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, John D. Bullough, Lighting Research Center, Rensselaer Polytechnic Institute, 21 Union St., Troy, NY 12180. Tel: 518-687-7100 Fax: 518-687-7120 e-mail: bulloj@rpi.edu.

NUMBER 104 SPRING 2018

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NEWS FROM THE NATIONAL CENTER OF METROLOGY OF MÉXICO (CENAM)

NEWS FROM THE CIE

NEWS FROM UNIVERSITIES

Overview of the CORM/ISCC 2018 Joint Annual Conference

The annual conference for CORM was held in conjunction with the Inter-Society Color Council (ISCC) at Rensselaer Polytechnic Institute in Troy, NY from July 30-August 2, 2017. CORM board members Michael Grather and Alan Tirpak, and ISCC secretary Ann Laidlaw served as conference coordinators.

On the first day of the conference, the initial session on Display Metrology was organized by Tim Moggridge and moderated by John Bullough and included presentations on color volume in high dynamic range (HDR) displays and perceived brightness of LED signal light sources. Michael Grather organized and moderated the second session on solid state lighting (SSL) technologies and metrology. Presentations included models of color stability for light emitting diode (LED) sources, manufacturing of SSL systems, analysis of spectrometers, and characterization of sky glow from LED outdoor lighting. Committee meetings occurred during the afternoon of the first day. The committees included Phosphor Efficiency Test Methods, Characterization of SSL Diffusers, Ultraviolet (UV) Measurement, and Lamp and LED Standards.

On the second day, a special session featuring emerging professionals and current students, organized by Mark Jongewaard, was held. This session featured presentations on the impact of spectral content of a glare source and its background on visual discomfort, and on quantifying spectral-based errors in measurements of luminance. Ann Laidlaw organized and moderated the next session on the optical properties of materials, including talks on dynamic visual adaptation, bidirectional reflection distribution functions, an overview of standards work in lighting and color, and matrix R theory. The final session of the day on UV radiometry, moderated by David Sliney, featured presentations on germicidal measurements, UV irradiance, UV LEDs, spectroradiometry in lamp safety, and noise in safety-related UV measurements. The day ended with the Franc Grum Memorial Banquet and Lecture. The lecture delivered by Mariana Figueiro, Director of Rensselaer's Lighting Research Center, and discussed measurement and application of circadian light in architectural spaces.

The third and final day featured a conference session on activities at national metrology institutes chaired by Ann Laidlaw. Presenters from the National Institute of Standards and Technology (NIST) and the National Research Council (NRC) of Canada discussed measurement uncertainty, radiometry, reflectance measurements, and spectral irradiance calibrations. Following the close of the session, conference attendees participated in a tour of the Lighting Research Center's laboratory facilities in downtown Troy.

CORM 2018 Annual Technical Conference

First Announcement and Call for Papers

July 29 – August 1, 2017

The CORM 2018 Annual Technical Conference and Business Meeting will be held in Gaithersburg, MD – in cooperation with the National Institute of Standards and Technology (NIST). The conference topics include:

- Solid State Lighting (SSL)
- Optical Properties of Materials
- UV Radiation Metrology
- Current Research Activities at NIST, NRC & CENAM
- and a special session for Emerging Professionals*

**The Emerging Professionals session is open to students and professionals with less than 5 years' experience in the field of Optical Radiation Measurement, Measurement with Optical Radiation and other topics within the scope of CORM.*

Preliminary Schedule

- Sunday, July 29 PM: Evening Reception-Cash Bar
- Monday, July 30 AM: CORM Technical Committee Meetings, PM: Technical Sessions
- Tuesday, July 30 AM: Technical Sessions, PM: Technical Sessions, Franc Grum Memorial Lecture and Banquet
- Wednesday, Aug 1 AM: Technical Sessions, CORM Business Meeting, PM: Facility Tour, NIST

The conference fee of $495 includes one banquet ticket for Tuesday evening. Additional tickets will be available for $65. Online registration information will be available shortly through www.cormusa.org.

The 2018 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.

- Deadline for abstracts is May 11, 2018
- Presentation materials are due by June 26, 2018
- Please contact the conference coordinators for details

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PML Scientist Leonard Hanssen Selected as Fellow of SPIE

Leonard Hanssen, a Physicist in the Sensor Science Division, was selected as a Fellow of SPIE. SPIE is the international society for optics and photonics, with a membership of approximately 18,700. Hanssen is being recognized for major contributions to infrared radiometry, particularly to the accurate measurement of the infrared properties of materials using integrating spheres and Fourier-transform spectrometers to develop world-leading capabilities in such measurements. He is responsible for NIST Standard Reference Material 1921, Infrared Transmission Wavelength Standard, which has sold approximately 7500 units since 1995 through NIST's Office of Standard Reference Materials. Hanssen has also performed many measurements that are foundational for many NASA and DoD aerospace programs that rely on infrared sensors, including weather and space weather satellites, space-based telescopes, and antimissile systems. The list of programs supported includes the following multimillion to multibillion dollar efforts: JWST, SIRTF, SABER, SBIRS, CLARREO, ABI, Suomi NPP and JPSS CrIS, GOES, HIRDLS, Suomi NPP/VIIRS, ACRIM III, SORCE/TIM, THAAD, and EKV. Hanssen is a past recipient of DoC Gold and Silver Medals, the NIST Judson C. French Award, and the Arthur S. Flemming Award. [POC: Gerald Fraser, x3797, gerald.fraser@nist.gov]

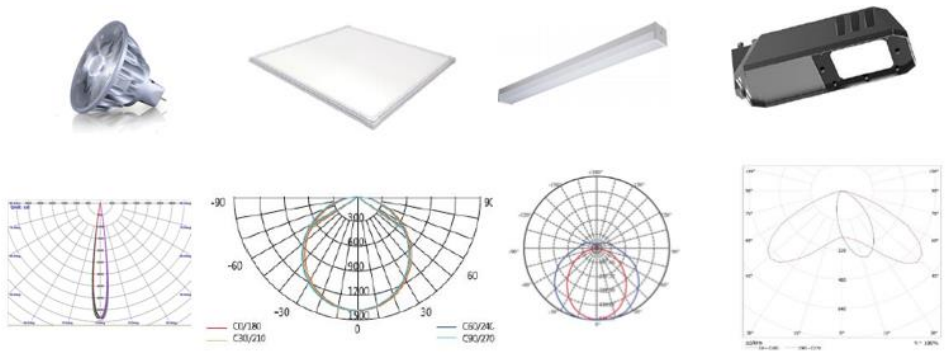
PML Role in the TSIS-1 Sensor Now in Space

