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PureView imaging technology

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on behalf of many dedicated Nokia imaging experts

This paper describes Nokia's new PureView Pro imaging technology as well as the product, Nokia 808 PureView, featuring it.

The Nokia PureView Pro imaging technology is the combination of a large, super high resolution 41Mpix with high performance Carl Zeiss optics. The large sensor enables pixel oversampling, which will be explained in detail in this paper but in a nutshell it means the combination of many pixels into one perfect pixel. PureView imaging technology is the result of many years of research and development and the tangible fruits of this work are amazing image quality, lossless zoom, and superior low light performance.

A revolution in imaging

PureView Pro imaging technology doesn't represent a step change for camera smartphones performance, so much as a quantum leap forward. The first device to feature Nokia PureView Pro camera technology is the Nokia 808 PureView, which gives people the means to take better images and video footage than ever before.

Nokia PureView Pro turns conventional thinking on its head. It dispenses with the usual scaling/ interpolation model of digital zoom used in virtually all smartphones, as well as optical zoom used in most digital cameras, where a series of lens elements moves back and forth to vary the magnification and field of view. Instead, we've taken a completely new road.

The result?

Unprecedented camera control and versatility, combined with truly spectacular-quality images and video. Nokia 808 PureView sets new industry standards — it will give you around 3x lossless zoom for stills, and 4x zoom in full HD 1080p. For 720p HD video, you're looking at 6x lossless zoom.

And for nHD (640x360) video, an amazing 12x zoom!

So how is this possible?

The starting point is a super-high-resolution sensor. This has an active area of 7728 x 5368 pixels, totalling over 41Mpix. Depending on the aspect ratio you choose, it will use 7728 x 4354 pixels for 16:9 images/videos, or 7152 x 5368 pixels for 4:3 images/videos as is shown in Figure 1.

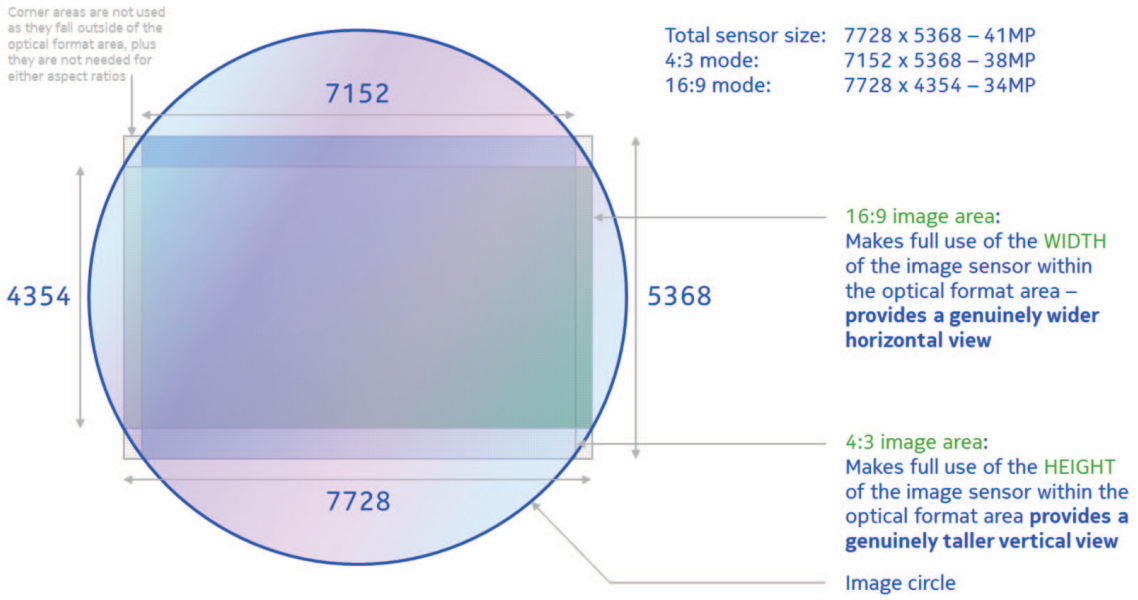

Figure 1. The image circle and the 16:9 and 4:3 image areas

What happens next depends on the settings and whether or not you're using zoom. But to give you an idea, the default still image setting is 5Mpix at 16:9, and for video it's 1080p at 30fps. Using these settings, the zoom is around 3x for stills and 4x for video. Conventional zoom tends to scale up images from a relatively low resolution, resulting in poor image quality. We were convinced there must be a better way, and we found it.

