Report Workshop 5
‘Let’s / LEDs go for quality’

During the CIE conference, a number of presentations showed results of performance tests on LED luminaires. They indicate, as stated by Howard Wolfman: “… that although many SSL products do perform well, a significant portion of SSL products offered in the marketplace neither meet their manufacturer’s performance claims nor comply with SSL standards “ (OP01 in conference proceedings).

As indicated by Dr. Paolo Bertoldi and Dr. Andreas Wente in their key note speeches, it is important to ensure LED products quality, to secure adaption of the technology. We need to prevent that the image of the technology is ruined in the introduction phase. This somewhat happened in case of the CFLi, where initial problems resulted in low user acceptance and low market adoption. Even though product quality has increased, skepticism amongst the public with respect to the CFLi is still available. As confirmed in the for example in the presentations of Dr. Michael Hamm (key note speech, available in the conference papers) and Mia Paget (summary below), new technologies can only be introduced if they find sufficient market acceptance and for this poor quality needs to be avoided.

On an application level it seems to be important to ensure quality as well. Due to the increased luminous flux and efficacy LEDs now start to compete with current light sources such as linear and compact fluorescent lamps and compact high intensity discharge lamps in luminaires for general lighting and for accent lighting. Typical LED characteristics, such as small sized, narrow beam and high brightness as well as the current spread over the LEDs in luminous flux, light color and luminous intensity distribution can have an impact on the (perceived) quality of products and lighting solutions. Martine Knoop – without having the intention of giving a complete overview – showed typical application topics linked to specific LED characteristics.

While being aware that some of these characteristics are found in other light sources as well, the combination of the LED characteristic and the application area might bring up new issues. Just as an example: a LED has a high brightness which might be comparable to the brightness of a number of high intensity discharge lamps. As such, the brightness might not be a problem, but in a functional indoor lighting application such as office work places, light sources with this high brightness are – up till now – typically not applied, whereas the LEDs are or will be used in these applications.

This indicates that a quality assessment on source as well as application level needs to be made.

Aim of the workshop

The aim of the workshop was to list typical quality issues in LED solutions, and draw up a roadmap of required activities to address these issues for LED products and LED lighting, to ensure lighting quality in working environments. The workshop focused on functional lighting and on LED specific topics only.

Therefore the workshop consisted of two parts.

Part 1 'Identification of the issues'

Three short presentations on already identified quality topics of LED solutions were given to introduce the subject. The participants in the audience were asked to put forward their own ideas on important issues in the discussion or through prepared response cards (see Appendix A).

Visual color matching of LED and tungsten-halogen light sources

Gerard Harbers, Kelly McGroddy, Raghuram Petluri, Peter K. Tseng and John Yriberri
Xicato Inc, San Jose, USA

Speaker: Gerard Harbers, Xicato

Color quality can be an issue with LEDs. Color differences both between different Light Emitting Diode (LED) and halogen sources have frequently been noticed in lighting installations. These color differences can be seen at the onset of installations, or they can emerge over time due to temperature variations and lifetime degradation .This is especially critical for close offset lighting, such as wall-washing.

Contributing factors to color variations are:

- Material(s) used in optics which may exhibit color shift over time.
- Electronics. The ability to accurately maintain the drive current, and the accuracy of any on-board color temperature sensor can affect color quality.
- The constitution of the LED array. LED arrays are not made of product from one bin, but a sample from a selection of bins statistically chosen to give the desired lit effect. Therefore placement of the LED's on the board is important, both in uniformity and color temperature effects.
- The LED can exhibit variation due to variation in phosphor deposition, variation in phosphor conversion efficiency, wavelength shift, binning accuracy and a shift in operating parameters between cold conditions (used for binning) and hot conditions typical in service.

In the research presented by Gerard Harbers the practical allowable color differences for architectural applications have been quantified by testing lighting specifiers' visual color sensitivity to test sources with specified controlled color differences. It shows that we are very sensitive to color shift. Accuracy to within two MacAdam ellipses is required for white scenes and architectural lighting. Accuracy to within four MacAdam ellipses is required for general lighting. These are over life, including color shift exhibited through life.

