CMOS Image Sensors in Cell Phones, Cars and Beyond

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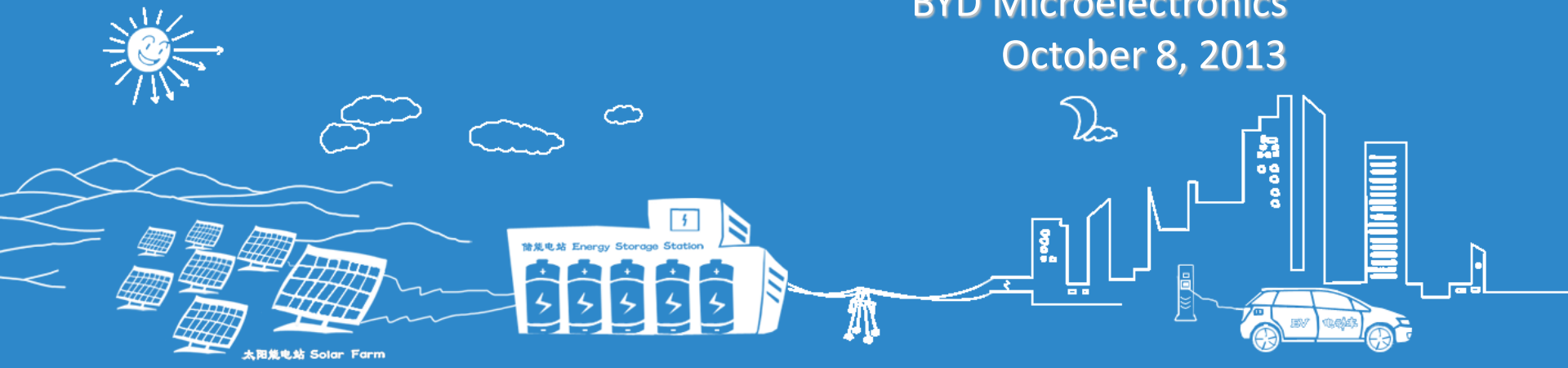
October 8, 2013



Build Your Dreams

BYD Microelectronics (BME) is a subsidiary of BYD Company Limited, Shenzhen, China. Formed in 2004, BME focuses on CMOS image sensors, touch solutions, power management IC, and power devices.

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1 CMOS Image Sensor (CIS) Markets

2 CIS Applications and Requirements

3 CIS Technical Efforts

CIS Shipment Forecast

Source: Yole Development

- A compound annual growth rate of 11%, from $6.6 billion in 2012 to $2017 in 11 billion
- Wide range of diversified applications for integrated CMOS image sensors
- 500K wafers/moth capacity
- The new and emerging applications (tablets, cars, and smart TV and appliance, etc) at much higher growth rate

