

PUSHING THE BOUNDARIES OF DIGITAL IMAGING

PUSHING THE BOUNDARIES OF DIGITAL IMAGING

This whitepaper introduces Nokia Lumia 1020 and its new hardware and software camera innovations. The Nokia Lumia 1020 re-invents zoom by combining a very large sensor with OIS for the first time. Also it pushes the boundaries of smartphone creative photography with a new intuitive touch UI that provides manual controls for shutter speed and other controls.

This whitepaper provides a background on how our Pure-View technology has evolved, and then introduces the new HW (sensor, lenses, OIS) and describes the evolved zoom. Nokia Pro Camera UI and its manual controls are introduced together with a new method of lossless editing of your images.

CONTENTS

Background.....	4
Best of both worlds: Sharpness and low light.....	4
Sharpness is more than just megapixels.....	5
Why 5MP?.....	5
Oversampling results in 5MP photos with amazing detail.....	6
High resolution zoom.....	6
Getting rid of hand-shake.....	8
Photos in the dark.....	8
Back side illuminated sensor.....	9
Exposure time.....	9
Flash.....	9
Real life sharpness measurement.....	9
Nokia Pro Camera.....	11
Zoom reinvented and reframing.....	12
Photography tools and creative control.....	14
Manual controls: EV, shutter speed, ISO, focus, WB.....	15
Nokia Pro Camera Video.....	16
Nokia Rich Recording.....	16
Photo examples.....	18
Key technologies and specs.....	21
Credits.....	22

BACKGROUND

The Nokia 808 PureView camera phone, launched in 2012, included world-leading advances in image quality in terms of resolution, sharpness and clarity. Innovative oversampling technology provided a level of image detail previously unseen in mobile, or even small scale, digital imaging systems. In addition, pixel oversampling combined many pixels to create a single super-pixel. This allowed us to keep virtually all the detail but to filter visual noise away from the image. Images looked more natural and were purer, giving a more accurate representation of the original subject than had ever been achieved before.

Nokia 808 PureView was pioneering and provided benchmark image quality. We received extremely positive feedback but users kept challenging us for even better low light imaging capabilities, especially without flash. This feedback influenced the development of our second generation PureView phone – the Nokia Lumia 920 PureView.

The Nokia Lumia 920 was the first global smartphone to implement optical image stabilization (OIS) to set a benchmark in low light image quality. We implemented a back-side-illuminated (BSI) sensor with f2.0 aperture, optical image stabilisation and the most sensitive pixels seen in a camera. All this was built on top of the Windows Phone 8 platform for seamless social media sharing, and equipped with Nokia's own state-of-the-art imaging algorithms. This allowed the Nokia Lumia 920 – and the more recently announced Lumia 925 and 928 – to revolutionise low light imaging.

In 2013 we had two kinds of camera phone in our PureView range, providing imaging capabilities previously unseen in mobile, each one leading different areas of digital imaging. One provided benchmark performance in capturing details, and another set records in low light imaging. The natural next step was to take those two



Figure 1. The latest generation BSI sensor captures a lot of light. Illustration only.

award-winning PureView innovations as the starting point to create the ultimate next generation imaging smartphone. Let us introduce the Nokia Lumia 1020.

BEST OF BOTH WORLDS: SHARPNESS AND LOW LIGHT

The second generation 41 megapixel sensor uses the latest generation 1.1 micron back-side-illuminated (BSI) pixels, providing excellent noise performance as well as benchmark resolution. The sensor format is 1/1.5" and it is up to five times larger than typical smartphone sensors. The redesigned sensor provides all the imaging innovations introduced with Nokia 808 PureView

– meaning high resolution zooming and pixel oversampling – plus new innovations in a revised, more modern camera module.

The Nokia Lumia 1020 introduces the second generation of our optical image stabilization (OIS) system first found in the Lumia 920 PureView, to provide a new benchmark in image stabilisation systems. We include the most sophisticated xenon flash and video-light LED implemented on any Nokia phone to help users freeze the moment.

One of the critical design decisions in a camera is balancing the subjective image sharpness and noise performance. Image sharpness and low light performance (noise or grain) are two sides of the same coin in camera

systems and it is extremely difficult to achieve benchmark performance in both simultaneously. However this is exactly what we have done with the Nokia Lumia 1020.

Sharpness is more than just megapixels

Resolution is the sum of several parts in the imaging chain, starting from how we capture images, how much hand-shake is involved, and ending with technical functions including the camera optics, the image sensor, and the algorithms. It's not enough to just include a high megapixel sensor – the lenses conveying the image to the sensor have to be of equally high quality.

Together with our partner Carl Zeiss, we yet again pushed the limits of optical design to match the resolution of the 41 megapixel camera sensor. To provide the best optical resolution we increased the number of lenses used from the five in the award-winning Nokia 808 PureView, to six. The first lens element is made of high precision glass, and five of the lenses are moulded high-performance plastic, taking lens manufacturing precision to the next level.

The lenses are physically very big for a smartphone, and the optical assembly alone is unique. But that is not all. We put the whole system inside a completely new kind of optical image stabilisation system, which uses an extremely high accuracy sensing system linked to very small motors which actively move the lens.

The extremely sharp image projected by the six-element lens system is recorded by the second generation 41MP BSI sensor, capturing even the smallest of details in the scene, including detail not visible to the naked eye.

The 41MP sensor can capture 34MP and 38MP image files at 16:9 and 4:3 aspect ratios respectively. In addi-

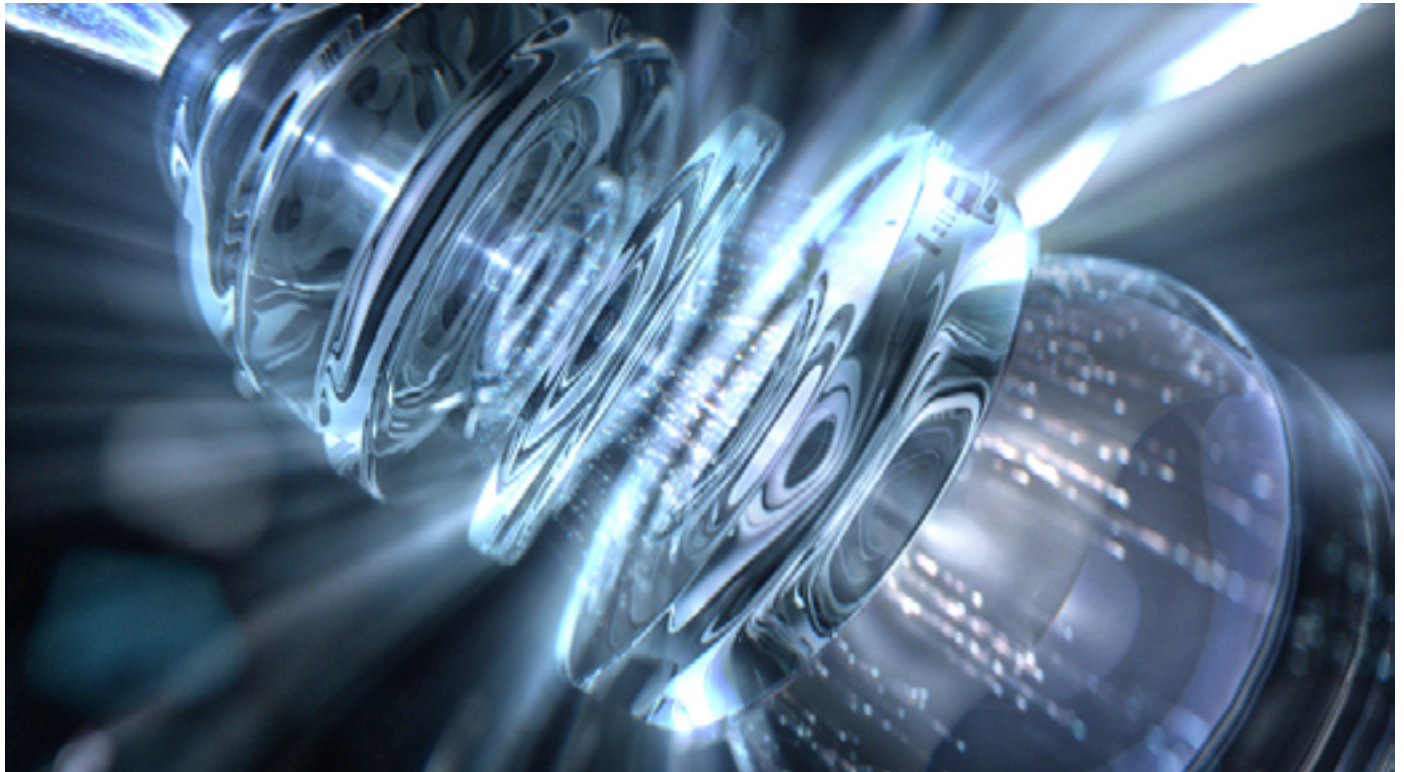


Figure 2. Six Carl Zeiss lenses including a high-precision glass element. Illustration only.

tion to the 38MP and 34MP full-resolution images, the Lumia 1020 camera captures 5MP oversampled images so that every pixel in the 5MP image has been created using the data from up to seven pixels of the sensor. The oversampling technology ensures that these 5MP images are incredibly sharp, natural and low noise. The best part is that the camera saves both the full resolution and oversampled image simultaneously.

