ILI 2014

Intelligent Lighting Institute | Edition 1, May 2014

/ Engineering natural light

/ Intelligent dynamic street lighting

/ Exploring the liberation of light

/ Color homogeneity in LED spotlights

/ Lighting control and interaction for the future

/ And more....

TU/e Technische Universiteit **Eindhoven** University of Technology

Cover: In a 240 meter long installation, OPENLIGHT demonstrated how colors are created in our minds.

TU/e Technische Universiteit Eindhoven University of Technology

Intelligent Lighting Institute

Sagitta Peters | Managing director

Welcome

Dear reader,

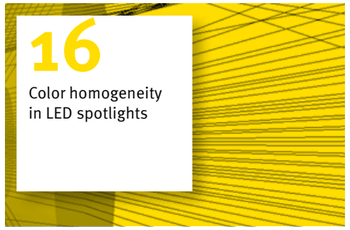
Since its start in 2010, the Intelligent Lighting Institute has created many opportunities for excellent research and education, all with 'engineering natural light' as the underlying theme. In this area many solutions for today's societal challenges will be provided, from energy saving to safety and wellbeing.

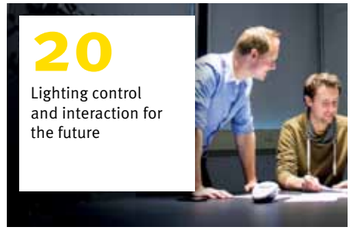
Within ILI we have set up successful collaborations with a number of partners including cities, companies and public organizations. We would like to thank all who have contributed with their passion and drive to make a difference in the science and innovation of intelligent lighting.

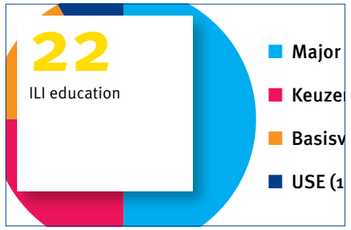
Through this magazine we will give you an overview of our contributions to the field. They range from student education to the organization of key conferences and state of the art research projects. Next to that our program leaders will give you an insight in their program lines.

We hope you enjoy reading.

ILI2014 CONTENT







Editorial // ILI 2014 is the yearly magazine of ILI for ILI members, colleagues, collaboration partners, policy makers and related companies. ILI is published in May. // Editorial staff - Sagitta Peters (editor in chief) // Design - Volle-kracht, Eindhoven // Illustrations - ILI // Article contributions - Moesasji & ILI // Photography - Bart van Overbeeke Fotografie, Jeroen Peerbolte, Lajla Borg Jensen, Josh Redman Photography, Rien Meulman, Philips Communications, ILI // Contact - P.O. Box 513, 5600 MB Eindhoven The Netherlands T: +31 (0)40 247 5990 E: ili@tue.nl //

Intelligent Lighting Institute
Engineering natural light

The TU/e Intelligent Lighting Institute (ILI) was established in 2010 to investigate novel intelligent lighting solutions that will become within our reach by the large-scale introduction of LED technology, with a special emphasis on how these new solutions might affect people. In addition ILI aims at providing scientific evidence for the claims that go with these novel lighting solutions.

At the TU/e, ILI researchers are developing new concepts for interactive lighting solutions, as well as the requisite technology. This often requires combining the competences of various disciplines. The institute also consciously seeks to coordinate activities with the private and public sectors, which is a new dimension in the field of lighting innovation.

We focus on five research programs:
- Brilliant streets
- Sound lighting
- Lighting optics & rendering
- No switches allowed
- Open Light

There are approximately fifty people working on ILI research programs from the departments of Applied Physics, Industrial Design, Industrial Engineering & Innovation Sciences, Electrical Engineering, Mathematics & Computer Science and Built Environment. There are an additional fifty persons from industry who work with ILI.

More information can be found via our website www.tue.nl/ili. Please contact us via email ili@tue.nl or telephone + 31 40 247 5990 with specific questions or remarks.

Calendar

May 7-8, 2014
Smart lighting 2014
International Conference on Intelligent and Dynamic Lighting
Location: Barcelona Spain

May 14, 2014
PhD defense Rizki Armanto Mangkuto
Location: TU/e
Thesis: Modelling and Simulation of Virtual Natural Lighting Solutions in Buildings

June 12, 2014
Temp Team CollegeTour 'Innovation in unison: the powerful combination of technological and social innovation' (Dutch spoken event)
Location: TU/e
With a.o. Lodewijk Asscher and Yvonne de Kort (ILI)

September 3, 2014
PhD defense Corien Prins
Location: TU/e
Thesis: Inverse Methods for Illumination Optics

September 18, 2014
PhD defense Femke Beute
Location: TU/e
Thesis: Powered by Nature - The psychological benefits of natural views and daylight

October 18-26, 2014
Dutch Design Week
Location: Several places in Eindhoven

November 8-15, 2014
Glow Festival
Location: Eindhoven
Includes ILI OPENLIGHT installations at GLOW NEXT

November 10-11, 2014
Experiencing Light 2014, International conference on the effects of light on wellbeing
Location: Eindhoven

November 11-13, 2014
Ambient Intelligence conference
Location: Eindhoven

ILI Theses
January 2013 - April 2014

Studies in Ambient Intelligent Lighting
Dragan Sekulovski - April 2013
PhD advisors: prof.dr. E.H.L. Aarts, prof. dr. I.E.J. Heynderickx

