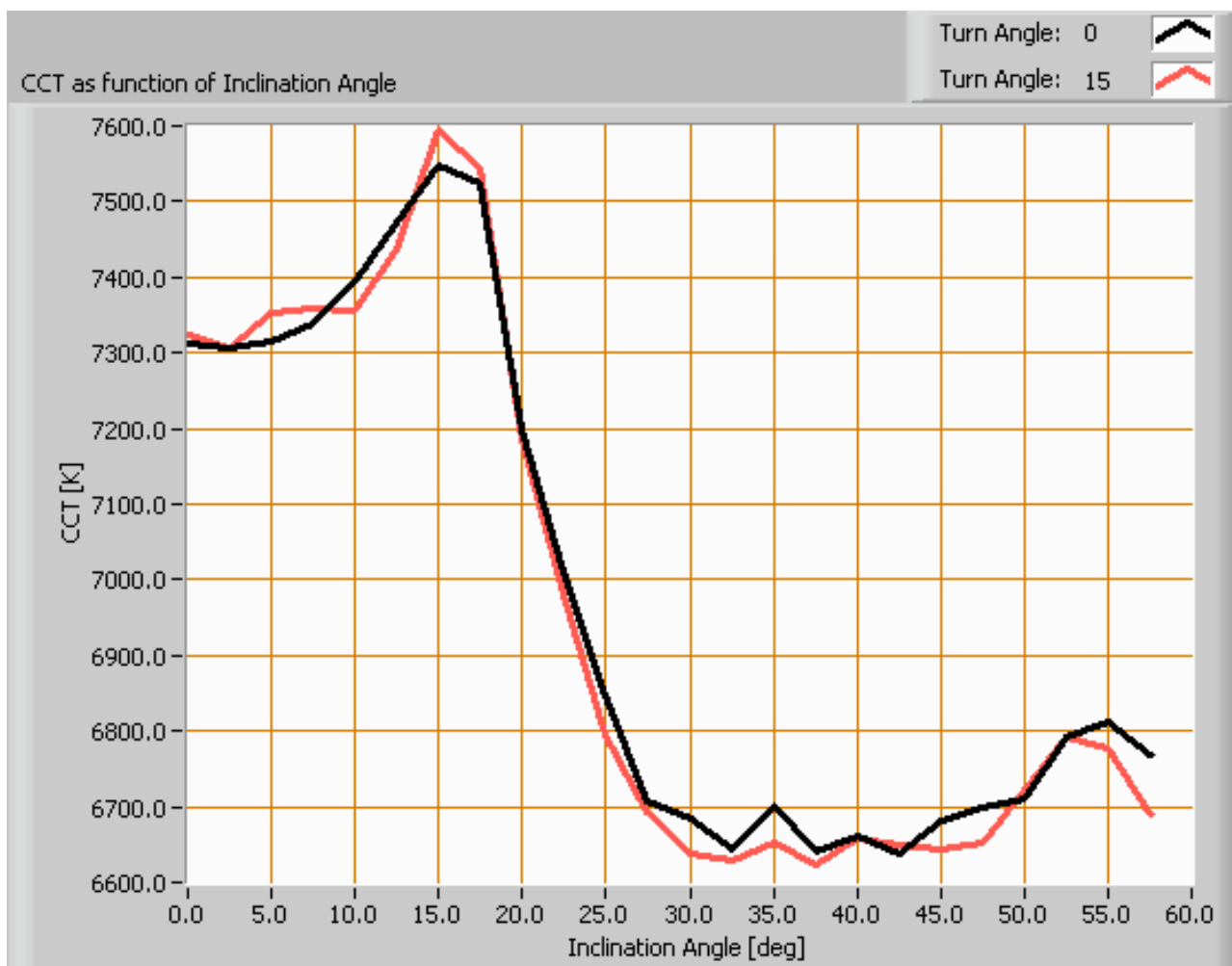


*The spectral power distribution of this light bulb, energies on y-axis valid at 1 m distance.*

The measured color temperature is about 7300 K which is cold white.