Not having the time to present this within the short presentation time of this workshop, Gerard Harbers would like to point out that the research indicates that color differences are observed between LED sources with different color rendering properties and between halogen and LED sources, even when they are matched to the same (CIE 1931) color point. Or the other way around, an LED and tungsten-halogen source that appear visually matched will have different x,y color coordinates. This is believed to be related to color matching function failures, which has a significant effect on the perception of visual color differences. More information on this topic can be found in paper WS 07 of the conference proceedings.

Gerard Harbers completed his presentation with the following conclusions with respect to the required next steps to get to an industry-wide color quality improvement:

- Color quality needs to be managed on system level - cannot rely on LED performance on component level
- Color consistency targets have to be accurate and tight – it is required to include margins for color shift over time and temperature
- Agree on color consistency targets
- Binning at operating temperature (hot binning) should be considered, or LED lamps with small color shift over temperature need to be used
- New color matching functions are required, to get consistency between Halogen and LED sources, and in between LED sources

Questions & answers:

Dr. János Schanda stated that it is know that the MacAdam ellipses are not optimal for LED, and refers to the work of professor Ronnier Luo, CIE Division 1. Besides this, he brought forward that we need to speak in a common terminology between divisions. For example color consistency is a measure of metameric difference.

Besides this, Gerard Harbers was asked if he has any experience of the benefits hot binning might bring. Gerard Harbers indicated that he has not practical experience, but it is very hard to get high accuracy otherwise.

Evaluation of **discomfort** glare caused by different light distribution of LEDs

Tomonori Tashiro[1], Takako Kimura-Minoda[1,2], Shunsuke Kohko[3], Tomoharu Ishikawa[1] and Miyoshi Ayama[1]
1) Graduate School of Engineering, Utsunomiya University, Japan, 2) Stanley Electric Co., Ltd, Japan, 3) Iwasaki Electric Co., Ltd, Japan

Speakers: Tomonori Tashiro, Miyoshi Ayama

Tomonori Tashiro gave a short introduction on existing methods to evaluate glare, such as UGR for indoor applications, GR for outdoor applications and TI for road lighting. It is questioned whether these glare evaluation methods are applicable to LEDs. A study was conducted to examine whether current glare systems may be applied to LEDs. Discomfort glare of three types of LED sources with different spatial arrangement was subjectively evaluated at seven intensity levels. First one (Type |) was composed of the LED elements with no lens, the second one (Type ||) was composed of the LED elements with lens cap, and the third one (Type |||) was the LEDs covered by a cloudy glass diffuser. Natural density filters were used to adjust the intensity of the test stimuli and four background levels were used: dark, 0.1, 1.0 and 10 cd/m^2. The glare source was positioned 3 m form the observers' eye, and 8.5^o above the observers line of sight (assumed to be representative for outdoor situations). The amount of glare was evaluated on a subjective scale (Matsuda), and illumination at the observers' eye position, equivalent luminance of the test stimulus, and luminance distribution were measured.

Professor Miyoshi Ayama presented the results of the experiment. Type | and Type || gave approximately comparable results of glare and were more glaring than LEDs with the diffuser (Type |||). When the scaling results of discomfort glare are plotted against either illuminance at the observer's eye or equivalent veiling luminance, graphs of Type | and Type || overlap well with each other, while that of Type ||| shifts toward a larger value. On the other hand, when the scaling results are plotted against the spatial summation of luminance larger then 100cd/m^2 (total luminance), all three curves excellently agree with each other. It is thus suggested that total luminance is a strong candidate for an appropriate index of discomfort glare for light sources having different spatial luminance distribution.

The authors conclude that illuminance at the eye and veiling luminance do not accurately describe the sensation of discomfort glare. Total luminance of the stimulus does give good correlation to the perceived glare. Further research is required.

More information on this topic can be found in paper WS 08 of the conference proceedings.

Questions & answers:

It is unclear what the total luminance is. Professor Miyoshi Ayama indicates that the luminance of the source is measured using a digital camera.

Besides this, it is pointed out that the work has only been performed at one distance to the source. The question is what happens if the source distance varied. Professor Miyoshi Ayama responded that the luminance should be distance independent, although there may be upper and lower boundary conditions.

