

# COST Action PEARL PV (CA16235)

**Performance and Reliability of Photovoltaic Systems:**  
Evaluations of Large-Scale Monitoring Data



## Workshop on Luminescent Solar Concentrator Photovoltaics (LSC PV)

14<sup>th</sup> November 2019

Eindhoven University of Technology in Eindhoven, the Netherlands

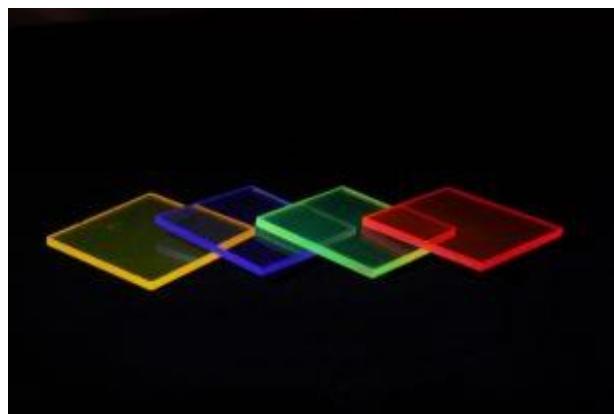




## Introduction

---

In the past decade, there have been great advances in not only the performance, but also the potential application range of Luminescent Solar Concentrator Photovoltaic (LSC PV) devices. New inorganic luminophores promise the elimination of reabsorption losses and extended lifetimes and complex organic dyes with large Stokes shifts have been developed in labs. Photonic coatings could significantly decrease surface losses, plasmonic enhancements can generate more emission and dye alignment can improve light focusing. New applications are being developed, such as switchable ‘smart’ windows, building integrated PV modules, daylighting elements, greenhouses and even hydrogen production with LSCs. With silicon cell efficiencies reaching values close to the theoretical maximum, LSC PV devices can reach a mature state, while new solar cell materials also can contribute to improvements in performance and commercialization of LSC PVs. Given this context, this workshop seeks to bring together the world’s experts in LSC PV research and development for a focused conversation on the performance enhancement of this intriguing device. Through a series of lectures ranging from fundamental science to device design and from applications to industrial opportunities, we hope to enliven the debate, foster new collaborations and tackle barriers that should be lowered or eliminated to create commercially available LSC PV applications with a good performance.



## Schedule of events

---

Time (h)	Speaker's Name & Affiliation – Theme – <i>Title of the presentation</i>
9:00	Welcome with coffee and tea
9:20	Angèle Reinders and Michael Debije, TU/e, Eindhoven, The Netherlands <i>Introduction to the workshop's program, welcome to TU/e &amp; COST Action PEARL PV</i>
9:30	Tim Schmidt, UNSW, Sydney, Australia – Plenary Speaker – Fundamentals <i>The whats, hows and whys of luminescent solar concentrators: where to from here?</i>
10:00	Glenn Alers, Soliculture, and Sue Carter, University of California at Santa Cruz, USA – Plenary Speakers – Applications <i>A commercial LSC for greenhouses with 250kW in the field</i>
10:30	Break with coffee and tea
11:00	Celso de Mello Donega, Utrecht University, The Netherlands – Fundamentals <i>Prospects and challenges of colloidal nanocrystals for LSCs</i>
11:20	Bruno Ehrler, Amolf, Amsterdam, The Netherlands – Fundamentals <i>Singlet fission and perovskites in LSCs</i>
11:40	Joe Kao, PHYSEE, Delft, The Netherlands – Applications <i>Electricity generating window – LSC based on inorganic, rare-earth metal doped coatings</i>
12:00	Guided discussion about LSC PV Fundamental research challenges
12:20	Lunch break
13:30	Rachel Evans, University of Cambridge, UK – Plenary Speaker – Devices <i>Engineering integrated lightguide-luminophore materials to overcome luminophore losses in LSCs</i>
14:00	Michael Debije, TU/e, Eindhoven, The Netherlands – Devices <i>Expanding the applications for LSCs</i>
14:20	Guided discussion about LSC PV Device research challenges
15:00	Break with coffee and tea
15:30	Jeroen ter Schiphorst, Lusoco, Eindhoven, The Netherlands – Applications <i>Luminescent solar concentrators as sustainable and autonomous signage</i>
15:50	Wilfried van Sark, Utrecht University, The Netherlands – Applications <i>Visual appearance of nanocrystal-based luminescent solar concentrators</i>
16:10	Angèle Reinders and Mohammadreza Aghaei, TU/e, Eindhoven, The Netherlands – Applications <i>Designing with LSC PV technologies: simulations and testing of prototypes</i>
16:30	Guided discussion about LSC PV Applications research challenges
17:00	Refreshments
17:30	End of the workshop

