GREATER CHINA TECHNOLOGY

CES 2017: Augmented reality (AR) pervades

CES 2017 provided a showcase for an increasingly technology-driven future, which includes everything from Artificial Intelligence (AI) devices and robots to self-driving cars. A few of the trends in the spotlight at CES are already attracting considerable public attention: 1) smart homes; 2) voice assistants and IoT platforms; and 3) self-driving and electric cars. During the exhibition, AR/VR was repeatedly highlighted as one of the best and latest developing technologies. We see increasing designs/solutions being built around VR/AR applications.

In our view, VR/AR will become an integral part of key devices around home entertainment, auto, or even AI applications. Continuing the themes laid out in our two previous reports with regard to VR/AR, namely *Will VR finally take off in 2016?*, dated 9 January 2016, and *From virtual to reality*, dated 2 August 2016, we discuss the latest developments, in particular in the AR industry, as we expect to see continuous development and opportunities in this area.

By taking a closer look at AR devices like HoloLens, we note that display accounts for about 50% of its cost, and few display technologies are currently available (such as LCoS and DLP projection technology) to create the necessary near-field 3D image. Processor unit chips also play an important role as they affect the response time, graphic performance, power assumption, data transmission, etc. We also expect the myriad new applications around AR to benefit sensor and camera module makers. For instance, there are six cameras and environmental sensors in HoloLens. Lenovo and Asustek's Tango AR-enabled phones both have additional cameras for motion detection. As motion tracking, area learning and depth perception are critical for AR applications, we see more opportunities in the longer term for sensor, camera and IC component makers in the hardware supply chain.

We believe universal platforms and ecosystems, including content and distribution, are required to drive successful and sustainable proliferation. Also, device costs need to come down to USD300 or below. We expect to see the technology/products mature over the next two years, and believe the ecosystem creator as well as key component suppliers will have the most control, rather than pure device makers.

Among our coverage of Greater China semiconductor and hardware companies, we remain positive on TSMC and Sunny Optical, thanks to their leading technology in chip manufacture and cameras, respectively. In the AR arena, we believe processing technology and camera applications will be critical.

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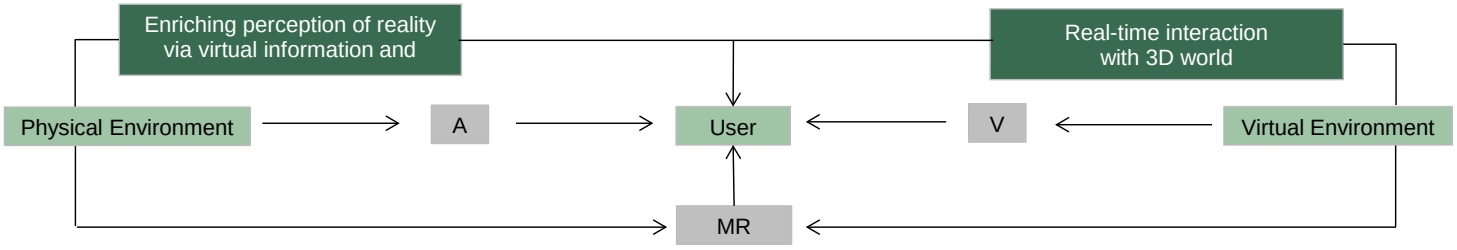
The pervasion of augmented reality (AR) after virtual reality (VR)

CES 2017 provided a showcase for an increasingly technology-driven future, which includes everything from Artificial Intelligence (AI) devices and robots to self-driving cars. A few of the trends in the spotlight at CES are already attracting considerable public attention: 1) smart homes; 2) voice assistants and IoT platforms; and 3) self-driving and electric cars. During the exhibition, AR/VR were repeatedly highlighted as one of the best and latest developing technologies. The Consumer Technology Association (CTA) boasts that CES 2017 was the biggest showcasing of gaming and AR/VR technology in its history. According to CTA officials, users seeking to gain the 3D gaming experience would focus on the gaming quality that can be achieved. HTC and Microsoft both attended, with HTC unveiling a new version of its Vive VR headset and Microsoft offering an update on its HoloLens augmented reality headset as well its next video game console, Project Scorpio, and its VR capabilities.

In our view, VR/AR will become an integral part of key devices around home entertainment, auto or even AI applications. Continuing the themes laid out in our two previous reports with regard to VR/AR, namely *Will VR finally take off in 2016?*, dated 9 January 2016, and *From virtual to reality*, dated 2 August 2016, we discuss the latest developments, in particular in the AR industry, as we expect to see continuous development and opportunities in this area. Still, we believe universal platforms and ecosystems, including content and distribution, are required to drive successful and sustainable proliferation.

AR embellishes the perception of reality through modification by a computer device, rather than creating a new reality. AR uses computerised overlays to add information to the real world. It therefore has a wide range of applications outdoors, in factories and in vehicles, etc, via various electronic devices such as projectors, smartphone headsets, and glasses.

Exhibit 1: VR, AR and MR



Source: BNP Paribas

We see AR being applicable to a broad range of markets, such as live events, video entertainment, retail, real estate, education, healthcare, engineering, and military. There has been some hype surrounding VR/AR since last year, and public attention to this theme continues to increase. We believe the proliferation of AR will come about through both consumer and enterprise demand.

