DVN Workshop • Tokyo

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Executive Summary

This report summarises the proceedings of the 2018 DVN Tokyo Workshop. It is not a substitute for having attended the event, but it conveys the main points of each lecture and describes the highlights of the expo booths. All in all, there were 21 lectures, a grand keynote address, and a panel discussion. The three most important points developed by all the speakers:
1. Lighting has a great future, helped—and not doomed—by the arrival of autonomous vehicles.
2. ADB is the primary main solution to improve safety by night, but we need to improve the performance; reduce system cost, weight, and volume, and get all the world's regulators onside.
3. The next big challenge is V2X communication by light. We have to work together and be involved to achieve proposals able to win technical, cultural, and regulatory support worldwide.

Highlights of this report include accounts of the presentations by Honda's Ryou Chijimatsu and Nissan's Hitoshi Nakagaki, who presented their vision of the lighting future in context of Japanese lighting culture; comments by Wolfgang Huhn on the possibility that last Spring's Uber pedestrian fatality could have been avoided with ADB, and lectures by Renault's Paul-Henri Matha and PSA's Whilk Gonçalves emphasising the importance of lighting to be seen.

Lighting suppliers described the status of their ADB and V2X research and development, and light source makers presented their great progress in LEDs and lasers.

There's coverage of the regulation session with two great lectures by Peter Bodrogi (about the lighting needs of ageing drivers) and Michel Locuffier (about how UN vehicle regulations must be developed in the 1998 Agreement).

Tier 2 suppliers presented their innovations and outlooks.

Where authorised by the speakers and their companies, links are provided to the lecture slides. Links are also provided to short video interviews with some of the speakers and exhibitors.

Introduction

A capacity crowd of lighting and vision VIPs and experts converged on the truly grand Ritz Carlton Tokyo Midtown for the 17th DVN Workshop. The rubric was advanced technologies, communication, and regulation, and 280 attendees made a real go of it—including representatives from 15 car makers, 13 set makers, 32 Tier-2 companies, ten organisations...in total over 70 outfits. The expo halls were well populated with 25 booths showing a wide array of innovative and intriguing products, services, and concepts.
The day after a gala welcome dinner soirée, speakers painted a multifaceted picture of how very many things are changing right now in vehicle lighting: whole new questions are being asked as new technology means longstanding fundamental assumptions must be rethought. Moreover, today's global vehicle industry and more-mobile-than-ever populace means decisions must be thoughtfully taken, with input from all over the world, to ensure the fastest, easiest, smoothest and safest possible uptake of new personal mobility technology.

There was live, real-time Japanese/English translation in both directions, readily accessible to attendees via infrared-receiver earpieces. And for the second time, attendees could easily manage the agenda and ask questions to speakers via the well-developed DVN Workshop smartphone app.

It's not just regulations and standards that determine the adaptability and suitability of a vehicle lighting technology or technique for a given locale: prevailing conditions vary markedly from one country to the next. Take ADB, for example: the speakers at last week's Workshop ably described how and why it is truly a must-have solution to improve safety by night—really, we ought to work towards making it mandatory—but before that becomes practical, or the technology can reach its full potential to save lives and prevent injuries and property damage, we need to improve its performance and its polyvalence. An ADB system designed and tuned to give optimal lighting on Europe's roads is useless in Japan's dense mega-cities, for example, so new operational modes and methods must be devised and refined. And all the while, we must work to decrease the cost, the weight, and the volume of ADB systems.

Other big questions loom over the driver vision and vehicle lighting world right now, and the Tokyo DVN Workshop was a fine opportunity to take a frank, candid look at them. For example: who needs headlamps if there's no human driver? Will autonomous vehicles obviate the need for much in the way of a car lighting system? That's a question that's been sending some shivers up and down the spines of lighting specialists, but the answer seems to be more and more clearly that tomorrow's most highly automated AV will still need a full lighting system. More, in fact, than what's today considered a full lighting system. AV status lights are actively under development, for example. That's an exciting thing, and a rare opportunity: to be involved in the devisement and specification of a whole new set of lighting devices and functions. It appears a blue-green colour of some kind will soon join the vehicle lighting palette, and discussions are well under way as to the intensity, placement, exact colour, and operational modes of an AV status indicator light. This is just one example of how the arrival and widespread deployment of AVs appears poised to bolster the future of car lights, not threaten it.

Tangentially related is the big, important field of V2X communications by light, notably the ways and means of enabling vehicles to convey messages to humans by dint of light. This was a major theme running through the whole of the program, starting from the start with Chijimatsu-san's keynote speech. We already use light to communicate—that's the entire raison d'être of every light on the car except the headlamps, and even those are used (as by flashing on or flashing off) to send messages.

But that's human-to-human communication, different to the question now at hand: When there's no human driver, how do we replace the many messages a human driver might send to a pedestrian or another driver? Whether such a message might be conveyed by a wave of the hand ("Go ahead", "Thanks for letting me in") or even just eye contact ("I see you"), it can't happen if there's no human hand to wave or human eyes to make contact with. So novel light signals have to be developed to do the job. It's not an easy task; just as drivers in different countries (or different drivers in a given country!) might mean something different when they flash their headlamps or put on their hazard flashers, a light signal on an AV that seems perfectly logical and intuitive in context of one country's cultural and social norms might be inscrutable, nonsensical, ambiguous, or even offensive in another context. So global input and thought is a sine qua non for effective devisement and fine-tuning of this new category of vehicle light signals.

Global input and thought were certainly evident at the Tokyo workshop, as was a great deal of networking in the expo hall during the coffee breaks, and over a delicious assortment of food at lunchtime. Again and again, participants cite the networking opportunities as a major benefit that sets DVN Workshops apart from other lighting-centred conferences.

Keynote: Future Prospect of Vehicle Lighting See Slides

Ryou Chijimatsu • Honda (Manager of Technology Development

After presenting Honda's wide array of products sold all round the world—cars, motorcycles, lawn mowers, generators, power products, jet airplanes, and new-value-creation items like their Asimo humanoid robot—Chijimatsu-san presented his company's principles with respect to individuals: initiative, equality, and trust. The vision of Honda, he said, is to serve people worldwide with three joys of buying, selling, and creating to expand their life's potential. All while assuring Honda's growth through the pursuit of quality.

Zooming in on lighting in particular, Chijimatsu-san explained that communication is important but also very complicated. He gave the examples of how to say "Thanks" or "Please go ahead; you first" to other traffic participants: customs in Japan can differ to customs in Europe, in America, and elsewhere—which has implications for how to replace human-to-human communication when the human is no longer the driver.

He also described the difficulty in showing drivers who's around a blind corner—a situation that causes accidents because the driver (human or otherwise), as an example of why the desire for the communication with other traffic users is not just for AVs but also for human-driven cars.
Chijimatsu-san believes addressing these conditions will be crucial to reducing traffic accidents in Japan.

These examples and comments served to illustrate what Chijimatsu-san regards as two primary main present and future challenges: reducing power consumption, and devising communication methods that everyone can understand in the context of automation and increasingly intelligent lighting systems.

DVN comment:
This was an ideal start to the Workshop: an engaging keynote speech presenting a clearheaded, thoughtful overview of new (and longstanding old) challenges in traffic communication, and important ideas to consider when thinking about how to use lighting in new ways with the arrival of autonomous cars.

Advanced Lighting Technologies: Culture & Regulation Aspects
Hitoshi Nakagaki • Nissan (Interior-Exterior Trim Engineering Department Manager)

Communication Lighting – Status and Outlook
Wolfgang Huhn • Audi (Lighting & Vision General Manager)

Lighting and Autonomous Vehicles – State of the Art and Investigations
Paul-Henri Matha • Renault (Lighting Expert)

PSA's New Advanced Signalisation and Regulation Evolution
Dr. Whilk Gonçalves • PSA (Lighting & Signalisation Head of Innovation)

Advanced Lighting Technologies: Culture & Regulation Aspects See Slides

Hitoshi Nakagaki • Nissan (Interior-Exterior Trim Engineering Department Manager) See Video

Nissan's Hitoshi Nakagaki started his presentation by describing current technology at his company: Nissan Intelligent Mobility with its three intelligences: intelligent driving to give more confidence, intelligent power to make the drive more exciting, and intelligent integration which improves connectivity. Then he presented the three aspects of advanced lighting: technology, regulation, and culture.

His technological emphasis was on ADB and projection with the different possibilities of light source and optical system: LCD, µAFS, DMD, laser scanning, and so on. Communication is becoming more and more important, he explained, with distance warning, reverse warning, parking, and vehicle status and driver intent all being crucial messages that need to be conveyed in new ways as the AV age dawns.

About regulations, Nakagaki-san described the status of new technical standards and regulations:
• SAE's J3134 Task Force for Autonomous Vehicle Lighting are defining test procedures, performance, and design guidelines;
• NHTSA's request for comment about regulatory barriers for AVs; they ask what research is needed to prove safety benefits of new exterior lighting functions for AVs;
• UNECE's GTB are prepared to sponsor independent research for AV signalling.
The basics of colour, message, and dynamic or static operation need to be figured out.

Culture is perhaps the most interesting realm Nakagaki-san described, with differents lighting use practices in different countries. He gave examples: in Japan the hazard flashers are used to indicate a vehicle is parked near traffic, and drivers commonly switch off their low beams at night while waiting at a red light to prevent glare to other drivers. Lighting usage in tunnels varies by country (low beams, position lamps, no lights, hazard flashers). Deliberately blinked high beams are used in some places to warn oncoming drivers of police speed checks ahead (or for any of numerous other reasons); low beams are briefly flicked off to indicate a driver may safely tuck back in lane after overtaking (or for any of numerous other reasons), etc.

As a conclusion, Nakagaki-san presented three questions for consideration: how to harmonise new lighting regulations to allow for different cultures; how different cultures will react and adapt to new lighting technologies, and how to convey the driver's mood and other culturally-important things as AVs join traffic.

DVN comment:

Nakagaki-san's presentation's emphasis on cultural aspects of car lighting brought to the fore a crucial factor that usually gets lost in the shadow of technical possibilities and regulations. The fact is that people use car lights differently in different places, and that must be accounted for in the design and deployment of new kinds of car lights for bidirectional car/human communication.

Communication Lighting – Status and Outlook See Slides

Wolfgang Huhn • Audi (Lighting & Vision General Manager)

Dr. Huhn's presentation had three main parts analysis of the Uber collision, possibilities with the construction-zone light function, and comments on GTB's strategy.

Uber collision

Dr Huhn first described the Uber collision that killed a pedestrian last Spring, before explaining how we need ADB even for autonomous vehicles**.** The most interesting point in this part was the demonstration of the strong influence of low-beam aim on effective safety performance, versus ADB which is almost aim-independent.

Construction Zone Light with Digital Matrix Light

Dr Huhn showed the prospects and possibilities offered by a new construction zone light function to guide drivers through tricky roadworks.

GTB Strategy

Dr. Huhn presented the major results of the strategy committee up to now:
- Funding for research projects organised
- 20 companies share research cost
- Quotations sent out in April
- Research projects already started: AV indication at TUD (Germany); information projection at ELS (France) and KIT (Germany).

The next steps are:
- TUD will finalise their study on AV indication display hardware and build five sets.
- Thes five sets will be given (together with TUD-results) to other international research institutes mainly in China, Japan, Korea and America.
- Details and time schedule according to progress of TUD work.
- Research work will be supervised by GTB's scientific group.

DVN Comment:

Dr. Huhn's very clear presentation effectively bolsters the links between ADB and safety. What we retain is the importance of ADB even in autonomus cars; with ADB, aiming is much less crucial, thus working around one of the main safety issues in the whole vehicle lighting world (bad aim as described in detail by Dr. Huhn's peer Dr. Hamm).

Lighting and Autonomous Vehicles – State of the Art and Investigations See Slides

Paul-Henri Matha • Renault (Lighting Expert) See Video

Autonomous cars are now real; the first SOP is scheduled in 2020 for an SAE Level 3 AV. Considering lighting, Matha asks three questions: What are the stakes for Lighting? Who is working? How shall we work together and for what results?

