2022 Micro-display Technology Report

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Senior Analyst
Tetsuo Urabe

Chief Analyst
Dr. Choong Hoon YI

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2.2 Near-Eye Display Product

- Google Glass was discontinued in 2015, but was later reoriented as Enterprise Edition for professional use. The demand for this business use is huge, and many manufacturers have entered the market since then. One example is shown below.
- There are three types: wearable display, where the user looks through a small display, AR (Augmented Reality), where the image is superimposed on the outside world, and XR (Mixed Reality), where the superimposed image matches the coordinate system of the outside world. In AR and XR, the waveguide method is the mainstream.

VUFINE
540 x 960(QHD) LCoS full color

Vuzix M400 Smart Glass
Full color 640 x 360 micro-OLED

Wearable display

EPSON MOVERIO BT-300
micro-OLED 1,280 x 720

Sony Smart Eyeglass SED-E1
Green mono color, 1,000cd/m^2
Green LED light source + LCoS

Waveguide

AR

Microsoft HoloLens
LCoS Field Sequential Color
0.37” 1,366 x 768

Waveguide

Magic Leap one
LCoS Field Sequential Color
0.28” 1,280 x 960

Waveguide

MR

2.3 Optical system of Near-Eye Display

2.3.3 Waveguide Type Optical system

- Holographic Optical Element (HOE) can be designed to extract only a single diffraction mode while minimizing light scattering, thus providing higher diffraction efficiency and higher transparency for see-through. Although mass production of HOEs has been a challenge, Luminit established mass production technology for HOEs in 2017.
- The production of HOE is carried out by Mastering and Replication. （In Mastering, an interference pattern of two laser beams is irradiated onto a photosensitive material, and the pattern is recorded as a volume hologram. In Mastering, it is essential to minimize vibration as much as possible.

- Replication is made by overlapping the master and replica photosensitive materials and irradiating them as shown in Figure 1.
- DigiLens then enabled mass production of Reactive Monomer Liquid Crystal Mix (RMLCM), a material with high refractive index modulation.
- The refractive index modulation width of RMLCM is 0.16, which is six times larger than conventional materials. This is made with a thickness of 2 μm.
- The mass production method is to make a waveguide, inkjet print RMLCM on the waveguide, and then expose the waveguide to laser light, which causes phase separation of LC and monomer along the interference pattern of laser light.
- In the future, DigiLens aims to lower the production cost and pave the way for consumer use.

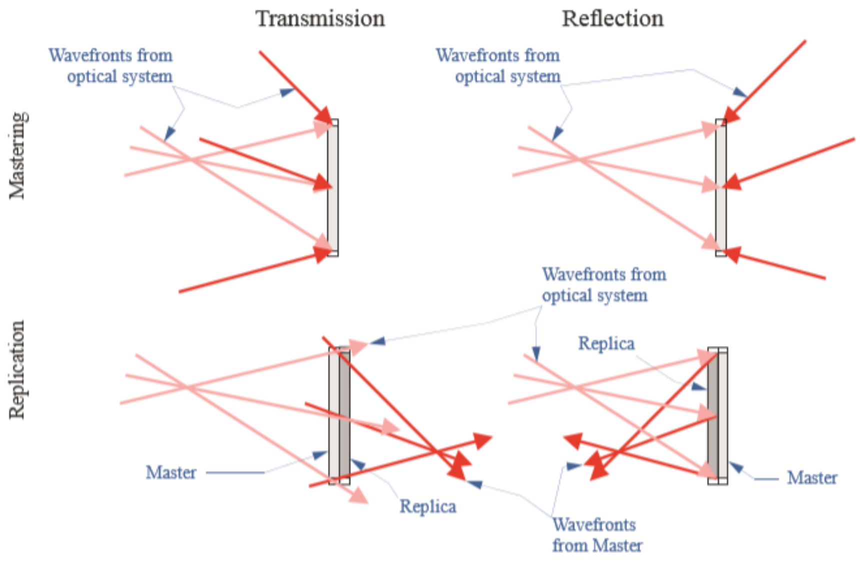


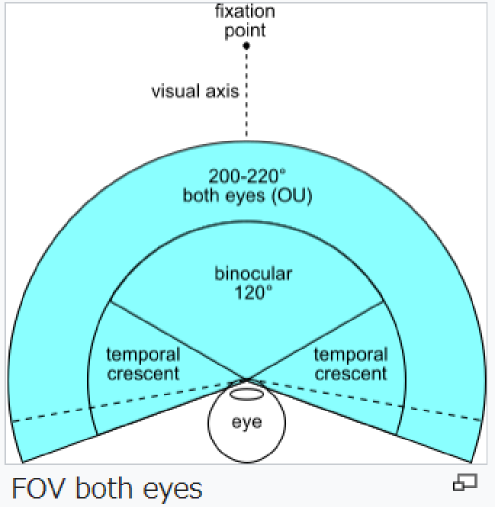
Figure 1

3.1 What is required of VR equipment

3.1.1 wide FOV

- The FOV of the human eye is said to be ~220° horizontally for both eyes and ~130° vertically, as shown in the figure below. Therefore, the display of a VR device should ideally have an FOV equivalent to this.
- However, not all of this FOV has the same resolution or color discrimination, and as shown in Figure 2, for example, the resolution required to distinguish text is limited to 5-10° of the center of the field of view. Therefore, it is important to consider the characteristics of the human eye when designing a display. 。

