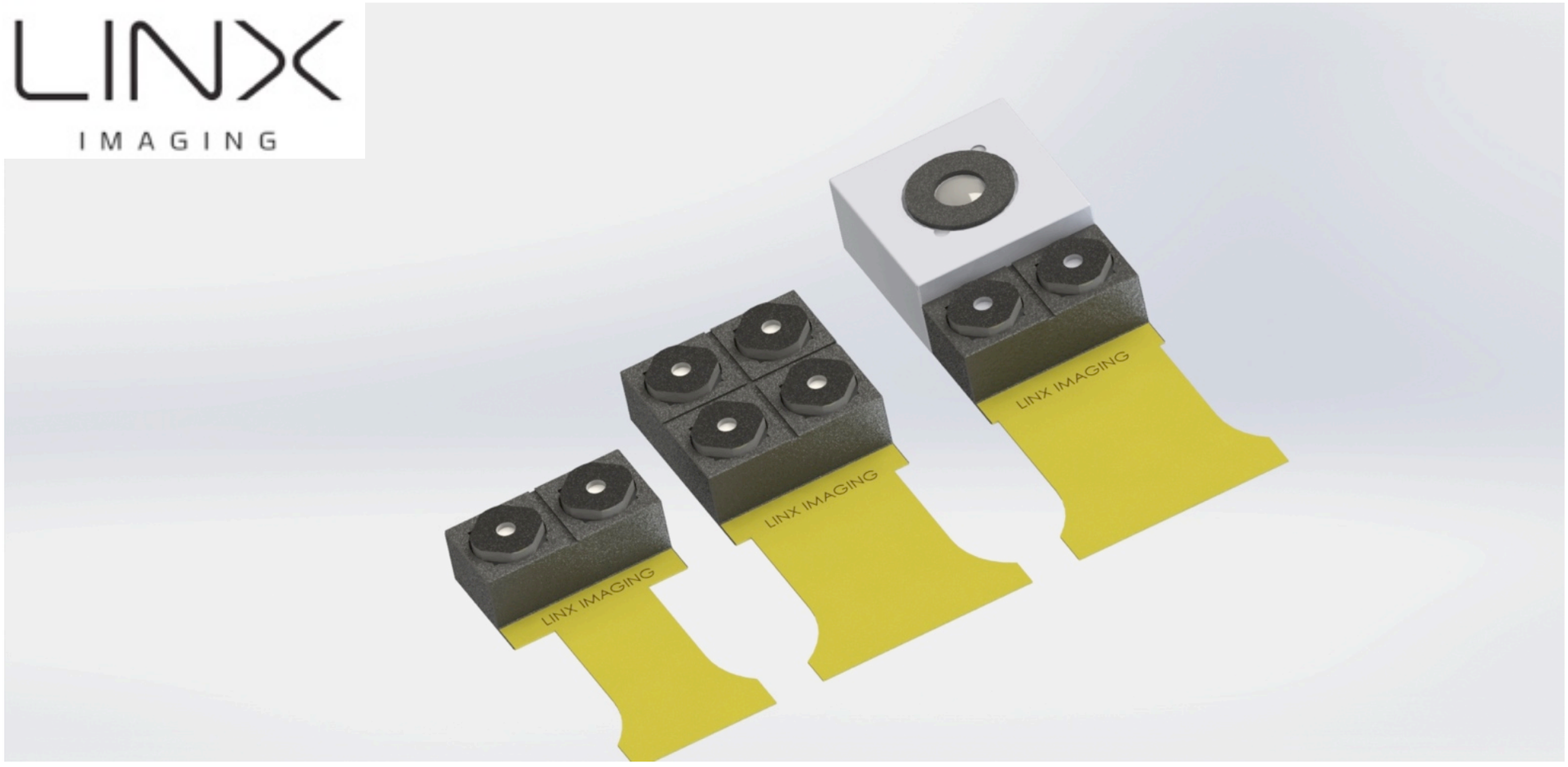
LINX IMAGING




# Array Camera Technology update - we are ready !

June 2014

# Image quality comes first

Multi aperture cameras have many advantages but for mobile device makers the decision of using such a camera in their products requires the cameras to meet the image quality standards of conventional single aperture mobile cameras.

There are many attempts by various companies to develop multi aperture cameras but many of them suffer from serious artifacts and low effective resolution despite using a large sensor and special expensive optics.

When designing our algorithms and modules our first priority has always been IMAGE QUALITY. We even leveraged the multiple channels to boost the sensitivity of the camera which allows us to capture stunning images at very low light levels and keep exposure times short at normal indoor light levels.

Our array cameras capture SLR like images in normal lighting conditions with very low noise levels.
The array camera can resolve more details than a conventional single aperture camera having the same pixel count !

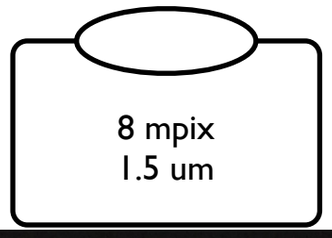
Our camera technology is not sensitive to pixel size and will pave the way for smaller and smaller pixels such as 0.9 um which is not suitable for standard single aperture cameras.

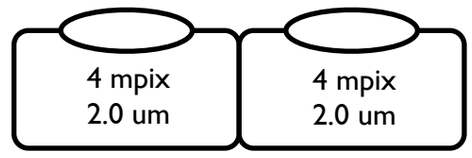
# Image quality comes first

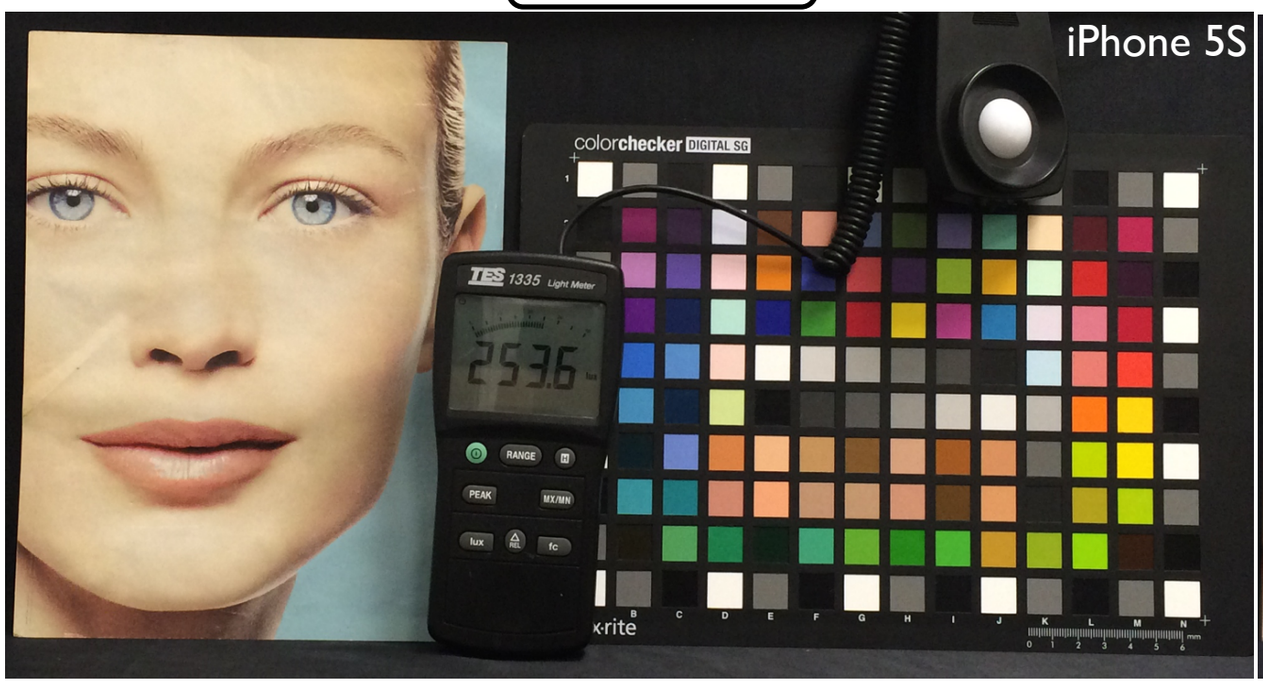
When comparing our cameras with standard single aperture cameras, we can compare with a camera having the same pixel count, same sensor size, same module height or same cost.
The sensors size dictates the focal length of the optics and therefor the length of the camera and the thickness of a handset.
The LinX 8 mpix array is a dual aperture camera which consists of **two 4 megapixels sensors with 2.0 um BSI pixels**.

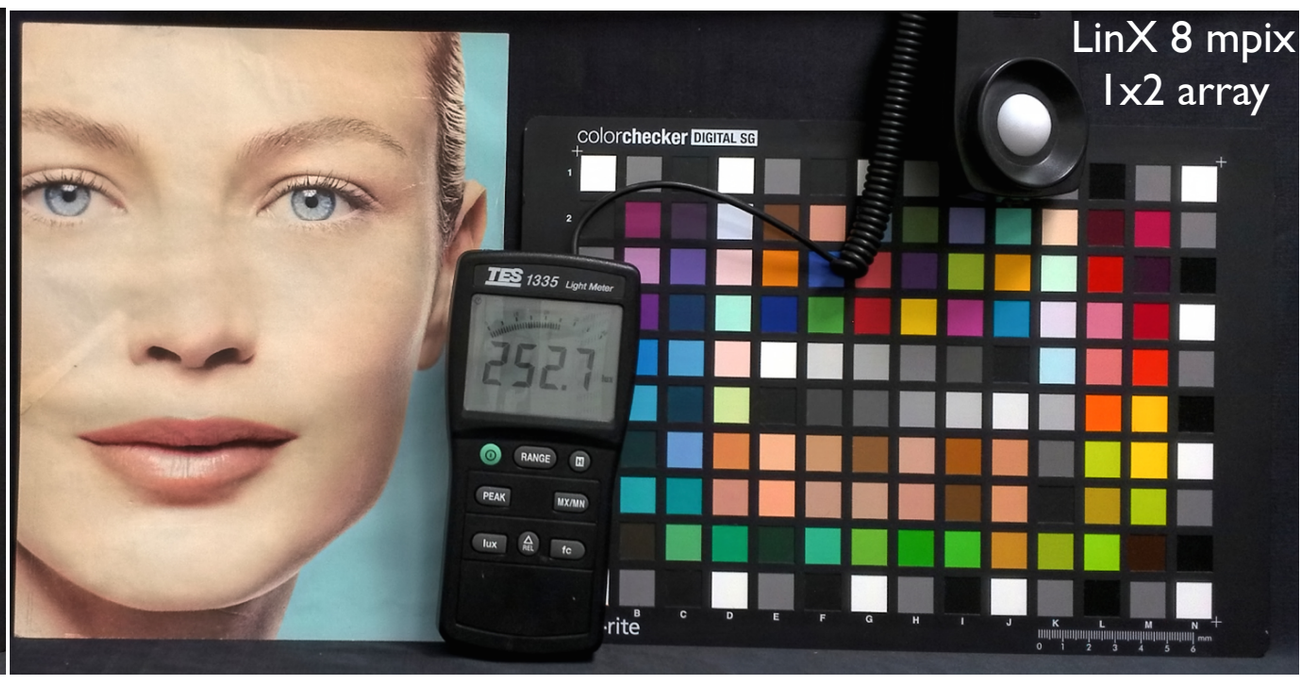
We compare with iPhone 5s which has also 8 mpix but with 1.5 um pixel.
The thickness of the array camera in this case is smaller than the iPhone 5s camera significantly and can fit in device thinner than the iPhone. The total pixel count is the same.

