Optical Radiation News

Published by the COUNCIL for OPTICAL RADIATION MEASUREMENTS (WWW.CORMUSA.ORG) to report items of interest in optical radiation measurements. Inquiries may be directed to the Editor, Daryl R. Myers, National Renewable Energy Laboratory 1617 Cole Boulevard, Golden CO 80401 Tel: 303-384-6768 Fax: 303-384-6391 e-mail: daryl.myers@nrel.gov

NUMBER 94 FALL, 2010

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CENAM news from the *División de Óptica y Radiometría* (DOR)

CIE News

CORM 2011
Annual Conference and Business Meeting

May 4 - 6, 2011

The CORM 2011 conference will be held at NIST in Gaithersburg, Maryland. The conference topics include:

- **Optical Properties of Materials including but not limited to Solar, Display, SSL Technologies**
- **Solid State Lighting: Novel Ideas/Applications & Standardization Updates**
- **Practical Ideas and Tips for Laboratory Measurement of / with Light**
- **Laboratory versus Production SSL Metrology**

The 2011 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.

Early conference registration begins in February 2011.

CORM provides pdf copies of Annual Conference presentations to attendees on USB drives at the CORM Annual Conference. CORM sees that the placing the presentations on its website, www.cormusa.org, would be of interest to the optical radiation measurement community and would be in keeping with CORM's mission to disseminate information on optical radiation metrology.

CORM is asking your permission to save and publish your CORM 2010 presentation in pdf format on its website. A CORM Presentation Release Request Form will be supplied to all presenters.

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CORM Council for Optical Radiation Measurements

CORM 2010
Annual Conference and Business Meeting Conference Summary

The CORM 2010 conference was held May 9-11, 2010 at the Planet Hollywood Resort and Casino in Las Vegas, NV. The conference preceded the Light Fair International conference. Approximately 50 attendees were present for the CORM conference. The conference was highlighted in LEDs Mags Daily Lightfair http://www.ledsmagazine.com/features/7/5/3

CORM technical committee meetings were held on May 9, followed by the conference on May 10 and 11. The conference provided a forum for a timely workshop entitled, "Display Metrology" prepared by Edward F. Kelley, PhD, KELTEK LLC. Papers related to General Topics in Optical Radiation Measurement (Session Chair: Bob Angelo) , Photovoltaics (Session Chair: Daryl Myers), Display Measurement (Session Chair: Ed Kelley) , and SSL Measurements and Standards (Session Chair: Andy Jackson) were presented. Comments from CORM conference attendees indicated that topics were timely, of the highest quality, relevant to technology advancements and needs, and generated much discussion. Additionally, valuable networking connections were made, and many attendees indicated they will be looking forward to the next conference.
Conference papers included:

- CQS – Test Results to Date – Dr. Wendy Davis (NIST)
- SSL Photometric Standards Update – Eric Richman (PNNL). Presented by Michael Grather (LTL; UL)
- Pitfalls in SSL Photometry – Michael Grather (LTL; UL)
- Solar Data Warehouse: Measured Solar Radiation Data form 3000 US Stations for Renewable Applications – Dr. James Hall (JHtech)
- SSL/LED Road to Standardization 2010 – Andrew Jackson (Philips)
- Display Measurement Standard from SID's ICDM – Dr. Edward Kelley (Consultant)
- Optimizing the Solar Photovoltaic Energy Capture on Sunny and Cloudy Days Using a Solar Tracking System – Dr. Nelson A. Kelly (General Motors Research and Development Center)
- Characterization of Remote Phosphor Type of LEDs – Arno Keppens (Guest Researcher NIST). Presented by Yuqin Zong (NIST)
- 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).
- Results, Finding, and Oddities from NVLAP SSL Proficiency Testing – Dr. Cameron Miller (NIST)
- Solar Resource Data and Uncertainties for Photovoltaic Systems Applications – Daryl R. Myers (National Renewable Energy Laboratory)
- Updated CALiPER Lifetime Testing: 2010 – Mia Paget (PNNL)

- SSL End Product Performance—Correlation from Chip or Device Performance – Mia Paget (PNNL)
- LED Lumen Maintenance Prediction Method – Dr. Emil Radkov (Illumitex, Inc)
- LED Depreciation Model Analysis – Eric Richman (PNNL)
- Development of an automated measurement system for LED lifetime test – Yuqin Zong (NIST)

Many of the presented papers are now available at www.cormusa.org.

The Franc Grum Memorial Lecture was given by Michael Fark of Light Up The World. The lecture was entitled, "The Socio-Economic Impact of Light on Development." Light Up The World (LUTW) is an international development organization that utilizes renewable energy and solid-state lighting technologies to bring affordable, healthy, efficient, and environmentally responsible sustainable energy and lighting solutions to people in developing countries who do not have access to electricity.

The CORM Conference was closed in the afternoon of May 11 and was followed by a short CORM Board of Directors meeting. Conference organizers for the 2010 CORM conference were Jim Leland (Copia LLC) and Andy Jackson (Philips).

CORM **Council for Optical Radiation Measurements**

CORM NEWS

Report on Joint ISSC CORM Conference
Lighting in Artistic, Commercial, and Retail Spaces
March 2-3, Gaithersburg MD

On March 2nd and 3rd this year, a group of about thirty five scientists, engineers, and museum professionals met in Gaithersburg, Maryland, to share on the topic of "Lighting in Artistic, Commercial, and Retail Spaces." This meeting was jointly sponsored by ISCC and CORM, and located on the facilities of the National Institute of Standards and Technology (NIST). The two days consisted of three technical sessions and a tour of the related NIST laboratories.

The first session was chaired by Steve Weintraub of Art Preservation Services. This session, *The Use of Lighting in Commercial and Artistic Spaces*, presented the full range of use and analyses of lighting in museums and commercial applications. Gordon Anson began the day discussing his experience lighting museum exhibits. Many creative solutions were shown for a wide variety of museum spaces and all genres of artwork. Chris Maines followed with the description of a portable micro-fading tester. This instrument could intensely illuminate a very small area and then accurately quantify the change in color of the sample. To follow this, Carl Dirk explained methods to design illuminants whereby artwork damage could be avoided. Steve Weintraub discussed the difficulties of balancing the divergent goals of preservation and exhibition. The best way to preserve artwork would be to never show it at all, but that clearly does not meet the goals of most artists. Finally, Paul Gregory wrapped up the presentation showing the end product of applying lighting in the commercial field. He displayed several fascinating large-scale applications, each with a detailed description of the design both from an engineering point of view as well as focusing on the experience of the end user. The session closed with a panel discussion where these five speakers fielded audience questions.

