Microdisplays - Market, Industry and Technology Trends 2020

Market and Technology Report 2020
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<th><strong>ACRONYMS</strong></th>
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<tbody>
<tr>
<td>AMOLED: Active Matrix OLED</td>
<td>HMD: Head mounted Device/Display</td>
<td>PPI: Pixel Per Inch</td>
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<tr>
<td>AR: Augmented Reality</td>
<td>HOE: Holographic Optical Element</td>
<td>PWM: Pulse Width Modulation</td>
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<tr>
<td>BLU: Back Lighting Unit</td>
<td>HRI: High Refractive Index</td>
<td>QD: Quantum Dot</td>
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<tr>
<td>CG: Computer Generated</td>
<td>IMU: Inertial measurement Unit</td>
<td>RMLCM: Reactive Monomer Liquid Crystal Mix</td>
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<tr>
<td>CGH: Computer Generated Holography</td>
<td>IPD: Inter Pupillary Distance</td>
<td>ROE: Reflective Optical Element</td>
<td></td>
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<tr>
<td>CMOS: Complementary Metal Oxide Semiconductor</td>
<td>LCD: Liquid Crystal Display</td>
<td>SDE: Screen door Effect</td>
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<tr>
<td>DLP: Digital Light Processing</td>
<td>LCOS: Liquid Crystal on Silicon</td>
<td>SPAD: Single Photon Avalanche Diode</td>
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<tr>
<td>DMD: Digital Micromirror Device</td>
<td>LED: (Inorganic) Light Emitting Diode</td>
<td>SRG: Surface Relief Grating</td>
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<tr>
<td>DOE: Diffractive Optical Element</td>
<td>MR: Mixed Reality</td>
<td>TFT: Thin Film Transistor</td>
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<tr>
<td>DOF: Degrees Of Freedom</td>
<td>MSLP: Manufacturer's Suggested Retail Price</td>
<td>UHD: Ultra High Definition</td>
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<tr>
<td>DSLR: Digital Single Lens Reflex</td>
<td>NIL: Nano Imprint Lithography</td>
<td>VAC: Vergence Accommodation Conflict</td>
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<tr>
<td>EVF: Electronic View Finder</td>
<td>NIR: Near InfraRed</td>
<td>VR: Virtual Reality</td>
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<tr>
<td>FOV: Field Of View</td>
<td>OEM: Original Equipment Manufacturer</td>
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Yole’s market forecast model is based on the matching of several sources:

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

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

**Preexisting information**

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**Top-to-bottom approach**
- Aggregate of market forecasts
  - @ System level

**Bottom-up approach**
- Ecosystem analysis
  - Aggregate of all players’ revenue
  - @ System level

---

**Top-to-bottom approach**
- Aggregate of market forecast
  - @ Semiconductor device level

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

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

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**Semiconductor foundry activity**
- Capacity investments and equipment needs
ABOUT THE AUTHORS
Biographies & contacts

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As a technology and market analyst for the display industry, Dr. Zine Bouhamri is a member of the Photonics, Sensing and Display division at Yole Développement. Zine manages the day-to-day production of technology and market reports, as well as custom consulting projects. He is also deeply involved in business development activities for the Displays unit at Yole.

Previously, Zine was in charge of numerous R&D programs at Aledia. In his time there he developed strong technical expertise as well as a detailed understanding of the display industry. Zine is the author and co-author of several papers and patents.

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Eric has spoken in more than 50 industry conferences over the last 10 years and has been interviewed or quoted in multiple media including: The Wall Street Journal, CNN, Fox News, CNBC, Bloomberg, Financial Review, Forbes, Technology Review, etc.

Prior to joining Yole, Eric held R&D, engineering, manufacturing and marketing positions with Fortune 500 Company Saint-Gobain in France and the United States. Eric received a PhD in Optoelectronics from the National Polytechnic Institute of Grenoble. He is based in Portland, OR.

