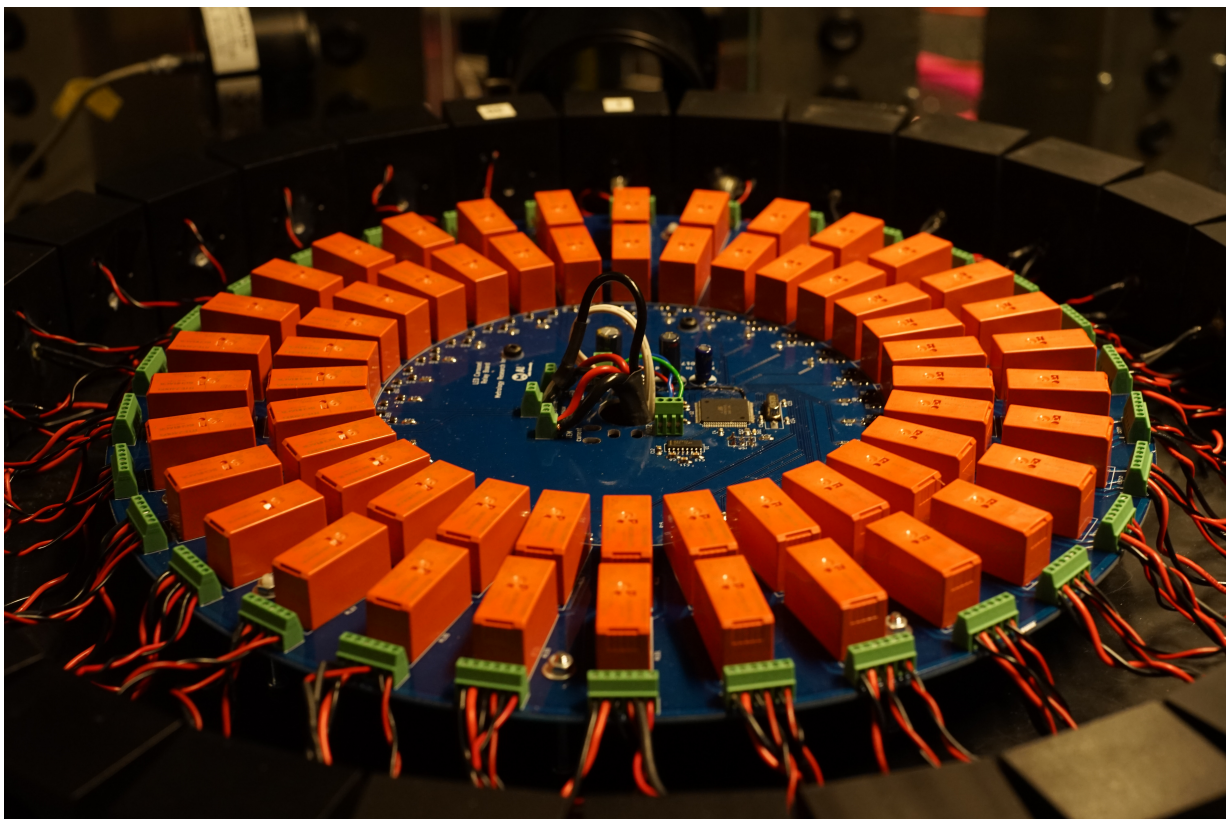


Triennial Report 2015 - 2017

Metrology Research Institute

Editor: Petri Kärhä



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1 INTRODUCTION

Close collaboration between the Metrology Research Institute of Aalto University and MIKES Metrology of VTT Technical Research Centre of Finland Ltd has continued after the merge of MIKES to VTT in the beginning of 2015, leading to many research highlights in the period 2015–2017 of this triennial report. An article on “Advantages of white LED lamps and new detector technology in photometry” by Pulli *et al* was published in *Light: Science and Application* (4, e332, 2015), a journal with high impact factor of 14.6. Another highlight of 2016 was the start and excellent results of the European PhotoLED project (Future photometry based on solid state lighting products), coordinated by Tuomas Poikonen at VTT and Aalto University. Finally, several oral contributions in top-class international conferences were achieved by researchers of the Institute: One invited talk and four oral contributions in the NEWRAD Conference (Tokyo 2017) and five oral contributions in the CIE Conference (Korea 2017).

The research group moved to new laboratory premises at Maarintie 8 in the beginning of 2017. The move was a major effort for all the personnel, because of the dedicated laboratory instruments that had to be re-installed and put into operation at the new place. The new premises offer better conditions for high-accuracy measurements than the old laboratories at Otakaari 5. It was an excellent achievement that all equipment was again operational by the end of 2017.

The Metrology Research Institute provides teaching within Aalto University and it operates under the Finnish name MIKES-Aalto Mittaustekniikka as the Finnish national standards laboratory for optical quantities. Seven doctoral degrees and seven M.Sc. degrees were achieved in 2015–2017. Four of the doctoral degrees were achieved in 2017, which is the highest yearly number of the Institute ever. The number of calibration certificates issued in 2015–2017 is 141, which leads to about the same yearly numbers as for the period 2013–2014. The 1000th calibration certificate issued by the Institute was celebrated at the end of year 2017.

2 PERSONNEL

Aalto University School of Electrical Engineering
Department of Signal Processing and Acoustics
Metrology Research Institute (MIKES-Aalto Mittaustekniikka)
P.O. Box 15500, FI-00076 Aalto, Finland

Visiting address: Maarintie 8, 02150 Espoo, Finland

Switchboard +358 9 470 01

Webpage <http://metrology.aalto.fi>

Use country code +358 with all telephone numbers.

In 2015–2017, the total number of employees working at the Metrology Research Institute was 30.

Name	Telephone	E-mail
Ikonen, Erkki, D.Sc. Professor, Head of Laboratory	50 550 2283	erkki.ikonen(at)aalto.fi
Hietala, Markku Secretary		Until summer 2017
Askola, Janne, M.Sc. Research scientist		janne.askola(at)aalto.fi
Baumgartner, Hans, M.Sc. Research scientist	50 400 9257	hans.baumgartner (at)aalto.fi
Dönsberg, Timo, M.Sc. Research scientist	50 421 0095	timo.donsberg(at)aalto.fi
Jaanson, Priit, M.Sc. Research scientist		Until April 2017
Kantamaa, Olli Research assistant		Since June 2016
Kokka, Alexander, M.Sc. Research scientist		alexander.kokka(at)aalto.fi Since March 2016

Kylmänen, Kasperi Research assistant		June 2015 – November 2017
Kärhä, Petri, D.Sc. Senior research scientist Quality manager	50 596 8469	petri.karha(at)aalto.fi
Lanevski, Dmitri, M.Sc. Research scientist		dmitri.lanevski(at)aalto.fi Since May 2017
Manoocheri, Farshid, D.Sc. Senior research scientist Head of calibration services	50 590 2483	farshid.manoocheri (at)aalto.fi
Mikkonen, Nikke Research assistant		June – December 2015
Mäntynen, Henrik Research assistant		Until January 2015
Oksanen, Johannes Research assistant		Until August 2016
Oksanen, Benjamin Research assistant		benjamin.oksanen(at)aalto.fi Since November 2015
Poikonen, Tuomas, D.Sc. Senior research scientist		Until October 2017
Pourjamal, Sara Research assistant		Until January 2015
Pulli, Tomi, M.Sc. Research scientist	50 408 2782	tomi.pulli(at)aalto.fi
Rabal, Ana, Dr. Senior scientist		Until May 2015
Rehman, Muhammad Ziaur Research assistant		Since June 2017
Shpak, Maksim, M.Sc. Research scientist		Until May 2015

Sildoja, Meelis-Mait, D.Sc. Senior research scientist		Until January 2015
Sillanpää, Teemu Research assistant		Until March 2015
Simonen, Tarmo, M.Sc. Network and PC Administrator	50 413 0179	tarmo.simonen(at)aalto.fi
Sirrola, Simo Research assistant		May – December 2017
Vaigu, Aigar, M.Sc. Research scientist		Until June 2017
Vaskonen, Eero Research assistant		May – August 2017
Vaskuri, Anna, M.Sc. Research scientist	50 411 3329	anna.vaskuri(at)aalto.fi
Vähänissi, Jonne Research assistant		May – August 2017

Docents and lecturers:

Häkkinen, Esa	Helsinki Institute of Technology (retired)
Jokela, Kari	STUK, Radiation and Nuclear Safety Authority (retired)
Kalliomäki, Kalevi	Centre for Metrology and Accreditation (retired)
Kauppinen, Jyrki	University of Turku (retired)
Laurila, Toni	Neste Corporation, Sensmet Ltd.
Ludvigsen, Hanne	Aalto University

3 TEACHING

3.1 Degrees

3.1.1 Doctor of Science (Technology), D.Sc. (Tech.)

Richard Högström (2015), *Metrological Developments for Aerosol and Mass Measurements*, Opponent: Professor George W. Mulholland, University of Maryland, USA.

