## Technical Development of Trend of Cameras

The past decade has seen revolutionary technical developments for camera products. The transition from DSLR to mirrorless cameras marks an important change in technical framework of cameras, bringing unprecedented improvements in terms of camera performance and features available. This paper will give a brief review of important camera technology development in the past 10 years.

### DSLR vs Mirrorless

The first major change in camera technology is the switch from DSLR to mirrorless. The DSLR has a single reflective mirror in front of its image sensors, reflecting the light into its optical view finder (OVF), and lift its mirror up when the shutter button is pressed and a photo is taken. Mirrorless camera has no reflective mirror; in contrast, it reads the image from its sensor, and output it to digital camera screen or electronic view finder (EVF). The mirrorless tends to be smaller and lighter because of the removal of reflection mirrors, but it is also more technically complicated because it requires the sensor to be more integrated and advanced, not only its read out speed, but also the integration of auto-focus systems onto the sensor chip. Both Sony and Samsung began their mirrorless cameras in APS-C format and point to shot form factor in 2010, and Sony launched its first Full Frame mirrorless camera A7M1 in 2013 (DPReview, 2013). Since then, the mirrorless camera has been more and more powerful and technically advanced than DSLRs.

### Case Study: Sony ILCE-A6300

In 601 lectures we talked about modularity in technology development. Such a practice and habit can allow important features and technology to be developed individually as a separate module, and thus ensures the overall smoothness of the development process. What the lecture did not talk about, is that the modules need to be combined together in a prototype platform or product for overall systematic testing and verification, and such a product will be worthwhile to dig into, as it forms the early technical framework of this type of product. The Sony ILCE-A6300 was a APS-C mirrorless camera launched by Sony in 2016 (Sony Electronics, 2016). Although it was never specified, it was the prototype for Sony modern mirrorless camera technologies, as it combined many important features from its predecessors and brothers from other product lineups. Reviewing this it will provide a clear analysis of modern mirrorless camera technology frameworks and structures.

The ILCE-A6300 featured the fastest and most accurate auto-focus system at its time. According to Sony, it can “lock on to moving subjects in as little as 0.05 seconds” (Sony Electronics, 2016). Additionally, it has 425 phase-detection auto focus (PDAF) points that covers almost the entire sensors, making it possible to focus on everything within the frame, something traditional DSLR cannot achieve.

The PDAF technology uses some pixels on the image sensor, dividing the incoming lights into 2 beams, and checking if the 2 lights beams can form up on this pixel. If the lights failed to match up, then the camera will instruct the lens to move the focus lens to the correct position. Comparing to contrast detection auto-focus (CDAF), the PDAF offers much higher focus accuracy and response speed to fast moving objects, and thus it has become the mainstream technology for modern cameras, providing highly reliable object tracking, making photography and videography’s job much more easier.

The ILCE-A6300 did not only provide a highly accurate and fast auto-focus, but it also managed to combine such auto-focus system with high speed continuous shooting. It is able to shoot 11 frame per second with continuous object tracking and auto exposure (Sony Electronics, 2016), a very remarkable performance for its $1000 price. In comparison, Canon EOS-1DX Mark ii, a flagship DSLR which was also launched in 2016, price at $6000, has only slightly higher performance of 14 frame per second continuous shooting (Canon, 2016).

Besides photography features, ILCE-A6300 managed to take an important step forward is the combination of its remarkable auto-focus system with professional level video capabilities. The ILCE-A6300 was the first mirrorless camera to have PDAF, 4k video capture, and S-Log3 gamma curve in the same body. The gamma curve is a log color space used in video captures. Similar to a log function in math, the gamma curve has a log like color and brightness calculation methods, compress both low brightness parts and high brightness parts, and achieved a higher dynamic range than normal color space can achieve. Since video is a sequence of images, it takes much more space than still images, and being able to compress a 12 dynamic range color space into 8 bits video encoding helps reduce the storage requirements a lot. What’s more, ILCE-A6300’s 4k video is in fact oversampled from 6k video readout, allowing noise reduction during the process, and deliver sharper images.