Dr. David Sliney indicates that discomfort glare and disability glare are different and should not be confused. Veiling luminance is related to disability glare. Professor Miyoshi Ayama indicates that the study was considering discomfort glare only.

Through a response card, Dr. David Sliney added the following to the topic “Discomfort glare is related to point brilliance, not veiling luminance, the ratio of source-to-background luminance, and spectral characteristics, but the LED industry seems to be ignoring these published criteria.”

Factors affecting LED lifetime in luminaires

Ralph Tuttle, Cree Inc.

Improvements in LED manufacturing technology have resulted in components with long lumen maintenance and excellent color control. But even when using the highest quality LED components available today, it is critical to select the correct materials in the construction of luminaires to insure optimum product performance. Improper material choices can lead to damage to the LEDs resulting in unacceptable performance.

The most common issues affecting quality in LED luminaires are:

1. Chemical Incompatibility (materials used in luminaire construction).
2. Electrical Overstress (poor driver design or testing practices).
3. Thermal Issues (poor heat sink design).

Considering issue one, chemical incompatibility, this is due to silicone based encapsulants (the silicone lens) reacting with volatile hydrocarbons. The silicone encapsulant has no crystalline structure and is very gas permeable. Materials used in luminaire construction (such as conformal coatings, adhesives, gaskets/O-rings, solder flux, etc) can emit volatile hydrocarbons that are trapped within the luminaire construction (such as the secondary lens). These then diffuse through the silicone lens and react with the LED chip. This causes discoloration, which results in a loss in light output.

The speed and intensity of this effect is mainly dependent upon heat, photonic energy (brightness) and wavelength of light. The effect occurs even when no phosphor is present, and occurs for blue and white LEDs. It does not occur for red or green LEDs. If the silicone lens is removed and the LED is activated the effect is reversed through out-diffusion and the discoloration disappears.

Ralph Tuttle concluded his presentation with the statement that it is very important to select suitable materials during luminaire construction.

Questions & answers:
No questions were asked

Intermezzo

With respect to LED quality issues, a number of aspects were listed on the response cards handed in by the participants. A summary is given below, the original remarks can be found in Appendix A.

Life time:

1. What to do at L70, where LEDs reach end of life, but will still function (Howard Wolfman, John Selander)
2. Product and technology change is so fast that by the time good lifetime data is available, the product is possibly not longer on the market (Paul Hartmann)

Application / perception topics (additionally) to consider

1. Maintenance: how to deal with the LMF / LLMF with a life time of up to 50 000 h and a lumen depreciation of 0.70? (Peter Dehoff)
2. Flicker (David Sliney, Peter Dehoff, Karin Bieske)
3. (advantages of) Spectral distribution of LEDs (Allan Horn, Elena Pedrotti)
4. Binning (e.g. thresholds and tolerances) (Karin Bieske)

Dr. Werner Jordan states on his response card that a LED is only a small source if one looks on the chip only. High brightness LEDs need cooling devices, which makes the system not smaller than classics lamp systems. Therefore he questions why we do not use lamp / luminaires standards for general lighting to assess quality of LED solutions. On the other hand, Dr. János Schanda brings up that “glare is something we will have to re-visit “, which is in line with the statement of professor Wout van Bommel in his closing paper (see CIE conference proceedings) that “ … a totally new glare evaluation system is needed as the present systems have been developed for circumstances totally different from solid state lighting”..

Fact is that currently a number of technical reports indicate that currently applied evaluation methods might not be applicable for all LED solutions. “ … the UGR system should not be used for sources smaller than 0.0003 steradian …” (CIE117:1995) , or “… large arrays of LEDs, especially LEDs with high chromaticity values (5000 K and above) appear to be more glaring in some arrangements and luminaires than in others …“ (R3-24 CIE Division 3). One needs to consider that these remarks are mostly related to qualities of a single LED, not per definition to LED solutions. As with other light sources, LED specific qualities can appear in a LED solution, the luminaire or the application might alter these characteristics as well (e.g. from point light source to diffuse light emitting luminaire), in which case the existing requirements and quality measures might be perfectly appropriate.