The Total and Spectral Solar Irradiance Sensor (TSIS-1) consisting of a Total Irradiance Monitor (TIM) and Spectral Irradiance Monitor (SIM) was successfully launched to space for operation on the International Space Station (ISS) on December 15, 2017, ensuring continuation of the long-term data record for measurements of the Sun's total and spectrally resolved light irradiance, with the former data record being reported by space-borne instruments since the late 1970s. The PML Sensor Science Division made important contributions to this sensor, including measurements by Toni Litorja of optical aperture areas that define the solar illuminated pupil area for determination of irradiance (watts per square meter), calculations by Eric Shirley of the corrections for optical diffraction of the solar radiation passing through the TIM aperture for the total solar irradiance measurements, transfer by Keith Lykke, Steve Brown, and John Woodward of the SIRCUS calibration technique and the loaning of specialized equipment to scientists at the instrument builder, the University of Colorado Laboratory for Atmospheric and Space Physics (LASP), enabling them to perform spectral response calibrations for the SIM instrument, measurements by Leonard Hanssen and Jinan Zeng of the infrared reflectance of the TIM optical cavities that collect and measure radiation following passage through the optical apertures, calibration by Joe Rice and Allan Smith of the LASP cryogenic radiometer that serves as the standard for TIM optical power calibrations, and participation by Carol Johnson and Joe Rice in formal reviews of the calibration strategy and calibration results for the sensors. The team members were recognized by a DoC Gold Medal for their achievements in advancing solar radiation measurements. [POC: Joe Rice, x2133, joseph.rice@nist.gov]

International Energy Agency (IEA) Interlaboratory Comparison of Goniophotometric Measurements for Solid-State Lighting Products

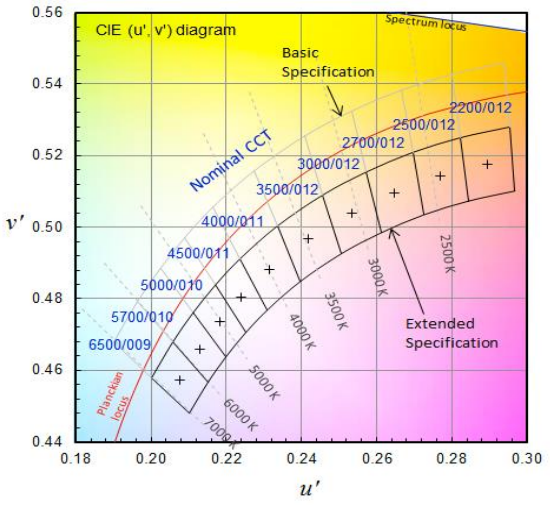
Under the auspices of the IEA 4E Solid-State Lighting (SSL) Annex (http://www.iea-4e.org), PML/Sensor Science Division NIST Fellow, Yoshi Ohno, is leading a large international

comparison (IC 2017) of measurements on LED luminaires, using goniophotometers including traditional rotating-mirror type and near-field type. This intercomparison is a follow-on of a previous intercomparison (IC 2013), which used LED lamps only, with 55 direct participants and 55 linked labs (total 110 labs). IC 2017 was launched in July 2017, participated by about 40 laboratories from 18 countries, and will provide assessment of the comparability of goniophotometric measurements of LED lighting products in laboratories around the world, and will aid standardization of measurement procedures. The comparison will also serve as proficiency testing for laboratory testing accreditation programs in support of national regulations in solid-state lighting products. Three LED luminaires including a street lighting luminaire and one narrow-beam lamp are used, and 15 measurement quantities are compared. The comparison is using CIE S 025:2015, Test Method for LED Lamps, LED Luminaires and LED Modules as the test method, but is also designed to serve accreditation programs using regional test methods such as IES LM-79. The measurements are carried out in three rounds. The 1st round measurements are completed and 2nd round is starting. [POC: Yoshi Ohno, x2321, yoshi.ohno@nist.gov]



New Version of ANSI Standard on the Chromaticity of Solid-State Lighting Products

A new version of ANSI C78.377-2017, Specifications for the Chromaticity of Solid-State Lighting Products, was published in July 2017. The development of this standard was led by NIST Fellow Yoshi Ohno from the PML Sensor Science Division as Technical Coordinator for this version and previous versions. This standard specifies the chromaticity ranges of white light to be used for LED lighting products, and is widely used not only in the US but also worldwide, often as requirements in regulations. This new revision added new ranges of white light chromaticity that are below the blackbody locus for the first time. This new white light region is considered to be more preferred than the traditional specification (around the blackbody locus) according to recent studies. It is anticipated that this standard will have a major impact on the lighting market. The standard is based in large part on NIST human subjects research using the NIST Spectrally Tunable Lighting Facility as published in two recent papers: Yoshi Ohno and Mira Fein (SURF Student), Vision Experiment on Acceptable and Preferred White Light Chromaticity for Lighting (2014) and Yoshi Ohno and Semin Oh (South Korea Guest Researcher), Vision Experiment II on White Light Chromaticity for



Lighting (2016). These studies showed that chromaticities below that of an ideal blackbody are generally preferred. [POC: Yoshi Ohno, yoshi.ohno@nist.gov, x2321].

American Geophysical Union Magazine Highlights PML's Lunar Calibration Project

EOS Earth and Space Science News, the news magazine for the more than 60,000 member AGU published a story on PML's effort to make accurate, SI-traceable measurements of the reflected solar radiation from the Moon [1]. Such measurements are needed to provide an on-orbit reference for the calibration and validation of shortwave infrared to ultraviolet radiometric measurements of the Earth made by multimillion to multibillion defense, land and ocean imagery, and weather satellites, such as the Joint Polar Satellite System series version 1 (JPSS-1) launched on Nov. 18. Additionally, it is anticipated that the availability of such a reference will reduce the cost of deploying micro and nanosatellites such as CubeSats for which prelaunch calibration costs can be a significant fraction of the total mission budget. The Moon will allow a check and adjustment of the prelaunch calibration of the optical and infrared sensors deployed in space due to changes caused by launch vibration, materials outgassing, and radiation damage. The news feature published on the AGU website on November 27, 2017 under the title, "Exact Moonlight Measurements Could Aid Earth Observing Missions," expands upon a highlight that appeared on the NIST website on October 13, 2017 [2] under the title, "How Bright is the Moon, Really." The EOS story is timely, since two staff members from the PML Sensor Science Division are visiting the NOAA Mauna Loa Observatory this week to determine the optimal site for deploying a pair of domes, one containing a telescope system and the other a calibration system, to allow multiyear SI-traceable measurements of the shortwave infrared to ultraviolet radiation from the Moon. The high-altitude of the Mauna Loa site (3,400 meters) minimizes scattering and absorption of the lunar radiation by the atmosphere. The effort is facilitated by a recently signed interagency agreement between NOAA and NIST to allow installation of the NIST equipment on the site. It also complements another PML effort funded by NASA to make measurements of the lunar radiation from a reprogrammed ER-2 spy plane that flies at altitudes up to 21,000 meters. The small number of measurements provided by the ER-2 flights will validate the residual atmospheric corrections required for the lower altitude Mauna Loa measurements. [POC: Steve Maxwell, x4950, stephen.maxwell@nist.gov; John Woodward, x5495, john.woodward@nist.gov; Steve Brown, x5167, steven.brown@nist.gov]

[1] https://eos.org/articles/exact-moonlight-measurements-could-aid-earth-observing-missions

