NOKIA

PureView Technology

PureView

PureView imaging technology white paper 2 – the next breakthrough in purity of imaging

This white paper describes Nokia's further development of PureView imaging technology which is the latest technology on mobile to be featured in a soon to be announced new Nokia Lumia smartphone

On February 27th 2012 we introduced our latest technology news which is the revolutionary Nokia 808 PureView, our first PureView product. Whilst some may associate the PureView moniker with specific features, specifications or functionality introduced along with the 808 PureView, Nokia's ultimate intent for PureView is to be synonymous with high performance imaging. We deliver our flagship imaging technology through a set of industry leading imaging technologies, rather than a single element, feature or specification. As time goes by, this will be especially important as PureView becomes greater than the sum of its parts.

The first PureView product, the Nokia 808 PureView was born out of the desire to provide a revolutionary zoom experience and incredible quality in a portable form factor.

If there was one recurring theme we hear time and time again from the consumer, is the need for significantly improved low light photography. As a result, for some time we've wanted to provide cameras with much better low light performance. The 808 PureView uses one solution to improve low light image quality through the innovative and highly acclaimed pixel oversampling technology but we needed to explore additional directions for improving the image quality in dim light.

This second development phase of PureView is therefore focused on exactly that - a significant improvement in low light whilst also making it available to a wide range of people.

Differences between the best smartphones today can in some cases be more and more difficult for the vast majority of people to discern with such subtle differences under normal viewing conditions captured in normal lighting.

Our aim is to focus more on the development of aspects which create a greater difference for as many people as possible. A few notable examples of this approach are:

Nokia pioneering wide-angle lenses multi-aspect ratio image sensors which provide a wider field of view than any other smartphones.

Such differences can be seen in a variety of situations by all users, whilst small differences in details are only visible when looking at images under extreme magnifications. Such behaviour has now been coined ‘pixel peeping’.

Having said that, there are still a number of areas that we feel warrant significant development to allow the capture of a wider range of environments – low light being perhaps the most significant of all. You’ll see us tackle other areas in the future, but this next step is focused on improving the ability to record in lower lighting conditions, as well as improve the ease of video recording.

You may have seen that despite the super high resolution sensor of the Nokia 808 PureView, we’ve been going to great lengths to communicate that despite the staggering number of pixels, it's not about the NUMBER of pixels but HOW YOU USE THEM. This message is just as relevant in the context of this 2nd phase of PureView development.

For a number of years Nokia had been considering the question:

Instead of producing images with unnecessarily high output resolutions, what if we assumed 5-8mp is all you *really* needed?

The 808 PureView was the first alternative thinking prompted by this original question. Assuming 5mp as an output resolution enabled us to create a product where a super high resolution sensor is used to provide lossless zoom, with super high quality images/video through pixel oversampling.

Before we go into details, let's be 100% clear, this is an **additional** direction in the development of Nokia PureView technology rather than a competing direction. **PureView is a promise of versatile capture capability and leading edge innovation.** We're very excited by both directions and firmly believe both take imaging to new and better places, rather than the endless focus on 'paper specs' often not directly associated with genuine benefits.

Although the core ingredients are the same, namely high performance optics, sensor and powerful image processing algorithms, this 2nd phase differs slightly to the 808 PureView. This time the sensor is purposefully of a lower resolution – 8.7mp, the optics are focused on providing the best possible low light performance in a beautiful product, whilst the image processing capacity will enable in the future new capabilities - that the combination of optics and sensor enable.