Another revolutionary technology advancement ILCE-A6300 had at that time was the first Sony camera to use a high refresh rate electronic view finders (EVF), up to 120fps from the traditional 60fps for A7S2, A7M2 and A7R2. Traditional DSLRs has optical view finder (OVF), which is a direct reflection of live images going through the camera, thus does not have the “refresh rate” problem. Mirrorless camera, however, does not have such a structure, and the images are actually electronically displayed in EVF. Having a higher refresh rate means that the image display is faster and more responsive for photographers, allowing them to capture important moments more effectively, and thus matching up a once deficiency with DSLR companions. It is also worth to notice that A6300’s EVF, similar to other Sony high end cameras at that time, has a relatively high resolution of 2.36M pixels (Sony Electronics, 2016). Both the improvements in image resolution and refresh rates of EVF mark a significant milestone for mirrorless cameras.

The ILCE-A6300 was one of the easiest mirrorless camera to have dual gain ISO sensitivity technology as well. It was never specified from Sony, but the dynamic range increase and read noise decrease when ISO reached 400 indicates such a technology does exist (JimK, 2016). Typically each pixel on a traditional CMOS sensor only has one group of readout circuit and analog-digital converter (ADC) to receive the photons and convert them to digital signals. Under sufficient lighting conditions, such as during a sunny day, the number of photons are sufficient enough to generate digital signals even with low light sensitivity; but when the lights are weak, for example, midnight, it is much harder to collect enough photons. The dual gain ISO technology, later involved to dual native ISO technology, equipped each pixel with 2 groups of ADC circuit, and allowing the sensor to generate stronger digital signals with lower readout noise. It is a common technology on almost all cameras and smartphones nowadays.

### Other Important Technology Revolution at That Time

Besides what was first available and integrated on Sony ILCE-A6300, there are two other important technologies first appeared in other Sony cameras that defined modern mirrorless cameras as well.

The first technology is in-body image stabilization (IBIS). Sony first introduced it with ILCE-A7M2 in 2014 (Sony Electronics, 2014). Image stabilization is the technology that reduces the blurry effects on images when the camera users did an unexpected hand-shake. During DSLR ages, it is achieved by built-in mechanisms in optical lenses, where certain parts of the lenses move in opposite to hand-shake direction to get a steady image (Optical Image Stabilization, OIS). IBIS, on the other hand, moves the sensor to compensate for the shake instead of having movable parts in lenses, and it is usually more effective than OIS in shorter focal range. IBIS and OIS can further work together, either by dividing camera movement to different axis and let separate parts be responsible for certain movements, or by combining the movements of sensors and lenses parts together in all axises to provide a steadier stabilization.

The second technology is back side-illuminated (BSI) sensor technology. Sony’s first Full Frame camera with BSI sensor is ILCE-A7R2 launched in 2015 (Sony Electronics, 2015). Traditional sensors are front side-illuminated (FSI), where the light receiving layer is placed behind the wires for sensor readout. The light has to pass the wire layer first, so there will be a energy and information loss for photonics. BSI sensors, on the other hand, have the receiving layer directly facing the incoming light, while the reading circuit layer is behind it, so it can increase the amount of light captured, and improve signal-to-noise ratio.

All these new technologies, during the 2014 to 2016 ages, including but not limited to IBIS, wide-range fast PDAF, 4k video and gamma curve videos, high speed continuous shooting, high refresh rate EVF, BSI sensors and dual gain/native ISO design, made the technical framework and definition of modern high performance mirrorless cameras. Even if we study popular inter-changeable camera products today, such as Sony ILCE-A7M4, Canon EOS R6 and R6 Mk2, Nikon Z6 and Z7, we can still find out that their technologies are originated from early pioneer products such as ILCE-A7M2, A7S2, A7R2 and A6300.

### Cutting Edge Camera Technology Today

It has been almost 8 years since the launch of ILCE-A6300, and almost 6 years since launch of the market redefining ILCE-A7M3 in 2018 (Sony Electronics, 2018), and technology of cameras, as well as smartphones and professional cinema cameras, so it is worthwhile to see what is new right now.

The first new technology is the use of Stacked CMOS sensor. First available for smartphones, the stacked CMOS puts the sensor together with a small onboard chip and integrated memory unit. Traditionally, the camera only has one processor, and this processor will send the readout request to the sensor directly, and receiving the data from the sensor entirely throughout the readout process. Since the wire distance from the sensor to the processor is relatively long, the data transfer process takes time, and this will cause rolling shutter effect that produce diagonal lines in images where they should be vertical. Stacked CMOS, on the other hand, will rapidly readout the entire image from the sensor, store it on its build-in memory unit, and do the data transfer to processor later, accelerating the readout process a lot and significantly reduce rolling shutter effect. The first professional camera with Stacked CMOS was ILCE-A9M1 launched by Sony in 2017 (Sony Electronics, 2017). Canon and Nikon launched their first stacked CMOS professional camera EOS R3 (Canon, 2021) and Z9 (Nikon, 2021) both in 2021.

