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New Trends and Functionalities in Automotive Tail Lighting

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Abstract: Styling of automotive tail lighting has become more and more important and evolved to a strong pusher for innovation in exterior lighting in recent years. Next generation and futuristic ideas of automotive exterior tail lighting which are considered within functionality and standards (Lee, 2019). The automobile industry is highly demanding for innovative technologies to equip luxury vehicles and low volume special series with unique lighting solutions. Beyond more and more homogenous rear lamps, all customers are asking for the next evolution or better revolution with marketing required wow-effect. All this in an environment of reduced space, shorter development cycles and higher quality expectations. Digitalization and automated driving will revolutionize our automotive lighting. The main purpose of lighting will no longer be the best visibility for the vehicle. Pedestrians and bicyclists are the new focus group. How we can give clear signals and information to them? The information has to come from the vehicle, not from the driver. What sort of lamps, lights or displays are needs? How could future vehicles then look like? (Berlitz, 2017). This paper will give a status to upcoming lighting solutions for communication. OLED, matrix lighting and projection lighting are shown as new concept vehicles enable the vehicle to interact with humans as well style attraction. These lighting technologies throw a glance on future possibilities for our automotive lighting business.

Keywords: OLED, Matrix Light, Projection, Tail Lighting

Introduction

Rear lamps have been used mainly for signaling. As a matter of fact, we noticed that rear lamps have a increasingly important role to define the style of the vehicle. Signalling needs to be beautiful. Therefore, we see that investment made by OEMs for their rear lamps has more than doubled in the past 5 years. Unlike front lighting, where “what you pay is what you see”, rear lighting value is “paid” by someone else than the driver: The OEM itself or a third party, as we move into the automated/autonomous vehicle (Evrard et. al., 2017). Road projection i.e. light signal projected on the road, offers the great possibility to design a new way of communication between the vehicle and other road users, paving the way to digital light interaction between the autonomous vehicle and its environment (Neumann, 2017). Lighting functions using road projection could hence represent an important step towards dedicated communication of autonomous vehicles with vulnerable road users (Pernkopf, 2017), and thus could contribute to the positive acceptance of autonomous vehicles (Neumann, 2017).

New Generation Lighting Style and Communication

OLED

OLED technology accomplishes entirely new design options for light sources and gains huge interest among customers in the automotive industry. OLEDs are flat light sources that achieve more homogeneity and can be steplessly and individually dimmed. Today the light emitted by the flexible OLED already fulfils the relevant

ECE standards for luminious intensity and emission colours for rear position lamps. With the successful completion of the project and the first mass produced vehicles with ultra low-profile but rigid glass-based OLEDs appearing right now on the market, flexible OLEDs are expected to be ready for series production in only a few years' time (Rosenauer, 2021).

OLED technology is showing increasing interest in rear lamp applications due to new style and design opportunities. The use of OLED into rear lamp has highlighted the need for new simulation tool. This communication describes the development of new in house tools to predict electro-optical behaviour of OLED source (including electrode and current density simulation), photometric light intensity simulation and color. In the last years, OLED technology has started to be more interesting in automotive market for rear lamps, especially fort the great number of possibilities it gives in terms of new aesthetical solutions and for the possibility to realize high homogenous lighting functions which is illustrated as sample in Figure 1.

(a) OLED Tail light of BMW M4 GTS (Osram, 2017) (b) OLED Tail light of AUDI TT (Audi, 2016)

Figure 1. OLED automotive tail lights

Widespread LED technology can be optically simulated with raytracing software: from standard rayfiles provided by suppliers, it is possible to simulate light propagation inside optical elements with high accuracy. On the opposite side, OLEDs are custom shaped objects and need to be specially modeled in the optical simulator wit the design department input. The different iterations design can introduce a prohibitive lead-time when the OLED performance must be checked at each steps. I order to give to customer an answer regarding photometrical performance and luminance as fast as possible without an iterative loop between OEM-TIER1-TIER2, two tools have been developed by Automotive Lighting (Bianco et al., 2017), which is illustrated OLED technology studies of AUDI in Figure 2.

