Department of Signal Processing and Acoustics

Biennial Report 2020 - 2021

Metrology Research Institute

Editor: Juho Karhu

Aalto University

SCIENCE + TECHNOLOGY

ANNUAL REPORT

Aalto University publication series
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Editor: Juho Karhu

Aalto University
School of Electrical Engineering
Department of Signal Processing and Acoustics
Metrology Research Institute

Cover photograph
Participants of the Quarter of a Century Celebration of Metrology Research Institute as the National Standards Laboratory of optical quantities (2021)

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CONTENTS

1 INTRODUCTION

During 2020–2021, covid-19 pandemic affected the activities of the Metrology Research Institute. After the first shock in spring 2020, however, the laboratory work continued quite normally. Examples of highlights include promising test results of new PQED photodiodes from the Chipscale project, development of a photoacoustic detector with broad spectral range in collaboration with Tampere and Helsinki Universities, and construction of a 3D gonioreflectometer for Earth observation applications. Furthermore, the effect of gas lens formation due to nitrogen flow was found and eliminated in the Predictable Quantum Efficient Detector (PQED).

Many new doctoral candidates have started their studies at the Institute. The research group personnel achieved four oral presentations in the NEWRAD 2021 conference, which is the main international event in radiometry/photometry research field. Three of those talks were given by the newly recruited staff which is a huge success when taking into account that NEWRAD conference does not include any parallel sessions. The online conference was organized by the National Institute of Standards and Technology (Boulder, USA) and the conference proceedings were produced by the Metrology Research Institute personnel (DOI 10.5281/zenodo.4882794).

The Institute was nominated as the national standards laboratory in optical quantities in 1996. In November 2021, the Quarter of a Century Celebration was arranged as an onsite event at Aalto University. It was very pleasant that despite the pandemic many international guests could attend in person, including the President of the Consultative Committee of Photometry and Radiometry.

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. One doctoral degree and one M.Sc. degree were achieved in 2020–2021. These numbers are significantly lower than during the previous two-year period and may be affected by the pandemic. The number of calibration certificates issued in 2020–2021 is 83, which is about the same number as for the period 2018–2019.

2 PERSONNEL

Aalto University School of Electrical Engineering
Department of Signal Processing and Acoustics
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Webpage http://metrology.aalto.fi

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In 2020–2021, the total number of employees working at the Metrology Research Institute was 25.

Name	**Telephone**	**E-mail**
Ikonen, Erkki, D.Sc. Professor, Head of Laboratory	50 550 2283	erkki.ikonen(at)aalto.fi
Aschan, Robin, M.Sc. Research scientist		robin.aschan(at)aalto.fi
Askola, Janne, D.Sc. Research scientist		janne.askola(at)aalto.fi Until December 2021
Danilenko, Aleksandr, M.Sc. Research scientist		aleksandr.danilenko(at)aalto.fi Since August 2020
Das, Sudatta, M.Sc. Research scientist		sudatta.das(at)aalto.fi Since January 2021
Haarnoja, Elias Research assistant		May 2021 – December 2021
Hakkarainen, Riina Research assistant		June 2020 – December 2020
Harju, Iiro Research assistant		Since June 2020

Huttu, Iikka Research assistant		June 2020 – August 2020, May 2021 – December 2021
Karhu, Juho, D.Sc. Research scientist		juho.j.karhu(at)aalto.fi Since August 2020
Korpusenko, Mikhail, M.Sc. Research scientist		mikhail.korpusenko(at)aalto.fi
Kärhä, Petri, D.Sc. Senior research scientist Quality manager	50 596 8469	petri.karha(at)aalto.fi
Lahti, Leo Research assistant		May 2021 – November 2021
Lampinen, Tuomas Research assistant		June 2020 – December 2020
Lanevski, Dmitri, M.Sc. Research scientist		dmitri.lanevski(at)aalto.fi
Laurila, Toni, D.Sc. Senior research scientist		toni.laurila(at)aalto.fi Until June 2020
Maham, Kinza, M.Sc. Research scientist		kinza.maham(at)aalto.fi
Manoocheri, Farshid, D.Sc. Senior research scientist	50 590 2483	farshid.manoocheri (at)aalto.fi
Mantela, Ville, M.Sc. Research scientist		ville.mantela(at)aalto.fi Since August 2020
Nordlund, Roope Research assistant		Since May 2021
Porrasmaa, Santeri Research assistant		Till May 2020
Rastgou, Masoud, M.Sc. Research scientist		masoud.rastgou(at)aalto.fi Since September 2021
Sharma, Sucheta, M.Sc. Research scientist		sucheta.sharma(at)aalto.fi