Jeremias Seppä (2015), *Linear and Traceable Scales for Nanometrology*, Opponent: Dr. Brian Eves, National Research Council Canada.

Maksim Shpak (2016), *Applications of Radiometric Measurements in Non-Contact Thermometry and Mesopic Photometry*, Opponents: Dr. Mohamed Sadli, Laboratoire commun de métrologie, LNE-Cnam, France and Dr. Yoshi Ohno, National Institute of Standards and Technology, NIST, USA.

Tomi Pulli (2017), *Improvements in Spectroradiometric Measurements and Applications*, Opponent: Prof. Alkiviadis F. Bais, Aristotle University of Thessaloniki, Greece

Timo Dönsberg (2017), *Development and Characterization of the Predictable Quantum Efficient Detector, and Its Applications in LED Photometry*, Opponent: Dr. Nigel Fox, National Physical Laboratory, NPL, UK.

Hans Baumgartner (2017), *Metrology for III-V Optosemiconductors*, Opponent: Prof. Peter Hanselaer, University of Leuven, Belgium.

Priit Jaanson (2017), *Angle-Resolved Measurements and Modelling of Diffuse Reflectance and Luminescence*, Opponent: Dr. Joanne Zwinkels, National Research Council of Canada, NRCC.

3.1.2 Master of Science (Technology), M.Sc. (Tech.)

Janne Askola (2015), *Characterization of an Integrating Sphere Setup for Measurements of Organic LEDs*, guided by Tuomas Poikonen and Tomi Pulli.

Alexander Kokka (2016), *Fisheye Camera Method for Determining Spatial Non-Uniformity Corrections in Luminous Flux Measurements with Integrating*

Spheres, guided by Tuomas Poikonen and Tomi Pulli.

Sampo Hyvärinen (2016), *Spatiaalisesti epätasaisen irradianssin vaikutus aurinkokennon toimintaan*, guided by Petri Kärhä.

Teemu Tomberg (2016), *Laser-Based Thermometry over Long Distances*, guided by Tuomas Hieta.

Mikko Jäntti (2016), *Laboratoriotilojen lämpötilan ja ilmankosteuden mittaukset*, guided by Timo Dönsberg.

Johannes Oksanen (2016), *LED-based Standard Lamp for Realization of Photometric Units*, guided by Tuomas Poikonen and Hans Baumgartner.

Ilmari Harilainen (2017), *Automaattinen visuaalinen tarkastus liikeantureille*, guided by Birgit Päivänranta.

3.1.3 Bachelor of Science (B.Sc.) Theses

Jalmari Laaksonen (2015), *Femtoampeerien mittaaminen*, guided by Timo Dönsberg.

Lari Tanner (2015), *Virtalähde LED-lamppujen testimittauksiin*, guided by Timo Dönsberg.

Mikko Kortetmaa (2016), *Kiihtyvyyssanturit ja gyroskoopit*, guided by Tomi Pulli.

Markus Huuhtanen (2016), *TO5-koteloiden hermeettinen suljenta*, guided by Petri Kärhä.

Panu Hildén (2016), *Differentiaalinen optinen absorptiospektroskopia*, guided by Tomi Pulli.

Niklas Lumio (2016), *Ledien vanhenemismekanismit ja niiden vaikutus ledin spektriin*, guided by Petri Kärhä.

Jouni Koponen (2016), *Elektroniset paine- ja virtausanturit*, guided by Hans Baumgartner.

Samuli Sirniö (2017), *Digitaalisten kameroiden geometrinen kalibrointi*, guided

by Alexander Kokka.

Olli Kantamaa (2017), *Virta-jännitemuuntimen suunnittelu PQED-detektorille*, guided by Timo Dönsberg.

Joonas Isometsä (2017), *Esineiden internet valaistuksen näkökulmasta*, guided by Petri Kärhä.

Iipo Härkönen (2017), *Ledin vanhenemismekanismien vaikutus ledin värisiirtymään*, guided by Petri Kärhä.

Eero Prittinen (2017), *Indoor solar panel energy harvesting for low power wireless devices*, guided by Petri Kärhä.

Jimi Brander (2017), *Digitaalikameroiden spatiaalivasteen korjausmenetelmät*, guided by Alexander Kokka.

Simo Sirrola (2017), *Kapasitiivisesti takaisinkytketty virta-jännitemuunnin biasoidulle fotodiodille*, guided by Timo Dönsberg.

Joel Lavikainen (2017), *Korkeataajuuksinen virtalähde ledien karakterisointiin*, guided by Timo Dönsberg.

Benjamin Oksanen (2017), *Komponenttien valinnan vaikutus virta-jännitemuuntimen sähköisiin ominaisuuksiin tarkkuusmittauksissa*, guided by Tuomas Poikonen and Timo Dönsberg.

3.2 Courses

The following courses were offered by the Metrology Research Institute in 2015–2017. Those marked by * are given biennially.

ELEC- C5070	Electronics Workshop, 5 cr (Petri Kärhä)
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ELEC-E5710	Sensors and Measurement Methods, 5 cr (Hans Baumgartner, Timo Dönsberg, Petri Kärhä)
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ELEC-E5720	Virtual Instrumentation, 5 cr (Tomi Pulli)
ELEC-E5730	Optics, 5 cr (Toni Laurila, Aigar Vaigu)
ELEC-E5740	Research Seminar on Measurement Science and Technology, 2 cr* (Petri Kärhä)
ELEC-E5750	Project Work in Measurement Science and Technology, 2–10 cr (Petri Kärhä, Timo Dönsberg)
ELEC-E5760	Project Work in Optical Technology, 2–10 cr (Erkki Ikonen, Timo Dönsberg)
ELEC-E5780	Postgraduate Course in Measurement Science and Technolo- gy, 10 cr* (Petri Kärhä)
S-108.3120	Project work, 2–8 cr (Erkki Ikonen, Timo Dönsberg)
S-108.1010	Fundamentals of Measurements A, 4 cr (Discontinued after 2015)
S-108.1020	Fundamentals of Measurements Y, 3 cr (Discontinued after 2015)
S-108.3020	Electromagnetic Compatibility, 2 cr (Discontinued after 2015)
S-108.4110	Biological Effects and Measurements of Electromagnetic Fields and Optical Radiation, 4 cr* (Discontinued after 2017)

4 NATIONAL STANDARDS LABORATORY

Metrology Research Institute is the Finnish national standards laboratory for the measurements of optical quantities, as appointed by the Centre for Metrology and Accreditation (now VTT MIKES) in April 1996.

The institute gives official calibration certificates on various optical quantities in the fields of Photometry, Radiometry, and Spectrophotometry. During 2015 – 2017, 141 calibration certificates were issued. The calibration services are mainly used by the Finnish industry and various research organizations. There are two accredited calibration laboratories in the field of optical quantities.

