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.

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Record Attendance at CORM's 2016 Annual Conference

Over eighty people attended this year's CORM conference held at NIST in Gaithersburg, MD in May 2016. This was the most active meeting in recent memory with twenty nine technical presentations, an interactive light booth demonstration and well organized and constructive technical committee meetings.

Always a highlight of the conference is the Franc Grum memorial banquet and lecture. This year's lecturer was Dr. David H Sliney, a world renowned medical physicist and laser safety expert. The topic of Dr. Sliney's lecture was: 'Can We Really Measure Optical Radiation Hazards?' The full lecture is available for download on the CORM website (www.cormusa.org) along with all of the other presentations.

Attendees took part in an impromptu study of the effects of melanopically enhanced lighting conducted by Musco Sports Lighting. Observers looked into a light booth and were presented with two lighting conditions then asked which scene was perceived brighter. Twenty nine out of thirty tested chose the melanopically enriched lighting condition. The light booth demonstration was supported by a presentation on the basics of melanopsin and brightness perception by Dr. Sam Berman.

The results of the 2016 CORM officers and directors election were announced. Jim Leland passed on the presidential duties to Andy Jackson. Jim will remain on the CORM board of directors. John Bullough has been elected as the new vice president. Massy Anaya was re-elected as treasurer. Thanks to Jim for his outstanding leadership and commitment during his term as president. And we all look forward to working with Andy and the incoming officers to help carry-on Jim's high standard of service.

The now-published CORM 8th report was very briefly discussed during the annual CORM business meeting that is open to all members. Plans for the CORM 9th report were presented with tentative completion date.

Many thanks to the conference coordinators Jim Leland, Bob Angelo and Heather Patrick-NIST liaison as well as the technical session chairs and technical committee chairs for their efforts in making CORM 2016 a success.

CORM/ISCC 2017 Joint Technical Conference

First Announcement and Call for Papers

July 31 – August 2, 2017

The CORM/ISCC 2017 Joint Technical Conference and Business Meeting will be held in Troy, NY – in cooperation with the Lighting Research Center at Rensselaer Polytechnic Institute. The conference themes include:

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

The CORM Technical Conference is structured to provide interaction between the optical radiation industry and National Metrology Institutes (NMIs) such as the National Institute of Standards and Technology (NIST), National Research Council (NRC) of Canada, and National Center for Metrology (CENAM) of Mexico. The ISCC Technical Conference is intended to further the Society's goal to stimulate work, to describe and specify color, to promote color applications and communications across diverse platforms, and to foster educational opportunities for color work being done in the public and private sector.

**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.*

Deadline for abstracts is April 17, 2017;
Presentation materials are due by June 26, 2017.
Please contact the conference coordinators for details.

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NIST

NEWS FROM THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

100th Anniversary of the Illuminating Engineering Institute of Japan

The Illuminating Engineering Institute of Japan (IEIJ) is the leading illuminating engineering society in Japan, with approximately 5,500 members. The IEIJ held a major event on September 2 that included a symposium, a ceremony, and a reception to celebrate its 100th anniversary. Yoshi Ohno, a NIST Fellow and the President of the International Commission on Illumination (CIE), participated as one of the 3 invited "Great Leaders" from international lighting organizations. Nobel Laureates Isamu Akasaki and Hiroshi Amano, who shared the 2014 Prize "for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources," also participated. Ohno's talk provided an overview of the last 100 years of research on the color quality of lighting, including recent research at NIST in this area using Sensor Science Division's Vision Science Laboratory. During the evening reception, he had the opportunity to meet and converse with Emperor Akihito and Empress Michiko of Japan. [*POC: Yoshi Ohno yoshi.ohno@nist.gov*]

Caption: On September 2, HM Emperor Akihito and HM Empress Michiko attended the reception to commemorate the 100th anniversary of the establishment of The Illuminating Engineering Institute of Japan, in Tokyo. Photo from Sankei.
https://imperialfamilyjapan.wordpress.com/ 2016/09/02/illuminating-engineering-institute/

NIST Successfully Transfers NIST-Developed SIRCUS Satellite Calibration Capabilities to NASA

In August 2016, NIST Sensor Science Division Physicists John Woodward and Steven Brown deployed the NIST Traveling SIRCUS (T-SIRCUS) laser system to Raytheon Space Systems in El Segundo, CA to assist NASA with the calibration of the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor that will fly on NOAA's Joint Polar Satellite System-2 (JPSS-2) weather-climate satellite in 2021. The T-SIRCUS laser-based calibration system can be tuned across a wide wavelength range in the visible and infrared to measure the sensor's response to different wavelengths of light. The VIIRS calibration marks a successful transfer of the laser technology to NASA. NIST will continue to provide radiometric transfer standards to NASA to maintain the SI-traceability of future satellite sensor calibrations. [POCs: *Steven Brown, steven.brown@nist.gov; John Woodward, john.woodward@nist.gov*]

NIST Co-Sponsored CALCON Meeting

The Meeting on Characterization and Radiometric Calibration for Remote Sensing (CALCON) was held at Utah State University in Logan, UT in August, 2016. Radiometric calibration continues to be a critical part of air and space-based remote sensing as measurement uncertainty requirements must continually improve to meet the increasingly stringent needs of numerical weather prediction and climate change modeling. NIST Physicist Joseph Rice was on the planning committee, and NIST staff served as session chairs and coauthored on multiple presentations. [POCs: *Joseph Rice, joseph.rice@nist.gov; John Lehman, john.lehman@nist.gov*]

Vision Science Research Enables New Lighting Products

A July 12, 2016 article on the website of LEDinside, a trade magazine for the light-emitting diode (LED) industry, highlights a new product line from Lumileds that is based in large part on NIST vision science research [1]. Lumileds LUXEON Stylist Series white LED products are designed to enhance the color appearance of products in retail displays and similar applications. The product's color enhancing technology is based on research in Sensor Science Division that was published in 2015. Furthermore, in their product design process, Lumileds used Illumination Engineering Society (IES) TM-30-15 Method for Evaluating Light Source Color Rendition, to which NIST research contributed. [*POC: Yoshi Ohno,* ***yoshi.ohno@nist.gov***]