Simonen, Tarmo, M.Sc. Network and PC Administrator	50 413 0179	tarmo.simonen(at)aalto.fi
Talvitie Sami Research assistant		May 2021 – August 2021

Docents and lecturers:

Ludvigsen, Hanne	Aalto University
Laurila, Toni	Sensmet Ltd.

3 TEACHING

3.1 Degrees

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

Janne Askola (2021), *Advances in LED Photometry and Ageing Procedures of LED Luminaires*, Opponent: Vicedirector Técnico, Dr. Joaquín Campos Acosta, IO-CSIC, Spain.

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

Joel Lavikainen (2021), *Fiber Optic Coupled Ultraviolet Spectrometer for Industrial Gas Analysis of Hydrogen Sulfide and Ammonia*, guided by Antti Heikkilä, Vaisala.

3.2 Bachelor of Science (B.Sc.) Theses

Juhani Tammela (2020), *Vuotovirran mittauslaitteiston suunnittelu ja toteutus*, guided by Petri Kärhä.

Jesse Räisänen (2020), *Filmikondensaattoripankin ominaisparametrien mittaus LCR-mittarilla*, guided by Petri Kärhä.

Iiro Harju (2020), *Mittauslaitteisto optisten radiometrien kulmavasteen karakterisointiin*, guided by Petri Kärhä.

Paul Sairanen (2020), *Kulma-antureiden liitäntämoduulien toiminnan testaus*, guided by Petri Kärhä.

Juha Rauhala (2020), *Safiirilasille tehdyn Fabry-Perot-interferometrin optinen karakterisointi*, guided by Petri Kärhä.

Tuomas Lampinen (2020), *LED-lamppujen eliniän arviointi eri ikääntymisen vaiheissa ja vertailu todennettuun elinikään*, guided by Janne Askola.

Oula Kekäläinen (2021), *Optisen kaasumittauslaitteen lämpötilajakauman analyysi*, guided by Petri Kärhä.

Iikka Huttu (2021), *Aurinkokennojen tehontuotto LED-valaistuissa toimistoissa asioiden internetin kuvakulmasta*, guided by Petri Kärhä

Niklas Rehnberg (2021), *Ultraviolettisäteilyyn perustuva liekinilmaisin*, guided by Petri Kärhä

3.3 Courses

The following courses were offered by the Metrology Research Institute in 2020–2021. Those marked by * are given biennially.

ELEC-E5730	Optics, 5 cr (Toni Laurila, Mikhail Korpusenko)
ELEC-E5710	Sensors and Measurement Methods, 5 cr (Petri Kärhä)
ELEC-E5720	Virtual Instrumentation, 5 cr (Petri Kärhä, Janne Askola, Ville Mantela)
ELEC-E5750	Project Work in Measurement Science and Technology, 2–10 cr (Petri Kärhä)
ELEC-E5760	Project Work in Optical Technology, 2–10 p (Erkki Ikonen)
ELEC-E5780	Postgraduate Course in Measurement Science and Technology, 10 cr* (Petri Kärhä)
ELEC-E5740	Research Seminar on Measurement Science and Technology, 2 cr* (Petri Kärhä)
ELEC- C5070	Electronics Workshop, 5 cr (Petri Kärhä)
ELEC-C5270	Insinööri työelämässä, 5 cr Petri Kärhä

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 (MIKES) in April 1996.

