Reporting Period: 1 January 2018 – 31 December 2018

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General details

1a. Details of programme leader

-Name, title(s): Prof. dr. A. Polman
-Affiliation: AMOLF
-Telephone: 020-7547100
-Email: polman@amolf.nl

1c. Title of research programme/project

Light management in new photovoltaic materials (LMPV)

1d. Programme/project number

FOM-131 (ISAAC **680.92.12.02)**

Grant details

2. Recruitment efforts, assignments and purchase of equipment

Since the start of the LMPV program in 2012, the personnel has strongly grown. The first three PhD students (Sander Mann, Sebastian Oener, and Freddy Rabouw) funded by LMPV have graduated in 2015/2016 (two *cum laude*) and have left the LMPV programme. They have all found postdoc positions at esteemed universities abroad. Rabouw is now associate professor at Utrecht University.

Personnel funded by the LMPV grant (situation 2018)

Name	Position	Group	Start date	End date	LMPV grant
Erik Garnett	Group leader	Garnett	1-9-2012		NWO part
Bruno Ehrler	Group leader	Ehrler	1-11-2014		NWO part
Esther Alarcon Llado	Group leader	Alarcón Lladó	1-2-2016		AMOLF part
Tianyi Wang	PhD student	Ehrler	1-12-2014	31-3-2019	NWO part
Dibyashree Koushik	PhD student	Creatore/Kessels	1-6-2015	31-5-2019	NWO part
Mark Aarts	PhD student	Alarcón Lladó	16-6-2016	15-6-2020	AMOLF part
Nasim Tavakoli	PhD student	Alarcón Lladó	16-11-2016	15-11-2020	AMOLF part
Jian-Yao Zheng	Postdoc	Garnett	16-10-2018	15-10-2020	NWO part
Ju Min Lee	Postdoc	Ehrler	1-3-2015	28-2-2018	NWO part
Eline Hutter	Postdoc	Ehrler	1-11-2018	31-10-2021	NWO part
Marco Valenti	Postdoc	Alarcón Lladó	1-04-2018	31-03-2021	NWO part
Marc Duursma	Technician	LMPV	1-1-2015	31-12-2020	NWO part
Hans Zeijlemaker	Technician	LMPV	1-1-2017	15-11-2020	AMOLF part
Wim Sinke	Advisor (0.1 fte)	Polman	1-4-2013		NWO part
Albert Polman	Programme leader	Polman	1-9-2011		AMOLF

Personnel funded by additional PV grants acquired by the LMPV group leaders (situation 2018)

Name	Position	Group	Start date	End date	Grant
Gede Adhyaksa	PhD student	Garnett	16-2-2014	15-2-2018	ERC/COMPASS
Jenny Kontoleta	PhD student	Garnett	1-9-2015	6-9-2019	NWO PHNA
Moritz Futscher	PhD student	Ehrler	1-12-2015	30-11-2019	FOM projectruimte
Benjamin Daiber	PhD student	Ehrler	1-9-2016	31-8-2020	TKI program
Verena Neder	PhD student	Polman	16-9-2016	15-9-2020	UvA/NWO-JSP
Harshal Agrawal	PhD student	Garnett	16-10-2016	15-10-2020	VIDI

Christian Dieleman	PhD student	Ehrler	16-1-2017	15-2-2021	AMOLF/ARCNL
Andrea Cordaro	PhD student	Polman	1-9-2017	31-8-2020	UvA
Tom Veeken	PhD student	Polman	16-9-2017	15-9-2021	NWO-Philips IPP
Stefan Tabernig	PhD student	Polman	16-10-2018	15-10-2022	NWO Mat4Sus
Parisa Khoram	PhD student	Garnett	1-1-2014	30-04-2018	ERC/Philips IPP
Hongyu Sun	PhD student	Garnett	1-10-2018	30-09-2022	NWO JSPIII
Julia van der Burgt	PhD student	Garnett	11-12-2017	10-12-2021	NWO Mat4Sus
Loreta Muscarella	PhD student	Ehrler	01-01-2018	31-12-2021	VIDI
Lucie McGovern	PhD student	Ehrler	8-01-2018	7-01-2022	VIDI
Eitan Oksenberg	Postdoc	Garnett	1-12-2018	30-11-2020	Top sector energy
Biplap Patra	Postdoc	Garnett	1-11-2016	31-10-2019	VIDI
Nick Schilder	Postdoc	Polman	1-1-2017	31-12-2019	ERC
Sven Askes	Postdoc	Garnett	1-6-2017	31-5-2019	NWO PHNA
Sophie Meuret	Postdoc	Polman	1-1-2016	15-11-2018	ERC
Piero Spinelli	Guest (0.2 fte)	Polman	1-12-2017	30-9-2018	ECN
Paula Bronsveld	Guest (0.2 fte)	Polman	1-12-2017		ECN
Mike Ah Sen	Guest (0.2 fte)	Polman	1-10-2018		ECN
Vacancy	PhD student	Ehrler			NWO Mat4Sus

3. Realisation programme/project expenses

Not applicable.

Specific progress in the reporting period

4. Specific aims of the reporting period

The FOM/NWO Focus Group "Light Management in New Photovoltaic Materials" (LMPV) was established at AMOLF in 2012, as one of the strategic initiatives of FOM to strengthen research on renewable energy in the Netherlands. The goal of the LMPV program is to develop fundamental understanding of the interaction of light with photovoltaic nanomaterials, and apply this knowledge to -eventually- realize photovoltaic conversion concepts that surpass existing technology. The LMPV research program targets three long-term efficiency goals: (1) *towards 30% efficiency*: light coupling, trapping and carrier collection geometries to reach or stretch the ultimate limits of Si technology; (2) *30-40% efficiency*: hybrid solar cell geometries based on organic/inorganic materials, and thin-film/wafer-Si tandem cells; (3) *beyond 40% efficiency:* novel III-V nanowire geometries and other hybrid material combinations on the nanoscale. The program brings together expertise in fundamental nanophotonics, materials synthesis, device physics, spectroscopy, nanofabrication, and nanocharacterization.

Achieving the goals of the program requires synthesis and development of entirely new materials and solar cell architectures, and fundamental research on hybridizing strategies combining concepts from dielectrics and metamaterials, to managing light on length scales from the molecular scale to that of a solar panel, and to harness extreme materials properties to reach the efficiency limits governed by reciprocity and thermodynamics. The LMPV program's primary goal is to achieve fundamental understanding of basic physical phenomena that are relevant for future (>5-10 years) application in photovoltaics. In many cases, demonstrator devices are made as well, either at AMOLF or with external collaborators.

The LMPV Focus Group research is carried out under the supervision of three group leaders that were hired at AMOLF on a tenure-track position (Erik Garnett, Bruno Ehrler, Esther Alarcón Llado) and the program leader, Albert Polman. In 2017, Erik Garnett received tenure at AMOLF and was appointed professor by special appointment at the UvA. Aside from the research at AMOLF, the LMPV program has funded two satellite PhD projects in the groups of Daniel Vanmaekelbergh (UU) and Ruud Schropp (later Adriana Creatore/Erwin Kessels) (TUE).

The LMPV Focus Group is funded by FOM/NWO (5.400 k€) and AMOLF (2.270 k€) for the period 2011-2019. The four research groups also acquire additional funds to expand their groups. So far 13.878 k€ was raised from projects funded by FOM, NWO, TKI, ERC, etc.. These external funds are an essential aspect of the LMPV program, and have enabled the program to grow to its present size of ~30 researchers (excluding masters students).

5. Deviations from original plan

The LMPV program is fully on schedule.

