HONOR

Counterpoint
Technology Market Research

WHITE PAPER

SMARTPHONE IMAGING TRENDS

New Directions Capturing Magic Moments

2022

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Introduction

The camera has always been a major component of the smartphone and a key selling point among consumers. In the past, smartphone cameras lagged far behind even the most basic DSLRs as form factor and size constraints impacted picture and video quality. But technology has now advanced to the point where today's top flagship devices are capable of delivering DSLR-like performance.

The rise of AI algorithms, advancements in multi-frame/multi-lens computational photography, more powerful processors, the addition of dedicated image signal and neural processing units and, of course, the compounding of R&D experience has resulted in today's smartphone cameras rivalling dedicated imaging devices.

In fact, the smartphone's comparatively compact form factor is an advantage, as clicking pictures and recording videos are becoming integrated into our daily lives through the growth of social media. The role of the camera has shifted to become a life tool, as end-users migrate from being simply consumers of content to creators.

This new direction that imaging has taken warrants further advancements in smartphone cameras, as we lean on technology to make the experience easier while allowing all of us to be more creative.

Smartphone Imaging Trends

Over the last few years, steady upgrades in CMOS image sensor (CIS) technology combined with the evolution of chipsets (and the improvements in AI they enable) have brought step-change improvements to the smartphone camera experience. There are three main areas of development: the race for more megapixels, the rise of multi-lens camera modules, and increasing processing power.

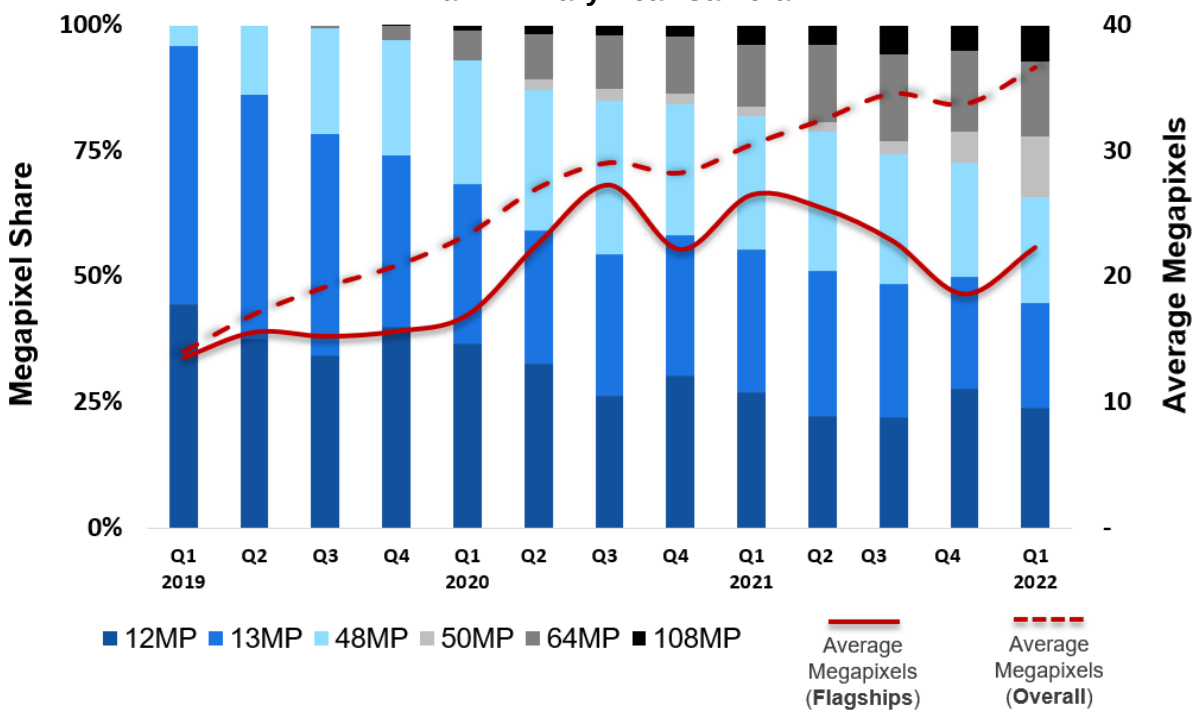
Megapixels: More is not necessarily better

Megapixels are what most people look at when comparing smartphone cameras, believing those with more megapixels take better pictures. While not entirely untrue, it does not tell the whole story. But this has not stopped average megapixel counts from steadily growing over the last few years.