Daytime light exposure - Effects and preferences
Karin C.H.J. Smolders - December 2013
PhD advisors: prof.dr. C.J.H. Midden, dr. ir. Y.A.W. de Kort

Designing for Adaptive Lighting Environments
Remco Magielse - April 2014
PhD advisors: prof.dr.ir. J.H. Eggen, prof. dr.ir. C.C.M. Hummels, dr.ir. J.W. Frens

Emile Aarts | Scientific director

Engineering natural lighting experiences

"Over the past centuries mankind has created extensive artificial environments in which we live, work, rest, and recreate. Many of these environments have contributed to our social wellbeing, but along the way we lost the use of natural (day)light, thus falling short on the beneficial qualities that can go with it. It is our profound belief that by using digital LED technology and deep insights in the effect of light on human behavior we can re-create the world's view on natural light in all domains of our daily life, such as health, wellbeing, safety, and sustainability."

This clear and direction setting vision drives the research programs of the Intelligent Lighting Institute (ILI) of the Eindhoven University of Technology. The ILI programs relate to outdoor and building lighting, light for health and wellbeing, design of advanced techniques for optics and rendering, light interaction and design, and extreme lighting experiences. ILI investigates intelligent lighting solutions with a scientific and application-based approach towards all human-centric aspects of light and lighting. We apply a multidisciplinary and multifunctional approach that is concept driven and evidence based. To achieve these objectives ILI has set up a network of fully operational Living Labs across the TU/e campus and the city of Eindhoven where human-centric real-life test bed approaches are used to validate novel lighting solutions.

The Eindhoven region has the ambition to sustain its leading position in lighting research and innovation, which it has built over the past century. With strong industrial leaders such as Philips and NXP and in close cooperation with the municipality of Eindhoven, ILI has set up a ground breaking lighting research program that should reveal the true benefits of the many novel solution opportunities that are enabled by the LED light revolution.

ILI Short

Kick-off Flagship Intelligent Lighting

On Monday March 10, 2014, TU/e and Philips celebrated the kick-off of their recently announced strategic partnership on intelligent lighting during a festive event at TU/e. During this event the joint research & innovation roadmap of the Flagship as well as the joint vision have been presented to a wider audience of researchers of TU/e and Philips. At the end of the event the joint vision was formally presented to the audience by the Flagship Steering Committee with representatives of TU/e and Philips.

From left to right: Emile Aarts, Ton Flaman (Philips EuroPartners), Ingrid Heynderickx, Kees van der Klauw (Philips Research) and Geert Depovere (Philips Lighting)

International attention for OPENLIGHT

After several presentations in the Netherlands, the fLUMENS installation was presented at Canary Wharf, London in December 2013. fLUMENS are completely powered by the wind and emit light from wind force 3 Beaufort.

They were developed by OPENLIGHT with DigiLuce originally for the Amsterdam Light Festival 2012.

Best full paper award British Computer Society

The article of Serge Offermans and colleagues for the 27th International BCS Human Computer Interaction Conference (BHCI 2013) has been awarded as the best full paper of the British Computer Society. The conference was held September 9-13, 2013 in London.

S.A.M. Offermans, H.A. van Essen and J.H. Eggen
Exploring a hybrid control approach for enhanced user experience of interactive lighting
In K. Hone, St. Love & Tom McEwan (Eds.).
Proceedings of the 27th International BCS Human Computer Interaction Conference (BHCI 2013) (2013)

Smart Light Eindhoven currently tendering

With Smart Light Eindhoven, based on the vision and roadmap Urban lighting Eindhoven 2030, the city of Eindhoven is currently tendering innovative lighting in the city. ILI LightHouse created the vision and roadmap with contributions of various organizations. By adopting the roadmap as their lighting policy the municipality of Eindhoven made clear its ambition to implement innovative lighting solutions in the public space in such a manner that it contributes to the quality of life in the city.

Lighting Energy Audit at the Palace of Parliament in Bucharest

On December 22, 2013, ILI signed a memorandum of understanding with the Chamber of Deputies and the University Politechnica of Bucharest to conduct an energy audit for the lighting system as part of the complete building energy audit performed by the Politechnica. The second largest building in the world hosts a number of different activities and functions and provides vast opportunities for smart lighting solutions.

Third prize best poster award at the ISPR 2014

PhD student Leon van Rijswijk has received the third prize best poster award at the 15th International Conference on Presence March 17-19, 2014. The poster has as title “Using immersive virtual reality for developing novel lighting applications”.

FP7 ENIGMA project started

ENIGMA, an EU FP7 funded project, aims to procure a smart ICT-based urban lighting solution. ILI is leader of the first work package, identifying the strategic ambitions of the partner cities (Eindhoven, Stavanger, Malmo, Espoo and Bassano del Grappa) and the societal needs in the selected pilot areas and ensuring the desired societal impact is translated into requirements for smart lighting solutions and suitable assessment criteria for the tender. The project runs from October 2013 to July 2016.

ENIGMA

Semantic Adaptive Infomedia Lighting granted additional funding

The Semantic Adaptive Infomedia Lighting project was granted EIT ICT Labs funding for one more year. It is one of the projects under the umbrella of EIT ICT Labs Smart Spaces Action Line. The task of ILI in this project is called “Smart/Semantic Info light for Interactive Advertising” and aims at light-based technology for counting and tracking the location of people in the vicinity of interactive advertising/point-of-sale display.