[2] https://www.nist.gov/news-events/news/2017/10/how-bright-moon-really

NOAA's JPSS-1 Satellite Successfully Launched

NOAA's JPSS-1 polar orbiting weather satellite, the second of five satellite sensors planned for the 43 year, $18.8 billion Joint Polar Satellite System program, was launched into orbit on November 18, 2017 from Vandenberg Air Force Base, CA. With the successful entry into orbit, JPSS-1 was renamed NOAA-20. In 2015, PML/Sensor Science Division scientists Keith Lykke (deceased) and Steve Brown deployed the Traveling SIRCUS laser-based calibration facility to Raytheon in El Segundo, CA to calibrate the Visible Infrared Imaging Radiometer Suite (VIIRS), one of several sensors on the Joint Polar Satellite System (JPSS-1). JPSS-1 is the second satellite to include a VIIRS-type sensor; the first sensor launched on the Suomi-NPP satellite was also calibrated with SIRCUS. PML scientists calibrated the spectral responsivity (absolute imager output as a function of wavelength) and polarization sensitivity of the sensor; the NIST support for JPSS-1 and Suomi-NPP VIIRS was recognized with a DOC Silver Medal in 2016. VIIRS provides imagery and radiometric measurements of the oceans, land, and atmosphere and is critical to NOAA's weather, ocean, and climate missions.

In addition to the VIIRS sensor, and also in 2015, Sensor Science Division staff Dana Defibaugh, Simon Kaplan, and Joe Rice provided calibration testing at Exelis Inc. (now Harris) in Ft. Wayne, IN of two infrared blackbody standards used to calibrate the JPSS-1 Cross-Track Infrared Sounder (CrIS). CrIS is a Fourier-transform spectrometer designed to provide on-orbit measurements of atmospheric pressure, moisture, and temperature spatial and altitude profiles. The testing was done in a thermal vacuum chamber under cryogenic conditions to simulate space-like conditions. NIST deployed its one-of-a-kind Thermal-infrared Transfer Radiometer (TXR) to calibrate the blackbodies used to calibrate the CrIS instrument, providing an independent validation of the radiometric scale of the CrIS instrument. The TXR team (Dana Defibaugh, Julia Scherschligt, and Joe Rice) provided similar measurement for the VIIRS infrared blackbody standard in a vacuum chamber at Raytheon in 2014 to validate the radiometric scale of the VIIRS infrared channels. [POC: Steve Brown, x3797, steven.brown@nist.gov; Joe Rice, x2133, joseph.rice@nist.gov]

NIST Collaborates on Stellar Flux Calibrations for Dark Energy Studies

PML Sensor Science Division scientists John Woodward and Joe Rice and NIST Associate and Space Telescope Science Institute (STScI) scientist Susana Deustua participated in a 2-week campaign organized by Professor Chris Stubbs and group members from Harvard University to test a new method for stellar flux calibrations planned for future Type Ia supernovae surveys used in the investigation of dark energy. The team deployed a collimated beam projector (CBP) developed by Harvard, together with a NIST wavelength tunable laser as its light source, to provide a relative spectral flux calibration of the 0.9 meter telescope at the Cerro Tololo Inter-American Observatory (CTIO http://www.ctio.noao.edu/noao/content/About-CTIO) in Chile. The team then used the same telescope to measure the photometric flux from several CalSpec stars (http://www.stsci.edu/hst/observatory/crds/calspec.html) that serve as flux standards for the Hubble Space Telescope and other astronomy programs. A silicon photodiode on the CBP monitored its relative spectral flux and holds the radiometric scale until the CBP can be calibrated at NIST. The published values of photometric flux from the CalSpec stars will be compared against freshly measured values based on the CBP calibration to assess how well the CalSpec stars are calibrated relative to NIST radiometric standards. This method of relative spectral stellar calibration complements the absolute calibration methods NIST is pursing at Mt Hopkins Observatory, Arizona for calibrating the spectral flux from Vega and Sirius. A version of the CBP is planned for implementation on the Large Synoptic Telescope Survey (LSST https://www.lsst.org/about) within the next few years, and NIST participation in testing the CBP technique is considered vital to the effort. [POCs: Joe Rice, x2133, joe.rice@nist.gov; John Woodward, x5495, john.woodward@nist.gov]

NIST Chaired CIE Committee Releases New Technical Report on Measurement of High-Power LEDs

A new technical report titled Optical Measurement of High-Power LEDs (CIE 225:2017) was published by the International Commission on Illumination on August 4, 2017 as a product of the more than 30 member Technical Committee TC 2-63 Chaired by PML/Sensor Science Division Engineer Yuqin Zong. This technical report covers all the aspects with regard to the measurement of high-power LEDs including the setting and controlling the junction temperature using a method developed at NIST; choosing optical measurement facilities; obtaining photometric, radiometric, and colorimetric values; and analyzing measurement uncertainties. The technical report is expected to lead to future standards that adopt many NIST developed methods for measuring high-power LEDS. The NIST method for setting and controlling junction temperature is particularly important contribution to LED measurement as junction temperature

must be precisely specified and controlled to ensure accurate power measurements that reflect the conditions in which the high power LED are actually used. [POC: Yuqin Zong, x2332, yuqin.zong@nist.gov]

PML and NASA to Collaborate on the Calibration of Next Generation Remote-Sensing Satellites

A four-year Inter-Agency Agreement (IAA) between NASA Goddard Space Flight Center and the NIST Sensor Science Division has been signed to support the prelaunch calibration of the NASA Plankton, Aerosol, Cloud, and ocean Ecosystem (PACE) Ocean Color Instrument (OCI) and the U.S. Geological Survey Landsat-9 Operational Land Imager 2 (OLI-2) being developed by NASA. Under the IAA, NIST will develop improved methods and standards for the calibration of NASA optical radiation standards at the NIST Spectral Irradiance and Radiance Responsivity using Uniform Sources (SIRCUS) facility.

The Ocean Color Instrument (OCI), will capture images of the Earth at spatial resolutions as high as one square kilometer spatial resolution from the shortwave infrared to the visible in various spectral windows. The instrument has a 0.5% to 4% pre-launch accuracy requirement (k = 1), depending on wavelength region sampled, for the measurement of the magnitude of reflected solar radiation from the Earth's surface, atmosphere, and clouds. The Goddard Laser for Absolute Measurement of Radiance (GLAMR) facility, which uses the NIST SIRCUS technique and was developed with NIST assistance, will be used for calibration of OCI and OLI-2 relative to NIST primary standards.