[1] http://www.ledinside.com/interview/2016/7/lumileds_luxeon_stylist_series_enhances_colors_in_various_applications

Sorting Particles using Optical Forces

Physicists in Sensor Science Division have devised a new method for sorting aerosol particles in a flowing gas using optical forces [1], building on more than 100 years of research in the interaction and manipulation of particles with light. In the new method, strong optical forces are created in one direction in a standing wave interference field. Spherical particles enter a flowing gas just outside of the field and are blown across. The particles interact with the field differently depending on their size, so the particle coming out the far end are sorted by position. Surprisingly, bigger particles do not always experience a larger force. As the diameter of a particle approaches half of the wavelength of light, different parts of the particle can be pushed both forward and back. Under special conditions, the optical force on the particle can be zero and is thus unaffected by the field. However, the condition is delicate, and a change in the radius of 1 % either way can lead to a large deviation in the final position. [*POC: John Curry,* ***john.curry@nist.gov***]

[1] J. J. Curry and Z. H. Levine, "*Continuous-feed optical sorting of aerosol particles*," Opt. Express 24(13) 14100–14123 (2016); **http://dx.doi.org/10.1364/OE.24.014100**

Temperature Metrology for Laser-Based Manufacturing

Material processing by laser is an enabling technology for advanced manufacturing. A better understanding of the laser-induced temperature profile, both spatial and temporal, would greatly benefit process developers and reduce development time. In a joint effort between the Sensor Science Division and Applied Physics Division, NIST scientists have demonstrated dynamic, spatially resolved temperature measurements of materials under laser-processing conditions in a proof of concept experiment. The researchers used "photonic thermometers," silicon structures with an optical resonance that shifts with temperature, and were able to measure the temperature rise due to a single 5 ns pulse from a 1064 nm laser. Preliminary results were presented at the recent TEMPMEKO conference in Poland. [POC: Brian Simonds, **brian.simonds@nist.gov**; Zeeshan Ahmed, **zeeshan.ahmed@nist.gov**]

NIST Researcher Yuqin Zong Discusses the Candela in *Nature Physics*

NIST and Sensor Science Division Researcher Yuqin Zong "sheds light on photometry's fundamental unit" in a recent invited submission to the "Measure-for-Measure" section of *Nature Physics.* Zong's provides a brief overview of the candela, one of the seven SI base units, and discusses the ongoing debate over the definition of the candela between backers of the radiant-intensity and photon-intensity formulations. This is not the first time that Sensor Science Division staff have been invited to submit an article for the Measure-for-Measure" section of *Nature* Physics. [POC: *Yuqin Zong, yuqin.zong@nist.gov*]

NIST Measurement Assurance Program (MAP) with 118 Participating Labs Assesses Industry's Ability to Measure the Performance of Solid-State Lighting Products

The NIST Sensor Science Division, in partnership with the Department of Energy and the Environmental Protection Agency Energy Star program, developed a MAP in solid state lighting measurements. A report on the results from this study, accepted on May 12, 2016 for publication in the IES journal LEUKOS, demonstrates that labs generally agree within ±4% (k = 2) on measurements for total luminous flux and luminous efficacy, with the latter number being a critical measure of the energy efficiency of a product. Larger discrepancies were seen in some of the accompanying electrical measurements, with the specific causes still being studied. A second MAP using a new set of artifacts to more accurately represent products now being offered in the rapidly advancing solid-state lighting market is under development. [POCs: *Cameron Miller, c.miller@nist.gov; Maria Nadal, maria.nadal@nist.gov*]

NIST Hosts SIM Workshop on Comparison Analysis on May 19 – 20, 2016

NIST Research Chemist Maria Nadal, as Chair of the Inter-American Metrology System (SIM) Metrology Working Group on Photometry and Radiometry (WG2), organized this two-day workshop. The goal of the workshop was to start planning and training for the upcoming SIM regional measurement comparisons in Photometry and Radiometry that are required to link the measurements from the SIM National Metrology Institutes to Key Comparison Reference Values (KCRVs). Attendees included representatives from the SIM countries of Argentina, Brazil, Canada, Columbia, Costa Rica, Mexico, and the United States. [POC: *Maria Nadal, maria.nadal@nist.gov*]

Society of Automotive Engineers Invite NIST Expertise on Flashing Light Measurements for Automotive Applications

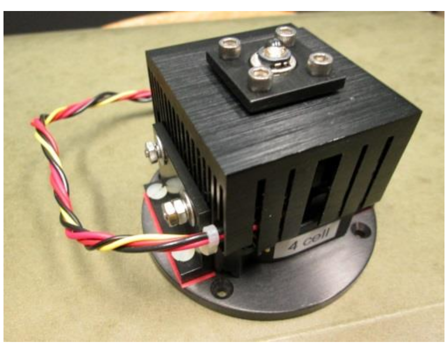
Sensor Science Division staff members participated in the Society of Automotive Engineers (SAE) Lighting Committee Standards Development Meeting held April 19-21, 2016. NIST staff presented work on calibration standards for flashing light such as for lx·s and cd·s, and on calibration services for flashing light photometers, e.g., for aircraft anticollision light photometers. NIST staff also presented the Technical Report of CIE (International Commission on Illumination) TC 2-49 *Effective intensity of flashing lights*, which includes a new method that allows evaluation of the effective intensity of not only rhythmic flashing light but also any waveforms of lights with any frequency, significantly broadening the applicability of the method. [*POC: Yoshi Ohno, ohno@nist.gov; x2321*]