Results from the ISLES 2014 project

Balancing energy consumption and safety with intelligent dynamic street lighting

Authors | Antal Haans & Elke den Ouden

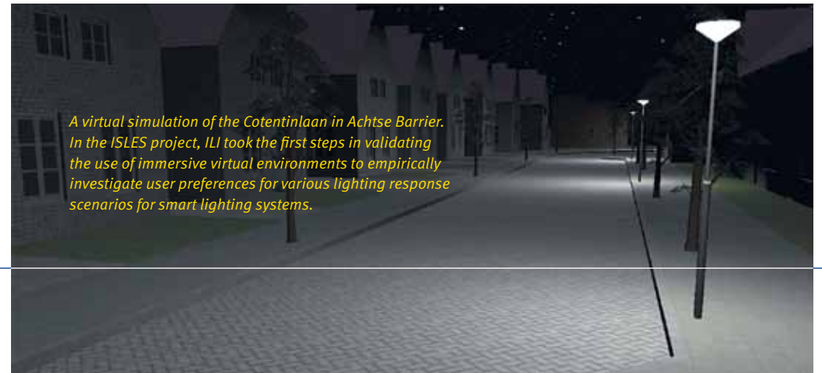
A persistent belief in urban lighting is that further energy savings will require sacrificing light levels at the expense of our sense of safety after dark. In the ISLES 2014 project, we have found that smart urban lighting solutions ameliorate such beliefs—demonstrating a reduction in energy consumption without affecting perceptions of safety.

In the ISLES project, ILI cooperated with industry (Philips and small and medium size enterprises) and the municipality of Eindhoven in the implementation and testing of intelligent dynamic lighting in residential area Achtse Barrier. Using the city as its living lab, ILI's main task was to evaluate the system's performance with respect to energy savings and safety perceptions. The evaluation consisted of three phases: a baseline period with existing luminaires, a LED replacement (June 2013), and an operational smart lighting system (October 2013). The project ended December 2013.

The higher efficiency of the new LED luminaires, compared to the 50-year old existing models, resulted in a 39.5% decrease in energy consumption. Another 18% in energy reduction was obtained with the intelligent lighting in place; totaling an energy reduction of 57.5% compared to the baseline period. At the same time, illuminance levels increased from 1.2 to 3.5 lux after the LED implementation. As expected, a survey amongst residents showed positive evaluations of the new LED lighting, and a marked decrease in resident's fear when walking in their own street after dark. More importantly, satisfaction with the lighting and the sense of personal safety remained high even with the intelligent lighting in place. In a more or less representative control area, where no lighting changes were implemented, no changes in light appraisals and sense of safety were observed.

Interviews with residents of Achtse Barrier highlighted the importance of focusing, not only on the lighting, but on the interaction between the users and the system. For example, if light levels are raised without residents being able to deduce what on the street causes the system's behavior, then the lighting system may be erroneously perceived to be malfunctioning. At worst, not being able to form an appropriate mental model of the system's workings may become a source of anxiety in a small proportion of the residents. Nevertheless, ISLES 2014 was successful in demonstrating the potential of smart lighting solutions for reducing energy consumption and light pollution without affecting perceived safety.

Installation of a passive-infra-red (PIR) sensor on the LED luminaires in Achtse Barrier.



A virtual simulation of the Cotentinlaan in Achtse Barrier. In the ISLES project, ILI took the first steps in validating the use of immersive virtual environments to empirically investigate user preferences for various lighting response scenarios for smart lighting systems.

Living Light Labs

ILI maintains several lighting laboratories to support its research and design endeavors. At the same time, ILI recognizes the importance of designing and researching lighting solutions in the wild—in the urban context in which they ultimately are to be used. Such living labs offer opportunities for testing the effects of lighting under natural circumstances, and allow design solutions to be swiftly iterated, for example, by timely adjustment to emergent system and user behavior; behavior that typically goes unnoticed in laboratory settings. Current living labs range from on-campus sites as Markthal or De Zaale to semi-permanent living labs within the boundaries of Eindhoven city, including residential area Achtse Barrier or recreational area Stratumseind. They are instrumental in gaining an understanding on how smart lighting solutions affect the experience, perception and behavior of people.

Spotlight on aggression

Author | Yvonne de Kort

Almost on a daily basis, the media report of aggression. Defusing aggressive escalation in such situations is no mean feat and sometimes requires the active intervention of experts. But in De-escalate, a strategic research project funded by NWO, researchers investigate whether interactive lighting may help serve to confine, contain and control aggressive events.

De-escalate: Intelligent light to control emotions

Even though we consider ourselves rational beings, emotions are still a very present and powerful force in our lives. Sometimes, situations run out of control because we become frustrated and agitated, resulting in verbal or physical aggression. During an escalation a person's attention narrows to the one thing that frustrates them, and this aroused, negative emotional state depletes their ability to carefully consider the situation, the other's perspective, and the consequences of the impulses they are about to give in to, resulting in risk taking and "commitment to aggression".

Interestingly though, attention, self-awareness, sociability and emotion are phenomena that we expect to be under the influence of light. De-escalate researchers examine psychological pathways through which exposure to dynamic lighting might defuse escalating behavior. They will test scenarios to lower arousal levels, induce positive mood, shift or broaden attention, facilitate social behavior, and increase self-control, of individuals and groups.

Living labs: From the laboratory to the real world

There are numerous situations in which emotions escalate and persons lose self-control, scream, get abusive, aggressive, and cross behavioral boundaries they normally would not cross. Such incidents may occur outdoors (festivals, urban night life) as well as indoors (prisons, help desks, psychiatric wards). Yet they hardly ever occur spontaneously in laboratories and it is extremely difficult to create and investigate realistic episodes there.