Exhibit 2: Microsoft's HoloLens

Source: Microsoft

Microsoft HoloLens- entering mass market from 2018

Microsoft did not show its HoloLens prototype during CES, and neither did we see its major AR rival, Magic Leap. However, Microsoft announced that is teaming up with a number of PC makers such as Dell, Acer, HP, Lenovo and 3Glasses, and will release PC makers' own headsets based on HoloLens technology in the coming months.

While the proposed price of these headsets is lower than that of HoloLens (USD299 VS USD3,000), these headsets require a computer to function. Computers compatible with these headsets must have a spec that includes 1) at least Intel Core i5, 2) 8GB of memory, 3) Intel HD Graphics 620 (or other DirectX 12 compatible graphics cards), 4) USB 3.0, and 5) HDMI/DisplayPort. It is also necessary to have a resolution of 2880 x 1440 with a 90Hz fps.

We think it is unlikely that these headsets will provide a similar experience to Microsoft HoloLens, given their less advanced hardware specs; while they are all based on HoloLens technology and use the same software, the hardware specs are likely to be key differential factors in determining users' experience, resulting in uncertain market demand.

What's inside the device?

Per Microsoft's previous announcement back in 2016, HoloLens includes a full set of sensors, from an accelerometer and gyroscope to a magnetometer and other sensors that detect the external environment, on top of three different computing units, namely CPU, GPU and HPU (holographic processing unit).

Moreover, there is an inertial measurement unit (IMU) embedded in the HoloLens, which includes an accelerometer, gyroscope and magnetometer, with an energy-efficient depth camera of a 120°×120° angle of view. According to Microsoft, HoloLens also has a 2.4-megapixel photographic video camera, a four-microphone array, and an ambient light sensor. While using an Intel Cheery Trail SoC, containing the CPU and GPU, HoloLens also features a custom-made Microsoft Holographic Processing Unit (HPU), which is a coprocessor manufactured specifically for the HoloLens by Microsoft.

The SoC and HPU each have 1GB LPDDR3 and share 8MB SRAM, with the SoC also controlling 64GB eMMC and running the Windows 10 operating system, whereas the HPU uses 28 custom DSPs from Tensilica to process and integrate data from the sensors, as well as handle tasks such as spatial mapping, gesture recognition, and voice and speech recognition, which is deemed to be terabytes of information from the HoloLens's sensors of real-time data.

More importantly, HoloLens has adopted two LCOS (Liquid crystal on silicon), which is widely recognised as the technology of choice for microdisplay in AR devices. A LCOS is a reflective microdisplay technology based on a silicon backplane. The electronic circuits controlling the liquid crystals are fabricated on a silicon chip, which is coated with a highly reflective surface resulting in very high image quality, because the circuitry is behind the pixel and does not create an obstruction in the light path.

In terms of display, it is basically a set of transparent holographic lenses. Each screen allows light through and also shows digital content the way a traditional monitor does. Each screen shows a slightly different image to create a stereoscopic illusion, like 3D glasses do at 3D movies. A depth-sensing camera works together with two environmental sensing cameras on either side of the device. It is used to capture the world around the user and help HoloLens understand the physical environment.

Exhibit 3: The HoloLens Development Edition

	----------The HoloLens Development Edition----------
Developer	Microsoft
Manufacturer	Microsoft
OS	Windows Holographic
HPU	Holographic Processing; manufactured by TSMC 16nm technology
CPU	Intel 32-bit (1GHz)
Input	Inertial measurement unit (Accelerometer, gyroscope, and magnetometer)
	4 x sensors
	120°×120° depth camera
Memory	2GB RAM / 1GB HPU RAM
Storage	64GB (flash memory)
Display	2.3 megapixel widescreen stereoscopic head-mounted display
Camera	2.4 MP
Sound	Spatial sound technology
Controller input	Gestural commands via sensors and HPU
Connectivity	IEEE 802.11ac, Bluetooth 4.1, LE
Price	USD 3,000
Released date	30 March 2016 for Development Edition

Source: Microsoft

Competition from Magic Leap in the AR space

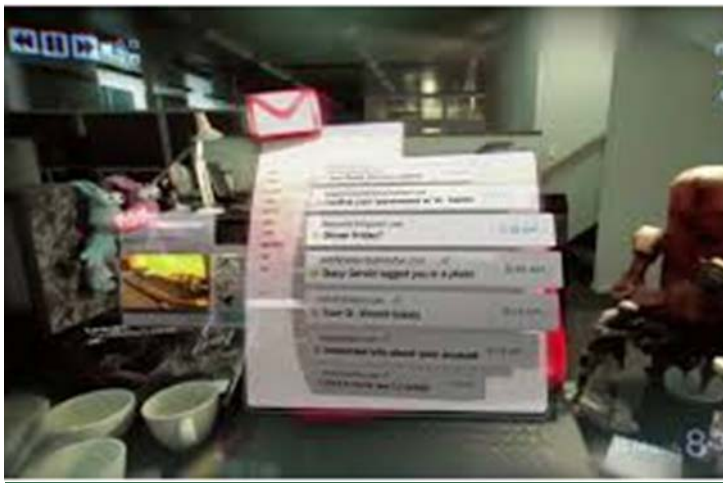
Magic Leap is a start-up company currently working on AR technology that uses an optical head-mounted display to project virtual images onto the real world. While most of the technologies owned by Magic Leap are secret, according to MIT Technology Review the signature technology that sets it apart from peers is called Dynamic Digitized Lightfield Signal™. The MIT article suggests this technology is able to generate images indistinguishable from real objects, which can then be placed seamlessly into the real world.