CMOS Image Sensor Applications

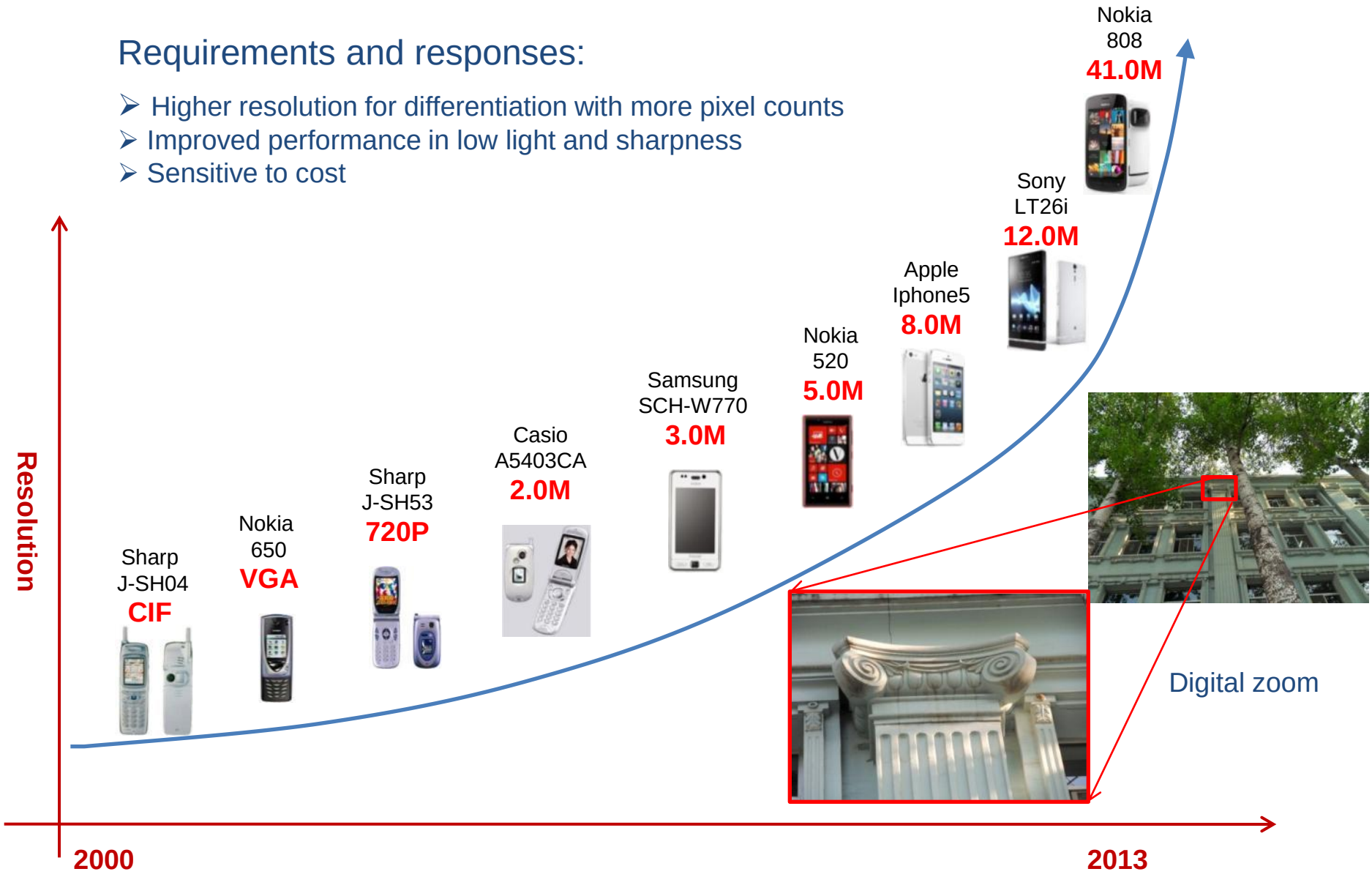
Source: Yole Development

- Spectrum of applications from high volume/cost sensitive to low volume/performance driven
- Three areas are most active in demand, growth and innovation
- Solution requirements at chip architecture, circuit design, packaging and wafer process

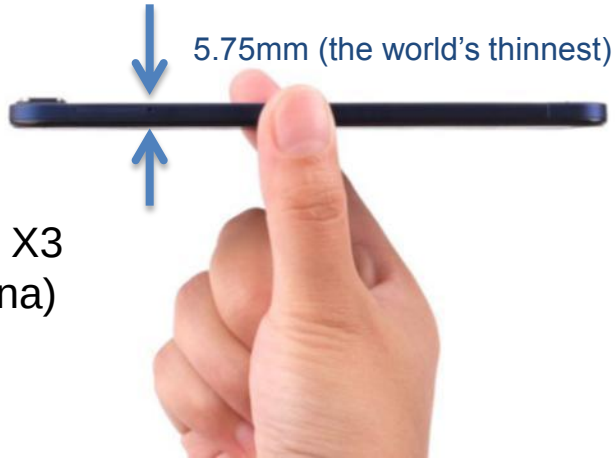
Higher Resolution

Requirements and responses:

- Higher resolution for differentiation with more pixel counts
- Improved performance in low light and sharpness
- Sensitive to cost



Camera Module Smaller

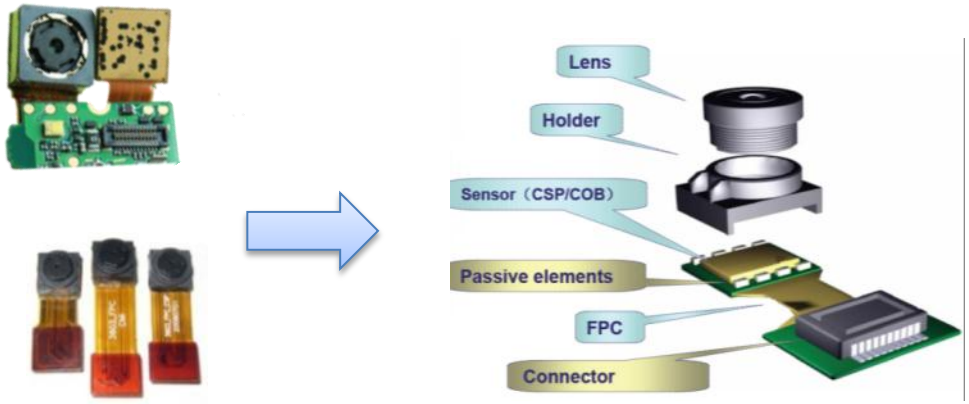


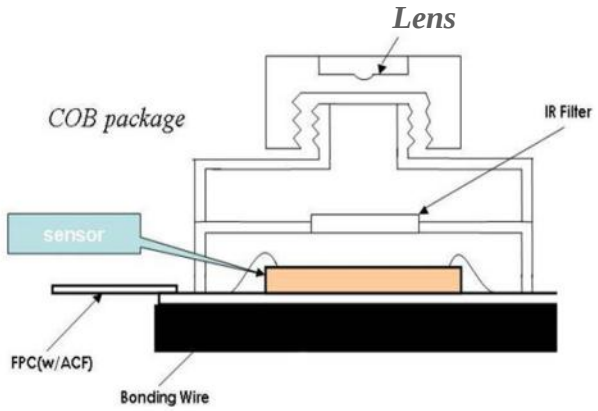
- 8M camera w/ 5M front camera
- 5" LCD display

iPhone 5s at 7.3mm

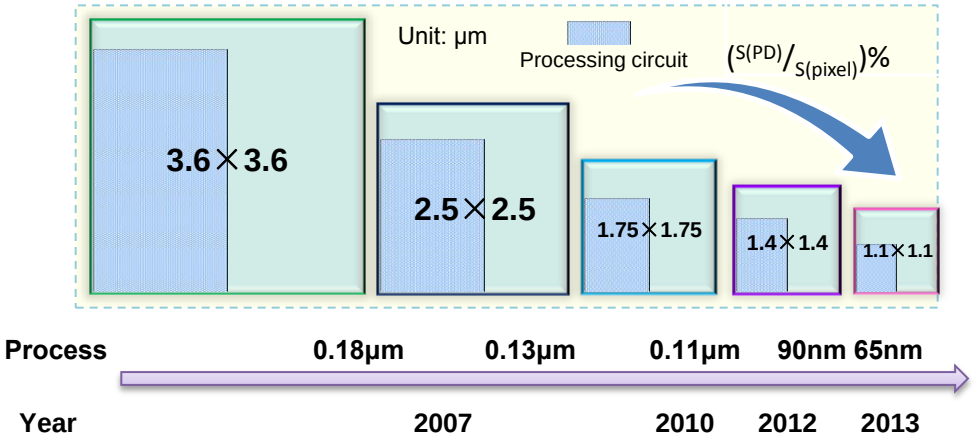
X3 Module Height	5.4mm

Sensor Pixel Size Smaller





Reduced pixel sizes are needed to meet higher resolution and shorter module



Module Height:

