CORM / CIE US & Canadian National Committees Joint Conference
November 14 – 16, 2022

Schedule and Program Guide

Monday November 14th All times are Eastern Standard Time

11:00 AM Opening Remarks, Mark Jongewaard, CORM, and Angelo Arecchi, CIE

11:10 AM – 1:40 PM LED Applications and Metrology – Jeff Hulett (Vektrex), session chair

- 11:10 AM Yuqin Zong/C. Cameron Miller (NIST) - "Study on Measurement of Temporal Light Modulation Waveforms"
- 11:35 PM Alexis Lockwood and Remington Bullis (Boulder Engineering Studio) - "SPICE Model Generation of LEDs using Pulsed Samples and Companion Software Analysis"
- 12:00 PM Brien J Housand (JENOPTIK) - "Compact, High Output, Pulsed LED Light Engine Design guided by DCP"
- 12:25 PM L. Prado Jr*, R. C. F. de Lima, C.E. Anderson (Pradolux Ind. Com. Ltda) - "Uncertainty Evaluation of the Chromaticity Coordinates of LED Signal Lights for Vehicles"
- 12:50 PM Jeff Hulett (Vektrex) - "Junction Temperature Assessment for LEDs & Lasers Operated in Pulsed Mode"
- 1:15 PM R. C. F. de Lima, L. Prado Jr*, C.E. Anderson (Pradolux Ind. Com. Ltda) - "Experimental Analysis of the Photometry and the Colorimetry of Signal Lights of Vehicles Designed for Filament Bulbs and Equipped with LED Bulbs"

1:40 PM – 2:15 PM Break

2:15 PM – 3:30 PM Advances and Applications in Spectrophotometry - Thomas Germer (NIST), session chair

- 2:15 PM Li-Lin Tay*, Shawn Poirier, Ali Ghaemi, Hal Bowen-Smith and John Hulse (NRC) - "Optical Properties of Plasmonic Paper"
- 2:40 PM Daniel Poitras (NRC) - "Learning from over 20 years of Optical Interference Coatings Manufacturing Contest"
- 3:05 PM Xiao Nie[1],*, Hoyeon Park[1], Heather J. Patrick[2], Jaeho Lee[1], [1]Department of Mechanical and Aerospace Engineering, University of California, Irvine; [2]Sensor Science Division, NIST Technology (NIST).– "Sprayable Cool White Coatings Based on Glass Bubbles and Solar Transparent Binders"

3:30 PM – 3:45 PM Break

3:45 PM – 5:25 PM Current Research at the NMIs - Luke Sandilands (NRC), session chair

- 3:45 PM Zeus E. Ruiz (CENAM) - "Fiber Optic Cryogenic Radiometer at CENAM"
- 4:10 PM Catherine Cooksey (NIST) - "The Digital NIST: Pilot Project for the Digital Transformation of NIST's Measurement Services"
- 4:35 PM Blair Hall (MSL New Zealand) - "Digital Transformation: A Pilot Study Explores Digitalisation in the Context of CIPM and RMO Transmittance Comparisons "
- 5:00 PM Jeongwan Jin (NRC) - "Progress in Few-Photon Metrology at NRC"

5:25 PM End of Day

Tuesday November 15th All times are Eastern Standard Time

11:00 AM – 1:30 PM Light and Health: Measuring the Stimulus and Response - Andrea Wilkerson (PNNL), session chair

- 11:00 AM Kore R. S., Reichenberger, D., Mundinger, J., Chang, A. M., Durmus D (Pennsylvania State University) – "Performance of a Mini Spectrophotometer as a Wearable Circadian Light Measurement Tool"
- 11:25 AM J. Alstan Jakubiec, Sadi Wali, Arsalan Khan (University of Toronto) – "Development of an Open, Wearable Optical Spectral Irradiance Sensor"
- 11:50 AM Jiaye (Jane) Li and Yoshi Ohno (NIST) – " TLM Measurements for Characterizing the Standardized Measures for the Visibility of Temporal Light Artefacts"
- 12:15 PM Lia Irvin and Eduardo Rodriguez-Feo Bermudez (PNNL) – "Temporal Light Modulation Waveform Generation, Distortion, and Correction"
- 12:40 PM Naomi Miller and Eduardo Rodriguez-Feo Bermudez (PNNL) – "Subject Perception of Flicker Experiment"
- 1:05 PM Jianchuan Tan (PNNL) – "Impact of Sampling Rate on Flicker Metric Calculations"

1:30 PM – 2:00 PM Break

2:00 PM – 3:15 PM Vision & Color – Yoshi Ohno (NIST), session chair

- 2:00 PM Jiaye (Jane) Li (NIST) – "Color Matching Accuracy Experiment: Characterizing the Current CIE CMFs and the Cone-Fundamental-Based CMFs"
- 2:25 PM Yuwei (Eunice) Wang, Dorukalp Durmus (Pennsylvania State University) – "Estimating the perceived colorfulness of images of indoor environments"
- 2:50 PM Christie Gonzalez, Rugved Kore, Dorukalp Durmus (Pennsylvania State University) – "The Effect of Illuminance and Gamut Shape on Preference and Saliency of Natural Objects"

3:15 PM – 3:30 PM Break

3:30 PM – 5:10 PM UV & IR Radiation: Measurements, Concerns & Applications – Robert Vest (NIST), session chair

- 3:30 PM Jason Tuenge (PNNL) - "Key Findings from Radiometric Testing of Direct-Irradiation GUV Products"
- 3:55 PM Cameron Miller (NIST) - "Current Documentary Standards Development for an Ultraviolet Germicidal Irradiance Economy"
- 4:20 PM Mike Schuit (US Department of Homeland Security) – "SARS-CoV-2 Inactivation by Ultraviolet Radiation and Visible Light is Dependent on Wavelength and Sample Matrix"
- 4:45 PM Holger Claus (Ushio America Inc.) – "Reflectance Measurements of Building Materials in the Far UVC (222 nm) Wavelength Range"

5:10 PM End of Day

Wednesday November 16th All times are Eastern Standard Time

Wednesday is reserved for CORM and CIE business meetings

- The US National Committee (USNC) of the CIE will be hosting a business meeting at 11:00 AM EST. This meeting is open to all USNC CIE members.
- The Council for Optical Radiation Measurements (CORM) will be hosting a business meeting at 1:00 PM EST. This meeting is open to all CORM members.

End of Conference

Session: LED Applications and Metrology

Chair: Jeff Hulett, Vektrex
November 14th, 11:10 AM – 1:40 PM EST

Study on Measurement of Temporal Light Modulation Waveforms

Yuqin Zong/C. Cameron Miller, National Institute of Standards and Technology (NIST), Gaithersburg, MD
Email: Yuqin.zong@nist.gov

Abstract
Solid-state light sources are prone to unwanted and perhaps hazardous temporal light modulations (TLMs), which are the change of light level and/or its spectral distribution over time. TLMs may cause undesired effects on human perception, health, performance, and safety. The severity of TLM of a light source is assessed by its associated temporal light artefact (TLA) metrics. Accuracy of the TLA values is determined by the accuracy of the measured TLM waveform.

The goal of TLM waveform measurement is to accurately acquire the TLM waveform (often with high-frequency components) without distortion under a specified condition. TLM waveforms are typically measured using a high-speed data acquisition (DAQ) system, which consists of a photometer, a transimpedance amplifier, a lowpass electrical filter, and a DAQ. Compared to measurement of DC signals using a digital multimeter (DMM), measurement uncertainty of a TLM waveform is much larger because of the natures of TLM signal and high measurement speed (e.g., >10,000 samples per second).