The Institute offers also other measurement services and consultation in the field of measurement technology. Various memberships in international organizations ensure that the laboratory can also influence e.g. international standardization so that it takes into account the national needs.

The Metrology Research Institute performs its calibration measurements under a quality system approved by VTT MIKES. The quality system is based on ISO/IEC 17025.

Further information on the offered calibration services can be obtained from the web-pages of the laboratory (<http://metrology.aalto.fi/>). Especially the following sub-pages might be useful:

Maintained quantities: <http://metrology.aalto.fi/calibration/>

Price list for regular services: <http://metrology.aalto.fi/files/pricelist.pdf>

Quality system: <http://metrology.aalto.fi/quality/>

Additional information may also be asked from Farshid Manoocheri (Head of Calibration Services) or Petri Kärhä (Quality Manager):

Farshid.Manoocheri (at) aalto.fi, Tel. +358 50 590 2483

Petri.Karha (at) aalto.fi, Tel. +358 50 596 8469

5 RESEARCH PROJECTS

Light is everywhere around us in the form of sunlight, artificial lighting and signaling. Most electrical equipment use either visible or infrared radiation for signaling, displays, sensing, data read-out, or digital communication. Color is one of the most significant properties in consumer products.

Metrology research of Optical Radiation Measurements is divided into three branches: Radiometry dealing with characteristics of light sources and detectors, Photometry measuring light as people see it, and Spectrophotometry investigating optical components as well as of optical properties of materials. Some of the facilities developed in the laboratory are at the world-leading level when comparing accuracy, compactness, and operating costs. The research activities of the group involve electronics, modern optics and optical radiation measurements.

Metrology Research Institute is a joint laboratory of Aalto University and VTT MIKES, and it is involved in many national and international projects. Most of the research in the laboratory is currently carried out within EURAMET EMRP and EMPIR programmes. Metrology Research Institute is the national standards laboratory for optical quantities in Finland maintaining national standards of optical quantities and carrying out calibrations at the highest level.

Recent research activities of the group can be browsed through the links below.

5.1 [Photometry](#)

- [EMPIR PhotoLED - Future Photometry Based on Solid-State Lighting Products \(2016-2019\)](#)
- [EMRP MESaIL - Metrology for Efficient and Safe Innovative Lighting \(2014-2017\)](#)
- [Uncertainty Analysis of Correlated Color Temperature \(2014-2017\)](#)
- [Lifetime projection of lamps and luminaires based on high power LEDs \(2009-\)](#)

5.2 Radiometry

- [Hyperspectral Camera Calibration \(2017-\)](#)
- [Modelling of Light-Emitting Diodes \(2009-\)](#)
- [EMPIR PV-Enerate - Advanced PV Energy Rating \(2017-2020\)](#)
- [EMRP SolCell - Metrology for III-V Material Based High Efficiency Multi-Junction Solar Cells \(2014-2017\)](#)
- [EMRP PhotoClass - Towards an Energy-Based Parameter for Photovoltaic Classification \(2014-2017\)](#)
- [EMRP ATMOZ - Traceability for Atmospheric Total Column Ozone \(2014-2017\)](#)
- [EMRP NewStar – New Primary Standards and Traceability for Radiometry \(2014-2017\)](#)
- [EMRP SIQUTE - Single-Photon Sources for Quantum Technologies \(2012-2015\)](#)
- [UVIADEM - UV Radiation Induced and Assisted Degradation of Materials \(2011-2015\)](#)

5.3 Spectrophotometry

- [EMPIR BiRD - Bidirectional reflectance definitions \(2017-2020\)](#)
- [EMPIR EMIRIM - Improvement of Emissivity Measurements on Reflective Insulation Materials \(2017-2020\)](#)
- [EMPIR SURFACE - Pavement Surface Characterisation for Smart and Efficient Road Lighting \(2017-2020\)](#)
- [EMPIR MetEOC3 - Metrology for Earth Observation and Climate \(2017-2020\)](#)
- [EMPIR PhotInd - Improved metrology for the photonics industry](#)

(2015-2018)

- EMRP MetEOC2 - Metrology for Earth Observation and Climate (2014-2017)
- EMRP Thinergy - Traceable Characterisation of Thin-Film Materials for Energy Applications (2014-2017)
- EMRP xDReflect - Multidimensional Reflectometry for Industry (2014-2017)

5.4 Electrical instrumentation

- EMRP MESaIL - Metrology for Efficient and Safe Innovative Lighting (2014-2017)
- EMPIR ELPOW - Metrology for the electrical power industry (2015-2018)

6 INTERNATIONAL CO-OPERATION

6.1 International Comparison Measurements

Since 2005, the Metrology Research Institute participates in key comparisons under the name MIKES.

Key comparison EURAMET.PR-K6.2015, spectral transmittance 380–1000 nm, pilot CNAM

This comparison is on average spectral regular transmittance of filters. Five neutral grey glass filter plates, 50 mm × 50 mm, with nominal transmittance, at the wavelength of 546 nm, of 0.92, 0.50, 0.10, 0.01 and 0.001, will be measured. Pilot has measured the samples twice and MIKES once. One measurement at MIKES is thus still needed.

XDReflect BRDF comparison 380-780 nm, pilot PTB

This comparison of spectral radiance factor was carried out within the European Metrology Research Program (EMRP) project JRPIND52, XDReflect. The final report was published in 2017 [C. Strothkämper, A. Ferrero, A. Koo, P. Jaanson, G. Ged, G. Obein, S. Källberg, J. Audenaert, F. Leloup, F. Martinez Verdu, E. Perales, A. Schirmacher, J. and Campos, “Multilateral Spectral Radiance Factor Scale Comparison,” *Applied Optics* **56**, 1996-2006 (2017)]. The results of MIKES are in good agreement with the white tile used, but with gray and dark grey samples, the results deviate slightly above 750 nm.

Key comparison EURAMET.PR-K4, luminous flux, pilot PTB

Measurements of MIKES-Aalto were completed in 2009. Final report was published in 2015 [Matthias Lindemann, Robert Maass, and Georg Sauter, “Final report on regional comparison EURAMET.PR-K4: luminous flux,” *Metrologia* **52**, 02001 (2015). <https://doi.org/10.1088/0026-1394/52/1A/02001>]. The results of MIKES were in good agreement with the key comparison reference value. The unilateral degree of equivalence was 0.0003 with an uncertainty of 0.0076. The uncertainty specified by MIKES was 0.0028 ($k = 1$).

6.2 Conferences and Meetings

EMRP ‘ThinEnergy: Traceable characterisation of thin-film materials for energy applications’ Project Meeting, January 7 – 8, 2015, Berlin, Germany; *Farshid Manoocheri*

Workshop on EURAMET TCPR related Metrology Research for Climate and Earth Observation, January 27, 2015, Delft, The Netherlands; *Erkki Ikonen*

EURAMET TCPR meeting, January 28 – 29, 2015, Delft, The Netherlands; *Erkki Ikonen*

Assessment Meetings of Technological Sciences in Lithuania, Research and Higher Education Monitoring and Analysis Centre, February 9 – 13, 2015, Vilnius, Lithuania; *Erkki Ikonen*

EMRP ‘Atmoz: Traceability for atmospheric total column ozone’ Measurement campaign, February 9 – 13, 2015, Sodankylä, Finland; *Petri Kärhä, Tomi Pulli*

CIE Board of Administration meeting, February 11, 2015, Vienna, Austria; *Erkki Ikonen*

EMRP mid-term review of IND 2012 projects, March 3, 2015, Espoo, Finland; *Erkki Ikonen, Tuomas Poikonen*

EMRP NEWSTAR project meeting, March 25 – 26, 2015, Turin, Italy; *Erkki Ikonen*

EMRP ‘Atmoz: Traceability for atmospheric total column ozone’ Project Meeting, April 15 – 16, 2015, Thessaloniki, Greece; *Petri Kärhä, Tomi Pulli*

