



CORM 2010

Annual Conference and Business Meeting

*Solid State Lighting, Display Metrology, Photovoltaics,
and General Topics in Optical Radiation Measurement*

May 9-11, 2010

Planet Hollywood Resort and Casino
Las Vegas, NV



Council for Optical Radiation Measurements

CORM 2010

Annual Conference and Business Meeting

May 9 - 11, 2010

The CORM 2010 conference will be held in Las Vegas, NV – preceding the Light Fair International conference. The conference themes include **Solid State Lighting, Display Metrology, Photovoltaics, and General Topics in Optical Radiation Measurement.**

The 2010 Annual CORM Technical Conference is structured to provide interaction between the optical radiation industry and National Metrology Institutes (NMI's) such as the National Institute of Standards and Technology (NIST), National Research Council (NRC) of Canada, and National Center for Metrology (CENAM) of Mexico.

Schedule

Sunday, May 9 1:00 PM: CORM Technical Committee Meetings

Monday, May 10 8:00 AM Session I: General Topics in Optical Radiation Measurement
10:00 AM Session II: Photovoltaics
1:00 PM Session III: Display Metrology
6:00 PM Reception
7:00 PM Franc Grum Memorial Lecture and Banquet

Tuesday, May 11 8:00 AM Session IV: Solid State Lighting
4:00 PM CORM Business Meeting

Early conference registration begins in February 2010.

Conference Coordinators

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CORM 2010 Annual Conference and Business Meeting

PROGRAM

Solid State Lighting, Display Metrology, Photovoltaics,
and General Topics in Optical Radiation Measurement

May 9-11, 2010 Las Vegas, NV

Sunday May 9th

CORM Technical Committees on Radiometry

11:00 **REGISTRATION OPEN**

12:00 LUNCH

13:00 **CORM Technical Committees on Radiometry**

(Detailed schedule to be announced)

Monday May 10th

8:00-8:30 **REGISTRATION OPEN - Continental Breakfast**

8:30 Opening remarks

Session 1 General Topics in Optical Radiation Measurement – *Chair: Bob Angelo*

9:00 **CQS – Test Results to Date**

Wendy Davis, NIST

9:30 **Pitfalls in SSL Photometry**

Michael Grather, LTL

10:00 BREAK

Session 2 Photovoltaics - *Chair: Daryl Myers*

10:30 **Solar Resource Data and Uncertainties for Photovoltaic Systems Applications**
Daryl Myers, NREL

11:00 **Solar Datawarehouse: Measured Solar Radiation Data from 3000 US Stations for Renewable Applications**

James Hall, JHTech

11:30 **Optimizing the Solar Photovoltaic Energy Capture on Sunny and Cloudy Days Using a Solar Tracking System**

Nelson A. Kelly, General Motors Research and Development Center

12:00 LUNCH BREAK

Session 3 Display Measurement – *Special Session*

- 13:00 **Display Measurement Standard from SID's ICDM**
Edward F. Kelley, PhD, KELTEK LLC
- 14:45 **BREAK**
- 15:15 **Workshop: Display Metrology**
Edward F. Kelley, PhD, KELTEK LLC
- 18:00 **Reception**
- 19:00 **Franc Grum Memorial Banquet and Lecture**
The Socio-Economic Impact of Light on Development
Michael Fark, Executive Director, Light Up the World

Tuesday May 11th

- 8:00- 8:45 **REGISTRATION OPEN Continental Breakfast**
8:45 **Introductions and Announcements**

Session 4 **SSL Measurements and Standards** - *Chair: Andy Jackson*

- 9:00 **LED Lumen Maintenance Prediction Method**
Emil Radkov, Illumitex
- 9:30 **SSL Statistical Analysis of Models related to TM-21**
Trenton Pulsipher, PNNL
- 10:00 **BREAK**
- 10:30 **Updated CALiPER Lifetime Testing: 2010**
Mia Paget, U.S. Department of Energy Solid-State Lighting CALiPER Program
- 11:00 **SSL End product Performance—correlation from Chip or Device Performance**
Mia Paget
- 11:30 **Development of an Automated Measurement System for LED Lifetime Test**
Yuqin Zong, NIST
- 12:00 **LUNCH BREAK**
- 13:00 **Results, Finding, and Oddities from NVLAP SSL Proficiency Testing**
Cameron Miller, NIST
- 13:30 **Near Field Goniometric Measurement Systems for Solid State Lighting Systems: Measuring Luminance, Intensity, Color, and Spectra as a Function of Angle**
Douglas Kreysar, Radiant Imaging
- 14:00 **Characterization of Remote Phosphor Type of LED**
Arno Keppens, Light & Lighting Laboratory
- 14:30 **BREAK**
- 15:00 **SSL Photometric Standards Update**
Eric Richman, PNNL-DOE (*presented by Michael Grather, LTL*)
- 15:30 **SSL/LED Road to Standardization 2010**
Andrew Jackson, Philips Lighting
- 16:00 **CORM Business Meeting**