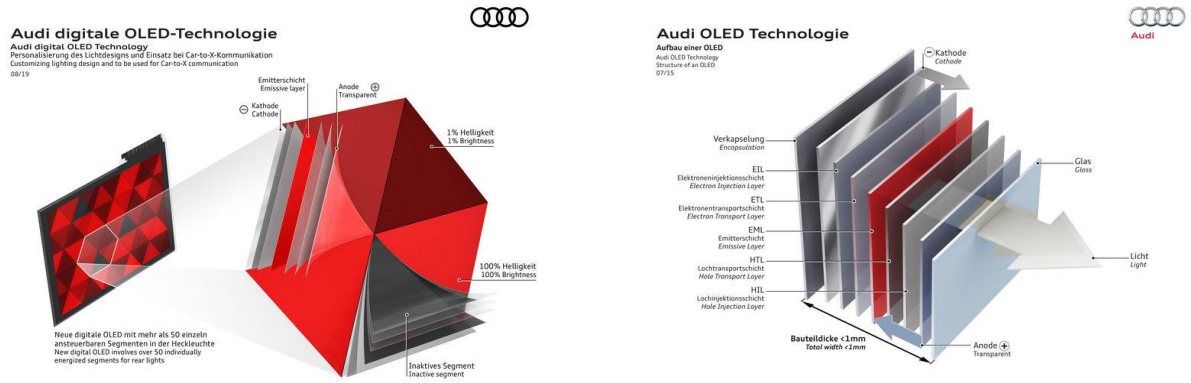


Figure 2. OLED Technology studies of AUDI (Audi, 2020)

Next to design driven modifications of the taillight signature, it is now also possible to take this highly segmented taillight to display further information in the rear of a vehicle, e.g. for following traffic or pedestrians. While sticking to the possibilities that are provided by current regulation, digital information within the vehicle or provided by the swarm of connected vehicles and infrastructure can help to improve the safety and gain trust in the field of autonomous driving vehicles.

With a high number of segments on each OLED element automotive exterior displays can be created within a tail lamp The usage of those Digital OLEDs will lead the way to Premium Car2X communication. In combination with new approaches on bendable glas to produce an OLED Audi will lead the application of the

most flexible display technology in taillighting. OLEDs create homogenous surface light directly within their full active region. Flexible OLED based tail lighting of AUDI is illustrated in Figure 3.

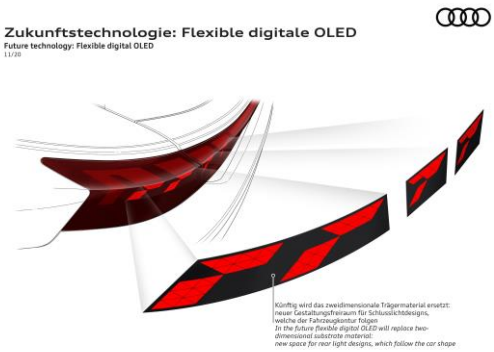


Figure 3. Flexible OLED of AUDI (Audi, 2020)

Flexible substrate technologies are needed and have to be adapted for the usage in automotive lighting applications. The flexibility of the substrates can be used as means to bend the OLED in the lamp production, creating a 3D OLED module that fits the curvature of the vehicle. In combination with its viewing angle independent color point stability and homogeneity, light weighted thin flexible OLEDs will be a unique light source for tail lamps which can never be mimicked by any other light source. The most flexible display for exterior lighting is born: FLEXIBLE-DIGITAL OLED (Kruppa et. al., 2019)

Matrix Lighting

Micro LED system has a key for the solution which has micro size of hundreds LED light sources with imaging optic. Imaging optic can match the each beam pattern to each single LED. Therefore, before developed a micro LED, it needs to be defined a certain beam pattern which can meet functionalities properly (Lee, 2019). In rear lighting World the idea of matrix technology is rather unknown. Unlike the individual switching of segments in rear lighting. Rear lighting is dominated by signal lighting, with the task to visualize the vehicle information on geometry, dynamic speed and direction indication. In future applications, also the segmentations will give the chance to either generate different patterns or combination of segments, or to attract the following driver's attention to the activated function (Hamm, 2017).

The next evolution step of the customizable tail light signature is the matrix tail light, illustrated in Figure 4 (Audi, 2021; Epic Photonics, 2020). Like the customizable tail light, this concept also has a static surrounding signature that fulfills legal requirements. The interior is equipped with a matrix that can be personalized in a wider range. Not only by means of light graphics, but also –as a type of display- with symbols and text. The matrix opens a new communication channel allowing clear warnings such as a "snowflake" in the matrix area of the tail light to indicate slippery road conditions. This can be done manually by the driver and also automatically via vehicle-to-x communication. It could also be possible to give an early warning at the end of traffic jam and thus help to prevent dangerous rear-end accidents.