EMPIR subcommittee meeting April 20 – 24, 2015, Braunschweig, Germany; *Erkki Ikonen*

EMRP SIQUTE project meeting, May 3 – 5, 2015, Erlangen, Germany; *Aigar Vaigu, Erkki Ikonen*

EMRP METCO final project meeting, May 5 – 7, 2015, Teddington UK; *Maksim Shpak*

Smart lighting conference, May 20 – 21, 2015, Berlin, Germany; *Erkki Ikonen*

EURAMET General Assembly, June 2 – 3, 2015, Krakow, Poland; *Erkki Ikonen*

EMPIR Committee meeting, June 4 – 5, 2015, Krakow, Poland; *Erkki Ikonen*

EMRP SolCell project meeting, June 10 – 13, 2015, Madrid, Spain; *Hans Baumgartner*

BIPM Workshop on Measurement Uncertainty, June 15 – 16, 2015, Paris, France; *Erkki Ikonen*

EMRP MESaIL project meeting, June 15 – 16, 2015, Borås, Sweden; *Tuomas Poikonen*

EMRP ‘xDReflect: Multidimensional reflectometry for industry’ project meeting, June 17 – 18, 2015, Stockholm, Sweden; *Priit Jaanson*

CIE Division Directors meeting, BA meeting, June 25 – 26, 2015, Manchester, UK; *Erkki Ikonen*

CIE 2015 Quadrennial Conference, TC meetings, Division meeting, EMPIR partnering meetings, June 28 – July 4, 2015, Manchester, UK; *Hans Baumgartner, Erkki Ikonen, Tuomas Poikonen*

CIE BA meeting, July 4, 2015, Manchester, UK; *Erkki Ikonen*

EMPIR Project Partnering Meetings, July 6 – 7, 2015, NPL, Teddington, UK; *Farshid Manoocheri*

EMPIR ‘MIQC2: Optical metrology for quantum-enhanced secure telecommunication’ Kick-off Meeting, July 17, 2015, University of Geneva, Geneva, Switzerland; *Farshid Manoocheri*

PTB International Summer School on Metrology, August 24 – 28, 2015, Druebeck, Germany; *Anna Vaskuri, Priit Jaanson*

EMPIR R04 “Metrology Research Potential Development in Baltic region” preparatory partnering meeting, August 31, 2015, Vilnius, Lithuania; *Petri Kärhä, Erkki Ikonen*

Japan-Finland Joint Symposium on Optics in Engineering, September 1 – 2, 2015, Joensuu, Finland; *Erkki Ikonen*

EMRP PVClass project meeting, September 1 – 4, 2015, Madrid, Spain; *Hans Baumgartner*

EMPIR PhotInd project kick-off meeting, September 15, 2015, Espoo, Finland; *Aigar Vaigu, Erkki Ikonen*

EMRP ‘METEOC2: Metrology for Earth observation and climate’ Project Meeting, September 17 – 18, 2015, Berlin, Germany; *Tomi Pulli, Erkki Ikonen*

International Congress in Metrology, September 21 – 24, 2015, Paris, France; *Timo Dönsberg*

CCPR WG meetings, October 26 – 29, 2015, Peking, China; *Erkki Ikonen*

EMRP ‘Atmoz: Traceability for atmospheric total column ozone’ Project Meeting, October 29 – 30, 2015, Prague, Czech Republic; *Petri Kärhä, Tomi Pulli*

EMRP SIQUTE project meeting, November 3 – 4, 2015, Teddington, UK; *Erkki Ikonen, Aigar Vaigu*

EMRP NEWSTAR project meeting, November 23, 2015, Braunschweig, Germany; *Timo Dönsberg, Erkki Ikonen*

EMPIR Committee meeting, November 30 – December 1, 2015, Prague Czech Republic; *Erkki Ikonen*

EMRP SollCel project meeting, January 12 – 13, 2016, Toulouse, France; *Hans Baumgartner*

EURAMET meeting, January 14, 2016, Braunschweig, Germany; *Erkki Ikonen*

EMRP ‘xDReflect: Multidimensional metrology for industry’ Project meeting, January 27 – 28, 2016, Ghent, Belgium; *Priit Jaanson*

EMRP Thinergy project meeting, January 27 – 28, 2016, Berlin, Germany; *Farshid Manoocheri*

EURAMET TC-PR Workshop and meeting, February 2 – 4, 2016, Warsaw, Poland; *Erkki Ikonen*

EURAMET BoD, BoD/TCC meetings, DI Workshop, February 16 – 19, 2016, Copenhagen, Denmark; *Erkki Ikonen*

CIE Board of administration meeting, March 2, 2016, Melbourne, Australia; *Erkki Ikonen*

CIE Energy Efficiency and Lighting Quality Conference, March 3 – 5, 2016, Melbourne, Australia; *Erkki Ikonen*

CIE Division 2 meeting, CIE TC meetings, March 6 – 9, 2016, Melbourne, Australia; *Erkki Ikonen*

EMRP ‘METEOC2: Metrology for Earth observation and climate’ Project Meeting, March 10 – 11, 2016, Teddington, UK; *Tomi Pulli*

Kansallinen seminaari UV-säteilyn vaikutuksista, March 18, 2016, Ilmatieteenlaitos, Helsinki; *Petri Kärhä, Tomi Pulli, Alexander Kokka*

EMPIR PhotInd project meeting, April 6 – 7, 2016, Teddington, UK; *Aigar Vaigu*

EMPIR Subcommittee meetings, April 12 – 14, 2016, Ljubljana, Slovenia; *Erkki Ikonen*

International Radiation Symposium IRS 2016, April 16 – 22, 2016, Auckland, New Zealand; *Petri Kärhä, Anna Vaskuri*

EMRP NEWSTAR project meeting, April 19 – 20, Madrid, Spain; *Timo Dönsberg, Hannu Ronkainen, Mikko Juntunen, Erkki Ikonen*

JRC ESTI assessment panel meeting, April 28, 2016, Ispra, Italy; *Erkki Ikonen*

EURAMET coordination study steering group meeting, April 29, 2016, Berlin, Germany; *Erkki Ikonen*

EURAMET BoD meeting, May 3 – 4, 2016, Ljubljana, Slovenia; *Erkki Ikonen*

EMRP MeSaIL project meeting, May 10 – 11, 2016, Espoo, Finland; *Tuomas Poikonen, Petri Kärhä, Hans Baumgartner, Anna Vaskuri, Erkki Ikonen*

EMRP ‘Atmoz: Traceability for atmospheric total column ozone’ Project Meeting, May 16, 2016, Ponta Delgada, The Azores, Portugal; *Petri Kärhä, Tomi Pulli*

Optics and Photonics Days, May 16 – 17, 2016, Tampere, Finland; *Anna Vaskuri, Erkki Ikonen*

Brewer Ozone Spectrophotometer/Metrology Open Workshop, May 17 – 19, 2016, Ponta Delgada, The Azores, Portugal; *Petri Kärhä, Tomi Pulli*

EURAMET TCC meeting, GA, Symposium, RC meeting, May 23 – 26, 2016, Oslo, Norway; *Erkki Ikonen*

EMPIR Committee meeting, May 26 – 27, 2016, Oslo, Norway; *Erkki Ikonen*

EMRP SIQUTE project meeting, May 30 – 31, 2016, Braunschweig, Germany; *Aigar Vaigu, Erkki Ikonen*

EURAMET coordination study steering group meeting, June 20, 2016, Teddington, UK; *Erkki Ikonen*

EMRP ‘xDReflect: Multidimensional reflectometry for industry’ project meeting, June 21 – 23, 2016, Turin, Italy; *Priit Jaanson, Farshid Manoocheri*

Partnering meeting for EMPIR project Metrology for Improved Energy Efficiency of Smart Lighting, SSL3, June 27 – 28, 2016, Paris, France; *Petri Kärhä*