Unlike traditional projectors that fire the light at a surface, which bounces it back into the human eye, Dynamic Digitized Lightfield Signal™ projects images directly into the human eye so it hits the retina. More interesting, Magic Leap claims that it is also using light field technology to reverse engineer what users see in real life and make it virtual. Although the technology is still being developed, there is a possibility that virtual objects can be achieved with different levels of focus. Generally speaking, a lightfield image contains not only the colours and intensity of the incoming ray but also the direction, which is presumed to be a static lightfield. With suitable optical microlenses, it is able to refocus the saved ray information with the depth perception of the scene in 3D view. In this way, Dynamic Digitized Lightfield Signal™ is an attempt to create a 3D micro-display.

Exhibit 4: Magic Leap's application-example 1

Source: magic-leap.reality.news

Exhibit 5: Magic Leap's application-example - 2



Source: venturebeat

Exhibit 6: Magic Leap's application-example - 3

Source: infinityleap

Exhibit 7: Magic Leap's application-example - 4

Source: opticsgamer

Magic Leap says it will focus on hyperpersonal computing, applicable to gaming, entertainment and communication with its initial apps and experience, and then branch off into other areas of business use, if any. However, to reach the same level of proliferation as smartphones and PCs, or even become an alternative for them, Magic Leap AR is likely to need a ground-breaking method of input and accommodating software to make it viable.

To enable its low-latency realistic visual effects, one can assume Magic Leap may need to build its own operating system with a heavy focus on real-time operation. Magic Leap's factory is already being set up in South Florida and the company has secured a number of investors, such as Google, Qualcomm Ventures, Legendary Entertainment, private equity firms KKR, Obvious Ventures, and Vulcan Capital, and venture capital firms Kleiner Perkins Caufield & Byers and Andreessen Horowitz, as has been widely reported.

Exhibit 8: About Magic Leap

---------- Company Background ----------		
Headquarters	Dania Beach, FL	
	Name	**Background**
Founder	Rony Abovitz	Prior to Magic Leap, Abovitz co-founded MAKO Surgical Corp., a company manufacturing surgical robotic arm assistance platforms. He attended the University of Miami, where he obtained a master's degree in biomedical engineering.
	Name	**Background**
Key People	Richard Taylor	The founder, Creative Director and head of New Zealand film prop and special effects company Weta Workshop. He will be working on projects relating to augmented reality and computer vision.
	Graeme Devine	A computer game designer and programmer who co-founded Trilobyte and was also Chairman of the International Game Developers Association (IGDA) from 2002 to 2003. He is the Chief Creative Officer & Senior VP Games, Apps and Creative Experiences of Magic Leap.
	Sundar Pichai	The chief executive officer (CEO) of Google Inc., and formerly the senior vice president (SVP) of products at Google. He is a board member of Magic Leap.
	Rio Caraeff	A former Vevo CEO. He will be tasked with the development, operations and business management of Magic Leap's cloud-based ecosystem and media network.

---------- Recent Fundraising History ----------		
Time	**Amount (USD m)**	**Investors**
Feb-14	50	-
Oct-14	542	Google VC, KPCB Holdings, Qualcomm Ventures, Legendary Entertainment, Andreessen Horowitz, Kleiner Perkins Caufield & Byers
Feb-16	794	Alibaba, Fidelity, Google, JP Morgan, Morgan Stanley, Qualcomm Ventures, T. Rowe Price, Time Warner, Wellington Partners

Sources: BNP Paribas; hupogu.com; Forbes

Major technology companies in AR - Apple, Facebook and Google

While the underlying technologies required to drive AR's proliferation are yet to mature, companies such as Apple, Google and Facebook are establishing a presence in this area. For example, Apple says it is working on AR/VR that could be incorporated into future iOS devices to enhance iOS functionality, and for automotive applications like 3D maps and driver assists/infotainment. Yet, Apple has also made a few key acquisitions in the AR/VR field, including purchasing Emotient, a company that builds tools for facial expression analysis, and Flyby Media in 2016. In addition, Apple bought motion capture specialist Faceshift and German AR firm Metaio in 2015, as well as PrimeSense in 2013. According to Appleinsider.com, Apple currently possesses a number of patents relating to augmented reality applications. The patents mainly covered display technologies, such as transparent displays, mapping solutions and iPhone-powered virtual displays.

Facebook, on the other hand, has confirmed that it also focuses on research and testing lightweight versions of AR technology, particularly in mobile apps such as MSQRD. MSQRD is an app that Facebook bought in March 2016 that allows users to add animated filters to videos, while the app also integrated with features such as face swapping and filters.