Autonomous cars need of a lot of hardwar: front, side, and rear cameras, radars, lidars, ultrasonic sensors, and so on.
Do they need light to see and be seen? Matha brought up the Uber pedestrian fatality in America, saying better lighting, increased lighting field of view, and better vertical headlamp aiming should have improve the detection.
Another example is the lane keeping assist where a bad lighting (or bad painting) creates poor detection.

Trains and planes have lights to be seen; does an Autonomous car need light to be seen?

What are the new needs:
Differentiation between AV and standard car
Differentiation between autonomous driving mode and standard mode
Communication between cars and exterior entities (other cars, pedestrians, etc)

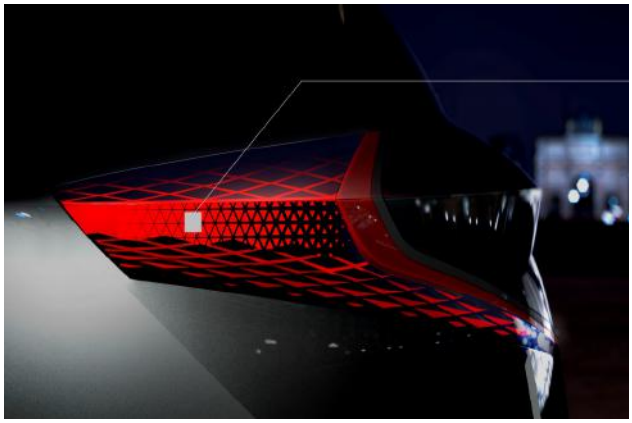
Matha summed up that everyone is convinced we need AD signaling and communication with light. UN lighting regulations need to be updated very quickly to be ready for Level 3 AD vehicles in 2020.
For automakers, harmonisation is very important to have common regulation in Japan, Europe, the US, China, and elsewhere in the world. To that end, everyone must work together—automakers, tier-1 and -2 suppliers, SAE, ECE, GTB, ISO, etc—to define the new regulations together.

DVN comment:
This is an excellent overview of the new needs in lighting with the arrival of autonomous vehicles, with Paul-Henri Matha leveraging his involvmen and his works in the GTB strategic committee to explain the current exigencies.

PSA's New Advanced Signalisation and Regulation Evolution See Slides

Dr. Whilk Gonçalves • PSA (Lighting & Signalisation Head of Innovation) See Video

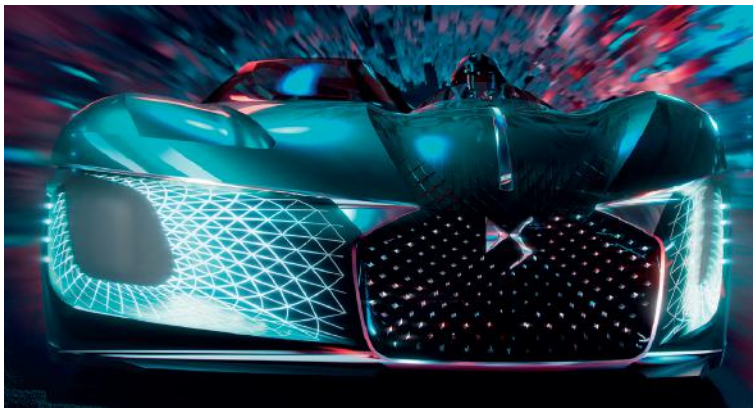
Dr. Gonçalves presented PSA's new concepts and the trends in advanced front and rear signals, which maintain the core safety functions, expand additional functionality, and simultaneously renew brand signatures thanks to "Smart Light" intelligent 3D structures, new materials, and animated signal modes.



For instance, in one rear lamp we see a variety of functionalities that can be achieved statically or dynamically by this "Smart Light":

01: Locate driver approaching 15m 02: Approach 3M 03: Unlock 04: Opening 05: Start 06: Off-Door opening 07: Lock	08: Trafic Alert 09: City Park 10: Pedestrian Front 11: Pedestrian Right 12: Electrical car 13: Hybrid Car

Of course, new regualtion must be established and approval evaluated for each new function.



PSA's DSX E-TENSE concept

As well as for the rear lights, the front signalisation is also highly impacted, as Gonçalves showed with the DSX E-TENSE concept. The DRL extended surfaces acquire 3D structures and bring new dimensions to the style and function expression. New materials and techniques will be needed to render the concept feasible and reliable, and regulatory revisions could be necessary: higher surfaces for the DRL, for example, adaptable intensities, and so on.

DVN comment: PSA's "Smart Light" concept illustrates the new possibilities offered by new materials, 3D structures and software for front and rear lighting—but regulations must adapt fast!

Session 2 • Advanced Technologies & Regulations: Set Makers' Vision

Advanced Technology of Mobis
Yuni Cheung • Mobis (Marketing team)

Challenge to Add Advanced Signaling Functions by Simplifying Regulations
Rainer Neumann • Varroc Lighting Systems (VP of Global Technology)

Affordable LED Headlamps – Standardisation is the Key – Purpose & Limitation
Gerd Bahnmüller • AL (VP of Lighting Technology R&D)

Advanced Technology of Mobis See Slides

Yuni Cheung • Mobis (Marketing team) See Video

Mobis' Yuni Cheung started her presentation with the perceptions of Mobis of new trends in lighting: environmental compatibility with reduced size and weight and less energy consumption; adaptability to AVs for safety with digital lighting and sensor integration; increased leverage of brand-signature design. Then she described the relationship between the level of autonomous vehicles and the adapted technologies with compactness and style, ADB matrix beam, digital light, and new communication modes.

For these different needs, Mobis have developed (or are developing) responsive technologies:
For compactness and design there's Mobis' low-cost reflector low beam with driver module and LED integrated in one single FR4 PCB, and their "Slim 4" projection low beam with ø22mm lens and silicone optics. Then there's the Mobis 3D Lit Image rear lamp with 3D holographic images realised with a lenticular sheet, and homogeneously-lit rear lamps and CHMSLs done by dint of side-emitting LEDs and micro optics.

For matrix beam, Mobis have a 12-segment high beam projection module, a slim dual-projection 32-segment ADB module with ø25mm lens aperture, and ADB systems with integrated ADAS components (sensors, navigation, steering...).

For digital lighting, Mobis' development work includes a micro-LED HD multi-array with 256 pixels (16 × 16); a DMD headlamp with HD matrix high beam and symbol projection with 410 megapixels.

And Mobis are working on communication lighting with V2X comms capabilities.

Cheung then presented Mobis' view of needs in regulation for a good development of new lighting technologies. For matrix beam, even if it is already allowed Europe, Korea and Japan, simplification with harmonisation in the different regions is necessary. For digital lighting, unclear questions for instance concerning risk of confusion, weather conditions or responsibility need to be clarified by standardisation in and around the regulations. And for communication lighting, systems that interact with other components in autonomous vehicles must have robus connectivity.

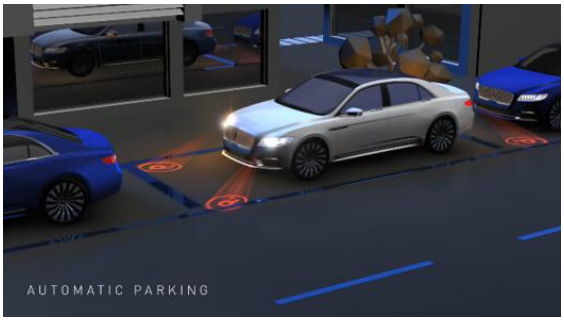
DVN comment:
This is an Interesting workup on the current main lighting technologies developed and their needs for regulation. It appears more and more that regulation has some difficulties to follow the rhythm of introduction of these new technologies, but rapid and long-term adaptation of the regulation is nevertheless absolutely necessary to keep safety and cost under control and make worldwide deployment possible.

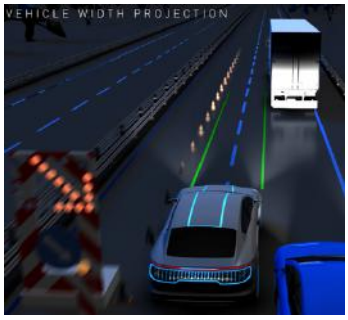
Challenge to Add Advanced Signaling Functions by Simplifying Regulations See Slides

Rainer Neumann • Varroc Lighting Systems (VP of Global Technology) See Video

Vehicle lighting rock star Rainer Neumann started his talk with the example of the signal to be used for vehicles running in autonomous mode. In America, the SAE J3134 task force's activities are ongoing with no decision yet, but with an orientation to have a signal in the front, with a colour in the turquoise area, probably optional. In the ECE world, the topic is covered in GTB by ordering some research studies to define how the signal should look like, where to be positioned with what colour and brightness, and it will most probably be mandatory. The target is to have a harmonised solution, as simple as possible.

Next, Neumann gave an update on the longrunning fight between visibility and glare, insisting on two points: visibility is the crucial key for safety, and new functionalities are producing information, but not visibility. On that backdrop, he gave examples of new functions related to lighting, for instance with automatic parking, vehicle width projection, anti-collision warning signal, and safety distance recommendation when overtaking. Neumann stressed the importance that each new function introduced must be useful for safety, not confusing, and with a simplified approval. To that end, a variety of studies launched by the GTB are currently under way and will be available for everybody's scrutiny and use once they're complete.





DVN Comment:

There are currently many proposals for new signal functions particularly for future autonomous vehicle, and Rainer Neumann is right to insist about the need for these functions to be realised in ways understandable by everybody including young and old people across different cultures, with safety first and standards validated by research studies.

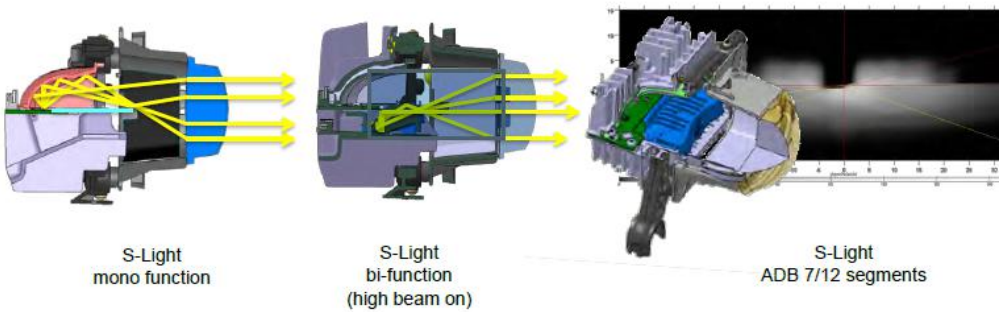
Affordable LED Headlamps – Standardisation is the Key – Purpose & Limitation

Gerd Bahnmüller • AL (VP of Lighting Technology R&D) See Slides

Gerd Bahnmüller described AL's size and scope—turnover of €3.6bn; 20,200 employees including 2,100 in R&D; 21.7m headlamps produced (of which 5.1m LED, 2.9m HID, and 13.7m halogen) and 28.7m rear lamps (16.7m LED and 12m incandescent).

He described the technological foci of AL's R&D right now: new, more compact laser systems with integral electronics and sensors that will be delivered in 2018-2019, and high-resolution matrix beams able to project a million pixels on the road. The first application will be soon on the Mercedes Maybach.

The goal of mass production implies a need for cost ontrol, and Bahnmüller desribed AL's strategy on that front: standardisation is key for cost reduction, and gave the example of AL's e-Light and new S-Light modules.



Standardisation is a difficult exercise for lighting, needing to take into account the evolution of the LED sources—In 10 years from 2008 to 2018, their efficiency has multiplied by three. Moreover, there's the reduction in number of LEDs sources on PCB, halved (at least) over the last decade with consequent changes of the optical design and mechanical parts; the need for more compact systems: for instance from e-light to s-light, width decreased from 110mm to 100mm, height from 90mm to 80mm and depth from 160mm to 130mm with the diameter of the lens evolving from 60mm to 45mm. Also crucial is customer expectations for performance, for instance with side illumination extended, improved range, and appropriate light at short distance.

DVN comment:
LED headlamps are fantastic compared to previous solutions: much better performance, energy consumption, and style possibilities. But currently LED headlamps are just 24% of AL's production. Bahnmüller's talk painted a clear picture that for LED headlamps to become a strong majority, costs must fall dramatically—and the recipe for that is standardisation.