Partnering meeting for EMPIR project Surface, June 27 – 28, 2016, Paris, France; *Farshid Manoocheri*

EMPIR SolCell and PVClass project meetings, June 27 – July 1, 2016, Berlin, Germany; *Hans Baumgartner*

EMPIR ‘MetAQ: Metrology for UV/VIS remote sensing of air quality’ Project Partnering Meeting, June 28 – 29, 2016, Berlin, Germany; *Tomi Pulli*

CIE Division Director’s meeting, June 30, 2016, Vienna, Austria; *Erkki Ikonen*

CIE Board of Administration meeting, June 30 – July 1, 2016, Vienna, Austria; *Erkki Ikonen*

EMRP Thinergy project meeting, July 4 – 5, 2016, NPL, UK; *Farshid Manoocheri*

EMPIR ‘METEOC3: Metrology for earth observation and climate 3’ Project Partnering Meeting, July 5 – 6, 2016, London, UK; *Tomi Pulli*

CIE Expert Symposium on Colour and Visual Appearance, September 5 – 7, 2016, Prague, Czech Republic; *Priit Jaanson, Erkki Ikonen*

Preparation of ministerial delegates’ meeting at SMD and Meeting with Director Peter Dröll at the European Commission, September 8, 2016, Brussels, Belgium; *Erkki Ikonen*

EMRP NEWSTAR project final meeting, September 13 – 14, 2016, Espoo, Finland; *Timo Dönsberg, Farshid Manoocheri, Erkki Ikonen*

Training course on the use of PQED (Predictable Quantum Efficient Detector), September 14, 2016, Espoo, Finland; *Timo Dönsberg, Anna Vaskuri, Tuomas Poikonen*

EMRP ‘Atmoz: Traceability for atmospheric total column ozone’ Project Meeting, September 15 – 16, 2016, Izaña Atmospheric Observatory, Tenerife, Spain; *Tomi Pulli*

EMPIR PhotoLED Kick-off meeting, September 15 – 16, 2016, Espoo, Finland; *Tuomas Poikonen, Timo Dönsberg, Alexander Kokka, Petri Kärhä, Erkki Ikonen*

CCPR working group meetings WG-CMC, WG-SP, WG-KC and CCPR meeting, September 19 – 23, 2016, BIPM, Paris; *Erkki Ikonen*

EURAMET General Secretary candidate interviews and EURAMET coordination study workshop, September 27, 2016, Paris, France; *Erkki Ikonen*

EURAMET BoD meeting, September 28 – 29, 2016, Paris, France; *Erkki Ikonen*

EMRP ‘METEOC2: Metrology for Earth observation and climate’ Project Meeting, October 5 – 6, 2016, London, UK; *Tomi Pulli, Anna Vaskuri*

EURAMET - Ministerial Delegates' meeting, October 11, 2016, Brussels, Belgium; *Erkki Ikonen*

EMRP SolCell project meeting, November 3 – 4, 2016, Krakow, Poland; *Hans Baumgartner*

EMPIR Project meeting MIQC2, November 7 – 8, 2016, Prague, Czech; *Farshid Manoocheri*

EMPIR Proposal review conference, November 14 – 16, 2016, Rotterdam, Netherlands; *Petri Kärhä*

EMPIR Proposal review conference, November 14 – 18, 2016, Rotterdam, Netherlands; *Erkki Ikonen*

EMRP PVClass project meeting, November 22 – 24, 2016, London, UK; *Hans Baumgartner*

EMPIR proposal review conference, November 22 – 24, 2016, Rotterdam, Netherlands; *Erkki Ikonen*

EMPIR Committee meeting, November 28 – 29, 2016, Torino, Italy; *Erkki Ikonen*

Interview by the EU Commission expert panel on the final review of EMRP and mid-term review of EMPIR, December 15, 2016, Brussels, Belgium; *Erkki Ikonen*

EURAMET - NMI/DI Director's Workshop on Coordination Study, January 17, 2017, Berlin, Germany; *Erkki Ikonen*

EMRP Thinergy project meeting, January 18 – 19, 2017, Paris, France; *Farshid Manoocheri*

EURAMET BoD, BoD/TCC and TCC meetings, January 24 – 26, 2017, Sarajevo, Bosnia-Herzegovina; *Erkki Ikonen*

Meeting with CIE General Secretary on CIE 2018 conference, January 27, 2017, Vienna, Austria; *Erkki Ikonen*

EURAMET TC-PR EMPIR call preparation workshop, January 31, 2017, Borås, Sweden; *Farshid Manoocheri*

EURAMET TC-PR contact persons meeting, February 1 – 2, 2017, Borås, Sweden; *Farshid Manoocheri*

EURAMET TC-AUV contact persons meeting presentation on behalf of EURAMET, February 2, Espoo, Finland; *Erkki Ikonen*

EMPIR Research Potential Projects' Mid-Term Review, February 24, 2017, Berlin, Germany; *Erkki Ikonen*

EURAMET coordination strategy and capacity building meetings, March 6 – 7, 2017, Braunschweig, Germany; *Erkki Ikonen*

EURAMET PM Candidate's interview, March 15, 2017, Paris, France; *Erkki Ikonen*

EMRP PVClass project meeting, April 3 – 6, 2017, Ispra, Italy; *Hans Baumgartner*

EMPIR subcommittee meetings, April 4 – 6, 2017, Espoo, Finland; *Erkki Ikonen*

EURAMET BoD meeting, April 25 – 26, 2017, Prague, Czech Republic; *Erkki Ikonen*

EURAMET TC-M contact persons meeting presentation on behalf of EURAMET, April 28, 2017, Espoo, Finland; *Erkki Ikonen*

Project preparation meetings at Justervesenet and Sintef, May 3 – 4, 2017, Oslo, Norway; *Timo Dönsberg, Erkki Ikonen*

EMPIR BiRD project meeting, May 4 – 5, 2017, Paris, France; *Farshid Manoocheri*

CIE/Mesail/PhotoLED workshops, May 11, 2017, Bern, Switzerland; *Tuomas Poikonen, Erkki Ikonen*

EMRP Mesail project meeting, May 12, 2017, Bern, Switzerland; *Tuomas Poikonen, Erkki Ikonen*

EURAMET General Assembly, May 15 – 18, 2017, Madrid, Spain; *Erkki Ikonen*

EMPIR Committee meeting, May 18 – 19, 2017, Madrid, Spain; *Erkki Ikonen*

EMRP Thinergy project workshop, May 24 – 26, 2017, Strasbourg, France; *Farshid Manoocheri*

Optics and Photonics Days, May 29 – 31, 2017, Oulu, Finland; *Timo Dönsberg, Erkki Ikonen*

EMRP ‘Atmoz: Traceability for atmospheric total column ozone’ Project Meeting and workshop, May 31 – June 1, 2017, El Arenosillo, Mazagon, Spain; *Petri Kärhä, Tomi Pulli*

Stakeholders meeting of the EC Expert Evaluation of EMPIR, June 1, 2017, Brussels, Belgium; *Erkki Ikonen*

EURAMET TC-EM Quantum subgroup meeting presentation on behalf of EURAMET, June 2, 2017, Espoo, Finland; *Erkki Ikonen*

CCPR WG-KC meeting and workshop, June 11 – 12, 2017, Tokyo, Japan; *Erkki Ikonen, Farshid Manoocheri*

13th International Conference on New Developments and Applications in Optical Radiometry (NEWRAD 2017) June 13 – 16, 2017, Tokyo, Japan; *Petri Kärhä, Erkki Ikonen, Farshid Manoocheri, Hans Baumgartner, Anna Vaskuri, Timo Dönsberg, Tomi Pulli*

EURAMET Coordination Strategy group meeting, June 19, 2017, Berlin, Germany; *Erkki Ikonen*

EMPIR Project Partnering Meetings, June 26 – 29, 2017, CMI, Prague, Czech Republic; *Petri Kärhä, Farshid Manoocheri, Timo Dönsberg*