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AN INTRODUCTION TO MICRODISPLAYS

The resurgence of microdisplays

- In the late 2000s, an interest in projectors rose, and with the nascent field of smartphones, newer projector embedded applications were demonstrated. However it never really penetrated the market much due to poor performance (brightness, contrast), battery lifetime usage and privacy concerns with the tablets getting into market providing a better alternative. And with the rise of the flat-panel industry, as the consumer became more and more accustomed to higher quality images all around her, the trend did not pick momentum. With wireless technologies development, casting remotely on a regular display is easier than ever. Though the picoprojector trend is there in emerging markets.

- In meeting rooms, classrooms and the like (e.g. cinemas), projector displays have been necessary to ensure high resolution on a very high diagonal screen for large audiences. The market has somehow stabilized today, and more and more regular flat-panel displays are eating market shares in these applications: larger TVs at low cost for meeting rooms, digital LED cinemas, etc.

- For DSLR cameras, electronic viewfinders allow for the image captured by the lens to be projected electronically onto a microdisplay, and most of them have one today. However, the DSLR market is also losing momentum, again due to more advanced smartphones being released every year. Reflex cameras are more centered around optical viewfinders.

- AR however has no credible alternative but to use microdisplays and the past five years have seen a strong effort towards microdisplay development for such applications in the consumer market.
The different kinds of spatial light modulator families that exist today

In all these families, some technologies are not used for display-related applications. Some others are not microdisplays per se. We shall focus on these related to the major identified applications.
AN INTRODUCTION TO MICRODISPLAYS

What’s new in the microdisplay world?

Investments, research and product announcements are getting more and more frequent.

January 2020
VividQ and Compound Photonics partner to deliver an integrated solution for Real 3D Holographic Display targeted at Augmented Reality devices

February 2020
Compound Photonics and Plessey light up first 0.26 inch fully addressable integrated microLED display module for AR/MR

March 2020
Facebook signs exclusive deal with Plessey

April 2020
Compound Photonics unveils world’s smallest wide field of view 1080p Optical Engine reference design for smart glasses

May 2020
Mojo Vision raises $51 million

June 2020
Kopin develops rugged 1440p ferroelectric LCOS

June 2020
Vice Minister Wang Yafu of County, Quanzhou City, signed the Huidong Industrial Park Micro OLED business

July 2020
Compound Photonics launches its IntelliPix microLED microdisplay backplane platform

July 2020
eMagin Announces a Direct Patterned OLED Microdisplay with 7,500 Nits

August 2020
LG Display shows an OLED-on-Si panel at Display Week, 4,000 nits, 3500ppi

August 2020
JBD announces the world’s smallest VGA microdisplay

August 2020
Kopin OLED microdisplay exhibits 7,000 nits

August 2020
Aledia shows the picture of a microLED microdisplay prototype, 423ppi, 122k pixels

September 2020
The new Mercedes S-Class comes with an AR HUD with TI projector

July 2020
Kopin OLED microdisplay exhibits 7,000 nits

August 2020
Vice Minister Wang Yafu of County, Quanzhou City, signed the Huidong Industrial Park Micro OLED business

February 2020
Compound Photonics and Plessey light up first 0.26 inch fully addressable integrated microLED display module for AR/MR
MICRODISPLAYS – MARKET FORECASTS

End-systems where microdisplays have a play

The TAM is driven by two growing applications: AR headsets and Auto HUDs.
MICRODISPLAYS – MARKET FORECASTS

End-systems where microdisplays have a play

Legacy applications with limited growth and for which microdisplays deliver what is required but no more.

Emerging applications with great growth potential, that require advancements in microdisplays. Pending their development success, this could lead to high business potential.

Complete module prices are considered, not chips only.
End-systems where microdisplays have a play

Microdisplays market value for AR headsets could represent as much as incumbent technologies market value.

Complete module prices are considered, not chips only.
AR headsets and Auto HUDs are creating a new momentum for microdisplays markets.

