

CMOS CAMERA MODULE INDUSTRY FOR CONSUMER & AUTOMOTIVE 2020

Market & Technology Report - August 2020

After proliferation, diversification of camera modules comes into play and sustains the growth of the CMOS camera module industry.

WHAT'S NEW

- Updated mobile, consumer, automotive camera ASP/revenue forecasts through 2025
- Forecast analysis per sub-component
- Added scenario for mobile sensing camera 3D and under-display fingerprint
- Updated multiple-camera and periscope camera penetration
- Updated trends for all markets
- Technology breakdown per sub-component and new technology

KEY FEATURES

- Camera module market forecast (in Munits and \$M) through 2025
- Camera module ecosystem mapping
- Camera module application trends - mobile and consumer, automotive
- Camera module technology trends – Image sensor/Lens set/Actuator/Camera module assembly

REPORT OBJECTIVES

Ecosystem identification and analysis:

- Determination of the application range
- Technical market segmentation
- Market trends and forecasts
- Key players, by market and analysis

Analysis and description of markets and technologies involved:

- Detailed applications per market segment
- Major global actors
- Technology trends
- Main technical challenges

THE CAMERA MODULE MARKET IS EXPANDING AT AN INCREDIBLE PACE

The desire to capture the perfect picture used to be accomplished through complex and expensive Digital Single-Lens Reflex (DSLR) cameras and the use of interchangeable lens systems. The multiple lens possibility has therefore been the cornerstone in the pursuit of extreme imaging performance. Today's mobile cameras follow a similar mindset but using multiple fixed lenses to improve photography performance. Quickly adopted by large manufacturers, this trend led to 10.2% year-over-year growth in 2019.

Yole Développement expects the volume of global camera module shipments to expand from 5.5B units in 2019 to 8.9B in 2025, at 8.2% Compound Annual Growth Rate (CAGR).

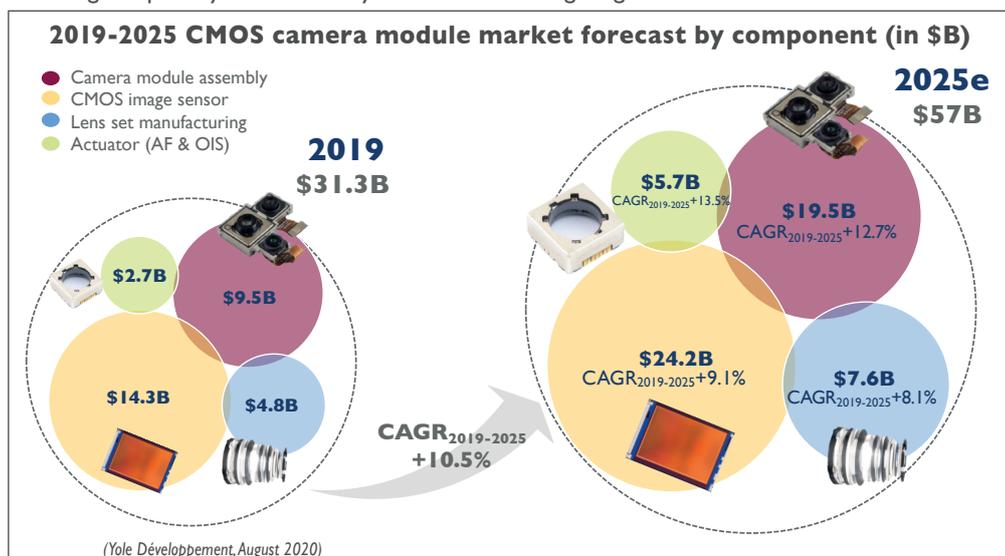
Mobile multi-cameras started in early stage 2015-2016, moving from single to dual cameras, then maturing to triple in 2018 and 2019. Now they have moved toward quad in 2020. Diverse modules implement diverse levels of zoom or wide angle capability. This diversity is enriched

by sensing camera modules. This is the case for front structured light for 3D facial recognition, the rear Time of Flight (ToF) for Augmented Reality (AR) applications, and the optical fingerprint module placed under the screen.

In the automotive market the trend is to massively adopt rear cameras and Advanced Driver Assistance System (ADAS) forward cameras. The average number of cameras per car goes up because of the need for new applications, such as the 360 degree view, in cabins and e-mirrors. Again in this market the diversity in camera design is very high.

In the consumer electronics field, vision is an important element of smart products, assistant personal robotics and consumer drones. These new applications will increase the demand for cameras, and drive the camera module market even higher in the years to come.