PureView Phase 1

Key benefits:

- Benchmark image/video sharpness
- Lossless zoom in stills and HD video

Key Technologies:

High performance sensor:

- True 16:9/4:3 aspect ratios
- Large 1/1.2” 41mp sensor

High performance Carl Zeiss Optics:

- High resolving capability
- Super wide-angle: 26mm – 16:9
- f/2.4 aperture

Advanced Image Processing:

- Pixel oversampling technologies

Additional:

Powerful xenon flash + Single LED

PureView Phase 2:

Key benefits:

- Benchmark low light performance
- Steady video in all lighting conditions

Key Technologies:

High performance sensor:

- True 16:9/4:3 aspect ratios
- Latest generation BSI sensor with 1.4 micron pixels

High performance Carl Zeiss Optics:

- Optical Image Stabiliser
- Super wide-angle: 26mm – 16:9
- f/2.0 aperture

Advanced Image Processing:

- Nokia image processing

Additional:

Next generation high power/short pulse LED flash

In detail:

What is PureView technology?

Next generation image sensor

We've been following extremely closely the development of BSI (Back-Side Illuminated) sensors since before even the first products equipped with this new sensor technology came to market. While even the first BSI sensor offered interesting advantages, there were some issues that we considered to be unacceptable for high-end imaging. Our technology analysis showed that with these very latest generation BSI sensors, the early disadvantages have been overcome, leaving maximum performance to now be realized, and our fans to get the best image quality from PureView devices. .

The difference between BSI sensors and more conventional FSI (Front-Side Illuminated) sensors essentially lays in the difference the path the light takes to reach the photosensitive area. In the case of FSI, the path of light can be restricted, or interference can be caused by the metal and wire structure between the micro lenses and the upper part of the photosensitive area at the base of the sensor. BSI sensors use a reversed structure, so the wires and metal are in the base of the sensor and the photosensitive diodes are directly below the micro lenses and colour filters. This results in more photons reaching the photosensitive diodes [pixels] and therefore superior pixel performance, most notably in low light.

To further improve low light performance we've adopted an extremely large f/2.0 camera aperture. Given our sensors are at least 10% larger than comparable sensors of the same resolution to accommodate the true 16:9 aspect ratio, this was even more of an optical design achievement than other cameras with a smaller sensor area.

Nokia's use of bespoke custom oversized sensors instead of 'off-the-shelf' sensors to provide true 16:9 and 4:3 formatted aspect ratios remains unique amongst smartphones. Only a few digital cameras incorporate such sensors.

But the most significant improvement comes from Optical Image Stabilisation (OIS). Yes there are smartphones, which include digital stabilisation algorithms, and whilst they have improved over time they are still far behind the possibilities of effective OIS systems. Whilst digital cameras have incorporated OIS for a while, it's virtually unheard of in smartphones due to the various size constraints. OIS works by detecting camera movement using a gyroscope – a highly accurate sensor used to detect the degree and direction of movement. But that's pretty much where the similarity between Nokia's OIS system and broadly comparable OIS systems ends.

In most OIS systems, a lens element moves in the opposite direction to the measured device movement to compensate for unintended movement, effectively cancelling out camera shake. This is a similar principle to the process of noise cancellation.

In itself, incorporating OIS in to a smartphone is challenging enough, but Nokia has been successful in surpassing the typical performance of OIS in many digital cameras by taking full advantage of the smaller components and therefore reduced mass to move during stabilisation.