The remark of Dr. Werner Jordan is legitimate, and it needs to be evaluate in what way LEDs are different from existing light sources, and if the existing lighting quality criteria are suitable to evaluate LED solutions. At the same time, existing measures might not cover all aspects that need to be taken into consideration to realise and evaluate quality lighting designs. Within CIE Division 3 a technical committee is started up to exactly address this topic: to review relevant CIE publications and standards to evaluate the suitability of existing lighting quality measures. Besides this, it will look into identifying the gaps and weaknesses in existing quality measures, exhibited in one of two ways: either the criterion is valid, but the evaluation method is not or a new criterion needs to be taken into consideration.

Part 2 'Tackling the problem'

A small number of response cards confirms that there are remaining questions and doubts about the reliability and performance of products, as well as the performed or required test methods, as already indicated in a number of presentations during the conference, e.g.:

- Is accelerated life test reliable? (YF Kwok)
- How can I guarantee that LED products purchased are satisfactory in performance? (YF Kwok)
- Which is the best set up for measuring CRI and color temperature of LEDs arrays? (Giuseppe Migale)

Quality labels, standardization activities, industry initiatives as well as research can be used to support quality solutions. Next to more fundamental research, a number of initiatives (CELMA, CIE, DOE …) are already running to ensure quality of LED products and quality in LED solutions, of which two were presented in this workshop. To indicate that this topic is picked up worldwide – but on a 'local' level - a short summary of the activities of the Illuminating Engineering Institute of Japan was given by Martine Knoop, based on material provided by Dr. Etsuko Mochizuki and Dr. Naoya Hara. The IEIJ has three main topics:

- adapt the measuring guidelines as proposed by the CIE
- conduct research - in the framework of the IEIJ - to get more insight into the technology, visual response on spychological and biological effects of LED sources
- organize seminars to collect and deploy the information

A summary of the presentations within part 2 of the workshop is given below.

CALiPER measured LED performance issues in 2010

Mia Paget, Pacific Northwest National Laboratory

Mia Paget presented the US Department of Energy CALiPER testing program. This program has measured and reported on hundreds of market-available SSL luminaires and replacement lamps since late 2006. Performance and quality have improved tremendously in four years, along with our understanding of how to test and how to compare SSL products. From the most recent CALiPER testing, the presentation gave an overview of current performance results for SSL products and nuanced quality issues that CALiPER was observing thus far in 2010 for a variety of lighting applications.

Testing is conducted according to IESNA LM-79 (absolute photometry) and evaluates long term operation characteristics (such as dimming, thermal issues, flicker, electrical characteristics,…). The tests are to determine:

- if luminaires / lamps are meeting photometric expectations as claimed with respect to fundamental performance expectations (e.g. light output and distribution, power use, color characteristics, light distribution)
- how products compare to more established technologies, as a benchmark;

Next to the fundamental performance expectations, functional expectations are evaluated, such as dimmability, flicker, power characteristics, replacement / interchangeability. Besides this, it is evaluated if the product survives shipping and handling.

When it comes to reliability, the LEDs expectations and claims are high, and Mia Paget pointed out in her slides that long-term reliability is impacted by

- LED device performance over time (current, voltage, temperature, materials incompatibility…)
- Driver life (temperature, vibration, inrush, design…)
- Optics, lens life, dirt accumulation (environment, materials, design…)
- Materials degradation (system impacts, interfaces…)

Mia Paget concludes that LEDs are starting to achieve good efficacies, but improved quality is needed. For LED technology to make a difference, high market adoption is necessary and for this poor quality needs to be avoided, and suitable standards need to be produced. Additional information on the CALiPER program and reports can be found on the CALiPER web-site (http://www1.eere.energy.gov/buildings/ssl/caliper.html)

Questions & answers:

Regarding dimmability and retrofit lamps, only some lamps dim with commercially available dimmers suitable for GLS lamps (the same problem as for CFL). The question was raised if CIE should promote solutions for this? Mia Paget responded that close cooperation between lighting, dimmer and driver manufacturers is required. Through a response card, Paul Hartmann proposes a joint effort of the dimming industry and LED bulb industry to develop new standards.