Resolution	Pixel Size (μm)	Module Height(mm)
VGA(BF3903)	2.0×2.0	2.6
5MP (FF,BF3A50,FSI)	1.4×1.4	4.7
8MP (AF, Sony, BSI)	1.1×1.1	4.9

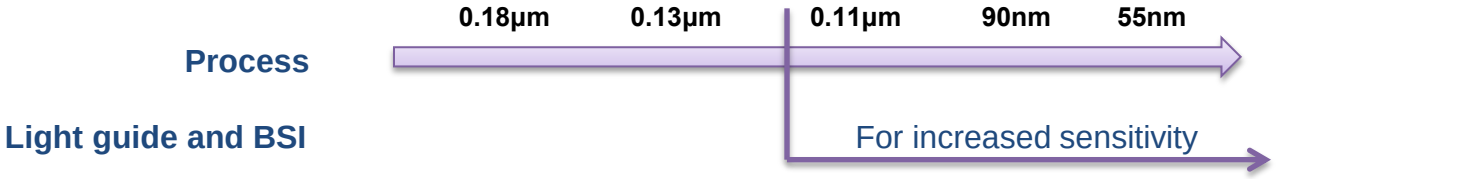
Sensor Performance Challenge

Resolution	VGA	VGA	VGA	720P	2MP	5MP
Pixel Size(μm)	6.0×6.0	3.15×3.15	2.25×2.25	1.9×1.9	1.75×1.75	1.4×1.4
Fill Factor	56%	46%	45%	42%	43%	30%

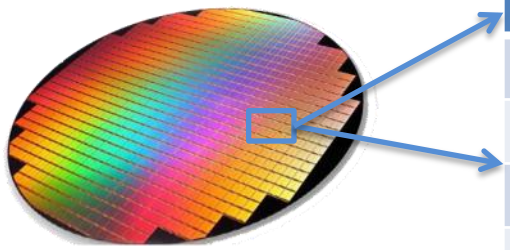
Smaller pixel area, lower fill factor bring poor low light performance:

low light performance

New process improvement:

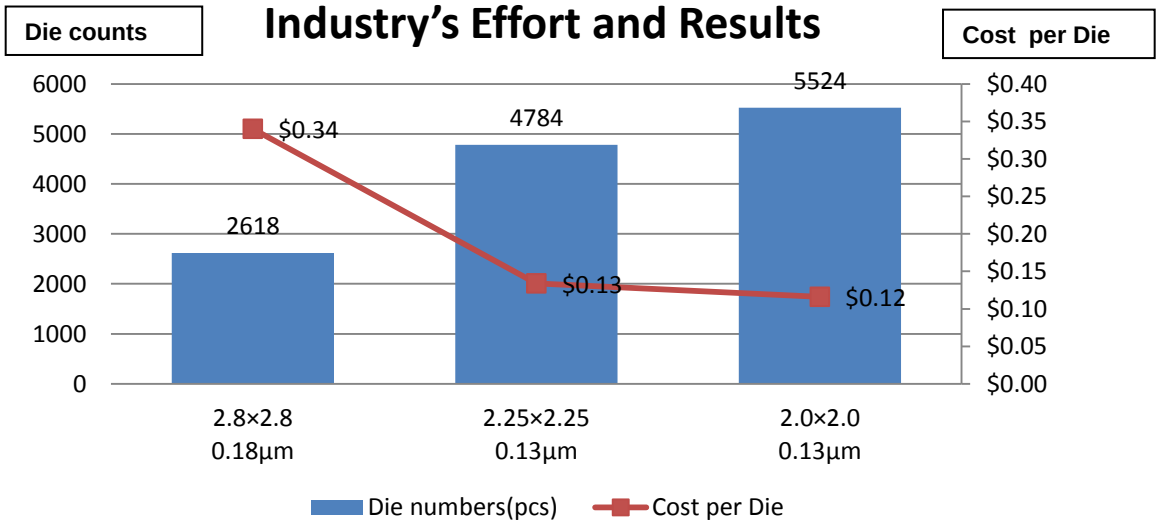


Sensor Cost Efforts



8'' Wafer
(CMOS Image Sensor)