The Stacked CMOS technology improves readout speed, but it only REDUCE rolling shutter effect, not eliminating it. To fully get rid of rolling shutter effect, the sensor must be able to readout all pixels at the same time, instead of traditional method of reading only one pixel at a time. This is where a Global Shutter sensor came into usage. A Global Shutter sensor usually has an individual memory for each pixels, so each pixel can “remember” its color value at specific moments, and all pixels are readout simultaneously. It is usually used for industrial and video productions, for example, the Red Komodo-X launched in 2023 (Red Digital Camera, 2023) and the Blackmagic Production Camera 4K released in 2014 (Blackmagic Design, 2014).

Global shutter also enables much faster readout speed and thus, continuous shooting speed. Sony recently launched ILCE-A9M3 with global shutter, with the abilities to do 120 frames continuous shooting per second (Sony Electronics, 2023).

Comparing to FSI technology, BSI has lower readout noise and thus signal/noise ratio, but to further improve the image quality, especially in low-light situations, 2-layer transistor sensor is needed. Samsung Isocell HP2, the main camera sensor for Samsung Galaxy S23 Ultra launched in 2023, uses a 2-layer vertical transistor gate to greatly improves the amount of light it captures (Samsung Semiconductor, 2023). Additionally, because each pixels goes vertical, its size and area has been decreased, and this allows more pixels on the same sensor size than before. The Isocell HP2 has an astonishing 200MP resolution in a small smartphone body, doubles from the previously generation Galaxy S22 Ultra with 100MP resolution. Sony also launched Xperia 1V with similar 2-layer transistor technology in 2023 (Sony Electronics, 2023). According to Albert Dros’s testing and sample images (2023), Xperia 1V has impressive low-light performance for smartphones in this size. The 2-layer transistor technology has the potential to deliver better image quality for professional cameras in the future.

As the camera technology is more and more advanced, it is now possible to integrate several important professional features together in the same body, making it more convenient even for professional level productions. Capturing video is different from capturing still photos; it needs a neutral density (ND) filter to reduce the amount of light coming into the sensors, so the aperture can open larger, and shutter speed can be slower to have a perfect 180 shutter angle for motion blur; it needs image stabilization for a constant steady and smooth footage, and since many high end cinema lenses does not have built-in OIS, the camera needs to have IBIS; it needs a reliable and accurate PDAF system, so an important footage or shot won’t be void because one or two seconds went out of focus. Sony recently launched CineAlta Burano (Sony Pro, 2023), the first ever cinema camera to have all these important features in the same body. Combining its ability to shot high resolution 8k videos, Burano gives a single shooter unprecedented flexibility and mobility. It is hopeful that other cinema cameras will be launched with this level of automation in the future.

A trend for still photography cameras is that the resolution and pixel densities of these cameras are getting higher. Sony ILCE-A7R2, as mentioned above, launched in 2015, has 42MP resolution in 35mm Full Frame format, so its pixel size is 4.5µm. Sony ILCE-A7R4, launched 4 years later in 2019, has 60MP resolution in the same 35mm Full Frame format, so its pixel size is smaller, 3.76µm. It also has the ability to do a pixel-shift multi shooting, delivering a 240MP image (Sony, 2019). Fujifilm XH-2, released in 2022, has 40MP in 23.5mm APS-C format, so its pixel size is even smaller to 3.04µm (Fujifilm, 2022). Since Fujifilm’s sensor technology is provided by Sony Semiconductor, it is reasonable to think that such technology will be used by Sony itself, and Sony will develop an approximately 100MP Full Frame image sensor for its high resolution ILCE-A7R series in the future.

Arri has been the leading company in cinema cameras, and it has great focus on image quality. The Arri ALEXA 35 launched in 2022, features a new sensor structure and technology that delivers huge improvements. It has 17 stops of dynamic range (ARRI, 2022), while cinema cameras from other manufacturers only have 15 stops or less. It is reasonable to think that such a sensor will be enlarged and used in other Arri products such as Arri ALEXA LF.