This is referred to as dual capture. It enables creative post-processing while still allowing users to share a high-quality small file size image straight after shooting.

Why 5MP?

5MP is the sweet spot for image quality that is easy to share and printable up to A3 size. And because our 5MP images condense the information from the 41MP sensor, they have amazingly high image quality.

The 5MP images get the full benefit of the oversampling technology and their quality is way above that produced by any traditional imaging device. In addition to oversampling, the 41MP sensor can also be used for lossless or high resolution zooming (see page 6).

Oversampling results in 5MP photos with amazing detail

In traditional imaging systems, the true resolution of the system is lower than that of the nominal sensor resolution. The traditional camera sensor resolution may be 5MP, but it does not really capture photos that have five million pixels of independent data. The data is spread across multiple pixels causing, for example, blurring and artifacts. There are two technical reasons for this: one is related to the optics design and aliasing, and the other to the way the sensor samples the data with Bayer colour filters. A traditional 5MP camera has only 2.5 million green pixels and 1.25 million red and blue pixels¹ for example. See Figure 3 for a comparison in sharpness of a standard 5MP image versus an oversampled 5MP image and Figure 4 for an illustration of how oversampling reduces noise compared with a standard sensor.

The oversampling technology in the Lumia 1020 makes it possible to solve both of these issues, and enables full details to be captured with the 5MP image, visible as amazing sharpness, naturalness and low noise. It is physically impossible to capture this with a traditional 5MP camera.

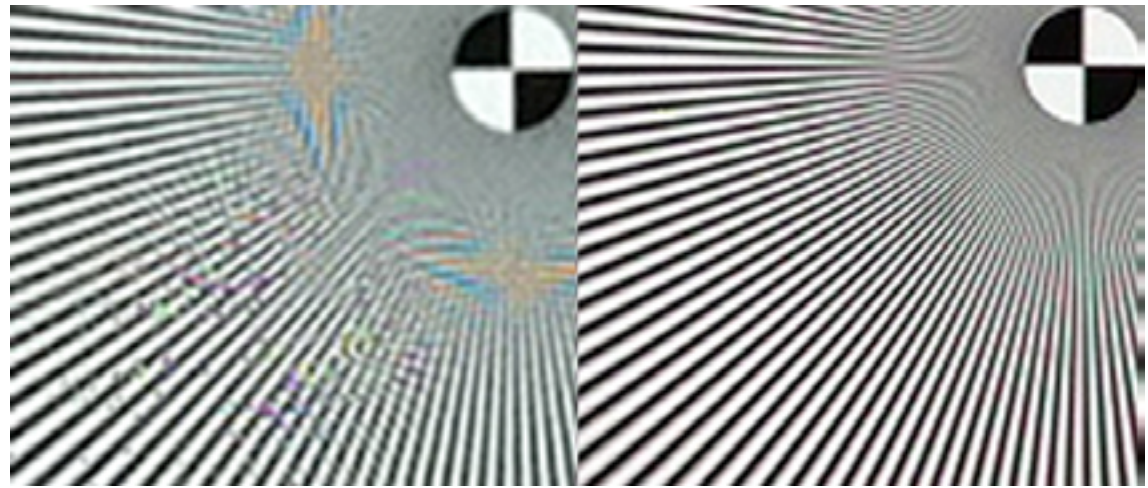
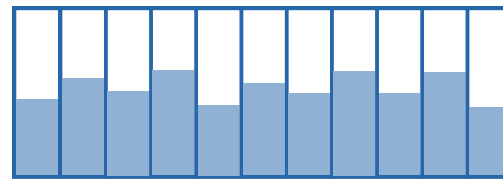
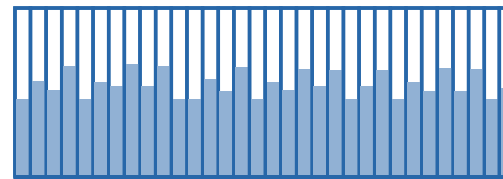


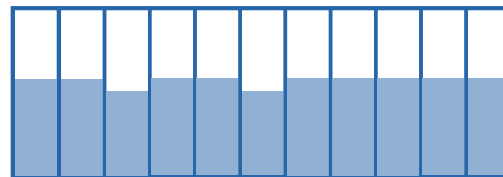
Figure 3. Comparison of a standard 5MP image and an oversampled 5MP image.



Output from a standard 5MP sensor shows noise as variance in the signal



Output from a high resolution sensor before oversampling



Output after oversampling reduces the noise

Figure 4. Illustration of how oversampling reduces noise compared with a standard 5MP sensor

High resolution zoom

In addition to oversampling, the large sensor also allows for high resolution zoom. As you zoom there is no drop in the default 5MP resolution; in other words the high resolution zoom is lossless. The level of pixel oversampling is highest when you're not using the zoom. It gradually decreases until you hit maximum zoom where the pixels start behaving in a more conventional way. The relationship between zoom level and oversampling is shown in Figure 5.

At maximum zoom, the Lumia 1020 system behaves more like a traditional camera, but there are still some advantages: as only the center part of the optics is used, the optical and geometric distortions are minimal and vignetting is negligible.

The problem with traditional digital zoom is that the zoom level is extremely limited without clearly visible loss of image details. This happens because the system needs to zoom further than the required output resolution of the final image, and the camera needs to upscale the captured image to achieve that resolution. In practice this means that, for example, a 12MP device might capture only 4MP after zooming, and the 4MP image is then digitally up-scaled back to 12MP. This up-scaling has a significant impact on image sharpness. However with Nokia Lumia 1020 we never need to upscale the final images, because the starting resolution is already so massive. In Full HD video mode the massive resolution means that the camera never zooms further than the required two megapixels, which ensures that the resolution stays excellent throughout the zoom range.

The advanced PureView method of lossless zooming also provides multiple benefits over traditional optical zoom. Traditionally the aperture of optical zoom systems becomes significantly smaller towards the long end of the zoom range compared to the wide end. This has a big impact on low light performance and usable exposure

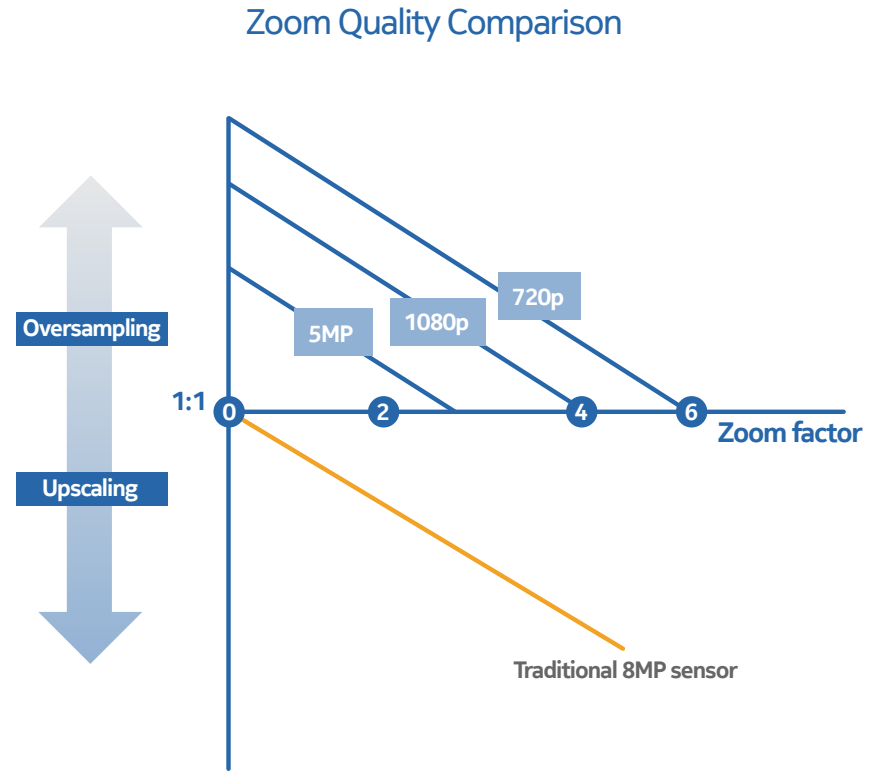


Figure 5. Oversampling vs. high resolution zoom in the case of Lumia 1020 (blue) compared with conventional digital zoom (orange). High oversampling means high image quality.

times. Also with traditional zoom lenses the macro distance often changes while zooming, which means that the photographer needs to change the physical camera-to-object distance while zooming for macro shots. In addition, most optical zoom lenses suffer from overall reduced sharpness towards the long end of the zoom range; this is because of optical design issues that often produce different distortions at the wide angle end compared to those at the telephoto end of the zoom range, which in the case of Full HD is up to 4X. See Figure 6 for a visual on the maximum high resolution zoom for 5MP (3X) and 720P video (6X) compared with the full resolution sensor in 16:9 and 4:3 aspect ratios.