Efforts of the European lighting industry to deliver high quality energy efficient LED lighting solutions

Allan Horn, Philips Lumileds, representing CELMA

Allan Horn started his presentation with a short introduction of ELC (representing the European lamp community and has a membership of seven companies) and CELMA (representing the European luminaire and ballast industry and has a membership of >1000 companies).

Many effective LED applications are now possible; some applications are still not possible but will become possible in the near future. Industry and user awareness of the realistic application of LEDs is vital. ELC and

CELMA want to encourage and accelerate adoption, whilst maintaining realistic expectations. Therefore there is a joint ELC/CELMA working group with the aim to achieve quicker market penetration of LED products by:

- Managing expectations
- Speaking with one voice
- Driving LED lighting standards
- Safeguarding minimum quality levels for LED products
- Optimizing the benefits of LED lighting products

At the moment, there is

- a CELMA/ELC guide on the status of standards relevant for LED products
- a CELMA guide to LEDs for OEMS
- an ELC paper concerning LED directional retrofit light sources

These documents are available www.celma.org and www.elcfed.org. A general FAQ document will also be available in the next few days.

In view of the time, it was not possible to present the summary & latest status of EU EcoDesign Regulations on LED light sources, LED modules and LED luminaires. The slides are included the slide pack of this workshop.

Allan Horn concluded his presentation with pointing out that the EU lighting industry, through ELC/CELMA, is active in helping draft EU regulations for LED lighting, and calling for a market surveillance program (similar to CALiPER).

Questions & answers:

It is asked if there is a working group on flicker? Allan Horn indicates that within CELMA there is no such working group. The topic ‘Flicker’ was brought up on response cards by Karin Bieske, Peter Dehoff and Dr. David Sliney as well, and needs to be taken into consideration.

Required activities

This workshop gave some indication of next steps CIE should take to bring forward lighting quality LED solutions. Topics that link to industry standards are not included in this evaluation.

From the presentations, the discussion and questions after the presentations, as well as the response cards following input on required activities can be obtained:

1. Terminology
   - There is a need for clear and common terminology, on an international level (Mia Paget, Dr. János Schanda)
   - ➔ For general terms one can refer to the International Lighting Vocabulary
   - ➔ For LED related: work is ongoing in Division 2, TC 2-66 ‘Terminology of LEDs and LED assemblies’, chaired by Dr. János Schanda. The terms of references of this Technical Committee: To Review LED and LED assemblies related terms and definitions in other international and regional organizations and prepare a recommendation for CIE.

2. Required research
   - A joint research program on accelerated testing methods for LEDs should be launched with the goal to establish a viable test setup and model for accelerated lifetime testing (Mia Paget, Rosa Wang).
   - ➔ CIE can play a coordinating role in this, and is already doing so, as for example reflected in the work done in Division 2, e.g. TC 2-64: High Speed Testing Methods for LEDs, chaired by Günther Heidel
   - Field studies (Sermin Onaygil)
   - ➔ Professor Jan Ehjed points out on a reference card, that there is a field study on LED lighting in public spaces outdoor: evaluation of LED installations in and end-user perspective. It is a EU-financed project, South Baltic Region, over 3 years started September 2009

3. Global coordination / standardization of testing methodologies and surveillance methods.
   - Specifiers / performance criteria / regulations in all countries need to require results from standardized testing (Mia Paget)
   - CIE / IEC need to recommend use of standardized testing methodologies (e.g. LM79 for integral lamps + luminaires) (Mia Paget)
   - Dr. Paolo Bertoldi indicated during the workshop that he is involved in activities to organize a European LED Quality Charter
   - ➔ Professor Marc Fontoynont indicates that the IEA 4E-SSL Annex will address the organization of world traceability of performances of SSL. This Annex focuses on providing governments with the tools to assess the performance of SSL sources and appropriate standards of performance that can be used by governments as the basis for policy measures to ensure the quality of SSL.
     The IEA-SSL will gather experts from 15 countries, from testing laboratories and lighting industry to:
     1) establish best possible testing methodologies worldwide, through close collaboration of laboratories in North America, Europe and Asia.
     2) organize traceability of SSL performance
     3) propose procedure for accreditation of labs
     4) propose suite of performance values to be adopted by governments within policy measures
     (from proposal Marc Fontoynont, march 2010).