To meet the OCI uncertainty requirements, NASA's GLAMR will obtain its spectral radiance responsivity scale from a set of transfer radiometers calibrated at the NIST SIRCUS facility to a standard uncertainty as low as 0.06 % in the visible, 0.3 % in the near-infrared out to 1600 nm, and 1 % in the shortwave infrared from 1600 nm to 2300 nm. While the NIST Primary Optical Watt Radiometer (POWR) primary standard is already capable of 0.01 % uncertainty in this spectral range for the measurement of spectral power responsivity, meeting the NASA GLAMR requirements will necessitate the development of new measurement science and improved radiometers to lower the uncertainty in scale transfers from power responsivity to irradiance responsivity between POWR and SIRCUS. The new IAA supports this development. The improved uncertainties in the infrared out to 2000 nm realized through this collaboration will also benefit astronomical missions and surveys that use high-red-shifted Type Ia supernovae as standard candles to advance dark-energy science. [POC: Joe Rice, x2133, joe.rice@nist.gov]

NASA, NIST, and Boston University Form Collaboration on the Characterization of the NIST Forested Optical Reference for Evaluating Sensor Technology (FOREST)

NIST (PML Sensor Science Division and ADLP Special Programs Office) and Boston University are collaborating on developing the NIST forest into a testbed for advancing measurement methods, tools, and standards for quantifying the productivity and health of small forests that populate urban, suburban, and rural areas. A section of the testbed has been instrumented to provide high-precision in situ measurements of plant activity. The sensors include sap flow, tree respiration, and a range temperature and moisture sensors that provide sufficient data for ecosystem modelling. The optical sensors at the test site include solar induced fluorescence (SIF), hyperspectral, lidar, thermal imaging, and color/near-infrared imaging. The measurements from these sensors can be compared with measurements provided by handheld, tractor, drone, aircraft, or satellite based sensors. One goal of the effort is to help the agriculture and forestry industries by ensuring that plant productivity measurements used in

precision agriculture and forestry are accurate, comparable, and tailored to the needs of these two industries.

The availability of this instrumented forest led David Allen of the Sensor Science Division to initiate a collaboration with NASA Goddard's LiDAR, Hyperspectral & Thermal Imager (G-LiHT) airborne imaging program to conduct overflight measurements of FOREST. The NASA G-LiHT program sensors have almost a one-for-one match to the NIST based sensors, but from an airborne vantage point. The need for standards to support solar induced fluorescence (SIF) measurements is a priority in the collaboration since SIF potentially provides the most direct measurement of plant productivity. The G-LiHT instrument suite was flown over the NIST forest plot on Friday August 4th. A significant amount of advanced planning was done and included an intensive field campaign of ground-based pre-flight measurements. NIST coordinated with the G-LiHT team on the flight paths, flight regulations, and mapping the areas of interest. The NIST security office was also notified of the flight plan in order to prevent any misunderstanding. This first observation was considered an initial trial run. Repeat data collections are in the plans and will introduce schemes to provide NIST traceability to multiple sensors simultaneously. [POC: David Allen, x 3680, david.allen@nist.gov]

NIST Scientists Investigate Light Scatter from Laser Refractive Correction in the Eye

NIST scientists are working with the University of Rochester and Clerio Vision to investigate light scatter from a new technique being developed for laser refractive correction in the eye. In the new technique, called Intra-tissue Refractive Index Shaping (IRIS), a femtosecond laser is focused and scanned below the corneal surface, inducing a spatially-varying change in the refractive index that corrects pre-existing myopia, hyperopia, or astigmatism. A concern with any laser eye correction technique is additional scatter induced by the process, which can have adverse effects on vision, especially at night. Preliminary light scattering measurements performed at NIST on patterns written into hydrogel surrogates (materials similar to contact lenses) showed four potential sources of scatter. These included: (1) scattering from stitching errors, which result from adjacent scanning fields not being aligned to one another; (2) scattering from the scanned lines themselves; (3) diffraction from Fresnel zone discontinuities; and (4) long-period variations in the scans that created distinct diffraction peaks and were probably due to inconsistent line spacing in the writing instrument. By knowing the amounts of these different effects, the researchers at the University of Rochester and Clerio Vision can work to modify and optimize the structure of their refractive designs to mitigate potential decreases in visual performance in human clinical trials. A PhD student will soon join NIST as a guest researcher to continue this collaboration. [POC: Thomas Germer, x2876, thomas.germer@nist.gov].

NIST Testbed for Measurement of Vegetation Productivity Based on Solar-Induced Fluorescence

Recent satellite, airborne, and ground-based measurements of vegetation solar-induced fluorescence (SIF) show tremendous promise as a means to dramatically improve measurement of vegetation productivity at high temporal frequency and across broad spatial extents. PML researchers together with the Special Programs Office and a team lead by Lucy Hutyra of Boston University have initiated a program for SIF metrology supported by ground-based observations at the Gaithersburg NIST facility. The testbed will allow for advancing theory, developing new methods, and testing new analytical approaches to characterize how vegetation productivity responds to an array of conditions. The testbed makes use a moderately sized forest on the NIST campus equipped with a wide range of sensors measuring sap flow, gas exchange, solar irradiance, along with temperature and soil moisture, as examples. The relative proximity

between the laboratories that provide radiometric and other scales and the testbed greatly facilitate the testing and deployment of sensors. This work will ensure U.S. based companies producing sensors have a means to evaluate new products against known standards. Advancing SIF metrology will also lead to potential gains in crop yields, lumber production, in addition to monitoring urban and remote areas. [POC: David Allen, x3680, david.allen@nist.gov]

NASA to Recognize PML Scientists for Contributions to the Laser-Based Calibration of the JPSS-2 VIIRS Satellite Sensor

Sensor Science Division Physicists Steven Brown and John Woodward and Supervisory Chemist Keith Lykke (deceased) have been recognized together with NASA employees and contractors with a NASA agency-level Group Achievement Award for their work on the laser-based radiometric calibration and characterization of the JPSS-2 VIIRS sensor. The Visible Infrared Imaging Radiometer Suite (VIIRS) is the premier sensor on NOAA's latest generation of polar-orbiting weather satellites, Joint Polar Satellite Systems 1 and 2 (JPSS-1 and JPSS-2). VIIRS provides data in support of weather and flood forecasting, fishery management, forest-fire monitoring, drought management, water quality, and hurricane prediction. The NIST-NASA joint calibration and characterization work was done at Raytheon in El Segundo, California, the primary aerospace contractor for the VIIRS instrument. The effort concluded a successful multi-year effort to stand-up a capability at NASA for the laser-based calibration of satellite sensors modeled after the NIST SIRCUS Facility. [POC: Steve Brown, x5167, steven.brown@nist.gov; John Woodward, x5495, john.woodward@nist.gov]

