Photonic Technologies for the Automotive Industry
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There is no doubt that photonics is revolutionizing the world and will have an influence similar to the semiconductor industry. Photonics includes all technologies that use light, create light, detect light, or modify light. Photonics is having a profound impact on a very diverse range of applications such as agriculture, energy, entertainment, life science, transport. Photonics is one of the six key enabling technologies recognized by the European Commission, and is well placed to address our most pressing societal challenges. The purpose of this short brochure is to summarize some of the photonics technologies relevant to the automotive industry, and to invite automotive manufacturers and component suppliers to engage with the photonics value chain. The photonics industry is very strong in Europe with more than 5000 registered companies. But, as an emerging industry, most of these companies are small and young. Indeed, 86% have less than a hundred employees, yet these companies are extremely innovative and therefore a rich source of technology and innovation. If you are looking for a technology supplier, a partner for a collaborative research project, and wish to engage with the photonics industry, you are invited to contact me personally and I will be pleased to connect you with our members.

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From being a very traditional industry just a few years ago, the automotive sector has become one of the main industries that drive innovation, both in R&D investments and in their practical application. The Boston Consulting Group annually report the ranking of the most innovative industries. Ten years ago there were only 3 car makers in the top 50 of the most innovative companies (Toyota, Ford and BMW), by 2013 the automotive industry was in first place, with 30% of the ranked companies in the TOP 50, before many high-tech and blue chip companies. Innovation in power, through hybrid and electric engines, was and still is the most funded domain. But connectivity of vehicles, advanced driver assistance systems and lightweight materials are gaining momentum. As described here, photonics is a perfect enabler for these domains through advanced sensors and lighting, new displays and new manufacturing processes. In the next few years, industrial photonics companies will benefit from the 8% annual growth of investment in automotive subcontractors and component suppliers.

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INTRODUCTION

1.1 CONTEXT

Despite the economic crisis, the production of cars worldwide is expected to double in 20 years, from 56.4 million cars manufactured in 2000 to 104.5 million forecast to be produced in 2019.

Worldwide, 82 million cars were made in 2013, with ~25% of these made in China. The European share of car production has decreased slightly in the last 3 years, from 20% in 2010 to 17% in 2013.

![Cars production share by country](image1.png)

The automotive market has a strong strategy towards the development of autonomous vehicles as shown in fig. 2. The objective for most OEMs and Tier 1 suppliers is to provide a highly automated vehicle by 2025.

![Autonomous vehicle](image2.png)
This goal of increasing automation in cars is driving the development of new technologies in all fields: robotics, electronics, communication, software and photonics. The automotive component market is expected to grow from 560 billion euros in 2012 to around 710 billion euros in 2020, with a significant share in Europe.

This brochure reviews the possibilities for the implementation of photonic technologies in the automotive industry i.e. the integration of photonic technologies in the car as well as in automotive manufacturing.
INTRODUCTION

1.2 SEGMENTATION OF PHOTONIC TECHNOLOGIES FOR THE AUTOMOTIVE INDUSTRY

The tables below present an overview of the photonic technologies available for the automotive industry.

They are split according to their domain of application:

- ADAS (Advanced Driver Assistance System): technologies that assist the driver
- Interior: technologies applied inside the car
- Exterior: technologies applied outside the car
- Green car and manufacturing: technologies to allow environmental-friendly driving and manufacturing

And according to their use in the car:

- Safety: technologies used to reinforce the safety of the driving
- Comfort: technologies used to improve the comfort of the driver and passengers
- Entertainment: technologies used for the entertainment of passengers (and in the future for the driver himself)

Technologies for ADAS:

<table>
<thead>
<tr>
<th>SAFETY</th>
<th>IMAGING &amp; SENSING INSIDE</th>
<th>IMAGING &amp; SENSING OUTSIDE</th>
<th>LIGHTING</th>
<th>COMMUNICATION</th>
<th>DISPLAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cameras for monitoring driver drowsiness. Thermopiles for detection of passengers presence.</td>
<td>Backup Camera. LIDAR and cameras for Adaptive Cruise Control and collision avoidance. Lane departure warning system. Active and passive IR systems for night vision and pedestrian protection. Blind spot detection (mirrors, Fresnel lens, ...). Photodiodes, IR sources for rain detection, luminosity monitoring, ...</td>
<td>Adaptive headlamps.</td>
<td>Camera for traffic sign recognition and cameras / scanners for Intelligent Speed Adaptation. Visible Light Communication (VLC) for V2V communication about traffic and safety issues.</td>
<td>Head-Up Displays (HUD), holography, projectors, combination with augmented reality.</td>
</tr>
</tbody>
</table>
Technologies for the exterior of the car:

<table>
<thead>
<tr>
<th>EXTERIOR</th>
<th>IMAGING</th>
<th>SENSING</th>
<th>LIGHTING</th>
<th>COMMUNICATION</th>
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</thead>
<tbody>
<tr>
<td>SAFETY</td>
<td>Cameras for gesture recognition and proximity detection.</td>
<td>Spectroscopy for outdoor air quality monitoring. IR active systems for gesture recognition.</td>
<td>Halogen lamps, HID (High Intensity Discharge), LEDs, Lasers, OLEDs for head lights and signal lights.</td>
<td>Optical communication (Photodiodes, VLC) for car to X communication.</td>
</tr>
<tr>
<td>COMFORT</td>
<td>Cameras for gesture recognition and proximity detection.</td>
<td>Spectroscopy for outdoor air quality monitoring. IR active systems for gesture recognition.</td>
<td>Halogen lamps, HID (High Intensity Discharge), LEDs, Lasers, OLEDs for head lights and signal lights.</td>
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Technologies for the interior of the car:

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<th>IMAGING</th>
<th>SENSING</th>
<th>LIGHTING</th>
<th>COMMUNICATION</th>
<th>DISPLAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMFORT</td>
<td>Cameras for rear passengers observation.</td>
<td>Spectroscopy for air quality monitoring. IR active systems for gesture recognition.</td>
<td>Halogen lamps, Neon lamps, LEDs, OLEDs for interior lighting. Optical fiber.</td>
<td>MOST (Media Oriented Systems Transport) for communication between media in the car. Plastic Optical Fiber.</td>
<td>LCD, electrochromic displays, ... for passengers.</td>
</tr>
<tr>
<td>ENTERTAINMENT</td>
<td>Diffractive optics.</td>
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Technologies for green cars and manufacturing:

<table>
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<th>SENSING</th>
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<td>TRACTION</td>
<td>Solar cells to supply the car.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMFORT</td>
<td>Spectroscopy for exhaust gas sensing.</td>
<td>Transparent solar cells to supply low consumption functionalities (air conditioning, ...).</td>
<td>Lasers for cutting, marking, welding, micromachining. Optical metrology. Industrial vision systems.</td>
</tr>
<tr>
<td>MANUFACTURING</td>
<td></td>
<td>Energy efficient laser processing.</td>
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2. CURRENT AND FUTURE PHOTONIC TECHNOLOGIES
FOR THE AUTOMOTIVE INDUSTRY

2.1 TECHNOLOGIES FOR ADAS (ADVANCED DRIVER ASSISTANCE SYSTEM)

2.1.1 Visible/NIR (Near-Infrared) cameras

INSIDE THE CAR

Inside the car, cameras can be used for driver attention monitoring. Technologies for driver attention monitoring can be split into 2 categories:

- Direct monitoring of the driver: the technology senses or measures parameters on the driver him/herself. It includes cameras for driver face monitoring or for bioelectrical signal monitoring.
- Indirect monitoring of the driver: the technology measures parameters of the driving showing that the attention of the driver is declining. It includes cameras for lane departure monitoring.

Currently, the most implemented method is indirect monitoring. Products for monitoring the face of the driver are arriving on the market as aftermarket products especially for truck drivers. The main challenge of this technique is in the algorithms used to detect the signs of drowsiness. Techniques based on remote monitoring of bioelectrical signals (mainly heart rate) are under investigation, but need a lot of improvements on the reliability before being implemented.