Lighting technology for self-driving cars
Motohiro Komatsu • Koito (R&D Manager)

Light Source Technology
Kazuhiko Ueno • Stanley Electric (Engineering Technologist)

Next Challenges for LED Modules
Xavier Artigou • AL (Lighting Modules Manager, LED)

Communication by Signaling - The New Language of Light
Hiroyasu Onuki • Ichikoh (General Manager of Innovation)

Communication by Signaling - The New Language of Light See Slides

Hiroyasu Onuki • Ichikoh (General Manager of Innovation)

Hiroyasu Onuki, General Manager of Ichikoh's Innovation Department, presented a thoroughgoing examination of communication by light. Not in the traditional sense of red, yellow, and white lights on, off, dim, bright, steady or blinking, but in the new sense of being able to communicate much more diverse and subtle messages and shades of meaning. This, Onuki says, becomes crucial as autonomous cars are very soon to be a significant and growing part of the traffic population. Not just because of novelty or commercial benefit, but for a variety of reasons: urbanisation, the effort towards fewer (and eventually zero) traffic deaths, a shrinking labour force, an ageing society, and other social issues are all looking at AVs as a solution.

But AVs will bring new problems, chief among which (for our purposes) is that there will no longer be a human driver to communicate with. Pedestrians will no longer be able to make eye contact or exchange gestures with a human being at the wheel of a car. Dependable substitutes must be found for this communications channel, and light-based messenging is going to be the way to do it. "Lighting", says Onuki, "connects cars and pedestrians as a bridge". As well as ensuring safety, he added, lighting can reassure people.

There are now three categories of lighting-based communication: by signalling (e.g., stop lights, turn signals), by projection (e.g., lane lines, artificial crosswalks, navigation symbols printed in light on the road), and by display (words or graphics made out of light, on the vehicle itself). The right type must be chosen for the task at hand: communication by signalling is constrained to low-complexity messages, but carries over long distances. Communication by display, on the other hand, can present highly complex messages, but carries only over short distances. Communication by projection is in the iddle between the other two.

A hot topic at the moment is what new kind of light might be applied specifically to AVs. It's probably going to be a turquoise light, and ideas are being kicked around as to how it should work. Ichikoh have a concept for a wraparound light band, encircling the entire car, large enough that the light colour and "motion" of light are clearly perceptible. This is in accord with extensive research work carried out by Ichikoh, asking people questions like "How do you react when you encounter a driverless car?" "Would you like to know that your car/another car is driving autonomously?" and otherwise like that. Two particularly interesting questions from Ichikoh's survey: "Can lighting be used for inter-vehicle communication or communication between drivers and pedestrians?". The majority response was "Lighting can be used if the rule is known by everyone". Overall, the rsults suggest that the general public want to be able to predict an AV's motion, and signal lights are a good way to do this but only if their characteristics are standardised and universally known and understood.

DVN Comment: Ichikoh's survey questions are particularly thoughtful, and the responses very informative. Input from the public is vital for shaping the design and implementation of a signal system for use by the public. The wraparound AV light seems a better idea than a small front-facing light bar.

Lighting technology for self-driving cars See Slides

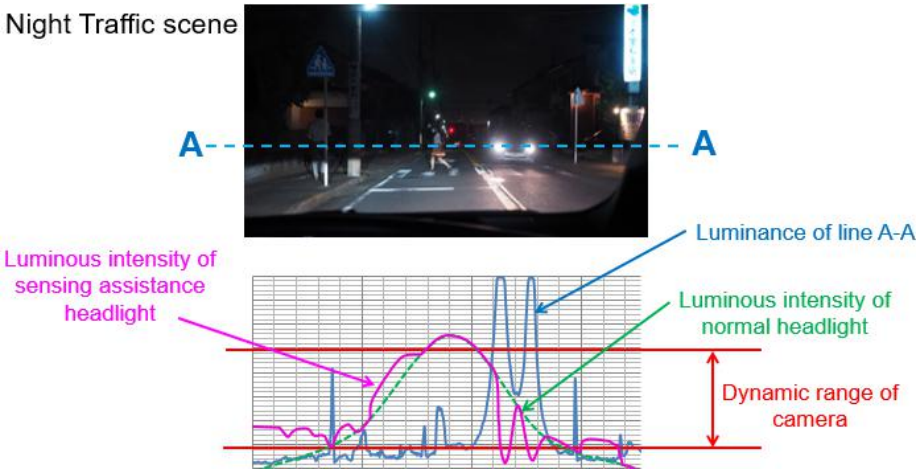
Motohiro Komatsu • Koito (R&D Manager)

Koito's Motohiro Komatsu first reminded the audience of the main necessities for self-driving car lighting, including the recognition of the surrounding environment that can be supported by sensing assistance and built in sensors, and the HMI functions where communication signals will have to be used. He then presented Koito's technical proposals: a communication lamp consisting of a display in a front or rear lamp, with projection of images on the ground for welcome or to inform other users. For examle, to inform crosswalkers of the existence of hidden cars, or telling pedestrians they can go first. There's also Koito's lamp with inbuilt sensors; the present mokups have lidar sensors in a headlamp and rearlamp enclosure.

Koito have done some experiments with these mockups, demonstrating the interest of this implementation for faster detection: pre-collision detection time can be 5.2 seconds with lamp-integral integral lidar instead of just a paltry 1.4 seconds with rooftop lidar.

As far as sensing assistance, Koito think cameras are the lone sensors able to provide details of objects such as pedestrians and other cars, and so cameras are necessary for automated driving. Cameras need light, as they are passive sensors...thus, AVs need good headlamps, and it is essential to improve the safety of autonomous cars by optimising the light distribution for cameras' needs.

Komatsu-san showed Koito's interesting concept for this kind of optimisation: a light distribution taking into account the limitations of current cameras with a dynamic range of 110 to 120 db (for the best HDR cameras but with some blur), and the luminance range of night traffic condition being at 120db: to secure that dynamic range, the future light distribution could be dynamically adapted.



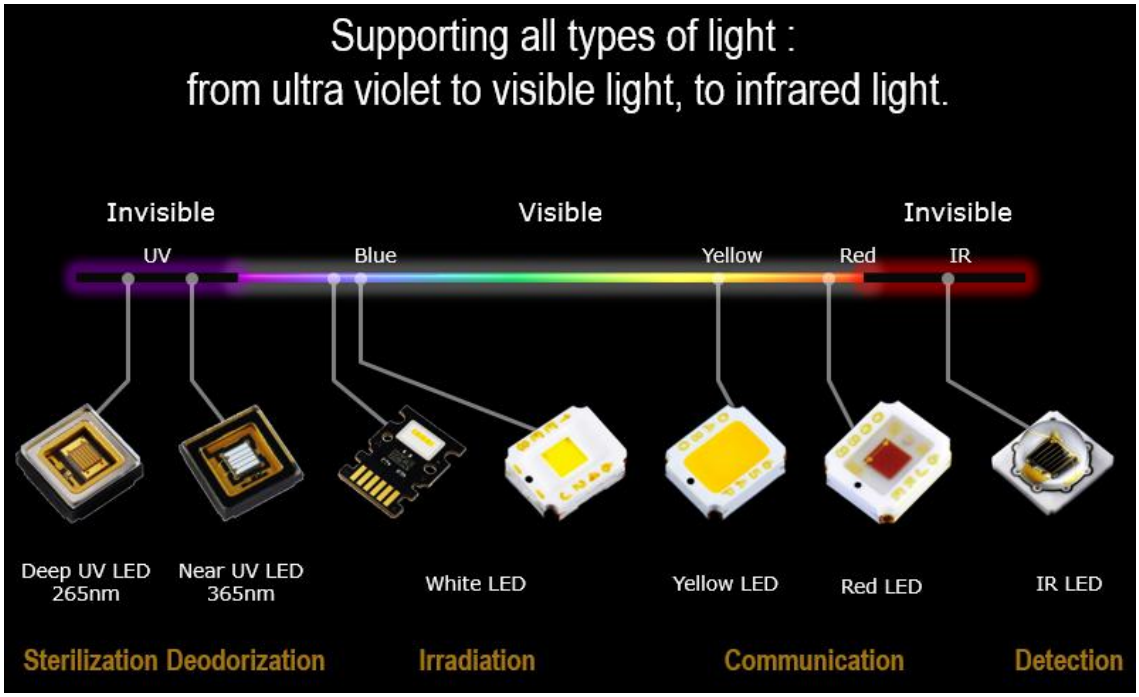
DVN comment:
The integration of sensors in front and rear lighting will be an important task for set makers in the future, but first they have to demonstrate the interest of this location and Koito have given some interesting arguments for that. The optimisation of the light distribution for cameras is an important task to be done, probably with HD headlighting, while maintaining acceptable headlamp performance for conventional human eyes.

Light Source Technology See Slides

Kazuhiko Ueno • Stanley Electric (Engineering Technologist)

Stanley's Kazuhiko Ueno presented the variety of applications of his company's LEDs in vehicle lighting.
For front lighting, he said, headlamps will most certainly come to integrate sensors—lidars, for example—and for that, they will need to be compact to a degree possible only with LEDs. Advanced LEDs such as COB (chip on board) and CLCC (ceramic leadless chip carrier) are bringing high reliability with high efficacy, while lending themselves to new technical solutions such as matrix beam applications.

For signal lighting, red and yellow LEDs are used for the traditional regulated functions, and will soon be also used for communication. For driving monitoring systems, low thermal resistance with high reliability package IREDs are used, for instance for security cameras and driver monitors. And finally for the interior space, UV LEDs can be used for sterilisation and deodorisation—a novel application of LED technology to vehicles.



DVN comment:
LEDs already have many applications in vehicle lighting, and this presentation by Stanley suggests we have a long way to go before we stop seeing whole new kinds of applications being devised. The idea of using UV LEDs for deodorisation and sterilisation is intriguing—could this be the end of the longstanding problem of air conditioner system odour caused by mould and mildew growth?

Next Challenges for LED Modules See Slides

Xavier Artigou • AL (Lighting Modules Manager, LED)

Xavier Artigou, building on the presentation of his colleague Gerd Bahnmüller, elaborated on the range of AL modules for front lighting, from the initial halogen modules to the current S-light modules for low and high beam, the LED adaptive 24-pixel low/high beam module, the 12- to 32-pixel adaptive high beam, the 84-pixel adaptive low/high beam, and under preparation the LED digital high resolution system with DLP.

For the development of these modules, AL are naturally focusing on performance and cost, but also on other important targets that Artigou emphasised in this lecture: styling, lighting homogeneity, reduction in mass and power, and a particularly interesting driver of the need for reduced package size: ever-larger car wheels.

About styling: some modules are visible, while others are hidden with different constraints for realisation. Examples of visible (above) and hidden (below) modules are shown here. In general, when low and high beam are hidden, the signal functions and DRL are emphasised.

The challenge for automakers is to keep the main part of the modules standard for both styling use cases. A good perceived lit homogeneity is also now called for, after previously being considered important only for signal functions.

Larger and ever-larger wheels are a strong trend illustrated for instance by the ø 20-inch (51-cm) wheels used as standard on the Renault Scenic. These affect lighting through their space consumption, driving a need to reduce the depth of lighting modules. Meanwhile, for mass reduction, Artigou presented two directions: improved efficiency allowing smaller heat sinks, and inbuilt electronics saving 1 kg in the whole vehicle.

For reduction of power consumption and CO_2 reduction, and particularly to have the benefit in Europe of a 1 g/km CO_2 reduction for the ECO innovation assessment, efficient modules for weight, size, and power consumption with no fan are necessary. AL are developing such a new module, called c-light.

DVN comment:

In our lighting domain, the main functions in relation to style and performance (and now communication) are often presented, but there is a huge part of developments focused on the hidden part of the "iceberg" with regard to the constraints interestingly presented by Xavier Artigou here. The large-wheels driver of smaller lamp packaging wouldn't necessarily occur to one on casual thought, but makes a lot of sense.

Session 4 • Global Technical Regulation See Slides

Chairman: Geoff Draper, GTB President See Video

Since 2011 Geoff Draper has been leading the debate relating to the need to remove barriers to innovation by simplifying and harmonising the current regulations and over the past six years much has already been achieved. This debate has now reached a stage where a step change is required to develop global technical requirements. These requirements must be suitable for global implementation of innovations instead of perpetuating the current system of parallel UN regulations and other national mandatory standards that are almost impossible to synchronise and which present major barriers for manufacturers.