Following its Daydream VR platform and first AR tango phone with Lenovo, Google has teamed up with device makers Lenovo and Asustek on its Tango AR applications.

The AR Tango phone from Lenovo and Asustek

Tango is Google's AR technology for smart devices that relies on a multi-camera and multi-sensor setup to detect three-dimensional depth and motion, and digitally maps space and identifies locations to create virtual interactivity for users. Google's Tango SDK supports users to develop more creative applications to enrich the entire Tango ecosystem. Current applications for Tango technology include facilitating navigation and interactivity through a designated place, such as a museum, and other commercial usage like interior design.

In 9 June 2016, Lenovo revealed its latest smartphone, PHAB2 Pro, the first smartphone with globally embedded Tango AR technology, during its Lenovo Tech World conference. PHAB2 Pro is the first generation of commercial Project Tango

smartphones and uses the third generation of Project Tango technology. At the same time, Project Tango was renamed as simply Tango.

Exhibit 9: Lenovo Phab 2 Pro vs Asus ZenFone AR

Product	Lenovo Phab 2 Pro	Asus ZenFone AR
Display	6.4'	5.7" (Super AMOLED)
Resolution	1440 x 2560	1440 x 2560
Processor	Qualcomm Snapdragon 652 (MSM8976)	Qualcomm Snapdragon 821 (MSM8996 Pro)
CPU	Quad-core 1.4 GHz Cortex-A53 & Quad-core 1.8 GHz Cortex-A72	Quad-core, 2150 MHz, Kryo, 64-bit
GPU	Adreno 510	Adreno 530
RAM	4GB	8GB
Storage	64GB	256GB
Battery capacity	4050mAh	3300mAh
Rear Camera	16mpx	23mpx
Front Camera	8mpx	8mpx
Others features	microSD expandable storage up to 256GB; Compass/ Magnetometer; Proximity sensor; Accelerometer; Ambient light sensor; Gyroscope; Barometer	Dual-camera, Optical image stabilization, Time-lapse video, microSDXC up to 2000 GB, LTE-A Cat 11, Accelerometer, Gyroscope, Compass, Hall, Barometer
OS	Android 6.0	Android (7.0), ASUS Zen 3.0 UI

Sources: Lenovo; Asustek

The PHAB2 Pro devices feature a 6.4-inch Quad HD (2K) screen with a resolution of 2560 x 1440 and IPS LCD Assertive Display. Around the edges, the frame is aluminium alloy unibody, and in the front there is 2.5D reinforced curved glass. The PHAB2 Pro also has a 4050mAh battery with the ability to use Qualcomm's Fast Charge technology; standby time per Lenovo is over 13 days, and talk time is 18 hours. A front-facing 8-MP fixed-focus camera is included with 1.4µm Big Pixel technology and an F2.2 aperture. The device's SoC is powered by Qualcomm Snapdragon 652 Processor built for Tango, with 4GB of RAM.

During CES 2017, Asustek unveiled its AR smartphone – Asus ZenFone AR. Notably, this is the first AR smartphone to be compatible with both Tango and Daydream, and by integrating two different platforms in one device. In terms of hardware, Asus ZenFone AR packs in a Snapdragon 821 processor and 8GB of RAM, a powerful SoC that is designed to deliver supreme AR and VR experience. One of the key features of Asus ZenFone AR is that it adopts a Super AMOLED QHD (2560×1440) pixels resolution within a 5.7-inch screen, enhancing the experience when viewing content in virtual reality. Given its Google Tango-ready feature, the main camera embedded in the Asus ZenFone AR is a 23MP Sony IMX 318 sensor with OIS and 4K video recording support, while there are another two cameras for motion-tracking and depth sensing.

The implementation of Tango technology allows a device to use motion tracking, depth perception, and area learning to know not only what it can see, but where it is in 3D space at any given time. Given the limited content, we think it will be mostly used for commercial applications in the near term, while we may see volume pick up when more device makers join the programme as more content is introduced by Google.

Key technology and components

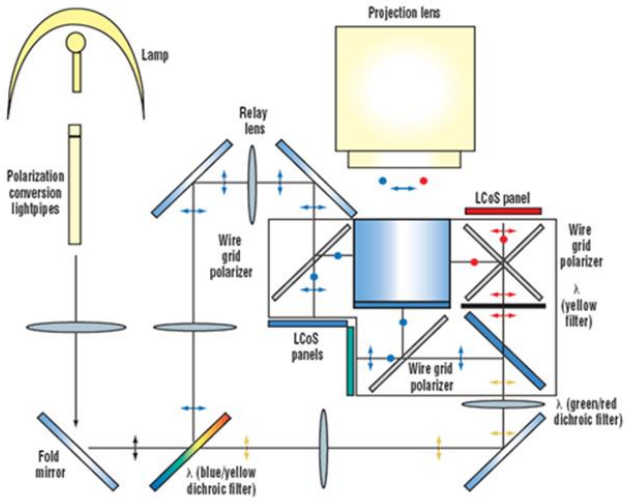
Display is the most expensive part

From a HoloLens teardown analysis by The Verge, we note that display accounts for about 50% of its cost, and few display technologies are currently available (such as LCoS and DLP projection technology) to create the necessary near-field 3D image.