In this field, regulation plays a major role in the adoption of new technologies.
OUTSIDE THE CAR

The first technologies that were developed for sensing outside the car were RADAR (RAdio Detection And Ranging) and ultrasound. These two techniques were first used for the detection of objects outside the car in order to assist parking and have, for example, enabled the adoption of automated parking. These technologies can also be used for collision avoidance (detection of pedestrians, animals, other vehicles, etc.). Currently, cameras in the visible / NIR range are integrated on cars for several applications:

- back-up cameras,
- road signs reading,
- blind spot detection,
- lane departure monitoring,
- other vehicles detection,
- distance to other vehicles or objects (time-of-flight systems, stereo vision systems) etc.

These technologies emit alarms to inform the driver and help him/her drive safely. Within 5 to 10 years, the information provided by these cameras will be implemented to make driving decisions without intervention of the driver: braking, parking maneuvers (already exists), overtaking maneuvers, speed control (Adaptive Cruise Control) etc.

Therefore, on the way towards automation it is important to develop not only the hardware, but also the intelligence that will process the data and enable the whole system to make safe decisions.
2.1.2 LIDAR (Light RADAR)

The wish for considerably fewer accidents has been expressed by a number of European stakeholders over the last 20 years. An ambitious safety goal to halve the number of victims on the road in 10 years (2000–2010) was almost achieved (see fig. 3), with a 44% decrease in fatal injuries between 2000 and 2010, linked to emerging products in adaptive cruise control (ACC), lane departure warning and passive safety (airbags).

The latest EU road safety policy aims to follow this trend by decreasing European road deaths by a further 50% by 2020 compared to 2010. This continuous decrease in fatality rates on the road will be linked with stronger adoption rate in active safety systems, where photonics is a key enabler.

Fig. 3 Number of road accident fatalities in the EU-24, 2000-2010 (red), compared with the initial objective (blue)

Today Intelligent Vehicle Safety Systems (IVSS) remain limited to a small part of the premium car segment. Since small and medium size cars dominate road traffic and thus most of the accidents, future safety systems must be made affordable enough to penetrate all vehicle segments.

LIDAR technologies currently under development for applications in active cruise control, collision avoidance and bad weather driving, etc. could be good candidates for IVSS (following the example of the Google car, formerly equipped with a >50k€ device). In 2014, several companies released LiDAR systems for between 3,000 and 5,000 euros (a 10 fold decrease since the early versions of LiDAR released 8 years ago). This ten fold decrease in LiDAR costs should allow a higher penetration rate beyond the premium segment.
Many manufacturers are now on the way to developing generic optical sensors that are affordable, durable and of compact size to be used in different locations in vehicles or in the infrastructure, providing fully reliable sensor data, in a 100cm³ footprint with a 2cm resolution at 100m. Technologies being developed include Velodyne design-LIDAR, downsizing footprint and the number of laser from 64 to less than 5, and frequency modulated or pulsed lasers requiring no moving parts in the system (displacing the technical challenges with pulsed VCSEL-arrays).

2.1.3 Active and passive infrared systems

Active and passive infrared (IR) systems are used to improve vision at night. Road accidents involving pedestrians are far more frequent at night than during the day. More than 14,000 pedestrians and cyclists are killed and almost 407,000 are seriously injured in the European Union every year. (Source: European Association for Injury Prevention and Safety Promotion (EuroSafe), 2012).

Among various root causes, driver’s dramatically reduced range of vision at night is one of the most frequently cited. Night-vision is only performed by photonics technologies, i.e. Far-Infrared (FIR) and Near-Infrared (NIR). FIR systems are passive, detecting the thermal radiation at wavelengths in the interval 8-12µm. NIR systems use a light source with a wavelength of around 0.8µm to illuminate the object and then detect the reflected light. The main advantage of NIR systems is the picture resolution and the resulting superior interface with the driver, with an easier picture to decrypt and understand. FIR systems on the other hand offer a superior range and a better pedestrian-detection capability compared to NIR, especially in noisy environments, like urban areas with a lot of light sources.