The institute gives official calibration certificates on various optical quantities in the fields of Photometry, Radiometry, Spectrophotometry and Fiber Optics. During 2020, 41 calibration certificates were issued. In 2021, the number of calibration certificates was 42. 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 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 including price list: https://www.aalto.fi/en/department-of-signal-processing-and-acoustics/calibration-services-at-metrology-research-institute

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 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 international projects. Most of the research in the laboratory is currently carried out within the EURAMET EMPIR programme. 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 MetTLM - Metrology for Temporal Light Modulation (2021-2024)**
- **EMPIR RevStdLED - Revision and extension of standards for test methods for LED lamps, luminaires and modules (2020-2023)**
- **Lifetime projection of lamps and luminaires based on high power LEDs (2009-)**

5.2 Radiometry

- **EMPIR QADeT - Quantum sensors for metrology based on single-**

atom-like device technology (2021-2024)

- **EMPIR SEQUME - Developing the metrology and instrumentation for single-photon sources, required for future advances in quantum technologies (2021-2024)**
- **EMPIR MeTISQ - Metrology for Testing the Implementation Security of Quantum Key Distribution Hardware (2020-2024)**
- **EMPIR Metro-PV - Metrology for Emerging PV applications (2020-2023)**
- **EMPIR MAPP - Metrology for aerosol optical properties (2020-2023)**
- **EMPIR chipSCALe - Self-calibrating photodiodes for the radiometric linkage to fundamental constants (2019-2022)**
- **Universal electromagnetic radiation detector (UNIDET) (2018–2021)**
- **EMPIR SIQUST project - Single-photon sources as new quantum standards (2018-2021)**
- **EMPIR PV-Enerate - Advanced PV Energy Rating (2017-2020)**

5.3 Spectrophotometry

- **EMPIR ATMOC - Traceable metrology of soft-X-ray to IR optical constants and nanofilms for advanced manufacturing (2021-2024)**
- **EMPIR Smart PhoRa - Supporting smart specialization and stakeholder linkage in Photometry and Radiometry (2021-2023)**
- **EMPIR MetEOC4 - Metrology to establish an SI-traceable climate observing system (2020-2023)**
- **EMPIR BxDiff - New quantities for the measurement of appearance (2019-2022)**
- **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)**

6 INTERNATIONAL CO-OPERATION

6.1 International Comparison Measurements

Since 2005, the Metrology Research Institute of Aalto University has participated in key comparisons under the name MIKES or MIKES-Aalto.

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

Measurements by MIKES-Aalto and CNAM have been carried out.

Key comparison CCPR-K5, diffuse reflectance 380 – 800 nm, pilot MIKES-Aalto

MIKES-Aalto has completed first round measurements.

Key comparison EURAMET.PR-K3, Luminous intensity, pilot METAS

First measurements by MIKES-Aalto have been carried out. Repeat Measurements are to be done fall of 2022.

6.2 Conferences and Meetings

Meeting on European Partnership on Metrology at Commission, January 16, 2020, Brussels, Belgium; *Erkki Ikonen*

EMPIR BxDiff project meeting, January 21–22, 2020, Bern, Switzerland; Robin Aschan

EURAMET TC-PR Workshop, January 28, 2020, Chisinău, Moldova; *Petri Kärhä*

EURAMET TC-PR Annual meeting, January 29–30, 2020, Chisinău, Moldova; *Petri Kärhä, Farshid Manoocheri, Erkki Ikonen*

EURAMET Quality Forum, January 30–31, 2020, Chișinău, Moldova; *Petri Kärhä*

EMPIR Chipscale Project meeting, February 12–13, 2020, Turin, Italy; *Mikhail Korpusenko, Santeri Porrasmaa, Erkki Ikonen*

EURAMET BoD meeting, February 19, 2020, Paris, France; *Erkki Ikonen*

EURAMET BoD/TCC/EMNC workshops, February 20–21, 2020, Paris, France; *Erkki Ikonen*

EMPIR project midterm review, February 27–28, 2020, Berlin, Germany; *Erkki Ikonen*

EMPIR SC-CB meeting, March 30, 2020, online; *Erkki Ikonen (Chair)*

EMPIR SC-R meeting, March 31–April 2, April 7, April 30, 2020, online; *Erkki Ikonen (Chair)*

EMPIR Committee meeting, May 27–28, 2020, online; *Erkki Ikonen (Chair)*

EMPIR MAPP Kick-off meeting, June 9–10, 2020, online; *Petri Kärhä, Kinza Maham, Iiro Harju*

EMPIR PV-Enerate Final project meeting, September 22–23, 2020, online; *Petri Kärhä*

EMPIR Metro-PV Kick-off meeting, September 23–24, 2020, online; *Petri Kärhä*

Meeting on cryogenic radiometer vs. PQED responsivity comparison, October 16, 2020, NIMT Bangkok, Thailand; *Erkki Ikonen*