For this central session of the Workshop, GTB President Geoff Draper furthered his work on building industry consensus to seek the support of governments in developing GTRs (Global Technical Regulations) under the UN 1998 Agreement. The Tokyo location of the Workshop inspired Draper to organise a regulatory session centred round the opinions of Asian stakeholders from Japan, China, India, and South Korea.

A high level, two hour, Regulatory session with contributions from eleven experts in the field of Automotive Lighting and light-signalling was led by GTB President, Geoff Draper. He launched the session with reference to the introduction, published in the DVN Newsletter of 15 May 2018, which explained his motivation to work on building an industry consensus to seek the support of governments to develop GTR's under the UN 1998 Agreement.

The two hour session consisted of:

An opening speech by Mr. Hiroyuki Inomata, Director of the Technical Planning Office of MLIT, the Japanese Ministry of Land, Infrastructure, Transport and Tourism. Inomata-san also holds very important positions at the UN Global Forum in Geneva as Chair of WP.29-AC3 (the administrative committee for the UN 1998 Agreement) and Chair of the WP.29 Informal Group on ITS/Automated Driving.

Then there was a keynote presentation by Dr. Peter Bodrogi, Senior Research Fellow in the Laboratory of Lighting Technology at TU-Darmstadt in Germany. Dr Bodrogi's lecture—The Worldwide Demographic Development and Consequences for the Development of Global Automotive Lighting Technical Regulations"—dealt with the major challenge of specifying and providing lighting that works for all users. It's difficult because older traffic participants' lighting needs greatly exceed those of younger people for any given level of visual performance, as the human visual system loses contrast with age. But at the same time, glare sensitivity increases with age as well. See Slides

A second keynote presentation was given by Michel Loccufier, Director and Head of the Regulation, Licence, and Enforcement Unit at the Belgian Ministry of Transport and Mobility. Mr Loccufier also, having succeeded Marcin Gorzkowski, presides over GRE, the WP.29 Working Party on Lighting and Light-Signalling in Geneva. Loccufier's talk was "The UN 1998 Agreement and the Procedures to Develop GTRs: Experience of Developing GTRs and Lessons Learnt". One of the main points of the speech was that given today's exigencies, high priority should be placed on broadest possible agreement to arrive at a regulation—even if the technical prescriptions in the regulation don't start out where it would be desirable for them to wind up eventually. See Slides See Video

These three opening speeches provided a solid backdrop and logical introduction to the panel discussion that posed two questions: Are GTRs the future of global automotive lighting regulation? And what are the pros and cons? The panel consisted of experts almost entirely from Asia, listed here as shown Left to Right in the photo:

- **Sung Uk Choi**, Vehicle Manufacturer, Hyundai (South Korea) • Leader, exterior lamp system engineering design team
- **Takayuki Amma**, JAPIA (Japan Auto Parts Industries Association)
- **Venkataramaiah Belavadi Shamsundara** ARAI (India) • General Manager
- **Xiaoping (Sally) Zhou**, Independent Tier 1 Equipment Manufacturer, Xingyu Lighting (China) • CEO and Chair of the Board, See Video
- **Teruyoshi Fujita**, Toyota (Japan) • Chair of the JAMA Lighting Committee
- **Hiroyuki Inomata**, MLIT (Japan) • Chair of WP29- AC3 , Chair WP29 «Automated Driving»
- **Michel Loccufier**, (Belgium) • GRE President; Director of Regulations at Belgian Ministry of Transport and Mobility
- **Geoff Draper** (UK) • GTB President, discussion moderator

Contributions from experts who were unable to be present but wanted to explain their positions were read to the audience. These experts were:

- **Mr. Aleksander Lazarevic, (**EU), Policy Officer, DG GROW, The European Commission
- **Mr. Charles Uthus,** (USA), Vice President AAPC, (American Automotive Policy Council representing Fiat Chrysler Automobile, Ford Motor Company and General Motors Company)
- **Professor Yuntang He**, (China) Auto Standardization Research Institute (ASRI), China Automotive Technology & Research Centre (CATARC), Representing China in the UN ECE World Forum - WP29 / GRE

Background to the Session

Traditionally, Lighting and Light-Signalling Regulations have been based upon a classic standardisation approach and in many cases are focussed on specific technologies. This has resulted in regular amendments of the regulations to accommodate technical progress. In 2012 the European Union and Japan introduced an initiative in the UN World Forum on Harmonisation (WP.29) calling for a new simplified approach based upon the principle of technology neutral requirements, meeting minimum performance levels based upon safety criteria. In 2015 the Chinese Government launched a similar initiative to simplify the GB Mandatory Standards. In both cases the motivation was to produce regulations that are not subject to frequent amendment.

In response to the initiative of the EU and Japan, the GRE SLR Informal Working Group was launched in September 2014 and developed its two-stage plan to produce technology neutral, performance based technical requirements. The Stage 2 was launched in January 2018, with the opportunity to work with the Chinese

simplification group to harmonise the device requirements by the end of 2020. The harmonisation of the installation requirements requires more time with expected completion in 2024.

Ground-breaking work on development of the SAE J-3069 Adaptive Driving Beam and NHTSA'S approach to adaptive head lighting systems is now the subject of a Notice of Proposed Rulemaking. This provides a foundation for developing objective performance based requirements compatible with the self-certification approach to regulation.

These important initiatives by the UN, China and USA are all aimed at technology neutral simplified technical requirements focussed on assuring road safety, regulatory certainty and reducing barriers to innovation. There are also initiatives to introduce New Car Assessment Programmes (NCAP) to encourage the development of features to further enhance the minimum requirements laid out in the Regulations. This is a means of simplifying the regulations to make them more stable by reducing the need for frequent amendment without unnecessary restrictions to the implementation of new technologies.

Looking to the future there are new challenges and opportunities associated with the possibilities of adapting lighting to suit special needs such as:

- Mega cities
- The ageing population
- The complexities of mixed traffic consisting of more cycles, more trucks, more pedestrians and the presence of vehicles equipped with Automated Driving Systems (ADS)
- Special signals to indicate the operational status and intended manoeuvres of ADS vehicles

Emerging technologies will increasingly have the capability to adapt lighting and light-signalling to satisfy these important special needs and, clearly, there will be a requirement to develop stable technology neutral requirements for systems that can be intuitively operated, or their signals can be understood, by all users. This implies the need for technical regulations that are globally harmonised and synchronised. The platform for the development of these requirements is the UNECE World Forum for Harmonisation of Vehicle Regulations and its 1958 and 1998 Agreements.

The regulatory aspects of lighting and signalling for ADS Vehicles are under discussion at the UNECE and it is clear that the technical requirements will be developed as GTR's under the UNECE 1998 agreement and in conjunction with WP.1 (1968 agreement – "Vienna Convention") because a unique global solution will be necessary.

The Contributions of the Panel

Mrs. Xiaoping Zhou

Xingyu lighting is among the largest automotive lighting companies in China and serves OEM brands all over the world , I am very glad to address the DVN workshop to share our opinions.
For the first question, I think that GTR's should be the future of global automotive lighting regulation and the trend of its development because the ultimate goals of national and regional regulations are the same; they mainly focus on safety, environmental protection and economy. GTR's can promote the technical consistency and innovative technology development for different markets, and therefore benefits for international trade. However, the consolidation for the different regulations shall be big challenge for the coordinator,due to the different traffic situations and different regulation bases among different regions. For example, in Asia there are many mega cities and the road traffic situations are very complicated. Perhaps the field of Automated Driving System (ADS) lamps and Road projection will be the good breakthrough points.

Mr. Venkataramaiah Belavadi Shamsundara

India in 2020 is looking forward to smart, safe and sustainable mobility like other developed countries. At this juncture;

- India is crossing 30 million vehicles production annually
- India is 2nd largest two-wheeler manufacturer
- India is 5th largest heavy truck manufacturer

- India is 6th largest car manufacturer

Considering the environmental challenges of pollution and fossil energy depletion, technological innovations would be required to meet the rising need of urban and rural mobility in India. Also the development of automotive regulations harmonised with Europe and the technological advancements would be critical to ensure the safety and environmental performance of future vehicles in India. The Indian Automobile Industry in the last decade has made significant progress on the environmental and safety front by adopting stringent standards, and is progressively aligning technically with international standards.

While formulating the national standard in India considerable assistance is drawn from existing UN Regulations. Additionally being a signatory to 1998 agreement, India actively participates in the formulation of GTR and their subsequent transposition into national standards. While formulating its standards, India has drawn references from 116 out of the 143+ UN regulations and has completed the task of formulating the India Lighting standards with the reference to the UN regulations, with the exception of UN R88 related to retro reflective tyres for 2-wheeled vehicles. Similarly India has formulated standards which are technically aligned to 7 GTRs out of 19.

As a matter of fact, India has tabled several informal documents while formulation of Lighting GTR long back. As a 1998 signatory, we have strongly supported the formulation of GTRs in lighting. India is ready to take any assignment, if WP-29/GRE provides an opportunity to work in this regard.

India has all the global automobile players and, having equal share of Asian and European countries as well as US base a GTR will really help us to make life easier. India has always been in agreement for the technology neutral simplified technical requirements and less frequent amendments. It assures more road safety, regulatory certainty and reduces barriers to innovation.

We feel there is no negative concern for the development of GTRs in the lighting areas. However before taking this task, we need to understand the following because GRE has worked / discussed more than two years in the past, but the outcome was zero.

1. Effective use and implementation of existing GTRs across the globe by the 1998 signatories
2. What are the problems faced by 1998 signatories while implementing these GTRs/ it may be feedback from respective countries.
3. Make an agreement from 1998 contacting parties and clearance from WP29 before start of formulation of lighting GTR.

Mr. Teruyoshi Fujita

To the question "*Are GTR's the Future of Global Automotive Lighting Regulation*", of course I hope so but it's difficult. I'm not familiar with GTR's. There are 20 GTR's now but there is no lighting GTR.
When I started my regulatory work in JAMA, the trial making GTR for lighting installation had just ended in failure. Most of OICA members are negative to GTR because of this bad experience and when the OICA GEE chairman saw the GTB document for GTR, he said, "It's a dream!"
I think lamps are like languages; they are communication tools and they are like cultures. It is difficult to harmonize cultures. People in US are accustomed to red direction indicators whereas, in Japan, people would be surprised at red direction indicators. However, there may be a possibility of GTR for new lamp systems, like ADS lamps.

To question the question "*What are the pros and cons*?" the pros are that we can sell the same lamps to all over the world but the cons are that innovations may be delayed. I hope that regulations will be made at the same speed as innovations.

Mr. Takayuki Amma

The view of JAPIA is that GTR's are a very good idea for future and new lighting technologies, especially for signalling and marking lamps of autonomous vehicles in the near future, The GTR is important and necessary for the pedestrian and other road users to understand the signals and markings easily and to communicate between them correctly all over the world.

For the global harmonization, the important point is to involve not only the 1958 agreement countries but also other countries including China, India, and the US in this activity and rulemaking, and the question is how to make the GTR in line with other countries rules such as China GB standard and USA FMVSS.

Regarding ADB we will see a good example soon, because we can expect NHTSA will issue a NPRM for allowing ADB in the near future. The question is whether NHTSA could accept UN/R123 or not. I'm afraid the GTR for ADB might be difficult. But, for the future lighting technology, we really need the GTR, and in order to do so, at the beginning of the development of GTR, we should discuss with many countries including China, India and US, and consider how to resolve this question.

Anyway, basically JAPIA would like to support the development of GTR for the future and new lighting technology.

Mr. Sung uk Choi

The Korean industry supports the development of GTR's but as mentioned by the Japanese members Korea has a different culture and environment so harmonisation is difficult. However the car manufacturers have a need to harmonise. Korea already has a close harmonisation with the UN Regulations but other countries outside the UNECE have different requirements so a GTR becomes an important approach.
Concerning new technology we heard in this morning's presentation that there are already so many different signals and signs proposed for the ADS vehicle but we should not be concerned about only one ADS vehicle on the road but, for example, one vehicle projects a pedestrian crossing on the road and another does the same thing, the result is confusion for the other road users.