However with Nokia Lumia 1020, the aperture stays at a constant f2.2 throughout the zoom range which is, in SLR terms, 25/27-69/74mm (16:9/4:3) for stills and 25-100mm for Full HD video. These zoom range/aperture combinations are rare, and expensive even in the SLR world.

Also as the aperture stays the same throughout the zoom range in the Lumia 1020, the macro distance of ~15cm also stays the same. With Nokia Lumia 1020 we are actually using the centre part of the lens where distortions, diffractions and lens shading are smallest, giving extremely high levels of resolved details and distortion-free images and videos throughout the zoom range.

The advantages of the Nokia Lumia 1020 zoom compared to an optical zoom are:

- The aperture size of a typical optical zoom drops dramatically when zoomed in. For example, a typical optical zoom can have aperture size f2.8 in wide, but it can drop to f6 in tele. This means that the camera needs almost a five times longer exposure time in the tele position. The problem is multiplied by the fact that the camera is most prone to hand-shake in the tele position – and the user should actually use shorter exposure times to avoid blurred images. In the Lumia 1020, the aperture size and exposure times stay the same throughout the zoom range.
- The smaller aperture size required for telephoto shots with an optical zoom camera increases diffraction which can make images blurry even when there is no hand-shake.
- The optics in Lumia 1020 are simplified and robust compared to optical zoom – a key enabler for the amazing image sharpness.
- As the Nokia Lumia 1020 is based on a huge image sensor, it enables much higher performance and oversampling in the wide-angle position.
- Lumia 1020 macro distance stays the same throughout the zoom range.
- As the zooming is done without mechanically moving any parts, it is silent, fast, and intuitive. Additionally the Lumia 1020 slide zoom can be operated by using one hand only.
- Dual capture allows for post capture zooming and reframing . More on this in the reframing section on page 12

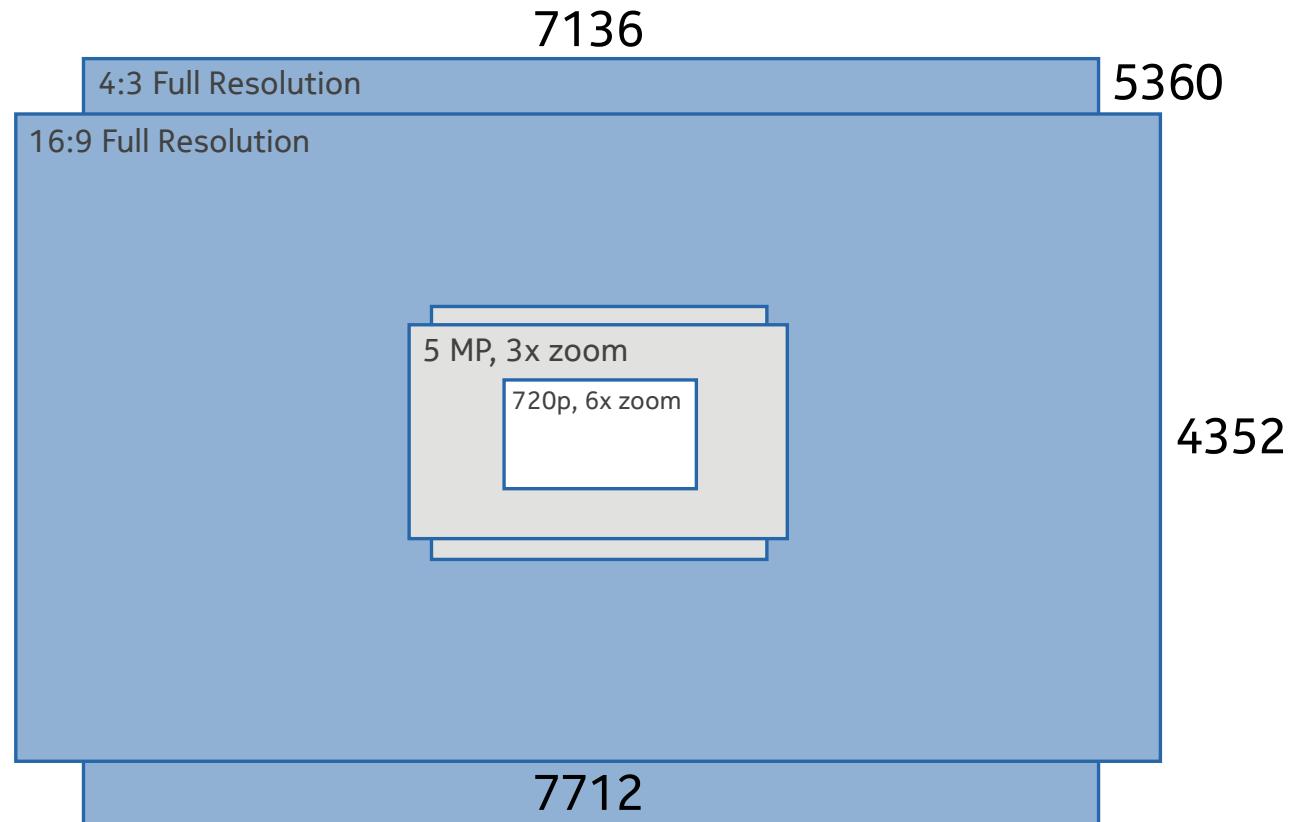


Figure 6. The high resolution zoom is limited to 3X for stills, ensuring that the output is 5MP. Full HD video can be zoomed 4X whereas 720P video has 6X zoom.

Getting rid of hand-shake

Lens design and sensor resolution are often the only factors considered when discussing camera sharpness, but an equally important factor is totally neglected – hand-shake. Even the sharpest optical systems in the world can't capture a sharp image if the camera is moved during capture. We have implemented a completely new OIS system to overcome this. In traditional SLR OIS systems just one lens element in the lens stack is moved to counteract hand-shake, but in our OIS the whole optical assembly is moved to cancel out unwanted camera movements. What

this means is that we are able to cancel out larger movements compared to traditional OIS systems, enabling super-sharp images.

Technically our OIS is the barrel shift type first seen in the Nokia Lumia 920. (Other ways of making optical image stabilisation systems include barrel tilt, sensor tilt or module tilt, but for our purposes barrel shift gives the best quality.) In the Lumia 1020 the optics are much bigger, and adding OIS technology to optics of that size required some really clever engineering: the whole lens system is resting on top of ball bearings and is actively

moved with very small motors to counteract the unwanted camera movements detected by a gyroscope.

If you lightly wobble the phone and listen to the camera, you can actually hear the module that absorbs the shaking of your hand. Once the camera is activated, give the phone the same wobble and the magnets kick in and soak up the movements.

Photos in the dark

The standard factor used for determining good low light performance is the amount of visible noise in the image captured. But there is a lot more to it than just the amount of noise.

Back side illuminated sensor

It is extremely difficult to make a high resolution sensor with just a small amount of visible noise because pixels must be kept small to keep the sensor size reasonable. The smaller pixel size is especially problematic with traditional front side illuminated (FSI) sensors, because each pixel needs many wires to power up the photo diode and

to transfer the photons out from the pixel. With traditional pixels all these wires are located on top of the pixels and light must bypass the wires to reach the photosensitive area of the pixel. We used a modern-generation BSI sensor where all these wires are located underneath the pixel. With this design a significantly larger amount of light can actually reach the photosensitive area of the pixel. This again means that we can amplify the signal created by much lower levels of light, significantly reducing the amount of visible noise.

Exposure time

Another extremely important factor contributing to low light performance is the exposure time. A camera can be compared to a dam where the shutter plays the role of the gate. The longer the gate is open, the more water can flow through it. In a camera, the longer the shutter is open the more light can be gathered by the sensor.

However, if the shutter is open too long, the captured image can suffer from hand-shake, which means reduced sharpness. With its OIS system, the Nokia Lumia 1020 camera can actually tolerate up to of 3-5 times longer exposure times compared to traditional mobile cameras – a significant benefit in low light situations. Using the Lumia 1020 together with a tripod, users can manually set the exposure time up to 4s, which allows you to take amazing images in nearly complete darkness.