EMPIR ‘Electromagnetic Interference on Static Electricity Meters’ Project Partnering Meeting, July 4 – 5, 2017, Delft, Netherlands; *Alexander Kokka*

EMPIR partnering meeting, July 4 – 5, 2017, Espoo, Finland; *Timo Dönsberg*

EMPIR partnering meeting, July 6, 2017, Espoo, Finland; *Erkki Ikonen*

EMPIR Emirim project meeting, July 11, 2017, Paris, France; *Farshid Manoocheri*

EMRP MetEOC2 project meeting, July 13 – 14, 2017, Teddington, UK; *Priit Jaanson*

EURAMET PM candidates' interview, July 19, 2017, Berlin, Germany; *Erkki Ikonen*

EMPIR MIQC2 project meeting, September 5 – 6, 2017, Bern, Switzerland; *Farshid Manoocheri*

Japan-Finland Joint Optics in Engineering Symposium, September 11 – 14, 2017, Sado Island, Japan; *Erkki Ikonen* (invited talk)

EURAMET Coordination Strategy advisory group meeting, September 19, 2017, Paris, France; *Erkki Ikonen*

EMPIR PV Enerate project meeting, September 12 – 14, 2017, Braunschweig, Germany; *Hans Baumgartner*

International Congress of Metrology, September 19 – 21, 2017, Paris, France; *Timo Dönsberg*

EURAMET BoD meeting, September 25 – 26, 2017, Vienna, Austria; *Erkki Ikonen*

EMPIR 'PhotoLED - Future Photometry Based on Solid-State Lighting Products' Project Meeting, September 28 – 29, 2017, Prague, Czech Republic; *Alexander Kokka, Tomi Pulli, Tuomas Poikonen*

'The Quantum Revolution in Metrology' Workshop, September 28 – 29, 2017, BIPM, Paris; *Erkki Ikonen*

EURAMET - NMI Director's Workshop on European Metrology Networks, October 3 – 4, 2017, Berlin, Germany; *Erkki Ikonen*

EMRP PhotInd project meeting, October 4 – 5, 2017, Bern, Switzerland; *Aigar Vaigu*

EMPIR METEOC3 project meeting, October 10 – 11, 2017, Teddington, UK; *Farshid Manoocheri, Dmitri Lanevski*

CIE Division Directors' meeting, October 20, 2017, Jeju Island, Korea; *Erkki Ikonen*

CIE Board of Administration meeting, October 21, 2017, Jeju Island, Korea; *Erkki Ikonen*

CIE General Assembly, October 22, 2017, Jeju Island, Korea; *Erkki Ikonen*

CIE Midterm Conference, October 23 – 25, 2017, Jeju Island, Korea; *Erkki Ikonen, Hans Baumgartner, Tuomas Poikonen, Alexander Kokka, Janne Askola, Timo Dönsberg, Tomi Pulli*

CIE Division 2 meeting, October 26, 2017, Jeju Island, Korea; *Erkki Ikonen, Hans Baumgartner, Tuomas Poikonen, Alexander Kokka, Janne Askola, Timo Dönsberg, Tomi Pulli*

CIE TC meetings, October 27 – 28, 2017, Jeju Island, Korea; *Hans Baumgartner, Tuomas Poikonen, Alexander Kokka, Janne Askola, Timo Dönsberg, Tomi Pulli*

EMPIR Proposal Review Conference, November 7, 2017, Monaco; *Erkki Ikonen*

Meeting with Quantum Flagship representatives, November 8, 2017, Berlin, Germany; *Erkki Ikonen*

EMPIR Proposal Review Conference, November 13 – 16, 2017, Monaco; *Erkki Ikonen*

EMPIR Committee meeting, November 20 – 21, 2017, Berlin, Germany; *Erkki Ikonen*

Meetings with EC representatives on possible continuation program of EMPIR, November 30 – December 1, 2017, Brussels, Belgium; *Erkki Ikonen*

6.3 Visits by the Laboratory Personnel

Erkki Ikonen, Kaunas University of Technology, Kaunas, Lithuania, February 10,

2015

Erkki Ikonen, Vilnius Gediminas Technical University, Vilnius, Lithuania, February 12, 2015

Erkki Ikonen, State Scientific Research Institute, Vilnius, Lithuania, February 13, 2015

Petri Kärhä and Tomi Pulli, Finnish Meteorological Institute (FMI), Sodankylä, February 10 – 12, 2015

Tomi Pulli, TNO, Delft, The Netherlands, April 13, 2015

Erkki Ikonen, University of Southampton, Southampton, UK, March 27, 2015

Aigar Vaigu, Max Planck Institute, Erlangen, Germany, April 27 – 30, 2015

Petri Kärhä, Erkki Ikonen, Vilnius Metrology Centre, Vilnius, Lithuania, August 31, 2015

Timo Dönsberg, Paris Observatory, Paris, France, September 23, 2015

Erkki Ikonen, Technische Universität Berlin, Berlin, Germany, January 13, 2016

Metrology Research Institute personnel, University of Tartu and Tartu Observatory, Estonia, June 8 – 9, 2016

Erkki Ikonen, University of Southampton, UK, November 21, 2016

Farshid Manoocheri, Invited visit to National Research Council Canada, Ottawa, Canada, February 13 – 17, 2017

Erkki Ikonen, Czech Metrology Institute (CMI), Prague, Czech Republic, April 26, 2017

Petri Kärhä, Erkki Ikonen, Farshid Manoocheri, Hans Baumgartner, Anna Vas-kuri, Timo Dönsberg, Tomi Pulli, NMIJ, Tsukuba, Japan, June 16, 2017

Alexander Kokka, VSL, Delft, The Netherlands, November 27 – December 1, 2017

6.4 Research Work Abroad

Timo Dönsberg, Czech Metrology Institute (CMI), Prague, Czech Republic, January 26 – 29, 2015

Meelis Sildoja, Physicalisch-Technische Bundesanstalt (PTB), Berlin, Germany, February-April, 2015

Timo Dönsberg, Czech Metrology Institute (CMI), Prague, Czech Republic, June 12 – 17, 2016

Anna Vaskuri, National Physical Laboratory (NPL), Teddington, UK, September 1, 2016 – April 30, 2017

6.5 Visits to the Laboratory

Dr. Ana Rabal, (post doc at Aalto from CSIC), January 1 – April 30, 2015

Dr. George Mulholland, University of Maryland, January 15 – 16, 2015

Dr. Gael Obein, CNAM, France, March 3, 2015

Dr. Toomas Kübarsepp, Metrosert, Estonia, March 12, 2015

Dr. Saulius Nevas, PTB, Germany, March 12 – 13, 2015

Dr. Marek Smid, *Geiland Porrovecchio*, CMI, Czech Republic, September 14 – 15, 2015

Dr. Toomas Kübarsepp, *Martin Parker*, Metrosert Ltd., Estonia, February 11, 2016

NewStar and PhotoLED training course, September 14, 2016: *Dr. Anders Thorseth*, DTU, Denmark; *Dr. Toomas Kubarsepp*, Metrosert, Estonia; *Dr. Giorgio Brida*, INRIM, Italy; *Dr. Armin Sperling*, *Dr. Thorsten Gerloff*, PTB, Germany; *Péter Gál*, MKEH, Hungary; *Dr. Alicia Pons*, *Dr. Alejandro Ferrero*, CSIC, Spain; *Dr. Elena Revtova*, VSL, Netherlands; *Dr. Marek Šmíd*, *Petr Kliment*, CMI, Czech Republic

Dr. Jarle Gran, Justervesenet, Norway, October 30 – 31, 2017

Prof. Peter Hanselaer, University of Leuven, Belgium, June 9, 2017

Prof. Alkiviadis F. Bais, Aristotle University of Thessaloniki, Greece, August 31 – September 1, 2017