CORM 2010

ABSTRACTS

CQS – Test Results to Date

Wendy Davis

National Institute of Standards and Technology (NIST)

ABSTRACT

The Color Quality Scale (CQS) has been proposed by the National Institute of Standards and Technology (NIST) as a possible replacement for the Color Rendering Index (CRI). The CRI has a number of problems, particularly when applied to light-emitting diodes (LEDs) and the CQS was developed to solve those problems. Experimental testing of the CQS is underway in the Spectrally Tunable Lighting Facility (STLF). The STLF can create various spectra with precise control of illuminance, chromaticity, and object color rendering.

The most controversial aspect of the CQS is its inclusion of a “saturation factor,” whereby lamps are not penalized for increasing the chroma/saturation of illuminated objects. Using the STLF, a series of spectra were created that either decreased or increased object saturation, in systematic steps. Two experimental tests were conducted: in one, observers compared pairs of light sources based on the appearance of objects in the room with them; in the other, observers compared pairs of sources based on their own skin tones. In both tests, the results of the visual evaluations were more consistent with the output of the CQS than the CRI

Pitfalls in SSL Photometry

Michael Grather

Luminaire Testing Laboratory, Inc.

ABSTRACT

As SSL luminaires become more prevalent in the marketplace, the variations in their design and underlying technology are presenting new challenges to photometric testing laboratories. These “pitfalls” in the goniophotometry of SSL luminaires include the effects of the spectral power distribution of the source, source instability (including source flicker), polarization, luminaire mounting methods, and photometric test distance. This paper will address the effects that these characteristics may have on the photometric test results, and offer some procedures and methods that may help to minimize their impact on the measurements.

Solar Resource Data and Uncertainties for Photovoltaic Systems Applications

Daryl R. Myers

National Renewable Energy Laboratory (NREL)

ABSTRACT

The design and performance of renewable energy conversion systems that depend upon sunlight, such as photovoltaic systems, require knowledge of solar radiation resources available as 'fuel' for these systems. Various approaches to design of photovoltaic energy systems, and the issues associated with each, are briefly described. A wide variety of solar radiation resource data sets are available, and are beginning to proliferate as commercially available products. We briefly introduce the various sorts of data sets available for system design and performance monitoring. Because there is a definite lack of measured solar radiation, particularly for extended periods of time, the large majority of the available data sets contain solar radiation data estimated using various types of solar radiation models. We briefly discuss the uncertainties associated with measurement instrumentation and measured data. Next we address the uncertainties associated in the various approaches to modeling solar radiation, and validating the models. Finally, a few examples of the relative performance of several data sets are given to substantiate the uncertainties quoted for both modeled and measured solar radiation data. These uncertainties are typically $\pm 5\%$ (measurement) to $\pm 10\%$ (modeled) for total hemispherical radiation, and $\pm 2\%$ (measured) to $\pm 25\%$ (modeled) for direct beam radiation. In the current economic climate, such uncertainties often compromise the ability to achieve financing for proposed PV systems. Improving on these uncertainties will require development of better instrumentation and more accurate solar radiation models.

Solar Data Warehouse: Measured Solar Radiation Data from 3000 US Stations for Renewable Applications

Dr. James Hall
JHtech

ABSTRACT

Agriculture has recently provided a demand for global solar radiation data for crop modeling, disease prediction, and water conservation. As a result, there is a lot of new measured data that was previously unavailable. This data comes from over 3000 weather sites across the United States sponsored by dozens of local, state, and national organizations. While these weather sites do not use the scientific-quality instrumentation used by groups such as NREL and BSRN, they are still professionally-maintained and there are two orders of magnitude more of them. The Solar Data Warehouse's strength is in the large number of stations. Because there are so many stations, it's possible to remove many of the unavoidable errors using statistics. The end result is a national solar radiation dataset that is even more accurate than the models generated by the scientific sites and satellite data. During the presentation, we will compare the different data types and average errors.

The Solar Data Warehouse servers collect hourly and daily data from dozens of sources and rationalize everything into a single database with consistent units. The data passes through multiple layers of quality control and servers generate derivative products (e.g. gridded data, hourly and daily datasets, estimates of diffuse and direct components, climate information, and data from international sources).