Primary rear camera megapixel counts have rocketed over the past two years to reach an average of 37MP in Q1 2022 compared with only 14MP in Q1 2019. The rise can be attributed to growth across the 48MP and above segments, and most recently, hyper-resolution 64MP-108MP sensors.

However, looking more closely at the numbers, primary cameras on high-end flagships ($600 and above) are actually seeing decreases in the number of megapixels, with counts sitting at less than two-thirds of their lower-priced peers. This is because megapixel counts are not the only factor contributing to image quality. Furthermore, the broader industry is plateauing at 108MP, and benefits from greater resolution are offset by less light sensitivity and increased noise.

Exhibit 1: Global Smartphone Sales by Key Megapixel Segments, Main Primary Rear Camera



*Source: Counterpoint Research; * Flagships represent the premium $600 and above price segments.*

> *"The camera is one of the primary differentiating factors for smartphones today, and is probably the area where technology is progressing the fastest. But it's not just what's on paper; what happens behind the scenes is just as, if not more, important as what is listed on the spec sheet."*
>
> **Jan Stryjak**
> *Associate Director, Counterpoint Research*

A larger sensor generally means better image resolution as more pixels can fit onto it. Meanwhile, larger pixels capture more light, performing better in low light with less noise and a higher dynamic range. Hence, there is a trade-off between resolution and light sensitivity. For example, assuming the same size sensor, a 12MP camera could have better light sensitivity and therefore brighter pictures with less noise than a camera with more megapixels. However, a 48MP camera will have a larger and more defined picture, albeit possibly somewhat noisier.

This is why some of the highest-rated smartphone cameras have comparatively low megapixel counts, and why flagships – the most expensive segment – are increasingly rebalancing to larger image sensors with larger pixels.

Multi-camera modules: Covering all scenarios

Much has changed since the first phone with a built-in camera, the Kyocera Visual Phone VP-210, was launched in May 1999. OEMs later realised that the way to give consumers the best photography experience was to add multiple cameras to the device.

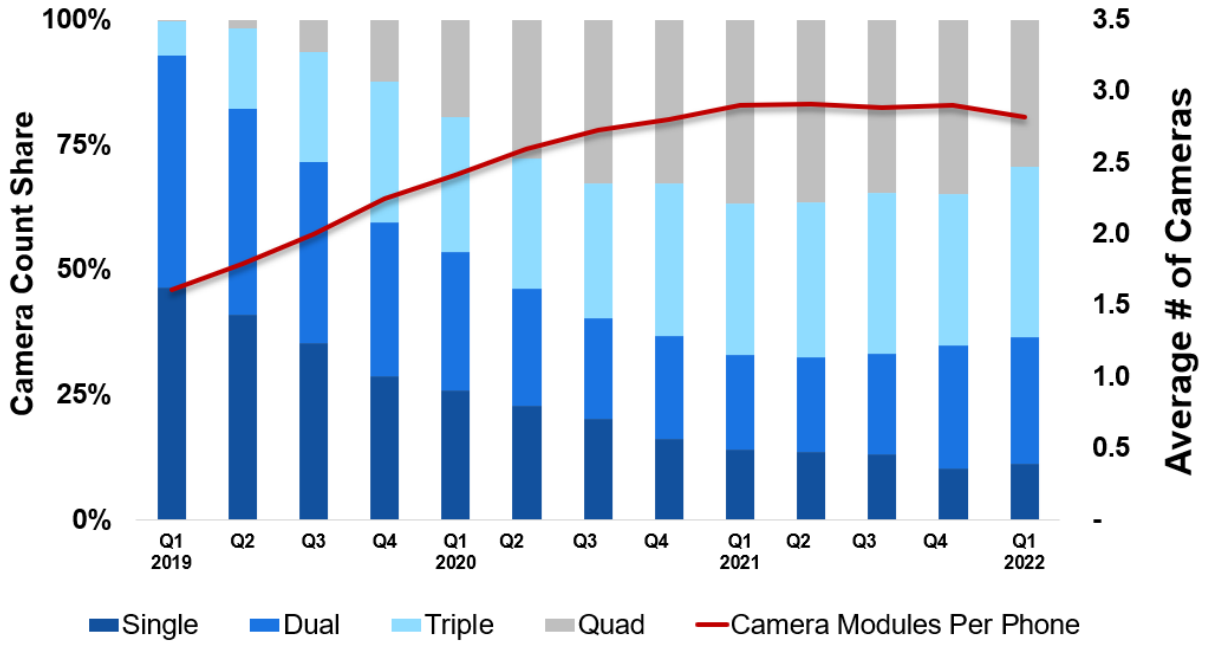
In traditional cameras, the ability to zoom is handled by a lens with variable focal length, which varies the distance between the centre of the lens and where light converges on the sensor by moving glass elements in the barrel of the lens. However, movable glass elements are not ideal for a smartphone that needs to be as thin as possible. OEMs have solved the problem by using multiple lenses, each with its own fixed focal length, that function independently but work together through the use of software.