We compare image quality which can be broken down to resolution, noise levels, color accuracy and contrast.

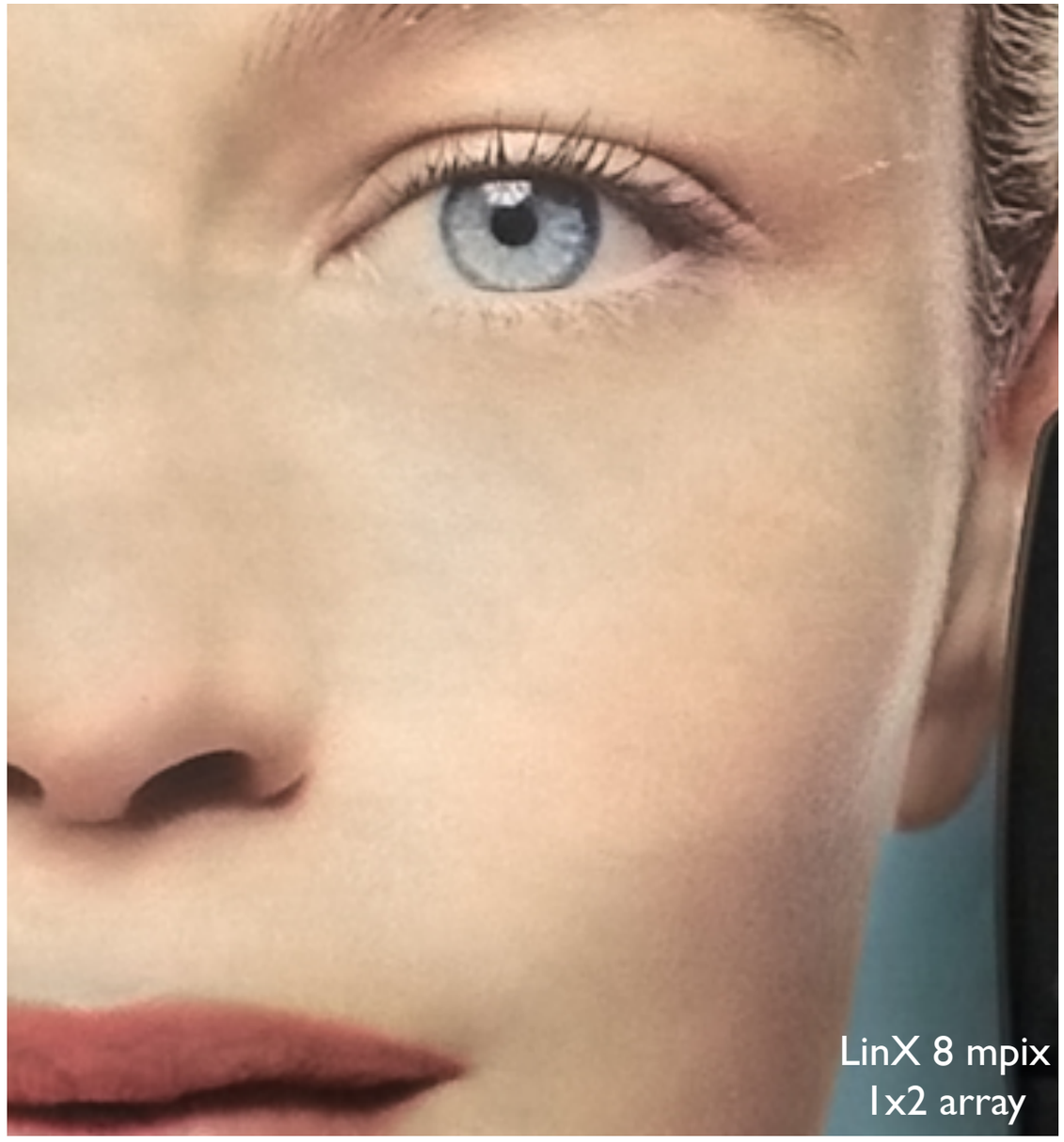


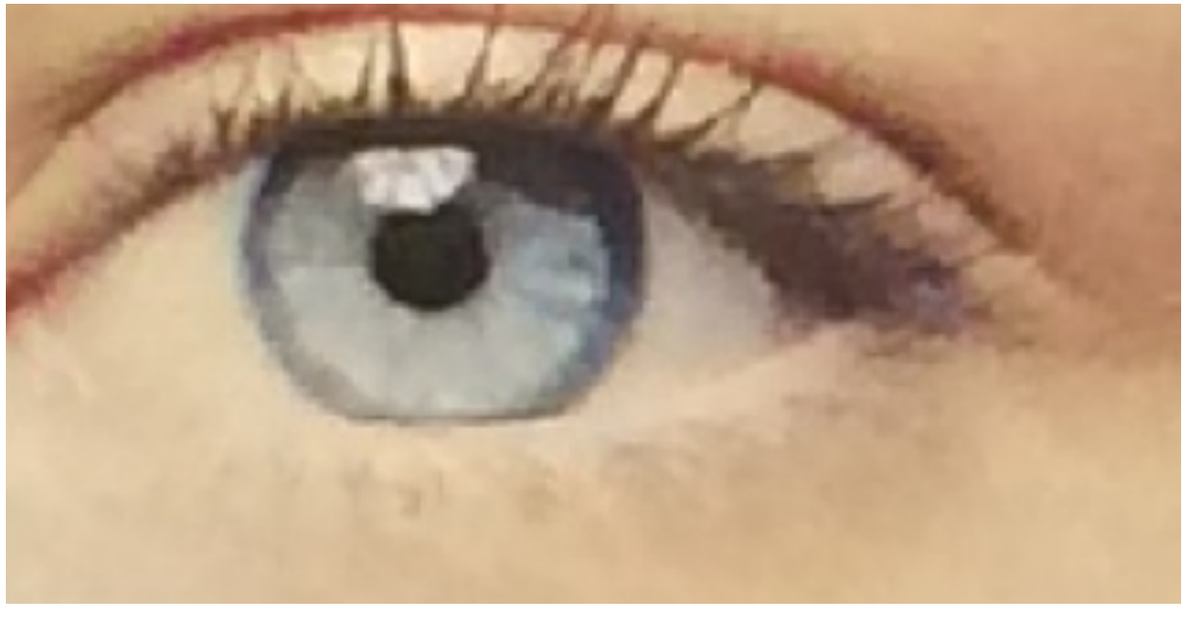



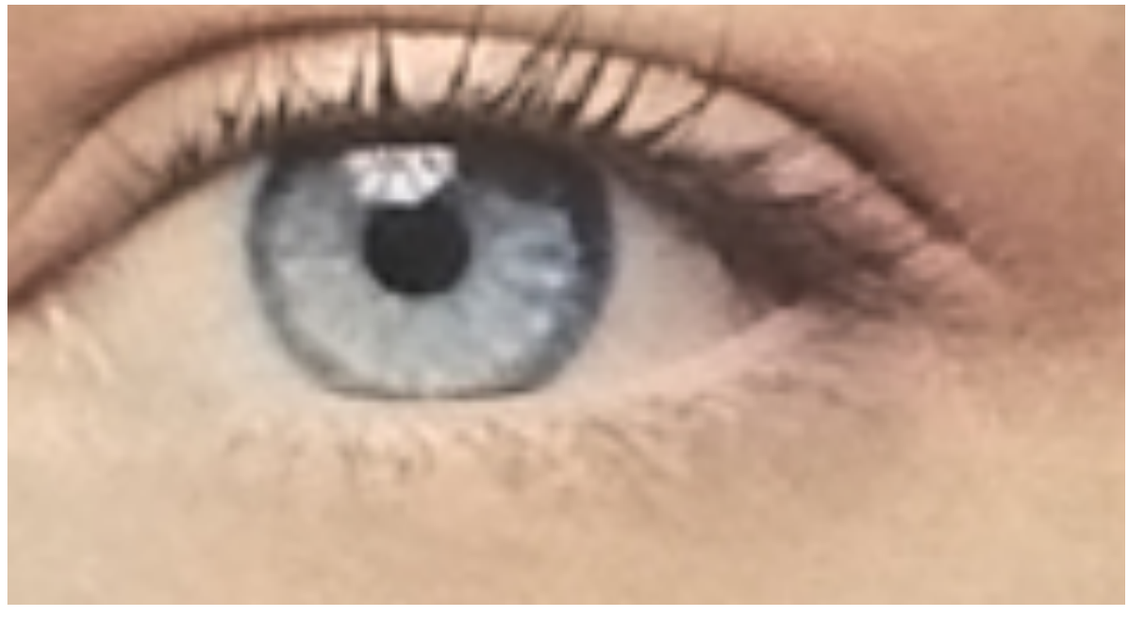




iPhone 5S


LinX 8 mpix
1x2 array






iPhone 5S


LinX 8 mpix
1x2 array

# Outdoors

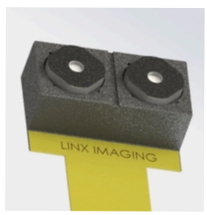
# Outdoors

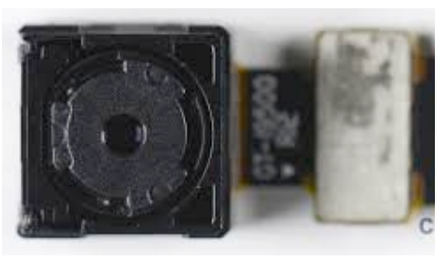
**LinX 8 mpix**
**1x2 array**

# Indoor image quality

Below we see some more comparisons with iPhone 5 and Samsung Galaxy S4 in mid light levels of around 40-50 lux. Such light levels are typically found in our houses, restaurants and bars.