6. Programme/project results of the reporting period

6a. Scientific highlights

Quantum wires enhance radiative recombination rate and photoluminescence quantum yield
Erik Garnett (group Garnett)
Halide perovskite vertical nanowire arrays have been fabricated in anodic aluminium oxide (AAO) nanoporous templates with diameter from far above the exciton Bohr radius to well below it. Photoluminescence lifetime and quantum yield (PLQY) measurements were used to demonstrate that the quantum confinement increases the radiative recombination rate by a factor of 54 and the light outcoupling by a factor of 2.2, leading to an increase in PLQY by a factor of 130. This was enabled by an ultralow surface recombination velocity of 18 cm/s, arising from outstanding surface passivation from the AAO template. Photodetectors made from the quantum wires also showed superior stability to both thin films and larger diameter nanowires.

Molecular coupling needs to be in balance for efficient singlet fission
Tianyi Wang (group Ehrler)
Singlet fission is a process in organic semiconductors that allows converting one high-energy photon into two lower-energy excited states. This downconversion could help to make much better use of the high-energy part of the solar spectrum. Singlet fission is known since the 1960s, but we still do not understand the microscopic mechanism fully. For example, it is not clear how molecular coupling influences the rate of singlet fission. We have used hydrostatic pressure to measure the ultrafast (picosecond) dynamics of a singlet fission material (rubrene). The applied pressure reduces the intermolecular distance, and hence increases the coupling between the molecules. We found that singlet fission becomes more efficient for materials where coupling limits the rate (amorphous rubrene). However, if the coupling is already high (crystalline rubrene), higher coupling can affect the energy alignment between the states leading to a reduced singlet fission rate.

Optically coupled ultrathin cells for tandem PV
Nasim Tavakoli (group Alarcón Llado)
Introducing high efficiency, thin and light weight Si-based tandem cells is a next major step towards integrating highly efficient solar cells into urban landscapes and technologies. We have designed an optically coupled tandem cell consisting of a GaAs nanowire array cell on a micrometer-thick Si cell. The coupling of solar light to guided modes of the 1D wires not only boosts the absorption in the wires, but also efficiently transfers the below bandgap photons to the Si bottom cell. By the array diffraction the momentum of the transmitted light is matched to that of guided modes of the 2D Si thin film. Consequently, infrared light is up to four times more efficiently trapped in the Si bottom cell compared to when the film is not covered by the nanowires.

Nanoscale additive manufacturing
Mark Aarts (group Alarcón Llado)
Electrocrystallization (the reduction or oxidation of ions at an electrode into crystalline solid matter) can revolutionize the fabrication of nanoscale-based (opto)electronic devices. While the biggest challenge is the controlled down-scaling of chemical reactions, we have demonstrated highly localized electro-

deposition of metal nanostructures beyond cluster size, with lateral dimensions down to tens of nanometers and thickness up to a few hundredths, by using electrochemical atomic force microscopy.

Atomic layer deposition fills nanogaps for solar cell passivation

Dibyashree Koushik (group Cretaore/Kessels)

Koushik applied in situ infrared (IR) spectroscopy and X-ray photoelectron spectroscopy (XPS) to study the ALD growth of Al_2O_3 on methylammonium lead halide perovskite films. She has shown that ALD reactions are limited to the sub-surface region of the perovskite and that the methylammonium group is abstracted during TMA interaction with the perovskite, whereas the inorganic counterpart stays unaffected. Koushik utilized Doppler-broadening positron annihilation spectroscopy (DB-PAS) to investigate for the first time whether ALD growth affects the open volumes of the perovskite. In addition, she proved that when perovskite films are decorated with ultrathin ALD Al_2O_3, the later suppresses the changes in open volumes and chemical transformations of the perovskite under exposure to ambient air. The research line is in collaboration with TUD (dr. Eijt).

Furthermore, she also worked on the development of metal oxide hole transport layers, such as NiO for single junction perovskite solar cells as well as for tandem perovskite/CIGS devices. This research is in collaboration with the Helmholtz Institute in Berlin (dr. Albrecht) and with University of Valencia (prof. Bolink).

Combined metagratings for efficient broad-angle scattering metasurface

Verena Neder (group Polman)

Spectrally controlled diffusion and reflection of light are key operations for light management in many optical devices. Integration of this operation in complex nanophotonic devices requires a 2D interface that provides tailored spectrum and directivity control. We developed a metagrating superstructure that realizes a resonant light reflector with tailored angular scattering profile. Millimeter-sized metasurfaces are built from arrays of combined supercells of 20-50 μm, composed of 5-7 differently pitched metagratings that tailor at will and with large efficiency the angular response. Each supercell is composed of one or more Si Mie resonators, arranged in a periodic array above a Ag back plane and tailored to resonantly scatter light at 650 nm into only the ± 1 diffraction orders with very high efficiency. By varying the pitch and supercell design, we can tailor the overall metasurface reflection profile with large flexibility, realizing a broad-angle Lambertian-type scattering metasurface, as well as a large-angle (35-75°) scattering metasurface, both with resonant optical scattering efficiencies above 70%. These ultra-thin structures, fabricated using thin-film deposition, electron beam lithography and reactive ion etching, can find applications for light trapping and spectrum splitting in solar cells and other devices.

6b. Valorisation, outreach and patents

See under 10.

6c. Status Milestones & Deliverables

This work concerns long-term fundamental research and does not involve milestones and deliverables; it targets high-quality science.

6d. Status secondments

Not applicable.

6e. Added value of the programme

The LMPV program acts as a strong team with many collaborations between the four groups. Laboratory equipment, cleanroom facilities and optical characterization tools are shared between groups. Several teams of PhD students/postdocs from different groups work on joint projects.

LMPV progress meetings

The LMPV program holds quarterly *Progress Meetings* at AMOLF. Each meeting has the following schedule:

- Invited presentation by an external speaker from another Dutch university/institute.
- Oral presentation of new LMPV team members presenting their project goal and planning
- Poster session at which all LPMV team members present their work.
- 1-slide oral presentations of all collaborative projects between two or more research groups.
- Plenary discussion on new developments, equipment, collaborations.

LMPV/Nanophotonics colloquia, meetings

The LMPV program is tightly incorporated in the Center for Nanophotonics at AMOLF. This encourages our researchers to incorporate the latest developments in fundamental nanophotonics in solar cell devices. Every week, AMOLF's Nanophotonics department, which is composed of seven research groups including the four LMPV groups, holds the "Nanophotonics colloquium". The program is alternatingly a colloquium in which two PhD students, postdocs or master students give a 45 min. presentation, or a poster session in which every group presents one or two posters. The seven Nanophotonics/photovoltaics group leaders hold a weekly work lunch to coordinate activities and discuss recent developments. In addition, the four LMPV group leaders hold a bi-weekly meeting to discuss LMPV-related items.

LMPV summer symposia

The LMPV program holds a yearly summer symposium for which the entire Dutch PV research community is invited. Erik Garnett, Bruno Ehrler and Esther Alarcón Llado serve as symposium chairs. The LMPV summer symposium on June 15, 2018 attracted around 80 attendees. Plenary speakers were Silke H. Christiansen (Helmholtz Center Berlin): *Nanomaterials for solar cells,* Aditya Mohite (Los Alamos National Laboratory/Rice University), *Hybrid perovskites: An ideal materials platform with emergent functional properties*, Varun Sivaram (Council on Foreign Relations): *Taming the Sun: Innovations to Harness Solar Energy and Power the Planet,* and Filippo de Angelis (University of Perugia): *Electronic structure and the success of lead-halide perovskites in photovoltaics.* A lively poster session was also held.