We investigated issues associated with measurement of TLM waveforms to develop the measurement capability for TLM waveforms at NIST. Three representative DAQs, 8 bits, 16 bits, and 24 bits, were used in this study for comparison. The measured TLM waveforms were used for calculation of the three commonly used TLA quantities: the short-term flicker index, P_{st}^{LM}, the perception modulation, Mp, and stroboscopic effect visibility measure, SVM. The influences of sampling speed and sampling duration on the TLA results were also studied.

Bio
Yuqin Zong is an optical engineer at the Sensor Science Division, National Institute of Standards and Technology, Gaithersburg, Maryland. His research covers calibrations of optical sensors and imagers using tunable lasers, measurement methods for LEDs and solid-state lighting products, and correction of stray light for array spectroradiometers and imaging instruments.

SPICE Model Generation of LEDs Using Pulsed Samples and Companion Software Analysis

Alexis Lockwood and Remington Bullis, Boulder Engineering Studio
Email: alex@boulderes.com; remington@boulderes.com

Abstract
In order to accurately design critical and novel drive circuits around new LED devices, an electronics engineer needs accurate simulation models. To support rapid modeling of large numbers of new high-power devices, Boulder Engineering Studio (BES) has developed a complement of pulsed measurement equipment and companion data-collection software. A pair of PCBA-based fixtures drives the LEDs based on external control and buffers signals to be measured by conventional test equipment. The first fixture uses a large inductive ballast and a current-steering bridge to divert pulses of up to 50A into an LED for programmable durations as short as 2µs. This short pulse duration minimizes self-heating so the diode is characterized at the correct temperature. The second fixture provides high-impedance buffering into the nanoampere regime to support sub-threshold measurements. Both fixtures are designed for operation up to 85°C so they may be placed into temperature-controlled chambers. Once collected, data is processed by our suite of SPICE modeling software. To produce accurate models for unusual semiconductors, this software uses conventional analysis methods for some parameters. For others, a least-squares method is used where parameters are trimmed directly in situ to give the correct response inside a real simulation. From start to finish, a complete model takes no more than a couple hours to produce from a single device. This talk is a tour of our design approach, modeling methods and capabilities, process optimization to produce these results, and an open discussion of the potential benefits for the industry.

Bio

ALEXIS LOCKWOOD:
Alexis Lockwood is senior electronics engineer at Boulder Engineering Studio. Alexis designs electronic hardware, with a focus on analog, power systems, and layout Alexis also acts as a liaison between the Boulder systems team and the worlds of software and hardware at Boulder Engineering Studio. Before joining BES, Alexis was a computer engineer in information security, working on low-level hardware security research and hypervisor development. In that role they contributed to multiple research efforts in the fields of chip-level information security and image processing.

REMINGTON BULLIS:
Remington Bullis (Rem) designs software architectures and develops code with a focus on embedded systems. As a secondary capacity, he crosses the bridge between hardware and software, overseeing microcontroller selection, pinout, timer, and communication protocols in products developed at Boulder Engineering Studio.

Compact, High Output, Pulsed LED Light Engine Design Guided by DCP

BJ Housand, Jenoptik Inc.
Email: brien.housand@jenoptik-inc.com

Abstract
The core to designing LED light engines is accurate characterization of the electro-thermo-optics of the device. For our application we needed spectral power distribution, peak wavelength (not dominant), radiant wattage, etc. as a continuous function of electrical current, voltage, and junction temperature. This data was needed to avoid or, at least, minimize, the trial-and-error process often used in light engine design where heat management is crucial. We needed to hit the mark on SPD (spectral power distribution) and radiant output, and we needed to know, precisely, what current/voltage is required and how much heat will be generated and must be removed. The Differential Continuous Pulse (DCP) measurement method was ideally suited to the task. Large amounts of data from the measurements were compiled into spreadsheets and processed into our integrated electro-radiant-thermal ensemble of functions. This presentation will tell the story of accurate electro-radiant measurement meets precision radiometric simulation meets diligent thermal modeling to “be right the first time”.

Bio

Brien Housand is an optical engineer and physicist, trained to be a lens designer at Lockheed Martin (Orlando/MFC) where he spent many years. Most known for inventing the optical concept for the world-renowned Sniper Targeting Pod (US6359681B1, EP1372112A3), popular for fixed wing allied aircraft. Following his aerospace contributions, he became a vision scientist at Alcon Labs where he developed an FDA approved Shack-Hartmann aberrometer to customize ablations for LASIK. More recently and prior to joining JENOPTIK as Principal Optical Engineer, Mr. Housand managed the Optical Sciences Group (Illumination Design and Photometrics Lab) at Hubbell Lighting where he was the NVLAP contact.

Uncertainty Evaluation of the Chromaticity Coordinates of LED Signal Lights for Vehicles

L. Prado Jr*, R. C. F. de Lima, C.E. Anderson , Pradolux Ind. Com. Ltda – Brazil

Abstract

The color standard of vehicle signal lamps is defined in the US regulations FMVSS Standard No. 108 [1], on lamps, reflective devices and associated equipment, and SAE J578 [2], on chromaticity requirements for ground vehicle lamps and lighting equipment. These regulations define chromaticity coordinate limits according to the CIE 1931 standard observer [3] for all the signaling functions. The limits of acceptance of the chromaticity coordinates, according to the standards, can interfere with the measured values and their uncertainties. Therefore, it is necessary to assess the uncertainty for the approval of test samples. The work presents SPD measurements with an integrating sphere equipped with a spectroradiometer for 6 LED lamps. The samples are grouped by three colors widely used in vehicle signal lamps: white, yellow (amber) and red. The sensitivity of the uncertainty of the chromaticity coordinates is evaluated with the Monte Carlo method, according to the GUM [4] (Guide for the expression of uncertainty in measurement). The computational method uses the recent LuxPy [5] library in Python language for color science. The calculation results suggest upper bounds for the uncertainty of the chromaticity coordinates as a function of the spectral uncertainty.

Bio

Luis Prado, Jr.:

Luis Prado is the founder and CEO of of Luxparts, a Brazilian high-technology manufacturing company of automotive signal lights and headlights. Luis is a former scientist who left academia to undertake the auto parts market. He now has 15 years of experience in this market. He excels in knowledge in photometry and product development focused on energy efficiency and LED technology. He is a certified in project management by PMI and has successfully developed teams focused on high performance within the Lean Manufacturing mindset.

diretoria@pradolux.com.br

Rodrigo Congio Faria de Lima:

Rodrigo is a laboratory analyst at Pradolux-Luxparts Group. He specializes in photometry with extensive experience in the development of automotive lighting products. He led the commissioning of various equipment in the photometry laboratory of the "Pradolux-Luxparts" group. In constant development, he is managing the laboratory's ISO 17025 certification.

engenhariadeteste@pradolux.com.br

Carlos Eduardo Anderson:

Carlos is the manufacturing director at Pradolux-Luxparts Group. He has ten years working in the development of automotive lighting products, with experience in design, simulation and manufacture of automotive signal lamps and headlights. Recently named for the position of Manufacturing director of the group, he is ready to face new challenges involving the strategic, economic, and business point of view of the Pradolux-Luxparts group.

engenharia@pradolux.com.br

Junction Temperature Assessment for LEDs & Lasers Operated in Pulsed Mode

Jeff Hulett, Vektrex, San Diego California
Email: jhulett@vektrex.com

Abstract
Laser diodes and LEDs may be driven with pulsed current for several reasons. For example, the end application (e.g., video projection, etc.) may require pulsing. Pulse drive may be employed to reduce average junction heating. Pulsing is also often used in laboratory or production testing. For example, the new DCP measurement method utilizes 10 µs and 20 µs pulses.
As many device characteristics, such as its peak wavelength and output power, are temperature dependent, it is useful to know the device's expected junction temperature during pulsed operation.
With DC drive, this is easy to do. Junction temperature may be calculated as input power x thermal resistance. However, with pulsed drive, the device thermal resistance is not constant, rather it increases as the heat flows through various structures in the device. This makes it more difficult to calculate junction temperature.
This paper presents techniques for quickly determining junction temperature during pulsed operation using the JEDEC Electrical Test Method (ETM). The principals of the technique are presented, and then actual laser and LED component test data is presented, along with typical best practices and test setups. Two different techniques for determining temperature are presented, and the results from both are compared.