De-escalate aims to provide fundamental insights in human behavior, but also to deliver lighting schemes applicable and effective in real-life conditions. It therefore employs a multi-method and multi-site strategy. Theory-informed 'Light principles' are tested in controlled environments; then light scenarios are implemented in two escalation-prone locations designated as Living Labs: a psychiatric care facility of the GGzE, and 'Stratumseind', Eindhoven's largest inner-city entertainment area.

Social innovation: Managing emotions and managing crowds

ILI explores societal value creation through evidence-based lighting design. But social innovation can never be realized in isolation. The two PhDs and their team collaborate with GGzE, who have appointed a clinical psychologist for this project. Philips provides the intelligent lighting hardware and software, Gemeente Eindhoven's sensor-intensive testbed Stratumseind provides the dreamed backdrop for the outdoor tests, Polyground coordinates the collaboration with the local stakeholders, DITSS and CrimiNee! offer their expertise in video surveillance, and Het Lux Lab advises in lighting design. Jointly, this consortium provides an excellent and unique opportunity for valorization in the context of public health and safety.

A new research direction for the sound lighting program line

Sound Lighting is the program in ILI that studies the effects of light on human functioning and aims to develop light designs, scenarios and applications in the service of human health and wellbeing. Core themes are Light for Health, Light for Performance, Perception of Light, and the De-escalate project marks the start of its fourth theme: Light, Emotions and Social Behavior.

Exploring the liberation of light

Emile Aarts: "You can say that light is our next digital medium."

Kees van der Klauw: "Unique in this Flagship is the broad approach. We are researching across the complete value chain."

After 130 years of lighting based on glowing filaments and gas discharge, there is now LED, revolutionizing the way we use and 'consume' light. In the Intelligent Lighting Institute (ILI), Philips and the TU/e dive into this new world and join forces in researching and developing new intelligent lighting systems.

March 2014, TU/e and Philips celebrated the kick-off of a new Flagship, an intense strategic partnership in which 16 PhDs will explore new concepts and systems in Intelligent Lighting in the coming years.

Kees van der Klauw: "The programmability of LED will put the focus on the quality of light. Can it support productivity, wellbeing, health and safety?"

Emile Aarts, TU/e professor and scientific director of ILI, and Kees van der Klauw, senior vice president and program manager at Philips Lighting, reflect on the collaboration. Emile Aarts: "I have seen a lot of partnerships, but I find this one particularly unique: we are actually exploring the liberation of light."

The human side of light

This so-called liberation is enabled by two elements. First there is the invention of LED-based lighting technologies, which dates back to the mid-fifties of the past century and has grown industrially mature over the years. Second, new insights in the influence of light on the human brain have opened the venue for many ground-breaking lighting applications. Kees van der Klauw: "LED offers opportunities we did not have with traditional lighting technology, it is transforming the business." Emile Aarts: "Since the emergence of LED, the way we look at light has been changing. LED is energy effective, that's an advantage, but increasingly it turns light into a medium that has a significant effect on the behavior of people. For the last 15 years, the attention for the influence of light on people has been growing steadily.

Emile Aarts: "We are entering an era of research for intelligent lighting solutions that will help us to be more productive, happy, and healthy."

This influence is rooted in our biological processes. It appears that we have photoreceptors that connect to the hormones in our brain, thus influencing our emotional state and our behavior. We are entering an era of research for intelligent lighting solutions that will help us to be more productive, happy, and healthy."

Living labs

Kees van der Klauw: "Unique in this Flagship is the broad approach. We are researching across the complete value chain. In our joint program we will be working on components (physics and optics of light sources), systems (adding ICT to lighting systems) and the effects of light on people. To be able to accurately test and validate new concepts, we use Living Labs, real-life environments where we explore the concepts in close collaboration with the users." Emile Aarts adds, "A good example of this approach is our ISLES-project in the Achtse Barrier district in Eindhoven. We equipped a large number of lampposts with LED technology. Saving energy was a motive, but an even stronger motive were the effects on the district's residents. We developed different adaptive light settings for the system and explored which lighting conditions the residents prefer. The results were overwhelming. The residents found the energy-saving part relevant, but were thrilled by the adaptive light control."

LEDification

LED is rapidly transforming the world of light. The first wave is LEDification, the emergence of retrofit LED light bulbs and luminaires to be used in traditional ways. The next wave can be seen as the digitalization of light. Kees van der Klauw: "LED is cheap, small and electronically programmable. The luminaires we are familiar with will soon be overtaken by completely new concepts. We used to be confronted with finding solutions for the large, inefficient and hot light sources, guiding the light with mirrors, reflectors and diffusers. Now we can fully integrate LED into ceilings, furniture, tables or whatever else.

Kees van der Klauw: "LED is cheap, small and electronically programmable. The luminaires we are familiar with, will soon be overtaken by completely new concepts."

The programmability will put the focus on the quality of light. Can it support productivity, wellbeing, health, and safety? De-escalating qualities of light are being researched in a number of environments, including our project in the nightlife area Stratumseind in Eindhoven. And once you equip your LED sources with microprocessors, you open a new world of applications. Our lighting networks are dense, inside and outside. Imagine what you could do through integrating sensors into your LED sources: tracking traffic, providing intuitive way finding via light, climate control. This goes far beyond energy saving."