This color temperature is measured straight underneath the light bulb. Below a graph showing the color temperature for different inclination angles.

## Lamp measurement report – 28 July 2009



*Color temperature as a function of inclination angle.*

The beam angle is 18 degrees, meaning at an inclination angle of 9 degrees there is 50 % left of the initial illuminance value at 0 degrees. Most of the light energy is within this area. In this area the color temperature remains within 1 % of its value at 0 degrees inclination angle.

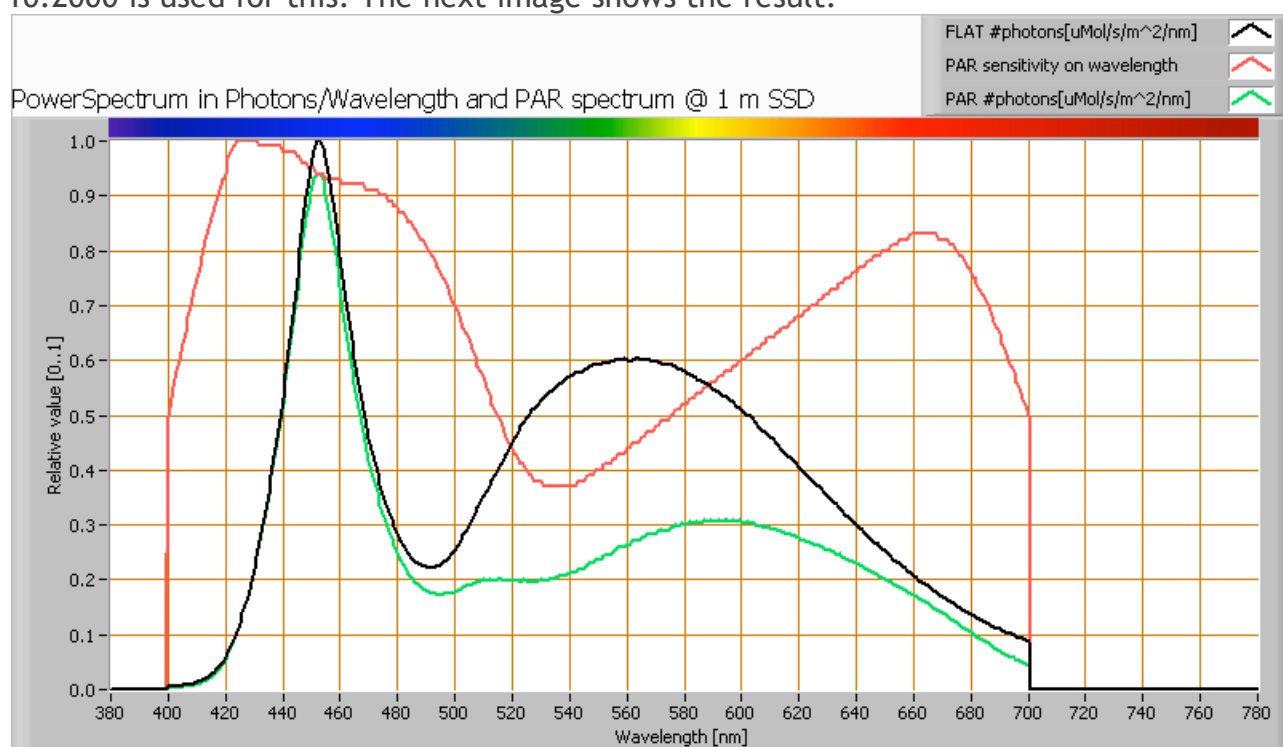
### PAR value and PAR spectrum

To make a statement how well the light of this light bulb is for growing plants, the PAR-area needs to be determined. PAR stands for Photosynthetic Active Radiation which is that radiation that participates actively to photosynthesis and is expressed in  $\mu\text{Mol/s/m}^2$ . Photosynthesis is the essence for growth and flowering of plants, where the blue part of

## Lamp measurement report – 28 July 2009

the light spectrum is responsible for growth and the red part is responsible for flowering and budding (for gemmation). For photosynthesis it is more important to count the number of photons rather than the power in the light.