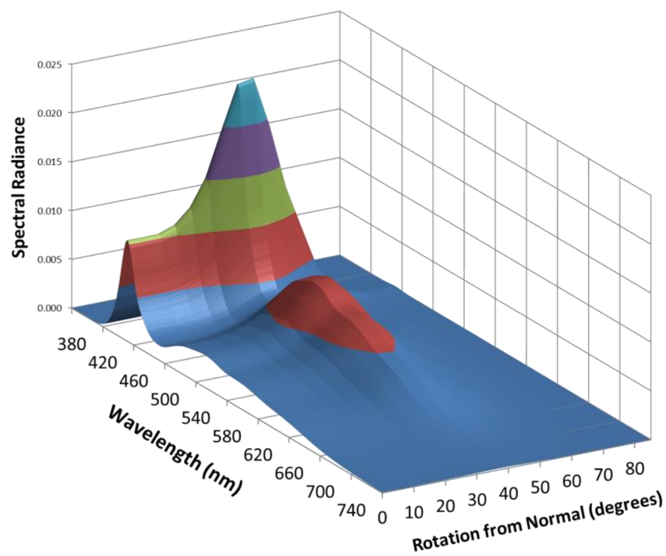
NATIONAL RESEARCH COUNCIL OF CANADA

National Research Council Canada   Conseil national de recherches Canada

NRC LIAISON REPORT

NRC Solid-State-Lighting Measurement Lab: New 3D Angular Measurement Capabilities
The angular distribution of the light output of solid state lighting (SSL) modules is an important characteristic for any subsequent lighting application. Multi-LED modules combine the directional features of individual LED components to produce a wide variety of geometric output distributions. The NRC Measurement Science and Standards (MSS) portfolio is continuing the development of its SSL measurement facilities to include a robotic goniometer that will enable the 3-D angular measurement of photometric and spectral output of small SSL modules into the 2-π emission hemisphere from the devices. To test the feasibility of applying the robot for these measurements, we have measured the spectral output of a sample device in one angular plane. The device tested is shown in the accompanying photo and the (approximately) spectral radiance distributions as a function of the rotation angle are shown in the accompanying plot. This device has a large spectral output in the blue (450 nm) that peaks at angles near 40° from the normal. The broad secondary peak in the region of 550 nm also varies with angle, combining with the blue peak to give a correlated colour temperature that varies from near 10,000 K at normal to 8,000 K at 80° from normal. We are developing control software and measurement equipment to enable spectral measurements over a wider range of the full 2-π emission angles.

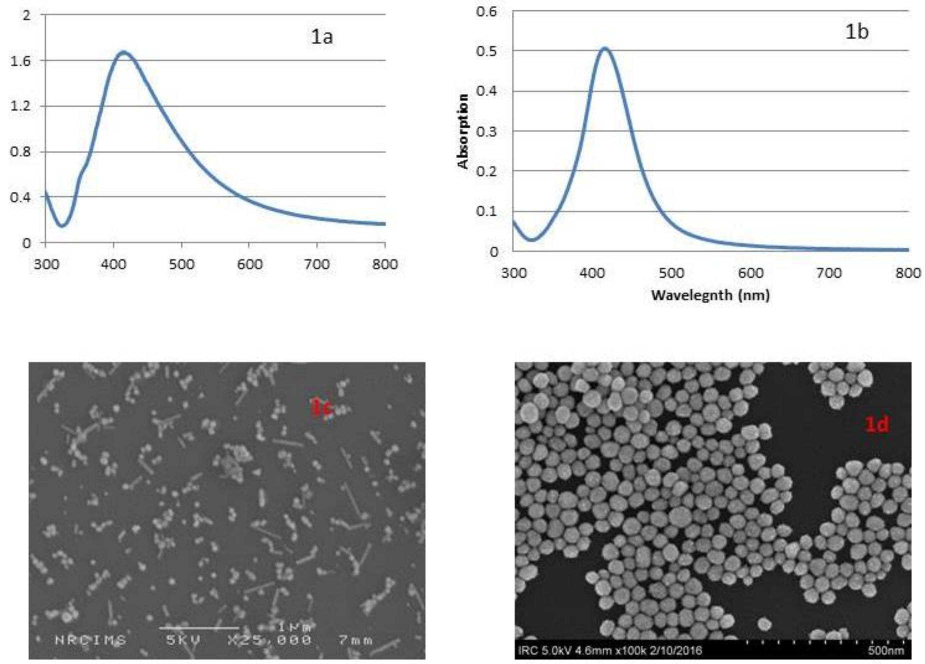




For further information contact: Arnold Gaertner (613) 993-9344 (arnold.gaertner@nrc-cnrc.gc.ca)

Development of Homogenous Ag Nanoparticles for Surface Enhanced Raman Spectroscopy
The surface enhanced spectroscopy project in the photometry and spectrophotometry group has develop new protocol for chemical synthesis of plasmonic nanostructures that supports strong surface plasmon resonance and surface enhanced Raman scattering activities. The common silver nanostructures synthesized through the citrate reduction protocols produces heterogenous morphology of silver nanoparticles with a very broad surface plasmon resonance response as

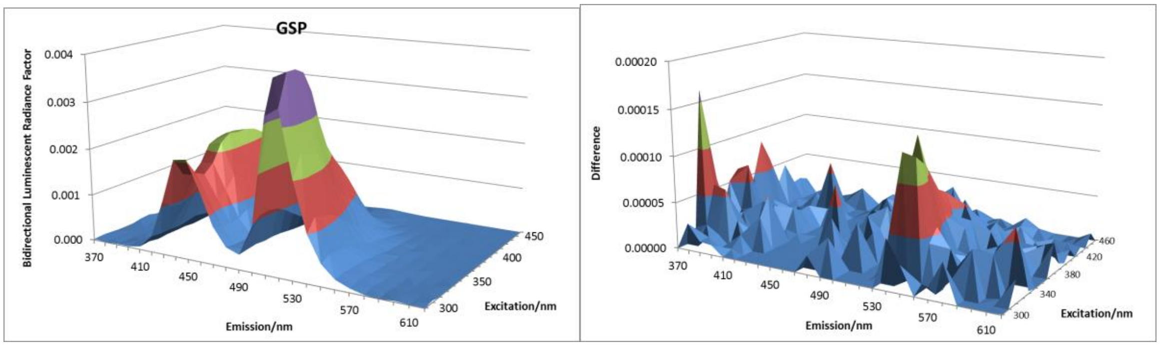
shown in figure 1a below. A new synthesis protocol based on low temperature and near neutral PH synthesis produces much more homogenous silver nanoparticles and a narrower surface plasmon response as shown in figure 1b. Scanning electron microscopy images of the two corresponding Ag NPs are shown in 1c and 1d.