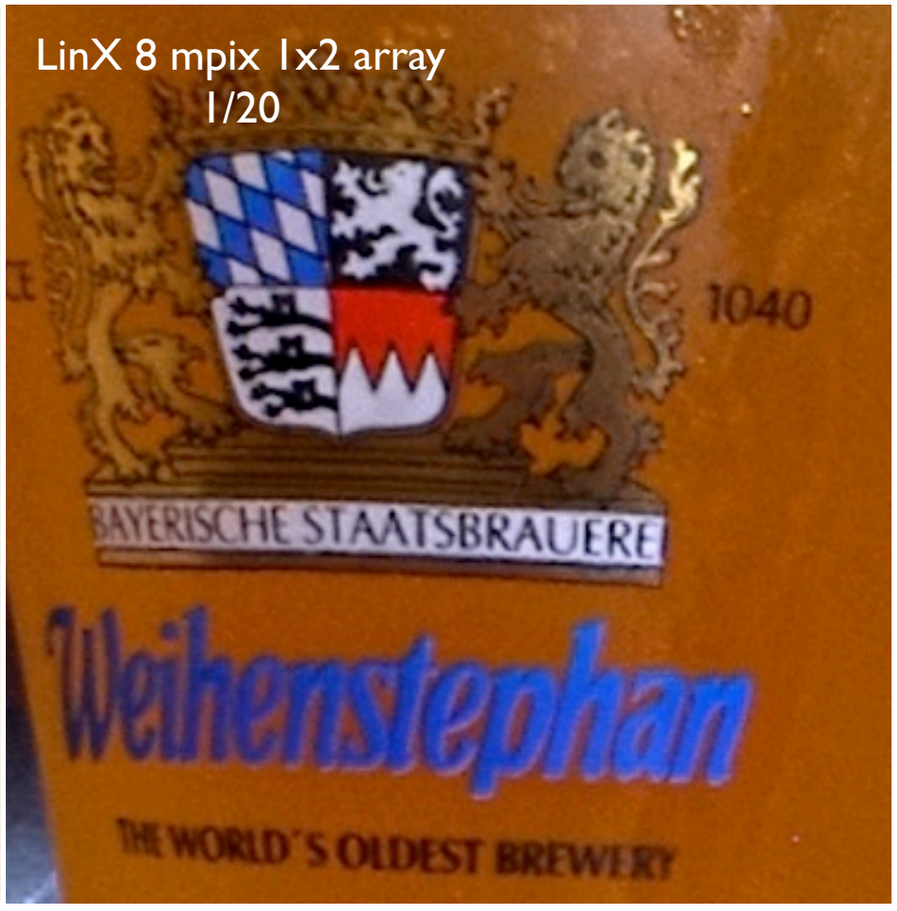



# Indoor image quality


If we observe the differences we will notice a much cleaner and sharper overall feel to the images captured by the LinX array camera.

# Indoor image quality


# Indoor image quality

LinX 8 mpix 1x2 array
1/20 sec

# General indoor

Samsung GS4 13 mpix
1/17 sec

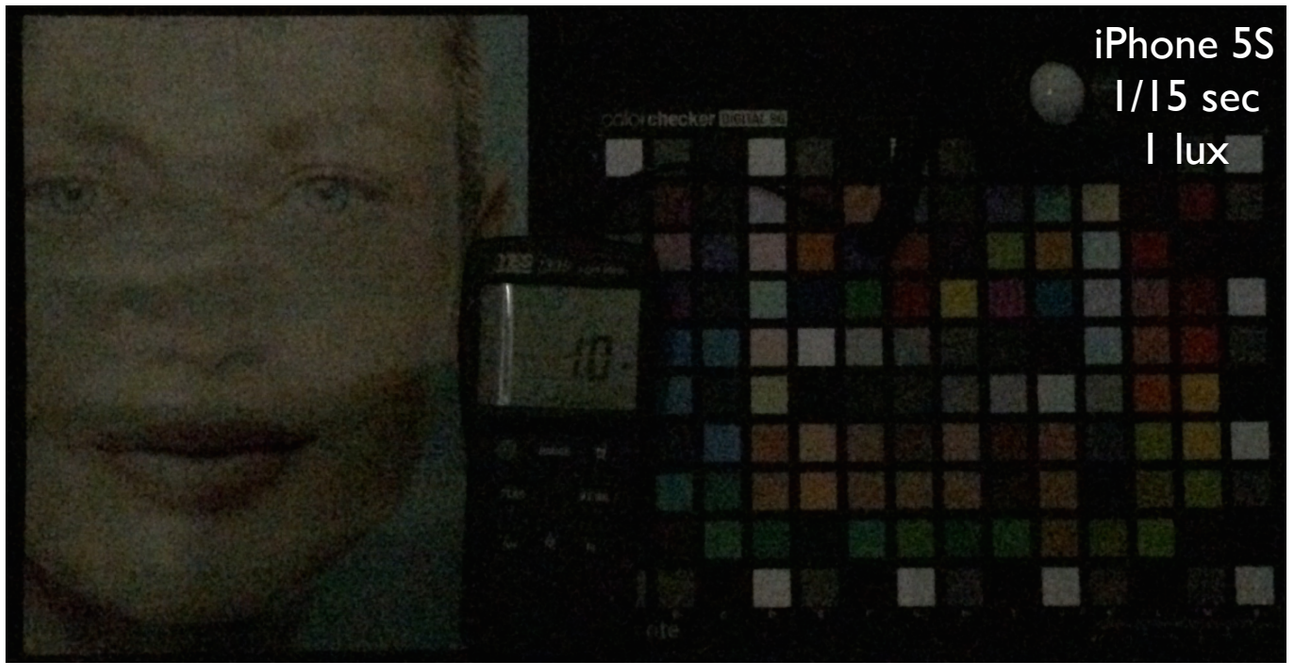
LinX 8 mpix
1/20 sec

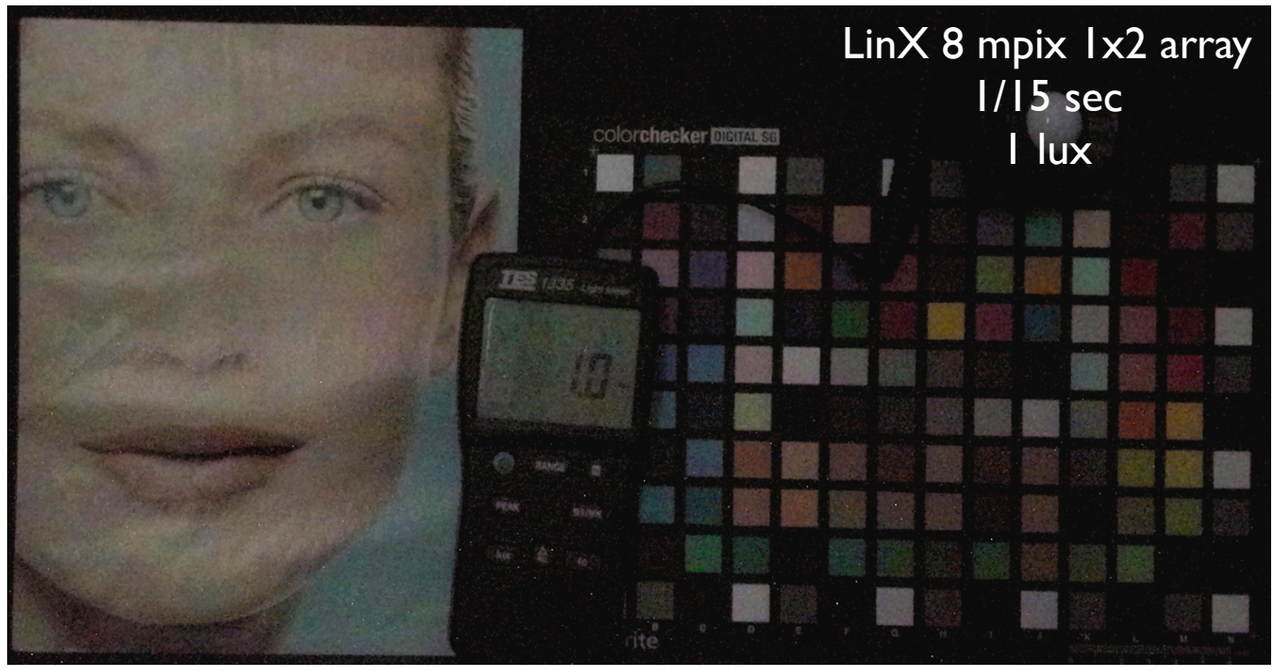

A typical portrait scene captured in 150 lux office light at 4000K

# Low light performance

Our camera architecture and algorithms leverage the multiple channels to boost the sensitivity of the camera which allows us to capture stunning images at very low light levels and keep exposure times short at normal indoor light levels and by that to avoid smearing.

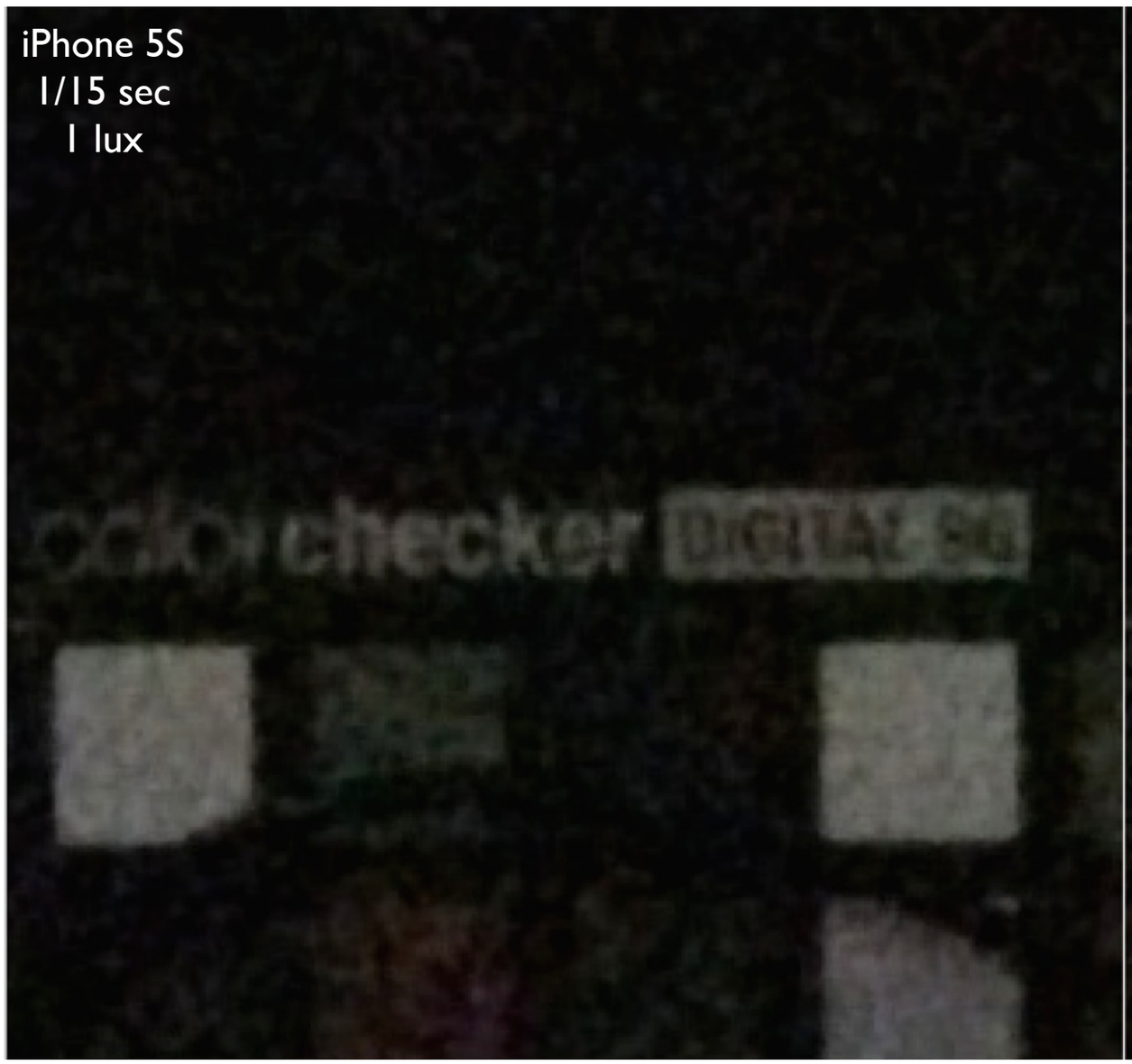
The following images show an indoor scene with light level of **1 lux** captured by Iphone 5s and the LinX 8 mpix array