National coordination of PV research

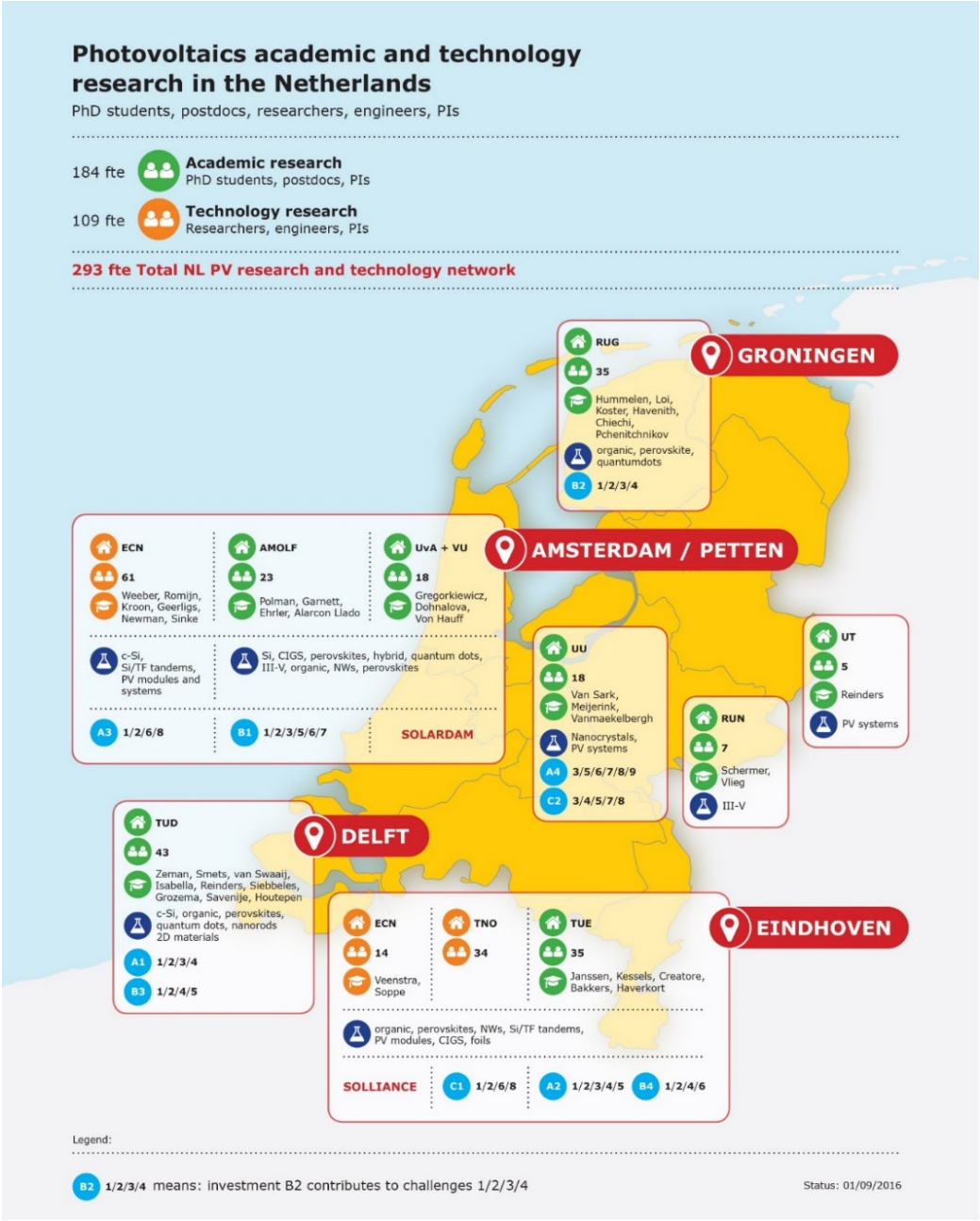
One of the LMPV programs' goals is to help coordinate PV research in the Netherlands. Coordination can lead to enhanced collaboration between groups across the Netherlands, better sharing of resources, and more efficient transfer of ideas to applications. And in general, coordination increases the visibility and voice of PV science and technology in the Netherlands and abroad.

Albert Polman chaired the report "Dutch Materials – Challenges for materials science in the Netherlands" that now plays a central role in strategic planning of NWO, with "materials for sustainable energy production and storage" as one of the six themes. A Theme Committee Materials Science now coordinates the initiatives to start programmatic materials calls within NWO. As a first initiative, the Theme Committee coordinated the Program Call entitled "Materials for Sustainability (Mat4Sus)" with a total budget of 9 M€. In January 2018, 15 projects were awarded to groups at WUR, TUD, RUN, TUE, UvA, UL, RUG, UT, UU and AMOLF.

As a parallel initiative a route was established in the National Science Agenda (NWA), entitled "Materials – made in Holland", in which research on photovoltaic materials is one of the key themes. This initiative was carried out by a Steering Committee chaired by Albert Polman. In June 2018 a workshop was held at AMOLF that attracted 80 participants, with the aim to help form consortia that would submit proposals to the NWA Call in September 2018. A total of 16 materials-related NWA proposals were submitted in 2018.

National PV research network SOLARLab

In 2017, LMPV took the initiative to bring together all Dutch PIs in PV research in order draft a joint strategic vision for photovoltaics research in the Netherlands. The 35 PIs represent over 180 PhD students and postdocs at academic institutions, and over 100 technical specialists at ECN and TNO. The new national PV network, named SOLARLab, aims to carry out a national joint research program towards ultrahigh-efficiency and low-cost photovoltaics. It is led by a Steering committee composed of Albert Polman (chair), Kees Hummelen/Maria Loi (RUG), René Janssen (TUE), Arno Smets (TUD), Wim Sinke (ECN part of TNO), and Ronn Andriessen (TNO/Solliance). The Steering committee held several meetings in 2018.



SOLARLab Dutch photovoltaics network coordinated by LMPV. The Dutch PV network is composed of over 180 academic researchers and over 100 research engineers in 4 main hubs: Groningen, Delft, Eindhoven and Amsterdam/Petten. Smaller groups are active in Utrecht, Nijmegen and Enschede. Names of PIs, group size, and expertise, are indicated.

The aim of the Steering committee is to coordinate national PV research. Being a community that is organized on a national scale is beneficial when funding becomes available for large-scale initiatives such as the NWA and the upcoming Mission-driven knowledge and innovation programsin for the national climate agreement. The SOLARLab Steering Committee also coordinates contacts with industrial partners for co-funding. In 2018, the Steering Committee coordinated the submission of the ENW-PPS program *Nanolayer and Interface Innovation for Silicon Solar Cells* that is presently under review at NWO. A major initiative in 2018 was the submission of an NWA proposal on behalf of all Dutch PV groups entitled: "SOLAR: every surface generates renewable energy". Two Workshops were held at AMOLF with all participants in February 2018 and October 2018. A total amount of 1.3 M€ in co-funding was attracted from industrial and other participants. Unfortunately, the proposal was not selected for the full proposal round. The Steering

Committee now helps support two new proposals for the 2019 NWA route. Furthermore, the steering committee is preparing for the new call for Mission–driven innovation programs in the National Climate agreement.