For further information, contact: Li-Lin Tay, 613-993-3919 (lilin.tay@nrc-cnrc.gc.ca).

NRC Fluorescence Capabilities – Improved Traceability for Different Illumination and Viewing Measurement Geometries

The development, characterization and validation of a versatile reference goniospectrofluorimeter (GSP) for traceable fluorescence measurements using different illumination and viewing geometries specified in practical colorimetry, has been completed for both a bidirectional (45:0) and a sphere (8:d) geometry. This work has been written up in a two part paper series. The first paper that reviews the background to this work and provides details of the basic design of the new instrument and its characterization for measurements using a bidirectional geometry, including a representative uncertainty budget, has been recently accepted for publication in *Metrologia*. For stable fluorescent white plastic standards, the relative expanded (k=2) uncertainty in the visible range is 0.8%. The validation of this new NRC reference instrument for bispectral fluorescence measurements in a bidirectional (45a:0) geometry with the well-established NRC Reference Spectrofluorimeter for the measurement of a fluorescent blue-green plastic sample is shown below with the (absolute) difference plot shown on an expanded scale.



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

NRC's Routine Spectral Responsivity Facility Upgrade

As part of our effort for continual improvement of the radiometric measurement chain, an upgrade of the NRC Routine Spectral Responsivity Facility has been completed, including electronics, computer hardware and software. The computer upgrades have greatly improved the instrument automation, by consolidating a number of instrument operation and data acquisition programs into one versatile piece of code that will be easier to maintain. Full validation of the new code has been completed.

For further information, contact Charlie Bamber, 613-990-3990 (Charles.bamber@nrc-cnrc.gc.ca).

CORM TECHNICAL BULLETINS

A new feature in Optical Radiation News is the inclusion of short reports describing presentations made during previous CORM conferences and other technical topics. This issue contains two reports. CORM presenters from previous conferences and prospective contributors are invited to contact the editor (bulloj@rpi.edu) with suggestions for short articles summarizing recent technical advances or research findings.

Uncertainty Evaluation of Luminous Flux given Spectral Flux Uncertainty

Rolf Bergman, Rolf Bergman Consulting

Abstract

Calculation of the lumen uncertainty from the spectral uncertainty of a calibrated spectral total flux incandescent/halogen lamp is done using an EXCEL spreadsheet to solve the full uncertainty equation including both correlated and uncorrelated values. The solution is found for various values of the correlation coefficient. Also insight into how the spectral uncertainty in different regions of the spectrum affect the lumen uncertainty is gained.

Introduction

Modern labs use spectral detectors, usually CCD array spectrometers, to obtain values of the luminous flux from lamps of luminaires measured in an integrating sphere. The sphere is usually calibrated using an incandescent-halogen standard lamp provided by an accredited laboratory traceable to NIST. The calibration certificate accompanying the standard lamp states the uncertainty of the spectral measurements at each wavelength recorded, usually at 10 nm intervals from 380 to 780 nm. The software provided by the spectral detectors calculates the luminous output of a given lamp/luminaire from the measured spectral values. The question arises of how the uncertainty in the calculated value of the luminous flux is obtained from the given uncertainty of the spectral data provided by the standard lamp.

The paper presents a detailed description of the solution process following the GUM procedure for uncertainty calculations and show typical results for the luminous flux from the halogen standard lamp using assumptions on the values of the spectral uncertainty. Both uncorrelated and correlated measurements are assumed. The correlation coefficient, r, is used as a variable to show how the lumen uncertainty changes as the uncertainty changes from uncorrelated to fully correlated.

The solutions to the uncertainty equations derived below were obtained using an EXCEL spreadsheet formulation. While this is cumbersome to create, once created it provides quick results to what-if-questions that are instructive in understanding what is important.

Luminous Flux

The luminous flux, Φ, is numerically calculated from the spectral flux, S(λ) as follows:

$$\Phi = 683 \sum_{i=1}^{N} V_i(\lambda) \cdot S_i(\lambda) \cdot \Delta\lambda \qquad (1)$$

Where:

- $V_i(\lambda)$ is the luminous efficiency function at some wavelength increment i between 380 and 780 nm
- $S_i(\lambda)$ is the spectral flux at the same wavelength increment, i.
- $\Delta\lambda$ is the wavelength increment.

Uncertainty

What we wish to do is to propagate the uncertainty in $S_i(\lambda)$ to an uncertainty in Φ. The uncertainty in Φ, written $u(\Phi)$, is equal to the combined uncertainties in each of the elements of the sum. From the ISO Guide to Uncertainty in Measurements[1] it is noted that:

$$u_c(f) = \sqrt{\sum_{i=1}^{m} \left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) + 2\sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \frac{\partial f}{\partial x_i}\frac{\partial f}{\partial x_j} u(x_i)u(x_j)r(x_i, x_j)}. \qquad (2)$$

This is the expression when both uncorrelated and correlated uncertainty between the variables is assumed. The uncorrelated uncertainty is given by the first summation under the square root sign in Eq. 2. The correlated part is the double summation after the '+' sign in Eq. 2. Note that the value of the correlation coefficient $r(x_i, x_j)$, (or $r_{i,j}$) at the end of Eq. 2 determines the amount of correlation. Eq. 2 can be thought about as a matrix where the uncorrelated values are the diagonal values of the matrix and the uncorrelated terms are the off-diagonal terms.