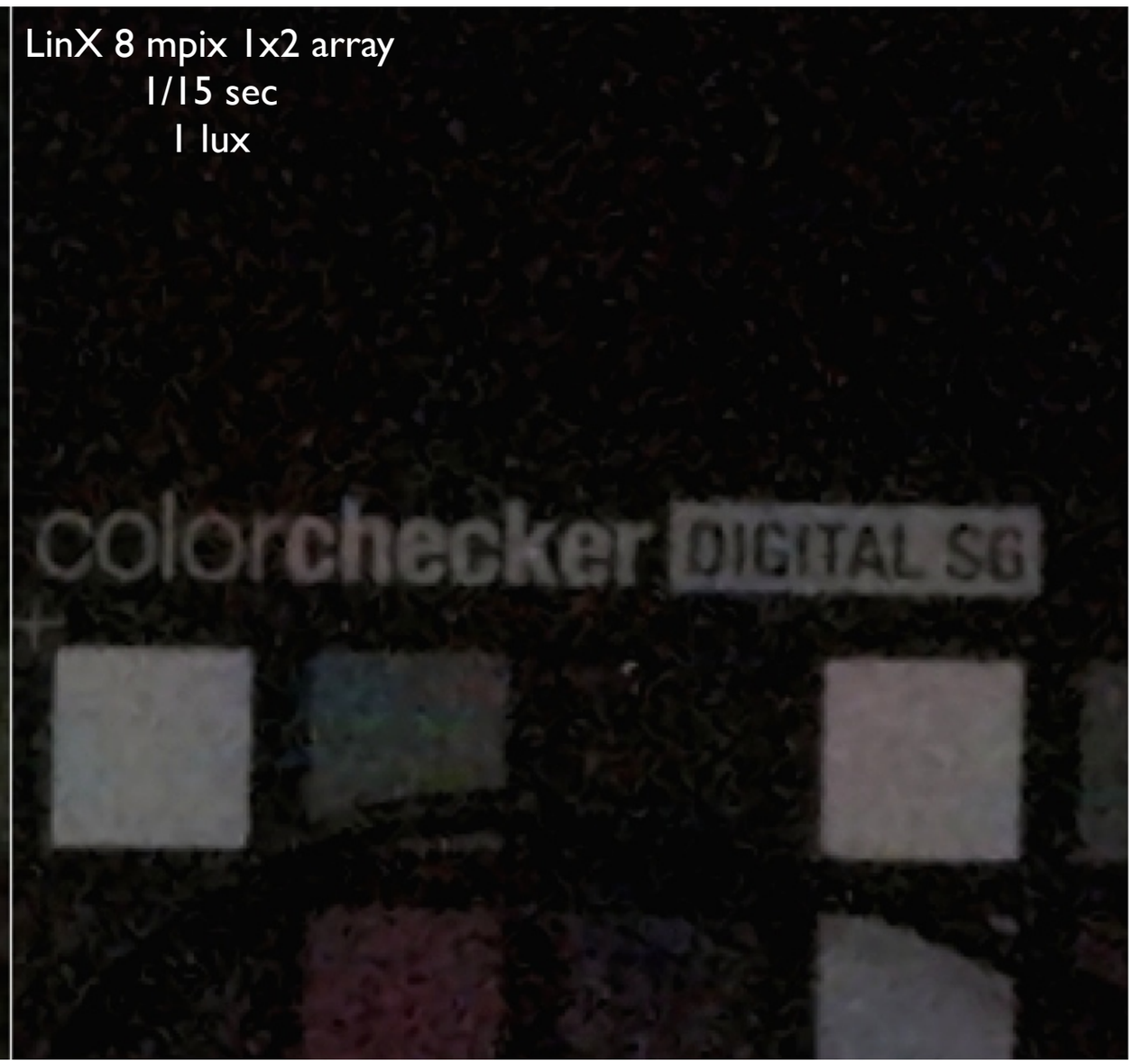



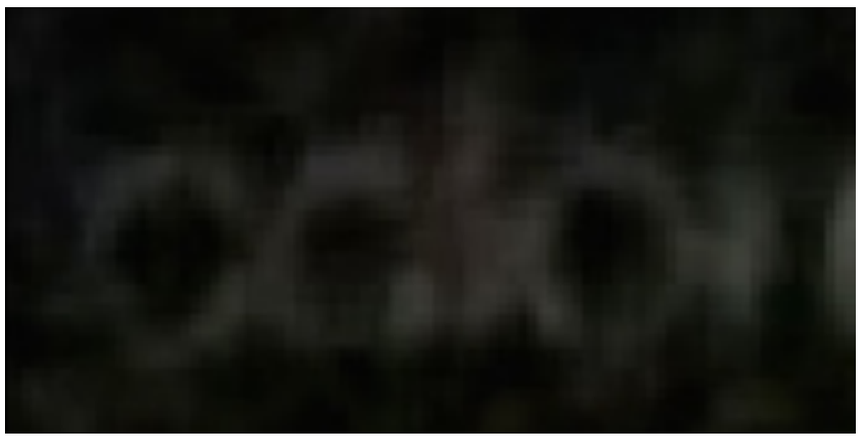
# Low light performance

iPhone 5S
1/15 sec
1 lux

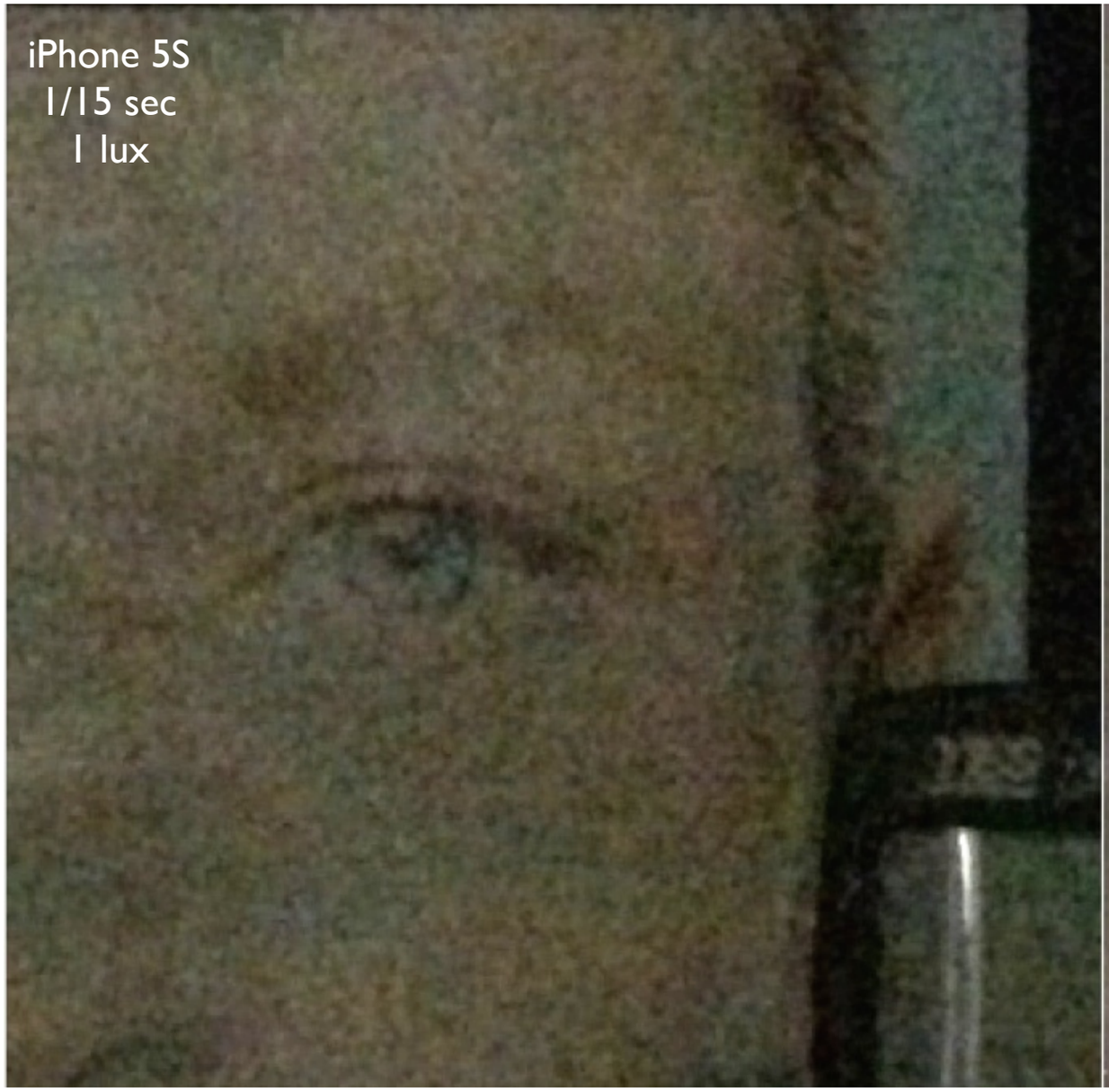



LinX 8 mpix 1x2 array
1/15 sec
1 lux

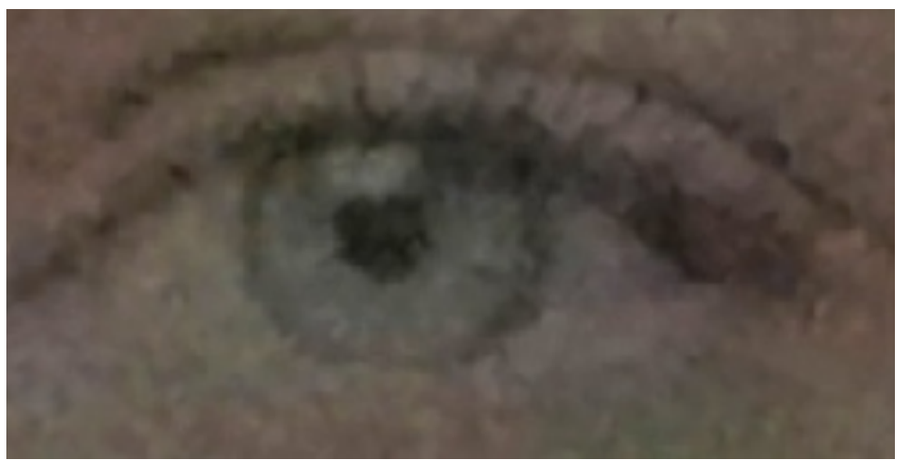


# Low light performance

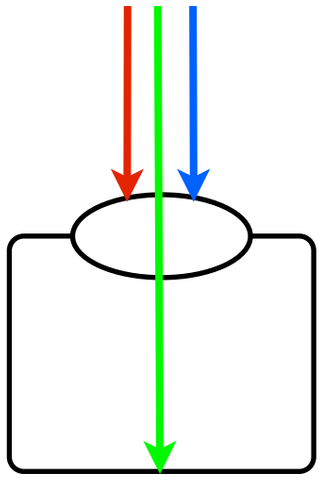




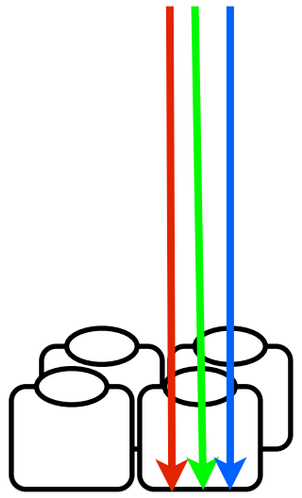


# The future towards smaller pixels

Pixel size has decreased over the years and many CMOS cameras in mobile device use a 1.12 um pixel and sensor makers are already working on their next generation which includes a 0.9 um pixel.
Single aperture traditional cameras as used in all mobile devices do not perform well with such small pixels due to pixel cross talk and other physical effects which occur when the pixel size approaches the wavelength of light.