Flash

When discussing low light performance it's only natural to also consider the flash. Even though many prefer the natural ambient feeling in images captured without flash, even with the very best of cameras we occasionally run into situations where the use of flash is mandatory, especially if the target is moving. Flash performance is often assessed by comparing the light output of different flashes, however flash pulse duration is an equally important parameter to consider.

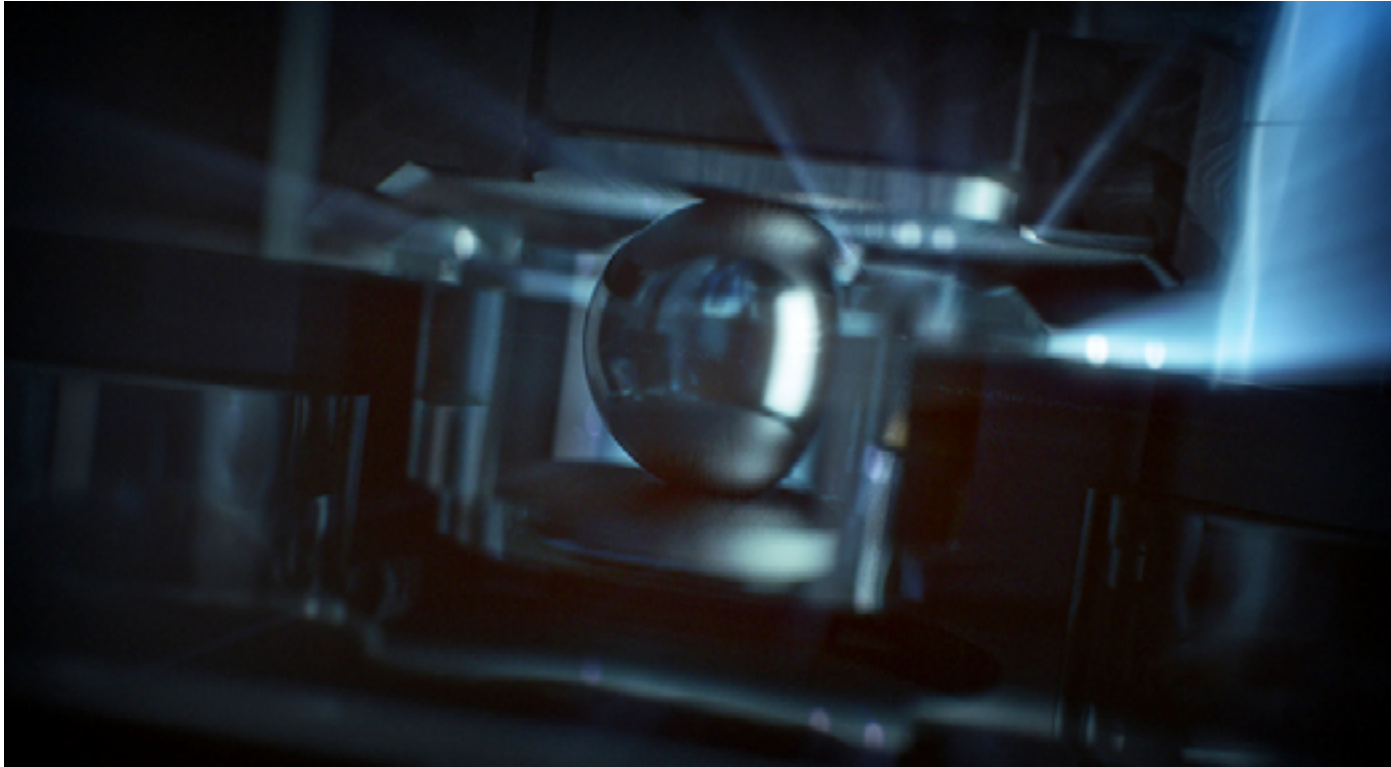


Figure 7. Clever engineering: Ball bearings float the large lens system. Illustration only.

With the Lumia 1020 we use a no-compromise xenon flash with very high light output and extremely short flash pulse duration. High flash output provides excellent illumination to targets three metres away, and the short pulse of the xenon flash ensures that the final captured image is extremely sharp while preserving the ambient lighting of the background.

Real life sharpness measurement

Image sharpness is usually measured using a tripod (an accessory that the average person rarely carries) in good lighting conditions (also a luxury). We replicated real life situations, using a hand-shake simulator running at 4Hz frequency, with the Nokia Lumia 1020 challenging a market leading 13MP device in multiple lighting conditions. The Lumia 1020 was tested using the more 'shareable' 5MP images and the measurements were done from centre frame for both devices. The results are depicted in Figure 8. The graph shows that Nokia Lumia 1020 resolves very close to the theoretical maximum of the 5MP image in good lighting conditions, but what is even more remarkable is that because of the combination of OIS and xenon flash we can provide practically the same huge resolution also in extremely dark conditions. And this was measured while introducing handshake to the device! Even without help from the xenon flash the resolution never drops below 50 percent of the theoretical maximum.

In low light conditions the competitor device was only able to provide around 10 percent of its theoretical maximum resolution, and even in really bright lighting conditions only 40 percent of its capability was used. So one might ask, why use 13 megapixels, if only 10 percent of the theoretical resolution can be used?

We have explained how image quality, sharpness and good low light imaging capability are a result of multiple features and the whole imaging chain working seamlessly together.

Image sharpness measured with handshake as function of illuminance

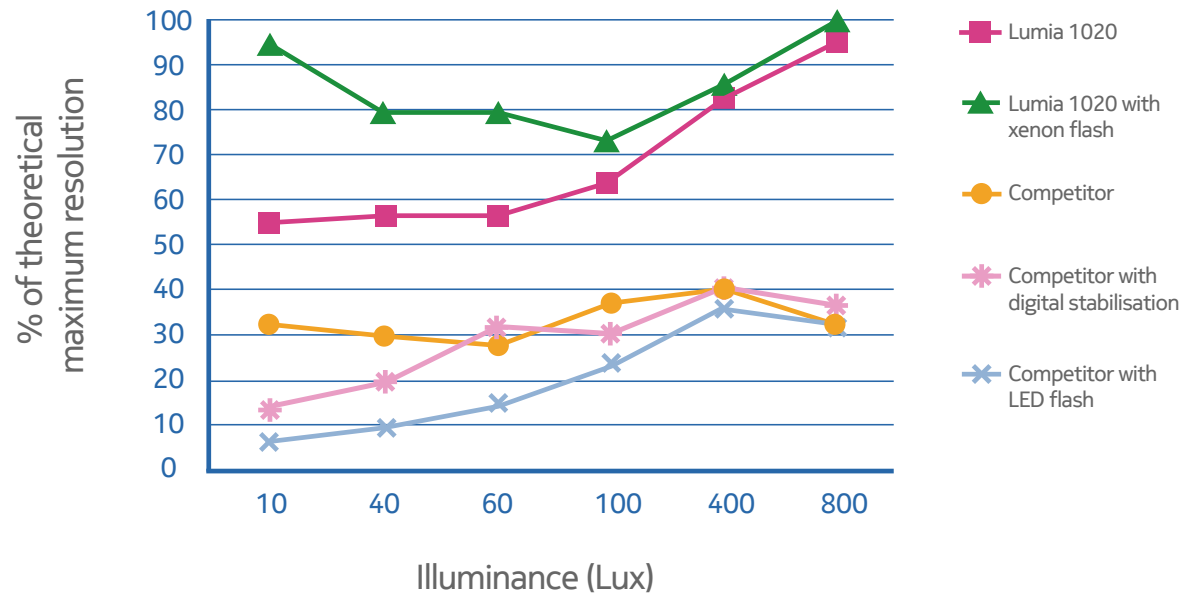


Figure 8. Image sharpness, during simulated 4Hz 0.5 degree hand-shake, as a function of illuminance. The results are shown for Lumia 1020 with/without flash and for a leading competitor device with and without flash as well as with digital stabilisation.

Image quality is not only about megapixels but also about carefully optimising the whole imaging system to let people capture moments that matter the most - wherever, whenever.

NOKIA PRO CAMERA

"You don't take a photograph, you make it."

- Ansel Adams

To make the most out of the innovative hardware in the Nokia Lumia 1020 we have designed a new camera application called Nokia Pro Camera. It helps you to create the photo you want, and to become a better photographer. It is filled with features previously only found in digital SLR cameras. Taking excellent photos has never been so easy, as complex settings are turned into easy adjustments with immediately visible results.