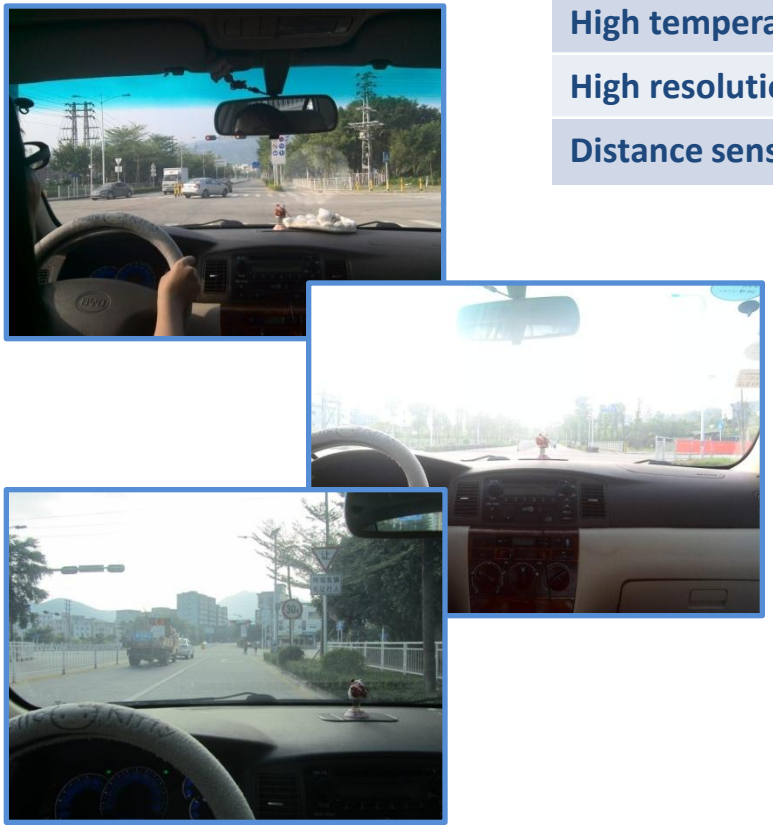
Resolution	Process	Pixel Size (μm)	Die numbers (pcs)
VGA(BF3403)	0.18μm	2.8×2.8	2618
VGA(BF3703)	0.13μm	2.25×2.25	4784
VGA(BF3903)	0.13μm	2.0×2.0	5524
2MP(BF3920)	0.13μm	1.75×1.75	1716
5MP(BF3A50)	0.11μm	1.4×1.4	1134



Cost reduction through wafer process and design improvement

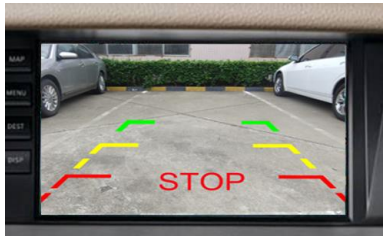
Demanding Automotive Conditions

Natural requirements	Difficulties or needs	Approaches
Low light and night	Low light sensitivity	Passive/active
Fog, rain, or snow	Low visibility	Gated imaging
High speed	Image blurring	Sensitivity/frame rate
High contrast	High beams, sun	Design/compensation
High temperature	High sensor noise	Design/process
High resolution	Object recognition	Design/process
Distance sensing	Collision warning	TOF, stereo vision



Visual Assistance

- The national highway traffic safety administration (NHTSA) proposed a mandate by September 2014 all vehicles sold in the USA must have a rearview system
- However, there are concerns expressed by automakers of the costs associated with implementing proposed new standards



The panoramic and rearview systems on BYD minivan M6

4 cameras on BYD minivan M6

Night Vision

According to the US national highway traffic safety administration (NHTSA) statistics, while driving at night time only accounts for a quarter of total drive time, but an accident causing death rate accounts for 1/2.

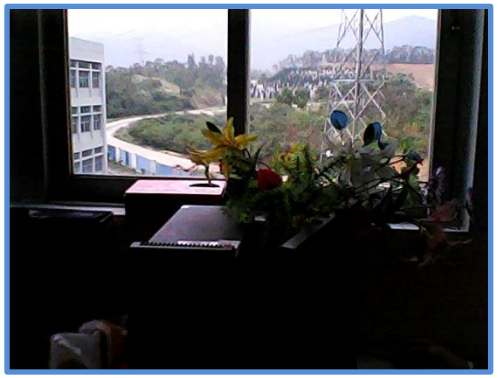
Active system:

- IR assisted
- CMOS image sensor
- High dynamic sensing
- Power modulated

The night vision system on BYD automobile 思锐

High Dynamic Range

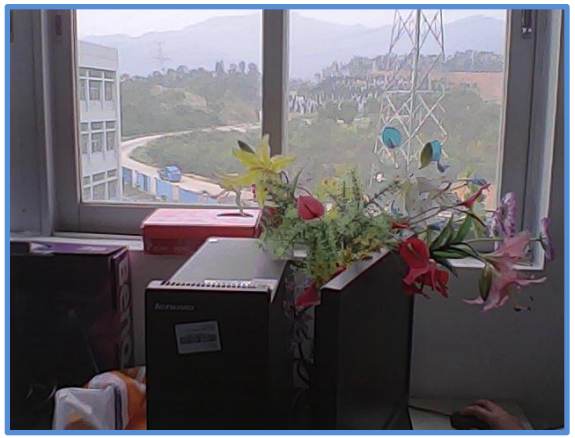
• Exposure for interior



Exposure for outdoor

Efforts to improve drivers visual experience:

- **Imager allows more details in both the bright and dark areas**
- **Without assisting light**
- **Real time and video form**



Improved dynamic range by a BYD sensor

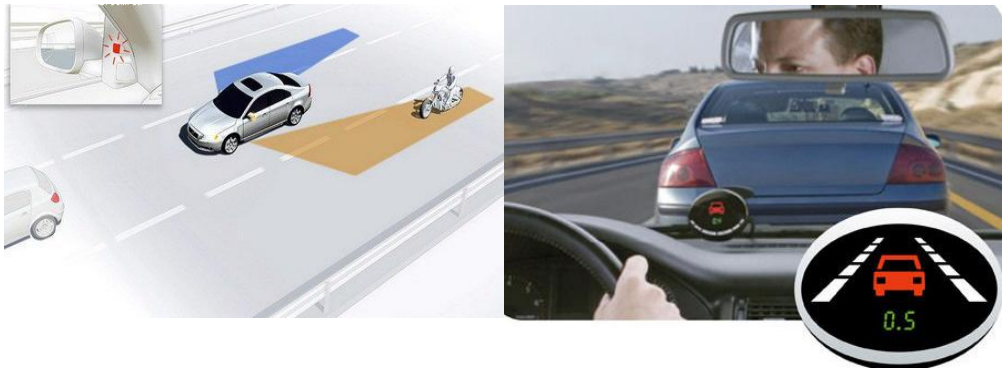
Intelligent Automobile

The automobiles are becoming more intelligent both for ease of driving and safety.