The Linx cameras, utilizing the clear pixels, are less sensitive to cross talk and are more tolerant to low SNR of the pixels as the camera collects more photons per pixel generating images with low noise levels.



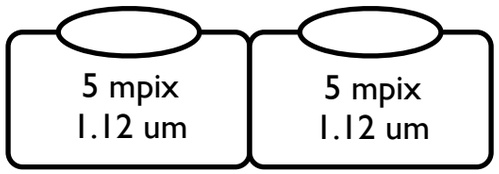
Single aperture Bayer CMOS

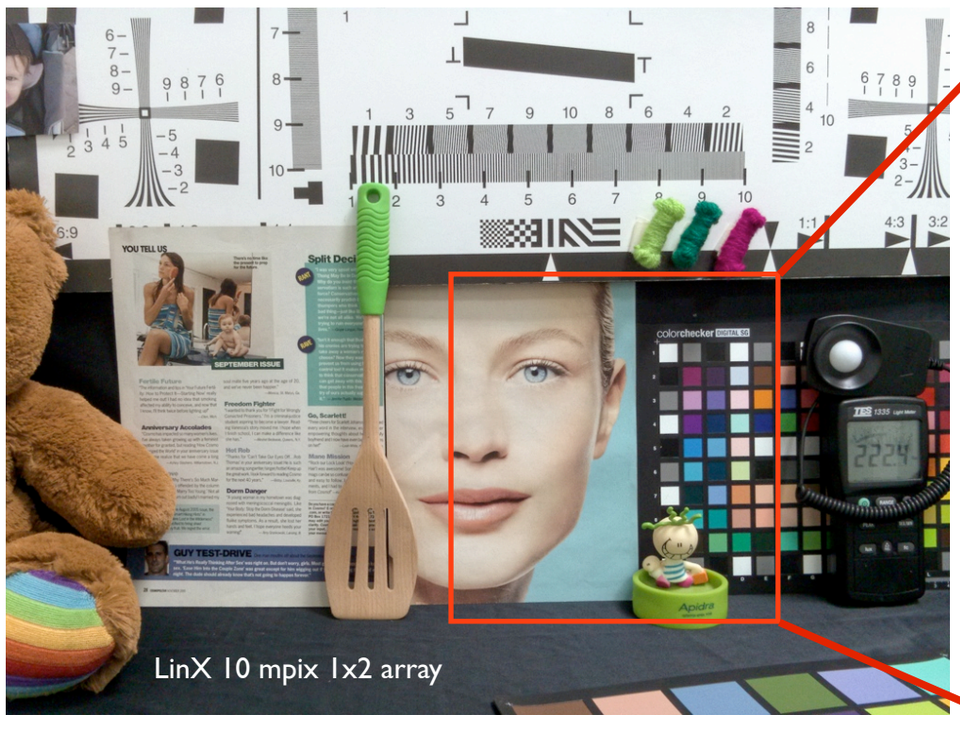


Clear pixel channel on a Linx Array Camera

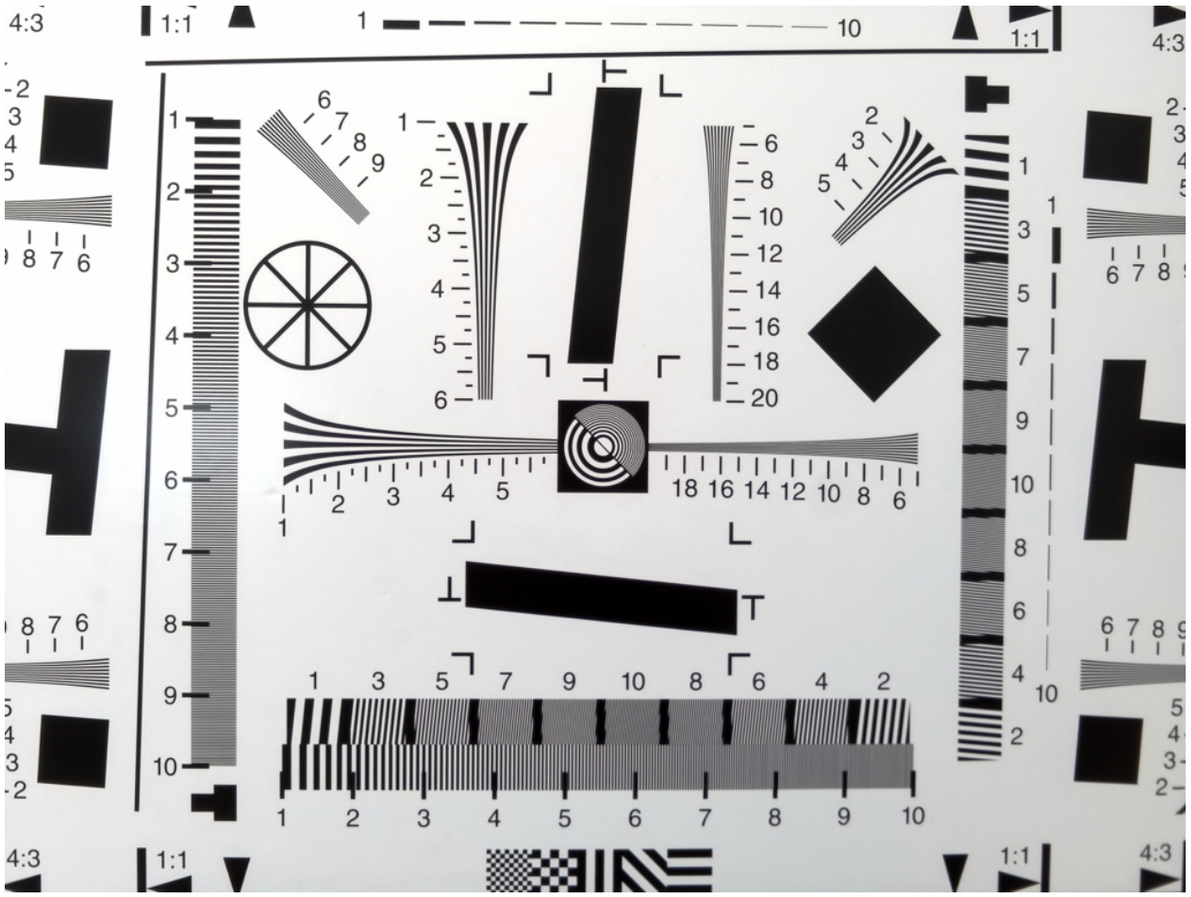
# 1.12 um pixel - Low costs / Small size / High quality

LinX has developed a module architecture that is intended for super-slim handset with very limited space for the camera module.
The module is a **1x2** with a **5 mpix** sensor on each channel using a **1.12 um BSI pixel**.
The costs of the module is approximately 50% less of a high end 8 mpix or 13 mpix such as the ones found on iPhone 5S or Galaxy S4.
The module is about 5x11x3.2 mm and is capable of capturing similar resolution as the iPhone 5S despite its low price and size.