Bio

Jeff Hulett is CTO and founder of test & measurement specialist firm Vektrex, based in San Diego, CA. Over the course of his career, Hulett has acted as chief engineer on products ranging from single-board computers for spaceflight to power supplies for DNA sequencing systems to current sources used in the LED and laser industries for product and system evaluation. Hulett holds several patents related to LED testing and has authored technical articles for publications such as LEDs Magazine, Photonics Spectra, and LED Professional. He chairs the Illuminating Engineering Society's LM-80 Working Group, he was a key contributor to the IES LM-85 and LM-92 working groups, and he is presently working within the CIE's TC2-91 group.

Experimental Analysis of the Photometry and the Colorimetry of Signal Lights of Vehicles Designed for Filament Bulbs and Equipped with LED Bulbs

R. C. F. de Lima, L. Prado Jr*, C.E. Anderson, Pradolux Ind. Com. Ltda – Brazil
Email: diretoria@pradolux.com.br

Abstract

The present study aims to demonstrate the limits of the application of LED bulbs in signal lights of vehicles. Such devices must be compliant to the standards FMVSS108 [1] and SAE J578 [2]. The photometric and colorimetric performances were evaluated with a type A gonio-photometer and an integrating sphere with a spectroradiometer for 20 samples. The samples were built as combinations of four different filters among red and yellow (amber) colors, and five different bulbs among the types, incandescent filament, cool white LED and warm white LED. The study shows that the photometric and colorimetric performances of the combinations with incandescent filament and warm LED bulbs are very similar. On the other hand, it is experimentally demonstrated, that there is in some cases a deficit of almost 50% in flux and intensity for the combinations with red lenses and cool white LEDs. The results also show that the colorimetry of the combination of amber lenses and cool white LEDs can be affected. The chromaticity coordinates for such combinations may not satisfy the regulations.

[1] 571.108, Section 571.108 - Standard No. 108; Lamps, reflective devices, and associated equipment, Federal Motor Vehicle Safety Standards, 2004. Available at:
https://www.govinfo.gov/app/details/CFR-2021-title49-vol6/CFR-2021-title49-vol6-sec571-108
[2] SAE J578_202004, Chromaticity Requirements for Ground Vehicle Lamps and Lighting Equipment, 2020. Available at: https://www.sae.org/standards/content/j578_202004

Bio

Luis Prado, Jr.:

Luis Prado is the founder and CEO of of Luxparts, a Brazilian high-technology manufacturing company of automotive signal lights and headlights. Luis is a former scientist who left academia to undertake the auto parts market. He now has 15 years of experience in this market. He excels in knowledge in photometry and product development focused on energy efficiency and LED technology. He is a certified in project management by PMI and has successfully developed teams focused on high performance within the Lean Manufacturing mindset.

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Rodrigo is a laboratory analyst at Pradolux-Luxparts Group. He specializes in photometry with extensive experience in the development of automotive lighting products. He led the commissioning of various equipment in the photometry laboratory of the "Pradolux-Luxparts" group. In constant development, he is managing the laboratory's ISO 17025 certification.

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engenharia@pradolux.com.br

Session: Advances and Applications in Spectrophotometry

Chair: Thomas Germer, National Institute of Standards and Technology (NIST), Gaithersburg, MD

November 14th, 2:15PM – 3:30 PM EST

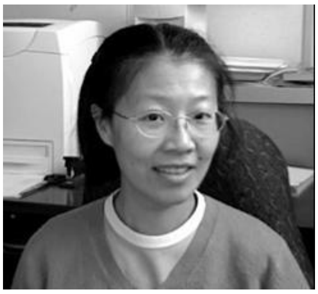
Optical Properties of Plasmonic Paper

Li-Lin Tay*, Shawn Poirier, Ali Ghaemi, Hal Bowen-Smith and John Hulse, National Research Council Canada, Metrology Research Centre, Photometry and Spectrophotometry, Ottawa, ON Canada
Email: lilin.tay@nrc-cnrc.gc.ca

Abstract

Optical excitation of coupled plasmonic nanoparticle generates intense and localized electromagnetic field which can sustain a variety of surface enhanced spectroscoies with the best known example being the surface enhanced Raman scattering (SERS) phenomenon. Coupled with many commercially available handheld Raman analyser, SERS has evolved to be a powerful analytical technique used in trace chemical detection and identification. Our team has recently developed a paper-based SERS sensors. Our paper-based SERS sensors have a number of advantages over counterparts fabricated on rigid substrates. They are flexible, easy to handle, economical and sensitive. Most importantly, they provide simple point-of-need sampling (e.g. filtration, swabbing or chromatography) that is particularly suitable for field applications when used with a handheld Raman analyzer. These plasmonic paper are fabricated by inkjet printing of a colloidal gold sol onto a paper substrate [1-3]. To better monitor the amount of gold nanoparticles deposited on the paper substrate and to ensure the best batch-to-batch reproducibility, diffuse reflectance (and transmittance) measurements were carried out. In this presentation, we will discuss the correlation between the spectrophotometry measurements and the sensor performance as well as the important role they play in meeting performance consistency required by the end-users.

Bio



Li-Lin Tay holds a B.Sc. in Physics and Ph.D. in Physical Chemistry, both from University of Toronto. She joined the NRC in 2002 as a research associate and led the research effort on light scattering of quantum confined semiconductor devices. Since 2012, she has focused her research on the development surface enhanced spectroscopy and Raman Metrology. She is well recognized for her work in the optical properties of plasmonic nanostructures, surface enhanced Raman scattering (SERS) and their application in field deployable chemical and biological sensing. She has published over 90 peer reviewed publications as well as numerous book chapters and technical reports. Dr. Tay is the Team Leader of Photometry and Spectrophotometry. She has been leading the team in the research and development of the state-of-the-art optical radiation measurement capabilities, solid-state-lighting standards and advanced optical spectroscopies in support of Canada's commitment to the international committee on Weights and Measures Mutual Recognition Arrangement and NRC's services for a broad base of national and international clients.

Learning from over 20 years of Optical Interference Coatings Manufacturing Contest

Daniel Poitras, Photonics Team, Advanced Electronics and Photonics Research Center, National Research Council of Canada, 1200 Montreal Rd, Ottawa ON Canada
Email: daniel.poitras@nrc.ca

Abstract

Since 2001, every 3 years the organizers of the OSA's (now Optica) Optical Interference Coatings conference present a contest on the manufacture of optical coatings, for which participants are asked to design and fabricate an optical filter that meets special optical requirements. Submitted filters are measured at independent labs (including NIST and NRC) and are ranked based on a figure of merit describing how well they match with the requirement target. We will review some results from these contests and extract some conclusions on the progress and limitations in designing, fabricating and measuring complex optical filters.

Bio

Daniel Poitras received the Ph.D. degree in physics engineering from Ecole Polytechnique, Montreal, QC, Canada, in 2000, with focus on plasma deposited inhomogeneous optical films and coatings. He is currently a Senior Researcher with the National Research Council of Canada, Ottawa, ON, Canada. His main research interests include the application, design, fabrication, and characterization of optical coatings, including optical coatings on waveguide facets.