<table>
<thead>
<tr>
<th>Incumbent applications</th>
<th>AR headsets</th>
<th>Auto HUDs</th>
<th>Others</th>
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<tr>
<td>2020e</td>
<td>$1.9B</td>
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<td>2025e</td>
<td>$4.2B</td>
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</tbody>
</table>

- **AR headsets**: $1.8B, CAGR 2020-2025: +110%
- **Auto HUDs**: $242M, CAGR 2020-2025: +110%
- **Others**: $285M, CAGR 2020-2025: +48%

Complete module prices are considered, not chips only.
MICRODISPLAY MARKET TRENDS

Microdisplays as spatial light modulators – a market segmentation

The consumer market is the one where most anticipation is coming from.
MICRODISPLAY MARKET TRENDS

Technology requirements per application

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**TOTAL** 25 22 21 17 21

Technology requirements are somehow similar, but some critical elements of differentiation exist among them.
MICRODISPLAY MARKET TRENDS

Technology of choice per application? AR headsets

The best technology is not necessarily the most adapted as the application requirements vary from one to the other.

AR headsets

Most technologies cannot handle the brightness level requirements. MicroLEDs could deliver on everything but for their lack of reliability/availability and cost, they are a no go at the moment.

They are at the pinnacle of the AR consumer electronics revolution. For now, the trade-off is on XXX.

Status quo

XXX is preferred for their lower cost as the target is the consumer market.
MICRODISPLAY MARKET TRENDS

Technology of choice per application? Auto HUDs

The best technology is not necessarily the most adapted as the application requirements vary from one to the other.

Auto HUDs

Most technologies cannot handle the brightness level requirements. MicroLEDs could deliver on everything but for their lack of reliability/availability and cost, they are a no go at the moment.

They are not blocking HUDs today though as optics are the main blocking element. For now, the trade-off is on XXX.

Status quo

XXX is preferred for their better temperature range.
### Microdisplay Market Trends

Technology of choice per application? 3D displays

The best technology is not necessarily the most adapted as the application requirements vary from one to the other.

<table>
<thead>
<tr>
<th>3D Displays</th>
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<tbody>
<tr>
<td>Most technologies cannot handle the pixel size requirements. MicroLEDs could deliver on everything but for their lack of reliability/availability and cost, they are a no go at the moment.</td>
</tr>
<tr>
<td>True real computer-generated holography requires very small pixels with phase modulation. For now, the trade-off is on XXX.</td>
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</tbody>
</table>

**Status quo**

This is a very emerging market and for true holography, phase modulating SLMs are preferred, so mostly XXX.
Focus on AR headsets – The consumer needs?

- The use cases for professionals are clearly defined and have been known for years now: logistics, safety, repair, training, treatment, education, etc.
- However, there is huge uncertainty on the consumer use case: why would someone put something on their head? What value can it bring them? Gaming? Tourism? Something more compelling?
MICRODISPLAYS MARKET TRENDS

Focus on AR headsets – Apple getting in the game?

Back in the day, Apple created the smartwatch as an accessory to the iPhone. The idea was to “create a device that you couldn’t use for hours at a time the same way you could an iPhone — a device that filters out all the irrelevant information and feeds you only what’s important” (David Pearce, Wired).

A bit like the smartwatch, we expect that the market will remain slow until a major player like Apple joins the game with a decent value proposition, which will allow for the market to soar from the consumer’s point of view.

Form factor and performance can be expected as it is the whole part of the company culture.

Apple’s CEO Tim Cook mentioned in an interview with The Independent in late 2017: “Today I can tell you the technology itself doesn’t exist to do that in a quality way. The display technology required, as well as putting enough stuff around your face – there’s huge challenges with that. [...] The field of view, the quality of the display itself, it’s not there yet.” What we do know though, is they are working on several aspects that would help for an AR headset.

Of course, the other big consumer OEMs, such as Huawei and Samsung, are for sure also intensively working towards AR. Though their strategies are bit blurry we can definitely expect them to get in the game around the same time, in full force.
MICRODISPLAYS MARKET TRENDS

Focus on AR headsets – Smartwatch history repeating itself

The smartwatch market started when there was a value proposition that was not extremely compelling: the use case was so much so that after a few minutes of this new “experience” one had almost explored all the possibilities.