4. Product issues are addressed on a global level, but at the moment application and perception issues as presented and brought forward by the participants (flicker, maintenance, spectral distribution, glare, …) seem to be dealt with on a 'local' level.
   - ➔ CIE can play a coordinating role in this. This could be taken into consideration in the work of Division 3 and Division 4 (e.g. TC3-50 and possibly TC4-47).

5. Industry and user awareness of the realistic application of LEDs is vital. Remaining questions and doubts amongst the public need to be addressed
   - ➔ A joint responsibility of CIE, industry, DOE, CELMA and other organizations

Conclusion

There are number of activities started within CIE, which play a role to bring the 'LED quality' topic further. Looking at the fast development of LED technology, there is an urgent need for speed in all activities and experts / volunteers for such activities.

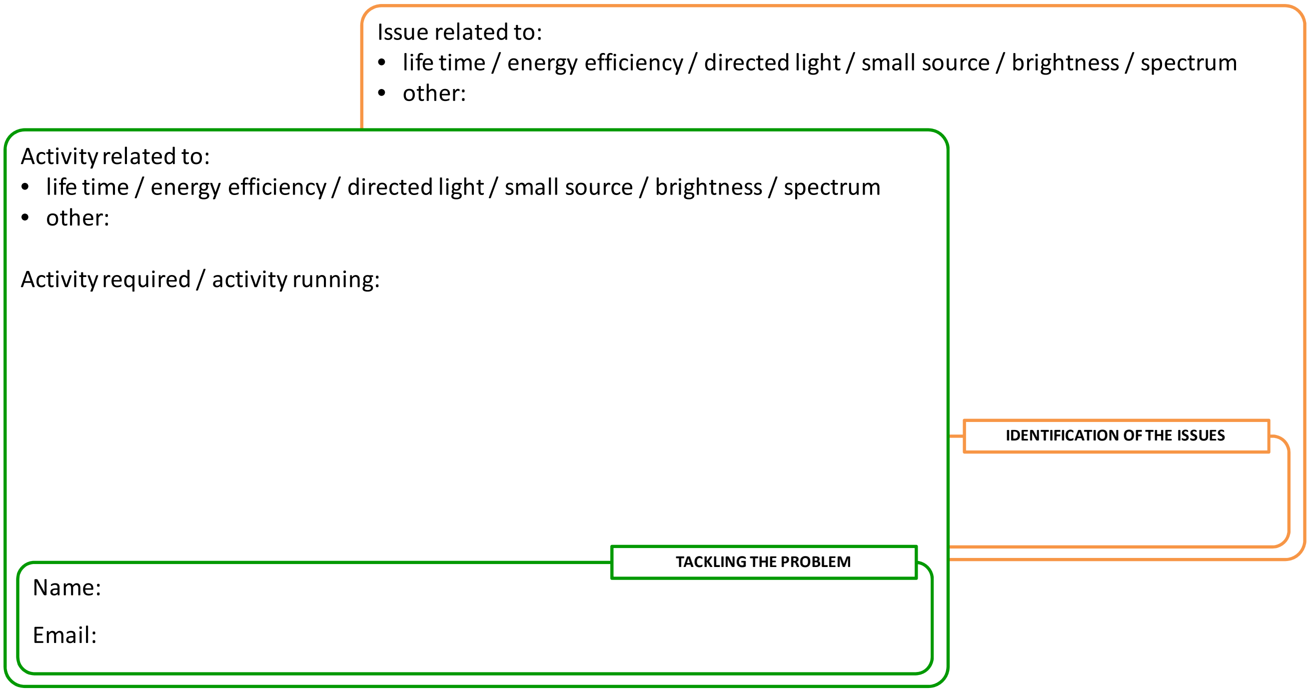
Background information about the Workshop

This workshop took place on Wednesday March 17, 2010, from 15:00 to 16:30 h, within the framework of CIE Conference on Lighting Quality & Energy Efficiency in Vienna, Austria.

Input from the participants was obtained in the discussion, as well as by means of response cards – see Appendix A. The majority of the responses is included into this report of the Workshop. Very specific questions or questions outside the scope of this workshop were answered with a responses mail to the participant directly.