Dr. Nigel Fox, National Physical Laboratory (NPL), United Kingdom, September 1, 2017

Dr. Meelis Sildoja, Physicalisch-Technische Bundesanstalt (PTB), Germany, September 1, 2017

Dr. Joanne Zwinkels, National Research Council of Canada (NCR), Canada, November 3, 2017

MRI Doctors' Club, *Dr. Antti Pietiläinen* (NSN), *Dr. Hannu Talvitie* (Vaisala), *Dr. Mikko Puranen* (Kone), *Dr. Jouni Envall* (FMI), *Dr. Mikko Merimaa* (VTT MIKES), *Dr. Martti Heinonen* (VTT MIKES), *Dr. Tuomas Poikonen* (VTT MIKES), *Dr. Richard Högström* (VTT MIKES), *Dr. Atte Haapalinna* (Okmetic), *Dr. Mart Noorma* (University of Tartu), *Dr. Maija Ojanen-Saloranta* (VTT MIKES), *Dr. Jari Hovila* (FMI), *Dr. Maksim Shpak* (VTT MIKES), *Dr. Meelis Sildoja* (PTB), March 28, 2017

6.6 Thematic Network for Ultraviolet Radiation Measurements (UVNet)

The Thematic Network for Ultraviolet Measurements (UVNet) was very active during this period. The UVNet including its mailing list was used to disseminate progress and results of the EU-funded EMRP project ATMOZ, Traceability for atmospheric total column ozone. This project was coordinated by Julian Gröbner and Luca Egli of the PMOD/WRC in Davos, Switzerland.

UVnet produced two newsletters, *UVNews 11* in March 2016 and *UVNews 12* in March 2017. These newsletters included altogether 21 articles on 104 pages presenting the project results and other UV and ozone related activities.

7 PUBLICATIONS

7.1 Articles in International Journals

A. Vaigu, T. Kübarsepp, F. Manoocheri, M. Merimaa and E. Ikonen, “Compact two-element transmission trap detector for 1550 nm wavelength,” *Meas. Sci. Technol.* **26**, 055901, 6 p. (2015).

T. Pulli, T. Dönsberg, T. Poikonen, F. Manoocheri, P. Kärhä, and E. Ikonen, “Advantages of white LED lamps and new detector technology in photometry,” *Light: Science and Applications* **4**, e332, 7 p. (2015).

A. Vaskuri, P. Kärhä, A. Heikkilä, and E. Ikonen, “High-resolution setup for measuring wavelength sensitivity of photoyellowing of translucent materials,” *Rev. Sci. Instrum.* **86**, 103103, 8 p. (2015).

A. Vaskuri, H. Baumgartner, P. Kärhä, G. Andor, and E. Ikonen, “Modeling the spectral shape of InGaAlP-based red light-emitting diodes,” *J. Appl. Phys.* **118**, 203103, 7 p. (2015).

P. Jaanson, F. Manoocheri, and E. Ikonen, “Goniometrical measurements of fluorescence quantum efficiency,” *Meas. Sci. Technol.* **27**, 025204, 8 p. (2016).

T. Dönsberg, H. Mäntynen, and E. Ikonen, “Optical aperture area determination for accurate illuminance and luminous efficacy measurements of LED lamps,” *Opt. Rev.* **23**, 510–521 (2016).

H. Baumgartner, A. Vaskuri, P. Kärhä, and E. Ikonen, “Temperature invariant energy value in LED spectra,” *Appl. Phys. Lett.* **23**, 231103, 4 p. (2016).

P. Jaanson, T. Pulli, F. Manoocheri, and E. Ikonen, “A reference material with close to Lambertian reflectance and fluorescence emission profiles,” *Metrologia* **53**, 1330–1338 (2016).

H. Baumgartner, D. Renoux, P. Kärhä, T. Poikonen, T. Pulli, and E. Ikonen, “Natural and accelerated ageing of LED lamps,” *Lighting Res. Technol.* **48**, 930–942 (2016).

E. Tetri, S. Bozorg Chenani, R.-S. Räsänen, H. Baumgartner, M. Vaaja, S. Sierla,

L. Tähkämö, J.-P. Virtanen, M. Kurkela, E. Ikonen, L. Halonen, H. Hyyppä, and I. Kosonen, “Tutorial: Road lighting for efficient and safe traffic environments,” *LEUKOS* **13**, 223–241 (2017).

A. Vaigu, G. Porrovecchio, Xiao-Liu Chu, S. Lindner, M. Smid, A. Manninen, C. Becher, V. Sandoghdar, S. Götzinger, and E. Ikonen, “Experimental demonstration of a predictable single photon source with variable photon flux,” *Metrologia* **54**, 218–223 (2017).

C. Strothkämper, A. Ferrero, A. Koo, P. Jaanson, G. Ged, G. Obein, S. Källberg, J. Audenaert, F. B. Leloup, F. M. Martínez-Verdú, E. Perales, A. Schirmacher, and J. Campos, “Multilateral spectral radiance factor scale comparison,” *Appl. Opt.* **56**, 1996–2006 (2017).

M. Shpak, P. Kärhä, and E. Ikonen, “Mathematical limitations of the CIE mesopic photometry system,” *Lighting Res. Technol.* **49**, 111–121 (2017).

T. Pulli, S. Nevas, O. El Gawhary, S. Van Den Berg, J. Askola, P. Kärhä, F. Manoocheri, and E. Ikonen, “Nonlinearity characterization of array spectroradiometers for the solar UV measurements,” *Appl. Opt.* **56**, 3077–3086 (2017).

P. Kärhä, A. Vaskuri, H. Mäntynen, N. Mikkonen, and E. Ikonen, “Method for estimating effects of unknown correlations in spectral irradiance data on uncertainties of spectrally integrated colorimetric quantities,” *Metrologia* **54**, 524–534 (2017).

A. Kokka, T. Pulli, T. Poikonen, J. Askola and E. Ikonen, “Fisheye camera method for spatial non-uniformity corrections in luminous flux measurements with integrating spheres,” *Metrologia* **54**, 577–583 (2017).

T. Dönsberg, F. Manoocheri, M. Sildoja, M. Juntunen, H. Savin, E. Tuovinen, H. Ronkainen, M. Prunnila, M. Merimaa, C. K. Tang, J. Gran, I. Muller, L. Werner, B. Rougie, A. Pons, M. Smid, P. Gal, L. Lolli, G. Brida, M. L. Rastello, and E. Ikonen, “Predictable Quantum Efficient Detector based on n-type silicon photodiodes,” *Metrologia* **54**, 821–836 (2017).

P. Jaanson, A. Bialek, C. Greenwell, H. Mäntynen, J.-L. Widlowski, F. Manoocheri, A. Lassila, N. Fox, and E. Ikonen, “Toward SI traceability of a Monte Carlo radiative transfer model in the visible range,” *IEEE Trans. Geosci. Remote*

Sens. (published online 2017, DOI:10.1109/TGRS.2017.2761988).

7.2 International Conference Presentations

H. Baumgartner, J. Oksanen, T. Pulli, E. Tetri, P. Kärhä, E. Ikonen, "Effects of intelligent control on the lifetime of LED street lights." *Proceedings of 28th CIE Session*, 2015, 1662–1668.

P. Jaanson, F. Manoocheri, H. Mäntynen, M. Gergely, J.-L. Widlowski, and E. Ikonen, "Goniorefectometric properties of metal surfaces," *Workshop on EURAMET TCPR related Metrology Research for Climate and Earth Observation*, January 27, 2015, Delft, The Netherlands. (Talk)

A. Vaigu, A. Manninen, T. Kübarsepp, C. Chunnillall, F. Manoocheri, K. Ojasalo, M. Merimaa, and E. Ikonen, "Metrology of quantum communication, standards for single photon sources and detectors," *Northern Optics & Photonics 2015*, June 2 – 4, 2015.