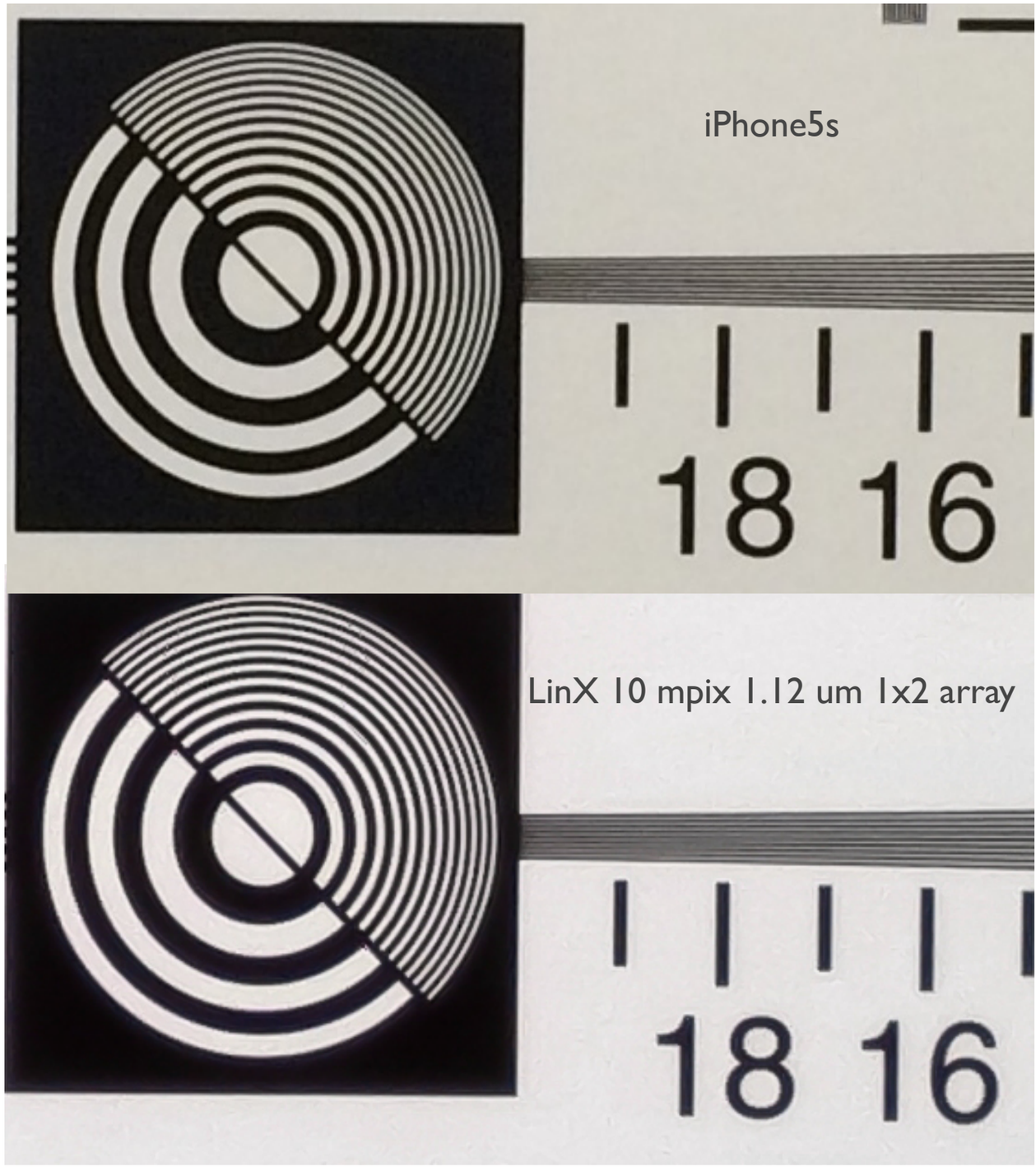



# 1.12 um pixel - Low costs / Small size / High quality



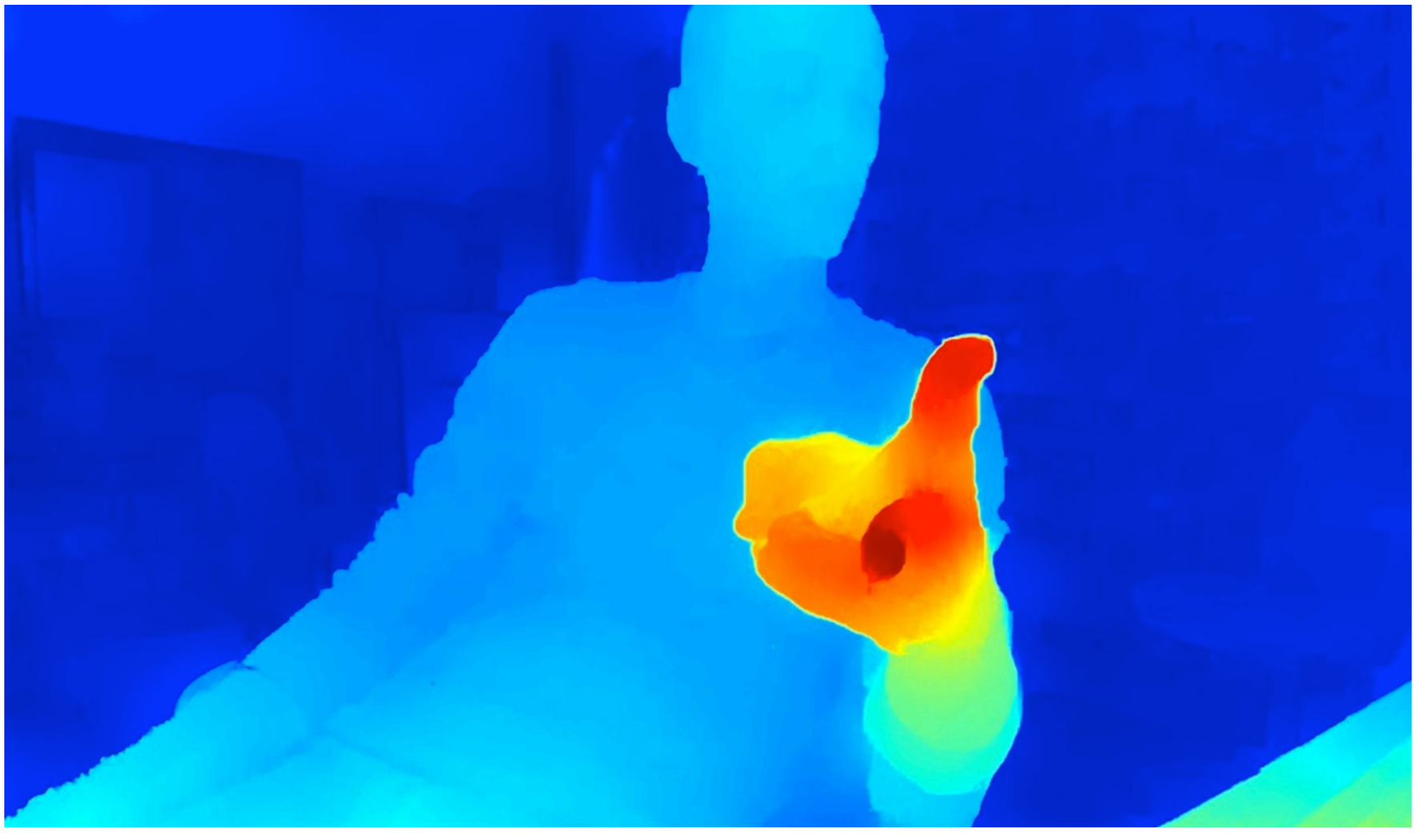
LinX 10 mpix 1.12 um 1x2 array



# 1.12 um pixel - Low costs / Small size / High quality

# RGBZ

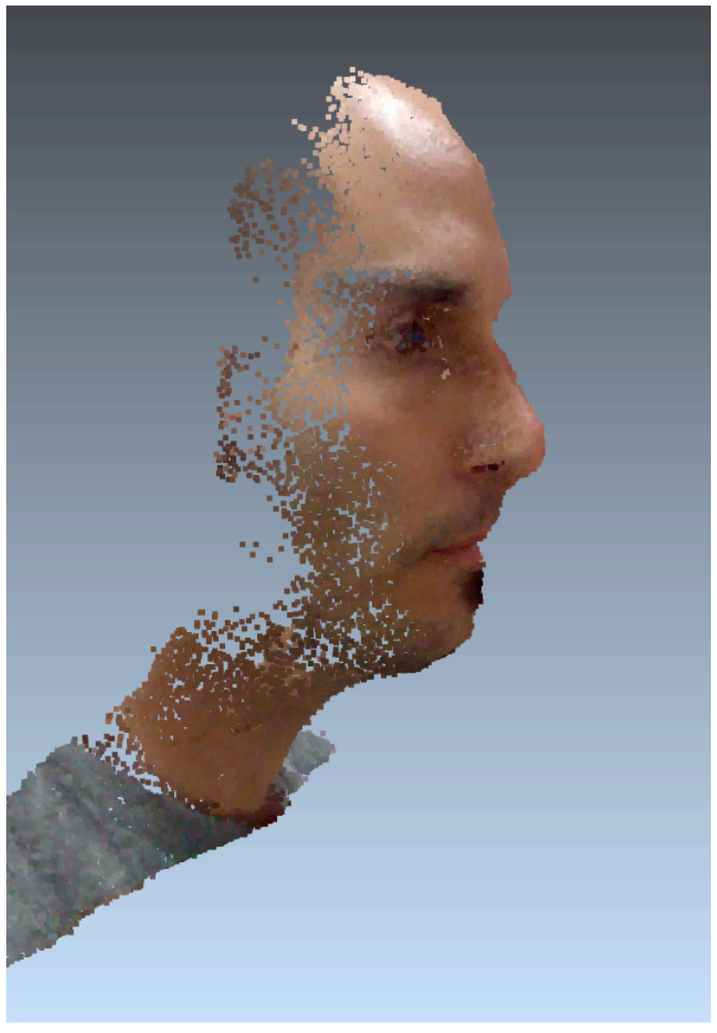
The Linx cameras can calculate ultra accurate sub pixel disparities between images allowing it to produce very accurate depth maps of a scene despite the small size of the camera module.

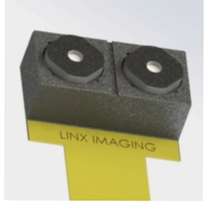


Depth maps captured by a 10x10x3 mm module

# RGBZ

Having depth information for every pixel in addition to RGB information allows us to create 3D point clouds of an objects from a single frame or a 3D model when combining numerous frames captured from different orientations






The point cloud was created from a single 10 miliseconds exposure while the camera was positioned directly in front of the face