The power spectrum (power per wave length) of the light of the light bulb is converted into the number of photons (number of photons per wave length) and then these number of photons is weighted against the relative sensitivity of an average plant (which varies in value dependent on the wave length). The relative sensitivity curve in DIN-norm 5031-10:2000 is used for this. The next image shows the result.



*The photon spectrum, then the sensitivity curve and as result the final PAR spectrum of the light of this light bulb*

The black curve gives the power spectrum of the light of this light bulb, in number of photons per wave length.

In red the relative sensitivity curve of an average plant (according to DIN norm 5031-10:2000).

Multiplying these two results in a curve showing the number of photos per wave length of the light of this light bulb, the PAR spectrum.

Summing all the photons, gives a PAR number that for this light results in 5.1  $\mu\text{Mol/s/m}^2$ . This value is valid at 1 m distance from the light bulb.



## **Lamp measurement report – 28 July 2009**

Dividing the PAR number by the total number of photons of the light of this light bulb gives a sort of PAR efficiency, which is 67 % (valid for the PAR wave length range of 400 - 725 nm). So maximally 67 % of the total of photons in the light is effectively used by the average plant (since the plant might not take 100 % of the photons at the frequency where its relative sensitivity is 100 %).

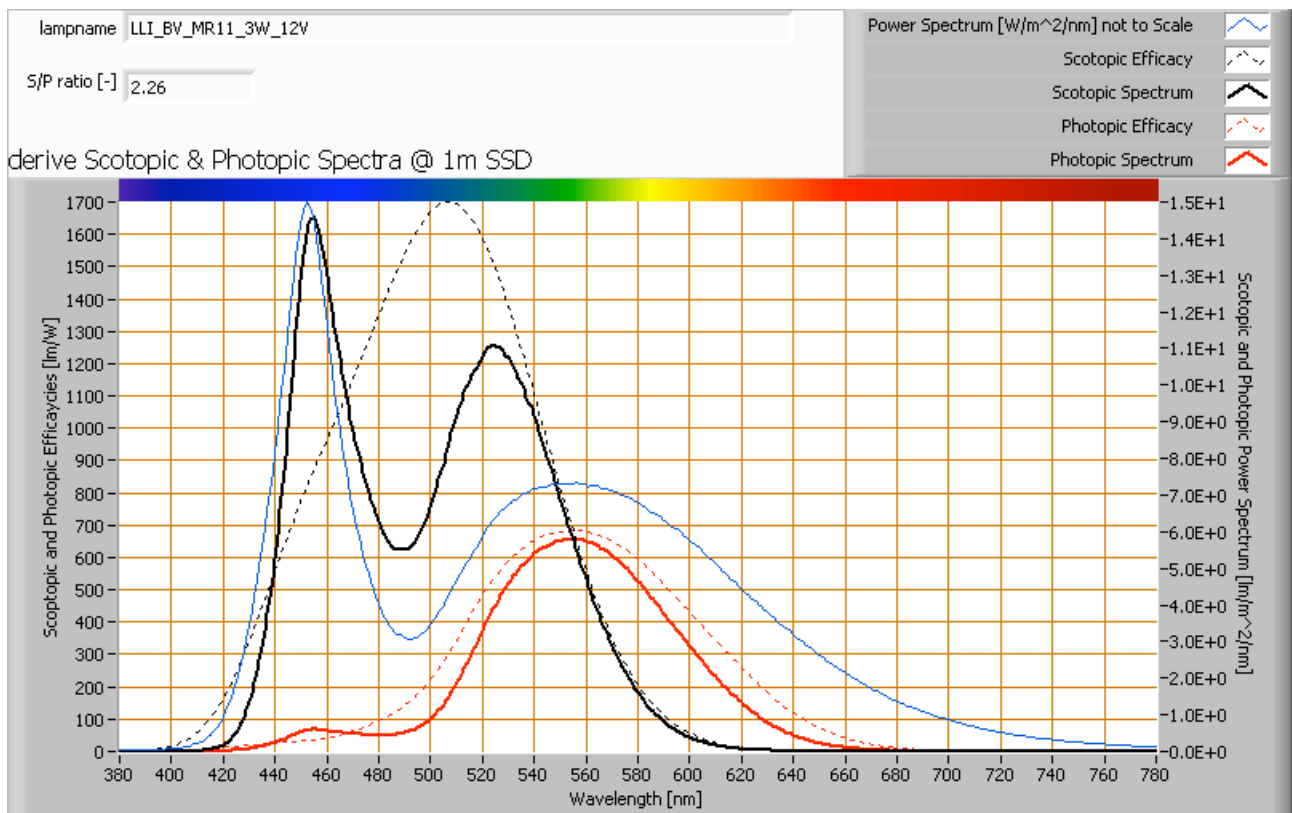
Note: when mentioning this percentage of efficiency, it is important to verify if all wavelengths are present in a sufficient manner. Not that only blue light is available, when the plant is going to be used for flowering where specifically red light is needed.