Note that if r=0 we have the uncorrelated part; on the other hand if r=1 it can be shown that Eq. 2 reduces to the following equation.

$$u_c(f) = \sum_{i=1}^{m} \frac{\partial f}{\partial x_i} u(x_i) \qquad (3)$$

The partial derivative of the main function, $\frac{\partial f}{\partial x_i}$, is called the sensitivity coefficient.

Application to Luminous Flux

The f in Eq. 2 or Eq. 3 refers to the flux Φ as shown in Eq. (1). The x_i and x_j in Eq. (2) refer to the variables on the right hand side of the equation for f. In our case the only variable with uncertainty in Eq. 1 is the spectral power, $S_i(\lambda)$.

Calculation of the sensitivity coefficient for luminous flux in Eq. (1) by taking the partial derivative of the flux with respect to the spectral power gives:

$$\frac{\partial f}{\partial x_i} = \frac{\partial\left[683 \sum_{i=1}^{N} V_i(\lambda)\cdot S_i(\lambda)\cdot \Delta\lambda\right]}{\partial S_i} = 683 \cdot \Delta\lambda \cdot V_i \qquad (4)$$

Next consider the spectral uncertainty, $u(x_i)$ term in Eq. (2). For convenience, as used on certificates, we will assume that the uncertainty is given as a fraction of the spectral power at a given wavelength, i.e.:

$$u(x_i) = h_i \cdot S_i \qquad (5)$$

Putting the definitions from Eqs. (4 & 5) into Eq. (2) we obtain:

$$u^2(\Phi) = (683 \cdot \Delta\lambda)^2\left[\sum_{i=1}^{N}(V_i)^2 \cdot (h_i S_i)^2 + 2\sum_{i=1}^{N-1}(V_i \cdot h_i S_i)\sum_{j=i+1}^{N}(V_j \cdot h_j S_j) \cdot r_{i,j}\right] \qquad (6)$$

Note that we have written the uncertainty $u(\Phi)$ as the square to avoid the square root sign.

Uncorrelated Uncertainty

If the correlation coefficient, $r_{i,j}$ is equal to zero, it is easy to see that we are left with:

$$u^2(\Phi) = (683 \cdot \Delta\lambda)^2 \sum_{i=1}^{N} (V_i)^2 \cdot (h_i S_i)^2 \qquad (7)$$

This is the result if the relationship at various increments is not dependent on each other, i.e., the data is **uncorrelated.**

Correlated Uncertainty

When the uncertainty of the spectral data is correlated, i.e., when there are aspects of the measurements such as wavelength inaccuracy, dark signal or stray light, that affect measurements at other than the wavelength interval of interest, then we need to include all the terms of Eq. (6). Solving Eq. (6) becomes rather complicated but we will do so in an accompanying spreadsheet discussed below.

If the results are fully correlated, i.e., if $r_{i,j}$ = 1.0 then, as shown in Eq. (3), the uncertainty in lumens can be written as:

$$u(\Phi) = 683 \cdot \Delta\lambda \sum_{i=1}^{N} V_i \cdot h_i S_i \qquad (8)$$

Eq. (8) is simply Eq. (1) multiplied by h_i, the spectral uncertainty. Thus if results are fully correlated we can do no better for the lumen uncertainty than that given by the spectral uncertainty over the visible region no matter how much data we take.

Usually the reality of the measured uncertainty lies somewhere between fully correlated and uncorrelated. In this case we need to solve Eq. (6) with a known value of $r_{i,j}$. Eq. (6) is solved in our case using a spreadsheet. What we are after is how the lumen uncertainty changes with values of h_i and $r_{i,j}$. The spreadsheet solution is discussed below.

Example Calculations

We will consider the lumen uncertainty of a 500-watt halogen lamp calibrated by NIST. The spectral values, in W/nm, with corresponding percent uncertainty, are given every 10 nm between 380 and 780 nm. An EXCEL spreadsheet is developed to solve Eq. (6) for the wavelength region between 380 and 780 nm using 5-nm intervals for $\Delta\lambda$; the 5-nm values are interpolated from the 10-nm data on the certificate. The spreadsheet is set up with a column of 81 wavelengths (5 nm increments from 380 to 780 nm) in column A. Other columns then have values of $S_i(\lambda)$, $V_i(\lambda)$, h_i, $\partial f/\partial x_i$ etc. Note that the double-summation depicted in the r.h.s. of Eq. (6) requires 80 columns on the spreadsheet. This makes setting up a spreadsheet method laborious, but once done many what-if questions can be answered quickly.

Results

If we set h_i = 0.01 (1 % uncertainty) for all values (not far from actual certificate values given), in the spreadsheet and calculate the lumen uncertainty as a function of the correlation coefficient we obtain the graph shown in **Figure 1**.