The afternoon session, chaired by Dave Wyble, of Rochester Institute of Technology, was titled *Vision and Aesthetics*. These speakers were recruited by Wendy Davis, of NIST, who was unable to attend the actual presentations. The first talk, authored by Mark Rea and Jean Paul Freyssinier, was presented by Jean-Paul Freyssinier. Their work combined two metric of lighting evaluation: color rendering index and gamut area index, to better predict the actual experience of observers in the retail lighting field. Next, Yoshi Ohno presented an improved color rendering index being worked on at NIST. He also described the Spectrally Tunable Light Source facility, which was a part of the tour, described below. Terry McGowan followed with a practical reminder of what it means to actually work in the retail lighting field. Applying the lighting metrics to the myriad of available fixtures, as well as the navigation of new energy saving legislation can be a daunting task. Gersil Kay closed this session on the benefits of engaging light designers early in an architectural project, the same time when construction or ventilation engineers are beginning to have input. Mostly this requires communication that lighting can impact the productivity, safety, comfort, and even profit.
The second morning started with tours of a variety of NIST laboratories. Details of the tours are presented below.

The final session, *Practical and Measurement Aspects of Lighting*, was chaired by Cameron Miller of NIST. The first talk, by Cameron Miller, traced the history of the candela from its roots as visual metric using actual candles to its current physical definition realized in NIST laboratories. He discussed transferring that standard to other instruments, using detector- and source-based methods. Finally, he warned of spectral mismatch between the calibration lamp and the source lamp for the application. Nick Lena followed with an interesting review of sources, measurements, and color. This in-depth presentation covered a host of topics valuable to anyone interested in color and lighting. Mike Grather closed the session with a description of IES files, which communicate the parameters of a particular light source. These profiles provide the input to modeling software used by architects and designers. Given the breadth of attendees, three diverse people were asked to submit their impressions of the tours. These reviews follow:

One expects to be impressed by the ultimate cryogenic radiometer or protocols that take all day to measure a small set of BCRA tiles, but not so much by psychophysics at a lab like NIST. At a time when dozens upon dozens of researchers have populated their computers and the Internet with multi-megabyte-sized Excel spreadsheets of colorimetric models for illuminants - some real; some imaginary – it's refreshing to see that someone is still interested in "ground truth." Of course I slightly overstate the case, but Yoshi Ohno's high-intensity LED room remains my highlight. And it does so for exactly this reason. While it is useful and important to measure the human response to common household objects under different illuminant SPDs, the issues in art museums or anywhere in which aesthetics and cultural preference become major components in the visual experience requires that simulations be as real as scientifically possible to construct. We tend to undervalue lighting when it comes to refined aesthetic judgments, thinking that aesthetics is a common and trivial subject. That it is something anyone can do, and we're all equally good at it. It also is assumed to be far less complex than it is. Aesthetics is not just about beauty. It is not by any argument that simplistic, and it can be learned, refined and expanded. It is facilities like Ohno's that pose questions like - can we measure this experience? Maybe not. Maybe it's too elusive. I'm sure Ohno thinks it may be too complicated. But it's still worth a try. That's what impressed me. It's a window of a sort into something really deep.

Jim Druzik, Scientist, Getty Conservation Institute

I enjoyed the NIST labs tour very much, and thanks to our gracious hosts for explaining their equipment, processes, calibrations, etc. I was especially intrigued by the Vision Lab, of course. This is a great opportunity to assess visual response to variations in lighting. (Since I'm greedy, I'd like to be able to assess other sources - non-LED - as well.) It was extremely interesting both to be in the environment as the object colors changed, and to be outside, observing the scene.

Ann Campbell Laidlaw, Global Supply Chain Program Manager, X-Rite Incorporated

During the ISCC-CORM joint meeting, there was a tour through seven NIST laboratories. Most attendees were experts on luminaries or on the technical aspects of metrology. My interests were more general. Most of us have our spectrophotometers and radiometers calibrated at laboratories whose measurements are traceable to NIST. The tour was an opportunity to learn exactly how the ultimate measurements are obtained. This is the place where the buck stops.

We were shown separate massive instruments that measure visible, ultra-violet and infra-red wavelengths. Although measurements at 5 or 10 nanometers are usually reported to clients, measurements are taken at single wavelengths, and the measurements made by each of these instruments overlap, making it possible to check that the three instruments, one of which is even in a separate location, are producing the same results. The care necessary to eliminate all factors that could affect a measurement was impressive. As an example, in a laboratory that contains spectrophotometer spheres of various sizes, there was a sphere large enough to hold a couple of men. As it was constructed it proved impossible to cover the inside of the sphere with a perfectly even coating of barium sulfate. The thickness of the coat was slightly greater toward the bottom of the sphere than at the top. There had to be a way to compensate for the small difference in reflection due to the difference in coating thickness. Surrounding the main instruments was a forest of smaller instruments that controlled for such variables.

We were told that the statement, "Traceable to NIST," as you might guess, has different degrees of meaning. Some companies hire NIST to calibrate their instrument, incurring a large expense, and then calibrate your instrument to theirs. Sometimes there is a path passing back to NIST through several companies. Accuracy may depend on the length of that path.

The hush and concentration that accompanied the tour through the first six laboratories turned into animated discussion in the last, where visual studies are done. There was a three-sided room containing couches, tables holding artificial fruit and food, and a Macbeth Color Checker. The entire ceiling contained sets of LED lights, which were sufficiently diffused to make the room seem to be lit from a single source; but the operator could select and tune various groups of LED lights to simulate different types of daylight, fluorescent and incandescent illumination. Several of us at a time sat in the partial room, the light in the main room was turned off, and we experienced the changes in the appearance that occurred as the different types of light illuminated the objects. We saw in a few minutes the changes that in everyday life take place over an extended period. After we had experienced the effect on color of different types of illumination, the saturation of the illumination was reduced or increased. We watched our skin tones shift, but everyone focused on the red square in the Color Checker, where small color variations were most evident.

Among other results, studies in this laboratory demonstrated again that most people like the saturation of object colors slightly increased over their appearance in natural illumination; however, above a certain point, objects begin to look unnatural, while below the natural level things look increasingly grayish. This was also discovered years ago when the dyes used to produce color photographs were selected. After study the goal became not realism, but dyes that would increase the saturation of natural colors somewhat. Colored film did not attempt to reproduce what is naturally seen, but a purer version of natural colors i.e., not how that blue fabric actually looks, but an ideal blue. People liked those photographs and bought that film.

Joy Turner Luke, Studio 231

ATLAS GmbH Conducts Round Robin Test of Spectral Irradiance Measurements

Dr. Joachim Hussong of Atlas MTT GmbH, Linsengericht-Altenhasslau, Germany, organized and provided financial support for a Round Robin Test (RRT) on the measurement of spectral irradiance. The RRT was organized and conducted in conjunction with the German Federal Institute of Physical and Technical Affairs of **Physikalisch-Technische Bundesanstalt,** (PTB; http://www.ptb.de/index_en.html).

Osram GmbH provided the 1000 watt tungsten halogen lamps, Opto.cal GmbH selected the lamps and configured the lamp sockets, and Heraeus Noblelight GmbH (HNG) designed and provided the optical setup. Figure 1 shows the measurement setup used by all participants. Participants were provided specific detailed instructions for setup, measurement, and reporting of spectral irradiance data and illuminance calculations. The spectral range of interest was the vacuum ultraviolet (VUV) to Visible (Vis) range of 200 nm to 800 nm. There were 13 participants, listed in the table below.