Today, the adoption of Night Vision Systems (NVS) in cars is still very low. Less than 15 luxury models (from Audi, BMW, Mercedes and Rolls Royce) offer it as an option at a cost of ~2,500 euros. Several component manufacturers are selling their night-vision cameras on the aftermarket.
In the far infrared range, the scale-up of the MicroBolometer industry following advances in CMOS (Complementary Metal–Oxide–Semiconductor) manufacturing will allow the mass production of cost effective products in the coming years. Consumer products below 150 euros will soon be available, as well as high-end automotive products. In the SWIR band (Short-Wave Infrared), core sensing technology and cost-effective InGaAs focal plane arrays with wide spectral response (VIS-NIR-SWIR) and wide dynamic range (120dB) are still in their infancy, but there is room for price reduction in the years to come.

Beside economic issues, other limitations for the adoption of NVS are linked with more general Human Machine Interface challenges like the interpretation of data (databases of thermal signatures of animals, humans, vehicles, etc. are on the way) or the way to provide the information to the driver (through a sound alarm, an image displayed on the dashboard or on the windscreen). Display technologies will be key for the deployment of NVS systems.

Active as well as passive night vision technologies are currently developed and integrated by OEMs. Current investigations include the use of both infrared technologies in a single device, to reduce the cost of the whole system. Other technologies such as infrared LIDAR or QDIP sensors (Quantum-Dot Infrared Photodetectors) are being investigated, but the technology is not yet reliable at the expected price.
2.1.4 Adaptive Driving Beam (ADB)

A lot of developments are made in the field of ADB (Adaptive Driving Beam) by both OEMs (Audi etc) and suppliers (Hella, Varroc Lighting Systems, etc).

ADB systems are lighting systems able to automatically adapt the high beam to avoid glaring of leading or oncoming vehicles whilst maintaining good visibility for the driver. A camera detects the presence of other vehicles and the light pattern is changed to block light where the vehicle is located. The first Glare Free High Beam (GFHB) systems were based on HID (High Intensity Discharge) lamps where the lamps are moved to avoid glaring. The latest systems are LED-matrix based and do not use mechanical movement. In a LED-matrix headlamp, each LED can be addressed individually, offering higher flexibility as several segments of the beam can be turned off at the same time.

2.1.5 Optical Components: Photodiodes and thermopiles

Photodiodes and IR sources (mostly LEDs) are used for the detection of rain and the automatic activation of wipers. In the same way, luminosity changes are detected by photodiodes in order to automatically switch-on headlamps when the luminosity decreases (at night, when entering a tunnel, etc).

These two functionalities use basic and cost-effective photonic components. They were introduced relatively early in cars, about a decade ago, and are now widely adopted in all car ranges.

The detection in luminosity variation with simple photodiodes is expected to be replaced by more complex systems allowing safer adaptive driving beam control.

Thermopiles are used to detect whether a passenger is present in the car or not. The aim of detecting passengers is to check that the seatbelt is fastened and to activate the airbags. Today, small and cheap components are used for the detection of passengers. In the future, visible or NIR cameras could be used if their cost decreases, or if they have other uses in the car such as passenger monitoring.
2.1.6 Head-Up Displays

Head-up displays (HUDs) are screens, or projectors that allow information to be displayed in the line-of-sight of the driver so that his eyes can remain on the road.

The aim of current development is to enable HUDs to project information on the entire windscreen and to combine it with augmented reality. The objective is to display information at exactly the right point on the road scene, e.g. highlight the presence of a pedestrian or an animal, or indicate the correct direction to follow.

The potential to create augmented reality vision has been investigated since the 1960’s. But most augmented reality systems require the use of a Head Mount Displays (HMD) to project a virtual image in the user’s eyes. Most of the commercial systems are based on a display decoupled from the optical system, creating constraints on the mechanical configuration of the eyewear with a bad trade-off in volume and mass. Moreover, those systems have difficulties to cope with corrective vision requirements of a significant number of potential users.

To prevent the use of HMD, development is required in 3 directions: larger field of view, better resolution and smaller dimensions of the whole system. New compact designs based on holography pave the way for future improvements, by providing the same brightness (10000cd/m²) virtual size (250cm²) and resolution than LED/LCD displays for a tenth of the energy and the volume.

Publicly funded research programs support the development of photonics technologies in automotive. For instance the project SERA (French FUI funding, OPTITEC label) aims to develop next generation HUDs, extending the field of view (blue to orange on the picture) and adding contextual content in the image.