Nokia Pro Camera has image quality at its core. In the full-auto mode it is simple to use, but if you want to take more control it offers a powerful UI with access to manual controls for creative photography. With the Lumia 1020, Nokia Pro Camera also introduces dual capture, which means that in addition to the quality optimised 5MP image, the original full resolution image is also stored. This allows reframing, which we describe below.

Nokia Pro Camera also revolutionises user-generated video content by offering superior Full HD video quality with hi-fidelity stereo audio without distortion. Full HD video comes with 4X high-resolution zoom, which means you can zoom 4X without any drop in resolution, and for 720P it is 6X.

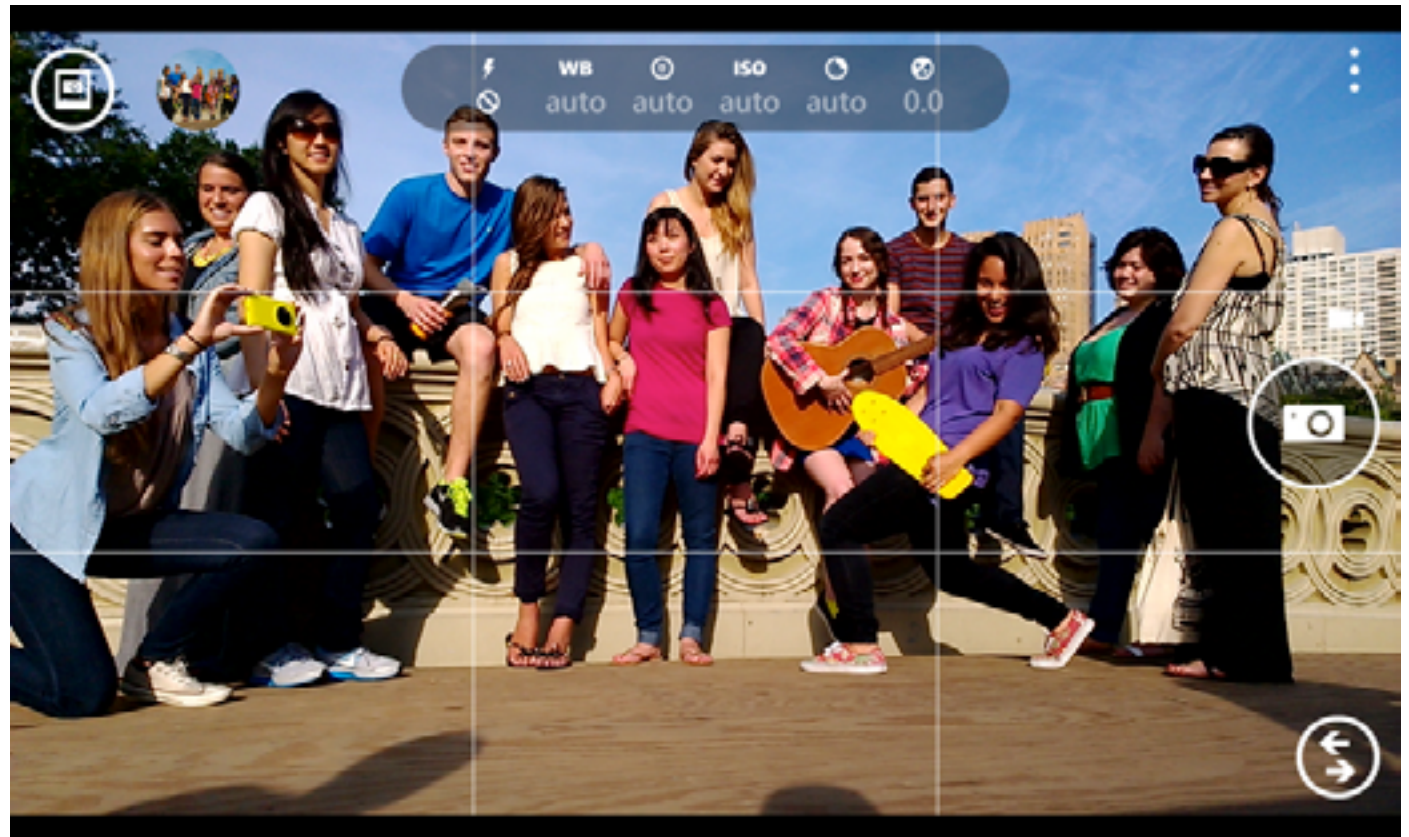


Figure 9. Nokia Pro Camera viewfinder

Zoom reinvented and reframing

For stills, the 3X high-resolution zoom has very high image quality, but what is even more interesting is what happens after the photo is taken.

By saving a full-resolution photo we can in fact zoom OUT or “un-zoom” from the 5MP image presented for easy sharing after capture, offering a unique way of zooming that has never been possible before. Unlike in optical zoom, the Lumia 1020 zoom is not permanent; you can open the photo afterwards and remove the zoom to reveal the full scene. And not only can you zoom out but you can also move around and zoom in to another part of the image, which can reveal details you did not see when you took the image. Find a new story within the full story!

Another benefit is that you can straighten a tilted scene without having to crop the sides and make the image smaller, or un-crop someone’s legs that you unintentionally cut off while shooting. An example of straightening and improving the composition is shown in figures 10 and 11.

Besides un-zooming and straightening, you can also zoom in, to discover details you might have missed during capture. The post-capture zoom can magnify the scene up to 25-31X (depending on aspect ratio). The 5MP resolution stays the same up until 3X zoom. After that the resolution drops as the graph in figure 12 shows.

One of the greatest benefits of the re-invented zoom is the reframing experience. It promotes creative storytelling by framing a small detail within a bigger story.

By always keeping the original full resolution image, you can reframe over and over again without losing any quality. The large Lumia 1020 sensor puts image quality first and creates a stunning detailed image in the wide



Figure 10. Saving the full resolution photo allows you to straighten and re-frame your image after capture without losing any corners. This is not possible with traditional digital zoom, nor with optical zoom.



Figure 11. After reframing: The photo is straightened using the full resolution original. The object is positioned according to the “rule of thirds”

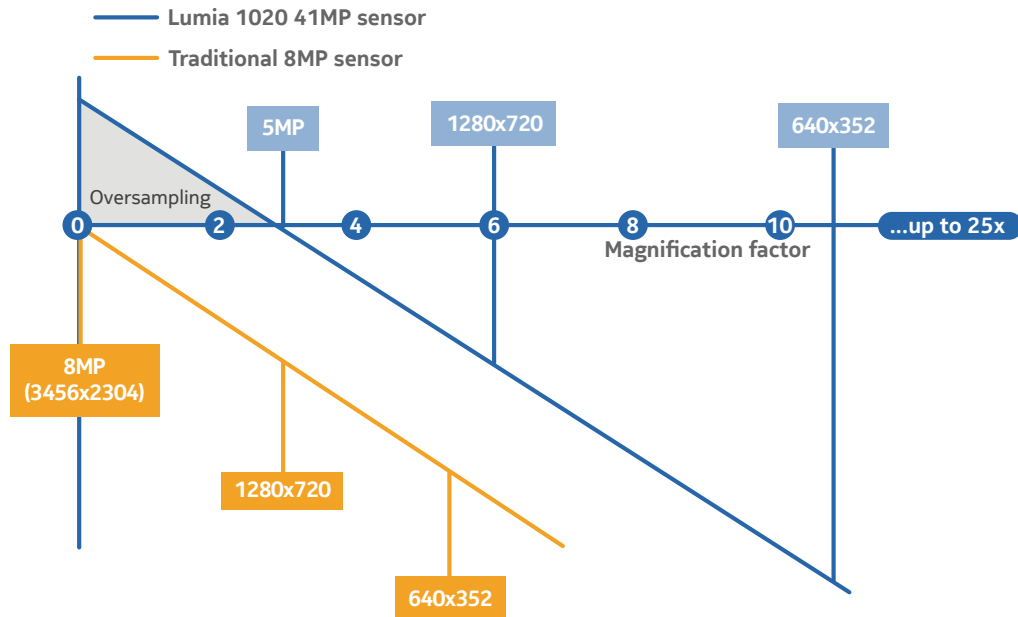


Figure 12. The high resolution zoom is not locked but can be zoomed out in the post-capture phase. Then magnification can be done all the way to 25X (or 31X for 4:3 images).

position, yet it allows for zooming too. Dual capture and zooming during or after capture are summarised in Figure 13.

You can zoom into every detail of a full resolution image, revealing detail you might have missed during capture, as shown in Figure 14.

You can toggle between the most popular aspect ratios such as 16:9, which is great for landscape, 4:3 which is good for portraits, 3:2 which is used by classical 35mm film situations, and the increasingly popular 1:1 square crop.