TABLE 1. ATLAS RRT Participants

	PARTICIPATING INSTITUTION	LOCATION
1	3M	USA
2	Atlas DSET	USA
3	Atlas MTT GmbH	Germany
4	Atlas MTT LLC	USA
5	Austrian Institute of Technology (AIT)	Austria
6	Federal Institute for Materials Research and Testing (BAM)	Germany
7	EKO Instruments Co., LTD. (EKO)	Japan
8	Fraunhofer Institute for Solar Energy Systems (FISE)	Germany
9	Gigahertz-Optik GmbH	Germany
10	Heraeus Noblelight GmbH (HNG)	Germany
11	National Renewable Energy Laboratory (NREL)	USA
12	Opto.cal GmbH	Switzerland
13	OSRAM GmbH	Germany

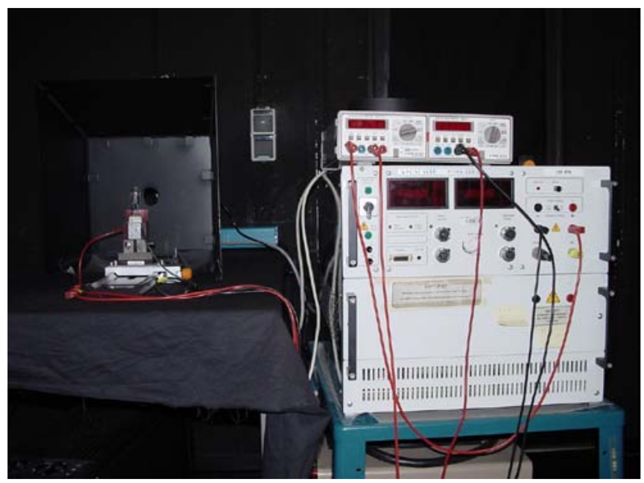


Figure 1 (right). Measurement configuration for the RRT showing Lamps, power supplies, current monitoring equipment, lamp installation, and radiation shield.

Five lamps were initially included in the RRT; however lamp # 2 failed during the RRT and was removed from the analysis. Representative results of the RRT are shown in Figure 2, and 3. Figure 2 shows typical departure from PTB results for a single laboratory. Figure 3 shows the standard deviation of integrated irradiances in specified spectral bands for the 13 laboratories.

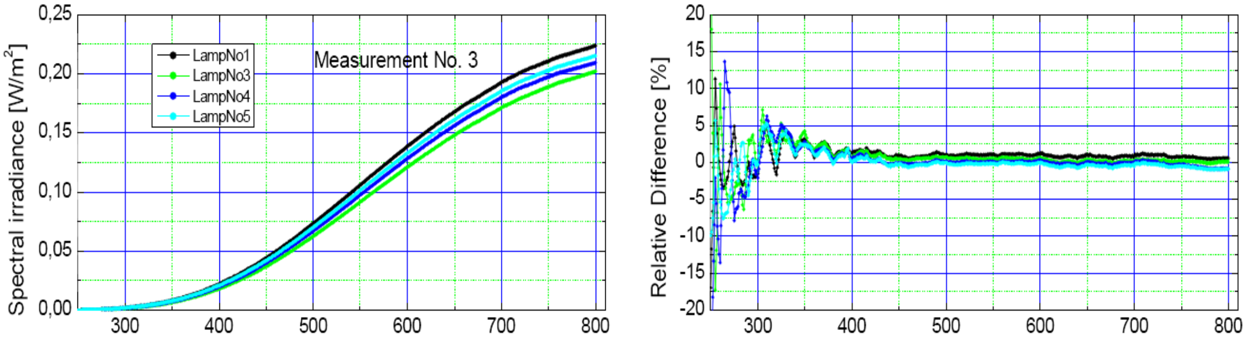


Figure 2. Representative results for spectral difference from PTB reference for one RRT participant.

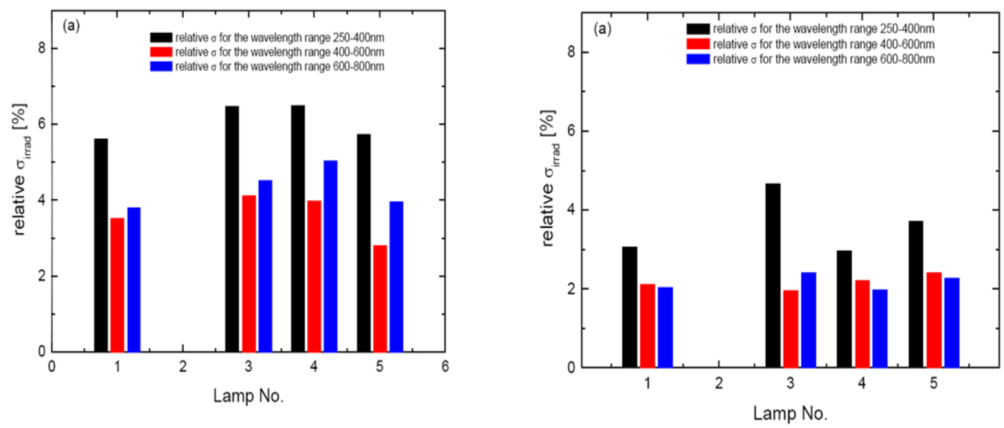


Figure 3. Standard deviation of band integrated irradiances among 13 labs in the RRT. Left panel represents 1 group of 11 measurements (7 participants, some with replicate measurements), right panel represents 2nd group of 6 participants, and one set of measurements each.

The conclusions summarized in the final report state:

> "....[The] purpose of the current RRT was the evaluation of the dispersion of measurement uncertainties. However, due to technical problems associated with the power degradation in the lamps No. 1 and 3, the results of the measurement do not strictly provide the values under interest. ... Within the framework of the chosen procedure of the data analysis, relative standard deviations of the illuminance calculated from the measured spectral irradiance are below 3.5 % for both sets of measurement results. In order to determine the lower limit of a signal, measurable by the corresponding spectroradiometer in the UV range below the wavelength of about 300 nm, measurements with the cut-off filter WG 335 are performed. The results reveal a significant variation of the least measurable true signal, even while comparing the results obtained with the same type of the spectroradiometer."

For more information, contact Dr. Joachim Hussong, JHussong@atlasmtt.de.

Waymouth Collection on Lamp Sciences and Technologies Available for Public Access

Troy, N.Y. – Through the generosity of Dr. John F. Waymouth, and with financial support from OSRAM SYLVANIA, the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute is pleased to make available a searchable database of Dr. Waymouth's extensive and annotated personal collection of papers, patents and reports on the science and technology of light sources. The "John F. Waymouth Collection on Lamp Sciences and Technologies," is housed in the LRC's Resource Collection and is available to interested researchers and students. The searchable database can be accessed from the LRC website at www.lrc.rpi.edu/library/waymouth/index.html.