New projects awarded to LMPV in 2018

In 2018, the LMPV team was awarded an ERC Proof of Concept grant for the development of a table-top cathodoluminescence (CL) microscope. Such an instrument can be used as a tool for nanoscale inspection of PV materials. Furthermore, the Australian Center for Advanced Photovoltaics awarded two collaboration grants for joint research between LMPV and the University of New South Wales, one on CL characterization of PV materials, and one on quantum dot solar cells. Also in 2018, ASML awarded LMPV with a used transmission electron microscope (TEM) for characterization of PV materials. An overview of the externally acquired projects for the LMPV team for 2018 is given in the Table below. The total amount of project funding acquired by LMPV since the start of the program in 2012 is 13.878 k€. This is 2.6 times the initial FOM/NWO grant.

Funding Agency	PI	Project title	Collaborators	Budget (k€)
ERC Proof of Concept	Polman	Table-top cathodoluminescence microscope		150
ASML	Garnett	Transmission electron microscope (TEM)	AMOLF, UvA, VU, ARCNL	200 (In-kind)
ACAP Collaboration Grant (Australia)	Polman	Development of CL characterisation techniques for silicon and CZTS solar cells	UNSW	39
ACAP Collaboration Grant (Australia)	Polman	Development of quantum dot solar Inks for economical massive-scale production of photovoltaic cells	UNSW	39
TOTAL				**428**

NON CONFIDENTIAL Results / highlights

7. Results and highlights of the reporting period of interest to the general public

Please, provide results/highlights of the programme/project in easily accessible language (in Dutch).

Dit onderzoekprogramma richt zich op het ontwikkelen van nieuwe materialen en structuren voor het maken van zonnecellen met een hoger rendement die kunnen worden gemaakt voor lagere kosten, en gebruikt in speciale toepassingen. We vonden onder meer dat in perovskite nanodraden de stralingsefficientie meer dan een factor honderd is verhoogd; door organische lagen onder hydrostatosche druk te zetten ontdekten begrijpen we beter hoe singlet fission in zijn werk gaat en we ontwierpen een flexibele tandemzonnecel op een ultradun silicon substraat. Daarnaast ontwikkelden we een gelocaliseerde electrodepositietechniek voor metaal-nanostructuren, een nieuwe methode om perovskietoppervlakken te passiveren, en een geometrie om gekleurde zonnepanelen te maken met een hoekonafhankelijk aanzicht.

Plan for next reporting period

8. Plan for next reporting period

The focus for Garnett's group for the next year will be on using directional emission in nanophotonics structures to eliminate reabsorption and waveguide escape losses in luminescent solar concentrators. Aligned halide perovskite quantum wires, quantum wells and quantum dots will be combined with nanophotonic lenses, directional metasurfaces and non-reciprocal waveguides. Nanomaterials will be screened for photoluminescence quantum yield approaching 100% and for chiral light emission. New hybrid perovskites with chiral organic anions will be explored to reach high levels of spin-polarized emission. Our

genetic algorithm for creating high directivity (>100) nanolenses will be used to make ideal (chiral) metasurfaces for non-reciprocal light guiding. Our roll-to-roll nanoscale transfer printing will be explored as an option for scalable fabrication of these metasurfaces and used to create mutual alignment between emitters and dielectric light-directing nanostructures (nanolenses or metasurfaces).

Ehrler's group will put emphasis on understanding ion migration in halide perovskites. This migration has been shown to be strongly related to device degradation, and many of the improvements in stability and efficiency with mixed halide perovskites or additives have been assigned to a suppression of ion migration. We have recently established transient ion-drift, a technique to accurately measure the activation energy, diffusion coefficient, and density of mobile anions and cations. We will study how and where ions migrate and how the different materials and additives, fabrication conditions, and degradation affect the ion migration. This knowledge will allow to guide the development of new stable and efficient perovskite materials.

In the next year, Alarcón Lladó's group will focus on the "low-cost" electrochemical fabrication of III-V semiconductor nanostructures (such as GaAs), where understanding and controlling the growth with optical probes will lead to improved material quality. New optical coupling strategies in ultrathin tandem cells will be also explored in the framework of multi-hyperuniform nanostructure arrangements. While patterns with correlated disorder offer the possibility to tailor light reflection and transmission in the k-space, different nanostructure morphologies control the efficiency of light-matter interactions in the energy space. By combining both, we will maximize light absorption with minimal material usage.

Polman's group will focus on using the metagrating concept described above for spectrum splitting and light trapping in Si/perovskite tandem solar cells. We will investigate directional emission from quantum dots coupled to Mie resonators to enhance Si-based singlet fission solar cells. We will also further explore the use of cathodoluminescence lifetime imaging as a tool to characterize the electrical quality of PV materials.

The experimental work for Koushik's project at TUE has been completed; her PhD contract ends on May 31, 2019. The remaining time will be dedicated to write the thesis.

Programme meetings

9. Programme meetings

Number of programme meetings held in this reporting period: 4

Meeting type	Date	Location	Attendants
LMPV quarterly meeting	2-2-2018	AMOLF	30
LMPV quarterly meeting	23-5-2018	AMOLF	30
LMPV quarterly meeting	10-10-2018	AMOLF	30
LMPV annular summer symposium	15-6-2018	AMOLF	80

Dissemination of results

10. Dissemination activities of the results

(personnel directly funded by LMPV underlined)

1. Academic publications

a. Peer reviewed Publications

Since the start of LMPV in 2012, 119 articles from LMPV research (LMPV grant + additionally acquired grants) have been published in peer-reviewed international journals. Below, the papers published in 2018 are listed.