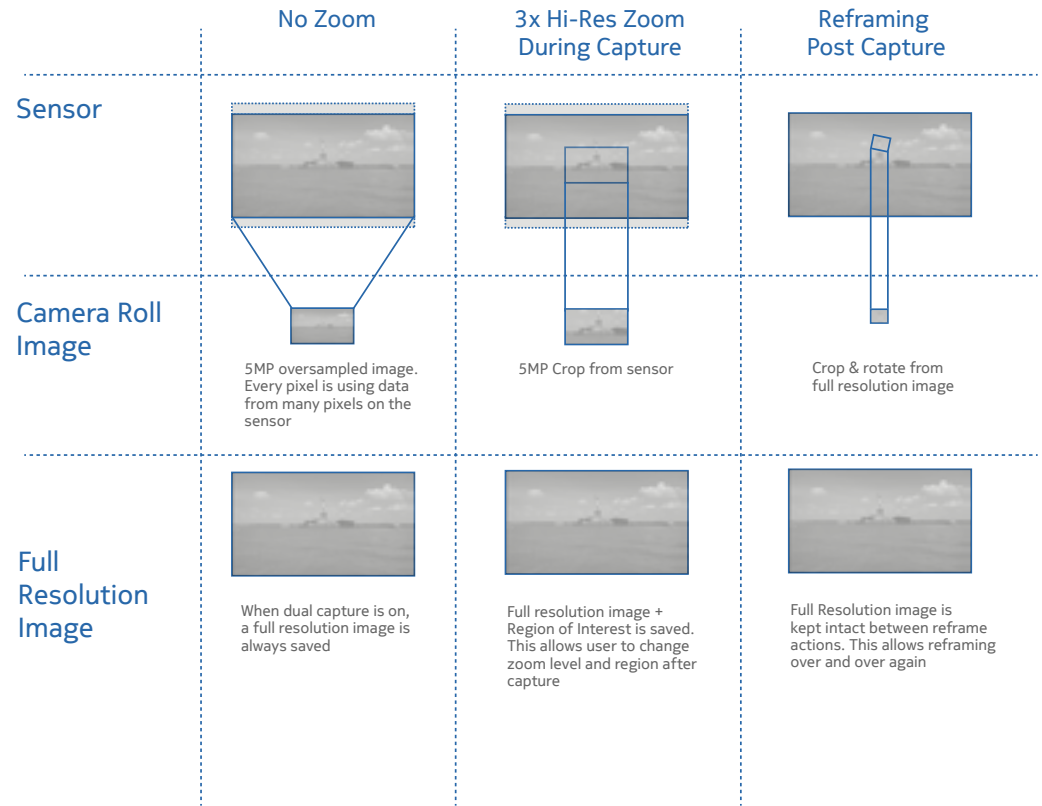


Figure 13. Dual captures saves two images, one oversampled 5MP image and one full resolution image. The full resolution image is stored for zooming out or for allowing after-capture reframing.

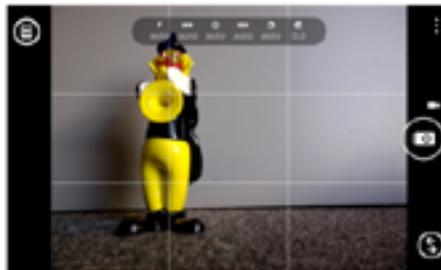


Figure 14. The high resolution zoom used while taking the photo is lossless and is 3X. The post-capture zoom allows for finding detail you might have otherwise missed.

Golden Ratio



Rule of Thirds



Square



Cross hairs



Figure 15. Rule of Thirds and Golden Ratio help make photos look visually pleasing in a classical way. Cross hairs helps with aligning the horizon correctly and Square helps you to compose if you intend to reframe it to 1:1 later.

Photography tools and creative control

To help you compose the shot, Nokia Pro Camera has a number of framing grids which can help place the subject in your photo. See figure 15.

On top of the viewfinder, you find a dashboard with indicators for all manual controls and their current settings. The default value of each control is auto but tapping the value brings up a control ring where you can adjust the value manually. You find a dashboard with indicators for all manual controls and their current settings (see Figure 16).

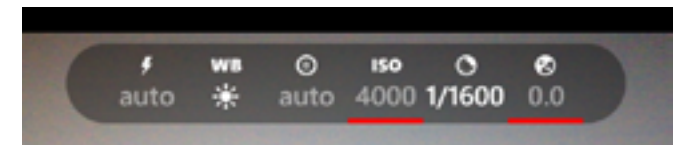


Figure 16. Dashboard with manual controls.

Controlling the flash is also done from the dashboard, and this also controls the focus light which is the lamp that helps the camera to find focus when it's dark. The settings for the flash are:

SETTING	FLASH	FOCUS LIGHT
Auto	Auto	Auto
On	On	Auto
Focus light only	Off	Auto
No focus light	Auto	Off
Off	Off	Off

If you put the flash to “focus light only” the flash is off but the focus assist light is on, which is great when you want to shoot sharp images without flash. With “no focus light”, flash works automatically but the focus light will not go off, and if you set it to “off”, both the flash and the focus assist light will be turned off which is good

if you are in a situation where you don't want to disturb anyone with the light from your phone.

Manual controls: EV, Shutter speed, ISO, Focus, WB

Nokia Pro Camera lets you take full control over your camera with a set of manual controls normally only found on advanced SLR cameras. Naturally the default for all controls is 'auto' but the UI is very intuitive and it helps you and encourages you to start experimenting with the controls so that you can become a better photographer.

EV stands for Exposure Value and it influences the brightness of the photo. The default value is 0 which means correct exposure for most situations. If you increase the EV it will make the picture brighter and you can see it in the viewfinder. This is great, for example, if your subject is in the shade, and you need to over expose. And if you slide it down, your photo will get darker, which is good if you want the sky to be dark blue. This is useful for example when you are at a concert and the stage is extremely bright compared to other areas. The EV can also be used creatively to make artistic-looking washed-out photos or silhouettes.

Shutter speed is also called Exposure Time, and defines how long the shutter is open to expose the sensor to light. You can set it to as low as one sixteen-thousandths of a second (1/16000s), which is good if you have a lot of light and want to freeze the motion. By setting the time all the way up to four seconds, you can capture amazing night shots like seeing the light streams from car lights.

ISO is how much the signal from the sensor is amplified. This is good when you don't have much light, but high ISO-numbers can introduce noise in the picture. In a dark situation with movement, you typically want to increase the ISO, to amplify the light, so that the camera

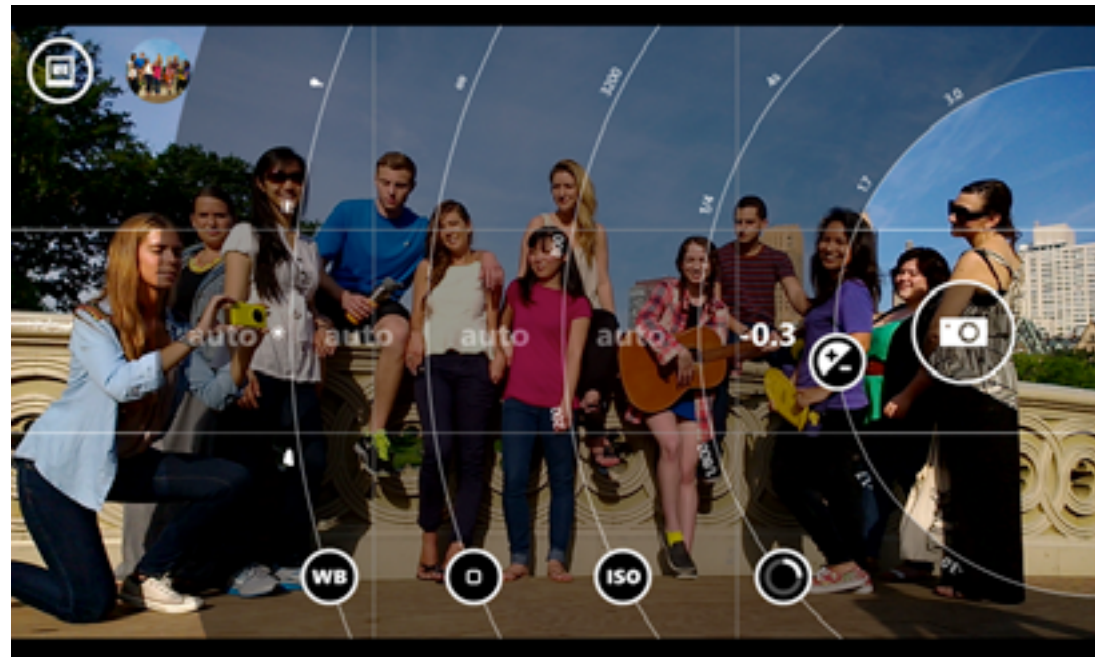


Figure 17. Nokia Pro Camera viewfinder with manual controls. From left to right: White balance, focus, ISO, shutter speed and EV.

does not have to keep the shutter open so long. Typically in daylight ISO 100 works well, and you might want to increase ISO to 800 in dark situations.