RGBZ

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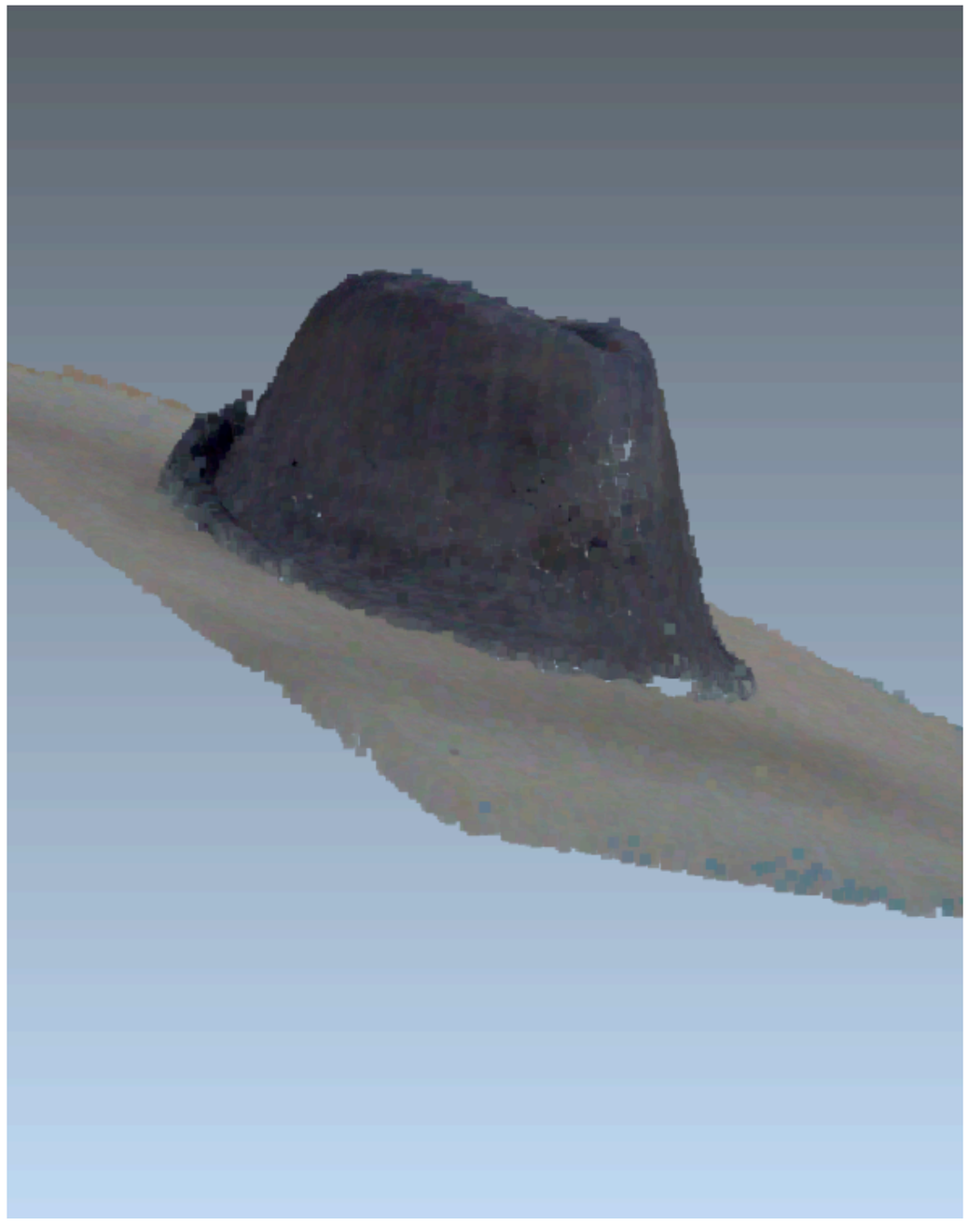
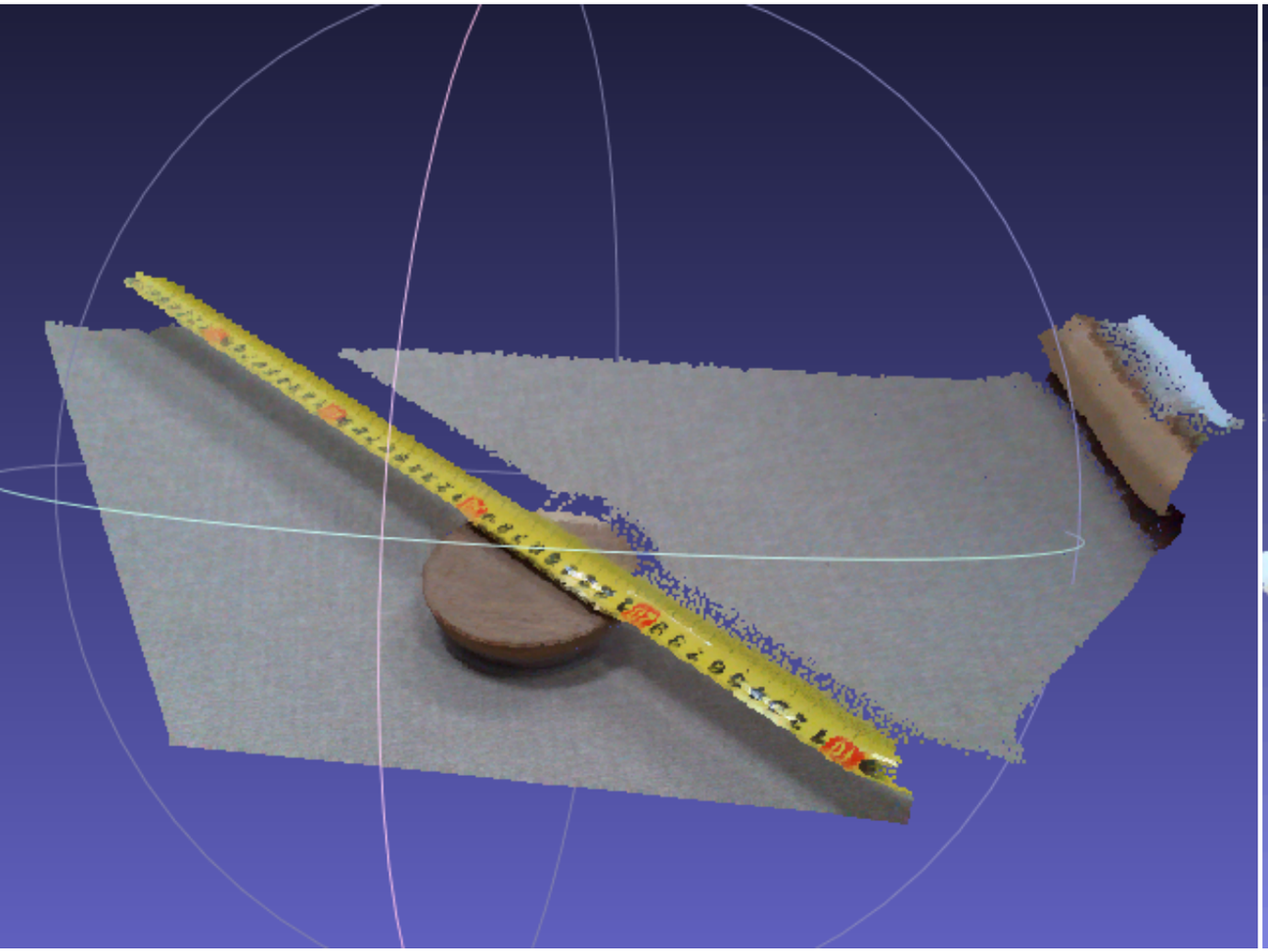
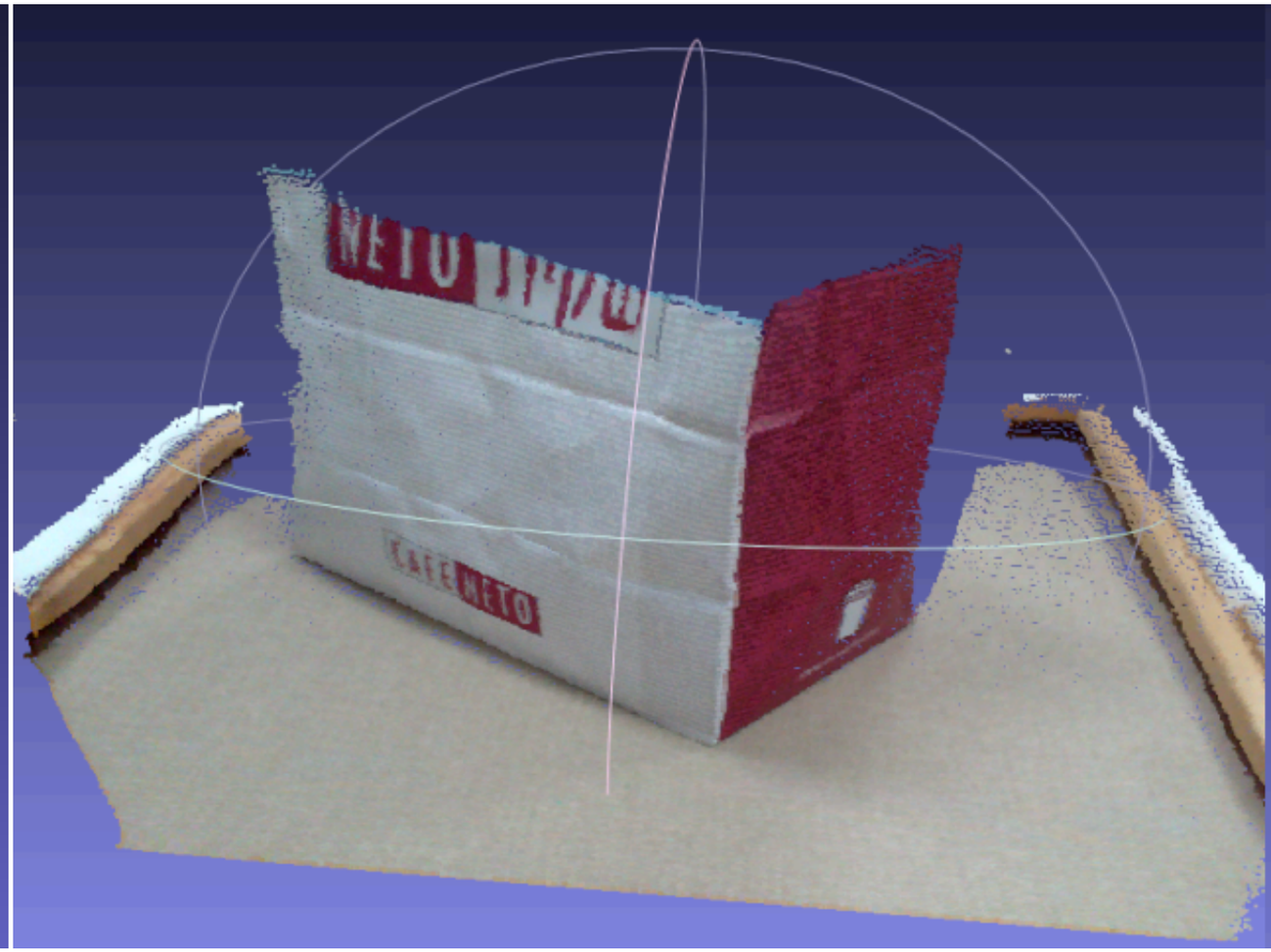
## Hat on a table