Requirements from CIS:

- Object recognition
- Range sensing (optional by other means)
- All weather and day/night conditions

Signal and sign recognition

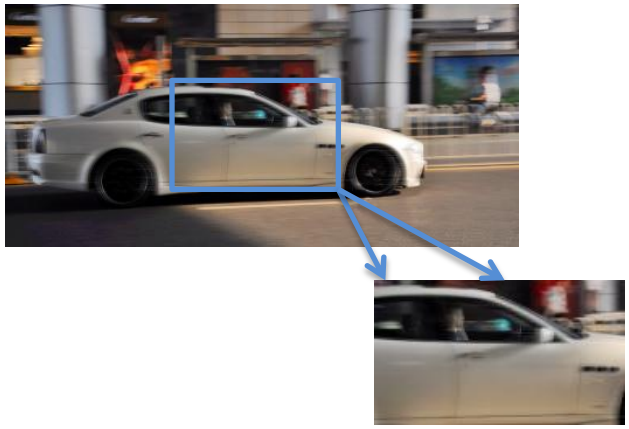


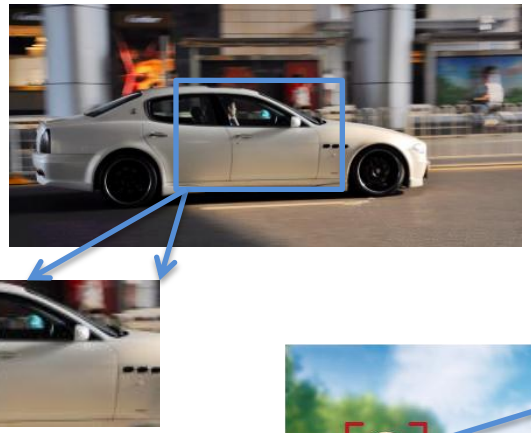
Lane departure and collision warning/avoidance

Google driverless car

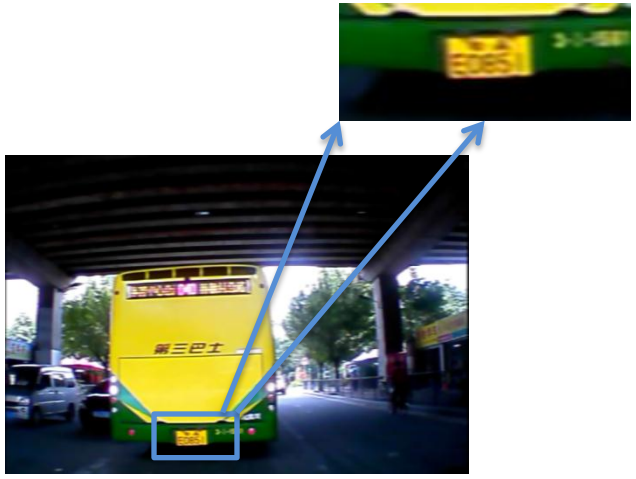
Resolution and Frame Rate

- Global shutter, or high frame rate



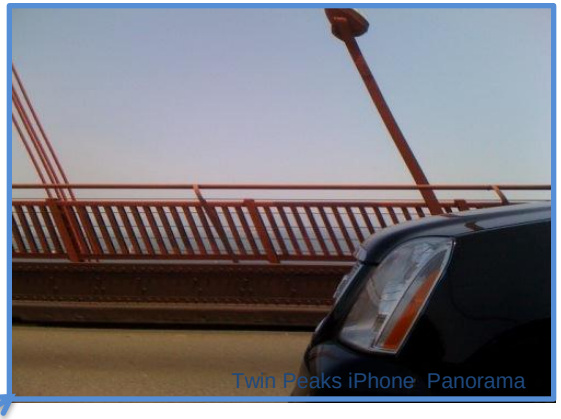


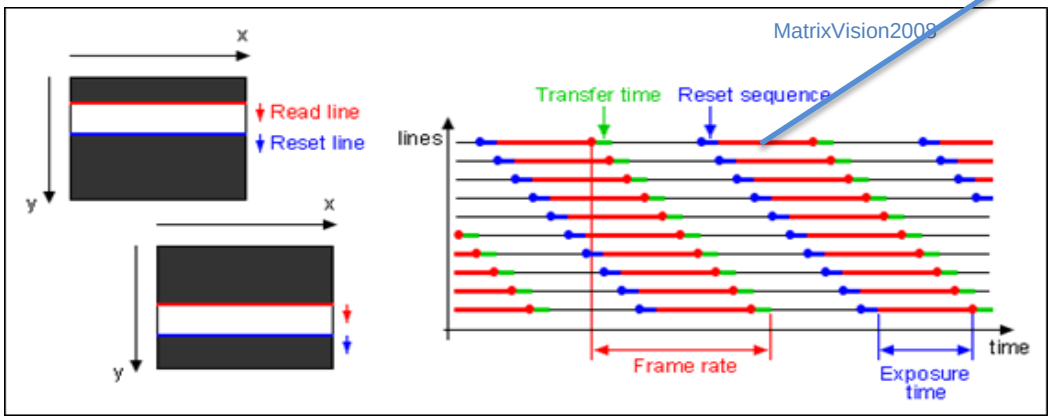
- High resolution



Rolling Shutter Effect

CIS with rolling shutter exposes each line of pixels at different time, deforming the images of moving objects (with global shutter being the solution)