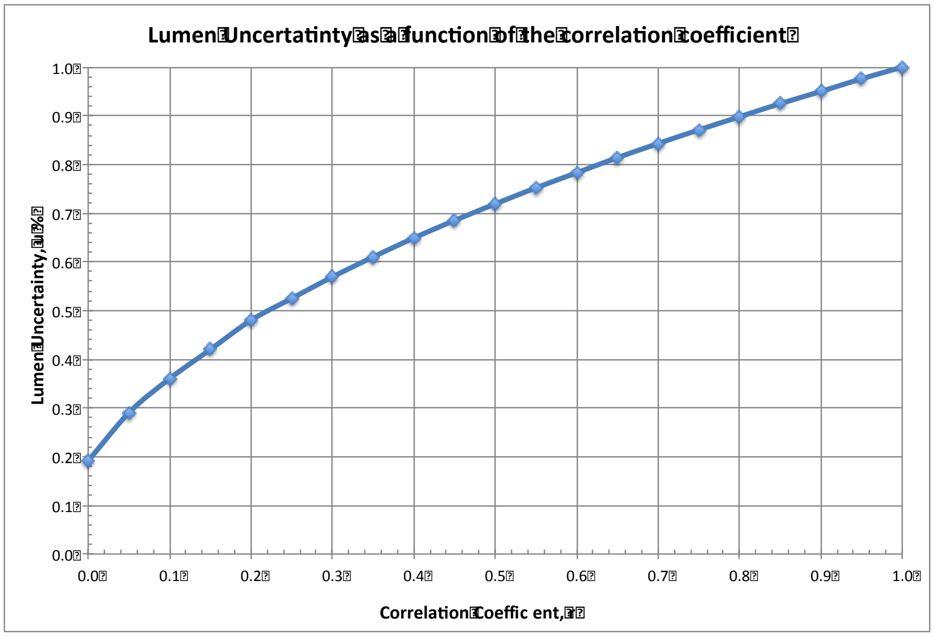


Figure 1: Dependence of lumen uncertainty on the correlation coefficient, r, for a uniform spectral uncertainty of 1 % of signal.

Note that for no correlation between the wavelength values the reduction in uncertainty is large; a little over a factor of 5. For a 50 % correlation however, the reduction is less than 50 %. Obviously at full correlation we obtain the value h_i as expected. The practical conclusion is that there is usually little to be gained in lumen uncertainty due to multiple values as it is expected that the correlation coefficient is high.

Normally the lamp standard certificates show that the spectral uncertainty is higher (about 3 % at 380 nm) at the low wavelength region of the spectrum due to the fact that the signal in the blue is usually significantly lower from an incandescent/halogen lamp as well as detector sensitivity is reduced. To investigate the importance of this it was assumed that the spectral uncertainty was 3 % in the wavelength range 380 to 450 (larger than actual). What one finds by inserting these values for h_i is that for a fully correlated situation the lumen uncertainty rises from 1 % to 1.004 %, i.e., almost no effect. The reason is that the spectral uncertainty is weighted by the luminous efficacy function V_i that has low values at either end of the spectral regions. Thus another conclusion we can draw from the analysis is that it is only the spectral uncertainty in the central region of the spectrum, i.e., from about 500 to 620 nm that is important. Reducing the spectral uncertainty near the peak of the luminous efficacy function has a direct effect on the luminous flux uncertainty even if the spectral uncertainty near the ends of the visible region, either blue or red end, are or remain large.

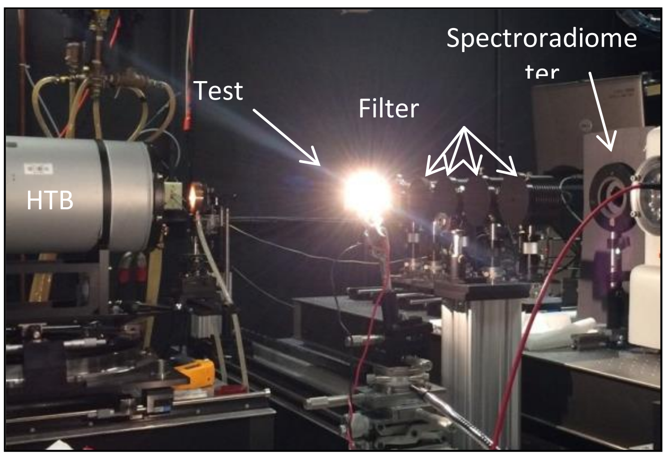
NRC's Spectral Irradiance Scale Upgrade

Angela Gamouras and Arnold A. Gaertner, Measurement Science and Standards, National Research Council of Canada

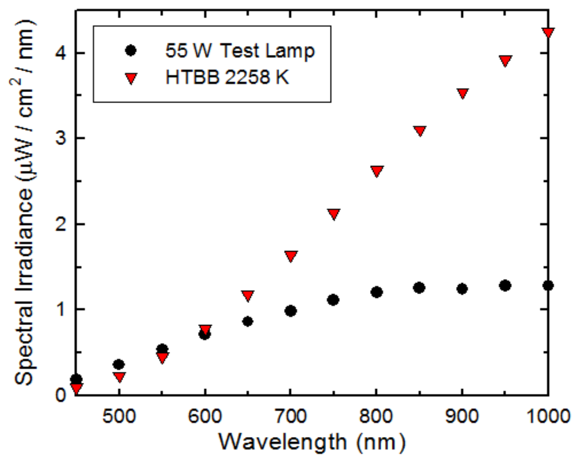
Construction of components and preliminary measurements have begun for extensive upgrades to NRC's spectroradiometric calibration chain. The present spectral irradiance scale uses an NRC detector based realization in the range of 700 nm – 1600 nm, together with NIST and a CIE traceability to provide a total spectral range from 200 nm to 2600 nm. A high temperature blackbody (HTBB) is being implemented as the primary standard light source for the calibration of irradiance standards from 200 nm to 2500 nm. Specialized photodetectors, called filter radiometers, are used to determine the thermodynamic temperature of the HTBB, which can operate up to 3500 K. Expected to be fully operational in 2016, NRC's new Spectral Irradiance Facility will have SI traceability from the cryogenic radiometer, providing a source and detector based spectral irradiance scale.

At the top of the optical radiation calibration chain, a cryogenic radiometer is NRC's absolute electrical substitution radiometer, with direct traceability to the watt. The cryogenic radiometer determines the spectral responsivity of transfer radiometers, which are then used to calibrate the wavelength dependent responsivity of other photodetectors, including the filter radiometers. NRC has a set of five filter radiometers, each with different optical glass filters to provide wideband spectral transmission centered at five wavelengths from the ultra violet to near infrared. The HTBB temperature, and consequently its spectral radiance, is calculated from the black body radiation measured by the filter radiometers.