Camera lenses are being more versatile, mobile and powerful as well. Lenses released by Canon, Nikon and Sony are becoming lighter, smaller yet sharper. Canon has developed a lot of unique usage yet well designed lenses in recent years. For example, the RF5.2mm F2.8 L Dual Fisheye lens is the first interchangeable lens that can capture spatial video for VR applications (Canon, 2021). It has an unique design of separated two way optical path, where the images for left eye and right eye are captured using different parts on sensor to create a virtual reality video. Canon RF 24-105mm f2.8 L IS USM Z, another lens released by Canon in 2023, is the first Full Frame 24-105mm focal length lens with F/2.8 aperture (Canon, 2023). It also has internal zoom in and out design and power zoom capability so it is ideal for video work. A third example is Canon’s super telephoto zoom lens RF100-300mm F2.8 L IS USM, which is also released in 2023, gives users a wide range of zoom in and out while still having the constant F/2.8 aperture (Canon, 2023). There are also other lenses with unique specifications and functionalities, such as RF 28-70mm F2 L and RF 10-20mm f4 L IS, which allows user to built up their lenses collection with more diverse choices.

### Summary

In summary, both camera technologies and camera lenses have been revolutionized in the past decade. Right now cameras are much more capable and powerful than their predecessors. The next imaging breakpoint will likely be VR spatial videos, and we shall see what these manufacturers will do on this new competition field.

### Reference

Adorama. (2022, October 3). *What is a BSI sensor (back side-illuminated sensor)?*. Adorama. https://www.adorama.com/alc/faq-whats-a-back-side-illuminated-sensor/

ARRI. (2022). *Alexa 35: Camera systems*. ARRI. https://www.arri.com/en/camera-systems/cameras/alexa-35

Blackmagic Design. (2014, February 10). *Products*. Blackmagic Design. https://www.blackmagicdesign.com/media/release/20140210-01

Butler, R. (2023, November 10). *What is global shutter: 3 ways it can change photography*. DPReview. https://www.dpreview.com/learn/6348932189/what-is-global-shutter

Canon. (2016). *Canon support for EOS-1D X mark II: Canon U.S.A., Inc..* Canon. https://www.usa.canon.com/support/p/eos-1d-x-mark-ii

Canon. (2021). Specifications - canon global. https://downloads.canon.com/change/RF5.2mm\_F2.8\_L\_Dual\_Fisheye\_Downloadable\_Spec\_Sheet.pdf

Canon. (2021, April 14). *Canon announces development of the EOS R3 full-frame mirrorless camera that delivers high speed, high sensitivity and high reliability to expand users’ range of photographic possibilities*. Canon Global. https://global.canon/en/news/2021/20210414.html

Canon. (2023). *RF100-300mm F2.8 L IS USM*. Shop Canon RF100-300mm F2.8 L IS USM | Canon U.S.A., Inc. https://www.usa.canon.com/shop/p/rf100-300mm-f2-8-l-is-usm

Canon. (2023). *RF24-105mm F2.8 L IS USM Z*. Shop Canon RF24-105mm F2.8 L IS USM Z | Canon U.S.A., Inc. https://www.usa.canon.com/shop/p/rf24-105mm-f2-8-l-is-usm-z

Chapman, A. (2019, July 12). *X-OCN and S-LOG3 - A tech talk*. Sony Cine. https://sonycine.com/articles/x-ocn-and-s-log3---a-tech-talk/

DPReview. (2013, October 16). *Sony announces A7 and A7R: First full-frame mirrorless cameras*. https://www.dpreview.com/articles/9946986042/sony-announces-first-full-frame-mirrorless-ilc-cameras-a7-and-a7r

Dros, A. (2023, June 24). *The Sony Xperia 1 V is amazing in low light!*. albert. https://www.albertdros.com/post/the-xperia-1-v-is-amazing-in-low-light

FUJIFILM. (2022). *Specifications: Cameras FUJIFILM X-H2*. FUJIFILM X Series & GFX – Global. https://fujifilm-x.com/global/products/cameras/x-h2/specifications/

JimK. (2016, March 11). *Sony A6300 - RN vs Iso - The Last word*. the last word - Photography meets digital computer technology. Photography wins -- most of the time. https://blog.kasson.com/the-last-word/sony-a6300-rn-vs-iso/

Mansurov, N. (2020, April 25). *How phase detection autofocus works*. Photography Life. https://photographylife.com/how-phase-detection-autofocus-works

NEW CAMERA. (2023, May 12). *What is Stacked CMOS Sensor?*. Thenewcamera.com. http://thenewcamera.com/what-is-stacked-cmos-sensor/