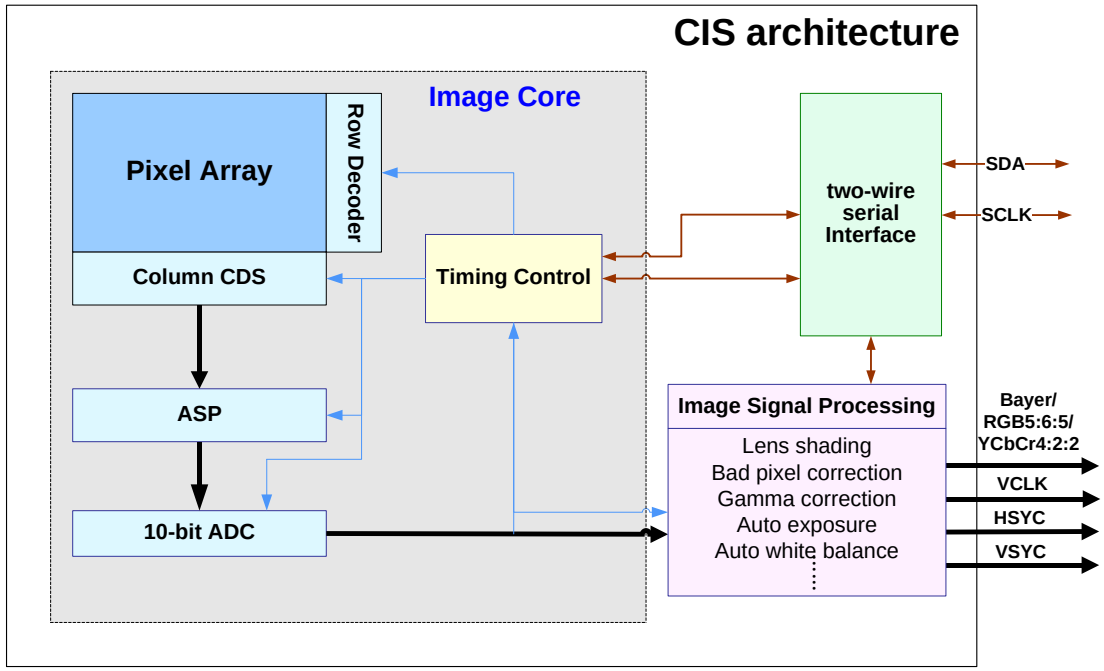


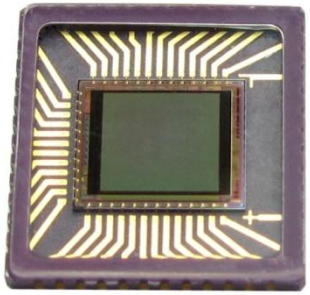
What To Do With CIS

- Anti-fog, rain or snow

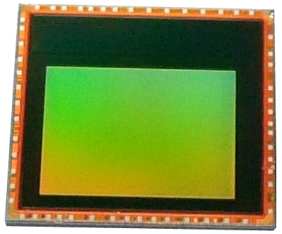
- Anti-blooming

CIS Basic Architecture





BYD NTSC/PAL VGA



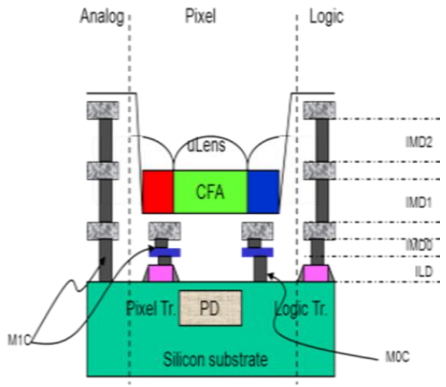
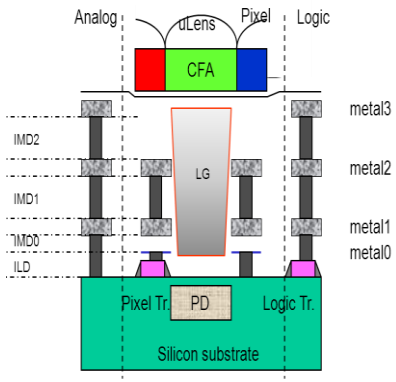
BYD 5MP

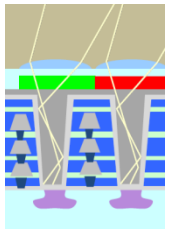
To meet the application needs,

- Wafer processes toward finer features, lower leakage, broader spectral response
- Pixels with better fill factors, global switching, other functions
- Periphery circuits with faster gain, parallel ADC