2.1.7 Visible Light Communication

Visible Light Communication (VLC) is a wireless communication network using light. It is based on LED lighting devices. LEDs are switched-on and off very rapidly (few nanoseconds or less) which allows transmitting information without being noticed by the human eye.
In automotive, it can be used for car to car communication. Indeed, more and more cars will be equipped with LED headlamps that can have a second role in transmitting information to other cars.

Data transmission between cars can be used to regulate traffic and avoid car accidents. VLC can also be used as a car-to-infrastructure communication network by using traffic light networks to transmit traffic and safety information to the driver.

Applications of car-to-car or car-to-infrastructure communication include:

- Cooperative Adaptive Cruise Control
- Cooperative Forward Collision Warning
- Intersection collision avoidance
- Approaching emergency vehicle warning (Blue Waves)
- Transit or emergency vehicle signal priority
- Electronic parking payments
- Rollover warning
- Highway-rail intersection warning
- Electronic toll collection

In the first place, the system would only alert the driver with a warning sound or light, but future developments will allow braking automatically, adapting speed or changing the direction of the car.

### 2.2 TECHNOLOGIES FOR THE EXTERIOR OF THE CAR

#### 2.2.1 Gesture recognition and proximity detection

IR systems are used for gesture recognition and proximity detection. Gesture recognition and proximity detection include the following applications:

- **INTERIOR:** Gesture recognition for controlling music, radio, etc.
- **EXTERIOR:** Detection of the presence or the absence of the driver (i.e. of the key) to open or close the car accordingly
  - Gesture detection for automatic opening of the trunk

3D CMOS Image Sensor e.g. for gesture detection or passenger detection (courtesy of Hamamatsu Photonics K.K.)
Photonic components available for gesture recognition and proximity detection:

- **Illumination Sources**: IR or NIR LEDs or laser diodes.
- **Controlling Optics**: optical lenses, precision beam-shaping components, bandpass filters to optimize illumination and detection by the sensor.
- **Depth Camera**: using a particular sensor or running a stereo algorithm on the frames, a high performance optical receiver detects the reflected, filtered light, turning it into an electrical signal for processing by the firmware.
- **Firmware**: very-high-speed custom-designed chips process the received information and convert it into a digital format that can be understood by the end-user application.

### 2.2.2 Head lighting

**SIGNAL LIGHTS** (e.g. Daytime Running Light (DRL), Rear Combination Lamp (RCL), Center High Mount Signal Light (CHMSL)).

In signal lighting, LEDs are slowly replacing halogen lamps and xenon lamps as they have a better efficiency, longer lifetime and are more environment-friendly.

Today, OLEDs have not reached the required intensity and lifetime but their compactness and high design freedom make OLED technology attractive for signal lights. Systems combining LEDs and OLEDs are on the way.

**HEADLAMPS**

Halogen lamps are the most adopted technologies for headlamps. Xenon lamps have developed fast, extending from high-end to mid-end cars and may replace halogen to become the leading technology in headlights. Headlight designs based on LEDs have also started to emerge. Although the price of High-Brightness LED dies has declined sharply in the past years, LED dies only represent a very small fraction of the cost of an LED headlamp. Cost the of LED module, heat dissipation and optical engines are still much higher than the cost of xenon and halogen lamps, limiting their deployment to date.

Different reliability tests have also hampered the development of LED headlights. The standardization of headlamp LEDs could allow their widespread adoption in all car ranges. It is currently under discussion and should be standardized by 2016. On a technological view, the blue InGaN LEDs still have significant performance limitations. Foremost among these is the decrease in efficiency at high input current densities widely known as “efficiency droop”. Efficiency droop limits input power densities, contrary to the desire to produce more photons per unit LED chip area and to make LED lighting more affordable.
Pending a solution to efficiency droop, an alternative device could be a blue laser diode. Laser diodes, operated in stimulated emission, can have high efficiencies at much higher input power densities than LEDs. The first laser source for head-lighting entered the market in commercial cars in 2014.

The advantage of lasers is their ability to light up the road up to 600m with a high intensity. The main limitations that prevent them from adoption today, include the high cost, with headlamps priced above several thousands of euros, and safety issues which could hamper the regulation of such systems.