Minute taker: Peter Thorns
Session chair and final report: Dr. Martine Knoop

Appendix 1: Response of the audience through 'Response cards'



General topics

1. We need extensive + clear definitions of terms, on an international level

Life time issues:

2. At L70 we need to replace board + LED driver. Will you have a warning sign: flash once per week, red LED in the board, illuminated by separate circuit, etc? (Don't recommend that we extinguish the luminaire at L70!)
3. LEDs at L70 have reached end of life'; however, an LED does not 'die' at L70, but continues to degrade. What will the user do in terms of replacement since the LED system will continue to operate? Tolerance of lumens and/or CCT either binning of lumen or CCT, tolerance within binning sample
4. Maintenance of LED or LED-luminaire. With a life time of up to 50 000 hrs and a lumen output loss of up to 70% and dirt in the luminaire – what should the LMF (LLMF) be?
5. Lifetime test standards and practical possibilities are mainly limited to nominal / ambient conditions and for 6000 h. LEDs are becoming better and more stable → not much changes over measurement time can be observed. Product and technology change is so fast that all the time when good lifetime data is available, the product is possibly not longer on the market.

Application / perception issues

6. Flicker when dimming: by PWM there might be perceptible flicker effects?
7. Flicker from LEDs appears to be significant issue; why was this not discussed?

8. Discomfort glare is related to point brilliance, not veiling luminance, the ratio of source-to-background luminance, and spectral characteristics, but the LED industry seems to be ignoring these published criteria.
9. Does the discoloration of chips compromise the Tc and the energy efficiency of the LEDs?
10. For example glare and glare restriction (discomfort glare). Why not use lamp/luminaires standards for general lighting? → picked up in TC3-50
11. The LED only is a small source if one looks on the chip only. High brightness LEDs need cooling devices, which makes the system not smaller than classics lampsystems! What about efficiency?!
12. Brightness – luminance ratio – discomfort glare
    Brightness/luminance is an old question that got new dimension with the introduction of "white light" light sources. Discomfort glare - just as pointed out by Wout van Bommel in his closing paper ("Here a totally new glare evaluation system is needed as the present systems have been developed for circumstances totally different from solid state lighting.") - is something we will have to re-visit.
13. I am interesting especially about applications with using LED luminaires / Lighting Quality Parameter / light distribution diagrams
14. Is the spectral distribution of LEDs vs. continuous spectrum an issue or an advantage for LEDs? Is it understood and what are the impacts on CRI and / or the perception of quality of light
15. Thresholds and tolerance limits of inuniformity within luminaires and between them → binning
16. Basics of dynamic
17. Basics of flicker
18. Present dimmers do not work well with LEDs
19. IpRGC → quality of light

LED Product quality

20. Is accelerated life test reliable?
21. Don't know how to guarantee LED products purchased are satisfactory in performance, i.e. specification issue
22. In a matrix of LEDs, necessary to obtain high luminous flux, have been a minimal distance establish to fixed the LEDs in order to they don't interference each other? Or is it not important if the chips are very near? Does the life time of the LED chips depend on the distance which they are installed?
23. Is it possible to join a white LED with a monochromatic LED that emits about 480 – 500 nm in order to complete the emitted spectrum by the white LED? Do any studies exist about this topic?

Measurement

24. LED lifetime acceleration test method
25. CRI / CCT: which is the best set up for measuring CRI and color temperature of LEDs arrays

Activity required:

26. Real field measuring. Studies for comparison of different lighting installations (about glare, cost analysis)
27. CIE / IEC need to recommend use of standardized testing methodologies (e.g. LM79 for integral lamps + luminaires)
28. Specifiers / performance criteria / regulations in all countries need to require results from standardized testing

29. Joint efforts of dimming industry and LED bulb industry to develop new standards
30. A joint research program on accelerated testing methods for LEDs should be launched with the goal to establish a viable test setup and model for accelerated lifetime testing.

Running activities

31. LED lighting in public spaces outdoor: evaluation of LED installations in and end-user perspective. EU-financed project, South Baltic Region, over 3 years started September 2009