Optimizing the Solar Photovoltaic Energy Capture on Sunny and Cloudy Days Using a Solar Tracking System

Nelson A. Kelly and Thomas L. Gibson
General Motors Research and Development Center

ABSTRACT

In order to maximize the amount of solar energy captured by a solar photovoltaic system under both clear and cloudy conditions we have designed an optimal solar-tracking algorithm for a 2-axis tracking system. The algorithm was derived by analyzing an extensive set of measurements of the solar irradiance obtained using four identical solar arrays and associated solar sensors (collectively referred to as solar collectors). The measurements included a variety of ambient conditions including different seasons and both cloudy and cloud-free conditions. The four sets of solar collectors had different tilt angles relative to the earth's surface. One set of solar collectors was always approximately pointed directly toward the sun (DTS) for a period around solar noon. These solar collectors thus captured the direct component of the solar radiation that predominates on sunny days. We found that on sunny days, solar collectors with a DTS configuration captured more solar energy in accordance with the well-known cosine dependence for the response of a flat-surfaced solar collector to the angle of incidence with direct radiation. In particular, such a DTS orientation was found to capture up to twice as much solar energy as a horizontal (H) orientation in which the array is tilted toward the zenith. Another set of solar collectors always had an H orientation, and this best captured the diffuse component of the solar radiation that predominates on cloudy days. The dependence of the H/DTS ratio on the solar-collector tilt angle was in approximate agreement with the Isotropic Diffuse Model derived for heavily overcast conditions. During cloudy periods, we found that an H configuration increased the solar energy capture by nearly 40% compared to a DTS configuration during the same period, in agreement with our earlier findings that were based on a much smaller data base. An energy-optimized 2-axis tracking algorithm would follow the solar disk on sunny days but attain a fixed H orientation during cloudy periods. Improving the harvesting of solar energy on cloudy days deserves wider attention due to increasing efforts to utilize renewable solar energy. In particular, increasing the output of distributed solar power systems on cloudy days is important to developing solar-powered home fueling and charging systems for hydrogen-powered fuel-cell electric and battery-powered vehicles, respectively, because it reduces the system size and cost for solar power systems that are designed to have sufficient energy output on the worst (cloudy) days.

Display Measurement Standard from SID's ICDM

Edward F. Kelley, Ph.D
KELTEK, LLC

ABSTRACT

We review the content of the new standard from the International Committee for Display Metrology (ICDM) of the Society for Information Display (SID). This measurement standard is an extension of a previous standard completed under a different umbrella. Attention will be focused on the structure, new parts, and philosophy of the document.

Workshop: Display Metrology

Edward F. Kelley, Ph.D
KELTEK, LLC

ABSTRACT

Display characterization presents some challenges to the application of radiometry, photometry, and colorimetry that metrologists would normally work to avoid. We discuss the difficult measurement problems associated with displays and how such measurement results are presently obtained. Difficult contrast, reflection, and detail measurements are discussed.

LED Lumen Maintenance Prediction Method

Dr. Emil Radkov

Illumitex

ABSTRACT

A systematic method is proposed for modeling the lumen maintenance and projecting the L70 value of LEDs, based on solving a 3-term, first order ordinary differential equation for the lumen decay rate. The first term is constant, the second is proportional to the luminous flux and the third is inversely proportional to time. This leads to a total of 8 model formulas containing all possible combinations of parameters (including the complete absence thereof), which can be refined from experimental data, e.g. as collected according to IESNA LM-80-2008.

For each integrated model, the sum of squared residuals at validation points is then calculated, in order to choose the best fit for extrapolation. This approach incorporates the previously proposed linear and simple exponential decay models, and in addition has the capability to model accelerating decay. Experimental examples are shown for each model, and related learnings are discussed.

SSL Statistical Analysis of Models Related to TM-21

**Trenton Pulsipher, John Hathaway, Amy Qiao, Kevin Anderson, Eric Richman
Pacific Northwest National Laboratory**

ABSTRACT

There is a strong need for a method to represent the potential life of LED products as a critical part of design decisions including payback analysis. The TM-21 group is working on a method that can use the lumen depreciation data collected per LM-80 to provide an extrapolated estimate of the time to reach an expected lumen depreciation level. PNNL has conducted an analysis of a series of LED degradation models provided by others to determine their applicability. The analysis has provided valuable information on how to apply the models to an estimation method and what depreciation data is truly needed to effectively estimate degradation over long time periods. This presentation will provide the results of the analysis and its application to the TM-21 method efforts.