Generally speaking, LCoS is a one of the latest technologies for "microdisplay". It uses a liquid crystal layer on top of a silicon backplane. By using standard CMOS processes, microdisplays with extremely small pixels, a high pixel aperture ratio, and lower manufacturing costs can be realised and have several advantages over other display technologies where high performance is required. These advantages include 1) ultra-high brightness, 2) high efficiency, 3) heating efficiency, 4) a high quality film-like image, 5) being highly scalable and able to create very small pixels, as well as suited for laser projection, and 6) being able to modulate amplitude, polarisation and phase, opening up possibilities other displays cannot achieve.

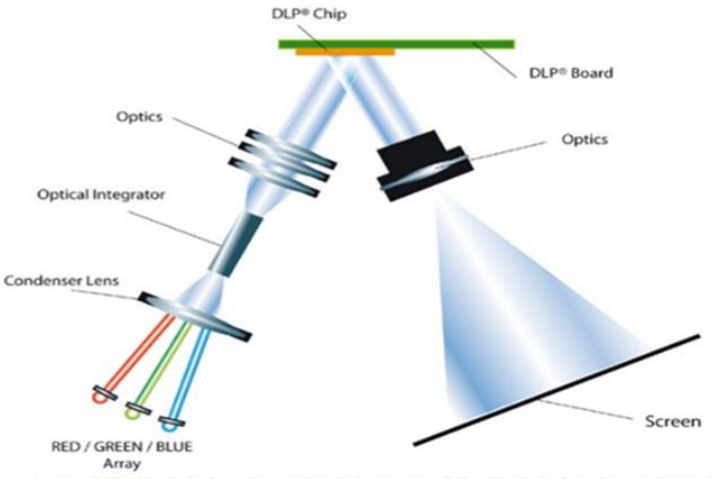
DLP (Digital Light Processing) could be another alternative technology for AR display, and is dominated by Texas Instruments. The design incorporates a number of tiny mirrors which reflect and manage the light received. The light received is segregated into three categories – red, green, and blue – and chips on the mirrors then use a combination of these categories to come up with a specified pixel. According to OPLI, DLP has the advantage of better resolution and contrast over LCoS; however, DLP's higher cost and limited suppliers are likely to be factors that constrain its popularity.

Exhibit 10: LCoS design



Source: naver.com

Exhibit 11: DLP design



Source: Texas Instruments

Exhibit 12: LCoS vs DLP

	LCoS	DLP
Driving	Uses LCD, On/Off each pixel with polarisation of light	Uses micro mirrors, On/Off each pixel with change of reflection angle
Efficiency	About 5-10%	About 15-20%
Panel	- Considering the deviation in efficiency from the sensitivity of polarisation coating angle on the PBS, so the incident angle to the PBS coating surface should be minimised as much as possible	- In the off state of micro mirror array, the stray light should not be incident to the projection lens system because it might produce flare to the image
	- Aware that the incident angle is increased, the Fno of projection lens should be lowered	- When using the simple mirror, care must be taken to align the optical axis
Strength	- Various resolutions and solutions	- No loss by the polarisation
	- Possible to have high resolution with comparably low cost	- High contrast (>1000:1)
Weakness	- Low efficiency, polarisation loss	- Expensive
	- Low contrast (about 200:1)	- Restricted resolution

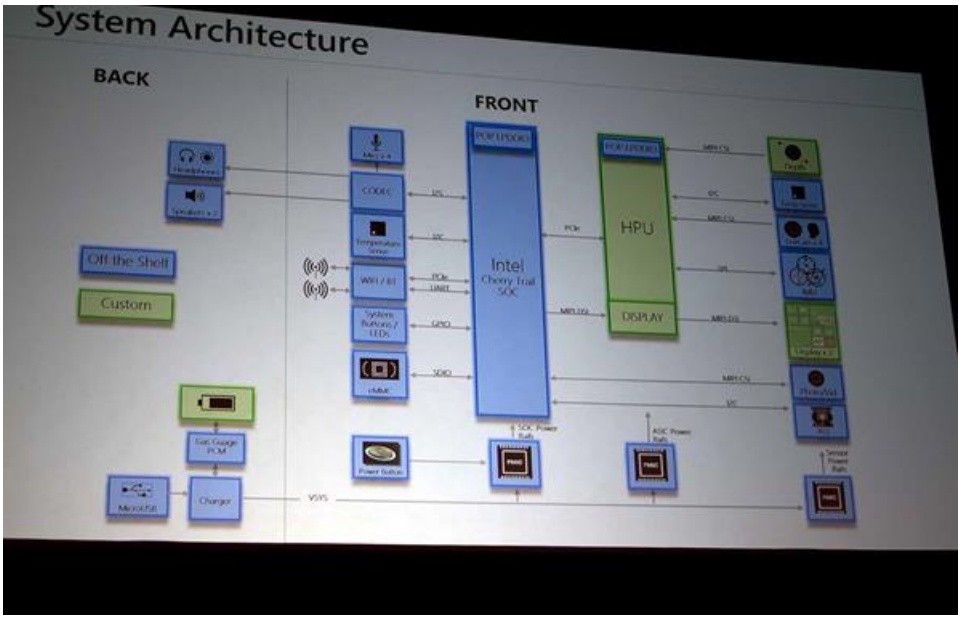
Source: OPLI

Other than the projection display, the holographic lenses or the waveguide is also critical. In order to provide good FOV, better see-through and light guide performance as well as less weight, we estimate the holographic lenses could cost USD200+.