The Spectral Irradiance Facility incorporates a one meter focal length spectroradiometer to transfer the known spectral output of the HTBB source to FEL incandescent lamps that will be used as transfer standards of spectral irradiance. During the construction phase, preliminary irradiance measurements have already been made using a 55 W test lamp.



Measurement of a test lamp in the Spectral Irradiance Facility.

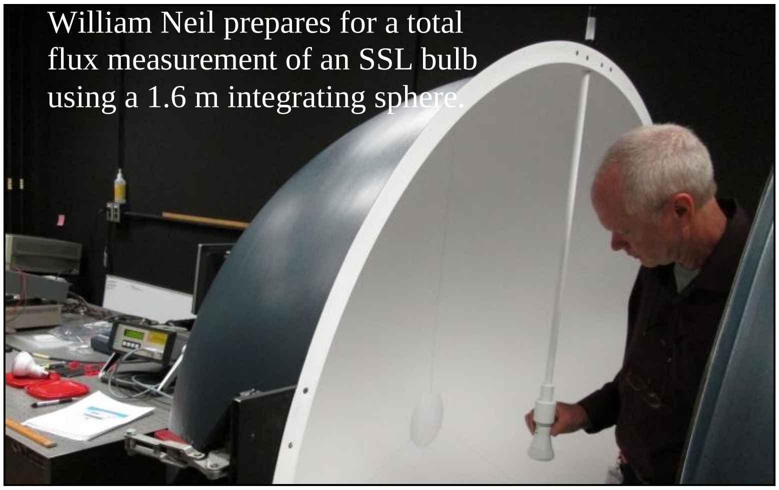


Preliminary data using 55 W test lamp and HTBB.

Solid State Lighting at NRC

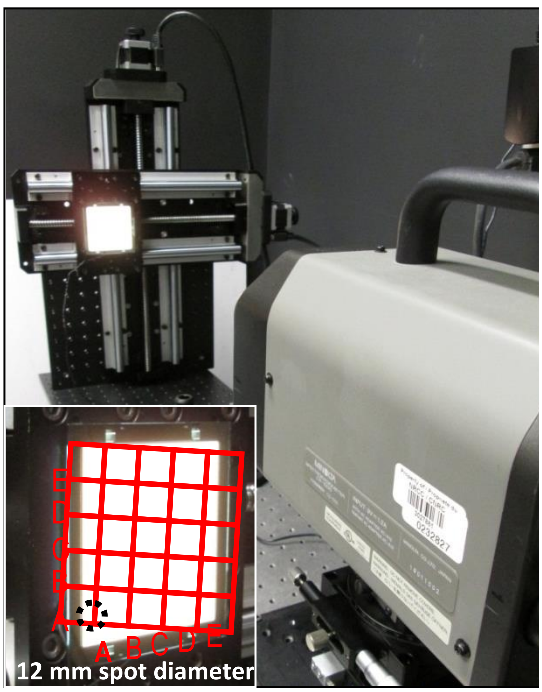
William Neil and Arnold A. Gaertner, Measurement Science and Standards, National Research Council of Canada

Inspired by our participation in the International Energy Agency's Energy Efficient End-Use Equipment Annex on Solid State Lighting (SSL) interlaboratory comparison in 2013, NRC has established an SSL laboratory focused on providing client calibrations. This facility has many capabilities, including total flux, intensity, irradiance and radiance measurements of SSL sources, both photometrically and some measurements available spectrally from 200 nm – 1700 nm. Several types of LED products can be calibrated, such as omnidirectional, directional, low power factor and high CCT LED sources. Position dependent and goniometric radiance measurements can also be performed. SI traceability is maintained through NRC's photometric and spectroradiometric calibration chain, where luminous intensity standards, total luminous flux standards and spectral irradiance standards are maintained on incandescent lamps.

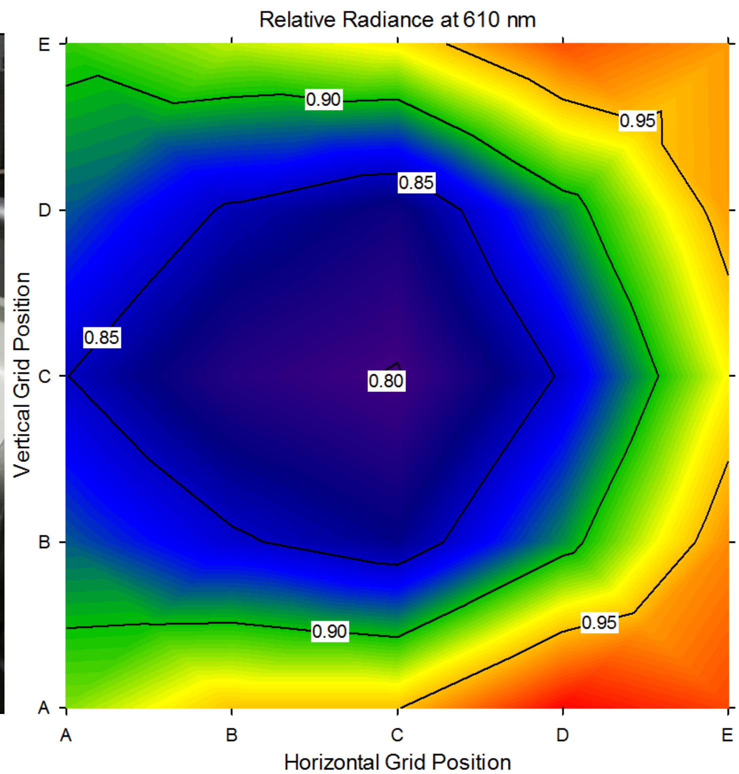


William Neil prepares for a total flux measurement of an SSL bulb using a 1.6 m integrating sphere.