Sprayable Cool White Coatings Based on Glass Bubbles and Solar Transparent Binders

Xiao Nie[1],*, Hoyeon Park[1], Heather J. Patrick[2], Jaeho Lee[1], [1]Department of Mechanical and Aerospace Engineering, University of California, Irvine; [2]Sensor Science Division, National Institute of Standards and Technology (NIST).
Email: xnie2@uci.edu

Abstract
Organic binders are widely used for optical coatings or white paints to meet the needs for efficient cooling of buildings since conventional cooling or air-conditioning approaches takes a lot of energy and even produce air pollutants. They are designed for sunlight reflection or surface cooling of buildings, but the inherent absorption of commonly used organic binders limits their reflectivity to the visible wavelength and not effective in the near-infrared wavelength regions. Here we present a coating solution that is sprayable and reflective across the whole solar wavelength region. Instead of using organic binders, we integrate glass bubbles in the diameter range of 2-40 µm within potassium bromide (KBr), with the advantage of having a lower solar absorption than the organic counterparts. The transmissivity of KBr approaches unity in the solar region according to our measurements. Solar reflectivity of white coating increases from 0.92 to 0.96 when replacing Polydimethylsiloxane (PDMS) with KBr as the binder since reflectivity in the near-infrared region is much enhanced. The net cooling power of the sprayable white coating is calculated to be 96 W/m2when assuming a solar intensity of 1000 W/m2and a constant ambient temperature of 25°C. The solar reflectivity increases from 0.90 to 0.97 with increasing thickness from 1 mm to 4 mm. We believe the sprayable white coating with the solar transparent binder provides a promising solution to improve reflectivity of white paints across the whole solar region and helps to resolve cooling issues for buildings with insufficient cooling systems.

Bio

Xiao Nie received his B.S. in Materials Science and Engineering at Shanghai Jiao Tong University in 2016 and his M.S. in Materials Engineering at University of Southern California in 2018 and is now pursuing his Ph.D. in Mechanical and Aerospace Engineering at UC Irvine. His research interests include nanomaterials, radiative heat transfer, and micro/nanoscale heat transport. His current project investigates engineered materials for radiative thermal management.

Session: Current Research at the NMIs

Chair: Luke Sandilands, National Research Council Canada
November 14th, 3:45 PM – 5:25 PM EST

Fiber Optic Cryogenic Radiometer at CENAM

Zeus E. Ruiz, CENAM
Email: zruiz@cenam.mx

Abstract
In 2017, the Sources and Detectors Group of the Applied Physics Division of the National Institute of Standards and Technology (NIST) in Boulder Colorado proposed the project called “Cryogenic primary standard for optical fiber power measurement” and invited CENAM to participate. The project goal was to develop an absolute radiometer for optical fiber power measurements with unprecedented accuracy and very low uncertainty. The technology behind this development is not only applicable to optical fiber power measurement, but also to radiant power measurement in general, across the broad wavelength spectrum from the ultraviolet to THz region.

This collaboration with NIST has had multiple benefits for CENAM, among which we can mention the following: the reduction of the traceability chain of fiber optic power measurements with a calibration system that is easier and cheaper to maintain compared to the liquid helium cooled electrical substitution radiometers (ESRs), a 50% reduction of the uncertainty in fiber optic power meter calibrations at 1550 nm and also the opportunity to modernize our fiber optic power meter calibration system.

In addition, this development has allowed us to promote continuous collaboration between NIST, CENAM and the Czech Metrology Institute (CMI) thanks to a pilot study on optical fiber power measurements that is being carried out.

Bio

Zeus E. Ruiz is a Metrologist specialized in optical fibers and radiometric measurements at the National Institute of Metrology of Mexico (CENAM). With more than fifteen years of experience working in the Optics and Radiometry Division, he is part of the scientific group in charge of the fiber optics, cryogenic radiometer and solar measurements laboratories. He is part of the list of evaluators of the Mexican Accreditation Entity (ema), and has had the opportunity to participate on several occasions as a technical expert for the evaluation of the technical capacity of national and foreign calibration laboratories. He also has several national and international publications related to the field of fiber optics, radiometry and telecommunications. He is currently part of the research group of the "Cryogenic Primary Standard for Optical Fiber Power Measurement"; a project that has been developed in conjunction with the National Institute of Standards and Technology (NIST) and the Czech Metrology Institute (CMI).

The Digital NIST: Pilot Project for the Digital Transformation of NIST's Measurement Services

Catherine Cooksey, National Institute of Standards and Technology (NIST), Gaithersburg, MD
Email: catherine.cooksey@nist.gov

Abstract

At the beginning of 2022, NIST embarked on a pilot project to produce a few examples digital calibration reports and certificates of analysis for the purpose of assessing the scope and challenges of digital transformation in these measurement services. The aims for the NIST pilot project are 1) to generate a digital calibration report from calibration data, customer metadata, and other data and metadata as needed; 2) to generate a digital Reference Material Certificate from certification data, descriptive information about the material, and other data and metadata as needed; 3) to generate a human readable report from the digital calibration report and digital Reference Material Certificate; and to hold a workshop to gather stakeholder feedback. I will summarize on the results of the pilot project and discuss future goals.

Bio

Dr. Catherine Cooksey is a research chemist at the National Institute of Standards and Technology (NIST) in Gaithersburg, MD. She serves as Co-Project Leader for Spectrophotometry, which includes reflectance and transmittance calibration services. She also serves as Quality Manager for the Sensor Science Division, which encompasses one of the largest programs for calibration services at NIST. In 2022, she served on the leadership team of the Digital NIST Pilot Project, a NIST-wide collaboration aimed assessing scope and challenges of digital transformation for NIST measurement services. Cooksey earned her B.S. in chemistry from the University of Kansas and her Ph.D. in chemistry from the University of Washington.

Digital Transformation: A Pilot Study Explores Digitalisation in the Context of CIPM and RMO Transmittance Comparisons

Blair Hall, Measurement Standards Laboratory of New Zealand
Email: blair.hall@measurement.govt.nz

Abstract
Metrological traceability is a service delivered by the quality infrastructure (QI) to end-users of measurement data throughout society. Traceability is highly valued, so it is often mandated when critical decisions are informed by measurement data. There is a world-wide trend to digitalise the processes in our QIs and thereby transform them, and the services they provide, in ways that will benefit society. To achieve this, we must codify our practices in logical models that are amenable to digitalisation. This talk discusses a recent pilot study that applied such modeling to the analysis and subsequent linking of CIPM and RMO measurement comparisons of transmittance. While this is a specialised topic, the task is in many ways similar to the delivery of traceable data along a chain of calibrations and measurements, which, of course, is the core business of QIs. The talk will explain how reporting the initial measurement results in digital form, using an appropriate data model, simplified downstream analysis and yielded more informative results.

Bio

Blair Hall leads a project in data metrology at the Measurement Standards Laboratory of New Zealand. He chairs the APMP Focus Group on Digitalisation in Metrology (DXFG) and is a member of the IMEKO TC6 committee on digitalisation. Blair holds a doctorate in physics from the Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, and has worked at the Swiss national metrology institute (METAS) and at Massey University, New Zealand, where he lectured in physics and electronics.

Progress in Few-Photon Metrology at NRC

Jeongwan Jin, National Research Council Canada
Email: Jeongwan.Jin@nrc-cnrc.gc.ca

Abstract
The National Research Council (NRC) of Canada is continuing its efforts towards developing characterization methodologies for single-photon sources and detectors. Recently, in collaboration with NIST, NRC has demonstrated and compared the SI-traceable detection efficiency calibration of a free-space single-photon avalanche photodiode by utilizing an attenuation-based substitution technique at 850 nm. This talk will present the results of this work and will introduce other quantum radiometry activities at NRC including photon-number-resolving detections for single-photon source characterization.