## **Speakers**

---

### **Prof.Dr. Timothy Schmidt**

**Professor and ARC Future Fellow, School of Chemistry Science, UNSW, Sydney, Australia**

Tim Schmidt gained his BSc (Hons) from The University of Sydney in 1998, winning the University Medal in theoretical chemistry. He then studied at Churchill College, Cambridge, gaining a PhD in chemistry from the University of Cambridge in 2001 for work on the femtosecond dynamics of molecules in intense laser fields under the supervision of Dr Gareth Roberts. Postdoctoral work was undertaken in the group of Professor John Paul Maier, FRS, in Basel, on the electronic spectroscopy of highly unsaturated hydrocarbons of astrophysical relevance. Tim returned to Australia in 2003 to work at the CSIRO (CTIP, Lindfield) on modelling of the RuBisCO enzyme in photosynthesis. He commenced as a lecturer in chemistry at The University of Sydney in April 2004. From January 2014, Tim is appointed as Professor and ARC Future Fellow at UNSW. He is the recipient of the 2010 Coblenz Award.

Tim is presently a Chief Investigator of the Australian Research Council Centre of Excellence in Exciton Science, which seeks excitonic solutions to energy problems. He is Theme Leader of Excitonic Systems for Solar Energy Conversion, which includes platforms which research Thin Film Upconversion Devices, Next Generation Luminescent Solar Concentrators and Solution Processed Next-Generation Photovoltaics. He also actively maintains research into electronic structure theory and astrochemical spectroscopy.



**Dr. Glenn Alers****President and CEO of Soliculture, California, USA**

Dr. Glenn Alers is President and CEO of Soliculture Inc., a company focused on improving the energy efficiency of greenhouse growing through greenhouse integrated photovoltaic panels that facilitate plant growth through optimizing the solar spectrum and the simultaneous generation of electricity. Dr. Alers was a professor of physics at the University of California at Santa Cruz until 2012 when he founded Soliculture has been focused on working with commercial and institutional greenhouse growers. In 2009, he was a visiting scientist at the National Renewable Energy Laboratory (NREL). He has been active in the solar panel research and reliability with numerous tutorials and invited talks through the IEEE, SPIE and NREL. Prior to working at the University of California, he was a principal engineer and senior process manager at Novellus Systems and a member of the technical staff at Bell Laboratories, Murray Hill. He received his PhD in 1991 from the University of Illinois, Urbana-Champaign and was a Research Associate in the Physics Department of Michigan State University. He has published over 60 papers in refereed journals and has received 22 US patents.