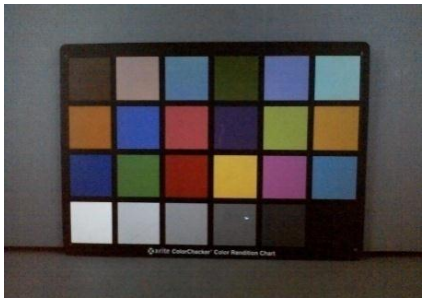
FSI With Light Guide

- **Light Guide Process**

Standard FSI	FSI with Light guide
	
480mV/Lux.s	**600mV/Lux.s**



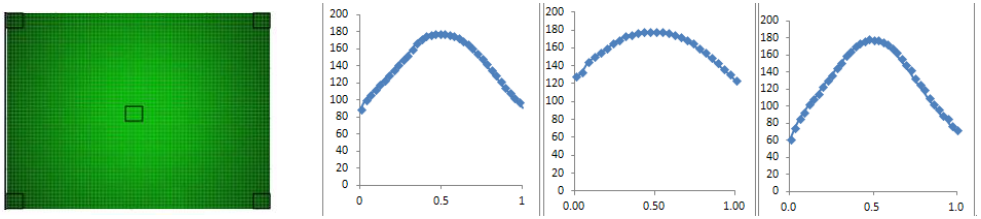
Standard FSI



FSI with Light guide

Better sensitivity and uniformity

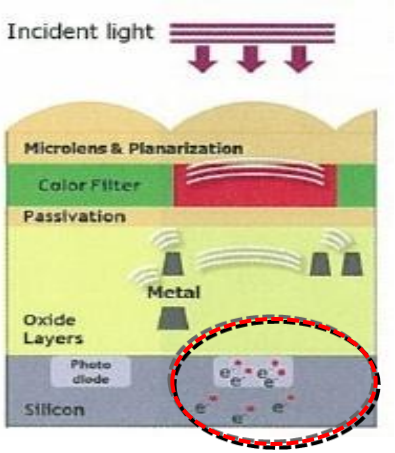
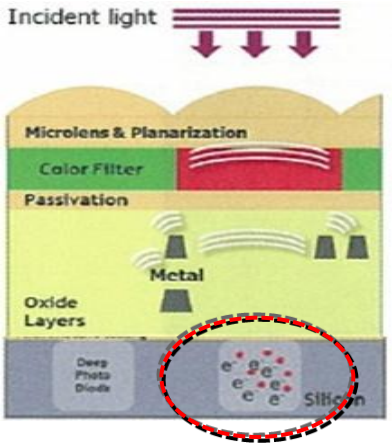
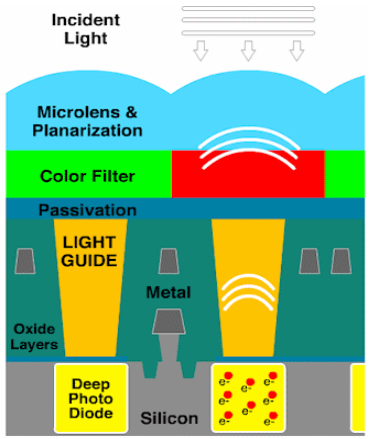
- Sensitivity improvement of 25-45%
- Uniformity improvement of 30%



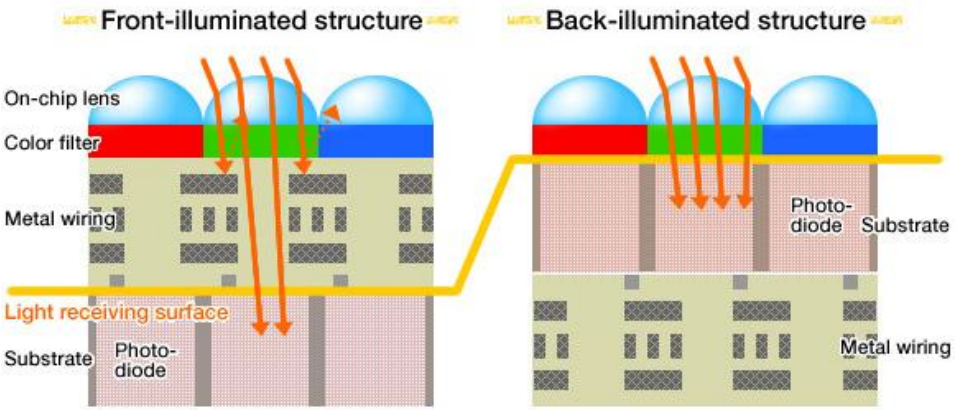
Light Guide & Deep Photo Diode

- **Deep Photo Diode Process**

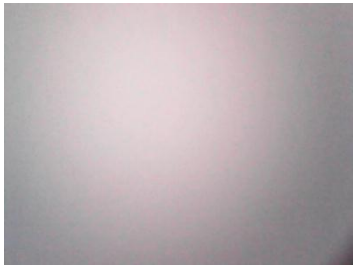
  Full well & SNR improvement

Standard Photo Diode	Deep Photo Diode	Light guide + Deep Photo Diode
		
Full well ~4000e SNR ~36dB	**Full well ~6000e SNR ~38dB**	**QE ~50% Sensitivity ~600mV/Lux.sec Full well ~6000e SNR ~38dB**

Backside Illumination (BSI)



FSI

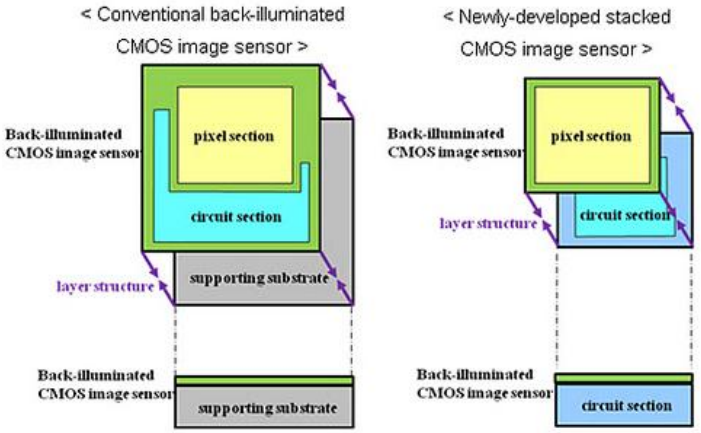


BSI

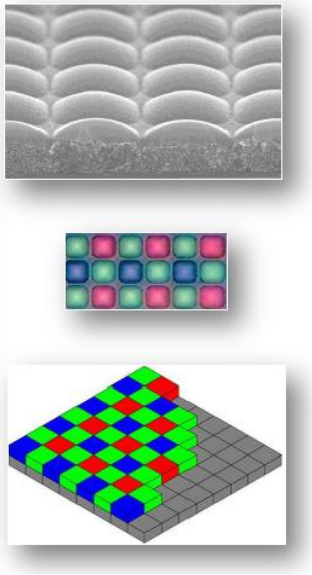
Backside illumination:

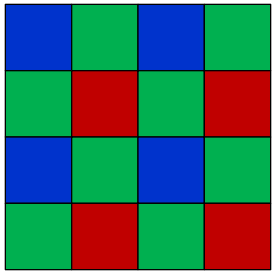
- Improved fill factor
- Quantum efficiency and SNR improvement
- Improved crosstalk and corner response

BSI image sensor accounted for 25% of total sales of CIS. The market share is expected to rise to above 70% in 2017, operating income increased to $ 7.7 billion.