We believe for the AR market to soar through consumer adoption that this conjunction of both technology development and functionality development, the latter being somewhat enabled by the former, shall bring it all.

To do so, we expect the number of collaborations between industry partners to increase. This has already started. However we believe that what is missing is having more advanced collaborations between technology developers and end-system designers, OEMs.
MICRODISPLAYS MARKET TRENDS
Focus on Auto HUDs – Automotive development trends, the C.A.S.E. acronym

Following these trends, it is not surprising to see top Tier-1s developing sensors to fulfil the autonomous goal.

Autonomous
Sensor suite and computing developments for safer roads.

Shared
Owning, sharing, or renting, the mobility of the future offers greater flexibility.

Connectivity
Comfort, safety and entertainment in a new dimension.

Electric
Alternative drive systems to reduce CO₂ emissions.

Most OEMs and Tier-1s are following this acronym to drive their developments.

Source: Daimler
Focus on Auto HUDs – More displays and more safety?

Displays require attention and though there is an increase in HMI development to avoid having to look at the screens directly, or to avoid controlling everything with touch, there is a dichotomy with the idea of having more safety.

On the road towards increasing safety while increasing autonomy, we are not at a level where “eyes off the road” can be done. However there is more and more information to manage during day-to-day driving, be it driving related or infotainment related more generally.

This conundrum led to the need for an increased demand for HUDs. It allows for keeping the eyes on the road while accessing data.
ECOSYSTEM ANALYSIS

One wafer to rule them all?

Whichever the kind of technology used, in terms of frontplane terminology (OLED, microLED, LCOS, DLP), there will always be the need for a driving solution, symbolized by the use of a CMOS backplane. Indeed using TFTs like in traditional displays is not possible given the typical size of a microdisplay.
ECOSYSTEM ANALYSIS

A strategic path towards frontplane agnosticism

CP Display which is now providing the smallest available pixel size on microdisplays (3µm) initially for LCOS displays, developed their driving technology and adapted it to be compatible with microLED displays. And they aim at providing a solution for phase-modulated LCOS, that would allow for enhanced computer-generated holography.

Some players try to sell their long-developed backplane technology for a given frontplane to the emerging hyped-up microLED.

A potential strategic move from OLED-on-Si makers, be they module or backplane manufacturers, as they do not have lots of traction for the future of AR nor the future of automotive and holography… would be to try and partner with microLED microdisplay companies to share their driving technology know-how and sell their solutions to capitalize on their long-acquired experience in the field of microdisplays.
MICRODISPLAYS – TECHNOLOGY

Competition benchmarking, SWOT by technology
To each technology its challenge to address the emerging applications we have been considering so far.

If we list all the challenges that come with each technology, we can notice a pattern:

- some common issues that can all be linked to the driving backplane;
- some specific issues for which each technology has a forte.

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<tr>
<th>ISSUE</th>
<th>CONCERN</th>
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<td>Backplane and frontplane specific</td>
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<tr>
<td>Frontplane specific</td>
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YOLE GROUP OF COMPANIES RELATED REPORTS

Yole Développement

Displays and optics for AR & VR 2020

Next Generation 3D Displays 2019

MicroLED Displays – Intellectual Property Status & Landscape 2020

Status of the MEMS Industry 2020
Magic Leap One – Augmented Reality Headset
Yole Group of Companies, including Yole Développement, System Plus Consulting and PISEO, are pleased to provide you a glimpse of our accumulated knowledge.

We invite you to share our data with your own network, within your presentations, press releases, dedicated articles and more, but you first need approval from Yole Public Relations department.

If you are interested, feel free to contact us right now!

We will also be more than happy to give you updated data and appropriate formats.

Your contact: Sandrine Leroy, Dir. Public Relations
Email: leroy@yole.fr