Personnel directly funded by LMPV

1. G.W.P. Adhyaksa, S. Brittman, H. Abolins, A. Lof, X. Li, J.D. Keelor, Y. Luo, T. Duevski, R.M.A. Heeren, S. R. Ellis, D. Fenning and E. C. Garnett, *Understanding Detrimental and Beneficial Grain Boundary Effects in Halide Perovskites*, Adv. Mater. **30**, 52: 1804792: 1-9 (2018).
2. E. Johlin, S. Mann, S. Kasture, A.F. Koenderink and E. C. Garnett, *Broadband highly directive 3D nanophotonic lenses*, Nature Commun. **9**, 4742: 1-8 (2018).
3. P. Khoram, S. Z. Oener, Q. Zhang, Z. Fan and E. C. Garnett, *Surface recombination velocity of methylammonium lead bromide nanowires in anodic aluminium oxide templates*, Mol. Syst. Des. Eng, (2018).
4. J. E. M. Haverkort, E. C. Garnett and E. P. A. M. Bakkers, *Fundamentals of the nanowire solar cell: Optimization of the open circuit voltage*, Appl. Phys. Rev **5**, 3: 031106 (2018).
5. G. DeLuca, A.N. Jumabekov, Y. Hu, A.N. Simonov, J. Lu, B. Tan, G.W.P. Adhyaksa, E. C. Garnett, E. Reichmanis, A.S.R. Chesman and U. Bach, *Transparent Quasi-Interdigitated Electrodes for Semi-transparent Perovskite Back-Contact Solar Cells*, ACS Appl.Energy Mater. **1**, 9: 4473-4478 (2018).
6. S. Z. Oener, A. Cavalli, H. Sun, J. E. M. Haverkort, E. P. A. M. Bakkers and E. C. Garnett, *Charge carrier-selective contacts for nanowire solar cells*, Nature Commun. **9**, 3248 (2018).
7. E. Kontoleta, S. Askes, L.H. Lai and E. C. Garnett, *Localized photodeposition of catalysts using nanophotonic resonances in silicon photocathodes*, Beilstein J. Nanotechnol. **9**, 2097-2105. (2018).
8. T. Holtus, L. Helmbrecht, H.C. Hendrikse, I. Baglai, S. Meuret, G.W.P. Adhyaksa, E. C. Garnett and W.L. Noorduin, *Shape-preserving transformation of carbonate minerals into lead halide perovskite semiconductors based on ion exchange/insertion reactions*, Nature Chem. **10**, 740-745 (2018).
9. I.A. Digdaya, B. J. Trzesniewski, G.W.P. Adhyaksa, E. C. Garnett and W. A. Smith, *General Considerations for Improving Photovoltage in Metal-Insulator-Semicondutor Photoanodes*, J. Phys. Chem. C **122**, 5462-5471 (2018).
10. S-H. Gong, F. Alpeggiani, B. Sciacca, E. C. Garnett and L. Kuipers, *Nanoscale chiral valley-photon interface through optical spin-orbit coupling*, Science **359**, 443-447 (2018).
11. M. Futscher, A. Rao and B. Ehrler, *The Potential of Singlet Fission Photon Multipliers as an Alternative to Silicon-based Tandem Solar Cells*, ACS Energy Lett. **3**, 2587-2592 (2018).
12. S.W. Tabernig, B. Daiber, T. Wang and B. Ehrler, *Enhancing silicon solar cells with singlet fission: the case for Foerster resonant energy transfer using a quantum dot intermediate*, J. Photonics Energy **8**, 022008: 1-12 (2018).
13. L. Song, T. Wang, V. Koerstgens, W.J. Wang, N. Saxena, C.J. Schaffer, T. Fröschl, N. Huesing and S. Bernstorff, *Wet Imprinting of Channel-Type Su in Nanostructured Titania Thin Films at Low Temperatures for Hybrid Solar Cells*, ChemSusChem **11**: 1179-1186 (2018).
14. S. Ardo, D. Fernandez Rivas, M.A. Modestino, V. Schulze Greiving, F.F. Abdi, E. Alarcón-Lladó, V. Artero, K. Ayers, C. Battaglia, J.P. Becker, D. Bederak, A. Berger, F. Buda, E. Chinello, B. Dam, V. Di Palma, T. Edvinsson, K. Fujii, H. Gardeniers, H. Geerlings, M. Hashemi Shabestari, S. Haussener, F. Houle, J. Huskens, B.D. James, K. Konrad, A. Kudo, P. Patil Kunturu, D. Lohse, B. Mei, E.L. Miller, G.F. Moore, J. Muller, K.L. Orchard, T.E. Rosser, F.H. Saadi, J.M. Schüttauf, B. Seger, S.W. Sheehan, W. A. Smith, J. Spurgeon, M.H. Tang, R. van de Krol, P.C.K. Vesborgag and P. Westerik, *Pathways to electrochemical solar-hydrogen technologies*, Energy Environ. Sci. **11**, 2768-2783 (2018).
15. Y. Kuang, V. Zardetto, R. van Gils, S. Karwal, D. Koushik, M. A. Verheijen, L. E. Black, C. Weijtens, S. Veenstra, R. Andriessen, W. M. M. Kessels and M. Creatore, Low-Temperature Plasma-Assisted Atomic-Layer-Deposited SnO_2 as an Electron Transport Layer in Planar Perovskite Solar Cells. ACS App. Mater. Interf. **10**, 30367 (2018)
16. M. Najafi, V. Zardetto, D. Zhang, D. Koushik, M. S. Dörenkämper, M. Creatore, R. Andriessen, P. Poodt and S. Veenstra, Highly Efficient and Stable Semi-Transparent p-i-n Planar Perovskite

Solar Cells by Atmospheric Pressure Spatial Atomic Layer Deposited ZnO. Solar RRL **2**, 1800147 (2018)

17. D. Koushik, W. J. H. Verhees, D. Zhang, Y. Kuang, S. Veenstra, M. Creatore and R. E. I. Schropp, Atomic Layer Deposition Enabled Perovskite/PEDOT Solar Cells in a Regular n–i–p Architectural Design. Adv. Mater. Interf. **4**, 1700043 (2017) (not reported in Year Report 2017)
18. D. Koushik, W. J. H. Verhees, Y. Kuang, S. Veenstra, D. Zhang, M. A. Verheijen, M. Creatore and R. E. I. Schropp, High-efficiency humidity-stable planar perovskite solar cells based on atomic layer architecture. En. Env. Science **10**, 91 (2017) (not reported in Year Report 2017)
19. H. A. Gatz, D. Koushik, J. K. Rath, W. M. M. Kessels and R. E. I. Schropp, Atomic Layer Deposited ZnO: B As Transparent Conductive Oxide for Increased Short Circuit Current Density in Silicon Heterojunction Solar Cells. Energy Procedia **92**, 624 92016) (not reported in Year Report 2016)

Personnel funded from PV projects acquired by LMPV group leaders

20. A.S. Brittman and J. Luo, Promising Beginning for Perovskite Nanocrystals, Nano Lett. **18**, 2747 (2018)
21. H. Kwon, D. Sounas, A. Cordaro, A. Polman, and A. Alù, Nonlocal metasurfaces for optical signal processing, Phys. Rev. Lett. **121**, 173004 (2018)
22. L. Gagliano, M. Kruijsse, J.D.D. Schefold, A. Belabbes, M.A. Verheijen, S. Meuret, S. Koelling, A. Polman, F. Bechstedt, J.E.M. Haverkort, and E.P.A.M. Bakkers, Efficient green emission from wurtzite $Al_xIn_{1-x}P$ nanowires, Nano Lett. **18**, 3543 (2018)
23. S. Meuret, T. Coenen, S. Woo, Y.-H. Ra, Z. Mi and A. Polman, Nanoscale relative emission efficiency mapping using CL g(2) imaging, Nano Lett. **18**, 2288 (2018)

b. Publications in proceedings or other journals

N/A

c. Contributions to scientific books (chapters or entire book)

N/A

d. PhD theses

Personnel funded from PV projects acquired by LMPV group leaders

1. G.W.P. Adhyaksa, Understanding Losses in Halide Perovskite Thin Films, University of Amsterdam, 22-5-2018
2. P. Khoram, Monocrystalline halide perovskite nanostructures for optoelectronic applications, University of Amsterdam, 25-4-2018

e. Open Access publications

All papers above are Open Access.

2. Invited lectures, posters, awards and other activities

a. Invited lectures at international conferences and meetings

1. E.C. Garnett, What can nano really do for solar?, MRS Fall meeting, Boston, USA, November 26, 2018
2. E.C. Garnett, What can nano really do for solar?, Gordon Research Conference, Hong Kong, 18 June, 2018
3. B. Ehrler, Ion Migration in Halide Perovskites, SPIE Optics + Photonics, San Diego, 21-08-2018
4. B. Ehrler, Beyond Solar Cell Efficiency Limits with Singlet Fission, Frontiers in Nanoscience and Nanotechnology Symposium, University of Waterloo, WIN Rising Star Award lecture, 6-06-2018
5. B. Ehrler, Towards singlet-fission sensitized silicon solar cells, ISPF2 Singlet Fission conference, Gothenburg, 18-04-2018