Bio

Jeongwan Jin is a Research Officer at NRC. He holds a Ph.D. degree in Physics from the University of Calgary. His specialty is experimental quantum optics and communication networks. At NRC, he is presently developing characterization methodologies for single-photon sources and detectors as well as novel quantum photonics measurement techniques.

Session: Light and Health: Measuring the Stimulus and Response

Chair: Andrea Wilkerson, Pacific Northwest National Laboratory (PNNL), USA
November 15th, 11:00 AM – 1:30 PM EST

Performance of a Mini Spectrophotometer as a Wearable Circadian Light Measurement Tool

Kore R. S., Reichenberger, D., Mundinger, J., Chang, A. M., Durmus D., Pennsylvania State University, University Park
Email: rsk97@psu.edu

Abstract
Light is one of the primary stimuli for the entrainment of human circadian rhythms. Past laboratory studies conducted in controlled environments highlighted the importance of photic history, intensity, spectrum, and timing of the light exposure. More recently, field studies indicated that analyzing the real-world impact of lighting on human health can be complex due to confounding factors. When properly designed, field studies can provide insight into occupants' daily light exposure and be linked to physiological and psychological outcomes. However, measuring the daily light exposure requires an accurate, durable, and affordable wearable light sensor that can be attached to a participant. Currently, researchers are using two types of wearable devices: RGB and multi-spectral sensors. Here, we evaluate the suitability of a mini-spectrometer and RGB sensor (Hamamatsu C12880 and LYS button, respectively) as a wearable device. Various lighting conditions were measured using two devices, and the data were compared to data from a calibrated spectroradiometer (Gigahertz-Optik S-BTS256) to analyze their accuracy. The suitability of the mini spectrometer for a wearable prototype was also analyzed based on its weight, size, and usability. Although LYS button only gives RGB output and melanopic equivalent lux (unlike Hamamatsu C12880 that provides full spectrum), due to its compactness on size, weight, and usability LYS was found to be more suitable to be used as a wearable prototype with the caveat of reduced accuracy. Future studies will utilize data fitting techniques to improve the accuracy of the RGB sensor in estimating circadian metrics.

Bio

Rugved Kore is a Ph.D. candidate at Pennsylvania State University and has a Master of Science degree in Human Factors Engineering. His doctoral research focuses on a light projection system that reduces damage to artwork without causing perceptible shifts. His goal is to develop a novel method of illumination in museums using spectral and spatially tunable light projection system.

Development of an Open, Wearable Optical Spectral Irradiance Sensor

J. Alstan Jakubiec, Sadi Wali, Arsalan Khan, University of Toronto
Email: alstan.jakubiec@daniels.utoronto.ca; sadi.wali@mail.utoronto.ca;
arsala.khan@mail.utoronto.ca

Abstract

We present the development of a new and open sensing device for spectrally-specific optical radiation between 350 nm and 1 000 nm. The sensor uses affordable sensors (nanoLambda brand), common and available microcontrollers, open-source operational code, publicly available wiring diagrams, and open 3D-printable case geometry. The sensor is small enough to be worn comfortably by human subjects in light exposure studies. The presentation will describe the development and validation of the sensor in terms of spectral and cosine response against a lab-calibrated diffraction grating sensor (Konica Minolta CL-500A). Error analysis will be presented in terms of spatial cosine and spectral wavelength response aligned with the CIE S 026 toolkit.

Bio

Alstan Jakubiec is a building scientist, educator, and architect specializing in building performance simulation. At U of The works with students to address the daylight, comfort, health and energy efficiency of buildings. Alstan co-creates the ClimateStudio and ALFA tools for calculating daylight and energy performance and develops new tools as part of his research.

Sadi Wali completed his undergraduate degree in Architecture from the John H. Daniels Faculty of Architecture and Landscape Design at the University of Toronto. Sadi is interested in robotics, software, and designing tools that make design and architecture more approachable through projects that utilize microcontrollers, sensors, motors, and user interfaces.

Arsalan Khan is currently in his third year pursuing a BSc in physics, computer science, and mathematics at the University of Toronto. He has an interest in machine learning and electronics and hopes to apply his knowledge to physics research in the future. Outside his coursework, Arsalan has applied his knowledge of software to two internships in software development and software architecture.

TLM Measurements for Characterizing the Standardized Measures for the Visibility of Temporal Light Artefacts

Jiaye (Jane) Li and Yoshi Ohno, National Institute of Standards and Technology (NIST), Gaithersburg, MD
Email: jiaye.li@nist.gov; ohno@nist.gov

Abstract
In the current study, the waveforms of 12 typical commercial lamps (60 Hz AC power operation), including new to several year-old products, were measured using a high-speed photometer and digitizer, and the stroboscopic effect visibility measure (SVM, M_{VS}) and the short term flicker index (P_{st}^{LM}) were calculated. The calculations used the MATLAB implementation provided by the IEC-TR-63158 and IEC-TR-61547 standards. To characterize the robustness of the two standardized measures, different sampling rates and sampling durations were applied to measured waveforms for calculations. CIE TN 012 recommends a minimum sampling frequency 20 kHz with a sampling duration of one second or longer for SVM calculation and minimum frequency 10 kHz and sampling duration 60 s or longer for P_{st}^{LM}. The IEC recommended a sampling frequency above 4 kHz and a sampling duration more than 20 seconds for P_{st}^{LM} metric. We tested variations of results for varied sampling rate from 5 kHz to 500 kHz. A digital lowpass (Butterworth) filter with varying cutoff frequencies and filter orders was applied to the measured waveform. The results show that for all lamps, the calculated SVM values have acceptable variations for different sampling rates and durations as well as for different filters. However, for certain lamps (with more complicated waveforms), the value of P_{st}^{LM} varies significantly at different sampling rates, and even at sampling rates higher than 50 kHz, the difference in P_{st}^{LM} values calculated with waveforms of different sampling rates can be more than a factor of 9. Furthermore, when the sampling frequency exceeds 100 kHz, for all the waveforms (including simulated waveforms), the MATLAB function only gives unreasonable results for P_{st}^{LM} value. For a sampling rate higher than 60 kHz, the calculated P_{st}^{LM} varies considerably for certain lamps, across different cutoff frequencies and the filter orders. Further investigation on the cause of this issue is needed.

Bio

Dr. Jiaye Li received her Ph. D. in engineering from Katholieke Universiteit Leuven (KU Leuven university) in Belgium. Her research interest is in color perception and lighting: color matching and individual differences, color rendition of LED light sources and color science in general. She worked as a Ph. D. researcher supervised by Prof. Kevin Smet and Prof. Peter Hanselaer in the Light & Lighting Lab of KU Leuven from 2018 to 2022. She is currently a guest researcher at NIST, working with Dr. Yoshi Ohno on Vision Science projects in Sensor Science Division.

Dr. Yoshi Ohno received his Ph. D. in engineering from Kyoto University Japan and joined NIST in 1992. He served as a Group Leader at NIST Optical Technology Division (now Sensor Science Division) in 2003 - 2012 and is appointed a NIST Fellow since 2010. He served as CIE President for 2015-2019 term, and prior to this, Vice President-Technical and Division 2 Director since 2007. He chaired several CIE TCs and led development of CIE S 025 among other publications. His recent research focused on color quality of light sources. He led development of CIE TN 001 and ANSI C78.377 chromaticity specifications for SSL products.