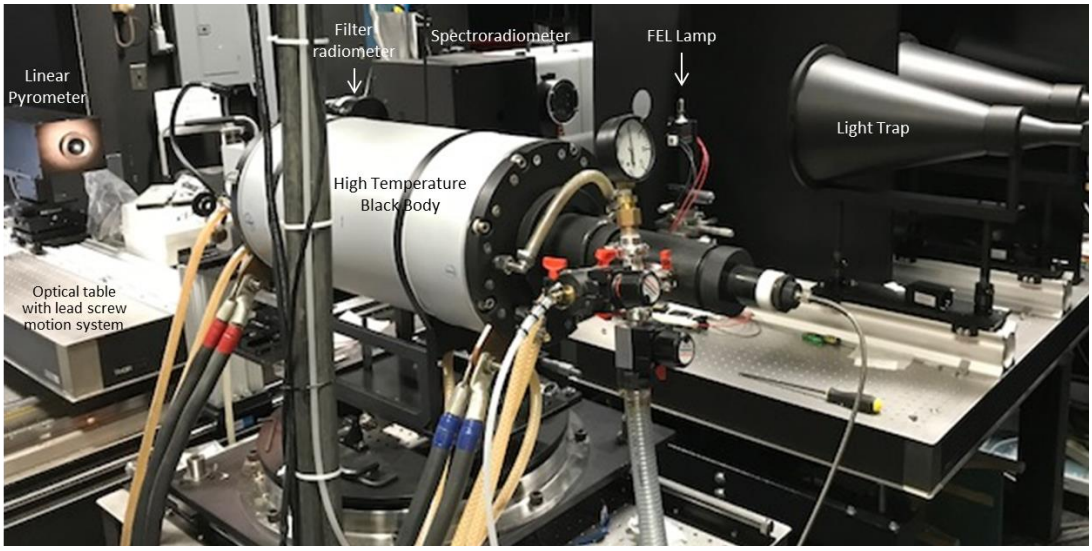
PML/Sensor Science Division Physicist at the Phosphor Global Summit 2017

Physicist Clarence Zarobila gave an invited talk on "Measuring Forward Fluorescence in Remote Phosphors Used in LED Luminaires: A Path to Reproducible Measurements?" at the Phosphor Global Summit 2017 held from March 13 – 15, 2017 in San Diego. The international conference focuses primarily on the application of phosphors in solid-state lighting where they are used with blue or UV LEDs to provide a broadband white light source. Improved measurements of phosphors are required to aid R&D towards higher efficiency phosphors, to ensure accurate and standardized specification of phosphor materials within the international supply chain, and to improve quality control in the manufacturing process. Zarobila's talk highlighted NIST advances in the measurement of the forward fluorescence and associated quantum efficiency of various inorganic phosphors being used in solid-state lighting products. The talk was well received by the community, which has concerns about the comparability of measurements of the quantum yield and other properties of phosphor materials. As noted by Mr. Thomas Paulos, Founder and CEO/CTO of DotLight in an email to Zarobila, "There is a growing need in the industry for third party companies to evaluate the quantum yield of these down converting materials." This view is shared by Mr. William Beers, Sr. System Engineer - Phosphors at GE Lighting in an email to Cameron Miller, "I think everyone in the LED business realizes powder [phosphor powder] measurements can vary from location to location and a NIST reference standard would be very useful to benchmark our systems." [POC: Clarence Zarobila, x2481, clarence.zarobila@nist.gov; Maria Nadal, x4632, maria.nadal@nist.gov, Heather Patrick, x4684, heather.patrick@nist.gov]

NRC LIAISON REPORT

NRC's New Spectral Irradiance Scale

NRC has a new primary realization of the spectral irradiance scale from 250 nm – 2500 nm. A high temperature black body is now implemented as the standard light source for transfer of the primary realization to 1000 W FEL standard lamps. Filter radiometers, with spectral responsivity traceable to NRC's cryogenic radiometer, are used to determine the thermodynamic temperature of the high temperature black body, where a linear pyrometer is implemented for monitoring the stability of the back body temperature. A spectroradiometer equipped with a prism predisperser and three photodetectors (photomultiplier tube, Si, and InSb) allow for measurements over the entire spectral range.



For further information, contact: Angela Gamouras, 613- 993-2489 (angela.gamouras@nrc-cnrc.gc.ca)

Advanced Radiometry Facility

NRC's new advanced radiometry facility is now operational. Improved uncertainties for silicon detector calibrations obtained with the new cryogenic radiometer system have been published in the Journal of Physics Conference Series: 972 012014. A double-subtractive monochromator and broad-band light sources are used to realize NRC optical radiant power scale. In the wavelength range of 300 nm - 400 nm, a xenon-based laser driven light source provides a more intense source of optical radiation in the UV range. From 450 nm to 1000 nm, a 100 W tungsten lamp is implemented as a spectrally flat, stable light source. The calibration uncertainties of InGaAs transfer standard detectors from 900 nm – 1600 nm will be updated in 2018.

For further information, contact: Angela Gamouras, 613- 993-2489 (angela.gamouras@nrc-cnrc.gc.ca)

Few-Photon Metrology at NRC

NRC is working to expand its efforts in optical radiometry by establishing a quantum metrology capability. A free-space single-photon detector efficiency measurement apparatus has been constructed. With SI traceability to the NRC cryogenic radiometer, detector efficiency measurements of silicon single-photon avalanche photodiodes are made using a substitution configuration with a calibrated transfer standard radiometer and a fiber laser source at 850 nm.

Preliminary results show great promise, however further testing and the development of an uncertainty budget are ongoing.

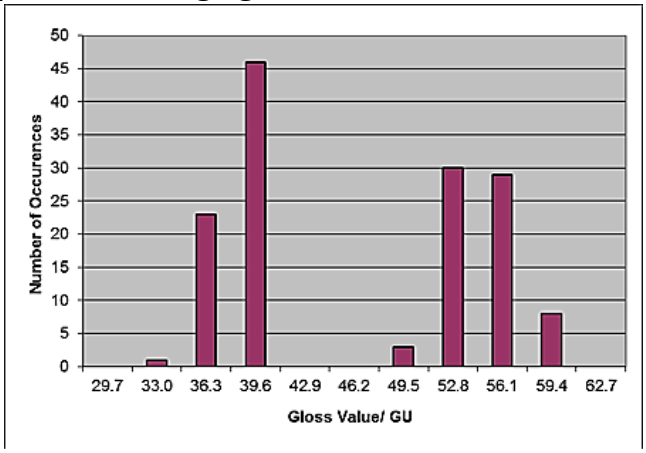
For further information, contact: Angela Gamouras, 613- 993-2489 (angela.gamouras@nrc-cnrc.gc.ca)

Extension of NRC Fluorescence Calibration Capabilities to a Sphere Geometry

NRC has new calibration and measurement capabilities (CMCs) for fluorescence calibrations in a sphere geometry with near-normal illumination (8 degrees) and diffuse viewing (specular component included or excluded) that have been published in the BIPM key comparison database (KCDB) on 2 February 2018. These calibrations are performed on the NRC Reference Goniospectrofluorimeter equipped with a 300 mm diameter integrating sphere accessory which, to the best of our knowledge, is the only reference instrument world-wide providing traceable calibrations of fluorescent reflecting materials in a sphere geometry. The design, characterization and performance validation of this instrument has been published in a 2-part series of papers in Metrologia (54 (2017),129-140; 53 (2016), 1215-30). The instrument uses a continuum xenon source and provides absolute calibrations in both a bidirectional (45:0) and sphere (8:d, 8:t) geometries of both the reflected and luminescent radiance factor components over the spectral range 300 nm to 850 nm with a 5 nm spectral bandpass at 5 nm or 10 nm intervals for CIE standard illuminant or client-specified illuminant conditions.