Strong partnership in research

Kees van der Klauw: "We have an excellent position worldwide when it comes to lighting. However, I'm careful not to become arrogant. LED is a whole new game, with new players and a disconnection of lifecycles in components, luminaires, systems and applications."
Emile Aarts: "At TU/e we will not be looking into the light sources and lighting technology themselves so much, we have a world leading partner to do that. Where we come in to play is the generation and exploration of concepts, prototypes, and the set-up of living labs.

Emile Aarts: "Media such as audio and video were analogue and turned digital. The same is happening here. Therefore you can say that light is our next digital medium."

This research program is a unique chance to transform young talent into the lighting engineers of the future. A distinctive and highly relevant scientific direction for TU/e, Philips and the Brainport region including the municipality of Eindhoven."

ILI In press

February 10, 2013 16.30. Dutch Television; Demo Intelligent Lighting System, SmartLife SBS6. Available online (at approx. 10.00 min).
http://www.kijk.nl/video/ytecqBYRfmLJ

NSA and our PhD Remco Magielse appeared on a Russian TV show!
http://vimeo.com/79332748

PhD candidate Serge Offermans was interviewed on our No Switches Allowed research on a Dutch TV show:
http://www.kijk.nl/video/ytecqBYRfmLJ

OPENLIGHT fLUMENS in London Time Out Magazine
http://www.viewlondon.co.uk/whatson/winter-lights-at-canary-wharf-article-12900.html

November, 2014. Leon van Rijswijk was invited to contribute to a special issue on light pollution in the Dutch magazine Milieu. Title:
Zoeken naar een veilig verlichte toekomst

Oktober, 2013. Radio interview NTR HOE?ZO! "kettingvraag" with Antal Haans.
http://www.wetenschap24.nl/programmas/hoezo-radio/Kettingvraag/2013/oktober/18-10-2013-lichtvervuiling.html

Augustus, 2013. Interview with Antal Haans (amongst others) for Quest article entitled:
"Om straten automatisch te verlichting werd in Eindhoven 'het internet van lantaarnpalen' ontwikkeld"

April 8, 2014. Interview Elke den Ouden (ILI) and Monique List (city of Eindhoven) were interviewed on smart lighting for cities by BNR Radio at the Hannover Messe.

After the press release about the de-escalate project and Stratumseind several television shows paid attention to the topic. RTL EditieNL
http://www.rtlxl.nl/#!/editie-nl-216694/22f48c69-0609-4217-a16e-d0600989d6fe.
NOS Journaal
http://www.uitzendinggemist.nl/afleveringen/1383619

Kick-off creative industries Click NL during Dutch Design Week.
http://www.clicknl.nl/blog/verslag-kick-off-nwo-projecten-24-oktober-eindhoven-dynamo/?lang=en

Yvonne de Kort delivered a lecture at 7th DIN Expert Panel 2013, a conference focused on the effect of light on human beings. An abstract of her lecture can be viewed here (2:40 – 5:12 min).
http://www.youtube.com/watch?v=Bhn3bH6tPm8&feature=youtu.be

Interview with Karin Smolders in Hoe?Zo! radio: 'actief door licht'.
http://www.wetenschap24.nl/programmas/hoezo-radio/Uitzendingen/2013/december/02-12-2013-chocolade.html

Januari 2014. News item in Psychologie magazine because of PhD defense of Karin Smolders
'Licht verjaagt lamlendigheid'

December 13, 2013. Kennislink (Dutch popular scientific website), interview with Yvonne de Kort
'Uitgaansgebied als lichtlaboratorium'

Color homogeneity in LED spotlights

Authors | Corien Prins, Teus Tukker, Wilbert IJzerman, and Jan ten Thije Boonkkamp

LED is a rising technology in the field of lighting. Halogen spotlights are nowadays replaced by LED spotlights because of their energy efficiency and long lifetime. However, color variation in the light output is a common problem. Poorly designed LED spotlights tend to have yellowish or bluish rings in the beam, which is undesirable. In this article we outline a method to design an optical component that annihilates this color variation.

A schematic drawing of a typical LED spotlight is shown in Figure 1. Light is produced in several LEDs, which emit light in the direction of the right hemisphere. An optical component, the so-called TIR (Total Internal Reflection) collimator, redirects the light into a compact beam. The problem of color variation originates from the LED: light emitted in the direction of the symmetry axis is typically more bluish, while light to the sides is more yellowish. We will eliminate the color variation of the spotlight by modifying the TIR collimator.

A TIR collimator is a rotationally symmetric lens, of which a profile is shown in Figure 2. For simplicity, we assume that all the light from the LED is emitted from a point source. All light rays are described by their angle with respect to the symmetry axis. Light at small angles is refracted by the lens-like surface A and subsequently by the flat surface T. Light at large angles is first refracted by surface S, then reflected by surface B or C and finally refracted by surface T. The reflection at surface B or C is due to total internal reflection, hence the name TIR collimator.

We need to compute the location of the so-called free surfaces A, B and C, which proceeds in two stages. First, we determine transfer functions, which define the relation between the angle t of a light ray when emitted from the LED and the angle Θ when leaving the collimator at T. This step requires the solution of a set of differential equations describing conservation of luminous flux and the rules of color mixing. Our objective here is to achieve a constant chromaticity color coordinate. Second, from the transfer functions we compute the free surfaces using basic geometry and the laws of reflection and refraction.