For example, the HONOR Magic4 Ultimate has, among others, a 64MP periscope telephoto lens with a focal length of 90mm to handle the zoom, working in conjunction with a 50MP wide-angle lens with a focal length of 23mm for standard photography.

Another factor is low-light photography. Traditional cameras have large sensors which are impractical for a smartphone. The common smartphone solution is to capture multiple frames with different exposure settings and then build a composite image with better low-light details than can be captured by a single frame. OEMs are now augmenting these techniques with advanced lenses, large apertures and super-large sensors to boost detail and color capture to authentically restore actual scenes.

In general, triple-camera systems consist of a wide, ultrawide and telephoto lens. Quad-cameras usually add a standalone depth or macro lens, although these are likely to become less widespread as the AI capability of SoCs for the mass market is increasingly able to support algorithm-based bokeh effect, and ultra-wide lenses are used more frequently for macro scenarios. This trend of adding extra cameras has gained pace over the last few years.

Exhibit 2: Global Smartphone Sales by Rear Camera Module Count



Source: Counterpoint Research.

In Q1 2019, single- and dual-cameras together accounted for over 90% of global smartphone volumes. Triple-cameras gained traction rapidly throughout 2019, closely followed by quad-cameras as integration technologies improved and camera module prices fell.

Indeed, the key aspect of the overall user experience in multiple-camera systems is seamless integration and cooperation between lenses. Most users are unlikely to know and appreciate the finer aspects of photography, and will not understand the importance of things like focal length, aperture size, shutter speed, white balance and ISO values. For the majority of users, therefore, the smartphone needs to adjust these settings automatically, and select the appropriate lens depending on the scenario.

Moreover, multiple lenses are sometimes used to solve the issue of digital zoom image degradation. HONOR, for example, combines data from two cameras into one to enhance the image quality of intermediate zoom points. Enabling all of this is more sophisticated AI supported by increases in processing power.

Image processing: Pushing the laws of physics

Smartphone cameras are limited by the laws of physics and by desired form factors — image sensors can only be so big before they require unwieldy camera bumps, and there can only be so many lenses before battery capacity becomes significantly affected. The key battleground is therefore shifting to image processing.

As outlined above, processing power is paramount for smartphone camera performance, as images need to be built up from a combination of sources (i.e. multiple lenses) and the context of the images (e.g. night mode, macro, portrait, etc.) needs to be properly managed. This is driving the need for faster and more powerful processing, especially among flagships, where the camera remains a key selling point.