(a) Individual lighting design (Audi, 2021) (b) Warning lighting function (Volkswagen, 2018)

Figure 4. Customizable tail light signature

Also, it will be important that assisted or driverless moving vehicles communicate with their environment e.g. via tail lights. Of course, clearly identifiable and distinct symbols are necessary to support traffic safety in that case. Additionally, countless other functions are conceivable such as a coming or leaving home animation that could be personalized. Or electric vehicles could display the current charge status via tail lights. The advantage is that no other component would have to be integrated as the tail light is always present. As soon as the relevant legislation allows its use, the final implementation could start. Furthermore, upcoming user studies are planned, in order to investigate symbols that are well perceivable as well as understandable. Of course, the matrix tail light would also be updateable so that a large range of different signatures and safety functions are certainly conceivable (Studeny, 2019).

Classical communication between drivers and road users outside the vehicle, such as making eye contact, nodding one's head or giving hand signs may will no longer be possible. Concerns are arising about safety and also acceptance by pedestrians and bicyclist. Many concepts and proposals for autonomous driving vehicles and automated-driving lights have been made, so we need to discuss on standards. However there is still no standard (s). This could lead to important discrepancies between regulations worldwide, making it very difficult and expensive for vehicle manufacturers to develop autonomous driving vehicles for a global market. The future focus of automotive lighting will no longer be optimized illumination for the driver but optimized signal lights for all other road users. First of all pedestrians and bicyclists, but mainly at least for the next few years the huge number of drivers in conventional non-automated driving vehicles. Optimized illumination instance for pedestrians and bicyclists is illustrated in Figure 5.

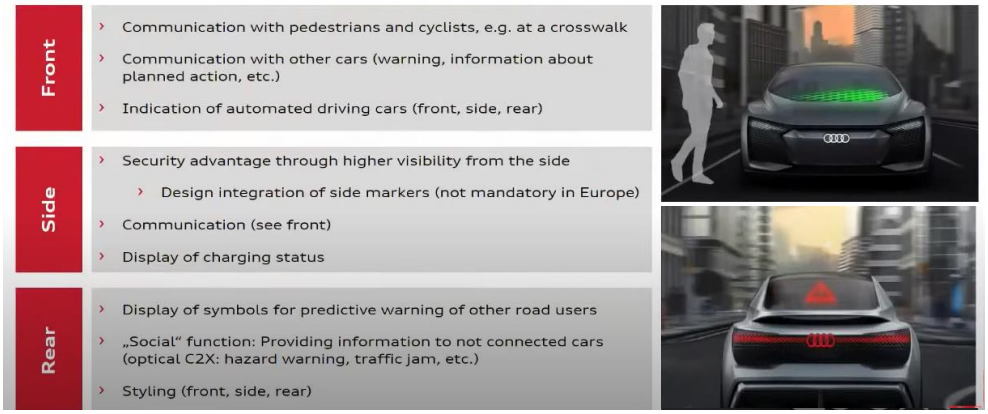


Figure 5. Optimized illumination for the pedestrians and bicyclists (Epic Photonics, 2020)

The mega trend digitalization will generate completely new players in the automotive and also automotive lighting market. New sensor technologies, unimaginable high computing power and the fast progress of the internet of things (IoT) with all the connected electronic smart devices enable complete new functionalities and business opportunities. The digital world will take over the automotive world. The rules of the game are changing and we will have to adopt our regulations to be compatible with our automotive lighting. Otherwise global lighting and mobile devices will occupy the new lighting, business and driven safety opportunities outside the vehicle (Berlitz, 2017). Communication instance between vehicle and pedestrian is illustrated in Figure 6.

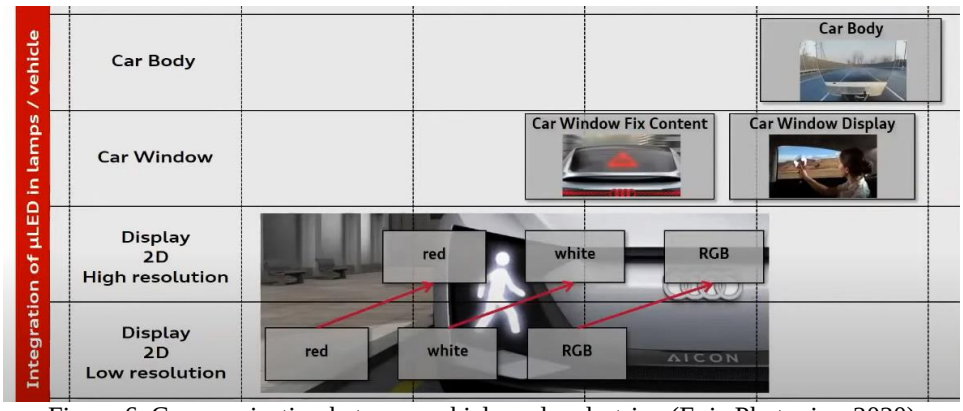


Figure 6. Communication between vehicle and pedestrian (Epic Photonics, 2020)