We have computed the profile of a TIR collimator and converted into a model for Monte-Carlo ray tracing in the LightTools code. A screenshot of this collimator with a set of rays is shown in Figure 3. The numerical results in Figure 4 show an intensity profile that closely matches the intended profile and a color variation that is invisible to the human eye.

Halogen spotlights are nowadays replaced by LED spotlights because of their energy efficiency and long lifetime.

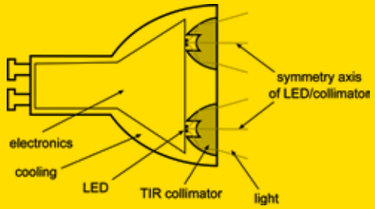


Figure 1: Schematic drawing of an LED-based halogen spot replacement.

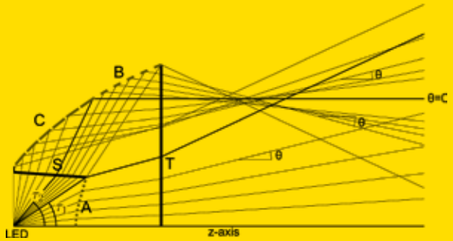


Figure 2: Profile of a TIR collimator, where the z-axis is the axis of symmetry.

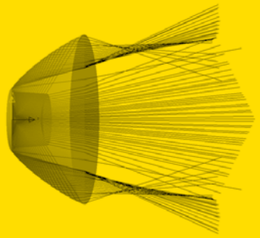


Figure 3: Screenshot of a 3D model of the designed TIR collimator.

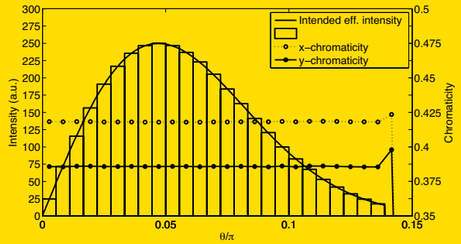


Figure 4: Intensity and chromaticity of the Monte-Carlo simulation and the required intensity profile.

ILI Short

NWO Strategic research grant De-escalate

NWO awarded the project proposal: De-escalate - Defusing escalating behavior through the use of interactive light scenarios. The project explores value creation through evidence-based lighting design. It combines theory-based and controlled research with the integration and evaluation of dynamic light scenarios in experiential design landscapes, providing excellent opportunities for valorization in contexts of public health and safety. Partners are ILI, Philips, city of Eindhoven, GGzE, DITSS, Polyground, Het LuxLab. The project started January 2014, and has a duration of 4 years.

EIT ICT Labs Smart Urban Spaces

The 2014 EIT ICT Labs activity "Smart Urban Spaces: Intelligent Outdoor Lighting Systems" is led by Tanir Ozcelebi, program leader of No Switches Allowed. Collaborators within the project are Philips Research and ST Microelectronics (Italy). The total funding received for 2014 is 300K euros.

Tanir Ozcelebi invited speaker in ACAIS 2013

Tanir Ozcelebi was an invited speaker in ACAIS 2013 (June 6, 2013). The title of his lecture was "The Learning Zone in Smart Spaces". More information can be found at http://svcognac.nl/acais/archive/life-2013/tanir-ozcelebi/

E3 SLIM at Hannover Messe

E3 SLIM, Smart Lighting In Metropolitan areas, is the knowledge sharing program between the cities of Amsterdam, Eindhoven and Rotterdam in the field of smart urban lighting solutions, facilitated by ILI LightHouse. In 2013 the project focused at understanding the new role of municipalities in strengthening the national industry through purchasing intelligent and sustainable solutions. Next to the cities, Philips Lighting, Cisco and Alliander participated in the project. The results were presented at the Hannover Messe in April 2014. Further implementation of the findings is scheduled in 2014.

IRIS and WAVES best works GLOW NEXT 2013

IRIS and WAVES are two projects made by Rombout Frieling and TU/e students, that were presented in November 2013 at GLOW NEXT. The underlying concepts originated from interactive GLOW workshops which were held in the period September-November, 2013. Both IRIS and WAVES were publicly voted in the top 5 of best works. Because of their impact on the audience WAVES was exhibited at the Evoluon in Eindhoven again in January 2014.

Light, Cognition, Behavior & Health (LCB&H) call open

The Light, Cognition, Behavior & Health (LCB&H) call targets health-related research and development, leading to the application of light to alter brain function, cognition, behavior and mood. This call is a joint initiative of the Netherlands Organisation for Scientific Research (NWO), the Netherlands Organisation for Health Research and Development (ZonMw), and the National Initiative Brain & Cognition (NIHC). The call is one of the first tangible results of the Light, Cognition, Behavior network, initiated and coordinated as a collaborative effort between NIHC and ILI.

Show it!

Why is the sky blue? What do light waves do? Does color exist in the world or in the brain?

Author | Rombout Frieling

Light is invisible. And so are many of its phenomena. "At OPENLIGHT we believe that insight and inspiration comes from answering those questions in an experiential way: Show how it works!" says Rombout Frieling, program leader for OPENLIGHT.

In four weeks, OPENLIGHT worked with fifteen students to develop two of such 'tangible answers': 240 meter long IRIS shows how color is produced in the mind while WAVES shows how waves, created by making sounds yourself, travel through a space. Both installations featured at GLOW NEXT in Eindhoven in November 2013 where they were seen by over fifty thousand visitors.