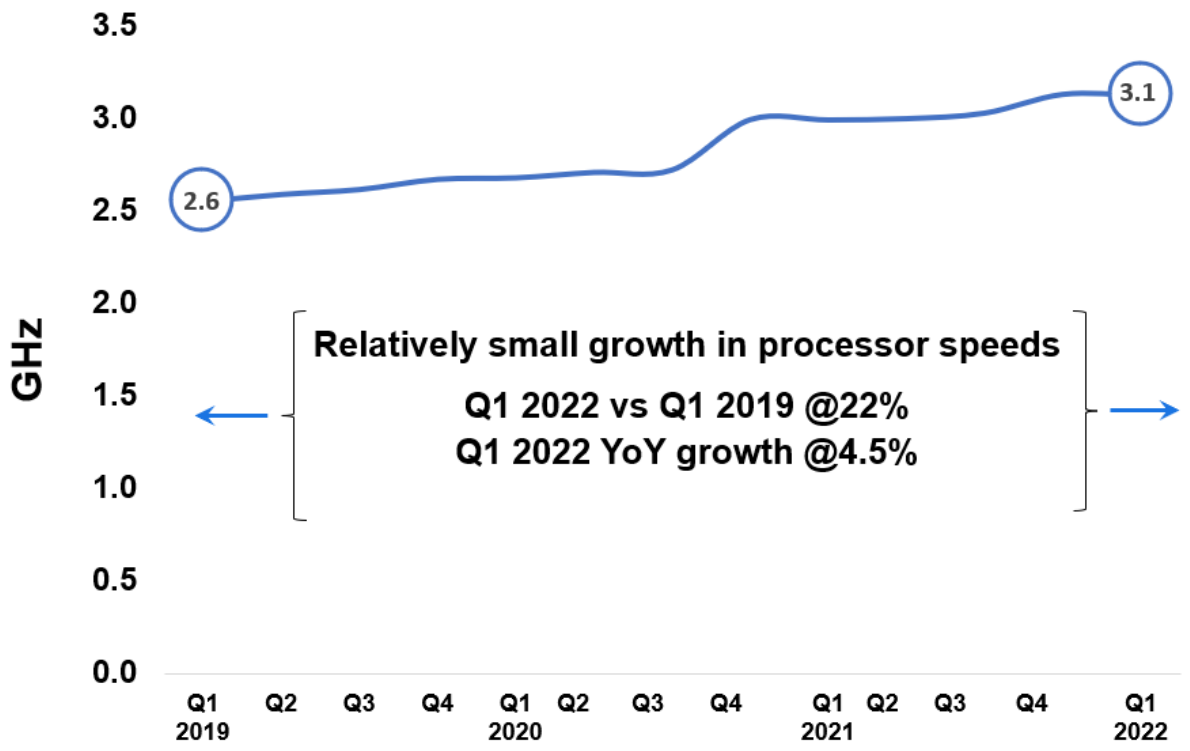
As image processing is carried out by the smartphone system on chip (SoC), processing speeds are critical to delivering great photos and videos.

Today's top-end SoCs, which clock in at 3GHz and above, support integrated image signal processors and neural processing units which handle data from the cameras.

But even these levels of performance can be improved upon and smartphone makers are turning to specialized components to boost speeds.

> *Today's camera setups require extreme image signal and neural processing, creating challenges on the chipset side. We see it as a tremendous opportunity to work with our OEM partners to help deliver amazing imaging experiences.*
>
> **Judd Heape**
> *Vice President, Product Management*
> *Qualcomm*

Exhibit 3: Flagship* Smartphone Average Processor Speeds



*Source: Counterpoint Research; *Flagship indicates $600 and above price segment.*

Increasingly sophisticated computational photography techniques relying on AI engines and neural processing are pushing OEMs to find additional performance improvements by adopting independent, proprietary ISP chips to augment the integrated components on the SoC. Examples include HONOR's AI ISP in the Magic4 Ultimate, OPPO's MariSilicon X in the Find X5 Pro and vivo's V1+ in the upcoming X80 Pro.

Exhibit 4: Imaging at the Forefront of Latest Processors

Custom ISPs are likely to grow in importance as smartphone manufacturers look to move beyond what is possible through lens and sensor technology advancements, while differentiating themselves from the competition. And this approach appears to be working – recent flagship smartphones with dedicated ISPs have been rated as having some of the best cameras yet. A prime example is the HONOR Magic4 Ultimate, which was recently awarded DXOMARK's highest ever smartphone camera score.