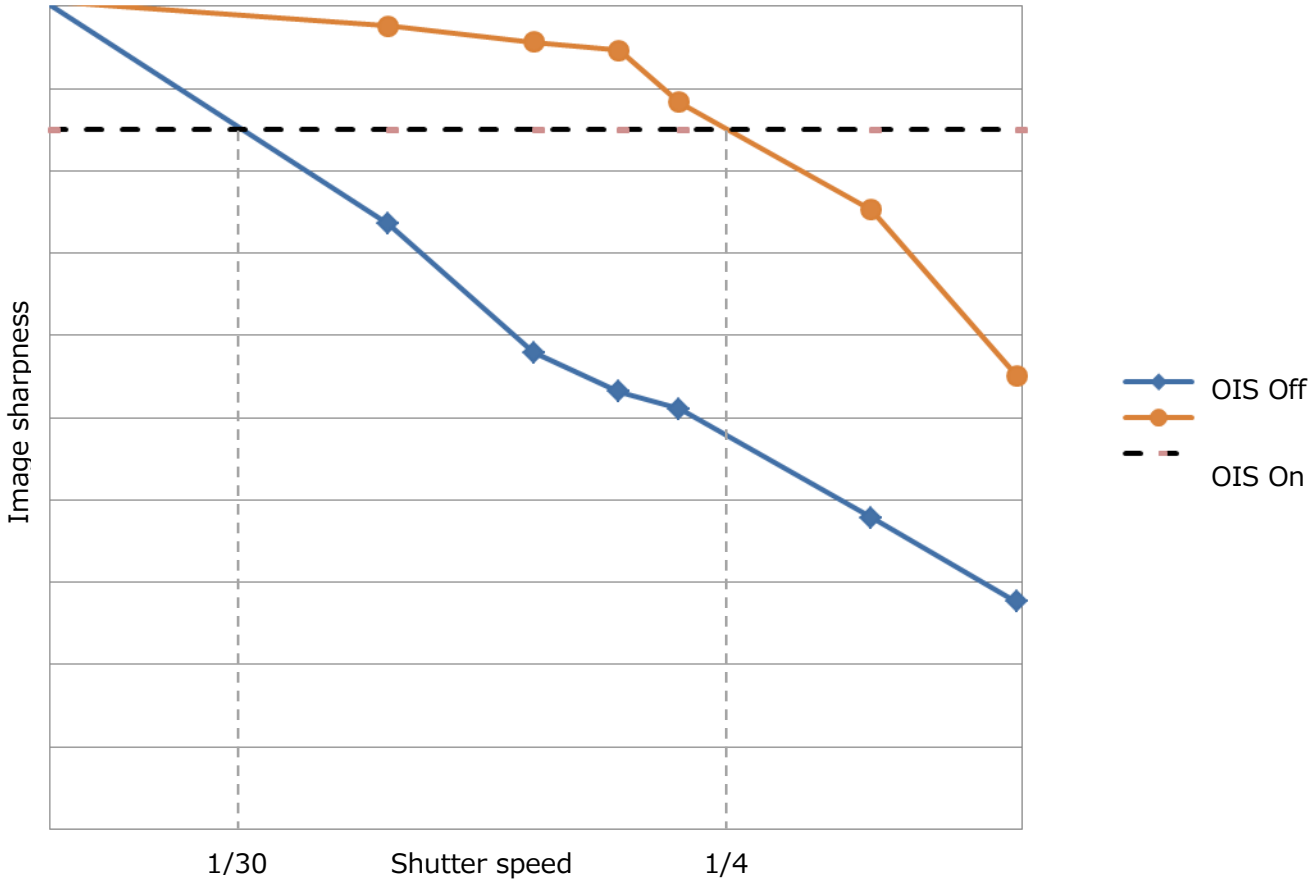
Rather than a single lens element being shifted to compensate for camera shake, Nokia's OIS system moves the entire optical assembly in perfect synchronisation with the camera movement, or to be more precise, unintended camera shake. The benefit of this approach is that the amount and form of camera movement that can be compensated for is much greater.

Many OIS systems may only be able to handle movement frequencies up to a certain level. Based on our lab tests, Nokia's new OIS system can cater for around 50% more movements per second than conventional OIS systems – **up to around 500 movements every second!** Besides the high frequency compensation, the system also needs to be able to respond extremely quickly to unintended movement to avoid so called "phase shift" or compensation lag. To help achieve this very fast reaction time, Nokia uses a closed loop system where the position of the lens assembly is monitored in real time, even whilst it's moving to its calculated position allowing it to be continuously

updated regardless of how random the camera movement is. This process of checking operates at a rate of up to 5x more frequently than typical OIS systems, approximately 300 times faster than that of the average human reaction time to an expected event.