Always true to the image

With the Nokia N8, we limited the digital zoom to just 2x to avoid too much compromise to image quality. But at the end of the day, this was still a conventional digital zoom. With the Nokia 808 PureView, zoom is handled completely differently — like nothing that has gone before. We've taken the radical decision not to use any upscaling whatsoever. There isn't even a setting for it.

When you zoom with the Nokia 808 PureView, in effect you are just selecting the relevant area of the sensor. So with no zoom, the full area of the sensor corresponding to the aspect ratio is used. The limit of the zoom (regardless of the resolution setting for stills or video) is reached when the selected output resolution becomes the same as the input resolution.

For example, with the default setting of 5Mpix (3072 x 1728), once the area of the sensor reaches 3072 x 1728, you've hit the zoom limit. This means the zoom is always true to the image you want.

New depth, new detail

The way Nokia PureView Pro zoom works gives you many benefits. But the main one is undoubtedly 'pixel oversampling'.

Pixel oversampling combines many pixels to create a single (super) pixel. When this happens, you keep virtually all the detail, but filter away visual noise from the image. The speckled, grainy look you tend to get in low-lighting conditions is greatly reduced. And in good light, visual noise is virtually non-existent. Which means the images you can take are more natural and beautiful than ever. They are purer, perhaps a more accurate representation of the original subject than has ever been achieved before.