This latest edition of Yole Développement's popular report offers you key insights for navigating the camera module market.



CAMERA MODULE TECHNOLOGY IS DIVERSIFYING AND IS BRINGING KEY OPPORTUNITIES TO PHONE MAKERS

In the mobile world, smartphone Original Equipment Manufacturers (OEMs) are in fierce competition to add camera functions and improve camera performance with increasing pixel resolution upgrades, combined with multiple-camera designs. The competition for the supply of high-quality CMOS Image Sensors (CIS)

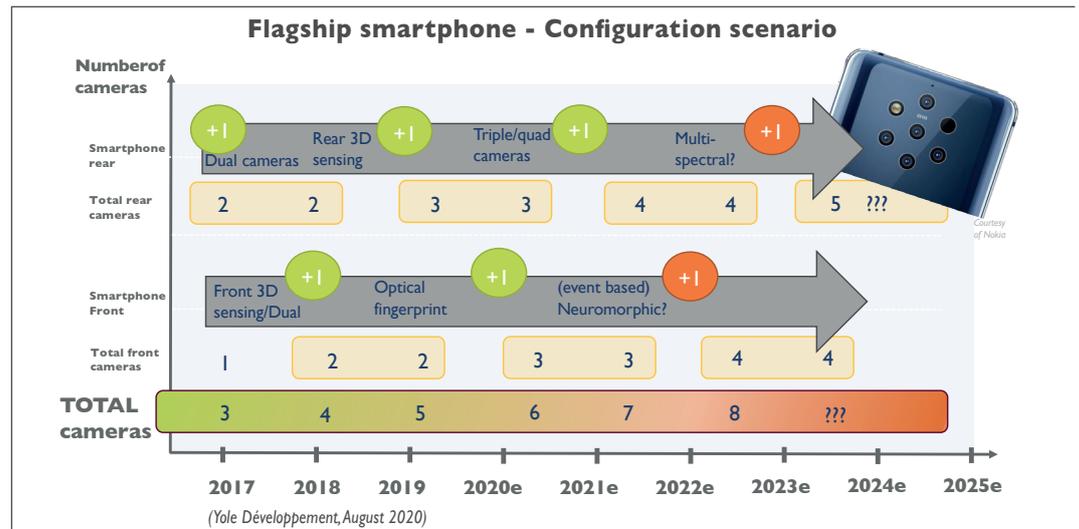
exceeded the worldwide capacity at the end of 2019, resulting in shortages and price hikes. While the recent pandemic tamed global economics, the camera module industry is expected to maintain double digit growth for the next five years.

Yole Développement expects the revenue of the global camera module market to expand

from \$31.3B in 2019 to \$57.0B in 2025, at 12.8% CAGR.

Beyond the sensor itself, innovations in all the different subcomponents of the camera module are in high demand. The introduction of periscope lenses was a major event that allowed 5x or even 10x optical magnification within the existing thickness of mobile phones. Optical image stabilization (OIS) is another critical technology for photography especially for telephoto, hence players are also looking for innovations in this area, using new materials, MEMS or liquid lens to replace the Voice Coil Motor (VCM) approach.

Thanks to the additional techniques and innovation, camera modules are increasing in value significantly over the years. Technical upgrades of camera modules include the “Active Alignment” process to align multiple cameras well. There will be several innovations in camera module integration, like pop-up cameras or side-up cameras, and under-screen cameras in future. These innovations will integrate different materials from various sources, which should provide a great deal of opportunity to the market and facilitate the application of camera modules to more new products.



