LiDAR for Automotive and Industrial Applications 2021

Market and Technology Report 2021
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# SCOPE OF THE REPORT

## Markets and applications

<table>
<thead>
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<th>Consumer</th>
<th>Automotive</th>
<th>Industrial</th>
<th>Defense &amp; aerospace</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR/VR</td>
<td>ADAS</td>
<td>Construction</td>
<td>Planets</td>
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<td>Robotic cars</td>
<td>Logistics</td>
<td>Atmosphere</td>
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<td>ADAS</td>
<td>Factory automation</td>
<td>Logistics</td>
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<td>Energy</td>
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<td>Smart buildings</td>
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<td></td>
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<td>Security</td>
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<tr>
<td></td>
<td></td>
<td>Smart infrastructure</td>
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<td></td>
<td></td>
<td>Smart agriculture</td>
<td></td>
</tr>
</tbody>
</table>

LiDAR consumer applications are covered in Yole’s 3D sensing report.

Your needs are out of scope of this report? Contact us for a custom study:

ADAS: Advanced Driver Assistance Systems
AR: Augmented Reality
VR: Virtual Reality
Yole’s market forecast model is based on the matching of several sources:

- **Top-down approach**
  - Aggregate of market forecasts
    - @ System level
  - Aggregate of market forecasts
    - @ Semiconductor device level

- **Bottom-up approach**
  - Ecosystem analysis
  - Aggregate of all players’ revenues
    - @ System level
  - Ecosystem analysis
  - Aggregate of key players’ revenues
    - @ Semiconductor device level

**Comparison with existing data**
- Monitoring of corporate communication
- Using other market research data
- Yole’s analysis (consensus or not)

**Comparison with prior Yole reports**
- Recursive improvement of dataset
- Customer feedback

**Market**
- **Volume (in Munits)**
- **ASP (in $)**
- **Revenue (in $M)**

**Preexisting information**
- **Primary data**
  - Reverse costing
  - Patent analysis
  - Annual reports
  - Direct interviews

**Secondary data**
- Press releases
- Industry organization reports
- Conferences

**Information Aggregation**

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**Pierrick BOULAY, Market & Technology Analyst**

Pierrick Boulay works as a Market and Technology Analyst in the fields of LED, OLED, and lighting systems. He performs technical, economic, and market analyses at Yole Développement, the ‘More than Moore’ market research and strategy consulting company. Pierrick has industry experience in LED lighting, including general and automotive lighting, and OLED lighting.

Prior to Yole, Pierrick worked in several R&D departments on LED lighting applications. He holds a master’s degree in Electronics from ESEO in France.

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**Alexis DEBRAY, Senior Analyst – Emerging Technologies**

Alexis Debray, Ph.D., is a Senior Analyst at Yole Développement (Yole), dedicated to the production of technology & market reports and custom consulting projects in the fields of photonics, sensing, and semiconductors.

Before joining Yole, Alexis spent 17 years in Japan. He worked for 2 years at the University of Tokyo developing expertise in MEMS technologies and then for 15 years at Canon Inc. as a research engineer, where he contributed to numerous developmental projects focused on MEMS devices, lingual prehension, and terahertz imaging devices.

Alexis is the author of various scientific publications and patents. He graduated from ENSICAEN (France) and was awarded a Ph.D. in applied acoustics.

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LIDAR: FROM TECHNOLOGIES TO APPLICATIONS

Technologies

- OCT: Optical Coherence Tomography
- PET: Positron Emission Tomography
- VCSEL: Vertical-Cavity Surface-Emitting Laser
- SiPM: Silicon Photomultiplier
- MEMS scanner
- Optical packaging
- Fiber-optic communication
- Laser diode

Applications

- Space
  - Up to $500M
  - $10,000
  - $1,000,000
- Topography
  - $30,000
  - $500,000
- Wind
  - $2,000
  - $100,000
- Logistics/Industry
  - $30,000
  - $500,000
- Mobility
  - $30,000
  - $75,000
- Consumer
  - $1
  - $10
  - $1000
- Robots
  - $500
- Cloud data
  - $1
  - $10
  - $100
  - $1000
- Automatic target recognition
  - $1
  - $10
  - $100
  - $1000

OCT: Optical Coherence Tomography
PET: Positron Emission Tomography
SiPM: Silicon Photomultiplier
VCSEL: Vertical-Cavity Surface-Emitting Laser
In the 1930s, EH Synge conceived of LiDAR.

Columbia University team led by Charles Townes build the first maser (microwave amplification by stimulated emission of radiation).

In 1939, Ellis A. Johnson, a Carnegie Institution Scientist, uses a searchlight to capture signals up to 40 km.

The Hughes Mark II Colidar is the first commercial LiDAR.

George D. Hickman flies the first bathymetric LiDAR.

York University (Canada) physicist Allan Carswell and his wife Helen found Optech.

Milton Huffaker founded Coherent Technologies to commercialize LiDAR wind-detection systems.

In 1960, TH Maiman conceived the first laser.

The Hughes Mark II Colidar is the first commercial LiDAR.

SRI build the SRI Mark I LiDAR for atmospheric studies.