Nikon. (2021, October 28). *Nikon releases the Z 9 full-frame Mirrorless Camera: News: Nikon about Us*. Nikon. https://www.nikon.com/company/news/2021/1028\_mirrorless\_01.html

Panasonic. (n.d.). *Panasonic dual native ISO camera technology for cinematic low-light video production*. Panasonic USA. https://na.panasonic.com/us/audio-video-solutions/broadcast-cinema-pro-video/dual-native-iso-camera-technology-cinematic-low-light-video-production

Red Digital Cinema. (2023, May 16). *Red Digital Cinema introduces new Komodo-X*. Red Digital Cinema. https://www.red.com/stories/komodo-x-launch

Samsung Semiconductor Global. (2023). *ISOCELL HP2: Mobile image sensor*. Samsung Semiconductor Global. https://semiconductor.samsung.com/image-sensor/mobile-image-sensor/isocell-hp2/

Shawn. (2022, November 9). *Ois vs ibis, which is better?*. Learn Photography Skills. https://www.learnphotographyskills.com/ois-vs-ibis-which-is-better/

Sony Alpha Universe || Sony Electronics, Inc. (2023, November 7). *Sony releases the alpha 9 III full-frame camera with global shutter system*. Sony | Alpha Universe. https://alphauniverse.com/stories/sony-releases-the-alpha-9-iii-fullframe-camera-with-global-shutter-system/

Sony Electronics. (2014, November 26). *Sony introduces the A7II, the world’s first full-frame camera with 5-axis image stabilization*. PR Newswire: press release distribution, targeting, monitoring and marketing. https://www.prnewswire.com/news-releases/sony-introduces-the-a7ii-the-worlds-first-full-frame-camera-with-5-axis-image-stabilization-300001547.html

Sony Electronics. (2015, June 10). *Sony’s new A7R II camera delivers innovative imaging experience with world’s first back-illuminated 35mm full-frame sensor*. Sony Group Portal - Home. https://www.sony.com/content/sony/en/en\_us/SCA/company-news/press-releases/sony-electronics/2015/sonys-new-a7r-ii-camera-delivers-innovative-imaging-experience-with-worlds-first-backilluminated-35mm-fullframe-sensor.html

Sony Electronics. (2016, February 3). *Sony introduces new α6300 camera with world’s fastest autofocus*. Sony Group Portal - Home. https://www.sony.com/content/sony/en/en\_us/SCA/company-news/press-releases/sony-electronics/2016/sony-introduces-new-6300-camera-with-worlds-fastest-autofocus.html

Sony Electronics. (2017, April 19). *Sony’s new α9 camera revolutionizes the professional imaging market*. Sony Group Portal - Home. https://www.sony.com/content/sony/en/en\_us/SCA/company-news/press-releases/sony-electronics/2017/sonys-new-9-camera-revolutionizes-the-professional-imaging-market.html

Sony Electronics. (2019). *Sony Α7R IV 35mm full-frame camera with 61.0MP*. Sony. https://www.sony.co.uk/electronics/interchangeable-lens-cameras/ilce-7rm4/specifications

Sony Electronics. (2023, May 11). *Sony Electronics launches New Xperia® 1 v smartphone*. Sony Group Portal - Home. https://www.sony.com/content/sony/en/en\_us/SCA/company-news/press-releases/sony-electronics/2023/sony-electronics-launches-new-xperia-1-v-smartphone.html

Sony Electronics. (n.d.). *Specifications*. ILCE-6300 Specifications | Sony USA. https://www.sony.com/electronics/support/e-mount-body-ilce-6000-series/ilce-6300/specifications

Sony Pro. (2023). *Burano Digital Cinema Camera with 8K Sensor - Sony pro*. Digital Cinema Camera with 8K sensor - Sony Pro. https://pro.sony/ue\_US/products/digital-cinema-cameras/burano

Sony Semiconductor Solutions Group. (n.d.). *PDAF*（*phase detection auto focus*）*: Technology*. Sony Semiconductor Solutions Group. https://www.sony-semicon.com/en/technology/camera/index.html

Sony. (2018, February 27). *Sony expands full-frame mirrorless line-up with new A7 III with the latest imaging technologies all compressed into a compact package*. Sony Asia Pacific. https://www.sony-asia.com/pressrelease?prName=sony-full-frame-mirrorless-a7m3