**Dr. Celso de Mello Donegá**

**Associate Professor, Department of Chemistry, Debye Institute for Nanomaterials Science,  
Utrecht University, Utrecht, The Netherlands**

Celso de Mello Donegá is an Associate Professor at the Department of Chemistry of the Debye Institute for Nanomaterials Science of Utrecht University. He has extensive expertise on the synthesis and optical spectroscopy of colloidal nanocrystals of binary and multinary semiconductors, and has established a solid reputation in the field, as evidenced by the impact of his publications (6 book chapters and 161 papers), which have received over 12400 citations (h-index of 54). His work resulted in new preparation methods for colloidal quantum dots and heteronanocrystals, thereby boosting photoluminescence efficiencies and other properties, and developing new compositions. The availability of these materials has in turn allowed his group to unravel new physical phenomena and to contribute toward a better understanding of the chemistry and physics of nanoscale materials. Research is also conducted on the application of these materials as biomedical imaging probes, in luminescent solar concentrators, and photocatalysts.



**Dr. Bruno Ehrler****Group leader Hybrid Solar Cells, AMOLF, Amsterdam, The Netherlands**

Bruno Ehrler is heading the Hybrid Solar Cells group at AMOLF since 2014. The group focuses on singlet fission and perovskite solar cells, both on the fundamental level, and for device applications. Before moving to Amsterdam, he was a research fellow in the Optoelectronics Group at Cambridge University following post-doctoral work with Professor Sir Richard Friend. During this period, he worked on quantum dots, doped metal oxides and singlet fission photovoltaics. He obtained his PhD from the University of Cambridge under the supervision of Professor Neil Greenham, studying hybrid solar cells from organic semiconductors and inorganic quantum dots. He received his MSc from the University of London (Queen Mary) studying micro-mechanics in the group of Professor David Dunstan.



**Ir. Joe Kao**

**Lead Research Engineer, PHYSEE, Delft, The Netherlands**

Joe Kao is a lead research engineer at PHYSEE where he works since he graduated at Delft University of Technology as MSc in Materials Science and Engineering. He is responsible for synthesis and integration of luminescent nanoparticles in a coating used for PHYSEE's electricity generating window. With a constant refreshing perspective from material research in the lab to strategic and creative brainstorming at events, to scoring 3-pointers on the court, he is valued as co-worker and person.



**Dr. Rachel Evans**

**Fellow and Director of Studies, Department of Materials Science and Metallurgy, Jesus College University of Cambridge, Cambridge, UK**

Dr Rachel Evans is a Reader in Materials Chemistry in the Department of Materials Science and Metallurgy at the University of Cambridge. She obtained her MChem and PhD in Physical Chemistry from Swansea University. She was previously an Associate Professor in Physical Chemistry at Trinity College Dublin, following postdoctoral fellowships at the Université Paris-Sud, France and the University of Coimbra, Portugal. Rachel's research is focused on the design of photoresponsive soft materials for luminescent solar devices, stimuli-responsive systems and organic photovoltaics. She was recently awarded an ERC consolidator grant to advance her work on spectral converter materials. Rachel is a Fellow of the Royal Society of Chemistry and the Institute of Materials, Minerals and Mining.



**Dr. Michael Debije**

**Assistant Professor, Stimuli-responsive Functional Materials and Devices Group,  
Eindhoven University of Technology (TU/e), Eindhoven, The Netherlands**

Michael Debije received a M.Sc. degree in High-Energy Physics from Iowa State University, Ames, Iowa in 1994 and a Ph.D. in Biophysics from the University of Rochester, NY, USA in 2000. After completing a postdoc at the Interfaculty Reactor Institute at the Delft University of Technology in the group of John Warman in 2003, he joined the staff of the Stimuli-responsive Functional Materials and Devices group at the Eindhoven University of Technology as an Assistant Professor, and is responsible for the Energy cluster within the program. He has been working on the LSC device for over a decade.