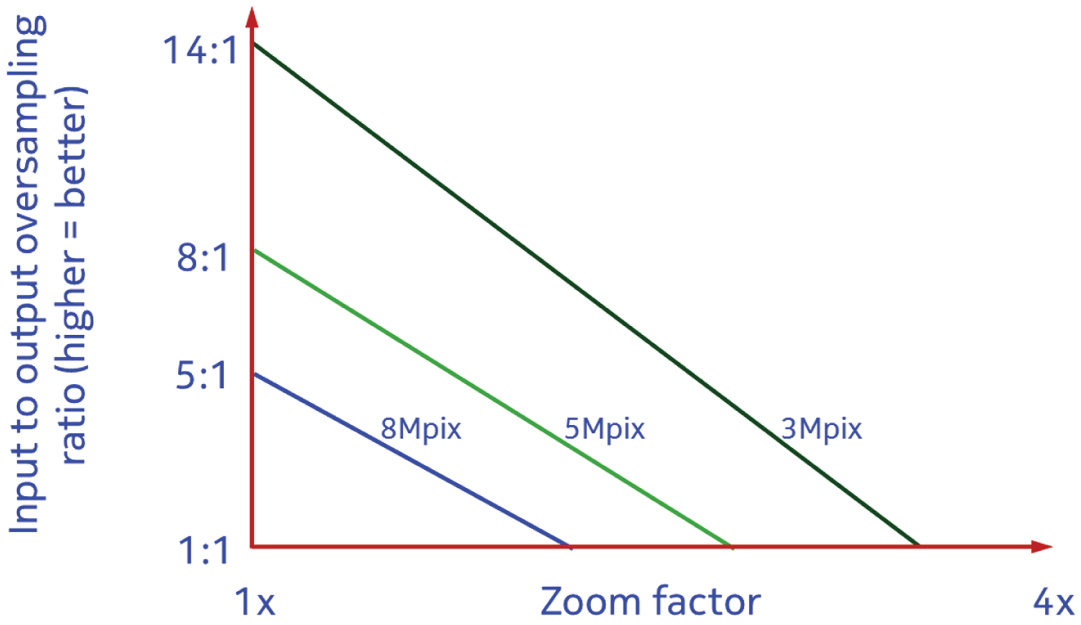

Figure 2. Oversampling vs. Zoom in the case of 4:3 aspect ratio

The level of pixel oversampling is highest when you're not using the zoom. It gradually decreases until you hit maximum zoom, where there is no oversampling. At this stage, Nokia PureView Pro optics and pixels start behaving in a more conventional way. But because only the centre of the optics are used where there is less diffraction, you get better optical performance — including low distortion, no vignetting, and high levels of resolved detail. And because all of this is taken care of for you, you don't need to think about it, the system gives you the best balance between zoom and oversampling based on how you frame and compose the scene or subject.
There are plenty more advantages...

Purity of detail.

Even digital SLR images have a certain softness. With oversampling, however, images can be noise free, yet incredibly detailed and defined. Zoom into the 5Mpix images at 100% magnification on your PC screen, and you'll see. There's something beautifully pure about the detail — not enhanced in anyway. Look closely at some grass... it's amazing.

Faster shutter speeds.

With the Nokia 808 PureView, you get effective maximum aperture throughout the zoom range. Whereas with optical zoom, less light tends to reach the sensor as the zoom increases. At maximum zoom, 5.4x more light reaches the Nokia PureView Pro sensor than a broadly equivalent optical-zoom digital camera (f/5.6 as opposed to f/2.4). And this means you get the benefit of faster shutter speeds.

> e.g. If a conventional digital camera set to ISO 100 uses a shutter speed of 1/30th second, the Nokia 808 PureView uses 1/180th second in the same lighting conditions. Or, looking at it another way, if a digital camera uses ISO 600 for a shutter speed of 1/30th, the Nokia 808 PureView could maintain the same shutter speed with ISO 100 — significantly reducing the visual noise you'd see in the resulting image. This also means that the Nokia 808 PureView's effective flash range is virtually maintained at all zoom levels, rather than being significantly reduced as the zoom increases.

Goodbye to distortion.

Distortion on all images is negligible. Whereas with optical zoom, images tend to get more distorted towards the edge of the frame (with bent vertical and horizontal lines) at the top of the zoom range.

Silent zoom.

The zoom function is completely silent — which is really important when shooting video.

Less is more.

The simple structure of Nokia PureView Pro beats more complicated designs hands down. Image definition is pin sharp, way superior to conventional zoom designs. Conventional designs need many more lens elements to provide the zoom capability and correct aberrations, but these interfere with definition and/or light transmission. Our simple structure has enabled a significant improvement in manufacturing precision, and our lenses are produced with 10x greater precision than SLR lenses. This was essential to allow the PureView Pro sensor and optics to work in complete synergy.

Neat and compact.

The size of the Nokia 808 PureView camera (including sensor and optics) is at least 50%-70% smaller than a conventional optical zoom design.

Effective zoom settings.

You can get right up close with any zoom setting. Typically, optical zoom gets closest with wide (rather than tele) lens settings. Which means you have to stand physically closer to whatever you're shooting, obscuring the light and possibly casting unwanted shadows. With the Nokia 808 PureView, you can use full zoom capability at a shooting distance of 15cm providing greater than ever magnification of small objects with full zoom.

On a more technical note...

oversampling eliminates Bayer pattern problems. For example, conventional 8MPix sensors include only 4Mpix green, 2Mpix red and 2Mpix blue pixels, which are interpolated to 8Mpix R, G, B image. With pixel oversampling, all pixels become true R, G, and B pixels. What's more, based on Nyqvist theorem, you actually need oversampling for good performance. For example, audio needs to be sampled at 44 kHz to get good 22 kHz quality.

Long focal length.