EMPIR SC-R meeting, October 21–22, 2020, online; *Erkki Ikonen (Chair)*

EMPIR Committee meeting, November 17–18, 2020, online; *Erkki Ikonen (Chair)*

CCPR WG-KC TG-4 meeting, LED-based key comparison lamps, January 22, 2021, online; *Erkki Ikonen (Chair), Robin Aschan (Recorder)*

EMPIR MAPP Project meeting, February 10–11, 2021, online; *Petri Kärhä, Kinza Maham, Iiro Harju*

BIPM Workshop on "SI for FAIR digital data", February 22–26, 2021, online; *Erkki Ikonen*

EURAMET BoD WG on Partnership meeting, March 3, 2021, online; *Erkki Ikonen (Convener)*

EMPIR SC-R meeting, April 7–12, 2021, online; *Erkki Ikonen (Chair)*

EMPIR SC-CB meeting, April 13, 2021, online; *Erkki Ikonen (Chair)*

Annual meeting of the Nordic Ozone and UV group, NOG2021, April 20–21, 2021, online; *Petri Kärhä*

EMPIR Metro-PV Project meeting, May 6, 2021, online; *Petri Kärhä, Kinza Maham*

EMPIR MetTLM Kick-off meeting, May 17 and 21, 2021, online; *Ville Mantela, Roope Nordlund*

EURAMET BoD WG on Partnership meeting, May 31, 2021, online; *Erkki Ikonen (Convener)*

EMPIR Committee meeting, June 10, 2021, online; *Erkki Ikonen (Chair)*

EURAMET BoD WG on Partnership meeting, June 10, 2021, online; *Erkki Ikonen (Convener)*

NEWRAD 2021 Conference, June 21–24, 2021, online; *Mikhail Korpusenko (talk), Petri Kärhä (talk), Kinza Maham (talk), Sucheta Sharma (talk), Janne Askola, Robin Aschan, Dmitri Lanevski, Erkki Ikonen (session chair)*

Online Workshop on Europe-China Metrology Development and Cooperation, June 22, 2021; *Erkki Ikonen (invited talk)*

EMPIR RevStdLED Project meeting, July 13–14, 2021, online; *Janne Askola, Ville Mantela*

Meeting on PQED measurements and transportation of a PQED to CMI, August 17–18, 2021, Prague, Czech Republic; *Erkki Ikonen*

International Congress on Metrology CIM2021, September 7–9, 2021, Lyon, France; *Petri Kärhä (talk), Iiro Harju (talk), Sucheta Sharma (talk)*

CIE 2021 Midterm Conference, September 27–29, 2021, online; *Erkki Ikonen, Kinza Maham (talk), Ville Mantela (talk)*

Meeting on research collaboration with PTB, October 25–27, 2021, PTB Braunschweig, Germany; *Erkki Ikonen*

Quarter of a Century Celebration of MIKES-Aalto as Designated Institute, November 3, 2021, onsite at Aalto University; *all staff*

EMPIR MAPP Project meeting, November 22–23, 2021, PTB Braunschweig, Germany; *Petri Kärhä, Iiro Harju*

EMPIR/Partnership Committee meeting, November 30 – December 1, 2021, PTB Berlin, Germany; *Erkki Ikonen (Chair)*

Optics and Photonics Days, December 1–3, 2021, Turku, Finland; *Sucheta Sharma, Erkki Ikonen*

6.3 Visits by the Laboratory Personnel

Petri Kärhä, Tallinn Technical University, Estonia, December 15, 2021

6.4 Research Work Abroad

Sucheta Sharma, Physikalisch-Technische Bundesanstalt, Berlin, Germany, August 16–20, 2021.

Mikhail Korpusenko, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany, August 3–15, October 12–17, October 24 – November 2, 2021.