**Dr. Jeroen ter Schiphorst**  
**Chief Technology Officer (CTO), Lusoco BV, Eindhoven, The Netherlands**

Jeroen ter Schiphorst holds a master degree in Chemical Technology at Eindhoven University of Technology, specializing in the Molecular Engineering track in 2014. In 2018 he finished his PhD research in the field of light responsive materials at Eindhoven University of Technology in the Functional Organic Materials and Devices group under the supervision of Prof. dr. Albert Schenning. He is the author of 13 scientific publications, 2 patent applications and won the plenary lecture award at the Dutch Polymer days in 2018. Concurrently, in 2017 Jeroen co-founded Lusoco B.V., a start-up company that was elected as finalist in the Gouden Kiem award for best chemistry start-up in the Netherlands. Lusoco B.V. is focusing on the development of high-tech printed luminescent solar concentrators for aesthetic energy harvesting. In his role as Chief Technology Officer (CTO) he is responsible for meeting the technological challenges in the field of ink development, inkjet printing and electronics for energy harvesting signage and windows.



**Prof.Dr. Wilfried van Sark**

**Professor of Photovoltaics Integration, Copernicus Institute of Sustainable Development,  
Utrecht University, Utrecht, The Netherlands**

Wilfried van Sark is full professor “Integration of Photovoltaics” at the Copernicus Institute of Sustainable Development of Utrecht University.

He has over 35 years of experience in the field of photovoltaics, ranging from thin film silicon and III-V solar cell experimental and modeling development and testing to solar cell processing development, out- and indoor performance of solar cells, policy and cost development. His current activities focus on employing spectrum conversion to increase solar cell conversion efficiency for next-generation photovoltaic energy converters as well as performance analysis of building-integrated and standard PV systems in the field. This in particular links to the integration of PV systems in smart grids in the built environment, in which Electrical Vehicles, demand response and self-consumption and self-sufficiency will play a major role.



**Prof.Dr. Angèle Reinders**

**Professor of Design of Sustainable Energy Systems, Energy Technology Group, Eindhoven University of Technology (TU/e), Eindhoven, The Netherlands**

Angèle Reinders received an MSc in Experimental Physics at Utrecht University (1993) where she also received her PhD degree (1999) in Chemistry. In the past she conducted research at Utrecht University, Fraunhofer Institute of Solar Energy in Freiburg, the World Bank in Washington D.C., ENEA in Naples, Center of Urban Energy in Toronto and in Indonesia, and she was a professor of Energy-Efficient Design at TU Delft. Based on these experiences she developed a new approach towards energy research that is design-driven in scope. Since 2017 she has been the chair of the EU COST Action PEARL PV on the performance of PV systems and she is conducting projects on smart energy systems. She is known for her books 'The Power of Design-Product Innovation in Sustainable Energy Technologies' (2012) and 'Photovoltaic Solar Energy From Fundamentals to Applications' (2017) and for her involvement in the international IEEE PVSC conference which she chaired in 2014 and 2017. In 2010 she co-founded the IEEE Journal of Photovoltaics for which she serves as an editor. She is also involved in various tasks of the International Energy Agency PVPS program, including Task 17 on PV for Transport. As well as being a professor at TU/e, Angèle Reinders is an associate professor at University of Twente, and a visiting professor of the School of Photovoltaics & Renewable Energy Engineering of UNSW in Sydney, Australia.



**Dr. Mohammadreza Aghaei**

**Scientist, Design of Sustainable Energy Systems, Energy Technology Group, Eindhoven University of Technology (TU/e), Eindhoven, The Netherlands**