Projection Lighting

The area lighting of the vehicle only covers the lateral area net to the vehicle and thus offers a support for a better orientation when approaching the vehicle or getting in and out. Often these lights realize patterns or graphics, providing an attractive design and a high customer value. Volkswagen now extends the functional scope of the area lighting respectively the manuevering lighting. Usually these lights are installed in the sill, the door handle or at Volkswagen in the side mirror or door trim. The idea of the so called "Optical Park Assist" developed by Volkswagen is the functional enhancement of area lighting (Volkswagen, 2018).

The aim of this function is to project information and navigation support of any kind on the ground behind, next to or in front of the vehicle. For example, this information can be used to clarify the driver's intention. This can contribute to increase traffic safety. In the case of the "Optical Park Assist" (Studeny, 2019), White stripes are projected behind the vehicle that indicates the width of the vehicle as illustrated in Figure 7. These stripes are perfectly visible through the side mirrors and provide an intuitive orientation support while parking. A conceivable option would be to integrate such a module in the tail light or in the bumper. The "Optical Park Assist" uses a micro lens array MLA and LEDs as a light source to project an arbitrary image. This technology offers a very high image quality as well as a compact space (Gocke et. al., 2015).

Figure 7. Optical park assist (Volkswagen, 2018)

In near future parking maneuvers will be fully automated with no drivers around. In this case the maneuvering path can be projected onto the road via the lines in order to communicate the parking process to other road users. This new function also provides additional safety in the event of a breakdown or opening doors. In this case, a safety zone or a light barrier around the vehicle can be projected on the ground to indicate the situation. In order to achieve a higher warning effect especially fort the last two use cases red or yellow would be a useful light color. However, these colors are actually not possible according to the current state of regulation. A discussion regarding updated regulations would be desirable due to the usage for these light functions and an enhancement of traffic safety should be evaluated by users studies (Volkswagen, 2018). Projection function of signal lighting on the ground is illustrated in Figure 8.

(a) Projection of signalling in tail light (Volkswagen, 2018) (b) Projection of signalling in front light (Blain, 2018)

Figure 8. Projection function of signal lighting

Safety Distance Projection

When the ego vehicle is getting too close from the leading one, alert messages as simple as highlighted zones or series of transversal light bars could be used. The setting of these bars, as well as the projection distance can be defined by the user, while their activation can be coupled with the front radar or LIDAR (Reiss et. al., 2019). Warning stripes of vehicle by projection lighting is illustrated in Figure 9.

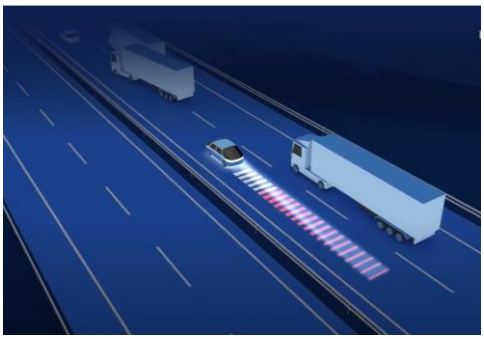
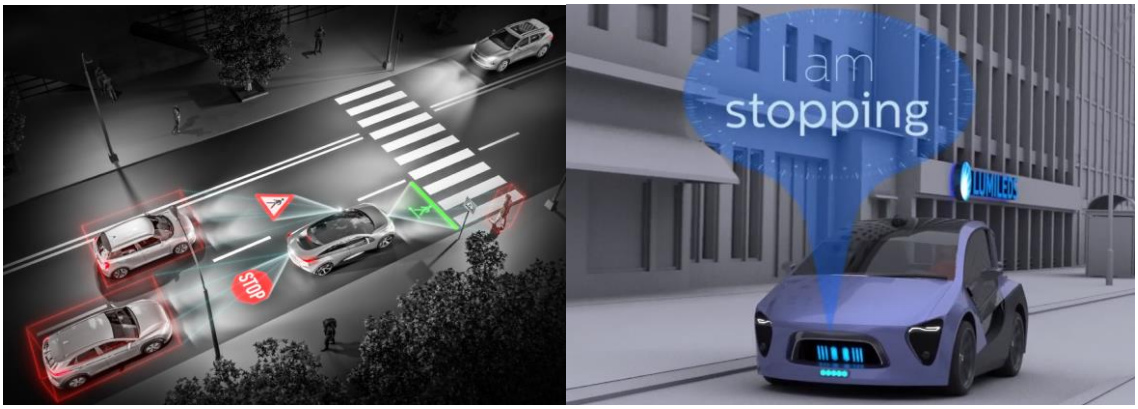