Apollo Lunar Ranging Experiment (LURE) lands on the moon with Apollo 11.

Johannes Riegl founds Riegl.

Cyra Technologies introduces the Cyrax 2400, the first tripod-mounted, commercial 3D scanner.

University of Texas at Austin team led by James Gibeaut create the first LiDAR-based digital elevation model of an archaeological site, at Copan, Honduras.

David Hall invents 3D real-time LiDAR and creates Velodyne LiDAR.

1930
1939
1953
1960
1962
1963
1968
1969
1974
1978
1984
1998
2000
2004
2005
Automotive is expected to have a major impact on the LiDAR market in the next five years.
LIDAR MARKET SHARES

2020 Market shares by revenue

- The LiDAR market remains dominated by traditional companies in topography (Trimble, Hexagon, Topcon) and factory automation (Sick AG).
- Velodyne saw its revenue decline slightly in 2020 due to a reduction in unit pricing. It is a strategy of the company.
- New-comers like Valeo and Ouster are beginning to generate LiDAR revenue.
- We have adjusted the revenues for several companies which have or plan to become public. This includes Velodyne, Ouster, Luminar, AEye, Aeva, Innoviz, and Hesai.
- Waymo produces LiDAR for its own robotaxis. The “market” for Waymo corresponds to the market price of the LiDAR.
- This total LiDAR market includes revenues for the Defense and Space market and some revenues going to research and development projects. These segments are not considered in the forecasts presented in the Market forecasts section. This explain the difference for the two 2020 LiDAR market data.

Total market: $1,819M

<table>
<thead>
<tr>
<th>Company name</th>
<th>LiDAR revenue - $M</th>
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<tbody>
<tr>
<td>Trimble</td>
<td>353</td>
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<td>Hexagon AB</td>
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<tr>
<td>Sick AG</td>
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<td>Topcon</td>
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<td>Velodyne LiDAR</td>
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<td>Riegl</td>
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<td>BEA (Halma)</td>
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<td>Pepperl+Fuchs</td>
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<tr>
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<td>Hesai</td>
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<td>Hokuyo Automatic</td>
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<td>Others</td>
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*Revenue is for hardware only.
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<th>Imaging technology</th>
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<th>Optical-phased array</th>
<th>Flash</th>
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<td>camira, i.com, Valeo, Velodyne, SureStar</td>
<td>Dicroxfield</td>
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<td>Other optical</td>
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<td>aurora, SiLC</td>
<td>Cruise</td>
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<td>Sequential flash</td>
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*Non-exhaustive list

*FMCW: Frequency Modulated Continuous Wave
Supply chain analysis – Known design wins (total of 29)

- Among the 29 design wins made public, 8 are for Valeo. This makes Valeo, by far, the leading LiDAR supplier for ADAS vehicles.
- 905nm from EELs is still the OEMs' wavelength of choice due to its low cost. Nonetheless, 1550nm-based LiDAR is gaining market.
- Even though MEMS and flash LiDAR are emerging, mechanical LiDAR remains widely used by OEMs.
905nm-based systems should continue to be used due to their low cost, though FMCW LiDAR based on 1550nm could emerge in the long term.

The second generation was released in 2020.

In 2021, BMW will start implementing LiDAR from Innoviz into its vehicles.

Similarities:
- 905nm EEL
- Pulse Time-of-Flight
- Silicon-based sensor

- Most popular ranging method as it is the easiest.
- Lower cost of components.
Mechanical LiDAR based on mature technologies will continue to be used but new technologies will emerge at the same time.

FMCW LiDAR

Similarities:
- Suitable for 1550nm
- Coherent detection.
- Radial velocity measurement.
- Alternative to mechanical or MEMS scanning.
- Still not ready for industrial applications.

OPA LiDARs

Credit: Blackmore
Credit: Insight LiDAR
Credit: Analog Photonics
Credit: SILC Technologies
Credit: Voyant Photonics
FREQUENCY MODULATED CONTINUOUS WAVE LIDAR (FMCW)

Focal plane array (FPA) technology

The California based company Pointcloud has used silicon photonics to realize an image sensor in a focal plane array (FPA) format with coherent detection. The image sensors therefore benefit simultaneously from the low or non-deformation imaging of FPA (compared to scanning techniques) and the high sensitivity of coherent detection.

The image sensor can be used to realize a frequency modulated continuous wave (FMCW) flash LiDAR. Applications are envisioned in automotive, robotics, smart city, smart office and consumer, including augmented reality (AR).

Coherent FPA image sensors are seen as the ultimate image sensor but are difficult to achieve due to the need for local oscillators (LO) at the pixel level.

A focal plane array with coherent detection represents a breakthrough in sensitivity.
Sensing and computing for ADAS vehicles 2020

Sensors for Robotic Goods Transportation 2021

Sensors for Robotic Mobility 2020

Artificial Intelligence Computing for Automotive 2020
Valeo SCALA Laser Scanner

LeddarVu8: The first off-the-shelf solid state high-definition LiDAR module from LeddarTech

Hamamatsu Photodiode and Laser in Livox’s Horizon LiDAR
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Email: leroy@yole.fr