OEM Imaging Comparisons

The holy grail of smartphone cameras is delivering image quality on a par with dedicated DSLRs. OEMs are using various hardware and software strategies to overcome photographic obstacles and generate the best images possible.

As hardware slows, innovation grows

Hardware has always been the fundamental driver of technology evolution in imaging, and this continues to be the case. However, though different smartphone makers deploy various camera hardware from a range of different vendors, differentiation is typically limited within specific price segments – especially as component technology growth slows significantly.

At the pinnacle, we are seeing flagship camera counts plateauing, lens focal lengths and sensor sizes being stretched, and image processing demands pushing chipset makers to keep pace with Moore's Law; where that is not enough, smartphone makers are now adding specialized image and neural processors.

Exhibit 5: Key Imaging Features/Hardware of Selected Flagship Smartphones

	HONOR	oppo	vivo	SAMSUNG		
	Magic4 Ultimate	Find X5 Pro	X80 Pro	Galaxy S22 Ultra	iPhone 13 Pro Max	12 Pro
						
Camera Setup	50 MP wide 64 MP ultra-wide 64 MP periscope tele-photo 50 MP wide	50 MP wide 50 MP ultra-wide 13 MP tele-photo	50 MP wide 48 MP ultra-wide 8 MP periscope tele-photo 12 MP telephoto	108 MP wide 12 MP ultra-wide 10 MP periscope tele-photo 10 MP telephoto	12 MP wide 12 MP ultra-wide 12 MP tele-photo	50 MP wide 50 MP ultra-wide 50 MP tele-photo
ToF	Yes	No	No	No	Yes	No
Optical Zoom	3.5x	2x	5x	10x	3x	2x
Main camera sensor size	1/1.12”	1/1.56”	1/1.3”	1/1.33”	1/1.9”	1/1.28”
Ultra-wide lens angle	126°	110°	114°	120°	120°	115°
ISP	Dedicated chip AI ISP	Dedicated chip MariSilicon X	Dedicated chip V1+	Integrated Exynos 2200	Integrated A15 Bionic	Integrated Snapdragon 8 Gen 1
Image stabilisation	OIS	Sensor Shift OIS (5 axes)	Micro-Gimbal OIS	OIS	Sensor Shift OIS	OIS

Sources: Counterpoint Research, company data.

Key imaging features OEMs address with hardware advancements:

- **Image stabilisation**: OIS (optical image stabilisation) is the approach most OEMs take, where the lens adjusts position to keep the image steady. But some take a different approach. vivo, for example, uses micro-gimbals to stabilise the image, while OPPO and Apple use Sensor Shift technology where the sensor moves instead of the lens to capture blur-free photos.
- **Zoom**: Standard zoom lenses with elements vertically stacked on top of each other are limited by the phone’s thickness, so are unable to provide much more than 3x magnification. However, some smartphones, such as the latest flagships from HONOR, Samsung and vivo, incorporate periscope, or L-shaped, telephoto lenses which, with a longer tunnel for light to pass through, can boost optical zoom to as much as 10x magnification. In addition, HONOR has developed Ultra Fusion technology which combines data from multiple cameras to enhance image quality across its full focal length range, from 0.5x ultra-wide through 3.5x optical zoom to all the way to 100x digital zoom.
- **Low-light photography**: There are three key features of a camera system that help with light capture: the size of the aperture, the size of the sensor and its pixels, and exposure time. The HONOR Magic4 Ultimate has one of the largest sensors available on a smartphone at 1/1.12”, and one of the widest apertures at f/1.6.
- **3D imaging and effects:** In addition to the now-standard multi-camera setup of a wide, ultra-wide and telephoto lens, some OEMs such as HONOR and Apple are including a ToF (time of flight) or LIDAR (light detection and ranging) depth-sensing lens which, while not used for taking images, assists in 3D mapping, biometric sensing and bokeh effects in portrait or artistic photography.

Where the magic happens

Sensors, lenses and processors are just part of the equation when taking pictures. Where the magic truly happens is in the software layer, which ties together each of the hardware elements. In particular, fresh approaches in computational photography and fusion technology are being implemented to help deliver great imaging experiences that, in some cases, are rivalling the quality of DSLRs.

