Lidar (light detection and ranging) measures like radar the distance of an object by means of the time the reflected laser beam needs to come back to the emitting system. This technology was originated in the early 1960s. First applications were measuring clouds and mapping the moon’s surface during the Apollo 15 mission. Nowadays, lidars are used to give sight to vehicles. They are so-to-say the third eye completing radars and cameras. They form 3D images by bouncing laser beams in the vehicle’s path. They can also function in snow and rain under certain conditions. After the deadly accident a Tesla car has had last year, when the so-called autopilot was on duty, it was speculated that the vehicle’s cameras could not identify the white trailer against the bright sky. The carmaker has stated before that Lidar technology does not make sense in automated driving cars. Lidars are able to overcome this camera weakness.  

To be serious, in the past lidars were expensive: up to €1000 and more. For high-volume applications, this is not acceptable. Using MEMS (micro electro-mechanical system) technologies this could be decreased dramatically. Continental and Valeo will produce solid-state lidar products by end of this decade. But there are still challenges to meet – especially, the carmakers requirements regarding temperature range, reliability, and robustness. Not to forget, not all lidars are eye-safe. Along with the cost factor, the lidars have to be improved regarding reliability. In the safety-critical aspects of automotive manufacturing, the equipment has to demonstrate the “six nines” – 99,9999-percent reliability.

Lidars could be used for lane tracking as well as obstacle and hazard detection. The lidar data is normally fused with other data coming for example from radars, cameras, GPS systems, odometers, or inertial sensors. The data fusion requires dedicated algorithms running on number crunching processors, e.g. such provided by Nvidia. Dibotics promotes another way: The French company has developed a 6-degree of freedom sensor-agnostic localization technology, relying exclusively on the data originated from a single lidar sensor. Demonstrated at the Concarexpo 2017 in Berlin, this approach does not need artificial intelligence (AI) and deep learning. It just uses state-of-the-art micro-controllers. The real-time results are predictable and comply with functional safety requirements, stated the company.  

Most lidars use a time-of-flight (TOF) method. Some sensors use just phase to get position by scanning with a modulated signal that changes in frequency, distance is determined by looking at the frequency and phase. These sensors are more costly. Other products use triangulation. These sensors can typically provide very accurate distance, however they are often not eye-safe. It is also possible to combine the described methods.  

The reflectivity of a surface is important for the maximum range of a lidar. A white surface will typically have a better return than a black surface (black rubber and coal are particularly bad). Another thing that affects reflectivity is the surface type. A smooth surface will typically reflect better than a rough surface.

Also the stop size (has some relevance for rain drops) should not be forgotten. It should be specified for both directions. As the range increases, the distance between each of the points increases. The spot size of each point can be over 1 m in distances of 100 m. If the lidar provides multiple returns, this improves the measurements in rain, snow, fog, or when leaves are falling.  

The first lidar generation was based on short-wave infrared (SWIR) diodes, avalanche photodiode or single-photon avalanche diode and used optical systems. It was a race on performance and durability. The need to reduce costs brought solid-state technology into the game: steerable lasers, MEMS-based micro-mirrors, and detector arrays.  

In the pipeline: solid-state lidars  

The contest has been started already: besides ST-Microelectronics, there are Ibbo (partner of ZF), Innoluce (cooperating with Infineon), Innoviz (partner of Magna), Ledartech
(partner of Valeo), Quanergy (cooperating with Sensata), Tri-
lumina (partner of Denso), Velodyne (cooperating with Ford),
and Xenomatix developing solid-state lidars. The Tier1s in-
tegrate them into ADAS (advanced driver-assistant system)
units featuring sensor data fusion. Xenomatic, for example,
provides the Xenolidar solid-state sensor packed into the
Xenotrack test-kit operating in all light and weather condi-
tions. The kit comes with the Xenoware software supporting
data transfer via CAN and other interfaces. Ibeo’s lidar prod-
ucts are also connectable to CAN networks using the CAN
gateway by HMS/Ixxat.

Quanergy’s 3S solid-state lidar has received the CES
2017 ‘Best of Innovation’ award. It is able to perform real-
time 3D mapping and object detection, tracking, and clas-
sification of objects in distances up to 200 m. The lidar sen-
ror has been integrated into Koito’s headlights. It emits
collimated light pulses in a 120-degree arc. Light receivers
detect the reflected light pulses. Signal processors calculate
the TOF. With the ability to scan in every direction, the unit
creates a live 3D-view around the vehicle. The company also
offers the S3-Qi lidar with a maximum range exceeding 100
m. This solid-state sensor is suitable for drones, robots, and
industrial automation. Quanergy cooperates exclusively with
Sensata integrating the lidar sensors with cameras and other
components.

Ibeo cooperating with ZF, another German Tier1 sup-
plier, has introduced the Scala fusion system comprising up
to five laser scanners. The sensors emit laser beams with a
wavelength of 905 nm, which ensures eye-safety. Each sen-
ror requires one Media Converter Box by Valeo. It packs the
lidar sensor data into Ethernet frames. The ECU, which per-
forms the data fusion, collects also vehicle speed and yaw
rate via its CAN interface. The camera data comes via the
USB port. The calculated and commanded vehicle motion
data is transmitted via the used in-vehicle network, normally
CAN or Flexray.

Microvision uses in its lidar sensors MEMS mirrors. But
instead of visible light laser diodes, the company utilizes one
or several invisible near infrared (IR) laser diodes. The IR
beam is reflected onto the biaxial MEMS scanning mirror that
scans the beam in a raster pattern. The lidar unit also
contains an IR photo-detector that detects reflections from
the scanner IR laser beam. Since speed of light is constant
and know the time is known when the specific laser pulse
is emitted and when the reflection back receive is received,
the unit can calculate the distance to the object. The lidar
sensor is able to capture 5.5 million points per second. The
MEMS-based laser scanners are scalable and can therefore
be used in very different applications. Microvision cooper-
ates with ST Microelectronics. The miniature laser scanners
are targeted for 2018. Also other companies have scheduled
production of MEMS-based lidars, e.g. Velodyne its Velarray
sensor and Osram its 4-channel unit.