Horizontal FOV ～220° (for both eyes)



Vertical FOV ～130°

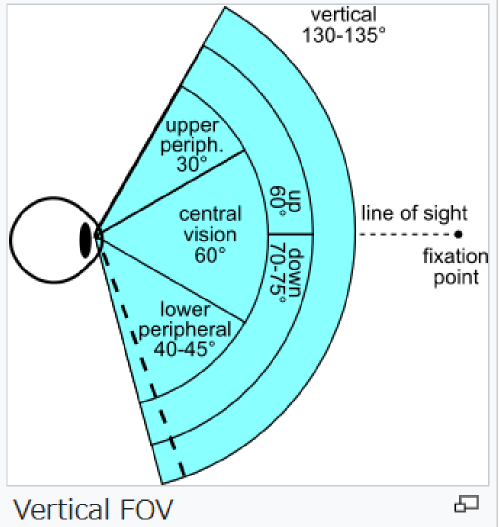


Figure 1

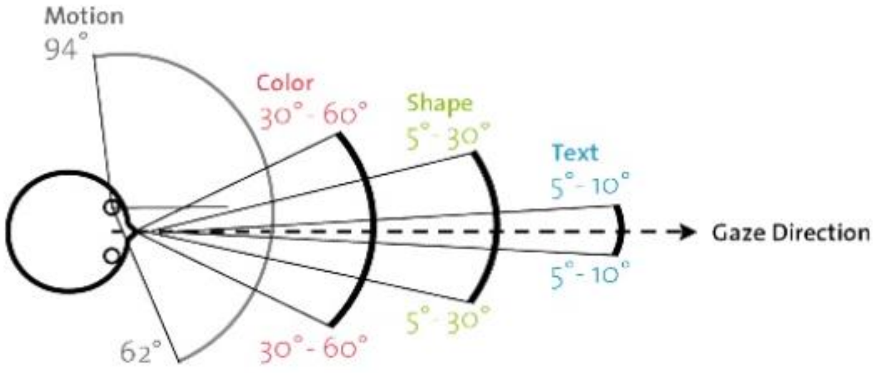
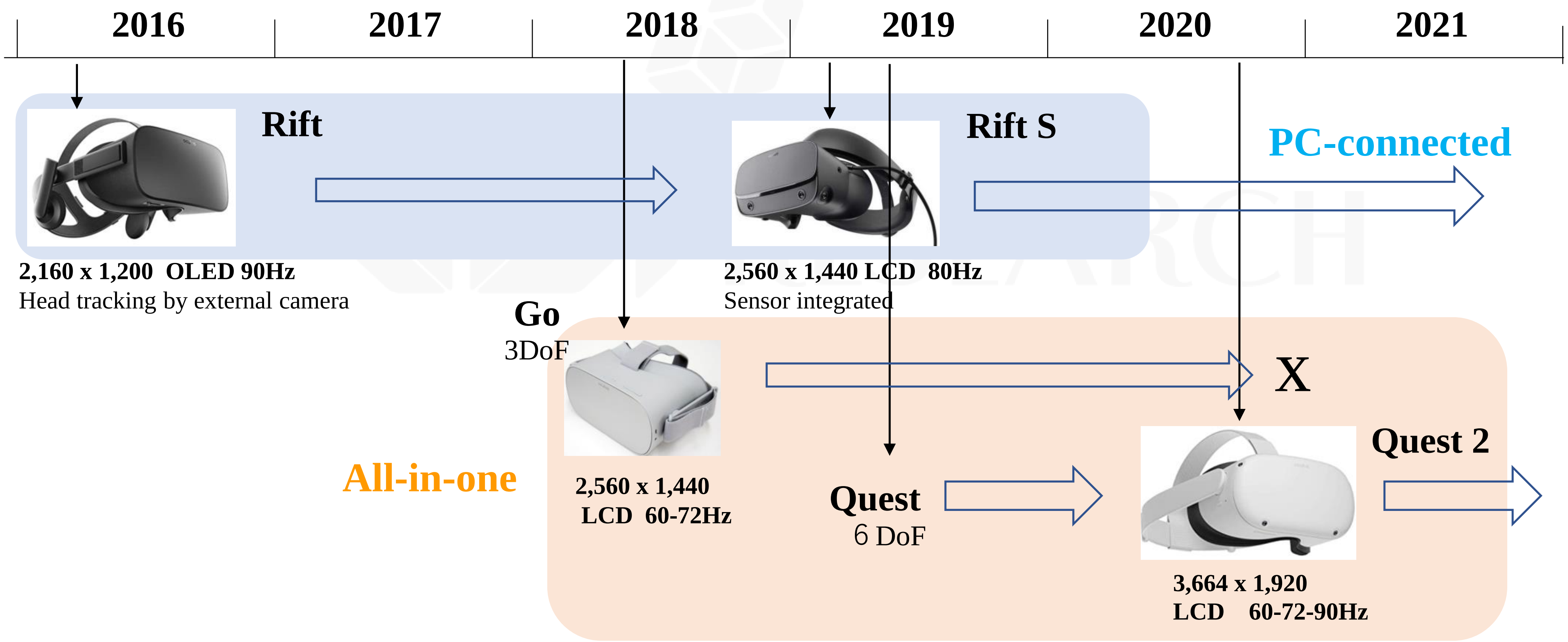