Continued advances in smartphone SoC processing power is enabling embedded AI algorithms to fuse multiple frames into one, selecting and correcting each to enhance dynamic range, improve clarity and remove noise.

All top-tier flagships – from Apple's iPhone 13 Pro to Samsung's S22 Ultra – leverage this technology in various ways.

> *There is a lot of science behind computational photography and our multi-frame and multi-camera fusion technology. But our objective is to remove as much complexity as possible so that our users can simply take great pictures.*
>
> **Dr. Hou Weilong**
> *Technical Expert,*
> *HONOR Imaging*

New magic, new directions

HONOR is taking fusion technology in new directions by enabling not just multi-frame fusion but now also multi-camera fusion in its latest Magic4 Ultimate smartphone. The technique blends images from two separate cameras, bringing significant improvements to:

- **Picture quality:** Enhanced across some of the most common use cases like intermediate zoom, low-light, portrait and action shots.
- **User experience:** Powered by a proprietary HONOR Image Engine, camera response times are faster, enabling quick shoot-and-click with minimal response and lag times.

Indeed, user experience is becoming the key differentiating factor for consumers. The adage that "the best camera is the one you have on you" means OEMs need to make using smartphone cameras as easy as possible.

Users with little or no experience should be able to get results similar to professional photographers, which is why OEMs like HONOR are taking the general experience of capturing pictures and videos into consideration in areas such as camera app usability, operational simplicity, shutter to image latency and preview accuracy.

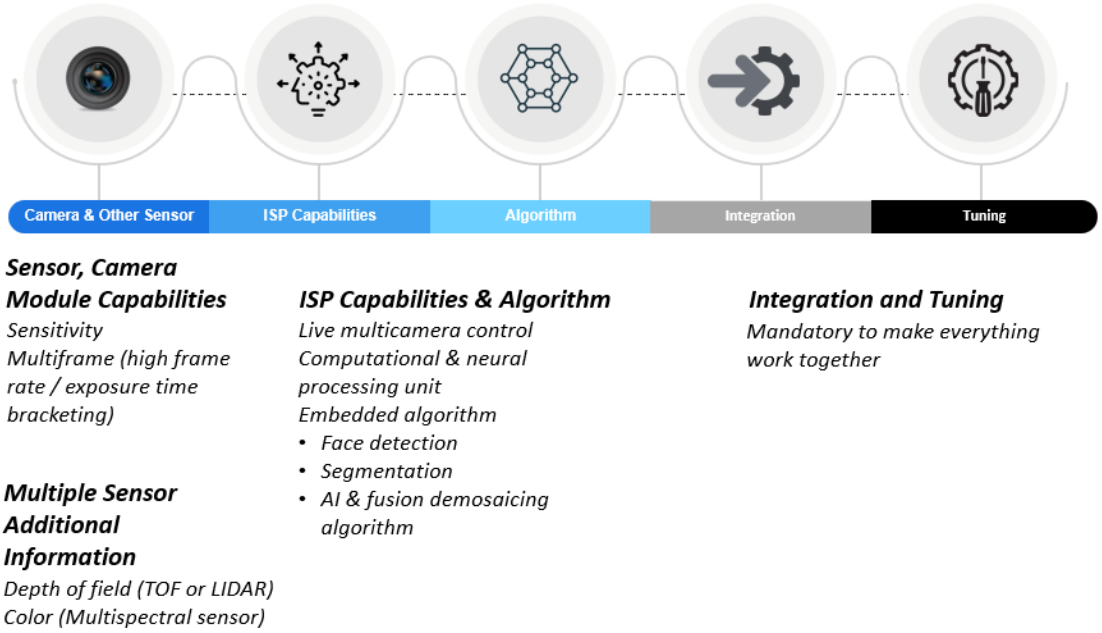
Measuring Quality

Traditional DSLR camera systems rely on the marriage of hardware and software to take pictures; smartphone cameras are no different. However, due to size constraints and its complexities, smartphone makers depend on the latter far more. As a result, the algorithms around image processing, as well as integration and tuning, are becoming the key areas of focus for smartphone camera differentiation.