Temporal Light Modulation Waveform Generation, Distortion, and Correction

Lia Irvin, Eduardo Rodriguez-Feo Bermudez, Pacific Northwest National Laboratory (PNNL), USA
Email: eduardo.rodriguez-feobermudez@pnnl.gov

Abstract

In the process of designing an experiment in which human subjects were to rate patterns arising from flickering LED output, a set of temporal light modulation (TLM) waveforms were created. They needed to be consistent in luminance but varied in frequency, modulation depth (MD), and duty cycle. However, it was discovered that the theoretically appropriate approach of keeping the area under the curve constant did not yield equal luminance, with values varying by 72%. Using simultaneous monitoring of the input and output waveform (Figure 2) and an iterative procedure of generation, validation, and adjustment of waveforms, inconsistencies in waveform shape were observed and corrected. At high frequencies (>1 kHz), the output rectangular waveforms had curved peaks/troughs and did not reach intended luminance values (Figure 3). The MDs were larger than expected, and the sine waves had flat troughs. The primary causes of these issues were determined to be the ramp up and down times from the driver and LED system, activation power requirements, and the diminishing return at higher power. After corrections, a close approximation of the goal TLM waveform set was achieved, reducing the luminance variance to ~20% and further to ~8% excepting one especially problematic waveform (within acceptable limits for the flicker perception experiment). Published methodologies utilizing TLM waveforms to drive LEDs rarely, if ever, state whether the LED output was verified as matching the input parameters, and none of the flicker literature surveyed makes note of the deformation at high frequencies.

Bio

Lia Irvin joined Pacific Northwest National Laboratory (PNNL) in 2018 and works on the Advanced Lighting Science and Technology Research program. Her research interests include human factors in lighting, such as flicker and perception of luminance uniformity, which she investigates in both laboratory and field studies. Lia earned a Bachelor of Science with Honors in physics from the University of St Andrews. During her studies, she completed a dissertation project working with nanofabrication and encapsulation to develop more efficient microdisk lasers for bio-applications.

Eduardo Rodriguez-Feo Bermudez received his Master of Science in Applied Physics from Michigan Technological University, and Bachelor of Science in Physics from University of South Florida. As a graduate student he has participated in optics-based experiments for Michigan Tech Cloud Chamber group and interned at the US Naval Observatory (D.C.). This has allowed him to accumulate a wealth of knowledge in the science of light scattering along with coding/investigative skills needed to aid and execute experiments.

Now Eduardo is an Associate Scientist at Pacific Northwest National Laboratory, in the Lighting Science Research group. Within the group he helps the progression of projects and experiments that try to illuminate our knowledge in the subjects of Light Uniformity, Glare, Flicker, and Connected Lighting Systems.

Subject Perception of Flicker Experiment

Naomi Miller and Eduardo Rodriguez-Feo Bermudez, Pacific Northwest National Laboratory (PNNL)
Email: Naomi.Miller@pnnl.gov

Abstract

Flicker caused by temporal light modulation (TLM) is a problem, especially to the 10-20% of the population that are highly sensitive to it. Although TLM occurs in a low percentage of products, it is visible in automotive lighting, holiday light strings, a range of residential lighting products, and a few architectural lighting products. In an experiment, subjects rated the visibility of TLM waveforms with different frequencies (between 90 Hz and 6,000 Hz), shapes (square or sinusoidal), modulation depths (9% to 100%), and in the case of rectangular waves, duty cycles (10% to 50%) . The results indicate the stroboscopic effect, and the phantom array effect are two different phenomena and metrics for one will not predict the other. Furthermore, the phantom array effect is visible, on average, in TLM frequencies as high as 6,000 Hz. This presentation will be on the methodology of the human subject study, results obtained, and what conclusions can be drawn. Ideas for the next phase of the study will follow.

Bio

Naomi Miller has enjoyed 13 years at Pacific Northwest National Laboratory in Portland OR as a designer/scientist in the advanced lighting team. Working to bridge the gap between technology and application, she is promoting the wise use of LEDs, and working with industry to overcome the hurdles facing this technology and its control. Some people call her The Flicker Queen, some with humor, some without.
Recent work includes publishing an extensive literature review on temporal light modulation (TLM, aka "flicker") in Lighting Research & Technology. She and PNNL colleagues conducted a human subjects study on the visibility of two forms of flicker: the stroboscopic and the phantom array effects. That study showed clear response differences between the two and was able to identify TLM-sensitive subjects who are more likely to experience headaches, migraines, nausea, or other negative responses from TLM. The results have been submitted to a journal for review, and it is hoped will lead to a metric that will help identify and mitigate problematic TLM.
Current work focuses on discomfort glare, examining human responses to glare sources in different areas of the visual field, and the effect of spectral power distribution on discomfort. Another interest is whether spatial frequency of LED arrays contributes to discomfort glare. In addition, she is an active member of CIE and IES committees developing recommendations on outdoor glare, flicker, and light's effect on human health.

Eduardo Rodriguez-Feo Bermudez received his Master of Science in Applied Physics from Michigan Technological University, and Bachelor of Science in Physics from University of South Florida. As a graduate student he has participated in optics-based experiments for Michigan Tech Cloud Chamber group and interned at the US Naval Observatory (D.C.). This has allowed him to accumulate a wealth of knowledge in the science of light scattering along with coding/investigative skills needed to aid and execute experiments.
Now Eduardo is an Associate Scientist at Pacific Northwest National Laboratory, in the Lighting Science Research group. Within the group he helps the progression of projects and experiments that try to illuminate our knowledge in the subjects of Light Uniformity, Glare, Flicker, and Connected Lighting Systems.

Impact of Sampling Rate on Flicker Metric Calculations

Jianchuan Tan, Pacific Northwest National Laboratory (PNNL), USA
Email: jianchuan.tan@pnnl.gov

Abstract

There are multiple metrics used in research and industry to describe the visibility of temporal light modulation (TLM), colloquially referred to as “flicker”. However, the metrics are not straightforward to calculate, and the values sometimes vary according to sampling rates. This work addresses the vagaries in processing TLM waveform data and calculating the metrics. For each TLM metric, its sensitivity to sampling rate is presented, followed by recommendations for improving the reliability and consistency of calculated metrics. Appropriate sampling rates are proposed according to the nature of the waveform and metric. The analyses of this study are based on ideal waveforms without noise or instability, but the effects of sampling rate also apply to real-world waveforms.

Some metrics, such as the Stroboscopic Visibility Measure (SVM), were relatively stable (i.e. produced the same value regardless of sampling rate)—within the ranges for which they are defined—for sinusoidal and/or rectangular TLM waveforms. In contrast, Short-term Flicker Indicator (P_{st}^{LM}) and Perceived Modulation (M_P) values exhibited greater variability based on sampling rate. Metric values from sinusoidal waveforms were generally more stable than those from rectangular waveforms, although P_{st}^{LM} showed inconsistency even with sinusoidal TLM.

Bio

Jianchuan Tan (JT) joined PNNL as a Lighting Research Engineer/Scientist in 2021. He is a Ph.D. from Lighting Research Center at Rensselaer Polytechnic Institute, with areas of expertise in Lighting and Architectural Science. He is also a PMP, LC and WELL AP. JT has more than 10 years of experience in lighting academia and industry. His works are mainly on research and development of lighting systems, lighting product management, application engineering, especially on human-centric lighting systems. He also has intense interest in lighting control on IoT platforms, as well as the implementation of human-centric lighting in the IoT environment.