Figure 2

3.2 Commercialized VR equipment

3.2.2 Oculus

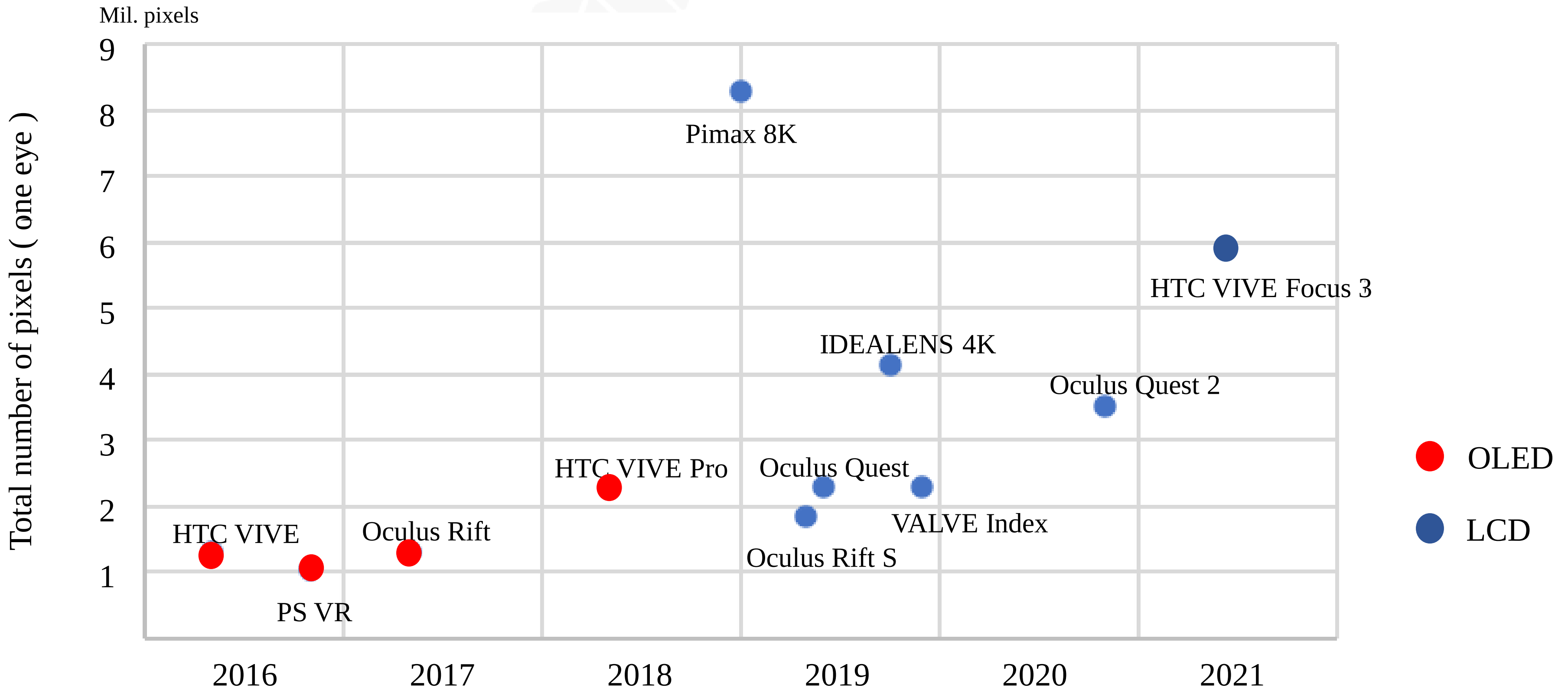
- - Oculus, a subsidiary of Facebook, initially used OLED as its display, but in recent years, it has been using LCDs in favor of higher resolution.
- - The latest Oculus Quest 2 (now Meta Quest 2) achieves a high resolution of 1,832 x 1,920 per eye.