"In many ways, the materials provided in this collection define the evolution of modern lighting technologies," said LRC Director and Professor Mark S. Rea, Ph.D. "We are proud to be the permanent home of this important collection and to make it available so it can help shape lighting in the 21st century."Dr. Waymouth joined the Sylvania Lighting Division in 1950 and remained with Sylvania, later GTE Sylvania, until his retirement in 1988 as director of research and development for GTE Sylvania's Lighting Group.

The American Physical Society awarded him the Will Allis Prize for the Study of Ionized Gases in 2000. Many former lighting and electrical engineering students are likely to be familiar with his book, *Electric Discharge Lamps*, a reference volume used throughout the world, according to Rea.

The Waymouth Collection joins others in the LRC's Resource Collection, including the L. B. Marks Library, once kept in the headquarters of the Illuminating Engineering Society; the Deane B. Judd Collection of his papers, letters and notebooks formerly housed at Ohio State University's Institute for Research in Vision; and Charles L. Amick's personal lighting library, donated by his family.

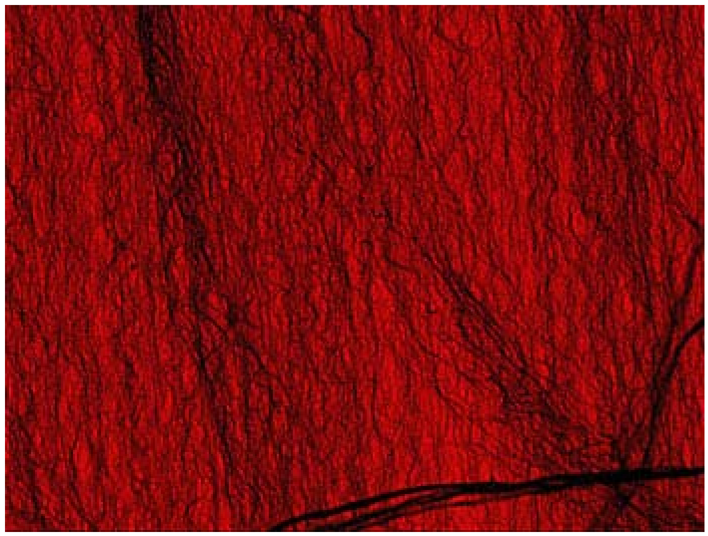
About the Lighting Research Center

The Lighting Research Center (LRC) is part of Rensselaer Polytechnic Institute of Troy, N.Y., and is the leading university-based research center devoted to lighting. The LRC offers the world's premier graduate education in lighting, including one- and two-year master's programs and a Ph.D. program. Since 1988 the LRC has built an international reputation as a reliable source for objective information about lighting technologies, applications, and products. The LRC also provides training programs for government agencies, utilities, contractors, lighting designers, and other lighting professionals. Visit www.lrc.rpi.edu.

NIST NEWS from the Optical Technology Division

Extreme Darkness: Carbon Nanotube Forest Covers NIST's Ultra-dark Detector

Harnessing darkness for practical use, researchers at the National Institute of Standards and Technology (NIST) have developed a laser power detector coated with the world's darkest material—a forest of carbon nanotubes that reflects almost no light across the visible and part of the infrared spectrum.



Colorized micrograph of the world's darkest material—a sparse "forest" of fine carbon nanotubes —coating a NIST laser power detector. Image shows a region approximately 25 micrometers across. Credit: Aric Sanders/NIST

NIST will use the new ultra-dark detector, described in a new paper in Nano Letters,* to make precision laser power measurements for advanced technologies such as optical communications, laser-based manufacturing, solar energy conversion, and industrial and satellite-borne sensors.

Inspired by a 2008 paper by Rensselaer Polytechnic Institute (RPI) on "the darkest man-made material ever,"** the NIST team used a sparse array of fine nanotubes as a coating for a thermal detector, a device used to measure laser power. A co-author at Stony Brook University in New York grew the nanotube coating. The coating absorbs laser light and converts it to heat, which is registered in pyroelectric material (lithium tantalate in this case). The rise in temperature generates a current, which is measured to determine the power of the laser. The blacker the coating, the more efficiently it absorbs light instead of reflecting it, and the more accurate the measurements.

The new NIST detector uniformly reflects less than 0.1 percent of light at wavelengths from deep violet at 400 nanometers (nm) to near infrared at 4 micrometers (µm) and less than 1 percent of light in the infrared spectrum from 4 to 14 µm. The results are similar to those reported for the RPI material and in a 2009 paper by a Japanese group. The NIST work is unique in that the nanotubes were grown on pyroelectric material, whereas the other groups grew them on silicon. NIST researchers plan to extend the calibrated operating range of their device to 50 or even 100 micrometer wavelengths, to perhaps provide a standard for terahertz radiation power.

NIST previously made detector coatings from a variety of materials, including flat nanotube mats. The new coating is a vertical forest of multiwalled nanotubes, each less than 10 nanometers in diameter and about 160 micrometers long. The deep hollows may help trap light, and the random pattern diffuses any reflected light in various directions. Measuring how much light was reflected across a broad spectrum was technically demanding; the NIST team spent hundreds of hours using five different methods to measure the vanishingly low reflectance with adequate precision. Three of the five methods involved comparisons of the nanotube-coated detector to a calibrated standard.

Carbon nanotubes offer ideal properties for thermal detector coatings, in part because they are efficient heat conductors. Nickel phosphorous, for example, reflects less light at some wavelengths, but does not conduct heat as well. The new carbon nanotube materials also are darker than NIST's various Standard Reference Materials for black color developed years ago to calibrate instruments.

* J. Lehman, A. Sanders, L. Hanssen, B. Wilthan and J. Zeng. 2010. A Very Black Infrared Detector from Vertically Aligned Carbon Nanotubes and Electric-field Poling of Lithium Tantalate. Nano Letters. Posted online Aug. 3, 2010.
** Z.P. Yang, L. Ci, J.A. Bur, S.Y. Lin and P.M. Ajayan. Experimental observation of an extremely dark material made by a low-density nanotube array. Nano Letters. Vol. 8, No. 2, 446-451.

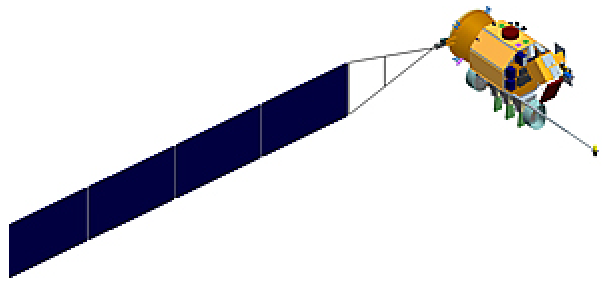
Contact: Lenard Hanssen (lenard.hanssen@nist.gov)

Extended Infrared Bi-directional Reflectance Distribution Function Measurements

Optical sensors used to observe the Earth often depend on white diffusers to establish scales of radiance. Despite the large number of Earth observing sensors which operate in the reflective solar region of the spectrum, there has been no direct method to provide NIST traceable Bi-directional reflectance distribution function (BRDF) measurements out to 2500 nm. Recent developments in detector technology have allowed the NIST reflectance measurement facility to cover the full solar reflective region out to 2500 nm. Using a cooled extended-range indium-gallium-arsenide (Extended InGaAs) detector, measurements were made with a PTFE white diffuse reflectance standard over the 1100 nm to 2500 nm region at a 0° incident and 45° observation angle. The scale was validated using two independent means. One was the overlap region of the well-established silicon detector near 1100 nm, and the second was the use of the spectral irradiance to radiance transfer facility. The direct measurement in this spectral region will allow for lower uncertainties in applications where white diffuse standards play a critical role in determining the sensors response.
Contact: David Allen (david.allen@nist.gov)

NIST, NASA Launch Joint Effort to Develop New Climate Satellites

The National Institute of Standards and Technology (NIST) and the National Aeronautics and Space Administration (NASA) have launched a joint effort to gather enhanced climate data from spaceborne climate observation instruments planned for a group of satellites now under development.