Key data for automotive lidar sensors is the range
of up to 200 m (objects with a 50-percent reflection) and
0.1-degree of 3D resolutions. The raw data amount is about
6 million pixels per second. This needs to be pre-processed,
when it should be transmitted via CAN. Alternatively, the raw
data could be sent via proprietary point-to-point connections
(e.g. based on Ethernet or USB) within the electronic control
unit (ECU).
On the market: lidar units

Continental was one of the early birds in lidar systems. Already in 2012, the Tier1 supplier introduced the SRL 1C lidar device, which could be installed in collision avoidance systems. It features a CAN interface, which is used for configuration as well as sensor state and data transmission. The product is equipped with 16 sensors and provides three thresholds and one hysteresis for each channel. The maximum measured distance for a channel is 14000 mm; the minimum is 1000 mm.

Figure 1: The Velarray lidar uses Velodyne’s proprietary ASICs and comes in a package size of 25 mm x 50 mm x 55 mm; it provides a 120-degree horizontal and 35-degree vertical field-of-view with a 200-m range (Photo: Velodyne)

In application: not just in cars

The recently introduced Audi A8 is one of the first cars using lidars in combination with cameras and radars giving the car a 360-degree awareness. The car complies with SAE’s Level 3 for autonomous driving. It will be available in 2018. Valeo is the supplier of the lidar units and Nvidia provides the central computer to process sensor inputs and to make driving decisions. In case, the A8’s emergency assist is activated due to no reaction of the driver (after visual and acoustic warning plus multiple brake jolts with flashing of the hazard warning light), the active lane assist takes over. It moves the car to the road’s shoulder and parks it there. Finally, it activates also the park brake. Other carmakers have demonstrated the usage of Lidar sensors in prototype vehicles. Ford recently drove autonomously its Ford Fusion Hybrid in the night on road in the desert, guided only by lidar systems without cameras. The lidar has been developed jointly with Velodyne.

Since many years, automated and automatic guided vehicles (AGV) and unmanned aerial vehicles (UAV) are equipped with lidars. Also in industrial applications such as high-bay storage systems, lifting gears, crane systems, side-tracking skates and truck storage vehicles as well as transfer machines distance measuring devices with lasers are applied. One of the industrial laser scanner provider is Micro-Epsilon. Its Scancontrol 2D- and 3D-sensor family measures 2.5 million points per second. Via Ethernet or ModbusTCP it can be connected to an external host controller or a PC.

Leuze, for example, offers the OMS2/1XX series of laser sensors featuring CANopen connectivity. The device complies with the CiA 406 profile for encoders. Last year, the CiA nonprofit association has released the CiA 462 profile for item detection devices. It standardizes the communication interface for obstacle detecting devices such as lidars, but could also be used for camera-based devices. Pepperl + Fuchs provides also laser sensors measuring distances with CANopen connectivity. The OMD6000-R2100 multi-ray LED scanner uses a proprietary device profile.

Sick is another industrial lidar pioneer. The company developed such laser sensors for non-automotive applications. They are based on Ibeo’s lidar technology. The LD-MRS (laser measurement sensor) by Sick comes optionally with one or two CAN interfaces. It can be integrated into AGVs and UAVs. The product connected to a drone demonstrated a working range of 300 m. Even with black objects and just 10-percent re-emission, the range is still 50 m. In a...
project, even the black tailcoat of penguins turned toward the drone was registered. The 3D-lidar sensor captures the environment without any gaps and, due to the integrated object tracking feature, reduces the time taken to count the animals across the large population area from several weeks to just a few hours. By the way, lidar units for drones are as price-sensitive as for cars. Seeed Studios offers its RP-Lidar for about €400, which is still not cheap.

The future: stand-alone, but integrated

The development of automated and autonomously driving vehicles is the driving force of lidar technology. The business seems to be huge: Markets-and-Markets estimated a €5-billion turnover for 2022. Others are more conservative: €0.9 billion in 2022 (Allied Market Research), €1.1 billion in 2023 (Global Market Insights), and €1.34 billion in 2024 (Grand View Research).

Anyway, it is a big business. Lidar is one of the key technologies for automated driving. Investors open their wallets for start-up companies such as Tetravue in California – this includes Tier1s and even OEMs, which invests or partners with innovative companies. Investors include Foxconn, Nautilus Venture Partners, Robert Bosch Venture Capital, and Samsung Catalyst Fund.

Lidar systems require as its sisters, camera and radar, a lot of bandwidth, which is not provided by the traditional in-vehicle network technologies. Of course, this bandwidth is only necessary for ADAS internal purposes. The results of the environment monitoring and observation are simple: maneuver the car in a safe position, as the Audi A8 is doing. The automated driving itself requires just a few commands and parameters. Classical CAN can achieve this; even if you require functional safety, CAN FD should provide sufficient bandwidth. However, this is only possible, if the raw sensor data are pre-processed in the ECU-embedded multi-core computers.

Lidar-based units cannot just calculate the distance of objects, but also classify them. They can detect lane edges and they work in daylight and at night in darkness. The applications are very different. This is why different device designers integrate MEMS-based sensors into housings together with processors running dedicated software algorithms. But lidar technology also has its limitations. Radar can recognize a wall and has a longer range and it also works in fog, while lidar and cameras can be confounded.