Adding up all of the advantages of Nokia's OIS system means camera shake in lower light can be compensated for to lower lighting levels than conventional OIS systems, ultimately resulting in low light photography. As a point of reference, and depending on the user's ability to hold the device still, shutter speeds slower than 1/30th second typically results in camera shake. Depending on the amount of camera movement requiring compensation we've found in testing that shutter speeds as long as 1/4th second can be used. This is a 3EV improvement or 8x longer shutter speed — which we believe to be a new benchmark! This extends the low light performance of the camera to a whole new level.

Below is real test data from our laboratory testing.



However, the advantages of OIS are not constrained to just still images in low light. OIS can also help provide one-handed usage. Sometimes capturing pictures or video one handed is more convenient and natural. However, even in reasonable lighting, this typically results in camera shake. This really helps to extend the spontaneous use of smartphones as a modern method of capturing moments as they occur during everyday life.

One of the most important aspects of good smartphone video recording is smooth recording. Capturing smooth video whilst moving can be extremely difficult. Even ensuring small movements are unnoticeable during playback can require constant concentration. This often results in video recording becoming tiring, other than for the shortest of video clips. In addition, for the individual who's recording it, it detaches them from the 'live' action as they concentrate continuously on the viewfinder. When capturing video OIS works slightly differently to when capturing stills. By detecting the different movements the OIS system is able to compensate for unintended movement rather than intended movements e.g. panning.

The fundamental elements of PureView announced as part of the first phase were pixel oversampling, enabled through the use of a high performance sensor, high performance Carl Zeiss optics and Nokia proprietary image processing. As part of the original announcement we outlined our intention to reuse the core elements, high performance optics, sensor and image processing in different combinations over time.

With this second phase development of PureView, these fundamental enabling elements are used again, but in different forms.

In place of the 808 PureView's 41mp sensor lies the latest generation BSI (Backside illumination) sensor with a total of 8.7mp. The new optics are again developed in conjunction with Carl Zeiss; our most challenging opto-mechanical design to date. The hardware has also been designed to accommodate further future developments in software image processing.