New Opportunities for semiconductor/chip companies

As we highlighted in our report *SEMICON Taiwan: From mobile to ubiquitous computing*, processor unit chips also play an important role and will affect the response time, graphic performance, power assumption, data transmission, etc. For instance, Microsoft's HoloLens has a Holographic Processing Unit (HPU) chip inside, which according to reports is "a custom-designed TSMC-fabricated 28nm coprocessor that has 24 Tensilica DSP cores arranged in 12 clusters. It has about 65 million logic gates, 8MB of SRAM, and a layer of 1GB of low-power DDR3 RAM on top, all in a 12mm-by-12mm BGA package. It can perform a trillion calculations a second". According to Microsoft, "it aggregates data from sensors and processes the wearer's gesture movements, all in hardware, so it's faster than the equivalent code running on a general purpose CPU. Each DSP core is given a particular task to focus on".

Exhibit 13: System Architecture – HoloLens



Source: tomshardware.com

Along with the HPU, there is an Intel Atom x86 Cherry Trail CPU, featuring its own 1GB of RAM and running Windows 10 and apps that take advantage of the immersive headgear display.

Sensors and cameras- more applications

We also expect the rising applications around AR to benefit sensor and camera module makers. For instance, there are six cameras and environmental sensors in HoloLens. Himax provides wafer level optics solutions for HoloLens.

Qualcomm and Intel's announcement around VR/AR applications

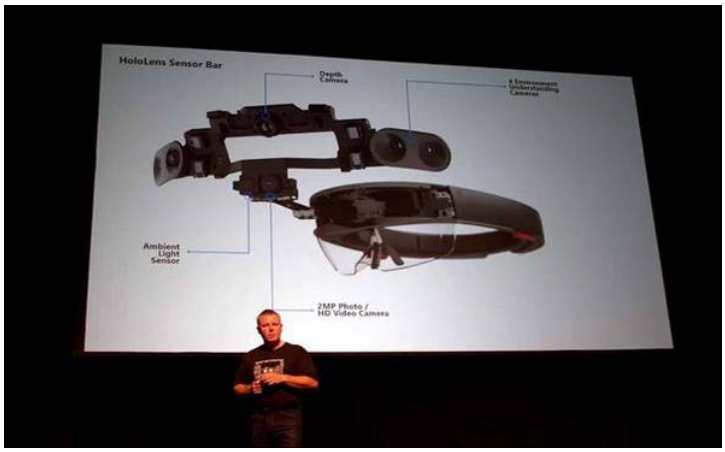
During CES, new technology from IC giants like Intel and Qualcomm all supported VR/AR applications with more advanced camera support. For instance, Qualcomm's Snapdragon 835 SoC has been optimised for AR/VR devices and aims to better support Google Daydream VR applications. From a hardware spec perspective, it is a 10nm SoC, and the design of CPU is based on an octa-core processor with four Kryo 280 performance cores clocked at 2.45GHz and four Kryo 280 efficiency cores at 1.9GHz. To better integrate with AR/VR software, it uses an Adreno 540 GPU, which supports OpenGL ES 3.2, Vulkan and DX12 and is typically considered to be 25% faster at graphics rendering and has 60x more display colours. It is also worth noting that Snapdragon 835 embedded an X16 LTE modem, which offers faster internet connectivity.

Snapdragon 835 can also support either two 16Mp rear cameras or a single 32MP camera and uses Qualcomm Spectra 180 ISPs for the image processor. Of particular note, it is able to support different kinds of camera modules. A Sony IMX298 sensor, a Snapdragon Clear Sight camera module and a Snapdragon optical zoom camera module are all compatible with it. It also features 4K UltraHD content at 30fps as well as 4K UltraHD video playback at 60fps. In addition, Snapdragon 835 is the first one to have Quick Charge 4 technology, which will improve charging times by around 20% and power efficiency by 30% compared with Quick Charge 3.0.

Intel's Project Alloy device was also shown at CES 2017. According to Intel, its Project Alloy is a 'headset device for merged reality that offers an immersive experience with RealSense technology'. The concept of merged reality is therefore the integration of VR and AR, and the company is aiming to have the device ready for commercial launch in 4Q 2017. Unlike the devices currently leading the market for VR, Project Alloy intends to aggregate all the computing requirements into the device itself and will adopt Intel's i7 core processor. Furthermore, other hardware such as vision processors, fisheye lenses and sensors, two RealSense cameras and a battery will be embedded in the device.

In developing better detection for multiple user occasions, such as 3D functions and 360 video for VR, we see lots of opportunities for camera module makers. For example, Sunny Optical is the sole supplier for Lenovo's time-of-flight (ToF) camera on the Tango Phab2 Pro. We would expect various types of IR-sensing cameras, such as structured light, Time of Flight (ToF) and hybrid, to be widely adopted for AR devices. IR-sensing cameras include a light-emitting source (e.g., Infrared laser projector) and a depth sensor that computes information on depth to create 3D mapping of the environment, in addition to a conventional RGB camera.