WAVES and IRIS are now both seeing their way to museums, festivals and other events around the world, while at OPENLIGHT we prepare ourselves for a series of new explorations into the fascinating world of light – experiential at GLOW NEXT in November 2014.

No Switches Allowed

Lighting control and interaction for the future

Author | Tanir Ozcelebi

Ever since the light bulb was first discovered, we have turned lights on and off with a switch. Today, the intelligent lighting technology allows many opportunities ranging from autonomous lighting control to advanced user interaction styles. If researchers in the No Switches Allowed program get their way, radical change is on the way.

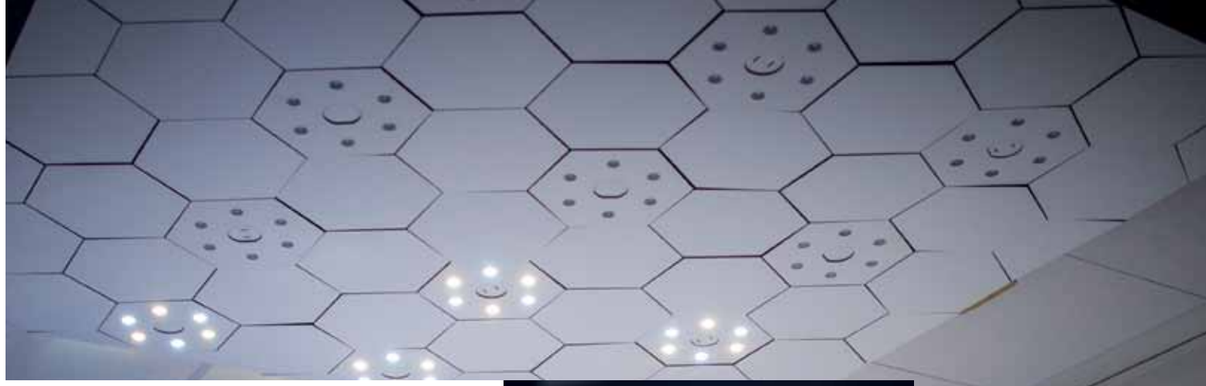
Thanks to the latest developments in the solid state lighting technology, miniaturization of processing hardware, and wide-spread usage of wireless communication, we are entering a new era of lighting. Light sources can now be embedded into everyday objects and be controlled by low power devices with digital computing capability. Thus, traditional light sources that just aim to light living and working spaces are slowly being replaced by networked intelligent lighting systems that are ideally energy and cost efficient. These systems have many goals ranging from simple illumination to performance and well-being support for people, aesthetics through decorative lighting and information delivery through coded light. This is a paradigm shift that will change the way we live in a way similar to the transition into the smart phone era.

Do you think a toggle light switch does not match your needs in terms of imposing desired lighting settings for different user activities and environment contexts? So do we!

The advantages promised by indoor intelligent lighting are compelling. There are opportunities to be seized in terms of advanced – and autonomous - control and user interaction capabilities, but there are difficulties to overcome as well. Intelligent lighting systems are composed of many devices that have digital computation and communication capabilities, e.g. smart lamps, interaction devices and sensors. Given such complexity, it is important to find a good balance between autonomous lighting behavior and user control. Currently, programming such a system requires significant expertise and writing lines of code. In NSA, we investigate how to identify activities and contexts in an environment and how to define and impose a corresponding desired lighting behavior on the system, as well as new methods of interaction between humans and light sources.

In the future, the Internet will reach all light sources, sensors and interaction devices in intelligent lighting systems.

Intelligent lighting is tightly linked to the developments for the realization of the Internet of Things (IoT) concept, which connects digital “things” to the Internet Protocol (IP) domain. Today, there are more IP connected devices than there are humans on the planet. According to a Cisco report on IoT, the number of IP connected things in 2020 will reach 50 billion. We envision that a fair share of these will be low capacity lighting and sensing components. In this direction, lighting systems as well as building management and other services that are enabled by an indoor lighting infrastructure will converge to all-IP solutions, with IP reaching end-points. In NSA, we aim to develop robust, dependable and secure full-IP intelligent lighting systems that are energy and cost efficient.



A personal, portable light controller that we call Bolb (design by Remco Magielse)

A meeting room intelligent lighting installation featuring Hyvve, a hexagonal light tile with computation and wireless communication capabilities (design by Remco Magielse)

ILI Education

A course program for TU/e's bachelor students

Authors | Yvonne de Kort
and Mariëlle Aarts

ILI recognizes the need for multidisciplinary trained engineers to forward research and development in intelligent lighting. In 2013, ILI started an ambitious joint course program in the bachelor phase, including a technical trajectory, a user-centered trajectory, and a TU/e certificate for bachelor students who participate in both trajectories. In the first year of this program, ILI is already servicing to over 80 students, and contemplating an advanced course program for the master phase.

Goal of the program

Three important developments have spurred a revolution in lighting: (1) society's growing awareness of the need to save energy, (2) recent insights in light's pathways through the brain and its impact on human functioning, and (3) the introduction of LED, a low power, flexible light source, offering potential for miniaturization, embedding, and advanced dynamic control. These developments have direct implications for users and society at large. We can – and should - now offer tailored light conditions to optimize human performance, health and wellbeing, and balance human needs with environmental impact. ILI's bachelor course program is designed to train engineers from different backgrounds, uniquely equipped to face these challenges in lighting innovation. The full program amounts to 25 credits, the equivalent of almost half a course year.