Mohammadreza Aghaei received the M.Eng. degree in electrical engineering from the Tenaga National University, Malaysia, in 2013, and the Ph.D. degree in electrical engineering from the Politecnico di Milano, Italy, in 2016. He joined to Fraunhofer ISE in Germany as visiting scholar in 2015. Moreover, he was a postdoctoral researcher and also project manager in division of photovoltaics in Fraunhofer ISE in 2017. Furthermore, he had been admitted as a guest scientist in department of Microsystems Engineering (IMTEK), Solar Energy Engineering (SEE), master program in University of Freiburg in 2017. Moreover, he was a postdoctoral scientist in Helmholtz-Zentrum Berlin (HZB), Competence Centre Thin Film and Nanotechnology for Photovoltaics Berlin (PVcomB), Germany in 2018. During his research journey, he developed new variation of CdZnTe/CIGS thin film tandem solar cell, investigated about novel methods in control and monitoring of PV systems namely autonomous monitoring approach. Furthermore, he was dealing with the Big Data Analytics (BDA) of outdoor measurement of the new PV technologies for energy yield assessment, degradation analysis, predictive monitoring and so on. Currently, he is working as postdoctoral scientist at Design of Sustainable Energy Systems group at Eindhoven University of Technology (TU/e), Netherlands to develop a new design and highly efficient concept of LSC PV devices in built environment. He is a member of the International Energy Agency (IEA), PVPS program - Task 13 and International Solar Energy Society (ISES). Since 2019 he has been the chair of the working group 2: reliability and durability of PV in EU COST Action PEARL PV.

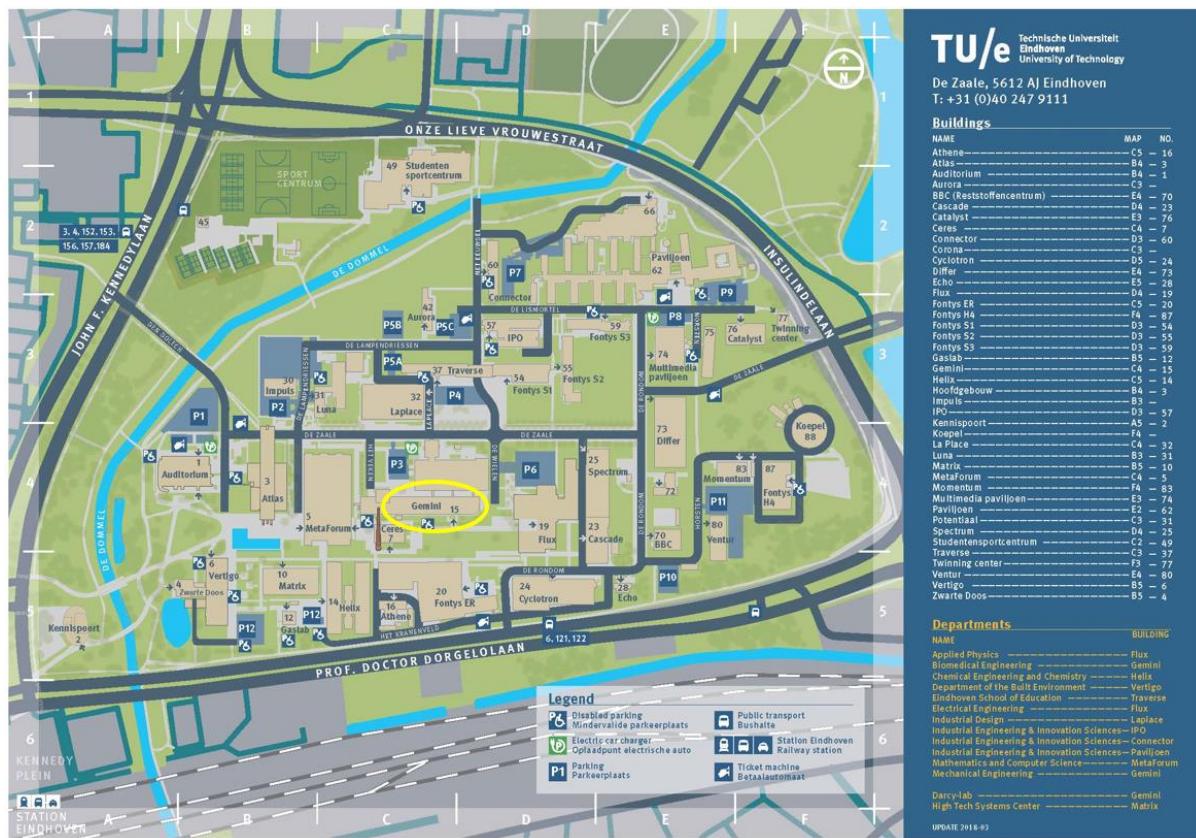


# Practical Information

## Venue and Campus Map

The TU/e Campus is located in the center of Eindhoven, at some eight minutes walking distance from Eindhoven railway station. This makes it easy to reach by public transport.