Exhibit 14: HoloLens Sensor Bar



Source: tomshardware.com

Exhibit 15: HoloLens Sensor Bar

Source: Microsoft

Potential beneficiaries in greater China semiconductor and hardware-TSMC and Sunny Optical

Compared with VR, we think mature AR technology could be more sophisticated, as it needs to combine the real world and specific applications. It is critical that AR devices can incorporate real-time interaction, enabling a user to navigate and view a three dimensional world while a computer generates sensory impressions for them. We think technology improvements in various segments, eg processing power, image resolution, communications (wireless) bandwidth, and hardware and software design, will be critical and may take time to come together.

Currently, there are very few companies leveraging A/R technology, which will probably remain the case until a clearer path of adoption emerges. However, early leaders in the space include Microsoft, which has developed one of the first pieces of A/R hardware, and done a significant amount of development on a number of programs, including Holograms, HoloStudio, HoloTour, and a more interactive version of Skype. In order for more companies to successfully pursue A/R, developers will need to be trained on 3D technologies, as well as see a more developed ecosystem for the hardware.

Among our coverage of Greater China semiconductor and hardware companies, we remain positive on TSMC [2330 TT; BUY; CP TWD184; TP TWD225] and Sunny Optical [2382 HK; BUY; CP HKD38; TP HKD45], thanks to their leading technology in chip manufacture and cameras, respectively. In the AR arena, we believe processing technology and camera applications will be critical. Other key potential beneficiaries are sensor makers and AMOLED/projector makers. We think hardware device makers may provide less value add, as the design features come more from the technology owner and not necessarily from the device manufacturer.

Exhibit 16: Key players in AR market during CES 2017

AR product	BBG code	Market cap (USD m)	AR related product
Microsoft	MSFT US	488,603	HoloLens
Asustek	2357 TT	6,231	ZenFone AR
Lenovo	992 HK	7,190	Phab 2 Pro & Own headsets based on HoloLens technology
Google	GOOGL US	561,731	Tango
Dell	-	-	Own headsets based on HoloLens technology
Acer	2353 TT	1,277	Own headsets based on HoloLens technology
HP	HPQ US	25,582	Own headsets based on HoloLens technology
3Glass	-	-	Own headsets based on HoloLens technology

IC component maker	BBG code	Market cap(USD m)	AR related product
TSMC	2330 TT	148,770	Processor, DSP,
Texas Instruments	TXN US	74,112	DLP
Intel	INTC US	172,879	SoC
Qualcomm	QCOM US	96,780	SoC (Snapdragon 835)
Bosch	-	-	Sensor
Sunny Optical	2382 HK	5,375	Camera
Sony	6758 JP	35,773	Camera
Himax	HIMX US	1,040	LCOS, Wafer Level Optical
NVidia	NVDA US	55,571	GPU

Market cap is based on 9 Jan 2017 prices for Non-US stocks and 8 Jan 2017 for US stocks
Source: BNP Paribas

Disclaimers and Disclosures

APPENDIX

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Company	Ticker	Disclosure (as applicable)
Sunny Optical Technology	2382 HK	2, 3, 4, 6
TSMC	2330 TT	2, 3, 4

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6. It makes a market in securities in respect of this company.
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Company	Ticker	Price (as of 09-Jan-2017 closing price)	Interest
N/A	N/A	N/A	N/A

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5. BNPPSK has taken financial advisory service regarding listing to the Company within the past 1 year.
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8. The Company that has signed a nominated advisor contract with BNPPSK as defined in Item 2 of Article 8 of the KONEX Market Listing Regulation.
9. The Company is recognized as having considerable interests with BNPPSK in relation to No.1 to No. 8.
10. The analyst or his/her spouse owns (including delivery claims of marketable securities based on legal regulations and trading and misc. contracts) the following securities or rights (hereinafter referred to as "Securities, etc." in this Article) regardless of whose name is used in the trading.
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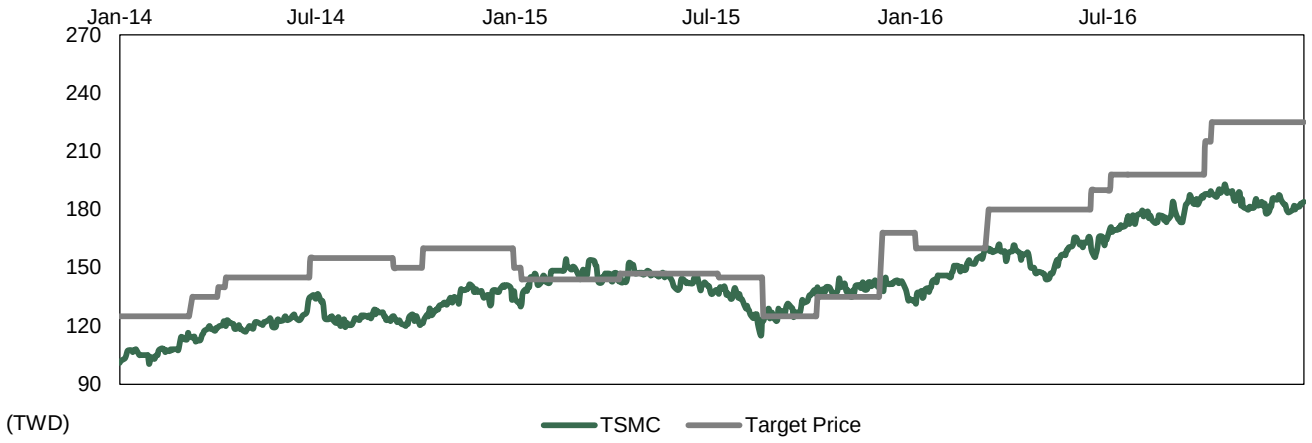
    2) Stock options of the Company whose securities dealings are being solicited.
    3) Individual stock future, stock option, and warrants that use the stocks specified in Item 1) as underlying.