Session: Vision & Color

Chair: Yoshi Ohno, National Institute of Standards and Technology (NIST), Gaithersburg, MD
November 15th, 2:00 PM – 3:15 PM EST

Color Matching Accuracy Experiment: Characterizing the Current CIE CMFs and the Cone-Fundamental-Based CMFs

Jiaye (Jane) Li, National Institute of Standards and Technology (NIST), Gaithersburg, MD
Email: jiaye.li@nist.gov

Abstract
The color matching functions (CMFs) are spectral response functions that characterize the trichromacy of human color vision. However, recent work indicates a discrepancy between visual metamers and those calculated using the standard CIE CMFs or other CMF sets, especially when narrow-band light sources are used. First, a 10° achromatic matching experiment was conducted under an immersive, neutral viewing condition at about 70 cd/m². Eight different LED primary sets were selected for providing the neutral matching stimuli. Fifty-four observers with an average age of 32 years (same as the average observer age for CIE standard CMFs) participated in this experiment. Second, to characterize the CMFs under different viewing field sizes, a series of achromatic matching experiments using the same set-up were conducted under 2°, 4°, 6°, 8° and 10° viewing fields. Twenty observers with an average age of 32 years participated in the experiment. The results of these experiments showed that the CIE's recommendation of the use of the 1931 2° and 1964 10° CMFs for field sizes smaller or larger than 4° respectively was reasonable. However, the performance of CIE 1931 2° CMFs was poor compared to CIE 2015 2° CMFs for all field sizes, while the performance of CIE 1964 10° CMFs was good and similar to that of CIE 2015 10° CMFs. It also showed that the CIE 2015 CMFs (2° and 10°) performed well for smaller and larger than 6° field sizes, respectively. A method was also developed to derive the individual observers' CMFs based on the collected color matches data using the individual colorimetric observer model.

Bio

Dr. Jiaye Li received her Ph. D. in engineering from Katholieke Universiteit Leuven (KU Leuven university) in Belgium. Her research interest is in color perception and lighting: color matching and individual differences, color rendition of LED light sources and color science in general. She worked as a Ph. D. researcher supervised by Prof. Kevin Smet and Prof. Peter Hanselaer in the Light & Lighting Lab of KU Leuven from 2018 to 2022. She is currently a guest researcher at NIST, working with Dr. Yoshi Ohno on Vision Science projects in Sensor Science Division.

Estimating the Perceived Colorfulness of Images of Indoor Environments

Yuwei (Eunice) Wang, Dorukalp Durmus, Pennsylvania State University, University Park, PA, USA
Email: ykw5337@psu.edu

Abstract

Lighting systems that illuminate objects to be over or under saturated may disturb occupants. Past research studies focused on the effect of illuminance and spectral power distribution of light sources on occupants' visual comfort and colorfulness. However, the spatial characteristics of visual scenes and their influence on subjective evaluations have not been widely studied. This study investigates the potential of using computational image quality metrics to estimate observers' subjective evaluations of colorfulness of images of indoor environments. A visual experiment was conducted to test the accuracy of 14 image quality metrics in estimating the visual colorfulness of indoor environments. Fifty images with varying spatial and chromatic characteristics were collected from online databases in ten categories (e.g., offices, residential spaces etc.). The images were scaled to the same height (709 pixels) and displayed on a calibrated display in random order. Participants rated each image using a nine-point Likert-type scale. The scales ranged from "Extremely uncolorful" to "Extremely colorful." A training was provided, and color, contrast, and visual acuity tests were conducted before the experiment. The strongest predictor of perceptual colorfulness was Hasler and Suesstrunk's colorfulness metric (M) ($r_s = 0.727$, $p < 0.001$) and CIELAB 1976 chroma (C*) ($r_s = 0.6002$, $p < 0.001$). Perceptual colorfulness was statistically negatively correlated with naturalness image quality evaluator (NIQE) ($r_s = -0.366$, $p = 0.0089$), energy (E) ($r_s = -0.356$, $p = 0.011$) and fractal dimension ($r_s = -0.356$, $p = 0.011$). Future research will investigate the perceived colorfulness of immersive architectural spaces.

Bio

Yuwei Wang is pursuing a doctoral degree in the Department of Architectural Engineering at Pennsylvania State University. Her research interests include investigating the perceived quality of architectural spaces, using computational image quality metrics to estimate visual preference, clarity, and complexity, and creating a comprehensive model for visual comfort.

Dr. Dorukalp Durmus is an assistant professor at the Pennsylvania State University. He received his Ph.D. in architectural sciences from the University of Sydney, Australia. His research interests are human factors and lighting, colorimetry, psychophysics, adaptive lighting systems, and image quality assessment.

The Effect of Illuminance and Gamut Shape on Preference and Saliency of Natural Objects

Christie Gonzalez, Rugved Kore, Dorukalp Durmus, Pennsylvania State University, University Park, PA, USA
Email: cvg5474@psu.edu; rsk97@psu.edu; alp@psu.edu

Abstract
Past research indicates that illuminance and light source gamut shape can affect the preference, naturalness, and saliency of objects. This study aims to quantify the effect of illuminance and gamut on visual interest and preference of natural objects. A visual experiment was conducted by using eye-tracking technology to detect gaze distribution on four natural objects (pear, green apple, orange, red apple). MATLAB was used to change the illuminance levels and spectrum of the 15-channel tunable LEDs in an immersive chamber. Two illuminance levels (50 lx and 400 lx) and three gamut shapes (neutral, red-green saturating, red-green desaturating) at equal CCT (4000 K, ~ Duv = -0.005) were presented to six participants in a randomized order. Participants were asked to judge the preference and naturalness of the objects in a 4afc experiment. Each trial lasted 20 seconds, followed by 2 seconds of darkness. Participants' subjective evaluations and gaze data indicate that the most preferred object was the orange seen under a desaturating light source. However, participants found the orange to be the least natural when the light source was saturating the red-green colors. Gaze data indicated that participants focus on objects that are either unnatural or preferable. Data from this study suggest that change in the spectrum (gamut shape) have a larger impact on subjective evaluations compared to illuminance. Results also support previous findings from the literature where slightly saturated warm-colored objects are preferred more compared to other hues.

Bio

Christie Gonzalez is an undergraduate student in Architectural Engineering at the Pennsylvania State University. She is part of the BE-SURE program focusing on color science, illuminance, and visual perception. She worked as a research assistant with Dr. Dorukalp Durmus and Rugved Kore in the Lighting Lab. She is now a fifth year Architectural Engineering student working on her senior thesis.

Rugved Kore is a Ph.D. candidate at Pennsylvania State University and has a Master of Science degree in Human Factors Engineering. His doctoral research focuses on a light projection system that reduces damage to artwork without causing perceptible shifts. His goal is to develop a novel method of illumination in museums using spectral and spatially tunable light projection system.

Dr. Dorukalp Durmus is an assistant professor at the Pennsylvania State University. He received his Ph.D. in architectural sciences from the University of Sydney, Australia. His research interests are human factors and lighting, colorimetry, psychophysics, adaptive lighting systems, and image quality assessment.

Session: UV & IR Radiation: Measurements, Concerns & Applications

Chair: Robert Vest, National Institute of Standards and Technology (NIST), Gaithersburg, MD
November 15th, 3:30 PM – 5:10 PM EST

Key Findings from Radiometric Testing of Direct-Irradiation GUV Products

Jason Tuenge, Pacific Northwest National Laboratory (PNNL), USA
Email: Jason.Tuenge@pnnl.gov

Abstract

The U.S. Department of Energy (DOE) launched the CALiPER program in 2006 to address a need for unbiased, trusted performance information for solid-state lighting (SSL) products, including those incorporating LED emitters. DOE testing and analysis, conducted by qualified test labs using industry-approved test procedures, helped to encourage high-quality products and discourage inflated performance claims. Early CALiPER testing also contributed fundamentally to the development of standardized photometric test methods specifically for SSL and the associated accreditation of testing laboratories.