As a demonstration of NRC's capabilities in this area, spectral measurements of an OLED sample are shown here. Radiance measurements were taken across the surface of a square OLED emitter using a motorized two-dimensional translation stage and spectroradiometer. The measurements show that there is some variation across the emitter, where the maximum radiance is at the edge of this particular sample.



Spectroradiometer and 2D translation stage for position dependent radiance measurements of OLED emitter. Inset: OLED measurement grid.



OLED radiance data normalized to the peak value at 610 nm.

For more information on NRC's SSL Laboratory and client calibration services, please contact Arnold Gaertner (arnold.gaertner@nrc-cnrc.gc.ca) or William Neil (william.neil@nrc-cnrc.gc.ca).

UPCOMING IES MEETINGS CALENDAR

The Illuminating Engineering Society (IES) is sponsoring the following meetings and conferences in 2017:

LIGHTFAIR International
May 7-11, 2017
Philadelphia, PA
www.lightfair.com

IES Teachers of Lighting Workshop
June 11-16, 2017
Somerset, NJ
www.ies.org/tolw

2017 IES Annual Conference
August 10-12, 2017
Portland, OR
www.ies.org/ac

2017 IES Street and Area Lighting Conference
September 10-13, 2017
Austin, TX
www.ies.org/salc

NEWS FROM THE CIE

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

Upcoming Events

CIE Tutorial and Practical Workshop on LED Lamp and Luminaire Testing to CIE S 025
May 8-11, 2017
Bern-Wabern, Switzerland
http://div2.cie.co.at/?i_ca_id=1013

CIE 2017 Midterm Meeting
October 20-28, 2017
Jeju, Korea
www.cie2017.org

Visit http://www.cie.co.at/index.php/Events/Future+CIE+Events for more information.

New Publications

Decision Scheme for Lighting Controls in Non-Residential Buildings, CIE 222:2017
This report offers guidelines in order to balance lighting quality, user comfort and energy efficiency in lighting controls solutions for lighting in non-residential buildings (i.e. for commercial, institutional and industrial buildings). It provides a decision scheme with a focus on the user requirements (visual comfort, performance, personal control) to determine the most applicable control solution, including the consequences for possible savings. In this, it assumes that there are no technological or financial hurdles. The decision scheme identifies 16 possible control strategies, for both daylight and electric lighting, and provides guidance for which strategy would be most effective in each of the 12 cases defined by space usage and occupancy.

ILV: International Lighting Vocabulary 2nd Edition, CIE DIS 017/E:2016
CIE has published Draft International Standard CIE DIS 017/E:2016 ILV: International Lighting Vocabulary, 2nd Edition. This draft of a new edition of the International Lighting Vocabulary (ILV) is the result of intensive work carried out by CIE JTC 8 in order to harmonize the content of the ILV in its version of 2011 (published as CIE S 017:2011) with the content of the International Electrotechnical Vocabulary (IEV), subject area "Lighting" (IEC 60050-845), considering the rules for drafting definitions as given in the ISO/IEC Directives. In addition parallel work in ISO/TC 12/WG 19 (Revision ISO 80000, all parts) was considered in the harmonization process. Supplementary to the review of existing definitions, terms and definitions of CIE S 017-SP1 have been included in this draft. Terms and definitions that had been under discussion in CIE TC 1-64, terms and definitions that have been agreed in ISO/TC 274, terms and definitions of CIE TN 002, and entries which proved to be reasonable during revision work were also added to the draft. A number of entries currently included in CIE S 017:2011 have been removed, either because they became obsolete as synonyms for other terms or because they were not explicitly related to light and lighting. The numbering of entries has been changed to a sectional system to be in line with the system used in IEC 60050-845.

Infrared Cataract, CIE 221:2016

There has long been a debate about the dose response curve, action spectrum and mechanism for the production of infrared cataracts. Some scientists believe that the damage mechanism is purely thermal, others suggest that there is some evidence that it could be photochemical. If the mechanism is photochemical, a strong wavelength dependence in the near infrared spectral region will be present, and this will have great significance for lamp safety, IR-A medical devices, occupational exposure limits and the design of industrial eye protection. With the advent of high-power infrared LEDs and diode lasers as well as wavelength-tuneable infrared lasers (e.g. Titanium Sapphire laser), it is now possible for the first time to conduct a definitive and conclusive laboratory study of the action spectrum for infrared cataract. Manufacturers of LEDs, lamps and lasers should be intensely interested in the results of such studies. If the aetiology (cause) is purely thermal, the ambient temperature as well as the spectral content of the infrared irradiation becomes important and this is reviewed in this report. Currently the weight of evidence suggests that the aetiological mechanism is thermal.

Characterization and Calibration Methods of UV Radiometers, CIE 220:2016

This technical document prepared by CIE Technical Committee TC 2-47 describes quality indices for UV radiometers, which are helpful for manufacturers and users to characterize instruments on a common basis. To harmonize CIE documents, the quality indices described in this document relate to the quality indices described in Joint ISO/CIE International Standard ISO/CIE 19476:2014(E) (formerly CIE S 023/E:2013), and references are made to those where applicable. Different from photometers, the subject of ISO/CIE 19476:2014(E), UV radiometers may be designed for various actinic spectra and different spectral ranges. Therefore, instead of only one defined reference-spectrum source (CIE Source A) used in ISO/CIE 19476:2014(E) three reference-spectrum sources are proposed in this document to support the generic spectral characterization of UV radiometers for various applications. The defined spectra of reference sources for the characterization of UV radiometers are given in Annex A. This document also describes source-based and detector-based methods along with measurement conditions and limiting boundary conditions for the calibration of UV radiometers used for laboratory as well as industrial applications.

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

Purpose of the Council for Optical Radiation Measurements (CORM)

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

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

Optical Radiation News Editorial Policy

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

Instructions for Contributing Authors

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

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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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