Most smartphones have quite small sensors, so focal lengths are short (less than 4mm), creating a wide-ranging depth of field. For some situations — grab shots, landscapes, architecture etc — that's great. But you're less able to use a reduced depth of field to focus attention on the subject. The Nokia 808 PureView combines a longer focal length (8.02mm) with large f/2.4 aperture — shooting at closer distances, the 'bokeh' effect is striking.

Quality, not quantity

People will inevitably home in on the number of pixels the Nokia 808 PureView packs, but they're missing the point. The 'big deal' is how they're used. At Nokia, our focus has always been capability and performance.

The main way to build smaller cameras over the years has been to reduce the pixel size. These have shrunk just over the past 6 years from 2.2 microns, to 1.75 microns, to 1.4 microns (which is where most compact digital cameras and smartphones are today). Some new products are on the way with 1.1 micron pixels. But here's the problem. The smaller the pixel, the less photons each pixel is able to collect. Less photons, less image quality. There's also more visual noise in images/videos, and various other knock on effects. In our experience, when new, smaller pixel size sensors are first released, they tend to be worse than the previous generation. While others jump in, banking on pixel numbers instead of performance, we prefer to skip early iterations.

Lessons learned

With the 12Mpix Nokia N8, for example, we were more concerned with capturing photons of light than ramping up the number of megapixels. We bucked the trend and went with a large sensor and 1.75 micron pixels — but the result was a new benchmark in image and video quality. This set the Nokia N8 apart at the time, and competitors are still trying to match it two years later. The Nokia PureView Pro comes is equipped with an even larger sensor, 1/1.2" approximately 2.5 larger than the sensor used in the Nokia N8. The result is an even larger area to collect photons of light. With PureView we're continuing to make choices focused on performance rather than pixels for pixels' sake. Fewer but better pixels can provide not just better image and video quality, but better overall user experience and system capability.

In fact, 5Mpix-6Mpix is more than enough for viewing images on PC, TV, online or smartphones. After all, how often do we print images bigger than even A4?

Why the megapixel fixation?

It all stems from the very early days of digital cameras, when image quality was affected by the limited number of pixels available. As the pixel numbers increased, image quality dramatically improved. However, once the resolution reached around 5Mpix-6Mpix, the real-world benefits became debatable.

But by then, the market had made a direct correlation between number of pixels and quality of image. The more pixels the better, was the received wisdom. And this thinking has stuck. Though today manufacturers would happily reduce the number of pixels in their cameras, and instead concentrate on their lenses and sensors, they're not so sure the market would accept this.

But let's consider why you might need more than 5Mpix. The most popular argument we hear is the versatility the extra pixels provide. Specifically the ability to crop images or create large prints.

Cropping

With the Nokia 808 PureView, you can frame your shots on the spot. However, if you prefer, you can defer framing until later, as there is a user setting in the Creative Shooting Mode for capturing 'full-resolution' images. You can choose to zoom into any part of the image, and find new creative views in the original.

Actually, we thought people might want to do both, so we decided to make it as easy as possible to switch. We hope this will open up greater creativity in composition — you can shoot quickly and crop later when you have more time and a larger display to work with. You can re-frame as many times as you like, scale the image to your preferred output resolution, and choose the relevant downscaling method depending on what you want to do with it.

Printing

If you rarely print your images or don't need them larger than A3 size, 5Mpix is more than enough. In fact, you can get superb poster prints as large as 50 x 75cm (the size limit of most commercial printers) from very good quality 3Mpix images. Of course, if your needs are different, there is a higher resolution 8Mpix setting and a 'full resolution' mode on the Nokia 808 PureView.

If you only ever view images on TV, PC or tablet, or upload to social sharing sites, we've provided an ideal 2Mpix lower-resolution setting. Oversampling is even greater here, and there's an increased lossless zoom range too, as can be seen in Figure 2.

Introducing… Slide Zoom

The Nokia 808 PureView uses a new zoom concept called Slide Zoom. Conventional zoom can be slow and imprecise, and sometimes you need to make adjustments to get the exact framing you need. Pinch to Zoom is great for viewing afterwards, but not so good for composition, especially video, where you need smoothness of movement.