Of course innovation is very fast and regulation is relatively slow but we need to be very careful because this is the time to find the correct solution for the future.

Mr. Michel Loccufier

As I said in my earlier speech we will only deliver good GTR solutions if we work together; everyone has to contribute.

First of all I think GTR's are a good idea but we also have a need to develop technology neutral and performance oriented requirements that can also be a good step and perhaps an easier step to finally have a GTR. It could be the principle that everything would be specified in the GTR so that we have uniform harmonised provisions that could be used on a national level according to national needs but not refused if installed according to those specified provisions. This could be useful because it is not like in the 1958 agreement where the provisions are obligatory.

Of course as a GRE Chair I will give support to all initiatives where needed and particularly to ensure safer and cleaner vehicles. I am also a "Belgian guy" and Belgian guys are familiar with working on compromises so take care when asking my opinion on some things!

Mr. Aleksander Lazarevic

Dear Geoff, please convey my sincere apologies to the audience for not being in position to participate in the panel personally. I would appreciate if you could express the following position:

"The European Commission has been actively involved in the process of simplification of requirements for automotive lighting and light-signalling. The process, the objective of which is transition towards performance based requirements will lead to technological neutrality and reduction of regulatory burden for the industry and administrations. Eventually, in the framework of UN 1998 Agreement, the simplification could lead to a universal recognition of this novel regulatory approach as early as 2025 and the European Commission would truly appreciate timely and earnest engagement of other key Contracting Parties in developing a new proposal for global technical regulations on lighting."

I would also welcome if you could openly thank Japan (MLIT and JASIC) on my behalf for providing the critical political support, which has allowed us to bring the first phase of this important process closer to completion. I wish you most successful panel moderation.

Mr. Charles Uthus

We sincerely appreciates the opportunity, which has been provided by GTB, for AAPC to issue this statement in support of the important and timely event covering a central auto regulatory subject matter – lighting regulations for road transportation.

Lighting equipment and their manufacturers have been at the forefront of vehicle safety and safety standards and regulations for a long time. In fact:

- One of the first technical lighting regulations was established in October 1915 in the United States (in the state of Massachusetts). It was what we would call today a "technology-neutral, performance-oriented standard." The regulation required: [1]
    - Headlamps to make all substantial objects visible to a distance of 150 feet (48 meters); and
    - That no dazzling rays of light be more than 3.5 feet (1.1 meters) above the ground for a distance of 50feet (15 meters) ahead of the vehicle.

- During the 1960s, the first harmonized regulations adopted by the group that is known as the UN World Forum for the Harmonization of Vehicle Regulations (WP.29) were all lighting regulations.

Initial lighting regulations often focused on particular technologies. But through trial and error we have come to understand that performance, not technology, provides the optimal basis for setting lighting standards and regulations. Keeping lighting regulations aligned with technological innovation is especially critical during this period of rapid technological progress through electrification and automation.

Furthermore, the global nature of these trends and the rapid and accelerating evolution of the automotive industry, demands that we take this opportunity to establish uniform regulations applicable worldwide without regard to the compliance and enforcement systems of individual countries or regions.

With this in mind, the American Automotive Policy Council wishes to take this opportunity to affirm its strong support for technology-neutral, performance-oriented, and globally applicable regulations. AAPC appreciates the efforts of the GTB, the EU, Japan, China, and WP.29 as well as those of SAE, the US Department of Transportation and the National Highway Traffic Safety Administration to establish a new 21st century global framework for lighting equipment. Through the use of advanced lighting solutions, we believe that these efforts, especially if pursued under the WP.29 1998 Global Agreement, have the capacity to improve safety on roadways around the world.

Prof. Yuntang He

GTR's should be a right choice for the future.

- ❖ Globalisation of auto industry needs worldwide harmonized rules.
- ❖ Introduction of GTR's could simplify the job of GRE IWG-SLR.
- ❖ Avoiding the complex UN Regulation system developed under the UN1958 Agreement.
- ❖ There is a need for GTR's to have a bigger influence

Pros

- ❖ International wide
- ❖ China joined 98 agreement, sharing the chance to develop a GTR
- ❖ Without certificate provisions, GTR could be easily accepted by different parties.

Cons

- ❖ UN Regs have been playing an important role.
- ❖ On the platform of GTB, China could carry out the jobs of UN Regs, although not being a 1958 Agreement Contracting Party.
- ❖ The existing Chinese standard system is nearly the same as UN Regs.
- ❖ Development process of GTR is too long.

Conclusion

In summary, the panel unanimously agreed that:

- ✓ GTR's shall be future basis for lighting and light-signalling regulation and the priority should be placed upon developing GTR's for the new technologies such as signalling for Automatic Driving Systems (ADS).
- ✓ There is some nervousness to commit resources to this major task because of the previous attempts to develop GTR's that failed, due to opposition from some parts of industry and reluctance of some contracting parties of the UN 1998 agreement to incorporate the Global Technical Requirements into their national laws.
- ✓ Notwithstanding the nervousness, it is time to start working on GTR's because the new technologies need to have globally harmonised technical requirements and be available for application in all markets.

Closing Comments

Geoff Draper referred to an important discussion that took place at the GRE 79th Session – April 2018 where the official report (ECE/TRANS/WP.29/GRE/79) states:

> "6. The expert from GTB pointed out the growing interest in global harmonization of lighting and light-signalling norms, in particular in China and the United States of America. According to him, stage 2 of the ongoing process for Simplification of the Lighting and Light-signalling Regulations (SLR), which focused on technology-neutral requirements, could pave the way to development of a new Global Technical Regulation (GTR). He also identified light-signalling functions of autonomous vehicles as a possible topic for a new GTR. The experts from the Netherlands, UK, EC, OICA and SAE supported this idea. The expert from the United States of America encouraged all stakeholders to start a dialogue on this issue."

He emphasised that this last sentence has been underlined to emphasise the important advice of the representative of the US; it is NOT underlined in the official report.

Finally he stated that, unfortunately due to time limitations, it was not possible to have a Q&A session and proposed that a teleconference, open to all DVN members, will be organised to give an opportunity to ask questions and to comment on the issues raised in this regulatory session.

Geoff Draper sincerely thanked all the participants for their precious contributions and for dedicating their time to join this regulatory session in Tokyo.

DVN Comment:

The pace of technical innovation practically demands global regulations, and it is very encouraging to see substantial progress every time we have an opportunity to glimpse Geoff Draper's ongoing work at the giant, daunting task of getting an enormous number of differently-interested stakeholders onside and working in a common direction—an activity surely more than a little akin to herding cats!

Session 5 • Advanced Light Sources

Essential SSL Technologies for the Coming Automotive World
Dr. Ulf Meiners • Nichia (Deputy Managing Director, Germany)

Light Source Developments & Enhanced Road Safety in a Regulatory Approach
Helmut Tiesler-Wittig • Lumileds (Strategic Standardisation Director)

Challenges for Advanced Front Lighting Technologies
Claus Allgeier • Osram (Automotive OEM VP of Business & Technology Development)

Engineering Visual Experience and Biological Impact of Interior LED Lighting
Dr. Bernard Stapp • Seoul Semiconductor (Global Automotive Strategist)

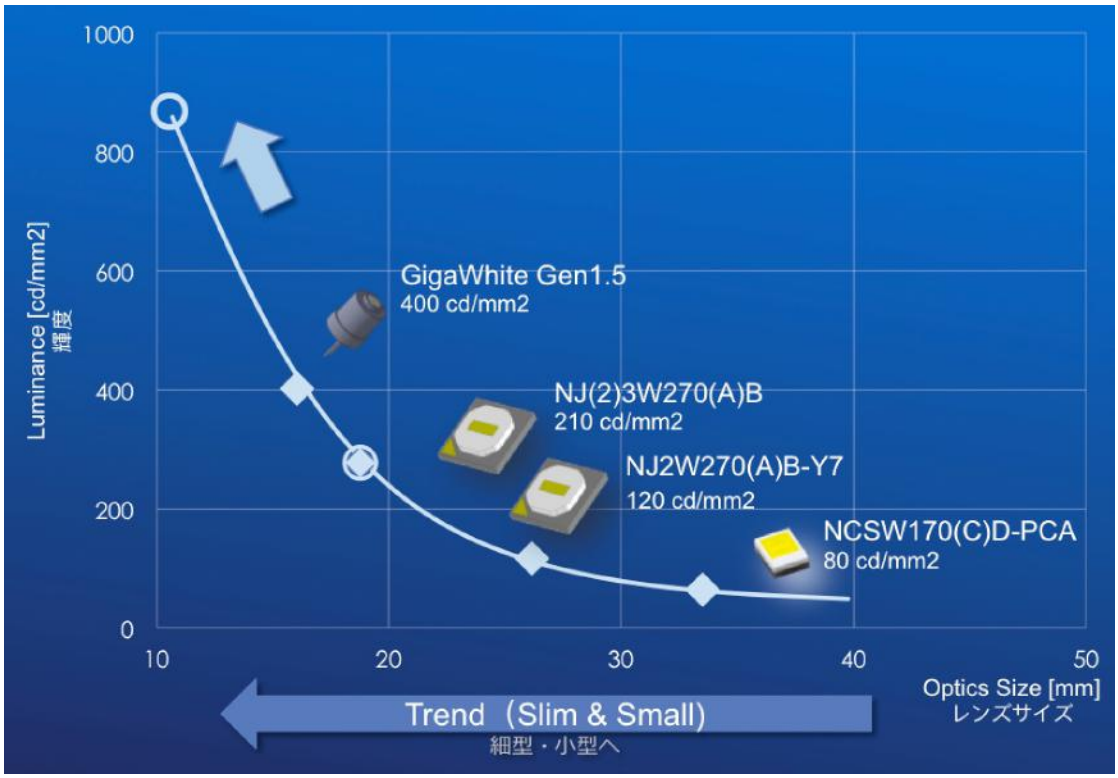
Advanced Light Source – Everlight Smart Multi LED
Shawn Li • Everlight (Light Source Development Chief)

Essential SSL Technologies for the Coming Automotive World See Slides

Dr. Ulf Meiners • Nichia (Deputy Managing Director, Germany) See Video

Nichia's Dr. Ulf Meiners started his presentation by pointing out the ubiquity of digital lighting in the cars of today and tomorrow: it's everywhere, from the ambient and instrument panel illumination inside the car to the taillamps, headlamps, and advanced functionality like ADB outside the car. "Digital lighting" really means digitally-controlled lighting, and it can only work effectively with optimal light sources. That need, in turn, is met by Nichia's core competencies in advanced chip, packaging, and conversion phosphor technologies.

With that overview on the table, Meiners described the pressing need for high-luminance light sources, driven by the present styling trend toward slim, small lights. A plot of Nichia's LED and laser diode offerings' luminance versus optic size in millimetres, shown here, graphically illustrated Meiners' point.



Having established the need for very high luminance, Meiners presented Nichia's latest solutions, including high-luminance LEDs (210 cd/m^2) with very small emitting surface (0.6 × 1.55 mm), three of which—each in its own 15 mm optical cell—can realise a full low beam. From there, Meiners proceeded to describe the optimal light sources for advanced lighting technology at various levels, such as ADB at standard, high, and super high resolution and, beyond that, the DMD concept. These include high-luminance LEDs with innovative monolithic phosphor technology for high-quality, "paper white" light and direct-to-heat-sink mount for good thermal management; as well as a tantalising multi-laser low beam with extreme source luminance (800 cd/m^2) wringing excellent performance (644 lm on th road, 61% optical efficiency, a hot spot of 35.2 kcd, and 1-lux beam width of 70°) from small size (32 mm W × 20 mm D × 8.5 mm H). The obvious next step from there, Meiners posited, is a laser scanning setup with a reflective converter plate accepting blue laser light from the MEMS and reflecting it as white light through the projection optics. An update was also provided on the output stability with age effects, and Meiners left the audience with a question to ponder: What is beyond digital lighting?

DVN Comment:

It is fasinating to see how a styling trend (toward small lamps) drives crucial performance aspects of light source technology. Very intriguing results from Nichia's experiments with new-generation light sources!