One of the CLARREO satellites, which will make observations of the energy the Earth absorbs from the sun and radiates back into space. The balance between them affects the climate. Credit: NASA

The Climate Absolute Radiance and Refractivity Observatory (CLARREO) Mission includes a fleet of satellites tentatively scheduled for launch later this decade that will gather data for long-term climate projections. The CLARREO mission will provide an accurate climate record of the complete spectrum of energy that Earth reflects and radiates back into space, measurements that should provide a clearer understanding of the climate system.

NIST's role will focus on the calibration of the instruments aboard CLARREO satellites, as well as on the accuracy that the sensors must meet. The measurements need to be characterized to far greater accuracy—from two to 10 times better, depending on the wavelength of light in question—and detector standards need to be developed for the far infrared region of the spectrum. NIST will also help NASA improve its own capabilities in instrument calibration. The collaboration was finalized in a Space Act Agreement on Feb. 4, 2010. CLARREO, led by NASA Langley Research Center in Hampton, Va., is now among NASA's top-priority missions because of its high ranking by the National Research Council, which designated CLARREO one of its four "Tier One" missions when it evaluated proposals in 2007. NASA is allocating $270,000 for NIST's contributions to the project this year.

The mission is part of a longer-term effort to establish global long-term climate records that are of high accuracy and traceable to the international system of units (SI). The CLARREO satellites and other instruments will be calibrated against international standards based on SI, so that observations from different times and locations can be compared usefully, creating a more reliable record of long-term climate trends.
Contact: Carol Johnson (carol.johnson@nist.gov)

Aperture Measurement Facility Upgrades Complete

The Optical Technology Division's Aperture Measurement Facility is back in operation after a major overhaul of the instrument due to obsolescence of various components. The method of measurement is unchanged, with an XY stage equipped with an interferometer for coordinate positioning, and a focusable microscope objective used to detect the location of the edge. The upgrade includes new coordinate measuring machine validation using the Manufacturing and Engineering Laboratories Standard Reference Materials for dimensional measurements and magnification, establishing traceability to SI. The new automated program is written in Labview and allows flexibility in measuring various types of apertures.
Contact: Toni Litorja (maritoni.litorja@nist.gov)

Spectroradiometry and Radiation Thermometry Short Courses

The 6th Spectroradiometry Short Course was held on March 16th to 19th, 2010 at NIST. The 12 lectures covered the basics of spectroradiometry, measurement processes and measurements uncertainties given by the NIST staff that specializes in the particular areas. The lectures were given in the mornings, and the hands-on experiments were performed in the afternoons. The experiments were meant to illustrate spectroradiometric examples, which include the measurement equations and uncertainty analyses for each of the experiments. The 11th Radiation Thermometry Short Course was held August 9th to 13th, 2010 at NIST. Offered every 2 years, the course covers the fundamentals of radiometric physics and instrumentation associated with determining temperature from observations of thermal radiation from materials. Participants gained a good understanding of temperature measurement using thermal radiation, proper uncertainty analysis, treatment of the measurement equation, and an understanding of the calibration chain for radiance temperature. The next Spectrophotometry short course is scheduled for April 2011 and the next Photometry short course is scheduled for August 2011. http://www.nist.gov/physlab/div844/sc/

For further information, contact Cameron Miller (c.miller@nist.gov).

Development of an Automated Measurement System for LED lifetime test

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 an 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, 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 for a 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. The uniqueness of the system is that it is completely automated and self contained with several reference standards internal and external to maintain the measurement scale with a small uncertainty for years. A set of several hundred of 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 two or three temperatures. The lifetime test will last years with datum acquisition as frequent as once every week. The prototype design of this measurement system is completed and the vendor that wins the contract will begin construction in the fall of 2010.Contact: Yuqin Zong (yuqin.zong@nist.gov)

National Research Council of Canada

NRC · CNRC National Research Council Canada Conseil national de recherches Canada

Liaison Report from the Photometry and Radiometry Group

Progress in NRC High Temperature Fixed Points

A new project is underway at NRC to contribute to the on-going international effort to develop high temperature fixed points based on metal-carbon eutectics to define the temperature scale above the melting point of silver. The NRC BB3500M high temperature furnace has been used to realize the melting transition of a Re-C fixed point (approximate temperature of 2747 K). The position of the fixed point within the furnace has been optimized and measurements with the NRC linear pyrometer LP3 indicate a melting range of approximately 0.4 K.

This project will eventually include fixed points of Co-C, Pt-C and Re-C with nominal melting temperatures of 1597 K, 2011 K and 2747 K, respectively. Assignment of the true thermodynamic temperatures of these fixed points will be determined via an international comparison scheduled to begin in January 2012.

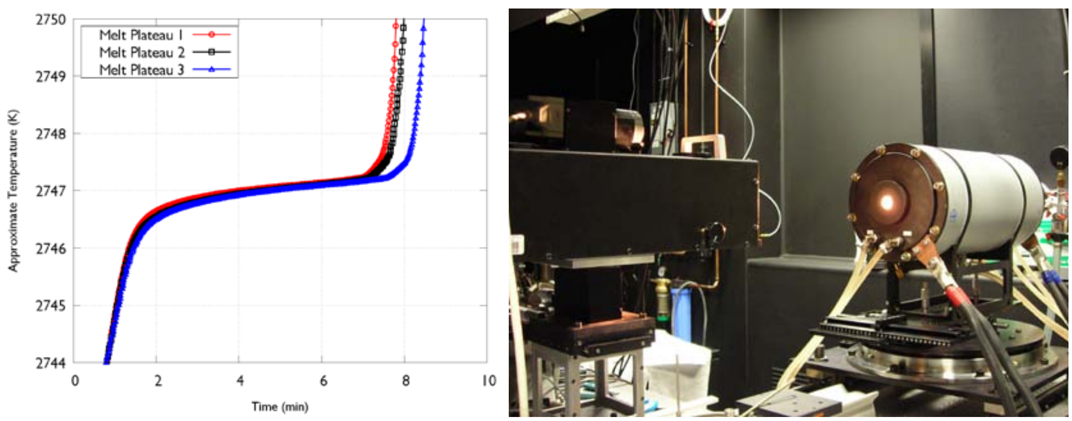


Figure 1: Melting plateaus of a Re-C eutectic fixed with the location of the fixed point in the furnace optimized (left) and the BB3500M furnace and LP3 (right).