6.5 Visits to the Laboratory

Aleksandr Dunaev¸ VNIIOFI, Russia, March 11–12, 2020

Meelis Sildoja, Metrosert, Estonia, September 15, November 3, 2021

Toomas Kübarsepp, Metrosert, Estonia, September 21–23, 2021

Joaquin Campos, IO-CSIC, Spain, October 21–22, 2021

Jarle Gran, JV, Norway, November 3–4, 2021

Maria Luisa Rastello, INRIM, Italy, November 3–4, 2021

Marek Smid, CMI, Czech Republic, November 3–4, 2021

7 PUBLICATIONS

7.1 Articles in International Journals

T. Dönsberg, T. Poikonen, and E. Ikonen, "Transconductance amplifier for optical metrology applications of light-emitting diodes," *IEEE Trans. Instrum. Meas.* **69**, 3704–3710 (2020). https://doi.org/10.1109/TIM.2019.2935596

E. Martikainen, A. Vaskuri, T. Dönsberg, and E. Ikonen, "Cryostat setup for measuring spectral and electrical properties of light-emitting diodes at junction temperatures from 81 K to 297 K," *Rev. Sci. Instrum.* **91**, 015106, 7 p (2020). https://doi.org/10.1063/1.5125319

P. Kärhä, H. Baumgartner, J. Askola, K. Kylmänen, B. Oksanen, K. Maham, V. Huynh, and E. Ikonen, "Measurement setup for differential spectral responsivity of solar cells," *Opt. Rev.* **27**, 195–204 (2020). https://doi.org/10.1007/s10043-020-00584-x

S. Porrasmaa, T. Dönsberg, F. Manoocheri, and E. Ikonen, "Predictable quantum efficient detector for low optical flux," *Opt. Rev.* **27**, 190–194 (2020). https://doi.org/10.1007/s10043-020-00580-1

K. Maham, A. Vaskuri, F. Manoocheri, and E. Ikonen, "Calibration of near-infrared detectors using a wavelength tunable light source", *Opt. Rev.* **27**, 183–189 (2020). https://doi.org/10.1007/s10043-020-00586-9

D. Lanevski, F. Manoocheri, A. Vaskuri, J. Hameury, R. Kersting, C. Monte, A. Adibekyan, E. Kononogova, and E. Ikonen, "Determining the shape of reflectance reference samples for curved surface reflectors," *Meas. Sci. Technol.* **31**, 054010, 8 p (2020). https://doi.org/10.1088/1361-6501/ab68bf

A. Hovi, M. Mottus, J. Juola, F. Manoocheri, E. Ikonen, and M. Rautiainen, "Evaluating the performance of a double integrating sphere in measurement of reflectance, transmittance, and albedo of coniferous needles," *Silva Fenn.* **31**, 054010, 22 p (2020). https://doi.org/10.14214/sf.10270

M. Ojanen, M. Shpak, P. Kärhä, R. Leecharoen, and E. Ikonen, "Corrigendum: Uncertainty evaluation for linking a bilateral key comparison with the corresponding CIPM key comparison (2009 *Metrologia* **46**, 397–403)," *Metrologia*

57, 049501 (2020). https://doi.org/10.1088/1681-7575/ab8cd1

M. Roiz, K. Kumar, J. Karhu, and M. Vainio, "Simple method for mid-infrared optical frequency comb generation with dynamic offset frequency tuning," *APL Photonics* **6**, 026103, 10 p (2021). https://doi.org/10.1063/5.0038496

J. Askola, P. Kärhä, H. Baumgartner, S. Porrasmaa, and E. Ikonen, "Effect of adaptive control on the LED street luminaire lifetime and on the lifecycle costs of a lighting installation," *Lighting Res. Technol.* **(**In press). https://doi.org/10.1177/14771535211008179

J. Askola, K. Maham, P. Kärhä, E. Ikonen, "Increased detector response in optical overfilled measurements due to gas lens formation by nitrogen flow through the entrance aperture," *Metrologia* **58**, 055008, 5 p. (2021). https://doi.org/10.1088/1681-7575/ac0e7b

J. Rossi, J. Uotila, S. Sharma, T. Laurila, R. Teissier, A. Baranov, E. Ikonen, and M. Vainio, "Photoacoustic characteristics of carbon-based infrared absorbers," *Photoacoustics* **23**, 100265, 10 p (2021). https://doi.org/10.1016/j.pacs.2021.100265

M. Tanabe, H. Shitomi, T. Dönsberg, and E. Ikonen, "Characterization of predictable quantum efficient detector in terms of optical non-linearity in the visible to near-infrared range," *Metrologia* **58**, 055012, 6 p (2021). https://doi.org/10.1088/1681-7575/ac1e35