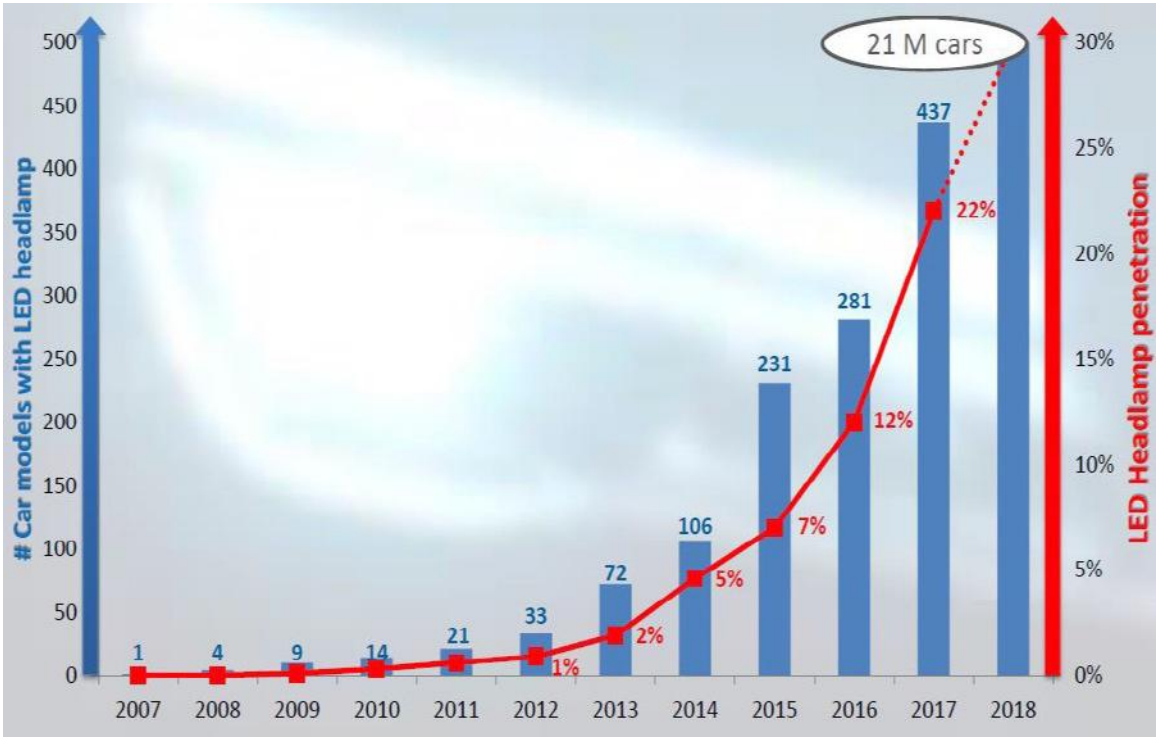
Light Source Developments & Enhanced Road Safety in a Regulatory Approach See Slides

Helmut Tiesler-Wittig • Lumileds (Strategic Standardisation Director)

Helmut Tiesler-Witting's lecture centred round recent progress and crucial new challenges in the coördinated slow dances of regulation and standardisation on the one hand, and economies of scale on the other. Technical regulations must be technology-neutral and performance-based to clear the way on an ongoing basis for new innovations, because technology-specific regulations are quickly rendered obsolete as soon as the next innovation comes along that "breaks" the language of such a rule. And because vehicle lighting is fundamentally about safety, that crucial aspect—safety—must be intrinsic to all steps of the design and function of new light sources for vehicles. While this sounds like an impediment to innovation, in fact it presents the opposite opportunity: the shift to LED technology leads to high-volume mass production, and economies of scale exert in favour of standardisation and its constellation of supporting elements.

Hence, for example, the drive toward "LED bulbs"—standardised, replaceable LED light sources for virtually every kind of signalling and marking light...and the UN Regulation (№ 128) that specifies and standardises them. In this example, safety is at the core in several ways: standardised "LED bulbs" make it much less expensive for automakers to use LED lighting, so LED benefits like instant light-up, low power consumption, and long burnout-free life become available to more people, faster. And the benefits extend beyond new-car build cost: if a part like a tail lamp assembly gets damaged in an accident, the broken lens-reflector housing can be replaced inexpensively, and the still-working LED bulbs transferred in. Likewise, if an LED bulb should fail, it can be replaced individually; the driver doesn't face paying for the whole expensive LEDs-and-driver-and-optics-and-housing assembly.

Tiesler-Wittig showed how similar reckoning applies to LED headlamps, with an exponential graph, shown here, of LED headlighting adoption between 2007 and 2018. He then described how aggressive standardisation and regulation efforts must be at the centre of all new lighting developments, from new kinds of car lights (digital headlights, etc) to how to handle data security, robustly shield cars from hacking while facilitating over-the-air updates, and the devisement of whole new lighting concepts (dynamic displays, artificially intelligent headlights, lighting for vehicle-to-person communication).



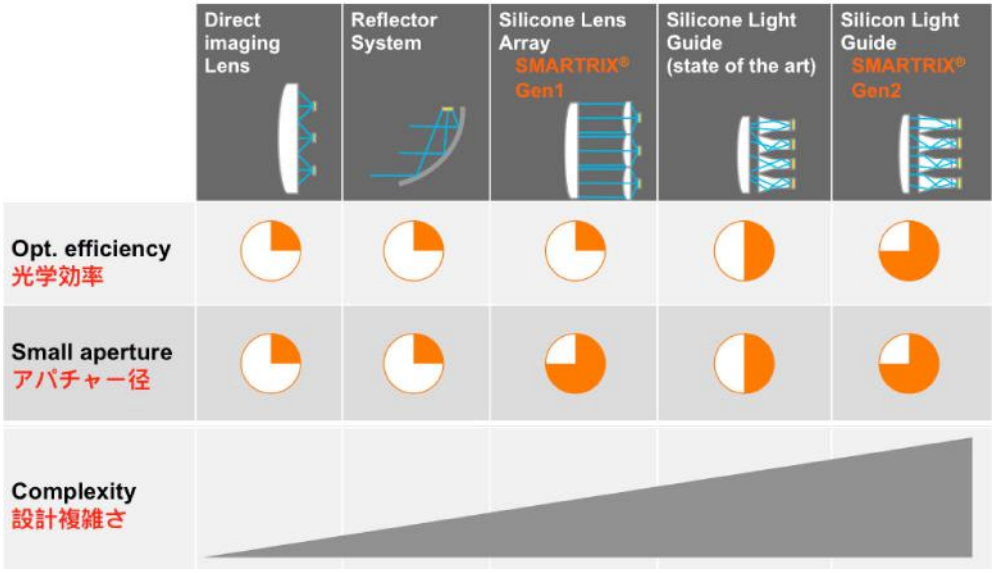
DVN Comment:
This presentation raised very important points about the best, most responsible way to handle new opportunities to define unambiguous new language for new kinds of signals, now that we are no longer constrained to just using crude colour, brightness, and steady or flashing modes. Tiesler-Wittig's focus on the need for rigourous science backing up new lights is highly respectable and quite correct.

Challenges for Advanced Front Lighting Technologies See Slides

Claus Allgeier • Osram (Automotive OEM VP of Business & Technology Development) See Video

The talk by Claus Allgeier got started with some discussion of the prospects for extremely small headlamp optics by using extremely high luminance light sources, i.e., LARP (laser-activated remote phosphor), along with a discussion of the evolution of Osram's blue lasers, which Allgeier reported are expected to reach >5w and >50% efficiency within five years. In parallel, there are developments under way that stand to greatly simplify the safety aspects involved with laser headlamps by dint of integral sensors instead of today's external optical sensors to detect if dangerous unconverted blue laser light is escaping.

Beyond that, the lecture was, centrally, a detailed progress report on the development of two Osram headlamp technologies: Smartrix® and Eviyos®. For starters, this rather stark plot was provided of the optical efficiency, small-optics potential, and complexity of a variety of ADB technologies. Direct-imaging lenses have low efficiency and not much potential for small optics, and the same is true of pure reflector systems. A silicone lens array such as Osram's own 1st-generation Smartrix® makes smaller optics possible, but still lacks efficiency. Silicone light guides, the current state of the art, give medium efficiency and medium small-optics potential, but Osram's 2nd-generation Smartrix® setup is poised to boost both factors, though with much increased complexity. To put numbers on it: with a rectangular lens of 50 × 24 mm, a direct-image ADB system has 18% optical efficiency, a Smartrix®-1 28% (with 35 lm/w), and a Smartrix®-2 40% (with 55 lm/w).



These advantages are further boosted Smartrix®-HD setup utilising an Eviyos® active LED pixel array. Up to four Eviyos LED chips can be integrated into an electronic module to give very high contrast of more than 300:1, with up to 5 lm per 0.125 mm² pixel. In this example, the result would be a 4096-pixel, 32-row full matrix beam with resolution of 0.25° both horizontally and vertically. Another example would feature two of the Eviyos® chips to provide visualisation (lane lines, caution/warning signs, snowflake signs, navigational arrows, and suchlike projected onto the roadway for the driver) in an area of ±8°H and +3°/-5°V. The Eviyos® range is under aggressive development, with future versions looking toward specs such as pixel count increased above 10 kilopixels, pixel density increased tenfold, pixel pitch of 0.1°, and different aspect ratios to cater for different lamp architectures, while maintaining the crucial key advantage of low power consumption, thus unlocking a universal solution for efficient, high-resolution ADB.

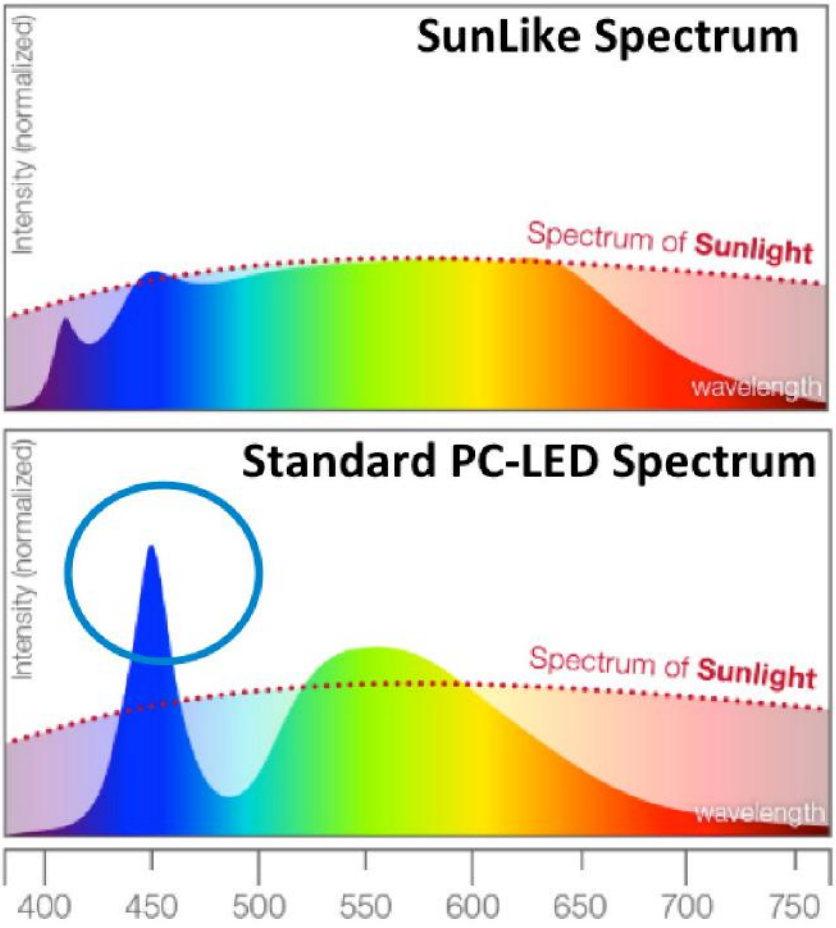
DVN Comment:

With the blistering pace of technological and technical innovation in this field, it is both refreshing and edifying to zoom in and take a close, detailed look at the evolution of one or two particular core components. Clearly, technology such as this will continue to be a hot prospect in the race to determine which methods of making advanced headlamps will win out in the long run.