The point cloud was created from a single 10 miliseconds exposure

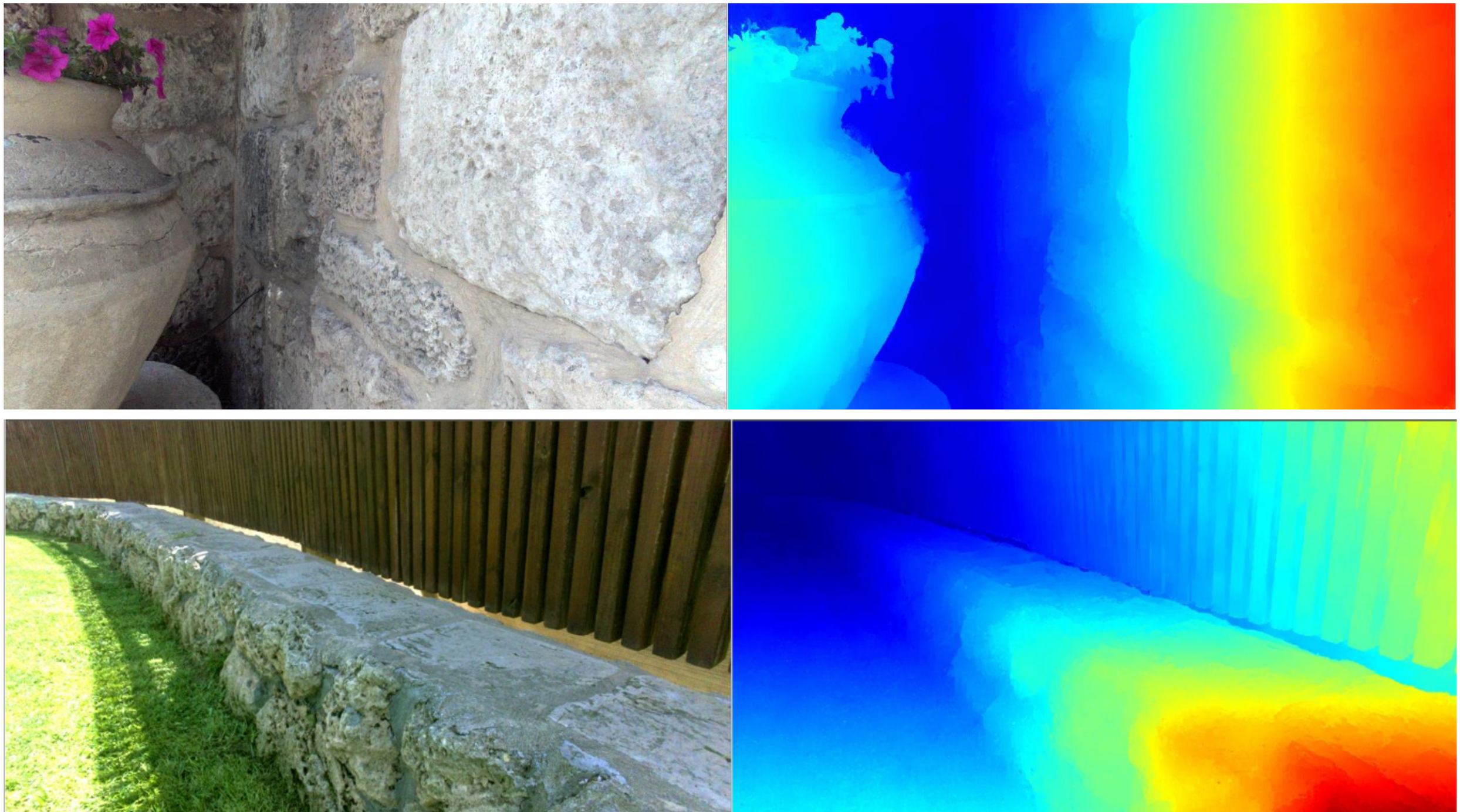
# RGBZ



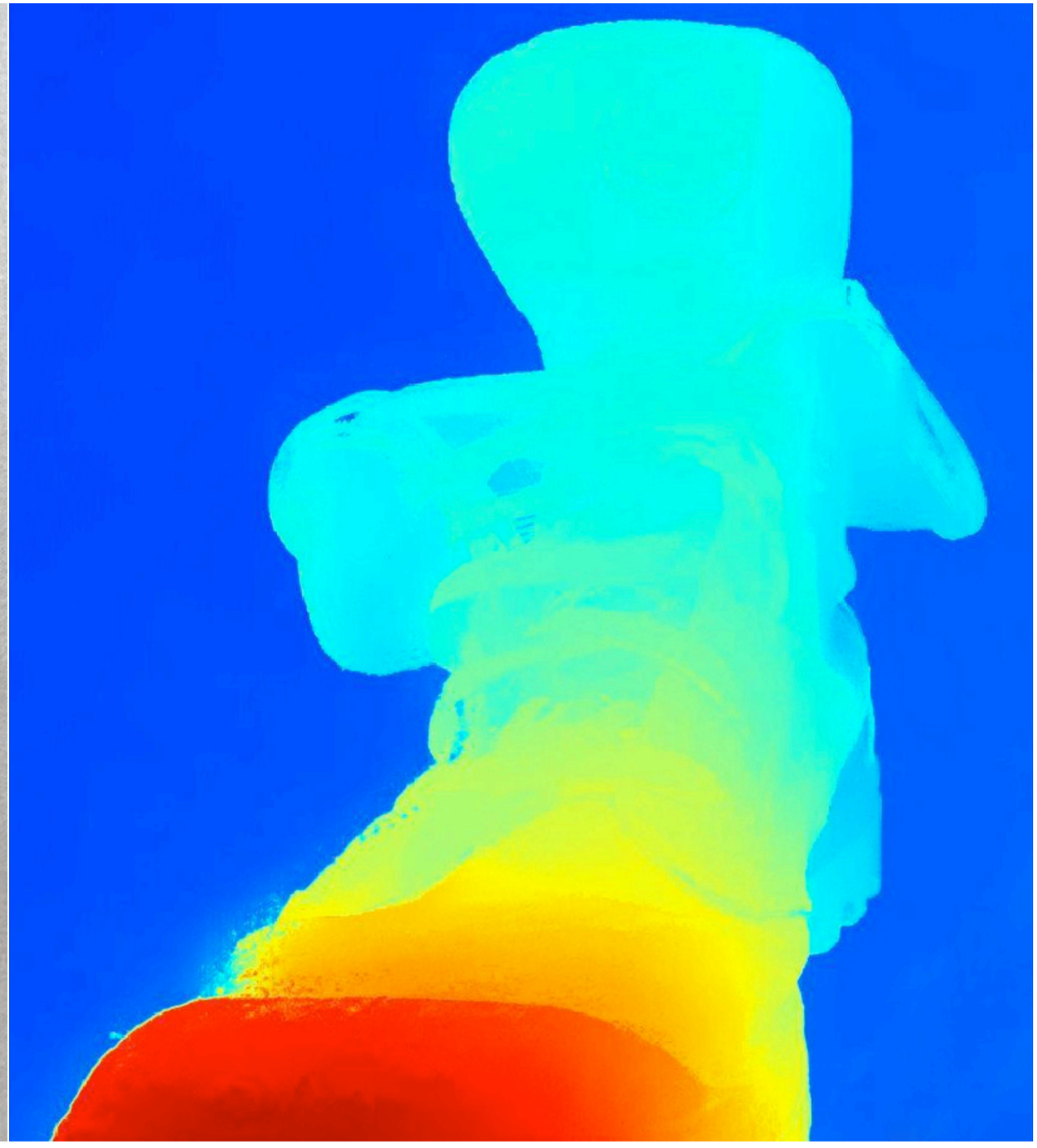



# RGBZ outdoors

The array cameras can calculate depth even when direct sunlight is illuminating the scene and in complete darkness with the help of a flash light that can be visible or near infrared



# RGBZ indoors



# RGBZ indoors

# Using the depth maps

**The LinX array cameras revolutionizes mobile imaging as we know it today**

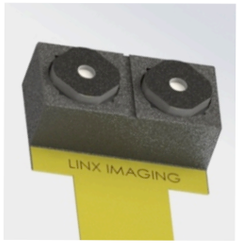
Better color accuracy and uniformity
HDR – Higher dynamic range
UHDR – ultra high dynamic range on dedicated modules
Low noise levels
Higher resolution
Low module costs
Better color accuracy and uniformity
No Autofocus for modules of up to 20 mpix
Zero shutter lag
Tiny package with up to 50% reduction in Z module height allowing slim devices and edge-to-edge display

**Depth maps can be used for various applications**

3D scanning of objects
Sizing of objects
Refocusing: knowing the depth at every pixels allows us to apply a synthetic blur to emulate a shallow depth of field
Background removal and replacement
Gesture recognition

# The optimal array

What is the ultimate array camera: 1x2, 2x2, 4x4, 1x4.... ?
There is no obvious answer and it really depends on the application and its constrains in terms of: costs, effective resolution, dimensions, dynamic range and algorithm complexity.
After years of research and development of numerous different configuration we explain here the pros and cons of some configurations:




*1x2 array with both color or both mono sensors - can be used for creating low quality depth maps. Practically has no advantage in terms of image quality*

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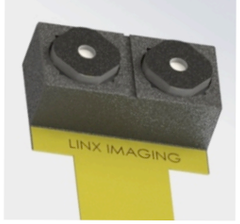


*1x2 array with one color and one mono sensor - can be used for creating low quality depth maps.*
*Has improved low light performance and general image quality*
*Lower costs than single aperture traditional cameras of same resolution*

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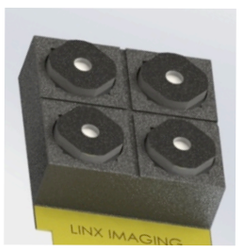


2x2 array with a combination of  color and mono sensors - can be used for creating high quality depth maps.
Improved low light performance and general image quality
Higher dynamic range

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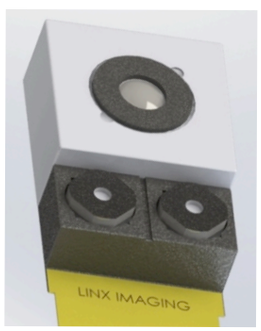


*Range Finder: 1+1x2 array: the two small apertures are used to create a depth map which serves as input  for the Auto Focus mechanism on the main aperture eliminating the need for focus hunting which often leads to false focusing, especially when pixel size is small.*
*Ultra Fast - error free focusing even in extreme low light*

# About us

Linx Imaging, founded in June 2011 by two imaging experts, is a startup company located in Caesarea, Israel
The company is dedicated to commercializing multi aperture technology in various devices and applications.

Since it was founded the company has developed cutting edge algorithms and module architectures which are manufactured by our close partners: Module, Sensor and Lens manufacturers.

Management & Founders:

**Ziv Attar** – CEO & Co-founder
Ziv holds a B.Sc. in Optical Engineering from the Technion institute of Technology in Haifa, Israel.
Over 15 years of experience developing & commercializing EO products for various markets and applications mainly in the consumer, medical and defense fields.

**Andrey Tovchigrechko** – Chief Algorithm Development & Co-founder
Andrey holds a M.Sc. in Applied Mathematics from the Moscow State University, Russia.
Over 15 years of experience in designing mathematical algorithms for nonstandard technological problems.

# Thank you & stay tuned

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www.linximaging.com