For further information, contact Joanne Zwinkels, 613-993-9363 (joanne.zwinkels@nrc-cnrc.gc.ca)

Gloss Study of the Impact of Converging and Collimated Beam Geometries



Very large inter-instrument differences have been reported in recent gloss comparison studies that greatly exceed both gloss manufacturer and test method specifications for repeatability and reproducibility. To understand the impact of differences in instrument beam geometries, we carried out a gloss comparison using the NRC reference goniospectrophotometer configured in both a converging and collimated beam geometry for measuring specular gloss of paper samples at 75° and 20° geometries. For the paper samples that were studied, it was found that for a given specular angle and beam geometry, the measurement reproducibility was very good, ranging from 0.6 -2.4 GU. However, for both 75° and 20° geometries, for a change in the beam condition, the measurement reproducibility significantly deteriorated. In the case of both the medium and high gloss coated paper samples measured at 75° geometry, the differences in the measured gloss values for the two different methods (6.3 –7.8 GU) were a factor of ~4 to 8 times larger than the measurement reproducibility for a given beam condition (0.7 -2.4 GU). In the case of the medium gloss paper sample (RG01) measured at 20° geometry, the NRC results showed a very large gloss difference of 23.4 GU in going from the converging (TAPPI) to the collimated (DIN) beam method compared with an excellent measurement reproducibility of 0.6-1.2 GU for a given beam condition. It is interesting to note that the NRC mean result for sample RG01 using these two methods (47.1 GU) is in very good agreement with the grand mean result of 44.9 GU that was

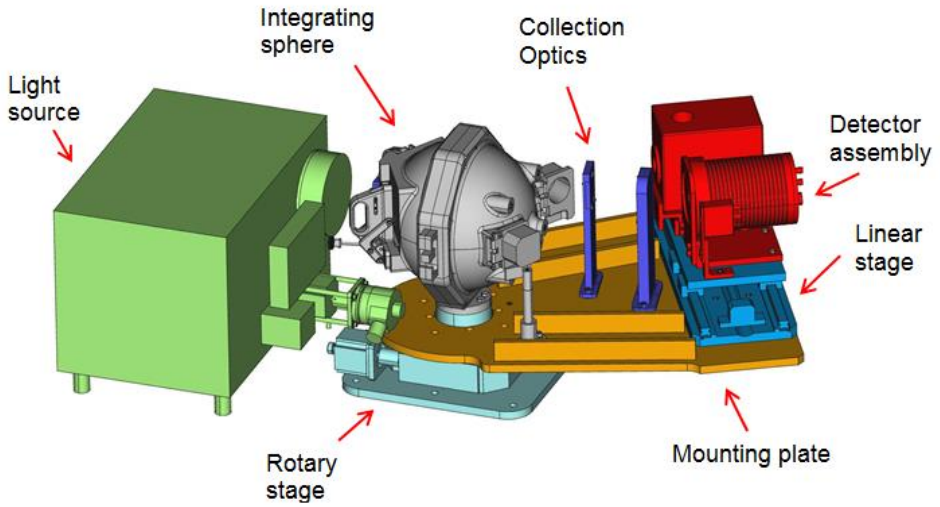
reported for the CTS 20° TAPPI round-robin study using this glossy paper sample (14 participating labs, see Figure below). These results have been published in the Journal of Physics Conf. Series: 972, 012025, 1-5 (2018).

For further information, contact Joanne Zwinkels, 613-993-9363 (joanne.zwinkels@nrc-cnrc.gc.ca)

Status of NRC's New Absolute Diffuse Reflectance Scale

NRC is currently constructing a new absolute reflectometer based on the integrating sphere Sharp-Little method to realize an absolute reflectance scale in a d:0 geometry over the UV-VIS-NIR range. The new system will feature an extended spectral range (250 to 1900 nm), full automation, and improved spectral resolution. The optomechanical design has been completed and characterization of the monochromator-based light source is presently underway. A custom PTFE integrating sphere is being constructed in-house. The main components of the system are expected to be in place by June 2018 at which point detailed characterization of the instrument, including an uncertainty budget, will begin.

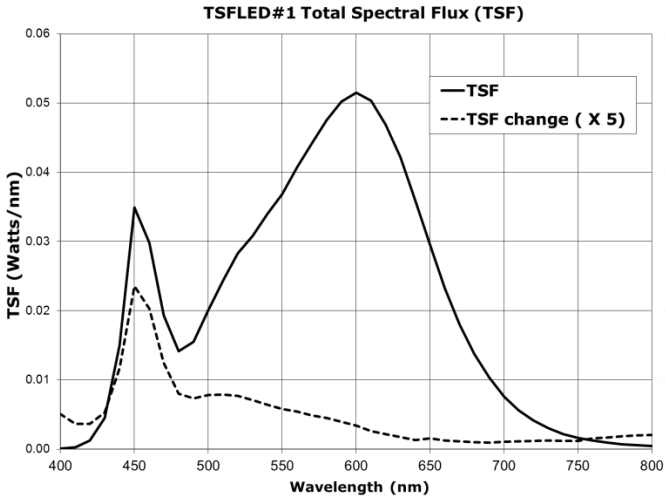
For further information, please contact: Luke Sandilands, 613- 990-8990 (luke.sandilands@nrc-cnrc.gc.ca).



NRC Solid State Lighting Measurement Laboratory

We have been testing Chip-on-Board (COB) LED modules for use in prototype total spectral flux standard sources. A COB is an array of blue pump LEDs covered with a phosphor, mounted on a small circuit board. Our custom test unit (TSFLED#1) was built using four COB's mounted to a forced-air cooled heat sink with the driver units in a separate box. The ageing and reproducibility characteristics of the device were measured spectrally and photometrically in an integrating sphere, with ON/OFF cycles of the driver. A sample of the spectral data obtained is shown in the figure below, where the solid curve is the total spectral flux (TSF) of the device, and the dashed line is the change in TSF output observed during the ageing period (multiplied by a factor of 5 for the plot). It can be seen that the change is predominantly in the 450 nm exciting wavelength and on the short wavelength side of the phosphor spectrum. The observed change corresponds to a photometric increase of approximately 2.4% in total luminous flux and a CCT change of approximately 130 K from 3303 K to 3433 K. At present, our measurements do not allow us to determine details of the causes of the change. The photometric data shows that daily thermal changes in the ac driver units are a component of these changes. A more detailed monitoring of the temporal and thermal behaviour of the source will be required to sort out the factors contributing to the ageing characteristics of the device.

For further information contact: Arnold Gaertner (613) 993-9344 (arnold.gaertner@nrc-cnrc.gc.ca).