M. Korpusenko, F. Manoocheri, O.-P. Kilpi, A. Varpula, M. Kainlauri, T. Vehmas, M. Prunnila, and E. Ikonen, "Characterization of predictable quantum efficient detector at 488 nm and 785 nm wavelengths with an order of magnitude change of incident optical power," *Meas. Sci. Technol.* **33**, 015206, 8 p (2021). https://doi.org/10.1088/1361-6501/ac367a

O. Koybasi, O. Nordseth, T. Tran, M. Povoli, M. Rajteri, C. Pepe, E. Bardalen, F. Manoocheri, A. Summanwar, M. Korpusenko, M. Getz, P. A. Ohlckers, E. Ikonen, and J. Gran, "High performance predictable quantum efficient detector based on induced-junction photodiodes passivated with SiO_2/SiN_x," *Sensors* **21**, 7807, 18 p (2021). https://doi.org/10.3390/s21237807

M. Roiz, J.-Y. Lai, J. Karhu, and M. Vainio, "Mid-infrared frequency comb with

25 pJ threshold via CW-seeded optical parametric generation in nonlinear waveguide," *Opt. Lett.* **46**, 4037–4040 (2021). https://doi.org/10.1364/OL.434485

J. Karhu, T. Hieta, F. Manoocheri, M. Vainio, and E. Ikonen, "LED-based photoacoustic NO_2 sensor with a sub-ppb detection limit," *ACS Sens.* **6**, 3303–3307 (2021). https://doi.org/10.1021/acssensors.1c01073

J. Karhu, J. Kuula, A. Virkkula, H. Timonen, M. Vainio, and T. Hieta, "Cantilever-enhanced photoacoustic measurement of light-absorbing aerosols", *Aerosol Sci. Technol.* (In press). https://doi.org/10.1080/02786826.2021.1998338

S. Sharma, T. Laurila, J. Rossi, J. Uotila, M. Vainio, F. Manoocheri, E. Ikonen, "Electromagnetic radiation detection using cantilever-based photoacoustic effect: A method for realizing power detectors with broad spectral sensitivity and large dynamic range", *Sens. Actuator A-Phys.* (In Press).
https://doi.org/10.1016/j.sna.2021.113191

M. R. Vogt, S. Riechelmann, A. M. Gracia-Amillo, A. Driesse, A. Kokka, K. Maham, P. Kärhä, R. Kenny, C. Schinke, K. Bothe, J. C. Blakesley, E. Music, F. Plag, G. Friesen, G. Corbellini, N. Riedel-Lyngskær, R. Valckenborg, M. Schweiger, and W. Herrmann, "PV module energy rating standard IEC 61853-3 intercomparison and best practice guidelines for implementation and validation," *IEEE J. Photovolt.* (In press).
https://doi.org/10.1109/JPHOTOV.2021.3135258

7.2 International Conference Presentations

M. R. Vogt, S. Riechelmann, A. M. Gracia-Amillo, A. Driesse, A. Kokka, P. Kärhä, C. Schinke, K. Bothe, J. C. Blakesley, E. Music, F. Plag, G. Friesen, G. Corbellini, N. Riedel-Lyngskær, R. Valckenborg, M. Schweiger, and W. Herrmann, "Interlaboratory comparison of the PV module energy rating standard IEC 61853-3 and reference parameter set for the PV community," *Proceedings of the 37th European Photovoltaic Solar Energy Conference and Exhibition*, online, September 7–11, 2020, pp. 811–815 (Talk).
https://doi.org/10.4229/EUPVSEC20202020-4BO.13.2

J. Rossi, J. Uotila, T. Laurila, E. Ikonen, and M. Vainio, "Broadband Electromagnetic Radiation Detector Based on Photoacoustic Effect," *2020 Conference on Lasers and Electro-Optics, OSA Technical Digest*, online, May 10–15, 2020, paper AF1K.5, 2 pages (Talk). https://doi.org/10.1364/CLEO_AT.2020.AF1K.5

E. Ikonen, "Introduction of European Metrology Research Programmes," *Workshop on Europe-China Metrology Development and Cooperation*, online, June 2021 (Invited talk).

J. Gran, T. Tran, and T. Dönsberg, "Three-dimensional modelling of photodiode responsivity," *Proceedings of NEWRAD 2021 Conference*, online, June 21–24, 2021, pp. 1–2 (Invited talk). https://doi.org/10.5281/zenodo.4882794

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7.4 Other Publications

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