6. E. Alarcon Llado, Managing the solar spectrum at subwavelength scales: Nanowire-enabled concepts for solar energy conversion, Spanish Conference on Nanophotonics (CEN2018), San Sebastian 2018
7. E. Alarcon Llado, Managing the solar spectrum at sub-wavelength scales, SPIE Optics+Photonics conference, San Diego, CA, USA, 2018
8. E. Alarcon Llado, Using Nanowires in Novel Device Concepts in Photovoltaics, Tutorial, MRS Fall Meeting, Boston, MA, USA, November 25-30, 2018
9. A. Polman, Silicon-based optical metasurfaces, International Conference on Nanoscience and Nanotechnology, Woollongong, Australia, January 29-February 2, 2018
10. A. Polman, Light management in photovoltaic materials (keynote), Energy Futures Symposium, UNSW, Sydney, Australia, February 5-7, 2018
11. A. Polman, Light management for high-efficiency flexible building- and landscape-integrated PV, Nanophotovoltaics Symposium, UNSW, Sydney, Australia, February 8, 2018
12. A. Polman, Silicon-based optical metasurfaces, MRS Spring Meeting, Phoenix, AZ, USA, April 2-6, 2018
13. S. Meuret, Complementary time-resolved cathodoluminescence imaging configurations in scanning electron microscopy, Workshop Cathodoluminescence of Semiconductor Nanostructures, Berlin, April 16-17, 2018
14. A. Polman, Light management and the dream of photovoltaic energy for 0.01 €/kWh, SPIE Photonics Europe, Strasbourg, France, April 22-26, 2018
15. A. Cordaro, Metasurface analog optical computing, SPIE Photonics Europe, Strasbourg, France, April 22-26, 2018
16. A. Polman, Optical nanoscopy using 30 keV electrons (keynote), Swiss Nanoconvention 2018, Zürich, June 6-7, 2018
17. A. Polman, Optical nanoscopy using 30 keV electrons, Gordon Research Conference on Plasmonics & Nanophotonics, Newry, ME, USA, July 8-13, 2018
18. A. Polman, Cathodoluminescence nanoscopy of Au nanostructures, Gold 2018, Paris, July 15-18, 2018,
19. S. Meuret, Time-resolved cathodoluminescence spectroscopy, International Microscopy Conference, Sydney, September 10-14, 2018
20. S. Meuret, Time-resolved cathodoluminescence spectroscopy, Conference women in science, Germany, September 28-30, 2018
21. A. Polman, Cathodoluminescence nanoscopy of Au nanostructures, Workshop Nanophotonics for Solar Energy, Berlin, October 17, 2018
22. A. Polman, Silicon-based optical metasurfaces, MRS Fall Meeting, Boston, MA, USA, November 25-30, 2018

b. Invited (inter)national seminars

1. E.C. Garnett, What can nano/perovskite really do for solar?, DIFFER seminar, 1 November, 2018, Eindhoven, NL
2. E.C. Garnett, What can nano really do for solar?, Lund University seminar, 20 September, 2018, Lund, SE
3. E.C. Garnett, What can nano really do for solar?, TU Delft seminar, 11 September, 2018, Delft, NL
4. E.C. Garnett, What can nano really do for solar?, RU Groningen seminar, 12 July, 2018, Groningen, NL
5. E.C. Garnett, What can nano really do for solar?, Leibniz INM, 6 February, 2018, Saarbrucken
6. B. Ehrler, Perovskites and Singlet fission: Can they be useful?, Clarendon Department, University of Oxford, 3-05-2018
7. B. Ehrler, Perovskites and Singlet fission: Can they be useful?, Optoelectronics Group, Cambridge University, 1-05-2018
8. E. Alarcon Llado, Design and characterization of nanostructured solar energy conversion devices, Utrecht University

9. E. Alarcon Llado, Managing the solar spectrum at sub-wavelength scales" at the PhotonicsEvent2018, Enschede
10. A. Polman, Time-resolved cathodoluminescence spectroscopy of optical metasurfaces, University of Sydney, February 5, 2018.
11. A. Polman, Light management and the dream of photovoltaic energy for 0.01 $/kWh, University of Toronto, July 5, 2018.
12. A. Polman, Optical nanoscopy with 30 keV electrons, Eindhoven University of Technology, October 25, 2018.
13. A. Polman, Smart materials processing to realize the solar revolution, 3TU Mechanical Engineering Conference, October 24, 2018
14. A. Polman, Time-resolved cathodoluminescence microscopy, University of Antwerpen, December 7, 2018

c. Other lectures, posters and contributed talks

Personnel directly funded by LMPV

1. T. Wang, Electronic Coupling—A Double-Edged Sword for Singlet Fission?, MRS Spring meeting Phoenix, AZ, USA, 05-04-2018 (oral)
2. M. Aarts, Additive electrochemical nanofabrication using close-proximity scanning probes, MRS Spring Meeting, Phoenix, AZ, USA (poster)
3. M. Aarts, Additive nanofabrication using EC-AFM in dilute electrolytes, Dutch Scanning Probe Microscopy Day, 2018 (oral)
4. M. Aarts, Electrochemical nanofabrication using scanning probes in dilute electrolytes, CHAINS 2018 (poster)
5. M. Aarts, Local Engineering of Solid/Electrolyte Energy Landscapes for Electrochemical Growth, Using SPM, Physics@Veldhoven, 2018 (poster)
6. N. Tavakoli, Combining 1D and 2D waveguiding properties for ultrathin tandem solar cells, MRS Spring Meeting, Phoenix, AZ, USA (oral)
7. N. Tavakoli, Combining 1D and 2D Waveguiding in GaAs-NW/Ultrathin-Si Tandem Solar Cells, NanoGe conference, 2018 (oral)
8. N. Tavakoli, Light Interaction with Standing GaAs Nanowires on Planar Silicon In a Multijunction Solar Cell, Physics@Veldhoven, 2018 (poster)
9. M. Valenti, Nanostructures for solar energy: from taming light to building nanoblocks, ICN+T conference, Brno (oral)
10. Y. Bleiji, M. Valenti, Electrochemical growth of InAs nanostructures, CHAINS 2018 (poster)
11. D. Koushik, Insights into ALD Al_2O_3 Growth on Hybrid Organic-Inorganic Perovskite Physics@Veldhoven, January 2018 (oral)
12. D. Koushik, In situ growth studies of atomic layer deposited Al_2O_3 on perovskites for efficient solar cells, Dutch Perovskite Workshop, June 2018 (poster)
13. D. Koushik, Insights into ALD Al_2O_3 Growth on Hybrid Organic-Inorganic Perovskite AVS65, October 2018 (oral)

Personnel funded from projects acquired by LMPV group leaders

1. S. Askes, Hot-electron driven photosynthesis of catalytic nanostructures, NanoBio, Heraklion, 27-9-2018
2. S. Askes, Preparation of plasmonic HfN nanoparticle arrays for hot-electron photochemistry, NanoOP, Rome, 1-10-2018
3. S. Askes, Preparation of plasmonic HfN nanoparticle arrays for hot-electron photochemistry, CHAINS, 5-12-2018, Veldhoven
4. J. Kontoleta, Does location matter?, Hot-electron driven selective photosynthesis of catalytic nanoparticles, NanoOp, 1-10-2018, Rome