Focus: With focus you can set the focal plane manually from 15cm to infinity. If you lock it to infinity most things beyond 10m are in focus. The manual focus is great if you know how far away your subject is, and want to take a picture quickly, without having to wait for the AutoFocus (AF). Manual focus is also useful when you shoot close-up or macro shots, and when you want to lock the focus to a point the AF is not able to focus on.

WB: White balance controls what is white in your picture. What looks white depends on the light sources in the scene and sometimes you might prefer warmer or colder tones than those the camera automatically provides, so you can experiment with the manual settings. The Lumia 1020 includes settings for cloudy, sunshine, fluorescent and incandescent.

Indicators

An alternative way to access the controls is by sliding the digital shutter key on the screen to the left. This gives an overview of all the controls and their value. You can swipe the shutter key a second time to the left to reset all the values to auto.

To help you get the best shot, the Pro Camera UI also offers guidance. The camera will show you when you are about to over- or under-expose, by showing a value between -3 and +3 in the EV field on the top right. Some values of ISO and Shutter speed might result in noisy images or a lot of blur due to hand-shake or movement. This is indicated in the dashboard by an underlined value. You can also see what value the camera is going to use in the auto-mode.

If you're in a low-light situation and decide to increase the ISO manually, keep Shutter speed set to auto. In this mode, the indicators on the dashboard will show you what shutter speed the camera is going to use. This is because ISO, Shutter speed and EV are interdependent as described in the diagram in figure 18.

Nokia Pro Camera video

Nokia Pro Camera records video in two different resolutions, 1920x1080 (Full HD) or 1280x720, and also supports three different frame rates, 24, 25 and 30 frames per second (fps), depending on which region you are intending to play back the video in.

The video mode also offers zoom, which can be used while recording by sliding a finger up or down the screen. For Full HD, the zoom is 4X and for 720p it is 6X. The zoom is high resolution, which means it is completely lossless and the resolution doesn't drop at all while zooming – there is no loss of detail.

The indicator bar shows three manual controls. You can turn the video light on and off. You can set the white balance. You can lock the focus manually.

If you're in a concert with a seat far away from the stage, you can zoom in while recording video to see more than you can with your own eyes. The video can be uploaded straight from the phone to Facebook, Twitter and other social networks. You can also edit the video straight from the phone before uploading.

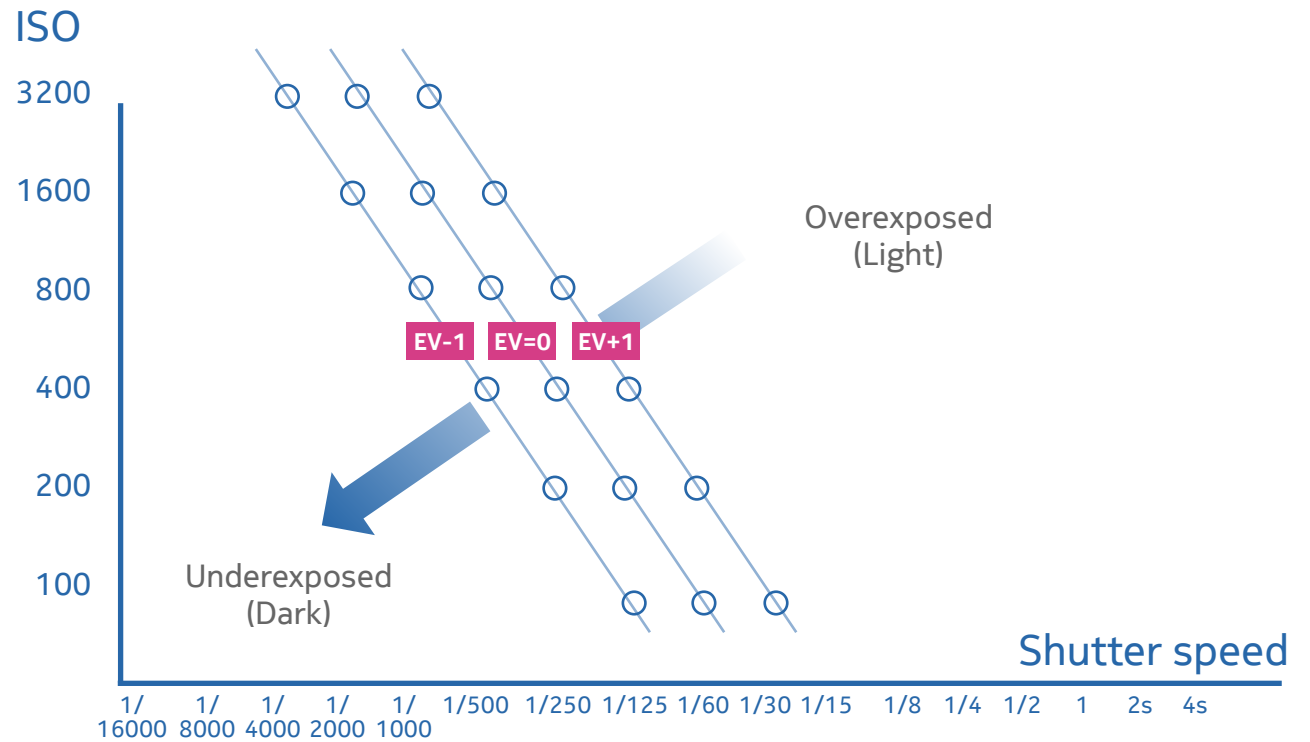


Figure 18. ISO, Shutter speed, and EV are interdependent

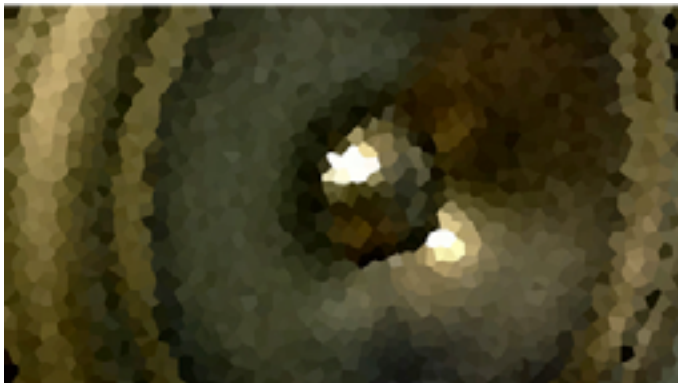


Figure 19. Conventional audio recording (on the left) vs. distortion-free Nokia Rich Recording (on the right). Illustration only.

Nokia Rich Recording

Sound quality is essential for high-quality video recording. In Nokia 808 PureView, we introduced Nokia Rich Recording, a technology developed exclusively to deliver the highest quality stereo audio recording. With Nokia Pro Camera Video we bring Nokia Rich Recording to Lumia 1020.

Nokia Rich Recording technology comprises two specially designed digital microphones with an extended dynamic range to handle high sound pressure levels. 32-bit arithmetics preserve the dynamic range in digital signal conditioning as well as acoustics design optimized for stereo image and full audio bandwidth.

Where the Lumia 1020 really excels is its ability to record high sound pressure levels such as when you are in a rock concert where the sound levels are high enough to be able to feel the bass. In such conditions conventional recording solutions fail by cutting off the low frequencies or clipping the signal entirely.

With Nokia Rich Recording you are able to record even the loudest concerts with good quality. It is possible to record about six times louder sound pressure level than with a conventional smartphone microphone. The result has to be heard to be believed - deep bass and bright treble without a note of distortion.

For more advanced users - based on the feedback from Nokia 808 PureView, we have provided a simple user interface to get the best from the hardware in different recording scenarios and applications.

Audio bass filter provides controls on the low frequency audio characteristics with three options:

The “Default” option is the best all-round setting and provides sonically balanced recordings in most conditions. It applies a shelf filter to 0...200Hz frequency band and works especially well in loud concert recordings, where the bass level can be too excessive for balanced playback.

The “Strong” option can become handy in the presence of wind-noise or in-car noise. It applies a 200Hz high-pass filter cutting effectively all low frequency content

from the recording.

The “Off” option is convenient for more advanced users who may want as flat a frequency response as possible for post editing. It extends the low frequency range down to around 20Hz without attenuation.

PHOTO EXAMPLES

The Nokia Lumia 1020 is designed to deliver the best possible results in real life situations. Be it a rocking sailing boat or a night club filled with motion. Unlike competing devices the Lumia 1020 delivers maximum resolution in all these situations.