Components of an exceptional smartphone camera

There are several basic elements in a smartphone camera; the best ones take the leading hardware specs and innovate around the algorithms, integration and tuning.

Exhibit 6: Key Smartphone Camera Elements



Source: DXOMARK

Image processing innovation

For smartphone makers, much of the innovation takes place around image processing, where advanced techniques leveraging computational and neural processing use multiple frames or even multiple cameras in taking photos. This ensures as much information as possible is captured to help construct a given photo, allowing the neural processing engine to select and combine the most appropriate parts for a given context.

The ability to quickly understand a user's intention combined with the resources to 'fuse' robust data from multiple sources is now table stakes for those wishing to participate in today's smartphone game.

> *A good smartphone camera makes taking great pictures easy by understanding intention and providing 'all-in-one' in the default mode. Multi-camera fusion computational photography is the bleeding edge technology helping to make that happen, and HONOR does it most elegantly.*
>
> **Herve Macudzinski**
> *Image Science Director, DXOMARK*

Many elements go into taking a great picture. As any professional will attest to, the camera should be an extension of oneself. Whether shooting portraits, action shots or something artistic, much effort is required by the photographer. Scene identification, framing and selection of the moment are just as important as the camera itself.

Hence, the best smartphone cameras make taking pictures easy by understanding user intentions, quick response times or great low-light performance.

DXOMARK Readout

HONOR's Eye of Muse camera setup on the Magic4 Ultimate provides what is arguably one of the best smartphone camera user experiences on the market today. It leverages multi-camera and multi-frame fusion computational photography techniques to blend together images from disparate sources to produce exceptional pictures across diverse contexts.

The results have been dramatic, with the Magic4 Ultimate achieving the top ranking in DXOMARK's[1] latest smartphone camera rankings with an overall score of 146.

Key to this was outstanding performance across a broad range of use cases such as portraits, night shots, cityscapes, action images and zooming.

Exhibit 7: DXOMARK Test Summary – HONOR Magic4 Ultimate

Source: DXOMARK March 2022 Smartphone Camera Rankings

Test highlights reveal a very user-friendly camera providing high-quality photo results in all test categories and lighting conditions. Night mode, zoom and ultra-wide all delivered high image quality with the camera excellent at capturing the instant.

[1] DXOMARK is an industry-recognized company specializing in the measurement of camera, audio, display and battery quality of all types of consumer electronics.

Capturing Magic Moments

Great photographs depend on the photographer's skills, ability to capture the moment and, of course, capabilities around image processing. OEMs are now going further to help users unlock creative expression by providing additional tools to expand the possibilities to create and express.

Recent innovations include:

- **Time-of-flight (ToF) camera systems:** Enable rapid focusing and effects like bokeh 3D imaging.
- **Phase Detection AutoFocus:** Enables superfast auto-focus for action shots and for capturing the moment.
- **IMAX Enhanced capabilities:** Provide the ability to shoot 'cinema-like' videos.

Taken as a whole, today's leading smartphone cameras provide an overall experience that is far greater than the sum of parts and appropriate for the full spectrum of photographers – from casual users through to professionals.

Powering art through technology

As a demonstration of the versatility and power of the most advanced flagship camera systems, renowned photographer and director Eugenio Recuenco recently shot Kaleidoscope, a short fashion film, exclusively on the HONOR Magic4 Pro.

Exhibit 8: 'Kaleidoscope' Shot on HONOR Magic4 Pro

Source: HONOR.

The quality and creative license afforded by imaging technologies and applications on the device helped to deliver a true cinematic experience – a testament to how far today's smartphone cameras have come.

Conclusion

Imaging trends show how technology has accelerated over the past few years. The race for more megapixels and modules has now shifted towards computational photography and AI-powered image processing.

Advances in lenses, sensors, processors and other hardware enable today's OEMs to make smartphone cameras that can take close-to-DSLR-quality shots. But only the best can conjure the magic to deliver performance across the broadest range of scenarios.

With the smartphone fully embedded in our lives, the smartphone camera has become more than just a tool for taking photos. It commands a much greater role by helping us appreciate life's big picture, enabling us to easily capture the countless tiny moments to the grandest effect.

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