Updated CALiPER Lifetime Testing: 2010

Mia Paget

U.S. Department of Energy Solid-State Lighting CALiPER Program

ABSTRACT

Most solid-state lighting (SSL) products claim to have lifetimes of 50,000 hours or more. The U.S. Department of Energy Commercially Available LED Product Evaluation and Reporting (CALiPER) program tested 25 SSL luminaires and replacement lamps through long-term continuous operation. Some samples were operated and monitored for up to 13,500 hours, measuring absolute photometric performance before and after long-term operation and measuring incremental relative light output and color shift. The test results reveal a very wide range of performance behavior, from products that do not provide even 50% of their initial light output after 1000 hours of operation to products that do not exhibit any significant reduction in light output after 13,500 hours. The majority of products exhibit significant color shift over the course of long-term operation. This presentation provides an overview of key results from the CALiPER 2010 report on long-term testing—adding depth and breadth to earlier results from CALiPER long-term testing.

SSL End Product Performance—Correlation from Chip or Device Performance

Mia Paget

U.S. Department of Energy Solid-State Lighting CALiPER Program

ABSTRACT

Understanding SSL replacement lamp performance and developing further methodologies for testing hinge upon assumptions about the correlations between LED device performance and ultimate performance in an integral luminaire or replacement lamp. The U.S. Department of Energy Commercially Available LED Product Evaluation and Reporting (CALiPER) program is initiating a study aimed at obtaining concrete data to examine, illustrate and help stakeholders understand these correlations. Replacement lamp samples will be tested and operated under different temperature conditions over the course of a year. Internal temperatures, correlated with LED junction temperatures will also be measured. Curves characterizing the performance of the LED devices will be used to estimate the expected performance in the replacement lamps at different operating temperatures. These estimates will be compared to the measured performance of the SSL replacement lamps. While limited in scope, this proposed study aims to provide valuable information for current SSL standards efforts.

Development of an automated measurement system for LED lifetime test

Yuqin Zong

National Institute of Standards and Technology (NIST)

ABSTRACT

Light-emitting diode (LED) lifetime is one of important issues concerning LED manufacturers, solid-state lighting (SSL) product designers, and government regulators. LED lifetime, denoted L_{70} , is the total operation time of an LED before its lumen value drops down to 70 % of its initial lumen output, according to the Illuminating Engineering Society of North America (IESNA) LM-80-08: Measuring Lumen Maintenance of LED Light Sources. LEDs typically have low lumen depreciation rate and long lifetime. Some LED manufacturers suggest that the lifetime of LEDs can be 50,000 hours or more, which corresponds to more than five and a half years time of continuous operation, which is much longer than an LED's production lifecycle. It is unrealistic to perform an LED lifetime test over such a long time, and therefore it is essential to develop a method/model that can be used to accurately predict lifetime of an LED based on testing data over a "short" period of time such as 6000 hours as specified in the IESNA LM-80-08. To address this issue, an IESNA task group is actively working on the development of Lumen Depreciation Lifetime Estimation Method for LED Light Sources (IES TM-21) based on limited initial test data. However, regardless the methods/models to be developed, the accuracy of LED lifetime prediction strongly depends on the quality of the limited test data. The test system for LED lifetime must have small measurement uncertainties and an excellent long-term stability.

To meet the need of significant amount of high quality test data for model development and validation, NIST, supported by DOE, is developing a fully automated measurement system for LED lifetime tests. The test will be done following the guidelines described in the IESNA LM-80-08. A set of 300 LED packages manufactured by major LED manufacturers are planned to be tested. Each type of LEDs will be operated under three different forward currents and at five temperatures of 25 °C, 55 °C, 85 °C, 120 °C, and 150 °C. The lifetime test will last 10000 hours or more with datum acquisition as frequent as every hour. Details in the design of this measurement system will be presented.

Results, Finding, and Oddities from NVLAP SSL Proficiency Testing

**Cameron Miller (presenter), Ri Qui, and Yuqin Zong
National Institute of Standards and Technology (NIST)**

ABSTRACT

As part of the National Voluntary Laboratory Accreditation Program (NVLAP) accreditation process, laboratories that are applying for initial accreditation to the Energy Efficient Lighting Program “for solid-state test methods shall participate satisfactorily in a bilateral proficiency testing with NIST before accreditation will be granted.” Through a sponsorship provided by the Department of Energy, the researchers in the NIST Photometry Project have obtained and characterized commercially available solid-state lighting (SSL) products to be used as bilateral proficiency test items. The results of these characterizations will be presented.