Figure 20. Manual setting of the long exposure time emphasizes the busy atmosphere at Grand Central station. This image was taken with the Nokia Camera Grip and a tripod (1/3 s exposure time, ISO 100, and EV -0.7)



Figure 22. Capture great images at night: Freezing motion with xenon flash.



Figure 21. Capture great images with exceptional sharpness even on a rocking sailing boat. OIS keeps the images free from blur.



Figure 23. The Nokia Lumia 1020 41MP sensor enables capturing a tremendous amount of detail.



Figure 24. A woman drinking tea

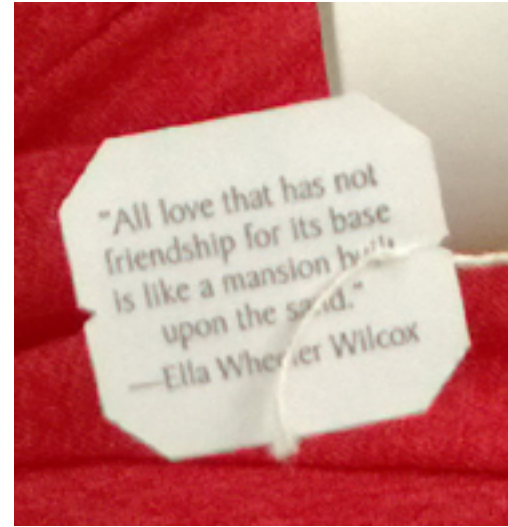


Figure 25. ...and her teabag tag.



Figure 26. Take control of shutter speed and create some breathtaking night scenes with light trails by exposing for up to 4s.

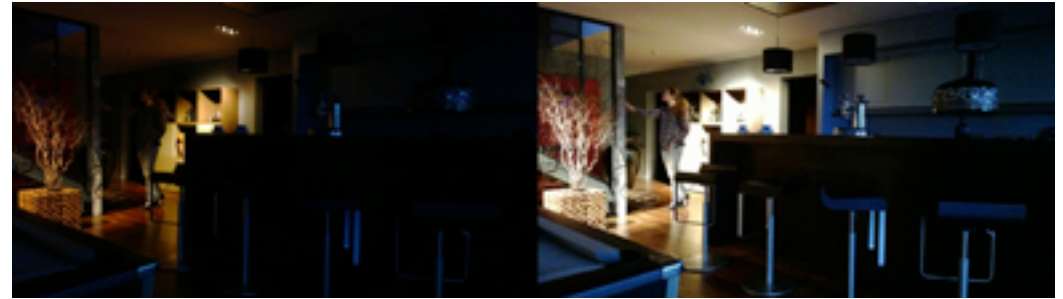


Figure 27. Crank the ISO up to 3200 to shoot brighter photos with higher shutter speeds.



Figure 28. Use exposure value creatively to play with light and to decide which areas are over- or under-exposed.



Figure 29. Manual focus makes it easy for you to experiment with distance. You can choose to have a nice Bokeh effect in the foreground or background.

KEY TECHNOLOGIES AND SPECS

- Latest generation high-performance BSI sensor
- Sensor size 1/1.5", 41MP, pixel size 1.1 micron, true 16:9/4:3 aspect ratio. Total sensor is 7712x5360=41.3MP. 16:9 mode is 7712x4352=33.6MP and 4:3 mode is 7136x5360=38.2MP. See Figure 30.
- 35mm equivalent focal length: 25mm for 16:9, 27mm for 4:3
- F-number: f/2.2
- Mechanical shutter
- Optical image stabilisation (new type of barrel shift actuator which enables moving a heavy and complex full lens assembly)
- System of 6 lenses (5 plastic molded high performance plastic, one high precision glass element)
- Nokia image processing and pixel oversampling technology
- Nokia-developed 3A algorithms (auto-exposure, auto-focus, auto-white-balance) to increase image quality
- New white balance technology
- New generation powerful xenon flash with flat capacitor technology which enables more power in a more compact package.
- Video LED light

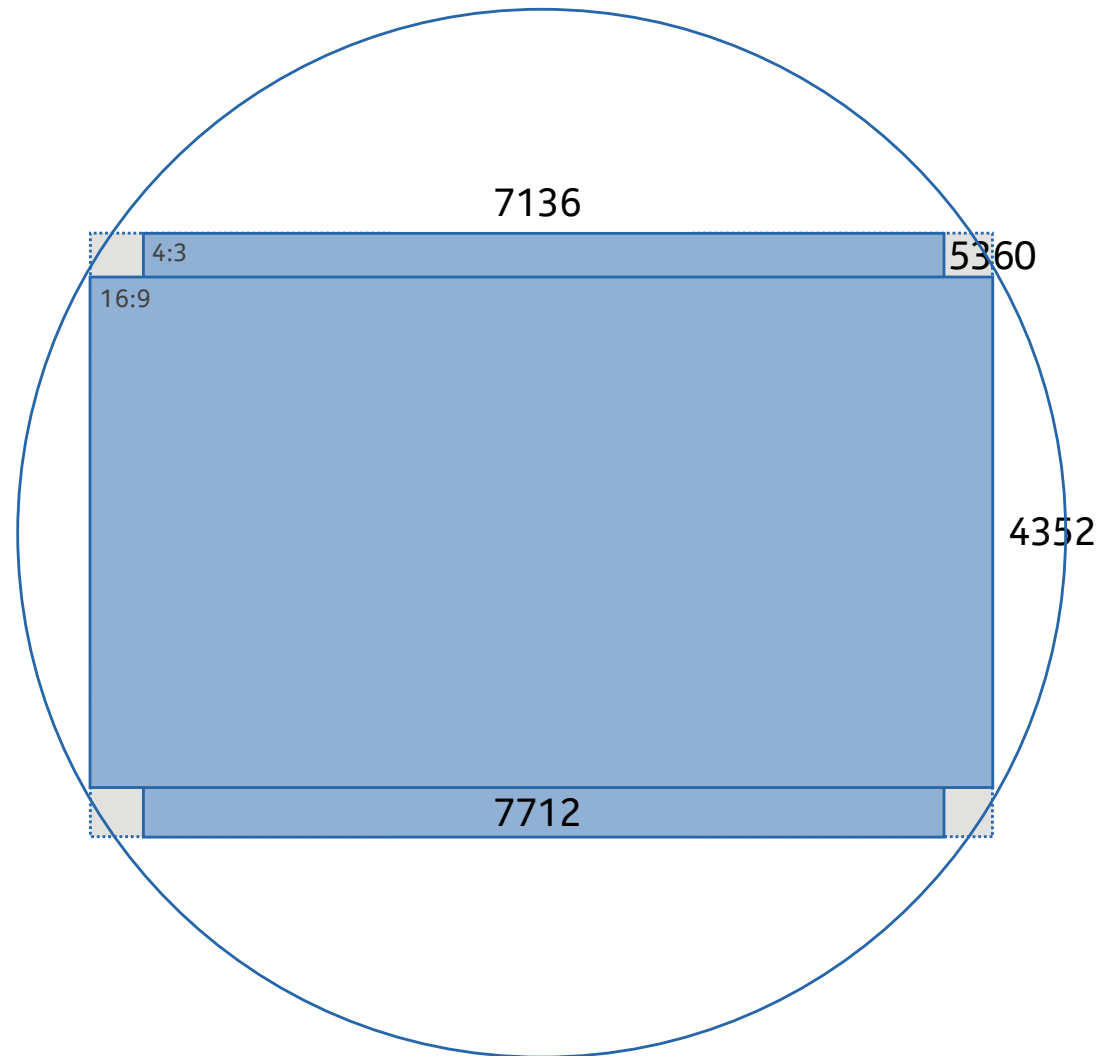


Figure 30. The total sensor size is 7712x5360=41.3MP. This image shows also the full optical circle and shows that the corners of the sensor are not used because they fall outside of the optical circle and additionally they are not needed for either aspect ratio. The 4:3 mode image makes full use of the height of the image sensor within the optical format area and provides a genuinely taller vertical view with a size of 7136x5360=38.2MP. The 16:9 mode image makes full use of the width of the image sensor within the optical format area and provides a genuinely wider horizontal view with a size of 7712x4352=33.6MP.



Figure 31. Mechanical shutter. Illustration only

CREDITS

Written by Juha Alakarhu, Kristina Björknäs, Marcus Olsson, Ari Partinen, Eero Salmelin, and Heikki Sassi on behalf of many dedicated Nokia imaging and audio experts.

Lumia 1020 photos taken by Ted Bergeron, Kristina Björknäs, Stephen Elop, and Ari Partinen.

¹ J. Alakarhu, S. Koskinen, E. Tuulos, “Image quality of oversampling cameras,” in Proc. 2013 International Image Sensor Workshop

NOKIA