The COVID-19 pandemic created a similar "wild west" environment for germicidal ultraviolet (GUV) products, where unsubstantiated performance claims proliferate, new technologies and test methods are in development, and the capabilities of commercial test laboratories are limited. In response, and further motivated by the desire to improve resilience to any future pandemics, the CALiPER program recently expanded its scope to include GUV products used to treat air and surfaces in occupiable spaces.

This presentation will share key findings from the first round of testing for three categories of GUV products using LED or low-pressure mercury (LPM) technology marketed as generating UV-C: plug-in "tower" products intended for use in vacant spaces (plus some integrated LED lamps that may be used in this manner), ceiling-mounted fixtures intended for direct irradiation of vacant spaces, and one ceiling-mounted fixture intended for direct irradiation of occupied spaces. Radiometric and electrical performance testing included traditional integrating sphere and goniometer measurements, plus application-distance measurements in accordance with ANSI/IES LM-91-22. Some products were additionally tested to IEC 62471:2006 for photobiological safety.

Bio

Jason Tuenge joined PNNL in 2008 as a Lighting Research Engineer, with broad experience in the lighting domain ranging from applications engineering for a luminaire manufacturer to lighting design at engineering firms. His recent work has included characterizing the energy performance of connected lighting systems, developing guidance on calibrating measurement equipment, and leading radiometric and electrical testing of germicidal ultraviolet products through DOE's CALiPER program. Jason has a B.S. in architectural engineering from the University of Colorado-Boulder, and a Master of Information and Data Science degree from the University of California-Berkeley.

Current Documentary Standards Development for an Ultraviolet Germicidal Irradiance Economy

Cameron Miller, National Institute of Standards and Technology (NIST), Gaithersburg, MD
Email: c.miller@nist.gov

Abstract

In the United States (U.S.), healthcare-associated infections (HAIs) infect one in every 25 hospital patients, account for more than 99,000 deaths and increase medical costs by more than $35 billion, each year. Ultraviolet-C (UV-C) antimicrobial devices are shown to reduce the incidence of many of these HAIs by 35% or more. The adoption of UV-C technology by the healthcare industry has been sporadic largely due to the lack of documentary standards to support an ultraviolet germicidal irradiance (UVGI) economy.

The development of a UVGI economy has several steps and phases of development requiring documentary standards which include, among others, standards to measure GUV device optical radiation distribution, measurement standards for minimum requirements to inactivate pathogens, methods for assessment of environment factors in applications, standards and guides on implementing the GUV devices in the application, standards or guides for the verification of correct implementation, guides on required maintenance and validation of the implementation.

This presentation will present current activities and future directions for these required standards.

Bio

Cameron Miller joined the National Institute of Standards and Technology in 1996 and from 2013 to 2021 was the group leader for the Optical Radiation Group. Currently, he is focusing on research include all aspects of Photometry & Radiometry and measurement uncertainty. Cameron is active in standards organization and professional societies, such as IES – Testing Procedure Committee, IES – Science Advisory Panel Member, International Ultraviolet Association (IUVA), CIE, ASTM, and ISCC. He is also an NVLAP assessor for the Energy Efficient Lighting Program and the Calibration Program. Cameron Miller obtained his PhD in Physical Chemistry from Cornell University (1994).

SARS-CoV-2 Inactivation by Ultraviolet Radiation and Visible Light is Dependent on Wavelength and Sample Matrix

Mike Schuit, US Department of Homeland Security
Email: Michael.Schuit@ST.DHS.GOV

Abstract
Numerous studies have demonstrated that SARS-CoV-2 can be inactivated by ultraviolet (UV) radiation. However, there are few data available on the relative efficacy of different wavelengths of UV radiation and visible light, which complicates assessments of UV decontamination interventions. The present study evaluated the effects of monochromatic radiation at 16 wavelengths from 222 nm through 488 nm on SARS-CoV-2 in liquid aliquots and dried droplets of water and simulated saliva. The data were used to generate a set of action spectra which quantify the susceptibility of SARS-CoV-2 to genome damage and inactivation across the tested wavelengths. UVC wavelengths (≤280 nm) were most effective for inactivating SARS-CoV-2, although inactivation rates were dependent on sample type. Results from this study suggest that UV radiation can effectively inactivate SARS-CoV-2 in liquids and dried droplets and provide a foundation for understanding the factors which affect the efficacy of different wavelengths in real-world settings.

Bio
Mike Schuit has earned a B.S. in Biology, an M.S. in Biomedical Sciences, and a Ph.D. in Microbiology and Infectious Diseases. He was employed at the National Cancer Institute's Frederick National Laboratory for Cancer Research from 2006-2010 and has been employed at the National Biodefense Analysis and Countermeasures Center (NBACC) from 2010 until the present. While at NBACC, he has worked in both the Virology and Aerobiology groups, both working on and leading studies in BSL-2, 3, and 4 containment laboratories. In his current role as an Associate Principal Investigator, his research primarily focuses on the effects of environmental conditions on infectious microorganisms and viruses in aerosols.

Reflectance Measurements of Building Materials in the Far UVC (222 nm) Wavelength Range

Holger Claus, Ushio America Inc., and **Catherine Cooksey**, National Institute of Standards and Technology (NIST)
Email: HClaus@ushio.com; catherine.cooksey@nist.gov

Abstract
Recently the application of Far UV-C optical radiation for disinfection of occupied spaces has seen a growing interest. Filtered Excimer KrCl lamps, which emit 222 nm, have been shown to provide similar or better pathogen reduction rates, while being safe for human eye and skin exposure at much higher levels than the typical 254 nm radiation. This opens new opportunities to provide disinfection of air and surfaces while people are present.
The physical placement of 222 nm luminaires for disinfection in a room is guided by light planning software. In order to achieve reasonably accurate radiation distribution models and predict the applied UV dose levels, the reflectance of walls, furniture, ceilings and floors has to be taken into account.

Unfortunately, while reflectance data at 222 nm are urgently needed, very few have been published. The paper presents a simplified setup, using an existing PTFE sphere, a 222 nm radiometer and a filtered 222 nm excimer lamp. The advantage of the setup is that total reflectance of materials representative for an actual lamp can be obtained quickly and with sufficient accuracy for the intended purpose of room modeling.
Common building materials have been investigated with this method and most of them showed a diffuse reflectance of about 10%. PTFE samples were measured at 222 nm by NIST and were used as reflectance standards. NIST also measured various other samples for the purpose of validating the method.

Advantages and disadvantages of the applied method are discussed.

Bio

Dr. Holger Claus is the Vice President of Technology at Ushio America Inc. He holds a Master's degree and PhD in lighting.
Throughout his career he has developed and produced various kind of light sources, like fluorescent lamps, UV lamps, short arc Xenon, laser driven Xenon and super high pressure Mercury lamps, LED and laser products, and excimer lamps.

He has extensive knowledge and experience of application related questions of these lamps including drivers, measurements and regulatory questions.
Recently he has been leading the technical and regulatory efforts of Ushio America Inc. to introduce 222nm lamps into the scientific community and the market. He is a member of IUVA, IES, CIE and ASTM.

Dr. Catherine Cooksey is a research chemist at the National Institute of Standards and Technology (NIST). She is responsible for transmittance calibration services and conducts research on reflectance and transmittance of optical materials. She also serves as Quality Manager for the Sensor Science Division, which encompasses one of the largest programs for calibration services at NIST. Dr. Cooksey earned her B.S. in chemistry from the University of Kansas and her Ph.D. in chemistry from the University of Washington.