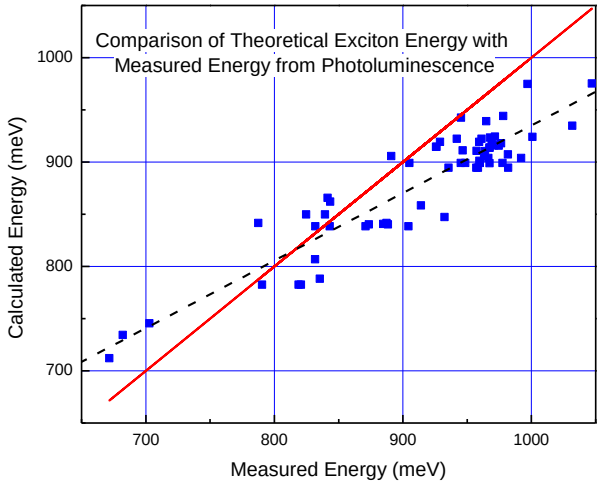


Recent Advances in Solid State Science

The optical absorption coefficient of pure Ge has been determined from new high-accuracy, high precision optical measurements at photon energies covering both the indirect and direct gaps. The results are compared with a new theoretical model that fully accounts for the resonant nature of the energy denominators that appear in perturbation theory expansions of the absorption coefficient. The model generalizes the classic Elliott approach to indirect excitons, and leads to a predicted optical absorption that is in excellent agreement with the experimental values using just a single adjustable parameter: the average deformation potential DΓL coupling electrons at the bottom of the direct and indirect valleys in the conduction band. Remarkably, the fitted value, DΓL = 4.3×108 eV/cm, is in nearly perfect agreement with independent measurements and ab initio predictions of this parameter, confirming the validity of the proposed theory, which has general applicability. These results were published in Physical Review B, 96, 121201 (2017).

For further information, contact Joanne Zwinkels, 613-993-9363 (joanne.zwinkels@nrc-cnrc.gc.ca)

The intense photoluminescence (PL) observed at energies from 600 to 1500 meV for many molecular beam epitaxy grown Si1-xGex epitaxial layers has been analyzed. These results show that the unexplained broad PL peak is due to self-assembled Ge nanocrystals (NCs) within the SiGe layers. The NCs are assumed lattice matched to the SiGe in the vertical, growth direction. As the Ge-fraction in the SiGe layer increases, the vertical strain in the NCs changes from compressive to tensile at x ~ 0.36, lowering the NC band gap (BG) below that of bulk Ge. The PL results for 64 samples exhibiting this broad PL peak were analyzed by examining how it follows the strained Ge BG for x from 0.05 to 0.53. The PL is resolvable as two narrower peaks separated by the TO phonon energy for Ge. Strain and confinement shifted NC bound exciton energies calculated numerically agree well with the measured ones.



Theory versus experiment for the Ge NC PL from SiGe samples with Ge fractions from 0.05 to 0.53. The dashed straight line is the result of a least-squares fit to the data.

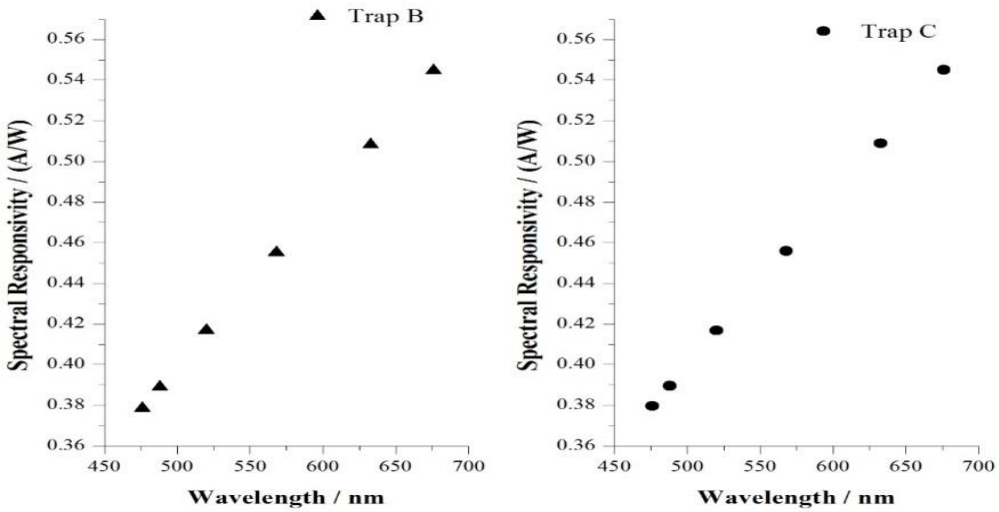
For further information, contact Nelson Rowell, 613-993-2377 (nelson.rowell@nrc-cnrc.gc.ca)

NEWS FROM THE NATIONAL CENTER OF METROLOGY OF MÉXICO (CENAM)

Improvements Made for the National Standard in Radiant Flux of Mexico

In 1999, CENAM established the primary standard for optical power (cryogenic radiometer, CryoRad II CRI Inc.), where the unit of radiant flux is performed at a wavelength of 632.8 nm. The cryogenic radiometers are commonly used together with silicon trap detectors in several NMI's to establish and maintain the radiometric scale of optical power.

To preserve the comparability in optical power between CENAM and other NMI, we have been working in the extension of the operating range of the cryogenic radiometer allowing us to perform the calibration of secondary standards (trap detectors) to a greater number of reference lines (laser source He-Ne, Ar-Kr and IR semiconductor laser). This improvement generates a greater strength of the current scale supported by the periodical responsivity calibrations of Si traps at 633 nm carried out for several years.



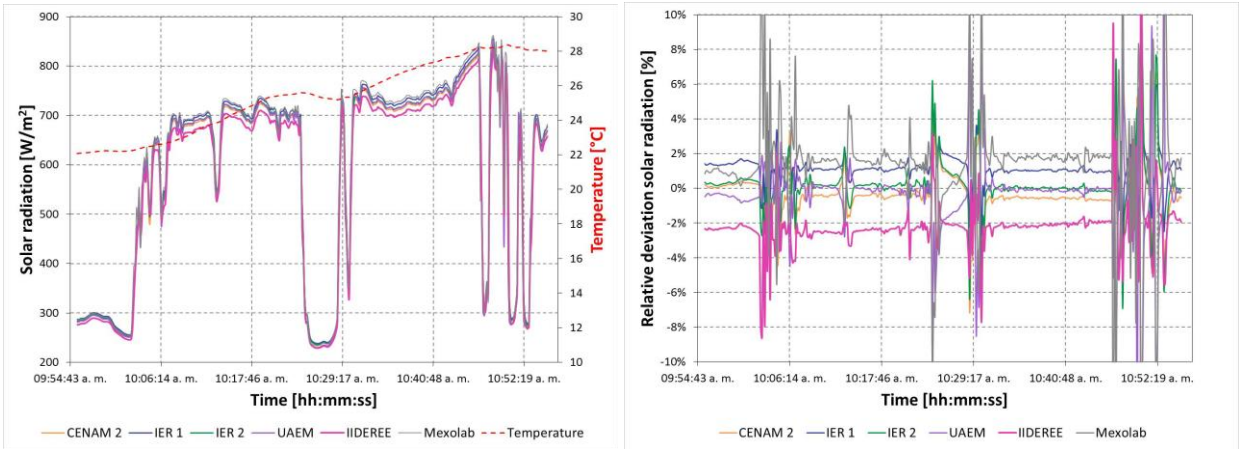
Spectral responsivity trap detectors named B and C

National Pyranometers Comparison of Solar Thermal Labs in Mexico

In order to support the implementation of quality infrastructure in the México market of solar water heating systems (SWH), test laboratories of solar water heating systems were invited to participate in a pyranometers comparison exercise in the facilities of Centro Nacional de Metrología (CENAM) as part of the PTB-German Mexican project: "Quality Infrastructure for Renewable Energy and Energy Efficiency". CENAM was chosen to host the comparison due to their development in measurement capabilities for instruments related with renewable energy, including calibration of pyranometers in laboratory with traceability of measurements to the international system of units via a cryogenic radiometer.