5. J. Kontoleta, Deposition of Pt catalytic nanoparticles on Au/TiO_2 photoelectrodes using "hot-electron" chemistry, CHAINS, Veldhoven, 5 December 2018
6. S. Brittman, Understanding Grain Boundary Effects in Methylammonium Lead Bromide Films Using Electron Backscatter Diffraction (EBSD), MRS, 26-11-2018, Boston, USA
7. M. Futscher, The Sobering Reality of Perovskite/Si Tandem Solar Cells under Realistic Operation Conditions, Physics at Veldhoven Conference, Veldhoven, 24-1-2018
8. M. Futscher, Quantification of Ion Migration in CH3NH3PbI3 Perovskite Solar Cells by Deep Level Transient Spectroscopy, 2nd Asia-Pacific Hybrid and Organic Photovoltaics Conference, Kitakyushu, Japan, 29-1-2018
9. M. Futscher, Performance Limitations and Prospects of Perovskite/Silicon Tandem Solar Cells, 2nd Asia-Pacific Hybrid and Organic Photovoltaics Conference, Kitakyushu, Japan, 30-1-2018
10. M. Futscher, What is the Fate of Triplet Excitons? The Effect of Trap States on Singlet Fission Device Performance, MRS Spring Meeting, Phoenix, AZ, USA, 3-4-2018
11. M. Futscher, Towards Reducing Thermalization Losses in Silicon Solar Cells using Singlet Exciton Fission, MRS Spring Meeting, Phoenix, AZ, USA, 4-4-2018
12. M. Futscher, Performance Limitations and Prospects of Perovskite/Silicon Tandem Solar Cells, MRS Spring Meeting, Phoenix, AZ, USA, 4-4-2018
13. M. Futscher, Charge-Carrier Traps in Hybrid Perovskites and the Consequences for Solar Cells, MRS Spring Meeting, Phoenix, AZ, USA, 4-4-2018
14. M. Futscher, Ion migration in halide perovskites with potassium passivation, LMPV Summer Symposium, Amsterdam, 15-6-2018
15. M. Futscher, Quantification of Ion Migration in Perovskite Solar Cells, Gordon Research Seminar on Electronic Processes in Organic Materials, Lucca, Italy, 21-7-2018
16. M. Futscher, Quantification of Ion Migration in Perovskite Solar Cells, 4th International Conference on Perovskite Solar Cells and Optoelectronics, Lausanne, 2-10-2018
17. M. Futscher, Quantification of Ion Migration in Halide Perovskites with Potassium Passivation, MRS Fall Meeting, Boston, MA, USA, 26-11-2018
18. M. Futscher, The Potential of Singlet Fission Photon Multiplier as an Alternative to Silicon-Based Tandem Solar Cells, MRS Fall Meeting, Boston, MA, USA, 27-11-2018
19. B. Daiber, Energy Transfer from Crystalline Tetracene Islands into Silicon, MRS Spring Meeting, Phoenix, AZ, USA, 5-4-2018
20. B. Daiber, Towards Enhancing Silicon Solar Cells with Singlet Fission—The Case for Förster Resonant Energy Transfer Using a Quantum Dot Intermediate, MRS Spring Meeting, 5-4-2018
21. B. Daiber, The Influence of Cation Dipole Moment on the Indirect Bandgap in Lead Halide Perovskites, MRS Spring Meeting, Phoenix AZ, USA, 5-4-2018
22. B. Daiber, Towards energy transfer from crystalline tetracene islands into silicon, LMPV Symposium, Amsterdam, 15-6-2018
23. B. Daiber, Energy Transfer from Crystalline Tetracene Islands into Silicon, Gordon Conference Organic Materials, Lucca, Italy, 22-7-2018
24. B. Daiber, Towards energy transfer from crystalline tetracene islands into silicon, NNV AMO, Lunteren, 25-9-2018
25. L. McGovern, Managing triplet excitons in singlet fission sensitized pentacene solar cells, LMPV Summer Symposium 2018, 15-62018, Amsterdam.
26. C.D. Dieleman, Exploring Quantum Dots as Extreme UV Photoresist, MRS Spring Meeting, Phoenix, AZ, USA, 4-0-2018
27. C.D. Dieleman, Quantum Dots as New Generation Extreme UV Photoresist, Physics @Veldhoven, Veldhoven, 22-0-2018
28. C.D. Dieleman, Modeling Real-Life Performance of Photovoltaic Materials, MRS Spring Meeting, Phoenix, AZ, USA, 5-4-2018
29. C.D. Dieleman, Novel Materials as Extreme UV resist, LMPV Symposium, Amsterdam, 15-6-2018
30. C.D. Dieleman, Novel Materials as Extreme UV resist, AMOLF/ARCNL workshop, Amsterdam, 20-9-2018

31. C.D. Dieleman, Patterning Colloidal Quantum Dots on the Nanoscale using Electron Beam Lithography, AMOLF/ARCNL workshop, Amsterdam, 20-9-2018
32. C.D. Dieleman, Direct Patterning of Colloidal Quantum Dots at the Nanoscale using Electron Beam Lithography, Leelis-III, Amsterdam, 12-11-2018
33. V. Neder, Wide-angle-colored solar modules using integrated resonant dielectric nanoscatterers, Physics@Veldhoven, Veldhoven, January 23-24, 2018 (oral)
34. V. Neder, Lambertian scattering metasurface for photovoltaics, SPIE Photonics, Strasbourg, April 22-26, 2018 (oral)
35. V. Neder, Lambertian scattering metasurface for photovoltaics, LMPV Symposium, Amsterdam, 15-6-2018 (poster)
36. V. Neder, Ordered Lambertian scattering metasurface for photovoltaics, Workshop on Correlated Disorder, Hyperuniformity and Local Self-Uniformity, University of Surrey, Guildford, June 25-26, 2018 (poster)
37. V. Neder, Ordered Lambertian scattering metasurface for photovoltaics, Plasmonics and Nanophotonics GRC 2018, Newry, Maine, July 7-13, 2018 (poster)
38. V. Neder, Nanostructures to control spectrum and direction of light in PV architectures, Sunday 2018, Bussum, November 7, 2018 (oral)
39. T.P.N. Veeken, Waveguide-based spectrum-splitting concept for parallel-stacked tandem solar cells, Physics@Veldhoven, Veldhoven, January 23-24, 2018 (poster)
40. T.P.N. Veeken, Waveguide-based spectrum-splitting concept for parallel-stacked tandem solar cells, SPIE Photonics Europe: Photonics for Solar Energy Systems, Strasbourg, April 24, 2018 (oral)
41. T.P.N. Veeken, Directing quantum dot emission to enable tetracene-silicon singlet fission solar cells, Gordon Research Conference on Plasmonics & Nanophotonics, Newry, ME, USA, July 8-13, 2018 (poster)
42. T.P.N. Veeken, Directing quantum dot emission to enable tetracene-silicon singlet fission solar cells, LMPV Symposium, Amsterdam, 15-6-2018 (poster)
43. S. Meuret, Time-resolved cathodoluminescence spectroscopy, Workshop JEELS, Porquerolles, June 11-14, 2018 (oral)
44. S. Meuret, Time-resolved cathodoluminescence spectroscopy, GRS Seminar, Gordon Research Conference on Plasmonics & Nanophotonics, Newry, ME, USA, July 8-13, 2018 (poster)
45. A. Cordaro, Non-local computing metasurfaces performing mathematical operations, MURI annual review meeting, Austin TX, February 7, 2018 (poster)
46. A. Cordaro, Non-local computing metasurfaces performing mathematical operations, SPIE Europe, Strasbourg, April 22-26, 2018 (poster)
47. A. Cordaro, Non-local computing metasurfaces performing mathematical operations, CLEO 2018, San Jose CA, May 13-18, 2018 (oral)
48. A. Cordaro, Light management in III-V/Si tandem solar cells, LMPV Symposium, Amsterdam, 15-6-2018 (poster)
49. A. Cordaro, Non-local computing metasurfaces performing mathematical operations, GRC Nanophotonics Nanoplasmonics, Newry ME, July 8-13, 2018 (poster)
50. A. Cordaro, Non-local computing metasurfaces performing mathematical operations, International School of Physics "Enrico Fermi" - Nanoscale Quantum Optics, Varenna, July 23-28, 2018 (poster)

d. Awards and recognitions

1. B. Ehrler, WIN Rising Star Award, University of Waterloo, Canada
2. A. Polman, Highly cited researcher (Clarivate, Web of Science)
3. B. Daiber, Best Poster award, MRS Spring meeting, Phoenix, AZ, USA
4. T.P.N. Veeken, QHQC Award, Quantsol International Photovoltaics Summer School, Hirschegg, Austria, September 9, 2018
5. D. Koushik, James Harper award, American Vacuum Society Symposium, Long Beach (CA), October 2018

e. Board/Committee positions in congress organizations, scientific consortia, advisory councils, international panels, editorships at journals