Location of the workshop is at Eindhoven University of Technology, room nr. GEM Z 0.05, building GEMini Zuid, Eindhoven, The Netherlands (no 15 on the map).



## **Travel Information**

---

### **By plane**

Eindhoven airport is located just five kilometers outside the city, and provides connections (with low cost airliners) with major cities such as London, Paris, Barcelona, Stockholm etc.

From Eindhoven Airport there is an airport shuttle between the Central Railway station of Eindhoven and Eindhoven airport. Tickets can be bought at the airport bus stand. Alternatively, bus 401 runs directly from the airport to Eindhoven's central Railway station in the city center every 10 minutes.

Alternatively, Schiphol Airport in Amsterdam is a 90 minute ride by train, with a direct connection between the airport and Eindhoven Central Railway station. From Eindhoven Central Railway station it is at some eight minutes walking distance to the TU/e campus.

### **By train**

When you arrive at Eindhoven Central Railway station, walk down the ramp at the railway station, turn right and exit through the north side towards the bus station. Walk 25 meters to the right and you will see the university buildings. Cross at the traffic light and follow the winding path towards the TU/e campus.

The path on the right side of the campus, called Prof. Dr. Dorgelo Avenue, is suitable for wheelchair users.

### **By car**

All motorways to and around Eindhoven (A2, A50, A58, A67 and A270) lead the way to the campus. Follow the 'Centrum' directions on the small blue signs, until you see 'University'.

## **City Map; welcome in Eindhoven**

---

Eindhoven is a municipality and a city located in the Netherlands. The city has a surface of 88,84 km<sup>2</sup> and a population of over 231.000, making it the largest city of the south. Eindhoven is centrally located in Europe and easily accessible via Eindhoven Airport (or three other airports within 1,5 hour drive).

Eindhoven is bursting with energy. When you google innovation, it is no coincidence that the first images you find are light bulbs. Over 125 years ago, Philips brought light to Eindhoven. The company transformed the city into a vibrant industrial success story. Nowadays, Eindhoven is a bustling city in transition, with a constant flow of new developments in the fields of creativity, innovation, technology, design, and knowledge.

Discover our broad selection of hotspots, highlights, events and other activities to help you get to know the design capital of the Netherlands. Visit the city center for some shopping and dining, wander through Eindhoven's technological past and future at the Strijp-S site or explore one of the other exciting city districts. Discover Eindhoven's vibe, both in popular hangouts and off the beaten track.

Further useful info:

- Tourist information: [www.thisiseindhoven.com](http://www.thisiseindhoven.com)
- Event Glow Eindhoven: [www.gloweindhoven.nl/nl](http://www.gloweindhoven.nl/nl), This is a really nice event which takes place during the workshop

## Wireless Internet

---



Wireless Internet is available in all buildings on the TU/e campus.

### Guest WiFi

External visitors may use Internet via the guest WiFi. All you need to do is accept the general conditions and you are immediately on-line as a guest. Access to the network is provided in 4-hour sessions. After a session expires, you must connect again to continue surfing.  
The TU/e also provides Eduroam hotspots ([www.eduroam.org](http://www.eduroam.org)).

## Contact person at TU/e

---

Linda Essink, Secretary Energy Technology  
Fluid Dynamics  
Department of Mechanical Engineering  
Eindhoven University of Technology  
[l.i.m.essink@tue.nl](mailto:l.i.m.essink@tue.nl)  
+31 (0) 40 247 3517  
[www.tue.nl](http://www.tue.nl)