3.2 Commercialized VR equipment

3.2.5 Display resolution of VR products

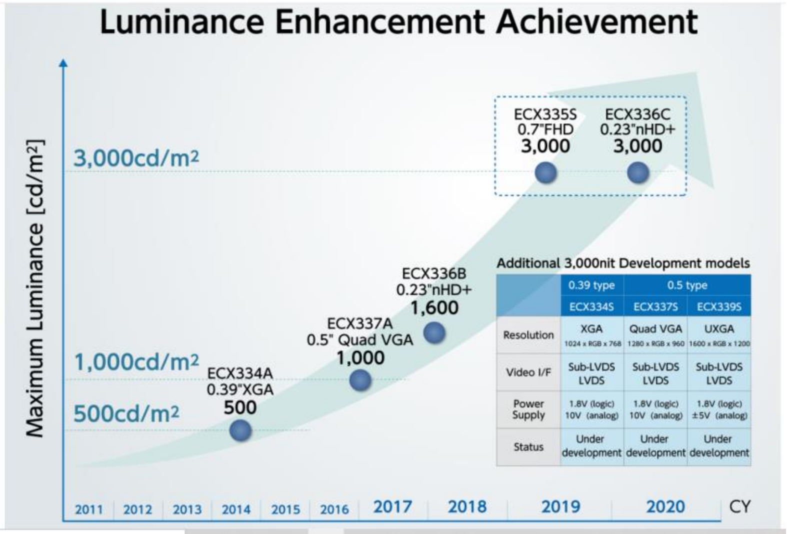
- The figure below shows the total pixel count of displays used in VR products. As the total number of pixels increases, OLEDs are being replaced by LCDs, which are relatively easy to upgrade to higher resolutions. The adoption of Micro OLED, which is still in the prototype stage, may indicate one of the possibilities for the future direction.



4.1 Status of Micro-OLED Business

4.1.3 Sony

- Sony is known for launching the world's first 11" OLED TV in 2008, and commercialized Micro-OLED in 2011 using the same technology. In 2018, the company plans to launch a 0.5-megapixel OLED.
- In 2018, the company developed a 0.5-inch UXGA (1,600 x 1,200) high-definition μOLED. This had a pixel pitch of 6.3μ and a high resolution of 4,032 ppi.
- In 2019, the brightness was greatly improved by integrating a Micro Lens Array, as described below.
- Sony has been increasing the brightness of its products as shown in the figure on the right.
- In 2020, Sony will apply this technology to a projector, and has developed the world's smallest projector with an ultra-high brightness of 1,000,000 nits, even though it is monochromatic green.
- Sony's current Micro-OLED product lineup is summarized in the table below.



	ECX336B	ECX336C	ECX334A	ECX334C	ECX337A	ECX339A	ECX335B	ECX333S
Pixel size	0.23”	0.23”	0.39”	0.39”	0.5”	0.5”	0.7”	0.7”
Pixel number	640 x 400	640 x 400	1024 x 768	1024 x 768	1280 x 960	1600 x 1200	1920 x 1080	1920 x 1080
Pixel pitch	7.3um	7.3um	7.7um	7.7um	7.9um	6.35um	8.07um	8.07um
Max. brightness	1,600cd/m^2	3,000cd/m^2	500cd/m^2	1,000cd/m^2	1,000cd/m^2	1,000cd/m^2	500cd/m^2	3,000cd/m^2
Contrast ratio	100,000 : 1	100,000 : 1	100,000 : 1	100,000 : 1	100,000 : 1	100,000 : 1	100,000 : 1	100,000 : 1
Interface	RGB 24bit	RGB 24bit	RGB 24bit	LDVS	LDVS	LDVS	LDVS	LDVS
Status	In production	To be produced	In production	In production	In production	In production	In production	In production

5.1 Hybridization of Monolithic Micro-LED and Driver Chip

- The full-color monolithic micro-LEDs being developed by Sharp are as follows.
- The fabrication process of the device is shown in the figure below. GaN micro-LED arrays formed on a sapphire substrate are bonded together by Au-Au press bonding, and the pixels are filled with carbon black resin to prevent cross talk.
- Next, a partition wall is installed to prevent cross talk between pixels, and Green and Red QDs for color conversion are formed by the photolithography process.
- The prototype panel was 0.38" 325 x 198 (pixel pitch: 1,053 ppi) with a luminance of 1,000cd/m^2. (Photo below)