Slide Zoom is fast, direct and precise — it gets the framing right first time. All you have to do is slide your finger up or down on the display to interact. There's no need to touch a specific UI element on the display.

As you move your finger on the display, a 'frame' appears on the screen which moves in sync with your finger. This allows you to preview the framing before committing, which is particularly useful for video recording. The moment you lift your finger from the display, it zooms directly to this setting. And because zooming uses the Nokia PureView Pro sensor rather than moving optics, it's silent too.

More processing power

One of the reasons the Nokia 808 PureView has taken so long to develop is down to processing power. We simply couldn't get hold of enough. Even the most powerful mobile chipsets have an upper limit of around 20Mpix image processing capability. The Nokia 808 PureView eats up more than double that.

For video, the amount of pixels handled through the processing chain is staggering — over 1 billion pixels per second, and 16x oversampling. That's a throughput of pixels 16 times greater than many other smartphones.

Most smartphone manufacturers crop off a section of the sensor to ease the processing load. By contrast, the Nokia 808 PureView has no limited field of view. Plus, it provides lossless zooming capability, which is output resolution dependent. Full HD 1080p gives you 4x zoom.

For 720p HD video, you're looking at 6x lossless zoom. And for nHD (640x360) video, an amazing 12x zoom! In addition, we are encoding at up to 25mbps in high profile H.264 format.

To make this all happen, we developed a sensor with a special companion processor that handles pixel scaling before sending the required number to the main image processor.

Like the Nokia N8 before it, and a few other Nokia smartphones, the Nokia 808 PureView records true stereo audio. Most smartphones record only mono, while some infer stereo by using dual mono recording.

In combination with the world's first implementation of Nokia Rich Recording technology, Nokia 808 PureView records best in class stereo audio with every detail. Whilst most high end smartphones can only record without distortion to around 110db, the Nokia 808 can comfortably continue to around 140-145 db, which is 4 times louder than conventional mics can record. Apart from that Nokia Rich Recording can also record very low frequencies also without any distortion. The combination of all of these elements means the Nokia 808 records audio with almost CD like quality. It has to be heard to be believed. In terms of both visual and audible performance, the Nokia 808 simply has no equal.

Improved video autofocus

Video autofocus was an area that needed to be dramatically improved. Because of Nokia 808 PureView's much larger image sensor (5x larger than rival smartphones) the optics give you a relatively shallow depth of field. What's more, we're also using oversampling techniques in video to achieve our holy grail of low visual noise with extremely high levels of detail.

As a result, we made our autofocus system more precise, sensitive and controllable. You get continuous autofocus in all shooting modes, but we've also provided easy access to an On/Off control. In Off mode, the lens is set to hyperfocal, making it easier to get acceptable focus across a wide range of subject distances while eliminating focus hunting. There's also Touch Autofocus for video and still images. In Creative Shooting mode, we've gone even further. A long touch on the viewfinder will bring up a pop-up UI window, where you can select Automatic or Macro. Close-up focus is much improved in Macro, while Automatic does all the work for you.

The technology:
PureView Pro imaging specifications

- 41Mpix sensor with pixel oversampling
- Lossless zoom: 3x for stills, 4x for full HD 1080p video
- Carl Zeiss optics

The product:
Nokia 808 PureView lens and sensor specifications

- Carl Zeiss Optics
- Focal length: 8.02mm
- 35mm equivalent focal length: 26mm, 16:9 | 28mm, 4:3
- F-number: f/2.4
- Focus range: 15cm – Infinity (throughout the zoom range)
- Construction:
    - 5 elements, 1 group.All lens surfaces are aspherical
    - One high-index, low-dispersion glass mould lens
    - Mechanical shutter with neutral density filter
- Optical format: 1/1.2”
- Total number of pixels: 7728 x 5368
- Pixel Size: 1.4 microns