The intrinsic directional property of lasers make this technology well suited for marking light, e.g. a laser beam turns on to enlighten the presence of a person or an animal on the side of the road.

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Dow Corning meets the demands of the automotive lighting market by offering a combination of flexible silicones with proven optical quality. Silicone technology offers unique optical design possibilities and excellent thermal and environmental stability, allowing the automotive lighting customers to develop original differentiated designs.

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2.3 TECHNOLOGIES FOR THE INTERIOR OF THE CAR

2.3.1 Cameras

Technologies for monitoring the activities of passengers are not integrated into cars today. Some aftermarket products like additional rear-view mirrors are available. More sophisticated systems based on one or more cameras and displays could be used, for example, for surveillance of babies or young children. The adoption of this kind of product depends a lot on customer acceptance, on cost and on attractiveness of the product and its functionalities.

2.3.2 Spectroscopy

Among the different gas sensing application in the automotive industry (indoor air quality monitoring, particle measurement, emission measurement, oil quality measurement), indoor air quality is envisaged to have the shorter time-to-market, mainly driven by environmental constraints and legislation in Asia, and by relevant trade-off between price and reliability.
MEMS (Micro-Electro-Mechanical Systems) suppliers are already well established in OEM and Tier 1 and new devices based on micro-calorimeter, quartz microbalance and photo-acoustic sensors are good candidates for indoor air quality. Nevertheless, NDIR (Non-Dispersive Infrared Sensor) devices now, and plasmonic sensors in the near future, have the potential to increase photonics use in interior air quality automotive sensors.

**2.3.3 Interior lighting**

In interior lighting, LEDs are currently replacing classic lamps such as halogen and neon. The penetration rate will be increased further by technologies maintaining brightness, efficiency and color rendering of white LEDs over their lifetime and increasing the uniformity of large-area luminaires.

For LED-chips, a majors axis of development is in the phosphor science (to overcome aging issues of the phosphor) or in the material itself to develop phosphor free structures and to improve light extraction modalities.

For large-area lighting, LEDs alone do not compete with OLEDs at this time. Nevertheless, by integrating light management structures combined with new color-changing coatings containing highly efficient and reliable organic fluorescent dyes with heat management solutions, LED chips and multispectral sensors for intelligent color-sensing feedback could fulfill the needs in interior lighting.

For special effects, optical fibers, compatible with flexible soft surfaces are entering the market not only for communication tasks, but also lighting functions.

Further adoption of optical fiber may be facilitated by combining lighting and communication within the same optical fiber.

*Corning® Fibrance™ Light-Diffusing Fiber is a glass optical fiber optimized for thin, colorful, ambient lighting. It can be embedded into tight or small places where other bulky lighting elements cannot fit. The fiber is nearly invisible when the light source is off, thereby enhancing a product’s overall aesthetics and user experience.*

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2.3.4 MOST (Media Oriented Systems Transport)

15 years ago, MOST (Media Oriented Systems Transport) networks based on plastic optical fibers were developed specifically for automotive applications.

The growing number of electronic control units (ECUs) in the automobile - up to 80 in some vehicles - in addition to increased networking in the automobile and between the vehicle and its environment, is placing new demands on automotive networking technologies. Drivers and passengers want access to the vehicle network from their mobile devices, in order to playback audio files over the car’s audio system, or to play movies for the children on screens built into the back of the seats. Conversely, audio content such as internet radio could be transferred to the passenger’s mobile devices via internet access in the vehicle.

Compared to the networked applications available to date, these and other applications are placing even more demands on automotive systems with respect to bandwidth, ease-of-integration, flexibility and real-time behavior. In addition, the network management system must be able to integrate mobile devices into the automotive system to ensure reliable operation. At the same time, competition in the automotive industry is driving down the cost of the individual components. That means manufacturers must be in a position to integrate networking technologies that offer higher bandwidth and flexibility at lower costs.

The first evolution in MOST allowed data rates from 25Mbps to 150Mbps and grew to an annual production of around 10M ports/year. The next step, to meet the requirements outlined above, is for data rates of 1 to 10 Gbps and requires a strong investment from stakeholders in the MOST business. The volume production and standardized of electronic Ethernet chips (1 billion chips/year) may hamper the wider deployment of optical solutions, despite the advantages of lower weight and EMI/EMC reliance for MOST technologies based on Plastic Optical Fiber.