### **S/P ratio**

The human eye uses rods and cones. The rods work at scotopic light levels (twilight, night) and the rods at high(er) light levels (daytime, but also close to twilight). Each type of receptor has its own sensitivity for light. The rods are 2.7 times more sensitive than cones, and most for light at a blueish-greenish color whereas compared to the cones' sensitivity for green light (555 nm). The S/P ratio gives the maximum difference in sensitivity of the rods at their most sensitive wavelength compared to the cones at their's. The more blueish (cold white) the light, the more the S/P ratio can be.

The light of this light bulb has a certain spectrum leading to an S/P ratio of 2.3. The light of this lightbulb at scotopic light levels is perceived this factor higher than it would be a photopic light levels.

## Lamp measurement report – 28 July 2009

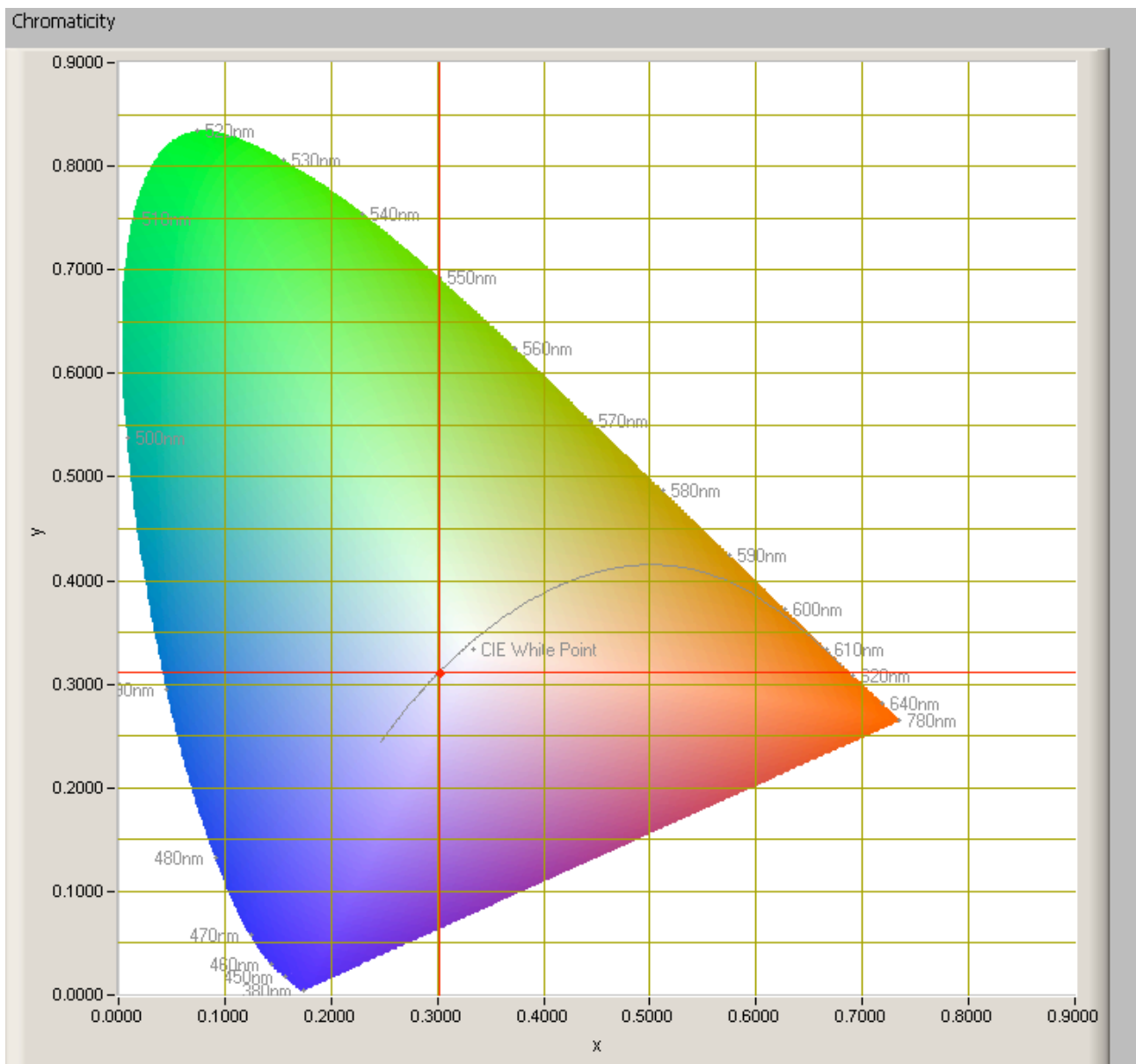


*The power spectrum, sensitivity curves and resulting scotopic and photopic spectra (spectra energy content defined at 1 m distance).*

Since there is a lot of blue in the spectrum, the S/P ratio is big.  
More info will come in a separate article.

## Lamp measurement report – 28 July 2009

### Chromaticity diagram



*The chromaticity space and the position of the lamp's color coordinates in it.*

The light coming from this lamp is on top of the Planckian Locus (the black path in the graph).

Its coordinates are  $x=0.3026$  and  $y=0.3119$ .

## Lamp measurement report – 28 July 2009

### Color Rendering Index (CRI) or also Ra















Herewith the image showing the CRI as well as how well different colors are represented (rendered). The higher the number, the better the resemblance with the color when a black body radiator would have been used (the sun, or an incandescent lamp).

Each color has an index Rx, and the first 8 indexes (R1 .. R8) are averaged to compute the Ra which is equivalent to the CRI.

☐ manual

Reference Illuminant: Planckian radiator CCT 7307 K

Chromaticity Difference DC= 3.5E-3

R1= 79.1		R8= 71.5	
R2= 84.6		R9= 7.1	
R3= 84.2		R10= 59.4	
R4= 79.5		R11= 75.6	
R5= 78.9		R12= 51.5	
R6= 76.5		R13= 80.7	
R7= 88.1		R14= 90.9	