Engineering Visual Experience and Biological Impact of Interior LED Lighting See Slides

Dr. Bernard Stapp • Seoul Semiconductor (Global Automotive Strategist)

Dr. Stapp provided an interesting new angle on the benefits of lighting that closely replicates the spectral distribution of sunlight. Seoul Semiconductor's SunLike LED technology is based on violet LEDs exciting Toshiba phosphors that provide high-quality red, green, and blue output light, admixed to provide a high-quality white. This versus traditional white LEDs that use direct-emitting blue LEDs, plus blue LEDs feeding through yellow and red converters that provide a lower-quality white light. Quality here refers to the output spectrum: traditional blue-based white LEDs have a spectral power distribution with a high blue spike, a deep trough in the blue-green region, and a rather steep falloff below the orange. This means the SunLike earns enviable CRI (97+) and CQS (97+) scores, compared to the poorer scores of a blue-based white LED. That, in turn, means excellent colour rendering for high-quality in-vehicle lighting.



But it's not just an æsthetic improvement. The newest science indicates there's a significant biological benefit to the improved spectrum from the SunLike LEDs: in addition to the well-known rods and cones in our eyes for scotopic and photopic vision, there is another kind of photoreceptive cell called ipRGCs (intrinsically photosensitive retinal ganglion cells). These play a key role in the circadian, hormonal, and behavioural responses to light. The trough in blue-based white LEDs' output is centred round 480 nm—which happens to be the peak sensitivity of melanopsin, the light-sensitive pigment in the ipRGCs. The SunLike spectrum's robust output in this wavelength range makes it more biologically active. This has been demonstrated in offices, medical centres, airplanes, and other spaces where LED lighting is gradually being understood to interfere and have negative effects on the human physiological response to light.

The automotive applications of a physiologically correct light include roadway safety by enhancement of alertness and reduction in micro-sleep; circadian synchronisation by replacing the unseen sun particularly in the morning, boosting the available effective light dosage to compensate for the lack of bright natural light in wintertime and cloudy conditions, and improving general comfort and wellbeing—seen as a strategic advantage dovetailing with the advent of autonomous vehicles (wherein the driver-turned passenger can be light-conditioned to have an effective, productive day, for example).

DVN Comment: While "close to natural daylight" and similar claims have been used for years without rigourous basis to promote light that is merely bluer than whatever came before, this time appears to be markedly different. With understanding growing of the significant effects of light on human health, spectrally-correct light seems likely to gain quite a bit of traction. One wishes and hopes for LEDs such as this to evolve to the point of providing enough light to make spectrally-correct headlamps possible!

Advanced Light Source – Everlight Smart Multi LED See Slides

Shawn Li • Everlight (Light Source Development Chief)

Everlight's Shawn Li launched his lecture by reminding us that normally an RGB LED package contains only red, green, and blue chips; traditional architecture involves separate IC packages and LED packages, so a relatively large amount of space is needed, circuitry is complicated, and onboard diagnostics and monitoring (e.g., for temperature or LED damage) are difficult or impossible to integrate.

Everlight's Smart Multi LED architecture improves on this by adding a driver IC within the LED package and directly connecting the LED chips to the IC pad. This involves surface-mounting the LED package and PCB, without need of an external IC and its attendant packaging issues. The light module is connected to the microcontroller, which transmits binary signals to control the LEDs so as to emit any colour within the RGB gamut, along with a wide range of designs and patterns. Onboard diagnostics and monitoring are readily integrable with high granularity—each individual LED can be monitored, and the Everlight setup allows more precise calibration and compensation for brightness & colour of the LEDs. There's minimal wiring, and circuitry is greatly simplified—in addition to the obvious packaging space and mass savings by eliminating the separate controller.

The Everlight package has six pins: $Data_{in}$, $Data_{out}$, $Clock_{in}$, $Clock_{out}$, V_{CC}, and ground. All LED packages share common ground and V_{CC} pinouts. The first package's $Data_{in}$ and $Clock_{in}$ are connected to the controller; each subsequent package's $Data_{in}$ and $Clock_{in}$ ports are connected to the previous package's $Data_{out}$ & $Clock_{out}$ ports, so they form a straightforward series circuit. The last package's $Data_{out}$ and $Clock_{out}$ are connected to the controller to provide LED feedback data from the IC. The IC contains temperature sensing and LED-open detection, as well as current adjustment, global brightness adjustment, and 12/15-bit PWM greyscale functions. All information is transmitted as binary data of two types: function data and image data.

The data collected are sent to the microcontroller, which analyses the feedback data and sends corresponding compensation and calibration commands back to the IC. The IC, in turn, uses these commands to adjust the current and global brightness. Current adjustment is done at the individual-LED-chip level. Global brightness involves RGB current equalisation; 12/15-bit PWM greyscaling determines the data length of the image data. Image data contains each LED's RGB value. Every LED has its own image data. After the LEDs have received their command data, the IC will output the relevant feedback data to the microcontroller.

The Smart Multi LED system is still in development; Li expects it to be ready for engineering sample-out by Q3-2018. Four package configurations are contemplated. The first will have dimensions of 35 × 35 mm, maximum of 25mA per chip. Intensity of 100 mcd (blue), 351 mcd (red), and 648 mcd (green). The second package has the same 35 × 35 mm dimensions adds three white chips within the package. The third package is a high-current version with a separate cavity to accommodate phosphor-converted red and green. It also has four channels to allow two green chips within the package, to enhance the brightness of green light, thus easily achieving RGB brightness ratios appropriate for good white balance. There's also a "tiny" compact version of this four-channel package, for space-constrained applications.

DVN Comment: This very compact, wholly-integral packaged system with closed-loop control, monitoring, and diagnostics appears to be a frontrunner in the technological race to meet the demand for ever-more-sophisticated and polyvalent lights inside and outside the car, while keeping cost and complexity under control.

Session 6 • Measurement, Simulation Tools, Condensation

Robotic Supported Goniophotometry for Automotive Lighting
Stephen Dahle • LMT (Board Member & Sales Director)

Light & Sensors integration for Autonomous Driving
Julien Muller • Optis (Product Owner Exterior Lighting)

Managing Condensation in Lamps with Gore Diffusion Vent
Masahiro Yagi • W. L. Gore & Assoc. (Product Manager, Automotive Vents)

Robotic Supported Goniophotometry for Automotive Lighting See Slides

Stephen Dahle • LMT (Board Member & Sales Director) See Video

LMT's Stephen Dahle presented, with an impressive video, his company's new Metrogon® 6-axis robotic supported goniophotometer meant to address special requirements associated with photometric measurements of very big lighting devices like the Audi A8 rear light assembly shown here. Each movement of the robot is automatically compensated to adjust for the torque generated by the the object size and weight once centred on the goniometer origin.

The Metrogon goniophotometer neatly sidesteps the problem of what to do with extra-large lighting devices, which would otherwise require impractical or problematic solutions (Dahle humourously suggested they might be cut into smaller pieces with a chainsaw!). It also is fully up to date with respect to other challenges in measuring the performance of today's lighting equipment: it is designed not to be foozled by PWM operation of LEDs, it automatically measures rise time when a lamp is being measured in a flashing mode to avoid thermic influence on photometric measurements (to check compliance with the UN Regulation requirement that sequential turn signals be fully lit within 200 milliseconds, for example), and it is also "smart" enough to know exactly when in a sequential turn signal's operating cycle to capture the measurements for accurate colourimetry.

DVN Comment:

As lighting systems and devices grow smarter and more sophisticated, naturally so must the equipment used to test them for compliance with the regulations. Testers tend to be creative problem-solvers, figuring out ways to adapt when the equipment they're using wasn't originally designed for the kinds of lamps they're testing, but this new LMT goniophotometer looks ready to solve a lot of that kind of problem with a large dose of future-proofing.

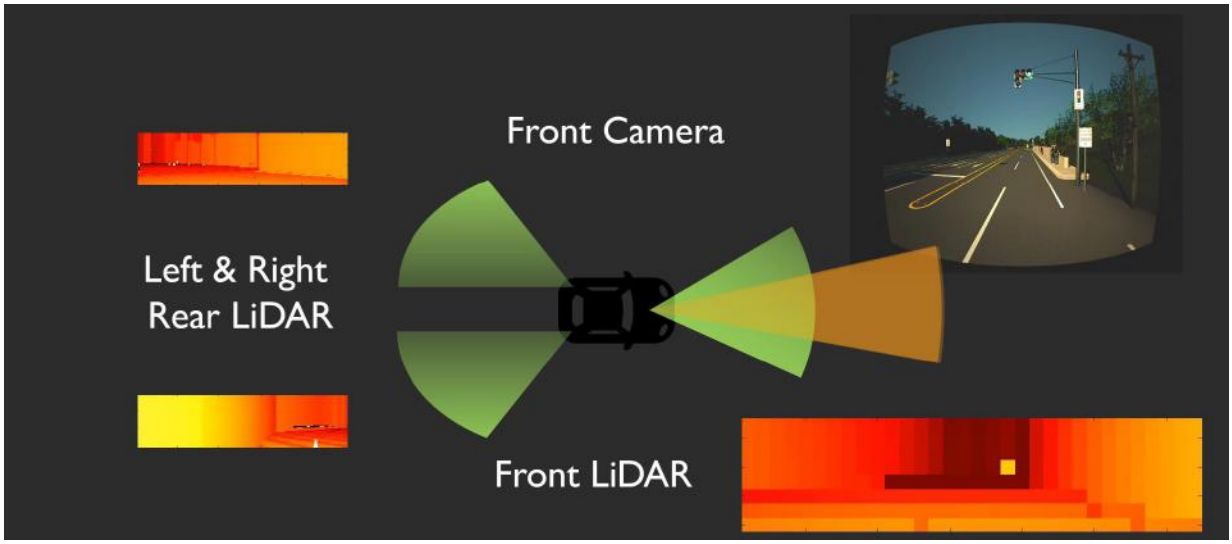
Light & Sensors integration for Autonomous Driving See Slides

Julien Muller • Optis (Product Owner Exterior Lighting)

Julien Muller presented how Optis' complete range of simulation products allows the modelling, simulation, and virtual testing of ADAS and AV complete machine vision systems Smart headlamps, software, cameras and lidars increasingly have to be selected, evaluated, and tested as models, hardware, software, Driver, and/or vehicles in the loop—MIL, HIL, SIL, DIL, and/or VIL—individually or as an integrated system .

Faced with the looming reality of AVs, real-world drive testing is critical; such testing is performed as VIL, HIL, or DIL, but can only be done on a limited basis. Most of the testing must be through simulation. Muller explained that Optis' simulation and testing solutions for ADAS and AV are based on detailed simulation of light sources (natural or artificial), sensor models for camera and lidar units, adjusted in accord with real component optical and design data.

Vision performance is analysed, and the machine vision system as a whole is tested and validated. Optis' toolbox enables reproducibility of the drive tests and analysis of the worst-case scenarios.



DVN Comment:

As with LMT's robo-photogoniometer, increasingly sophisticated vehicles and lights require increasingly sophisticated test and simulation equipment. This presentation gave a good overview of the state of the art from Optis' perspective, and it comes at a good time; if the progress towards the autonomous-driving future is to be protected from derailment by events like last Spring's Uber pedestrian fatality, robust and rigourous simulation-based testing of the kind described here will be an absolute must.

Managing Condensation in Lamps with Gore Diffusion Vent See Slides

Masahiro Yagi • W. L. Gore & Assoc. (Product Manager, Automotive Vents)

Vehicle lamps must cope with environmental conditions that change every day, and they have to be protected against dust, dirt, deposits, and condensation if they are to work effectively not fail. Gore's Masahiro Yagi first described the range of sorption coefficients and water vapour permeability of a variety of plastic materials that can or could be used in vehicle lights. Many of them exhibit characteristics that bring the likelihood of water-based problems (misting, fogging, condensation entrapment, and suchlike). But the material selection, says Yagi, by itself is not sufficient; some means must be provided for venting the lamp, allowing it to "breathe" so air pressure can be equalised, dirt and liquid water kept out, and water vapour expelled rather than entrapped.

A variety of headlamp breathability solutions are on the market—caps, membranes, labyrinthine tubes, and others. This talk by Yagi gave a detailed overview of Gore's membrane-based solutions. He described their strengths as including extremely simple packaging and integration of the membrane solution because of near-zero mass and bulk, finely-tailored ability to allow rapid and complete air pressure equalisation while excluding water and dirt, and high cost-effectiveness. Moreover, he said, Gore now offer products to actively eliminate condensation in lamps—improving the likelihood of proper function and appearance of the visible parts, and removing a water-based threat to the dependability and durability of electronic components within LED lamps.