MARKET GROWTH BENEFITING THE LEADERS BUT ALSO OFFERING OPPORTUNITIES TO SECOND TIER PLAYERS

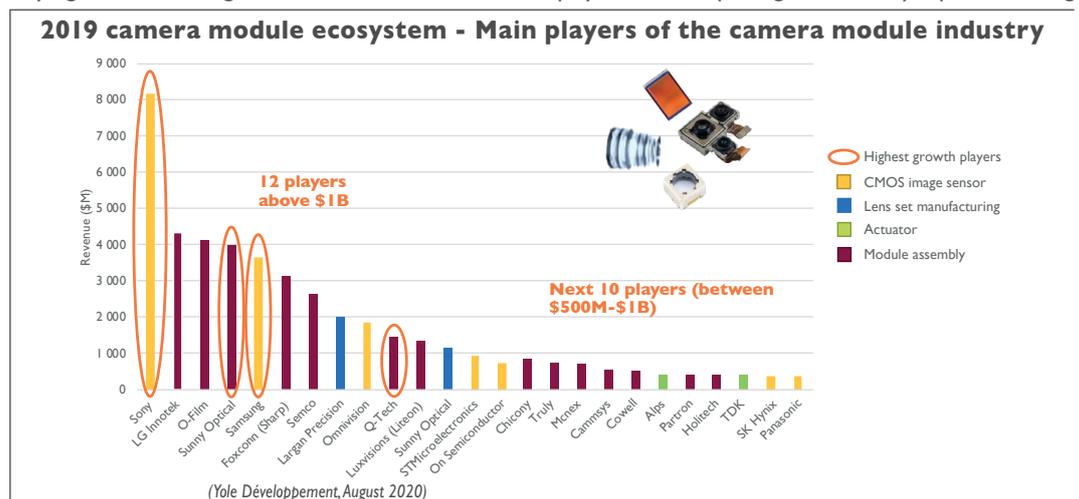
Camera modules are very precise optoelectronic components, which contains image sensors, lens sets, actuators and assemblies. They have become key components of the mobile industry, expanding into a rich ecosystem that has grown and matured after more than twenty years of development. It is currently enjoying a boom in demand, which is benefiting almost all players.

The industry leader LG Innotek continues to maintain its position due to the large orders from Apple. Closing in are Ofilm and Sunny Optical, who have climbed to the second and third positions by relying on the strong domestic market in China,

replacing Semco and Foxconn/Sharp. In the years to come the US-China trade war could play a big role in reorganizing the ranking of Compact Camera Module (CCM) players.

Image sensor providers used to push their technology to market at their own pace, shrinking pixels and increasing resolution. But with current trends mobile phone OEMs are now more aggressively developing specific image sensors with unique features. The rankings of the top three, Sony, Samsung, and OmniVision, is now well established.

Lenses are another area where there are a few players at the top, Largan and Sunny Optical, making



up most of the market. Other components, such as actuators for autofocus (AF)/OIS and drivers, infrared-cut filters, substrates and connectors have benefited as the industry has reached new heights.

The car camera application has just entered its growth stage and has become a broad

market with surround-view, ADAS and in-cabin applications. It has now attracted traditional tier one auto part manufacturers to enter, as well as many leading players of the mobile camera ecosystem. Sony, Ofilm and Sunny Optical are all vying to enter this market as tier two part manufacturers.

COMPANIES CITED IN THE REPORT (non exhaustive list)

AAC Technologies, Ability Opto, AGC, AMS, Alps, Apple, Asia Optical, ASM, Brigates, BYD Microelectronics, Calin Technology, Cammsys, Cha Diostech, Chicony, Continental, Cowell Optics, Cresyn, Crystal-Optech, Ddk, DJI, Foxconn, Fujifilm, Fujinon, Fujitsu, Galaxycore, Genius Optical, Google, Gopro, Haesung Optics, Himax, Hirose, Hoya, Huawei, IM, Intel, Jawah, Jabil, JSR, Kantatsu, Kinko Optical, Kolen, Kyocera, Largan, Lenovo, LG Innotek, Luxvision, Magna, Materion, Mcnex, Microsoft, Mitsumi, Mobileye, Nalux, New Shicoh, Nidec, NTK, Ofilm, OmniVision, On Semiconductor, OPPO, Optis, Panasonic, Parrot, Partron, Pixart, Pixelplus, Powerlogic, Primax, Q-Tech, Ricoh, Samsung, Schott, Semco, Sharp, Sekonix, SK Hynix, Softkinetic, Sony, STMicroelectronics, Sunny Optical, Sunex, Superpix, Suyin, TDK, Toshiba, Truly, Valeo, Viavi, Vivo, Volvo, Xiaomi, Xperi, Zeiss, Zeon, ZTE, and more.

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RELATED REPORTS, MONITORS & TRACKS



- Status of CMOS Image Sensor Industry 2019
- CMOS Image Sensor Quarterly Market Monitor
- 3D Imaging and Sensing 2020
- Smartphone Camera Module Comparison 2020 Vol. I
- Apple iPad Pro LiDAR Module

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ABOUT YOLE DEVELOPPEMENT

Founded in 1998, Yole Développement (Yole) has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 120 collaborators worldwide covering MEMS and Image Sensors, Compound Semiconductors, RF Electronics, Solid-state Lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Power Electronics, Batteries & Energy Management and Memory.