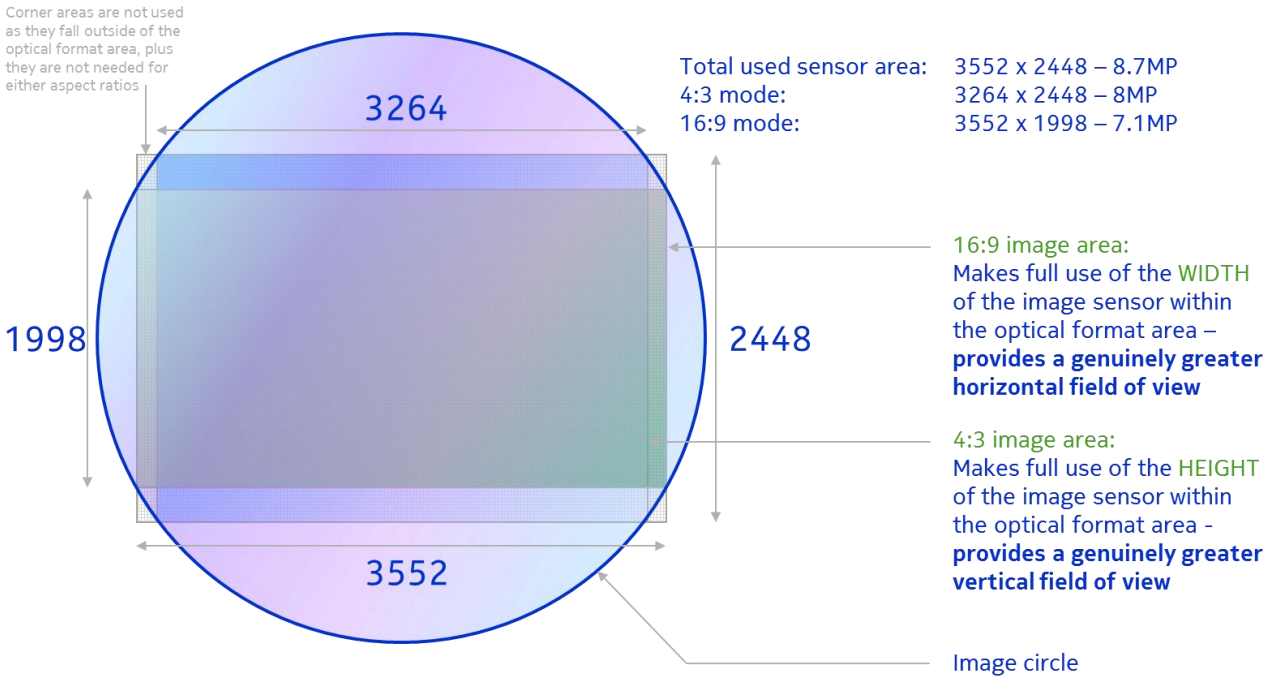


Figure 1: The image circle and the 16:9 and 4:3 image areas

Further low light improvements

Even though we've focused on the low light improvements enabled primarily by Nokia's new OIS system, optics and sensor, there are other improvement areas too.

Next generation LED flash

Whilst xenon, when married to a large capacitor, is perhaps the most powerful short burst lighting source, the performance of LED's have been increasing at a faster rate than xenon and capacitor technologies. To bolster the low light performance, we're introducing a new generation LED. It provides the benefit of being able to be used as a continuous light source e.g. for video or as a highly popular secondary function; a torch and now for the first time - a pulse flash burst. This provides a similar capability to xenon flash where the flash fires a short single flash of light. This flash is short enough in duration to effectively freeze subject movement. Whilst the duration of the flash is still

not as short as a xenon flash, it is short enough to provide a sharper picture of moving subjects than conventional LED's which provide no such benefit.

Nokia Proprietary Image Processing Technology

Working closely with Microsoft, Windows Phone 8 introduces a new imaging framework which allows the heavy integration of Nokia's wide range of image processing algorithms including autofocus, auto exposure and auto white balance, to name just a few.

But these don't even scratch the surface of what's new in Windows Phone 8 from Nokia.

One of the most important new algorithms is our new denoise algorithm for reducing visual noise, which helps to further improve low light performance while keeping the image very natural.

In the beginning of the project, we set ourselves a challenging target to create a product with the best low light performance ever in a smartphone, even in natural light. Every single part of the system was pushed for this goal: large aperture, new image sensor technology, optical image stabilizer and new image processing algorithms. When the technologies are combined, the improvements add up, and finally we have the results in our hand.

PureView

The technology: PureView imaging specifications

- 8.7Mpix BSI sensor
- Carl Zeiss low light optimized optics with Optical Image Stabiliser

The product: Lens and sensor specifications

- Carl Zeiss Optics
- Optical Image Stabiliser Barrel shift type
- Stabiliser performance Up to 3EV (8x longer shutter speeds)
- Focal length: 3.73mm
- 35mm equivalent focal length:
    - 26mm, 16:9
    - 28mm, 4:3
- F-number: f/2.0
- Focus range: 8cm – Infinity
- Construction: 5 elements, 1 group. All lens surfaces are aspherical
- Optical format: 1/3
- Sensor: BSI (Backside illuminated)
- Total pixel are used: 3553 x 2448 – 8.7Mpix
- Pixel Size: 1.4 microns

Additional Resources:

Nokia Beta Labs

- Nokia Beta Labs brings together developers and consumers keen on improving products and accelerating innovation.

Nokia Conversations

- Conversations by Nokia is a site that tells compelling stories about the global cultures, technology and people shaping mobile, and smartphone innovation.

Nokia Lumia Smartphones

- See the range of award winning smartphones that have the latest smartphone technology such as the Nokia Lumia 920