Fig. 4 : Courtesy of JASPAR
2.3.5 Displays

FOR THE DRIVER  Today, displays for the driver in the car are basic instrumentation (speed, fuel etc), audio infotainment systems and navigation systems with the latter frequently based on LCD flat panel displays.

   The trend is towards the use of HUD (Head-up Displays) for projection of information in the line of sight of the driver. Currently, some cars are equipped with a small HUD that provides basic information (speed, fuel level, etc).

FOR PASSENGERS  Screens for passengers started as aftermarket devices. Then OEMs started to provide screens integrated in the seats. Today, to provide larger display areas, projections on the windows or on the ceiling of the car are under study.

2.3.6 Power-by-light technology

The amount of sensors in automobiles is growing tremendously. Since usually each sensor requires its own power supply and data transmission channel, wiring complexity and related weight increases more and more. Also electromagnetic interference must be considered.

A future solution for powering automotive sensors or actuators that circumvents these challenges is power-by-light technology. Here, the power supply is realized in the form of light which is transmitted through an optical fiber. Right at the sensor the light is converted back into electricity by using a special photovoltaic laser power converter. As a consequence, copper wiring can be completely replaced by optical fiber. Another benefit is that also duplex data transmission will be realized within the same fiber, which additionally saves weight.
Power-by-light technology can also be applied to supply power to in-engine sensors in harsh environment or even enables power supply onto rotating systems.

2.4 TECHNOLOGIES FOR GREEN CARS AND MANUFACTURING

2.4.1 Solar cells

Solar energy is still a futuristic solution to power the car due to the extreme, and currently unreleased, performance required from the solar cell technologies as well as their high cost. Nevertheless, the use of solar cells in the car is currently being investigated to supply low consumption functionalities without using the battery.

The electrical loads of internal combustion engine (ICE) automobiles are related to multimedia, heating, ventilation, air conditioning (HVAC), body electronics (power windows and heated backlight), lighting (exterior and interior), with an average consumption above 3kW. An ICE uses part of the mechanical power (about 5kW) to drive the mentioned on-board equipment through the alternator; engine waste heat delivers cabin heating requiring 5-10kW, while mechanically driven air conditioning provides cabin cooling in summer.

On a fully electrical vehicle (FEV), electrical auxiliaries are supplied by the battery pack. The power consumption of any kind of auxiliary contributes to reduce the electrical vehicle range and to decrease the battery lifetime. Moreover the amount of heat available for cabin heating is very small (less than 5kW) and the energy available to supply an air conditioning system is far below than normally required in a conventional car. The development of autonomous smart roof integrating solar cells, energy storage systems and auxiliaries as thermoelectric climatic control, electrochromic glazing and LED lighting will increase comfort and fuel economy for both FEV and ICE vehicles.

Example of applications:

- Remote control of the HVAC to lower the inside temperature of the car before entering it
- Remote control of interior lighting to identify the car easily at night and provide comforting impression
- Supply of Head-Up Displays to save battery power
2.4.2 Process Control and QA/QC: Optical analytical methods and measurement

Whether it’s due to the time-consuming conventional testing techniques, the lawsuits that automobile companies face when accidents happen because of component failures, or the stringent quality control requirements expected by organizations, the automotive industry has reduced selective destructive testing of its components and has transitioned into non-destructive testing for its automotive parts. A malfunction of a component, however small, can have catastrophic consequences and it is usually the test and measurement quality control group who would be directly held responsible. Conventional methods are ultrasonic testing for e.g. laser welded tailored blanks, computed tomography, eddy current testing etc.

New photonic technologies for measurements are in strong growth in three applications:

2.4.2.1 Material characterization

All kinds of photometric devices allowing non-contact, non-destructive, fast, accurate, reliable measurement of temperatures, coating thickness, surface inspection/characterization and quality of adhesion in production, as well as measurement of exhaust gas emissions in engine development.

In addition, machine vision, active and passive infrared thermography, polarimetric imaging, interferometry, optical coherence tomography (OCT), shearography, ellipsometry, spectroscopy, profilometry, laser scanning 3D, reflectometry and deflectometry all use different features of light (intensity, phase, polarization, etc) to provide non-destructive data on materials.