The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO and Blumorpho, supports industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

CONSULTING AND ANALYSIS

- Market data & research, marketing analysis
- Technology analysis
- Strategy consulting
- Reverse engineering & costing
- Design and characterization of innovative optical systems
- Financial services (due diligence, M&A)

More information on www.yole.fr

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Definitions: **“Acceptance”**: Action by which the Buyer accepts these General Terms and Conditions of Sale in their entirety. It is done by signing the purchase order which states “I hereby accept Yole Développement’s General Terms and Conditions of Sale”.

“Buyer”: Any business user (i.e. any person acting in the course of its business activities for its business needs) placing an order pursuant to these General Terms and Conditions of Sale, with the exclusion of any individual consumer acting for his/her sole personal interest.

“Seller”: Headquartered in Villeurbanne (France), Yole Développement provides marketing, technology and strategy consulting, media and corporate finance services, reverse engineering/costing services as well as IP and patent analysis. With dedicated teams of technology & market analysts, Yole Développement operates worldwide with the key industrial companies, R&D institutes and investors to help them understand the market and technology trends.

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Reports are established in PowerPoint and delivered in a PDF format with an additional Excel file. 30 min of Q&A session with an analyst/author can be included for all purchased reports (except the ones bought as a one user license). More time can be allocated on a fee basis.

“Monitor”
Monitors are established and delivered in Excel. An additional PDF can also be added. Q&A with an Analyst is possible for each monitor (except where specified otherwise). Frequency of the release vary according to the monitor or service (quarterly and monthly). All monitor products are eligible for a Corporate License.

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1. SCOPE

1.1 Both Contracting Parties undertake to comply with these General Terms and Conditions of Sale.
ANY ADDITIONAL, DIFFERENT, OR CONFLICTING TERMS AND CONDITIONS IN ANY OTHER DOCUMENTS ISSUED BY THE BUYER AT ANY TIME ARE HEREBY OBJECTED TO BY THE SELLER, ARE DEEMED WHOLLY INAPPLICABLE TO ANY SALE MADE HEREUNDER, AND SHALL NOT BE BINDING IN ANY WAY ON THE SELLER.

1.2 These General Terms and Conditions of Sale shall be deemed valid and enforceable between the Contracting Parties after acceptance of an order from the Buyer by the Seller pursuant to Article 1.3 below. For such purpose, the Buyer, when signing the purchase order which mentions “I hereby accept Yole Développement’s Terms and Conditions of Sale” is deemed to have fully and unequivocally accepted these Terms and Conditions of Sale.

1.3 Orders are deemed to be accepted only upon written acceptance and confirmation by the Seller, within [7 days] from the date of order, to be sent either by email. In the absence of any confirmation in writing, no order shall be deemed to have been accepted.

2. MAILING OF THE PRODUCTS

- 2.1 Products are sent by email to the Buyer after Seller’s confirmation:
 - Within a few days from the Seller’s confirmation of the order for Products already released and paid; or
 - Within a reasonable time for Products ordered prior to their effective release. In this case, the Seller shall use its best endeavours to inform the Buyer of an indicative release date and the evolution of the work in progress.
- 2.2 The Seller shall by no means be responsible for any delay pursuant to Article 2.1 above, in particular in cases where a new event or access to new contradictory information would require the Seller analyst to dedicate extra time to compute or compare the data in order to enable the Seller to deliver a high quality Product.
- 2.3 The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in Article 3 above.

2.4. The mailing is operated through electronic means either by email via the sales department or automatically online via an email/password. The Buyer is responsible for ensuring that the Buyers platform has the required capacities and authorisations to receive the Product(s) emailed by the Seller. If the Product’s electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that the Seller is informed of the defective formatting within 90 days from the date of the original download or receipt of the Product.

2.5 The person receiving the Products on behalf of the Buyer shall immediately verify the quality of the Products and their conformity with the order. Any claim for apparent defects or for non-conformity shall be sent in writing to the Seller within 8 days of receipt of the Products. For this purpose, the Buyer agrees to produce sufficient evidence of such defects.

2.6 No return of Products shall be accepted without prior written notification from the Buyer to the Seller, even in case of delayed delivery. Any Product returned to the Seller without the Buyer providing prior notification to the Seller as required under Article 2.5 above shall remain at the Buyer’s risk. In no event shall the Seller incur any liability for Products erroneously ordered by the Buyer, or for any request from the Buyer to replace a Product previously ordered by a different Product.