Metrological support developed in the country is critical to the national net of secondary laboratories that test photovoltaic devices and solar water heaters. The metrological support ensures the measurement values and specifications that consumers receive on efficiency labels of products.

The pyranometers comparison exercise was held from August - September 2015 on the facilities of CENAM located at 20º 32.246' North latitude, 100º 15.320' west longitude. The exercise was thinking as a first pyranometers comparison between laboratories, regardless of the time of the last calibration of their instruments. Short measurement periods were considered to evaluate the agreement between the measurements of the pyranometers that laboratories use for routinary testing of SWH.



Measurement and results.

Metrology Symposium 2018

As every two years, the Metrology Symposium 2018 will be held from 8th to 12th of October this year in Queretaro City in the frame of the SI redefinition, focused on the technological and sustainable development worldwide, including topics from primary metrology development at NMIs, to applications of the metrology on industry and research.

More information: http://www.cenam.mx/simposio/

UPCOMING IES MEETINGS CALENDAR

The Illuminating Engineering Society (IES) is sponsoring the following meetings and conferences in 2018:

LIGHTFAIR International
May 6-10, 2018
Chicago, IL
www.lightfair.com

2018 IES Annual Conference
August 9-11, 2018
Boston, MA
www.ies.org/events/annual-conference

2018 Annual IES Aviation Lighting Committee Fall Technology Meeting
September 29-October 5
New Orleans, LA
www.iesalc.org/technology-meetings

2018 IES Street and Area Lighting Conference
September 30-October 3, 2018
Austin, TX
www.ies.org/events/street-area-lighting-conference

NEWS FROM THE CIE

International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

Upcoming Events

CIE 2018 Topical Conference on Smart Lighting
April 24, 2018 – Taipei, Chinese Taipei
http://taipei2018.cie.co.at/welcome-cie-2018

CIE Division 4 Annual Meeting 2018 and Workshop on Visibility for Roadway Lighting
May 22-25, 2018 – Berlin, Germany
http://www.cie.co.at/news/division-4-annual-meeting-2018
http://www.cie.co.at/news/cie-workshop-new-vision-visibility-roadway-lighting

CIE Division 2 Annual Meeting 2018
June 12-15, 2018 – Eindhoven, Netherlands
http://www.cie.co.at/news/division-2-annual-meeting-2018

CIE Expert Tutorial and Workshop on Research Methods for Human Factors in Lighting
August 13-14, 2018 – Copenhagen, Denmark
http://www.cie.co.at/news/cie-expert-tutorial-and-workshop-research-methods-human-factors-lighting

CIE Tutorial and Practical Workshop on CIE S025
November 5-7, 2018 – Moscow, Russia
http://www.cie.co.at/news/cie-tutorial-and-practical-workshop-cie-s025

CIE 2019 29th Quadrennial Session
June 14-22, 2019 – Washington, DC
http://www.cie.co.at/news/cie-2019-29th-quadrennial-session

New Publications

CIE 228:2018 Grey-Scale Calculation for Self-Luminous Devices
http://www.cie.co.at/publications/grey-scale-calculation-self-luminous-devices

CIE 227:2017 Lighting for Older People and People with Visual Impairment in Buildings
http://www.cie.co.at/publications/lighting-older-people-and-people-visual-impairment-buildings

CIE 226:2017 High-Speed Testing Methods for LEDs
http://www.cie.co.at/publications/high-speed-testing-methods-leds

CIE 225:2017 Optical Measurement of High-Power LEDs
http://www.cie.co.at/publications/optical-measurement-high-power-leds

CIE 224:2017 CIE 2017 Colour Fidelity Index for Accurate Scientific Use
http://www.cie.co.at/publications/cie-2017-colour-fidelity-index-accurate-scientific-use

CIE 223:2017 Multispectral Image Formats
http://www.cie.co.at/publications/multispectral-image-formats

CIE 150:2017 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations, 2nd Edition
http://www.cie.co.at/publications/guide-limitation-effects-obtrusive-light-outdoor-lighting-installations-2nd-edition

CIE x044:2017 Proceedings of the Conference at the CIE Midterm Meeting 2017 23 – 25 October 2017, Jeju, Republic of Korea
http://www.cie.co.at/publications/proceedings-conference-cie-midterm-meeting-2017-23-25-october-2017-jeju-republic-korea

CIE TN 008:2017 Final Report CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems
http://www.cie.co.at/publications/final-report-cie-stakeholder-workshop-temporal-light-modulation-standards-lighting

CIE TN 007:2017 Interim Recommendation for Practical Application of the CIE System for Mesopic Photometry in Outdoor Lighting
http://www.cie.co.at/publications/interim-recommendation-practical-application-cie-system-mesopic-photometry-outdoor

For information on all of the CIE technical publications, visit:
http://www.cie.co.at/publications

NEWS FROM UNIVERSITIES

New Publication from Rochester Institute of Technology Features LED Light Lab

Professor Michael Murdoch from the Munsell Color Science Laboratory at Rochester Institute of Technology recently published an article in *Optics Express* describing the calibration and lighting control of a new laboratory for studying human visual adaptation under temporally dynamic lighting. The article is an extension of a presentation Murdoch made at the 2018 CORM/ISCC Joint Technical Conference in Troy, NY. The paper can be downloaded at: https://doi.org/10.1364/OE.25.029605.

University of Colorado Boulder's Rocky Mountain Lighting Academy

To be held on June 21-24th, 2018, the Rocky Mountain Lighting Academy (RMLA) hosted by the University of Colorado, Boulder, will provide an in depth background for those working in the lighting industry. The Academy will cover a range of topics including vision, color, photometry, optics and lighting design. Both technical and design tracks are offered. For more information, visit: http://rmla.colorado.edu.

Lighting Research Center Professor to Chair Task Group Developing Circadian Lighting Recommended Practice

Mark S. Rea, Professor of Architecture and Cognitive Sciences at the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute has agreed to chair a task group with Underwriters Laboratories Inc. (UL) working to develop a recommended practice for the specification, measurement, and application of lighting to support circadian entrainment of individuals in daytime work environments. The task group will produce a set of practical recommendations and methods, grounded in science, that can be broadly implemented by addressing how to specify lighting for daytime applications, how to accurately measure circadian light, and how specification can be achieved, not only through the use of ceiling fixtures, but also by windows, skylights, luminous panels, and plug-in lighting. For more information visit: http://www.lrc.rpi.edu/resources/newsroom/pr_story.asp?id=393.

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 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.

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