At the time of this abstract four laboratories have participated in bilateral proficiency testing. For particular SSL products the agreement has been quite excellent, on the order of a percent or two. For other particular SSL products that agreement has not been so good, on the order of 30 to 40 %. The reasons for these differences will be explained and suggestions on how to reduced these discrepancies will be discussed.

Near Field Goniometric Measurement Systems for Solid State Lighting Systems: Measuring Luminance, Intensity, Color, and Spectra as a Function of Angle

**Douglas Kreysar
Radiant Imaging, Inc.**

ABSTRACT

Traditional goniometric measurements are done with a two axis rotation stage and a lux meter placed in the far-field to measure intensity. With the maturation of imaging photometry, goniometric systems are now available that use a camera placed in the near-field (less than 5x the length of the light fixture) to record tristimulus images of the fixture at different angles. These images can be used to calculate far-field intensity and color from a near field measurement. With the addition of a spectrometer, the system can also be used to measure spectral power distribution as a function of angle. This paper discusses a measurement system that uses an imaging photometer, a spectrometer, and a two axis rotation system to provide luminance, intensity, color, and spectra as a function of angle.

Characterization of Remote Phosphor Type of LEDs

Arno Keppens¹, Yuqin Zong², and Yoshi Ohno²

¹ Light & Lighting Laboratory, Catholic University College Gent, Belgium

² National Institute of Standards and Technology (NIST)

ABSTRACT

Despite their high manufacturing cost, remote phosphor type of light-emitting diodes (LEDs) are gaining popularity in solid-state lighting applications. Main reasons are their higher luminous efficacy, improved spatial color uniformity due to internal photon scattering, and better long-term color stability in comparison with proximate phosphor type of LEDs. The increased stability is due to a reduced phosphor heating, as the optical properties of a high-power white LED are highly dependent on its junction and phosphor temperatures.

For a proximate phosphor type of LED the phosphor is directly attached onto the emitter, so the junction and phosphor temperatures are typically very close. For a remote phosphor type of LED however, junction and phosphor temperatures can be very different. Junction heating depends on ambient temperature, heat sink, and forward current, while phosphor heating depends on ambient temperature, excitation light density, and thermal resistance to the junction. We have therefore studied the effects of junction temperature, phosphor temperature, and excitation light density on LED's spectral radiant flux by using a 1 m ambient-temperature-controlled integrating sphere and a temperature-controlled heat sink. The junction temperature of a test LED is set by using the NIST method for measurement of high-power LEDs. Measurement results of the effect of junction and phosphor heating on flux change and color shift for both proximate and remote phosphor types of LEDs will be presented. These results allow discussing advantages and disadvantages of those types of LEDs.

SSL Photometric Standards Update

**Eric Richman (Presented by Michael Grather LTL)
Pacific Northwest National Laboratory**

ABSTRACT

Much progress has been made towards developing the standards and test methods needed by the lighting industry to effectively apply LED technology. However, some critical areas of LED technology are still without appropriate standards. This presentation will provide an update on the existing standards in place and those that are in development. Standards and test methods from the major players in lighting related to LEDs will be covered including IES, ANSLG/ANSI, NEMA, UL. Other pre-standards documents such as white papers will also be summarized. Most importantly, the issues and areas where more involvement and support is needed will be discussed and information on how to become involved will be provided.

SSL/LED Road to Standardization 2010

Andrew Jackson
Philips Lighting Company

ABSTRACT

For over a century, traditional lighting technology has used standardization to provide the catalyst for the adoption of new technologies and configurations. SSL manufacturers, governmental bodies, and end users now recognize that standardization will drive quality and acceptance in the market place. The rapid adoption of SSL technology will require the development of interconnected standards covering: (1) Methods of Measurement; (2) Physical Parameters considering electrical, mechanical, and thermal characteristics; (3) Standards of Performance; and (4) Safety Standards. Additionally, standards will be required for premium product programs such as the US Energy Star for SSL and for the eventual regulation of SSL products for energy efficiency and color quality by governmental regulatory bodies.

This presentation will cover:

- Many of the standards development organizations and how they fit together
 - ANSI, IESNA, NEMA, IEC, CIE, and others.
- The many standards that have been developed and that are in progress.
 - Methods of Measurement, Color, Maintenance, Life, Binning, Safety, and more.
- An updated roadmap for SSL standards that will provide users with modularity, choice, confidence, information, reliability, and interchangeability.
- Accreditation, Mutual Recognition Arrangements, and Regulatory bodies – opportunities for streamlined cross-border commerce and product qualification.