3. PRICE, INVOICING AND PAYMENT

3.1 Prices are given in the orders corresponding to each Product sold on a unit basis or corresponding to annual subscriptions. They are deemed to be inclusive of all taxes applicable in the country where the Seller is based (except for France where VAT will be added). The prices are re-evaluated from time to time by the Seller. The effective price is deemed to be the one applicable at the time of the order.

3.2 Payments due by the Buyer shall be sent by cheque payable to Yole Développement, or made by credit card or by electronic transfer to the following account:
 HSBC, 1 place de la Bourse 69002 Lyon France
 Bank code: 30056
 Branch code: 00170
 Account n°: 0170 200 1565 87
 BIC or SWIFT code: CCFRFRPP
 IBAN: FR76 3005 6001 7001 7020 0156 587

To secure the payments due to the Seller, the Seller reserves the right to request down payments from the Buyer. In such case, the need for a down payment will be mentioned on the corresponding order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except as otherwise specifically agreed in writing by the Buyer and the Seller. If the Buyer fails to pay at the due date and fails to request and obtain from the Seller a payment extension, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the “BCE” + 7 points, in accordance with article L.441-6 of the French Commercial Code.

3.4 The Seller publications (reports, monitors, tracks...) are due for delivery only after receipt by the Seller of any payment due by the Buyer prior to delivery.

3.5 In the event of termination of the contract by the Seller attributable to Buyer misconduct during the contract, the Seller will have the right to invoice all work performed at the time of termination, and to take legal action for damages.

4. LIABILITIES

4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for the choice of the Products purchased as well as for the use and interpretations the Buyer makes of the documents it purchases, of the results the Buyer obtains, and of the advice and acts the Buyer bases thereon .

4.2 In no event shall the Seller be liable for:
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 b) Any claim attributable to errors, omissions or other inaccuracies in a Product or interpretations thereof.

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4.4 Any Product that the Seller sells may, upon prior notice to the Buyer from time to time be modified by Seller or substituted with a similar Product meeting the needs of the Buyer. Such modification shall not lead to any liability of the Seller, provided that the Seller ensures the substituted Product is similar to the Product initially ordered.

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4.7 The Seller does not make any warranties, express or implied, including, without limitation, those of sale ability and fitness for a particular purpose, with respect to any Products. Although the Seller shall take reasonable steps to screen Products for infection of viruses, worms, Trojan horses or other codes containing contaminating or destructive properties before making Products available, the Seller cannot guarantee that any Product will be free from infection.

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The Seller shall not be liable for any delay in performance directly or indirectly caused by or resulting from acts of nature, fire, flood, accident, riot, war, government intervention, embargoes, strikes, labour difficulties, epidemics, major health event (e.g. Corona virus), equipment failure, late deliveries by suppliers or other difficulties which are beyond the control, and not attributable to the fault of the Seller.

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- Posting any Product to any other online service (including bulletin boards or the Internet);
- Licensing, leasing, selling, offering for sale or assigning a Product or any derivative thereof.

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6.6 It is acknowledged and accepted by the Buyer that whether purchased in the form of Bundles or Annual Subscription, all unselected reports will be deemed cancelled and lost after a period of 12 month following acceptance of the corresponding order by the Seller in accordance with provisions of Article 1.3 above .

6.7 It is further acknowledged and agreed by the Buyer that any investor in the Buyer Company, any external consultant of the Buyer Company or any joint venture done with a third party in which the Buyer Company is involved , is not entitled to use a Product, without paying to the Seller the full price for a license to the required Product..

7. TERMINATION

If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be incurred by the Seller, pursuant to such cancellation or postponement.

8. MISCELLANEOUS

8.1 All the provisions of these General Terms and Conditions of Sale are for the benefit of the Seller, but also for that of its licensors, resellers and agents. Each of them is entitled to assert and enforce these provisions against the Buyer.

Any notices under these Terms and Conditions shall be given in writing and shall be effective upon receipt by the other Party.

8.2 The Seller may, from time to time, update these General Terms and Conditions of Sale, and the Buyer, shall be deemed to have accepted the latest version of such General Terms and Conditions of Sale, once they have been duly communicated to the Buyer by the Seller.

9. GOVERNING LAW AND JURISDICTION

- 9.1 Any dispute arising out or linked to these General Terms and Conditions of Sale or to any Licenses or Products purchased in application thereof shall be submitted to the French Commercial Court of Lyon, which shall have exclusive jurisdiction upon such issues.
- 9.2 French law (without reference to any applicable conflict of law provisions) shall apply to these General Terms and Conditions of sale and any agreement between the Buyer and the Seller made pursuant thereto.