**Ra**  
(mean value of R1 - R8)  
**80.3**

*CRI of the light of this lightbulb.*

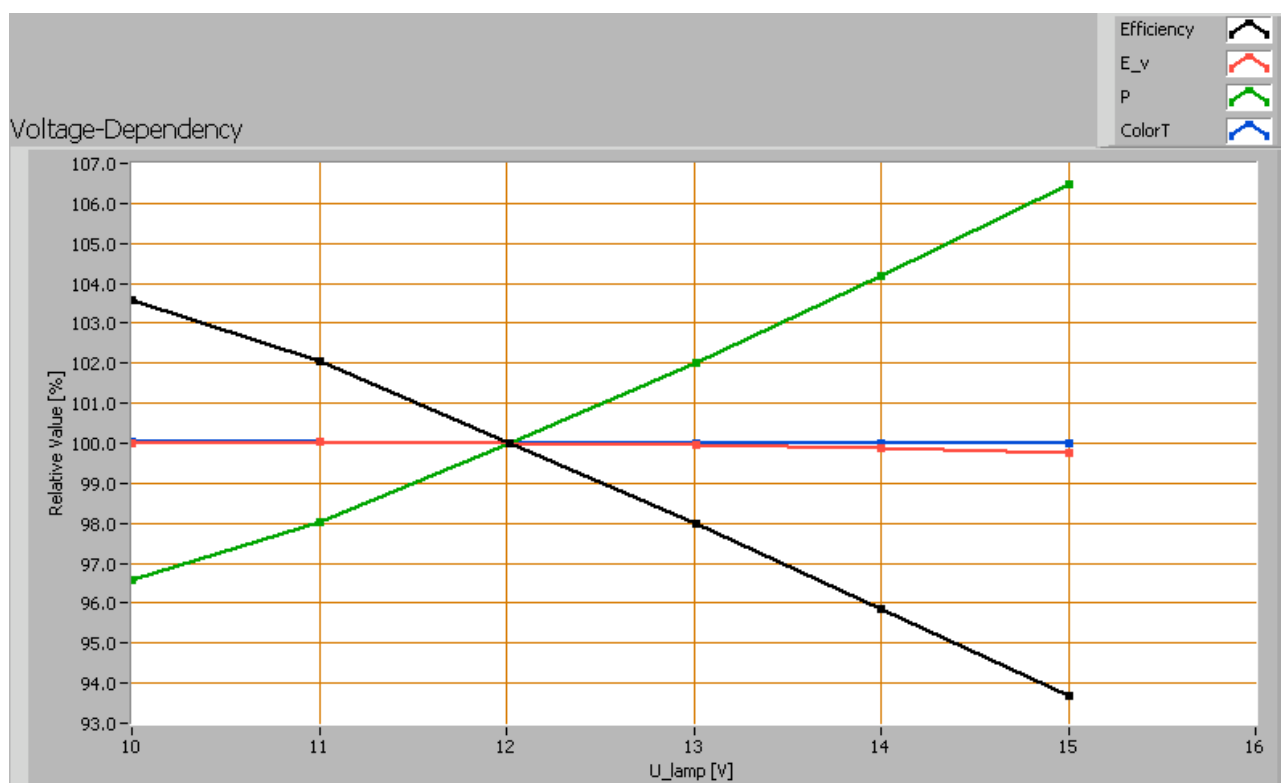
The value of 80 is equal to 80 which is considered a minimum value for indoor usage.

Note: the chromaticity difference is 0.0035 indicates the distance to the Planckian Locus. Its value is lower than 0.0054, which means that the calculated CRI result is meaningful.

### Voltage dependency

The dependency of a number of lamp parameters on the lamp voltage is determined. For this, the lamp voltage has been varied and its effect on the following light bulb parameters measured: illuminance E\_v [lx], the lamp power P [W], the (Correlated) Color Temperature [K] and the luminous efficacy [lm/W].

## Lamp measurement report – 28 July 2009



Lamp voltage dependencies of certain light bulb parameters, where the value at 12 V is taken as 100 %.