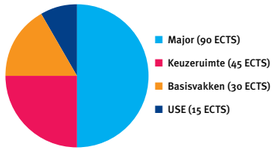
Multidisciplinary character

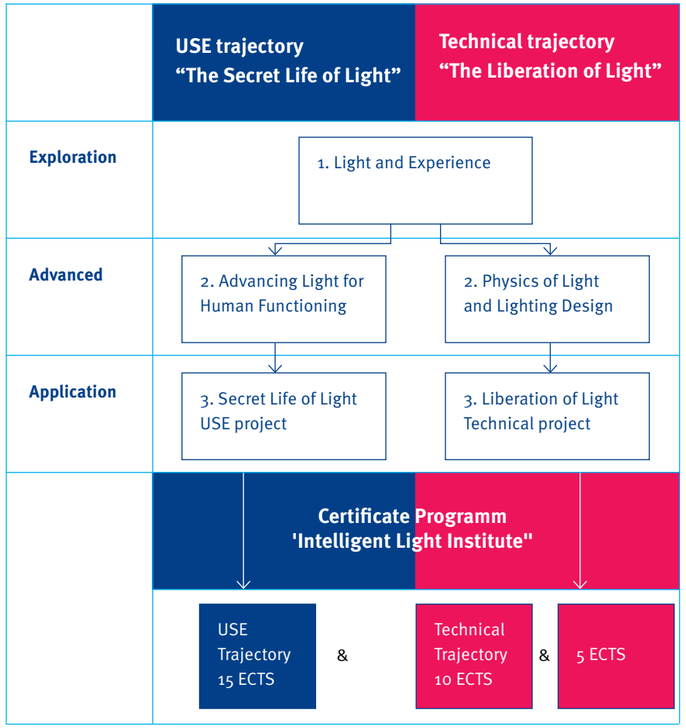
In the technical course trajectory, students will acquire knowledge in technical domains relevant to the multidisciplinary field of lighting: photometry and colorimetry; optics; light sources; energy efficiency; controls and interaction; materials; and on measurement and validation methods of architectural light designs; this should enable students to make an electrical lighting design and prepare them for participating in projects in the technical lighting domain.

The USE trajectory focuses on aspects that critically belong to users, society and entrepreneurship: user perception and experience, effects on human functioning, interacting with light technology, and business aspects of multi-stakeholder innovations.

In a collaborative effort of all departments and ILI program lines, the education program brings an attractive mix of lectures, practical assignments and applied projects. In addition to the educational goals, these projects also offer numerous opportunities for collaboration between the university, industry and governments.

Bachelor College // Light





ILI Top publications

January 2013 - April 2014

A. Kota Gopalakrishna, T. Ozcelebi, A. Liotta and J. Lukkien
Relevance as a Metric for Evaluating Machine Learning Algorithms
The 9th International Conference on Machine Learning and Data Mining (MLDM 2013), New York, USA, Jul 2013, (2013)

F. Beute and Y.A.W. de Kort
Let the sun shine! Measuring explicit and implicit preference for environments differing in naturalness, weather type and lightness.
Journal of Environmental Psychology, 36, 162-178 (2013)

D. Lakens, D.A.F. Fockenberg, K.P.H. Lemmens, J.R.C. Ham and C.J.H. Midden
Brightness differences influence the evaluation of affective pictures
Cognition and Emotion, 27(7), 1225-1246 (2013)

C.R. Prins, J.H.M. ten Thije Boonkkamp, T.W. Tukker and W.L. IJzerman
An inverse method for the design of TIR collimators to achieve a uniform color light beam,
Journal of Engineering Mathematics, Vol. 81, 177-190 (2013)

K.C.H.J. Smolders, Y.A.W. de Kort and S. van den Berg
Diurnal light exposure and feelings of vitality: Results of a field study during regular weekdays
Journal of Environmental Psychology, 36, 270-279 (2013).

E. den Ouden, R. Valkenburg and E.H.L. Aarts.
Participative Innovation in Smart Urban Lighting
Chapter in: Open Innovation 2.0. Open Innovation Yearbook 2013. Published by the European Commission, ISBN 978-92-79-25864-0 (2013)

S.A.M. Offermans, H.A. van Essen and J.H. Eggen
Exploring a hybrid control approach for enhanced user experience of interactive lighting
In K. Hone, St. Love & Tom McEwan (Eds.). Proceedings of the 27th International BCS Human Computer Interaction Conference (BHCI 2013) (2013)

R.A. Mangkuto, M.B.C. Aries, E.J. van Loenen and J.L.M. Hensen
Simulation of virtual natural lighting solutions with a simplified view
Lighting Research and Technology, 46(2), 198-218 (2014)

S.A.M. Offermans, H.A. van Essen and J.H. Eggen
User interaction with everyday lighting systems
Personal and Ubiquitous Computing (DOI) 10.1007/s00779-014-0759-2 (2014)

K.C.H.J. Smolders and Y.A.W. de Kort
Bright light and mental fatigue – effects on alertness, vitality, performance and physiological arousal.
Journal of Environmental Psychology, in press (2014)

M.B.C. Aries, M.P.J. Aarts and J.J.P.M. van Hoof
Daylight and health : a review of the evidence and consequences for the built environment
Lighting Research & Technology, in press (2014)

F. Beute and Y.A.W. de Kort
Salutogenic Effects of the Environment: Review of Health Protective Effects of Nature and Daylight
Applied Psychology: Health and Well-Being, 6 (1), 67–95 (2014)

TU/e Technische Universiteit **Eindhoven** University of Technology