History of change in investment rating and/or target price

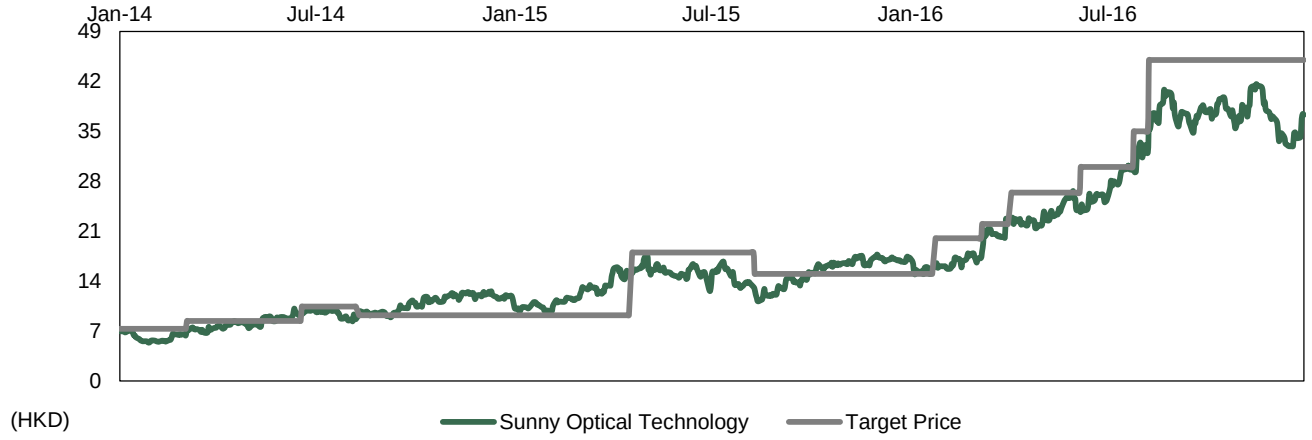
TSMC (2330 TT)



Date	Rating	Target price	Date	Rating	Target price	Date	Rating	Target price
09-Jan-14	Buy	125.00	08-Jan-15	Hold	150.00	14-Jan-16	Buy	160.00
17-Mar-14	Buy	135.00	15-Jan-15	Hold	144.00	21-Mar-16	Buy	180.00
10-Apr-14	Buy	140.00	16-Apr-15	Hold	147.00	24-Jun-16	Buy	190.00
17-Apr-14	Buy	145.00	16-Jul-15	Hold	145.00	12-Jul-16	Buy	198.00
04-Jul-14	Buy	155.00	26-Aug-15	Hold	125.00	07-Oct-16	Buy	215.00
19-Sep-14	Buy	150.00	15-Oct-15	Hold	135.00	13-Oct-16	Buy	225.00
16-Oct-14	Buy	160.00	14-Dec-15	Buy	168.00			

Laura Chen started covering this stock from 24 Jun 2016
Price and TP are in local currency
Sources: FactSet; BNP Paribas

Sunny Optical Technology (2382 HK)



Date	Rating	Target price	Date	Rating	Target price	Date	Rating	Target price
09-Jan-14	Hold	7.30	27-Apr-15	Hold	18.00	14-Jun-16	Buy	30.00
12-Mar-14	Hold	8.40	18-Aug-15	Hold	15.00	02-Aug-16	Buy	35.00
26-Jun-14	Hold	10.42	30-Jan-16	Buy	20.00	16-Aug-16	Buy	45.00
18-Aug-14	Hold	9.20	15-Mar-16	Buy	22.00			
27-Jan-15	Reduce	9.20	11-Apr-16	Buy	26.40			

Laura Chen started covering this stock from 03 Oct 2013
Price and TP are in local currency
Sources: FactSet; BNP Paribas

Company	Ticker	Price	Rating	Valuation & Risks
Sunny Optical Technology	2382 HK	HKD 38.00	Buy	Key downside risks to our P/E-based target price are worse-than-expected demand and faster-than-expected ASP deterioration.
TSMC	2330 TT	TWD 184.00	Buy	Key downside risks to our P/E-based target price are foundry competition and new tech ramp-up.

Sources: Factset, BNP Paribas

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REDUCE (R). The downside is 10% or more.
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