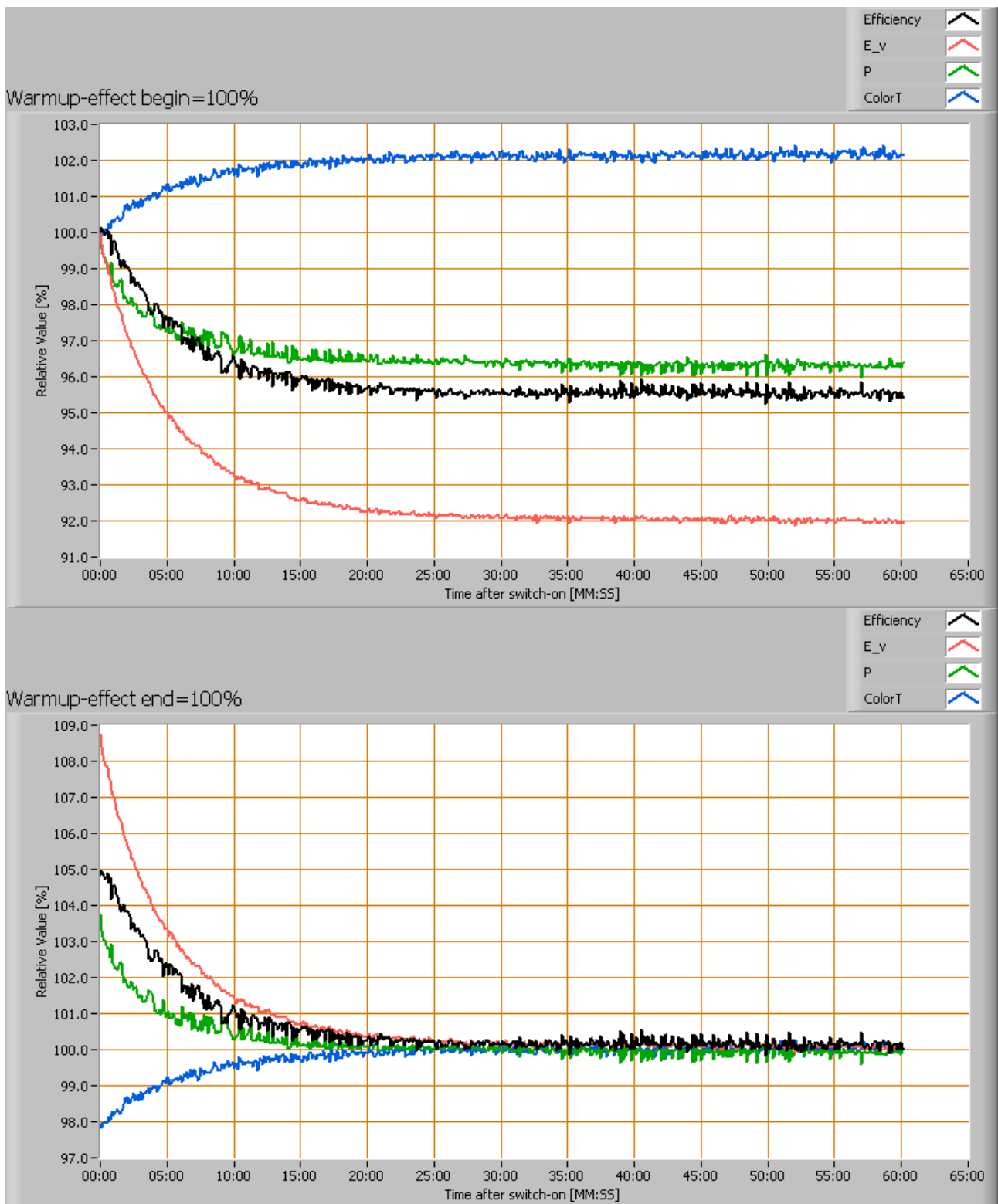
The consumed power varies about 6 % and the illuminance doesn't vary when the voltage varies between 10-15 V. This variation is insignificant.

When the voltage at 12 V varies with + and - 0.25 V, then the illuminance varies within 0.1 %, so when abrupt voltage changes occur this effect is not visible in the illuminance output.

### Warm up effects

After switch on of a cold lamp, the effect of heating up of the lamp is measured on illuminance E<sub>v</sub> [lx], color temperature CT or correlated color temperature CCT [K], the lamp power P [W] and the luminous efficacy [lm/W].