For further information contact: Andrew Todd, 613 993-7714, andrew.todd@nrc-cnrc.gc.ca

Update on NRC Quantum Candela Research Project

As reported in recent issues of ORN, a new facility has been developed at NRC to work in fundamental quantum metrology to explore the concept of reformulating the candela as a countable number of photons per second and investigate routes to absolute radiometry using quantum states of light. Our first project developed a device to measure the transverse wavefunction of a single photon. The transverse degree of freedom of photons is potentially of use to applications in quantum cryptography and quantum computing. In classical terms, the transverse wavefunction is equivalent to the spatial mode of the beam containing the photon. Our device directly measures both the real and imaginary components of the field of this mode. It does this by producing a small polarization rotation at a particular transverse position *x* in the beam. A lens then performs a Fourier Transform of the spatial mode and with a 15 micron wide slit we filter out the photons with non-zero transverse momentum. Of those that remain, the measured polarization rotation gives the real part of the wavefunction at *x* and the imbalance in circular polarization gives the imaginary part of the wavefunction at *x*. We have demonstrated this with a classical beam of light and have now created and optimized a source of single photons to test the device.

Our single photons are produced through spontaneous parametric downconversion in a nonlinear optical crystal (BBO). In this process, a strong pump beam occasionally produces pairs of photons at half the frequency. The detection of one of these photons heralds the presence of its twin, thus producing a single photon state of light. We can create 300 000 heralded photons per second fiber (with a wavelength of 800nm) coupled into a single optical mode.

We also had a coop student from the University of Waterloo Nanotechnology Program. The student designed and built an FPGA (field programmable field array) based device to count and correlate clicks from up to eight single photon counting detectors. The device has nanosecond timescale logic to handle correlating the clicks and communicates a histogram of the results to a computer via USB. The logical functioning of the device can be reprogrammed as desired to perform different tasks including outputting arbitrary sequences of TTL pulses. The device will enable, for example, the measurement of entangled states of many photons.

For further information contact: Charlie Bamber, 613- 990-8990 or Jeff Lundeen, 613-993-8913

Index of Refraction Effects upon Blackbody Radiation

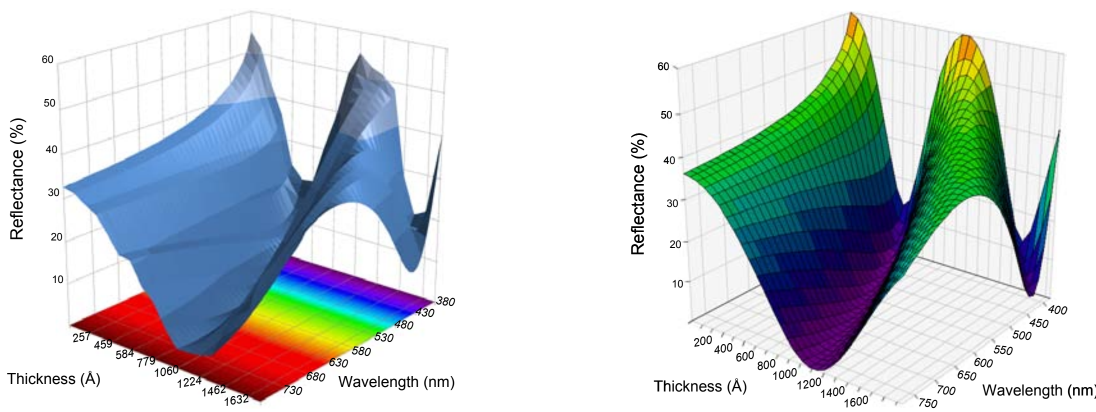
There has recently been considerable international discussion concerning the effects of the index of refraction of the radiation propagation medium in the high-temperature blackbody (HTBB) cavity and the index of refraction of the medium in which the radiation from the HTBB is measured, usually room temperature air. The determination of the influence of these two indices upon the spectrum of the radiation from the HTBB has important consequences upon the determination of the temperature in the HTBB, as a standard for temperature measurements, and for the determination of the spectral radiance and irradiance produced by the HTBB, as a standard for spectral radiance and irradiance calibrations. Earlier work had shown that the spectral radiance measured in the laboratory depended upon both indices of refraction. We have recently shown that the spectral radiance measured in the laboratory is only dependent upon the index of refraction of the medium in which the radiation is measured, usually that of the room temperature laboratory. This derivation has been submitted to the CCT (document CCT/10-11 at http://www.bipm.org/cc/AllowedDocuments.jsp?cc=CCT) and has been presented, in collaboration with MSL (New Zealand) and NPL (U.K.), at the Blackbody User's Group workshop held in conjunction with TEMPMEKO 2010 held in Slovenia in June 2010. The derivation and application to filter radiometer measurements of the HTBB temperature will be published in a forthcoming article in Journal of Modern Optics entitled: "Wideband Filter Radiometers for Blackbody Temperature Measurements", by L.P. Boivin, C. Bamber, A.A. Gaertner, R.K. Gerson, D.J. Woods and E.R. Woolliams.

For further information contact: Arnold Gaertner, 613-003-9344 arnold.gaertner@nrc-cnrc.gc.ca

Goniocolorimetric Study of Aluminum Oxide Films

A robot-based gonioreflectometer developed by NRC to measure the BRDF of reflecting materials was recently used to measure thin films of aluminum oxide deposited on silicon substrate by Atomic Layer Deposition (ALD). ALD is a gas-phase stepwise thin film deposition method that results in highly conformal coverage of even complex surfaces. Similar to Chemical Vapour Deposition (CVD) which is a continuous deposition process, ALD is distinguished by the self-limiting nature of the molecular monolayer formed at each step. The most common process sees a metal-organic precursor entrained over the target substrate until the surface is saturated with chemisorbed species which are designed to prevent further film growth. A pulse of inert gas followed by evacuation of the deposition chamber prepares the system for the next precursor which then reacts with the previous monolayer to form another saturated, self-limiting monolayer. Another pulse/purge step follows and then the process is repeated as desired until the target film thickness is reached. While production-level ALD for electronics is well-established, the precise and conformal subnanometer-thin films that ALD can provide can also be useful for protective and cosmetic purposes. Precise control of film thickness and composition leads to precise control of the films' optical properties.

The regular spectral reflectance of 18 samples was measured over the visible range from 380 nm to 780 nm and for incidence angles varying from near normal to near grazing. The thickness of the films varied from 13.9nm to 183nm. Chromaticity values were calculated and plotted in CIE chromaticity diagrams to show often strong angular dependency. While interference colours can be modeled with reasonable accuracy, it is found that the pertinent details of real physical systems differ significantly from idealized models and merit direct observation.