T. Poikonen, T. Pulli, T. Dönsberg, H. Baumgartner, P. Kärhä, and E. Ikonen, "Towards LED-based photometric standards," *Abstracts of the 28th CIE Session 2015*, Manchester, UK, June 28 – July 4, 2015, p. 174.

E. Ikonen, T. Pulli, T. Dönsberg, T. Poikonen, F. Manoocheri, and P. Kärhä, "Accurate measurement of illuminance and luminous efficacy of white LED lamps," *Abstracts of the 28th CIE Session 2015*, Manchester, UK, June 28 – July 4, 2015, pp. 138–139.

H. Baumgartner, J. Oksanen, T. Poikonen, T. Pulli, P. Kärhä, and E. Ikonen, "Effects of intelligent control on the lifetime of LED street lights," *Abstracts of the 28th CIE Session 2015*, Manchester, UK, June 28 – July 4, 2015, p. 459.

A. Ferrero, B. Bernad, J.-L. Velázquez, A. Pons, M.-L. Hernanz, P. Jaanson, "Measurement of goniofluorescence in photoluminescent materials," *Abstracts of the 28th CIE Session 2015*, Manchester, UK, June 28 – July 4, 2015, p. 102–103.

A. Vaskuri, P. Kärhä, A. Heikkilä, and E. Ikonen, "High-resolution setup for measuring wavelength sensitivity of photoyellowing of translucent materials," *PTB Summer School on Metrology*, Drübeck, Germany, August 24 – 28, 2015.

P. Jaanson, F. Manoocheri, and E. Ikonen, “Characterisation of fluorescence standard materials,” PTB Summer School on Metrology, Drübeck, Germany, August 24 – 28, 2015.

T. Dönsberg, M. Sildoja, F. Manoocheri, T. Pulli, T. Poikonen, H. Baumgartner, P. Kärhä, and E. Ikonen, “Methods for decreasing uncertainties in LED photometry,” *17th International Congress of Metrology*, Paris, France, September 21–24, 2015. (Talk)

H. Mäntynen and E. Ikonen, “Optical Aperture Area Determination for Accurate Illuminance and Luminous Efficacy Measurements of LED Lamps,” the Eleventh Finland-Japan Joint Symposium on Optics in Engineering (Joensuu, Finland, 2015) pp. 108–109. (Invited talk)

A. Heikkilä, A. Vaskuri, and P. Kärhä, “Photoyellowing of transparent materials as quantified with a setup of lasers,” In: Reichert T (editor): *Natural and Artificial Ageing of Polymers*, 7th European Weathering Symposium, September 16–18, 2015, Naples, Italy. CEEES Publication No 17, Gesellschaft für Umweltsimulation e.V. GUS, 2015, pp. 209–218. (Talk)

T. Poikonen, T. Pulli, T. Dönsberg, H. Baumgartner, P. Kärhä and E. Ikonen, “Review of challenges and disadvantages of possible LED-based photometric standards,” *Proceedings of CIE 2016 Lighting Quality and Energy Efficiency Conference* (Melbourne, Australia, 2016) pp. 59–60.

T. Pulli, A. Vaskuri, H. Mäntynen, P. Kärhä, and E. Ikonen, “Uncertainty evaluation of spectral integrals for LED lamps,” *Proceedings of CIE 2016 Lighting Quality and Energy Efficiency Conference* (Melbourne, Australia, 2016) pp. 89–94.

L. Egli, J. Gröbner, M. Blumthaler, O. El Gawhary, P. Kärhä, I. Kröger, A. Rondas, and M. Weber, “Sensitivity analysis of ozone retrieval using UV measurements and different retrieval methods,” *International Radiation Symposium IRS 2016*, Auckland, New Zealand, April 16 – 22, 2016, Paper 74. (Talk)

P. Kärhä, A. Vaskuri, N. Mikkonen, J. Gröbner, L. Egli, and E. Ikonen, “Monte Carlo analysis of uncertainty of total atmospheric ozone derived from measured spectra,” *International Radiation Symposium IRS 2016*, Auckland, New Zealand,

April 16 – 22, 2016, Paper 327. (Talk)

A. Vaskuri, P. Kärhä, A. Heikkilä, and E. Ikonen, “UV ageing facility for determining action spectra of photodegradation for translucent materials,” International Radiation Symposium IRS 2016, Auckland, New Zealand, April 16 – 22, 2016, Paper 329. (Talk)

K. Lakkala, A. Heikkilä, P. Kärhä, I. Ialongo, T. Karppinen, J. M. Karhu, A. V. Lindfors, and O. Meinander, “25 years of spectral UV measurements at Sodankylä, Finland,” International Radiation Symposium IRS 2016, Auckland, New Zealand, April 16 – 22, 2016, Paper 363. (Poster)

A. Heikkilä, S. Kazadzis, O. Meinander, A. Vaskuri, P. Kärhä, V. Mylläri, S. Syrjälä, and T. Koskela, “UV exposure in artificial and natural weathering: a comparative study,” International Radiation Symposium IRS 2016, Auckland, New Zealand, April 16 – 22, 2016, Paper 383. (Poster)

A. Heikkilä, K. Uusitalo, P. Kärhä, A. Vaskuri, J. Kaurola, K. Lakkala, and T. Koskela, “Quantifying exceptionality of UV indices in Jokioinen, Finland, over the years 1995-2015,” International Radiation Symposium IRS 2016, Auckland, New Zealand, April 16 – 22, 2016, Paper 385. (Poster)

T. Pulli, P. Kärhä, A. Vaskuri, M. Shpak, F. Manoocheri, T. Karppinen, J. M. Karhu, K. Lakkala, and J. Mes, “Out-of-range stray light and NiSO₄ filter characterization of single-monochromator Brewers,” Brewer Ozone Spectrophotometer/Metrology Open Workshop, Ponta Delgada, The Azores, Portugal, May 17 – 20, 2016. (Talk)

P. Kärhä, A. Vaskuri, N. Mikkonen, J. Gröbner, L. Egli, and E. Ikonen, “Model for simulating uncertainties of TOC from multispectral measurements,” Brewer Ozone Spectrophotometer/Metrology Open Workshop, Ponta Delgada, The Azores, Portugal, May 17 – 20, 2016. (Talk)

P. Jaanson, T. Pulli, F. Manoocheri, E. Ikonen, “A reference material with close to Lambertian reflectance and fluorescence emission profiles,” 4th CIE Expert Symposium on Colour and Visual Appearance, Prague, Czech Republic, Sept 6 – 7, 2016. (Talk)

E. Ikonen, P. Jaanson, T. Pulli, F. Manoocheri, “Uncertainty evaluation of fluo-

rescence quantities obtained from goniometric measurements,” 4th CIE Expert Symposium on Colour and Visual Appearance, Prague, Czech Republic, September 6 – 7, 2016. (Talk)

P. Kärhä, A. Vaskuri, N. Mikkonen, J. Gröbner, L. Egli, and E. Ikonen, “Monte Carlo analysis of uncertainty of total atmospheric ozone derived from measured spectra,” International Radiation Symposium IRS 2016, *AIP Conference Proceedings* **1810**, 110005 (2017); doi: <http://dx.doi.org/10.1063/1.4975567>.

A. Vaskuri, P. Kärhä, A. Heikkilä, and E. Ikonen, “Facility for determining action spectra of UV photodegradation,” International Radiation Symposium IRS 2016, *AIP Conference Proceedings* **1810**, 110011 (2017); <http://doi.org/10.1063/1.4975573>.

K. Lakkala, A. Heikkilä, P. Kärhä, I. Ialongo, T. Karppinen, J.-M. Karhu, A. V. Lindfors, and O. Meinander, “25 years of spectral UV measurements at Sodankylä,” International Radiation Symposium IRS 2016, *AIP Conference Proceedings* **1810**, 110006 (2017); <http://doi.org/10.1063/1.4975568>.

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7.3 National Conference Presentations

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7.5 Awards

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