2.4.2.2 Device characterization

The growing importance of LEDs, lasers, cameras and sensors in the automotive industry has a side-effect on the different ways to measure, qualify and control the optical properties of these devices. Integrating spheres, colorimetric and spectrophotometric systems will all be increasingly important for characterizing and verifying the performance of such devices.

2.4.2.3 Vehicle characterization during crash test

The automotive R&D tool ‘crash simulation’ can trace its origins to the military domain from the 1960s and is at present the predominant simulation used throughout the automotive industry. More than four decades of evolution in ‘crash simulation’ have molded R&D in the automotive industry and, at the same time, required advances in simulation technology. Photonics is playing a key role here with high-speed imaging and lighting system solution.

High-speed cameras are able to record up to 10.000 images per second and more, useful to analyse crash tests (picture courtesy Photon Lines/PCO)
2.4.3 Lasers for manufacturing

2D laser cutting in automotive started 40 years ago with the first installation of a CO₂ laser at the Ford factory in Cologne in 1974. The following decade (1980-1990) saw the widespread use of 500W CO₂ laser cutters with implementation of lasers systems in BMW, Austin Rover, Volvo, Fiat, etc.

After being widely adopted for cutting and welding, the introduction of fiber lasers around 2000, saw lasers also adopted for marking and drilling applications due to their speed, simplicity, ruggedness, and cost-effectiveness.

In the last years, ultrafast processing (pico and femtosecond lasers) have entered the automotive market for drilling small apertures or structures into difficult materials with specific shapes e.g. exhaust gas sensors developed by Robert Bosch on Bamberg site since 2007, or structuring the surface of diesel engine injector since 2009.

Currently, the market dedicated to laser systems for cutting, drilling, welding, marking, micromachining and surface texturing is shared among major companies such as IPG (35% of 2013 revenues), Rofin-Sinar (8% of 2013 revenues), Trumpf, JK lasers and Synrad (subsidiaries from GSI), Coherent and many others players.
KEY FINDINGS

Photonics entered the automotive market through core photonic functions e.g. head lights, laser welding and media communication networks. As example, there were around 10 million shipments of plastic optical fiber MOST transceivers in recent years.

The second generation of photonic products addressed passenger and driver comfort (interior lighting, gesture recognition, proximity detection, sensors for automatic wipers and headlamps). In 2018, LEDs will be fully adopted for interior lighting in all ranges of vehicles (>80 millions) and gesture control will reach 25 million units.

The third step will see the adoption of higher-value components and technologies for environment information acquisition and display for active safety (radar, vision and night vision). Key drivers are the increase in automated driving levels, from the current automated highway driving (2014), to a full monitoring of the surrounding environment (2022), to a complete autonomous vehicle (2028). These active safety applications already generate a market for 10 million units a year, corresponding to an estimated revenue of 1.18 billion euros in 2013. Growth above 30% is expected in 2014, i.e., 10-times the estimated growth of the overall automotive market.

It is one thing to gain market share, another not to lose it. Standardization is key in the automotive industry to maintain durably market share (e.g. in intra or inter vehicle communication) and to reach mainstream car markets. Regulation will also drive the timeframe towards automated driving and the adoption of additional technology.

Since its advent, the automobile has clearly won in terms of affordability, usability, applicability and image when compared to other modes of transportation. Photonics will be a key technology in enabling the car to advance in the 21st century and continue to excel in all of these areas.
To connect with key players of the photonics industry, please contact:

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EPIC is the European industry association that promotes the sustainable development of organisations working in the field of photonics. Our members encompass the entire value chain from LED lighting, PV solar energy, Silicon photonics, Optical components, Lasers, Sensors, Displays, Projectors, Optic fiber, and other photonic related technologies. EPIC is the industry association that promotes the sustainable development of organizations working in the field of photonics in Europe. We foster a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement. EPIC publishes market and technology reports, organizes technical workshops and B2B roundtables, coordinates EU funding proposals, advocacy and lobbying, education and training activities, standards and roadmaps, pavilions at exhibitions.

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