1. E.C. Garnet, Co-organizer of LMPV annual workshop
2. B. Ehrler, Co-organizer of LMPV annual workshop
3. B. Ehrler, Organizer, focus session Physics@Veldhoven conference 2019 on spectroscopy for photovoltaics
4. B. Ehrler, Organizer, symposium for nanoGe Fall meeting 2019, Berlin
5. B. Ehrler, Hosting a "Perspective" article selection for J. Phys. Chem. Lett. on excitonic up- and down-conversion
6. E. Alarcon Llado, Co-organizer of LMPV annual workshop
7. E. Alarcon Llado, Program Committee Physics@Veldhoven 2019
8. E. Alarcon Llado, Editorial board member and Guest Editor for a special issue in Journal Physics D
9. A. Polman, Chair, Royal Netherlands Academy of Arts and Sciences (KNAW) new member selection jury domain NTW.
10. A. Polman, Member, Jury, EPS Research into the Science of Light Prize.
11. A. Polman, Chair, Awards committee, Materials Research Society (MRS).
12. A. Polman, Chair, NWO Theme Committee Materials Science.
13. A. Polman, Chair, National Science Agenda (NWA) Route Materials – made in Holland.
14. A. Polman, Chair, Steering Committee National SOLARLab initiative
15. A. Polman, Member, International Advisory Board, Winton Renewable Energy Program, Cambridge University, UK.
16. A. Polman, Member, Board of Reviewing Editors, Science (AAAS).
17. A. Polman, Member, Editorial Advisory Board ACS Photonics (American Chemical Society).
18. A. Polman, Member, Editorial Advisory Board Applied Physics Reviews (American Physical Society).
19. A. Polman, Member, Editorial Advisory Board Advanced Optical Materials (Wiley).
20. A. Polman, Member, Editorial Advisory Board Nano Letters (American Chemical Society).

3. Knowledge transfer (economic)

a. Patents

1. Y. Kuang, R.E.I. Schropp, D. Koushik, M. Creatore, S.C. Veenstra, Perovskite contacting protection layer for solar cells, WO 2018/007586 A1

b. Contacts with industry (including consultancy or other functions), new business activity resulting from projects

1. Research contract with Philips Research on nanophotonics, Industrial Partnership Program Nanophotonics for Solid State Lighting
2. Research collaboration with Philips Group Innovation IP&S, soft imprint lithography, organisation Workshop SCIL technology transfer, AMOLF, 1-10-2018
3. Research contract with Delmic on cathodoluminescence imaging spectroscopy.
4. Research contract with ThermoFischer/FEI on cathodoluminescence imaging spectroscopy.
5. Research contract with ECN part of TNO on light management in solar cells.
6. Research contract with Global Climate and Energy Program (GCEP, Stanford University), funded by ExxonMobil, GE, Schlumberger, and Toyota.
7. Research contract with Shell, Exasun, Eternal Sun, Levitech and Tempress Systems on development of Si-based tandem solar cells (JSP3)
8. Research contract with Toyota, Surfix and ECN as part of the Mat4Sus programme

c. Other professional products (software, prototypes, etc.)

1. Perovskite/CIGS tandem solar cell with thin conformal NiO layer with power conversion efficiency (PCE) of 21.6% on a 0.778 cm^2 device area; the highest PCE reported in the literature for such cells with such a large area.
2. Three cathodoluminescence spectroscopy systems developed at AMOLF were brought on the market by Delmic in 2018:
   - CL polarimetry system
   - CL lifetime imaging system
   - CL auto-correlation spectroscopy system

4. Teaching - knowledge transfer (societal)

1. E.C. Garnett, B. Ehrler, E. Alarcon Llado, W. Sinke, and A. Polman, Lectures in master course Advanced Materials and Energy Physics (AMEP), University of Amsterdam, the Netherlands.
2. E. Alarcon Llado, Guest lecture on "Nanomaterials for Solar Energy", AUC, Amsterdam
3. E. Alarcon Llado, lecture on Solar Fuels, the Free University of Madrid (UAM)
4. E.C. Garnett, Host of UvA Physics 1 week Research Practicum (4 students)

b. Masters and Bachelors theses

1. MSc thesis: Determining the resolution of coherent CL and characterization of optical materials, J. Schefold, University of Amsterdam, June 2018
2. MSc thesis: Morphologically induced strain on MoS2 vertical flakes for hydrogen evolution reaction, Jose Luis Ocana Pujol, University of Amsterdam, June 2018
3. MSc thesis: In Operando Oxygen Evolution Imaging, Suzan Marsman, Utrecht University, 2018
4. MSc thesis: Electrochemical atomic force microscopy for the direct writing of metal nanocrystals, Ilya Kolpakov, University of Amsterdam, June 2018
5. MSc thesis: Single Nanowire Solar Cells. Hongyu Sun, University of Amsterdam, 2018
6. MSc thesis: Nanophotonic Lenses for Directional Light Emission in Nanoscale Solar Cells, Niels Agterhorst, University of Amsterdam, 2018
7. MSc thesis: Singlet fission, energy transfer and computational methods, Roan van Leeuwen, VU University Amsterdam (co-supervised with Ivan Infante, VU) (2018)
8. MSc thesis: Förster resonance energy transfer from PbS quantum dots to silicon: The missing link towards singlet fission solar cells, Stefan Tabernig, University of Amsterdam (2018)
9. MSc thesis: Harnessing singlet exciton fission to enhance silicon solar cells through direct charge-transfer; Koen van den Hoven, University of Amsterdam (2018)
10. BSc thesis: Outdoor solar cell performance – Improving a diffuseness measurement tool; Merlijn Kersten, University College Amsterdam (2018)

5. Outreach - knowledge transfer (societal)

a. Performances on television, radio or at public events

1. The sun rises for free, public lecture, Australian National University, 24-1-2018.
2. Waar haal je de energie vandaan?, Universiteitsdag, University of Amsterdam, 9-6-2018.
3. Voor niets gaat de zon op, theatercollege en werkgroep, Werkgroep Natuurkunde didactiek, Noordwijk, 15-12-2018
4. De toekomst van de zonnecel, popular lecture at AMOLF Open Day

b. Publications in public magazines, newspapers or on the internet

1. Twitter account Bruno Ehrler, total tweet impressions in 2018: 246.900
2. Twitter account Albert Polman, total tweet impressions in 2018: 63.686
3. Solar Energy can do it, Amsterdam Science Magazine, May 2018
4. Interview to E. Alarcon for the Elektronica Magazine (https://www.engineersonline.nl/artikelen/id1537-zonnecellen-van-nanodraadjes-benutten-het-hele-zonnespectrum.html)

c. Other outreach activities

1. Several contributions to AMOLF Open Day: Make your solar cell from berries, Zonnecellen met gevoel voor kleur, Solar booth

12. Output in numbers

Output for the current reporting period (personnel directly funded by LMPV only)				
1.	Academic publications	19	Publications in refereed journals	
		0	Publications in other journals and other scientific output	
2.	Book contributions	0		
3.	Monographs	0		
4.	PhD theses	0		
5.	Professional publications and products	0		
6.	Patents	1		
7.	Other			
	Number of Open Access publications (sum of all OA publications under 1-7)	19		

13. Confidential information

Not applicable.