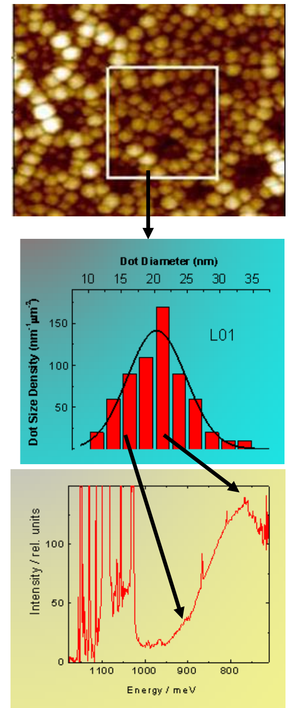
These figures compare the spectral reflectance measured with the gonioreflectometer at 10° viewing angle (left) to the predictions of a thin film modeling software (right) assuming bulk material physical constants.

This study was carried out in collaboration with the Chemistry department at Carleton University. For further information contact: Réjean Baribeau, 613 993-9351 rejean.baribeau@nrc-cnrc.gc.ca

Update on Photoluminescence Efficiency Measurements of Ge Dots Self-Assembled on TiO_2 Films

As reported in the last issue of ORN, NRC is measuring photoluminescence efficiency of Ge dots on TiO_2 films. This is a collaborative effort with the Institut Matériaux Microélectronique Nanosciences de Provence and Université Pierre et Marie Curie, in Paris Cedex, France.

For Ge nanodots ~ 20 nm in diameter grown by annealing a thin amorphous Ge layer deposited by molecular beam epitaxy on a mesoporous TiO_2 layer on Si(001), photoluminescence (PL) was observed as a wide near-infrared band near 800 meV. Using a tight binding theoretical model, the energy-dependent PL spectrum was transformed into a dependence on dot size. The average dot size determined the peak energy of the PL band and its shape depended on the size distribution, including bandgap enlargement due to quantum confinement. Combining the dot sample PL with an established dependence of emission efficiency on dot diameter, it was possible to derive a dot size distribution and compare it with results obtained independently from atomic force microscopy.



Top Figure: AFM image of self-organized Ge dots grown on a porous TiO_2 membrane. The square is 200 nm wide by 200 nm high is the area of the size distribution histogram.
Middle Figure: The dot size distribution with a best-fit Gaussian curve.
Bottom Figure: PL spectra at 5 K recorded with 20 mW of 458 nm exciting laser Light corrected for the PL instrument response.

For further information, contact Nelson Rowell, 613-993-2377. Nelson.rowell@nrc-cnrc.gc.ca

Peer Assessment of NRC Quality System for Fluorescence Calibration Services

The quality management system used in the NRC fluorescence procedures and associated calibration and measurement capabilities (CMCs) were peer-reviewed by Measurement Expert, Dr. Paul deRose (NIST) on June 17-18, 2010. This peer review provides additional technical support for the extension of the scope of the NRC photometric and radiometric (P&R) calibration services to be listed in Appendix C of the International Committee for Weights and Measures (CIPM) Mutual Recognition Arrangement (MRA). The results of this highly successful peer review will now be presented to the SIM Quality System Task Group meeting in November 2010 which, if approved, would then extend the list of NRC P&R CMCs published by the BIPM to include the following quantities: radiance factor, total (reflected plus luminescent) and radiance factor, reflected, spectral for fluorescent materials. As reported in the Fall 2009 issue of ORN, the full quality management systems of the already accredited NRC Scope of photometric and radiometric calibration services, with scope extension, was re-assessed by the Standards Council of Canada in April 2009 and NRC currently has 63 P&R CMC entries in Appendix C of the BIPM KCDB.

For further information, contact Joanne Zwinkels, 613-993-9363 or Mario Noël, 613-991-1637

CENAM news from the *División de Óptica y Radiometría* (DOR), Mexico.

Simposio de Metrología 2010 to be held on October 27-29 at Querétaro

The *Centro Nacional de Metrología* is now ready to begin this year's edition of the *Simposio de Metrología*, SM2010, next October 27 to 29 at the city of Querétaro, Mexico. This year the invited speakers includes Dr. Patrick Gallagher, Director of NIST, Dr. Myungsoo Kim, President of KRISS, Dr. Hector Nava, Director of CENAM, Dr. Rainer Engel (PTB), Dr. Thomas O'Brian (NIST), Dr. Eddy So (NRC), Ms. Aida Albuerne (PROFECO Labs. Mexico). In addition, the SM2010 will also offer short workshops, sponsors exhibition, and submitted contributions presented in poster and oral sessions.

For detailed information on program, topics, etc., please visit the SM2010 Website at: http://www.cenam.mx/simposio2010

New realization of the candela

Last August, new photometric responsivity calibrations of a set of three photometric detectors were completed, with traceability to the SI units through the national standards maintained at CENAM.

The three detectors were first calibrated in spectral responsivity against standard photodetectors traceable to the Watt realized with CENAM's electric substitution cryogenic radiometer. Those photometric detectors were used to calibrate a set of three incandescent FEL type lamps for luminous intensity; thus resulting in a new realization of the candela in Mexico. The national standard keeps the uncertainty level and range defined on its previous version.

Technical guide for luxmeter calibrations

As part of the support provided by CENAM to its users in the secondary calibration laboratories and industry; a technical publication for luxmeter calibrations and its use in lighting levels verification, was published last July.

This guide is intended to provide the readers with the basic knowledge needed to correctly use information obtained after luxmeter calibration, as well as for the appropriate utilization of the luxmeter when measuring lighting levels as regulated by NOM-025-STPS-2008 in Mexico.

Proficiency testing for smoke meter operation

The *Laboratorio de Caracterización Óptica de Materiales* (Optical Properties Laboratory) has started a proficiency testing program (PT) for opacity meters, also known as smoke meters, with six participants, four of which have already been accredited in Mexico. Two more laboratories are seeking to obtain this accreditation after passing this proficiency testing.

The first stage for this testing has been concluded, in which the equipment, one of the most used in Mexico, has been calibrated by the participants. The PT will also allow the participants to establish the minimum performance requirements to be fulfilled by the equipment.

Improvement of UV dose and irradiance measurement facility

As part of the continuous improvement of the measurement capabilities of the ultraviolet radiometric bench installed at CENAM, the uncertainty component for the combined special non-uniformity of the 254 nm radiant field and pyroelectric spectral responsivity has been estimated. The new declaration of the Mexican national standard for ultraviolet dose, planned for the end of 2011, will include 365 nm and 254 nm.

New realizations for length and attenuation in mono-mode optical fibers

After a few years of continued work conducted towards the improvement of the currently declared Mexican standards for length and attenuation in mono-mode optical fibers; the *Laboratorio de Potencia Óptica* (Optical Power Laboratory), is now building a new delay line for optical length, as well as reference fiber for spectral attenuation.

This work will allow CENAM to improve the national standard for those two quantities, in high demand by the Mexican telecommunications industry. CENAM is also capable of providing these standards to other industries as required.