## Lamp measurement report – 28 July 2009

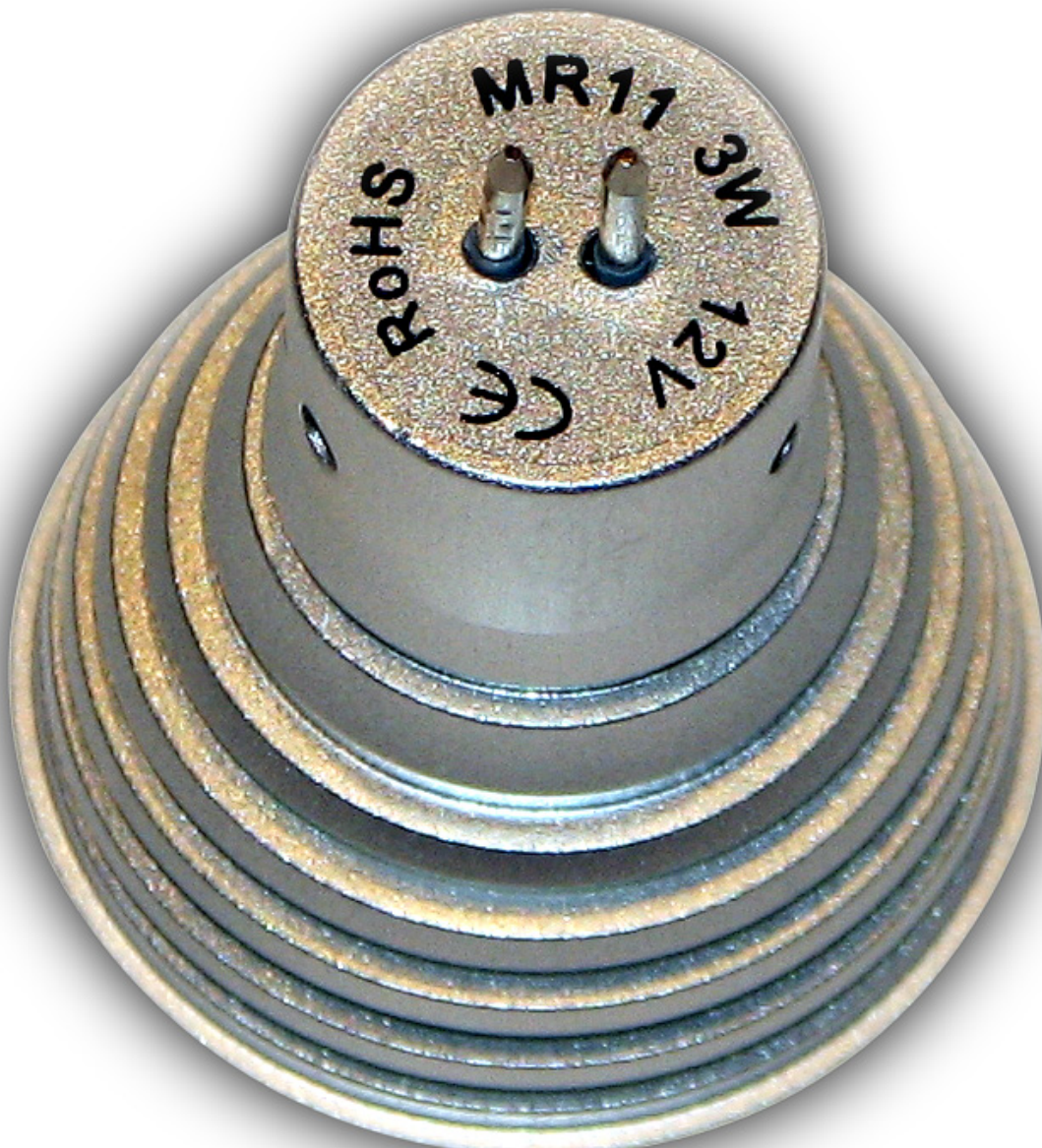


Effect of warming up on different light bulb parameters. At top the 100 % level is put at begin, and at bottom at the end.

## Lamp measurement report – 28 July 2009

The warm-up time is about 20 minutes, during which the illuminance and consumed power decrease with 8 % and 4 % respectively.

### Additional photo



*Photo courtesy by [www.OliNo.org](http://www.OliNo.org)*

*Back view of the led light bulb*



## **Lamp measurement report – 28 July 2009**

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