Figure 9. Warning stripes of vehicle by projection lighting (ZKW, 2021)

Digitalization, electrification, user experience and new mobility concepts – these megatrends will shape the future of automotive lighting. Intelligent lighting that automatically adapts to the situation on the road, and light for communication between the driver, vehicle and environment – a crucial factor in the development of autonomous driving. Exterior projections will ensure better visibility of turn signals and brake lights, among other things, and will display relevant driving information on the road. Interior projections will be used to improve the comfort, convenience and well-being of the occupants. In the future, projections will support autonomous vehicles in their direct communication and interaction with all road users (Rosenauer, 2021). Communication of vehicle between other vehicles and pedestrians on the road is illustrated in Figure 10.



(a) Communication of vehicle on the road (Osram) (b) Illustration of vehicle's behaviour (BestRide, 2017)

Figure 10. Communication of vehicle between other vehicles and pedestrians on the road

Projection systems expand the possibilities of classic headlamp technology. The use of light projections transforms the vehicle and its surroundings into a canvas for OEMs and mobility providers. Not only does light have the ability to increase safety and functionality, but it also affords the opportunity to differentiate their vehicles with lighting design and create customizable driving experiences that can evoke a sense of well-being for the driver. With the development towards autonomous driving, light will not only be needed for better visibility, but will also play a pivotal role for the communication of a vehicle to its environment (car2x), thereby contributing to the acceptance of autonomous vehicles. The advantages of light projections to create an emotional impact are already used widely in everyday life, for example to illuminate building facades for events. It is not only because of these emotional aspects that light projections are increasingly finding their way into the automotive sector. Exterior projection systems extend already existing lighting functions in relevant situations – for example clearer visibility of indicator or brake lights (Rosenauer, 2021). Projection based hologram and signal lighting is illustrated in Figure 11.

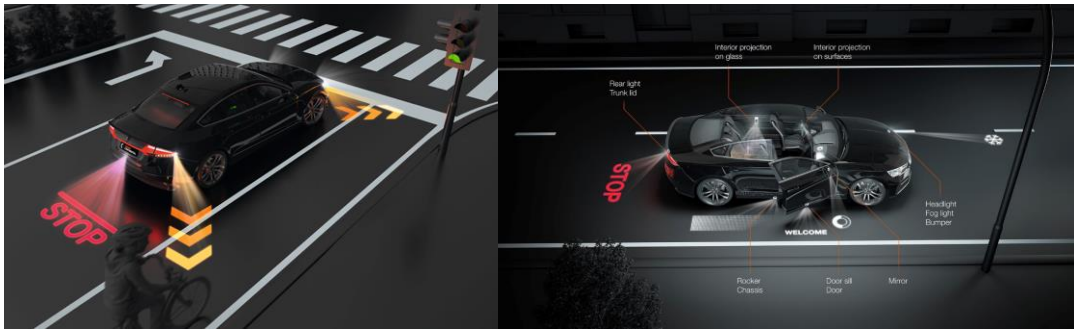


Figure 11. Projection based hologram and signal lighting (Osram)

New lighting Technologies as projector systems or displays and all the architecture for digitalization increase the costs for the systems and components. The safety benefit with better communication possibilities is obvious. Nevertheless, all OEMs will have to increase their investment in lighting technology. But, there are also ideas for using these new Technologies for new business plans. That is probably also the main reason for IT-companies to step in the automotive business. Projecting information outside the vehicle or displaying information on the outer side of the vehicle brings attention and is therefore idea for all applications where you want attention for your product (Berlitz, 2017).

Conclusion

In this paper, various new Technologies and functions for signal lighting were shown. These could soon open a large new spectrum of lighting functions and design. Many of the presented features have the potential to increase traffic safety (Studeny, 2019). Automated driving and digitization will revolutionize our automotive lighting business, new technologies will extend the communication with other traffic participants This will lead to increasing traffic safety. On the other hand, the light distribution will get completely personalized for safety but also for entertainment and commercial possibilities. Enriching the user experience will lead to more attractive lighting products and will lead to higher take rates and faster market penetration. This again will bring the modern lighting technology easier into market and can then increase traffic safety for all participants. All these ideas could be an opportunity for the automotive industry if development or regulation takes too long then IT-companies and service companies will take over this market and the chance to finance increasing vehicle safety with new business plans will be gone (Berlitz, 2017).

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

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