Spectral responsivity scale expansion from 400 nm to 900 nm

The *Laboratorio de Espectrorradiometría de Detectores* (Detectors Spectrorradiometry Laboratory) has started a project to improve the measurements for spectral responsivity of photodetectors. The project will be based on a theoretical model which will take advantage of the measurements performed for a Si trap detector carried out at 632.8 nm. SI unit traceability will be with respect to the electric substitution cryogenic radiometer installed at CENAM. With transfer of this calibration to standard detectors in the full range of operation, uncertainty will be reduced an order of magnitude.

CIE NEWS

COMMISSION INTERNATIONALE DE L'ECLAIRAGE

CIE/USA Seminars on Photometry, Colorimetry and Application of Solid-State Lighting TORONTO – November 10, 2010

The field of lighting is undergoing significant, even disruptive, changes in technology with solid-state lighting (SSL) entering the market. These new SSL devices require newer, advanced characterization and measurement methods. The CIE/USA, the U.S. National Committee of the International Commission on Illumination (CIE), is offering a one-day series of seminars on the photometry, colorimetry, and application of solid-state lighting. Invited experts will present basic concepts, advanced techniques, and state of the art research on the characterization and measurement of light and lighting, along with discussions of international lighting recommendations for roadway lighting and issues of vision and health. This event is scheduled in conjunction with the 2010 IES Annual Conference at the same venue.

Scheduled Seminars

Fundamentals of Photometry and IESNA LM-79
Dr. Cameron Miller, National Institute of Standards and Technology
Topics include photometric units and quantities, history of the Candela, luminous efficacy of radiation, mesopic photometry (TC 1-58), IESNA LM-79, and National Voluntary Laboratory Accreditation Program accreditation.

Fundamentals of CIE Colorimetry and Color Measurement
Dr. Yoshi Ohno, National Institute of Standards and Technology
Topics include the color matching functions, tri-stimulus values, chromaticity coordinates, correlated color temperature (CCT), signed distance from the blackbody locus (Duv), uniform object color spaces – CIELUV and CIELAB, and IESNA LM-79 color measurements.

Color Quality of Light Sources
Dr. Wendy Davis, National Institute of Standards and Technology
Topics include the Color Rendering Index (CRI), different aspects of color rendition, effects of narrowband spectra, the Color Quality Scale (CQS), and the status of TC 1-69.

Current Applications of Solid State Technology in Roadway and Street Lighting
Dr. Ronald Gibbons, Virginia Tech Transportation Institute
Topics include application of solid state lighting technologies to road and street environments, discussion of several test installations including safety and energy standpoints, and the current efforts of the IES and CIE.

Photobiological Effects of Optical Radiation
Dr. Rolf Bergman, Rolf Bergman Consulting
Topics include the blue light hazard, effects of flicker, and CIE S009.

Dark-Sky Concerns About Blue-Rich White Light for Outdoor Lighting
Mr. Terry McGowan, International Dark-Sky Association
LED white-light spectra compared to HID and fluorescent spectra as used in outdoor lighting, concerning human health issues, environmental issues, visibility, glare, adaptation, and sky glow

Standards Review Process - United States National Committee of the CIE
Mr. Philip Wychorski, Orion Standards LLC
Topics include ISO/CIE standards and the role of the U.S. technical advisory group (TAG).

Further details including the registration form are available at www.cie-usnc.org

Recommended System for Mesopic Photometry Based on Visual Performance Published Sep 7, 2010

CIE 191:2010
ISBN 978 3 901906 88 6

This report deals with visual task performance based approaches to mesopic photometry, with a major aim to establish appropriate mesopic spectral sensitivity functions to serve as the foundation of a system of mesopic photometry. A review of the most important visual tasks and the range of visual conditions typically encountered in the context of night-time driving is given.

The existing visual performance based systems for mesopic photometry were reviewed and tested with new independent data sources. The outcome of the analysis and testing is a recommended system for mesopic photometry based on visual performance. The report summarises the justifications for the recommended system and gives general guidelines for its use and application.

The publication is written in English, with a short summary in French and German. It consists of 79 pages with 27 figures and 17 tables, and is readily available at the National Committees of the CIE or via the website of the Central Bureau of the CIE (www.cie.co.at).

Purpose of the Council for Optical Radiation Measurements (CORM)

The Council for Optical Radiation Measurements is a non-profit organization with the following aims:

1. To establish and publish consensus among interested parties on national, industrial and academic requirements for physical standards, calibration services, and inter-laboratory collaboration programs in the fields of optical radiation measurement, including measurement of the transmittance and reflectance properties of materials, measurement of radiant sources, and characterization of optical detectors used for the measurement of these properties.
2. To establish national consensus on the priorities for these requirements.
3. To maintain liaison with the National Institute of Standards and Technology (NIST) and The National Research Council Canada (NRC) and to advise the Institute(s) of requirements and priorities.
4. To cooperate with other organizations, both public and private, to accomplish these objectives for the direct and indirect benefit of the public at large.
5. To assure that information on existing or proposed standards, calibration services, collaboration programs, and its own activities is widely disseminated to interested parties.
6. To answer inquiries about such standards activities or to forward such inquiries to the appropriate agencies.

Optical Radiation News Editorial Policy

Optical Radiation News (ORN) is published semi-annually in the April and October of each year. ORN reports upcoming technical meetings and news from NIST and other national metrology laboratories. News relating to the status and progress in optical radiation metrology from affiliated organizations, including, but not limited to, the *Commission International De Éclairage* (International Commission on Illumination, CIE), Inter-Society Color Council (ISCC), Lamp Testing Engineers Conference (LTEC), etc., is welcome. No commercial advertising, endorsements, or contributions with commercial content are included in ORN. Unsolicited contributions are subject to review and approval by the editor, CORM publications committee, and /or executive board prior to publication. Anonymous contributions will not be accepted. Contact information for a submission is required and will be published. ORN is included free with CORM membership.

Instructions for Contributing Authors

ORN is published in English. Deadlines for submission of News items and announcements concerning optical radiation metrology are 1 March and 1 September. Items may be submitted to the editor in via fax or e-mail attachments in plain ASCII text or common electronic word processing file formats, preferably Microsoft Word® or Corel WordPerfect®. Contributions should be in 12 point Times New Roman font with simple formatting, e.g., the "Normal" style and template in Word. *Use of complex style templates and formatting is strongly discouraged*. Submissions with high quality pertinent electronic graphics are welcome, however digital photographs and graphics will be reproduced in black-and-white or grayscale. Graphics included in hardcopy submissions via fax will not be reproduced. Submissions are credited to organizations, rather than individuals.

Policy on Commercial Activities at CORM Conferences

The Council for Optical Radiation Measurements (CORM) does not permit commercial activities in conjunction with technical sessions of CORM conferences and CORM workshops. Commercial activities include, but are not limited to, product exhibition and dissemination or display of advertising in any format. Speakers at CORM conferences and workshops may not use talks for overt commercialization of products. Commercial activities as defined above are permitted for a fee for defined periods prior to social activities associated with the conference or workshop at the discretion of the CORM Board of Directors. Registration requirements, details of the structure of the allowed activities and fees are (event and site) specific.

Council for Optical Radiation Measurements

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