DVN Comment:

The packaging advantages of a membrane-based lamp venting solution are well known in terms of assuring and maintaining as-intended lamp function and appearance. Yagi made an excellent point about the crucial need to keep humidity as low as possible in today's high-tech lamps, so their inbuilt electronics aren't subject to corrosion, short-circuiting, or other water-induced damage or degradation.

Sponsors & Exhibitors

A2Mac1

See Video

A2Mac1 showed off their capabilities in vehicle lighting analysis as part of their core competence in benchmarking.
They do advanced functional and technical study and description of the complete lighting systems of a vehicle: all lamps are scrutinised, analysed, 3D-scanned with and without lens. Around 200 parts are reviewed per lighting system with data on mass, dimensions, materials, suppliers, and fasteners. The report includes pictures, videos of lighting and adjustment functions, electronic review of all wiring harnesses and PCBs, fastener dimensions, and more. Annually they do ten vehicles in Europe, five in North America, ten in India, and ten in China.

Auer Lighting

See Video

Auer's show space contained examples of their precision glass components and high-quality coating solutions for LED, matrix LED, and laser headlamps. Auer believe that as material engineering grows more crucial with increased thermal load due to ever-smaller lamps, optics made from glass are the best choice

Exhibition, cont'd

AML Systems

See Video

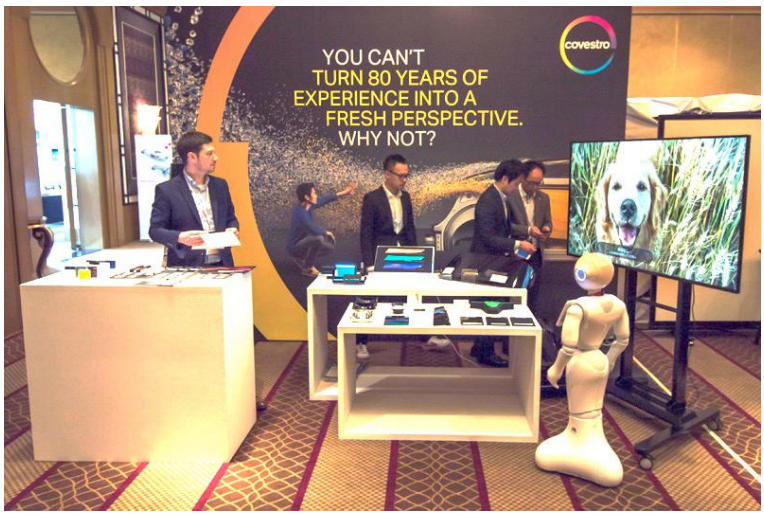
AML were proud to show a range of innovations at the DVN Workshop in Tokyo, including:

- Enhanced levelling actuators suitable for new lighting functions
- New internal levellers and swivelling actuators with improved connectors for the latest requirements in Japan
- A low-cost, high-definition nonglare high beam system based on the scanning of 3 LEDs
- High-precision autonomous automatic levelling systems working without a link to the vehicle network

Bicom Optics

Bicom are engaged in plastic optical lens research, design and manufacturing, with an experienced optical design R & D team. The company have ultra-precise manufacturing equipment, injection moulding equipment, and many multi-level dust-free workshops, and achieved TS16949 certification in 2010. Bicom have been coöperating closely with Cree, Lumileds, Osram, Nichia, Citiaen, Samsung, LG, and Seoul Semiconductor.

Covestro



Covestro brought along their interactive humanoid robot, which—together with videos and display samples—showed the company's efforts to drive lighting evolution with Makrolon and Apec polycarbonate materials. Echoing the display concept "Let's Play", they encouraged attendees to interact with their materials while also having fun. Materials on display included LED diffuser chips and colour plates for automotive aesthetics. Through their showcase at DVN, Covestro worked to inspire customers and OEMs with their innovative lighting material solutions and commited support.

Docter Optics

Docter are an ISO-certified global supplier of custom-designed and -manufactured double side molded aspheric and free-form lenses of glass and PMMA for projection headlamps. They supply most of the world's lamp makers. Alongside their innovative optical elements, Docter Optics exhibited their latest non-circular, bi-convex lens solutions for the next generation of LED headlamps with low- and high-beam function, and their first PMMA lens.

Everlight

Everlight showed their Smart Multi LED which, as described in detail in their technical lecture, fits the current automotive trend toward dynamic digital light sources. It embeds the control IC within the LED package with a microcontroller controlling the LED chain so each LED can be individually addressed.

W.L. Gore & Associates

W. L. Gore & Associates introduced various types of their venting products for automotive applications, both individually and as applied realistically in headlamps and tail lamps. Other applications using Gore's automotive vents—sensors, ECUs, and suchlike—were also on display.

Ichikoh

Ichikoh brought in their ¼-scale car promoting new roles and modes of communication lighting for the self-driving car society coming in the near future. The lighting, as described in the Ichikoh lecture, is visible from all around the car, and large enough that the colour and motion of light are easily noticeable. It can alert to dangerous situations, and lower pedestrian anxiety by communicating next moves of a self-driving car. Also on display were Ichikoh's wide variety of compact, slim, affordable LED front lighting modules.

Instrument Systems

See Video

Instrument Systems showed their Optronik DSP 200 photometer, perfectly suited for extremely fast scanning of exterior lighting with unique spatial resolution for ADB and pixel headlamps. And their high-resolution LumiCam 2400 is an optimised imaging photometer to measure automotive interior displays' luminance and colour, also suitable for checking luminance homogeneity of signal lamps. Furthermore, Instrument Systems launched their partnership with parent company Konica Minolta Sensing in the promotion, sales, and after-sale service of their products in the Japanese market. Japanese customers now have direct access to consultation and support in Japan.

Exhibition, cont'd

Koito

Koito showed the mockups they described in their technical lecture: front and rear lamps with inbuilt sensors essential for AVs. Moreover, their Lexus LS headlamp showed off its LED array ADB with 2 rows and an ultra-compact projector, and the stylish "3 eyes" Bi-LED units which can improve far-field visibility. Several attractive rear lamps were shown, and a powerful LED front fog lamp, with replaceable "LED bulbs" according to UN Regulation 128.

Lear Corporation

Lear entered the light source world some years ago, then with Daimler co-developed and manufactured the entire ADB system of ECUs and the 84-light source. All while investigating next-generation high-resolution light sources they demonstrated based on 5 Eviyos chips.

At the booth, Lear ran a similar application in both the 5 × 1024 Eviyos setup and the E-Class 84-pixel light system to show the differences in resolution. They are also working on DLP solution to provide another cost effective approach for cross-carline lighting systems.

LMT

LMT premiered at DVN their newly developed 6-axis Metrogon® robotic goniometer system for testing of automotive lighting. The new type of goniometer enables automatic testing of all lighting and signalling functions of XXL objects in a single software routine without intermediate remounting; testing of dynamic functions such as the rise time and colour of sequential turn indicators in blinking mode; and performance of luminance-camera based panorama photometry of intensity distributions projected on a screen, significantly reducing scanning times necessary for grid creation.

Lumileds

Lumileds' booth sparkled and glittered with adaptive front-lighting systems and main-beam applications, Luxeon Matrix for ADB with close die spacing and smaller dies enabling compact optics, Micro-optics applied onto WLP LEDs, 3D LEDs for new styling possibilities, laser scanning, and a line of standardised "LED bulb" light sources as specified in UN Regulation 128.

Mentor Graphics

Mentor showed off their fast, accurate thermal simulation and LED measurement tools to support future lighting product development. These included the FloEFD fully CAD-embedded CFD for frontloading analysis into the design process, and MicReD T3Sster TeraLED for LED thermal & radiometric characterisation and simulation of performance degradation with age.

Nichia

Exhibition, cont'd

NXP

See Video

Optis

Optis' booth showed videos of VRX at work for headlamps and ADAS. For VRX as a headlamp simulator, the bike demo with adaptive headlamp, the IIHS demo, and the matrix beam demo were presented. For VRX as a sensor simulator, two global ADAS demos, the park assist demo, and the camera-focused demo were presented. VRX is helpful to test car-embedded algorithms using Matlab Simulink or C++ plugins, as the tests can be automated, or each parameter can be changed and the effect seen in the simulation in real time. Moreover, VRX can simulate in real time different type of sensors, to test sensor fusion algorithms or hardware-in-loop processes.

Osram

Osram's booth was a colourful, sparkling parade of prototypes, proofs-of-concept, and novel light sources. Plenty of display space was given to the Smartrix and Eviyos products described in detail in lectures, and new edge-lit technology was shown that could give OLED a real run for the money in terms of novel signal lamp styling. Also on display was the XLS product family (eXchangeable LED Signals), Osram's version of the standardised "LED bulbs" specified in UN Regulation 128.

Seoul Semiconductor

Seoul Semiconductor had a neat display very conspicuously showing the difference in colour rendering between conventional blue-based white LEDs and the company's innovative violet-based SunLike LEDs with biologically-correct output, as described scientifically in their technical lecture. Seoul Semiconductor's other adavanced technologies such as WICOP and nPola, were also on display.

Stanley Electric

Stanley Electric are the only lamp setmaker with their own capability to mass-produce LEDs. Their exhibition focused on light sources, ranging from UV to visible and IR, and how the application of these light sources can contribute to traffic safety. Also on display were LED-lit devices with multiple applications, such as the usefulness of UV-LEDs for air sanitization and disinfection in the car sharing economy, and how smaller LED modules result in more compact headlamp units, thus enabling the integration of sensors required for future autonomous driving.

Synopsys

Synopsys and Cybernet Systems exhibited the LucidShape product family, a complete set of design, simulation, and analysis tools for the development of forward, rear, and exterior lighting. Backed by proprietary algorithms to calculate optical surfaces optimised for automotive applications, LucidShape empowers designers to develop, verify, visualise and deliver high-quality designs while reducing product development time.

Varroc Lighting Systems

Varroc's booth was well stocked with their latest and greatest production lamps, including full-LED pixel headlamps with laser high beam booster and many full-LED headlamps from serial production with the great range of technologies available (ADB, AFS, AFS 2, progressive turn signal, etc). The portfolio of Varroc's diverse, scalable LED projector units was also on display. The place of honour, in the middle of the booth, was given over to Varroc's miniature car with its wraparound light-based display and signalling technology. It's an exterior communication lighting concept car demonstrating user-friendly features such as exterior display screens and ambient lighting to address the emerging sharing economy and personalisation trends in mobility.

Varroc team present at the DVN Tokyo workshop

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Bentley, UK
BMW, Germany
Changan Design Center, Italy
FCA, USA
Daimler, Germany
Ford, Germany
GM, USA
Great Wall, China
Harley-Davidson, USA
Honda, Japan, USA
Hyundai, Korea & Europe
Jaguar-Land Rover, UK
Mahindra Mahindra, India
Nio, China
Nissan, Japan, Europe, USA
Opel, Germany
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PSA, France
Renault, France
SAIC TC UK
Shanghai-Volkswagen, China
Seat, Spain
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Toyota, Japan, Europe, USA
Volkswagen, Germany
Volvo Cars, Sweden

19 Univ., labs, Consultants
Darmstadt university, Germany
DEKRA laboratory, Nederland
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LAB, France
Light Sight Safety, Belgium
Nuremberg university, Germany
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Parma university, Italy
Rensselaer university, USA
SLD Laser—formerly SoraaLaser
UMTRI, USA
University of California, Santa Barbara
YoungNam University, South Korea
Mr Shunxing Wang, China

38 Set Makers and Tier 1s
AL, Germany, USA
Denso, Japan
Elba, Romania
Farba, Turkey
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Flex'N'gate, USA
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Harbin Good Time, China
Hella, Germany
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Lite-On, Taiwan
Lumax, India
Magna, USA, Austria
Microlight Auto Parts, Taiwan
Mobis, Korea
NAL, USA
Neolite ZKW, India
Nordic Lights, Finland
Odelo, Germany
Olsa, Italy
Plastic Omnium, France
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Rebo Lighting&Electronics, China, Germany
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