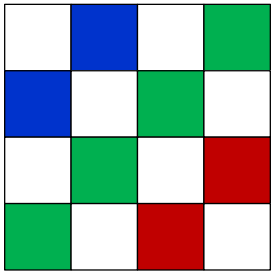


Color Filters

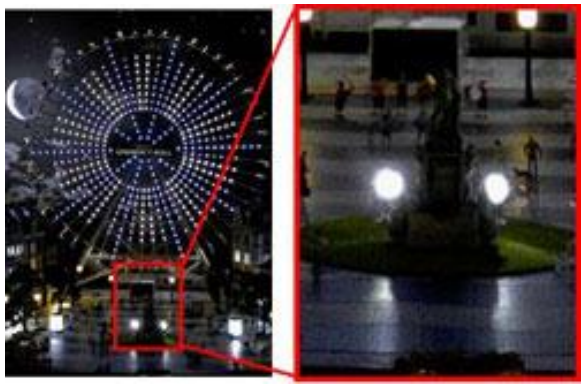




Standard pixel array (Bayer)

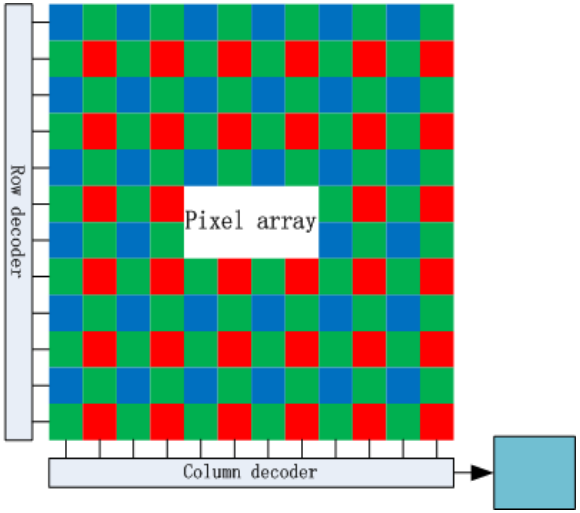


A RGBW pixel array



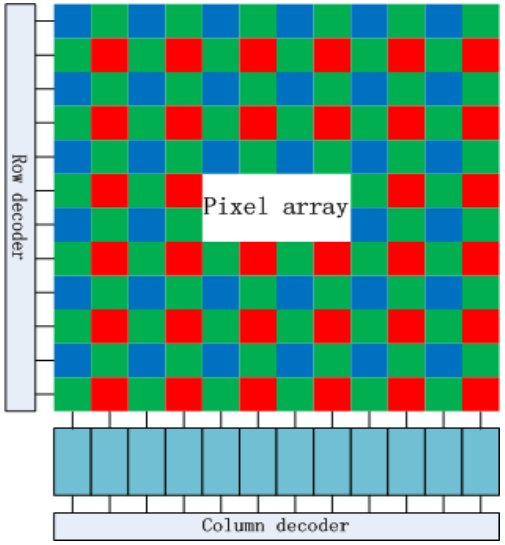
➢Higher sensitivity with 1.12um RGBW pixel equivalent to RGB 1.4um size pixel

Pixel and Array Architecture



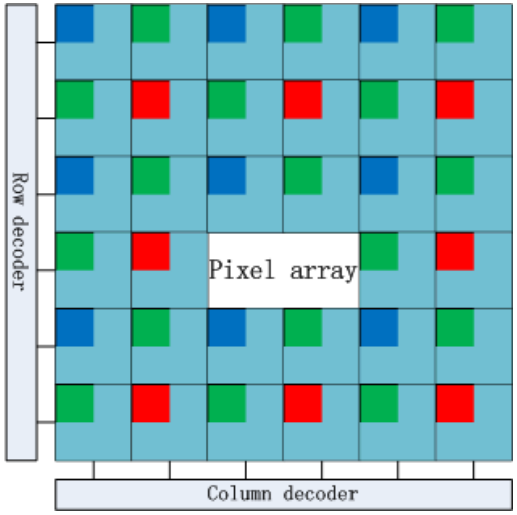
Standard

- High fill factor
- Limited frame rate
- Small pixel



Column-parallel

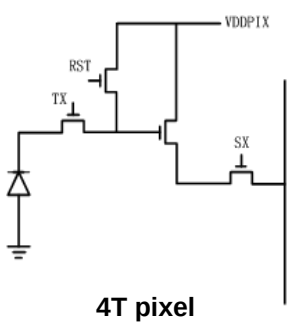
- High fill factor
- Fast and accurate
- Low power
- Medium or small pixel size
- Column digitization



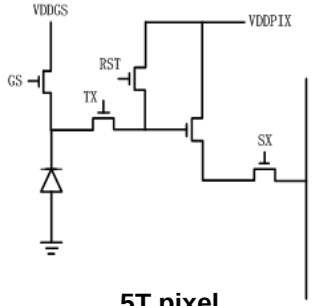
Pixel-parallel

- Low fill factor
- High throughput
- Special applications
- Large pixel size

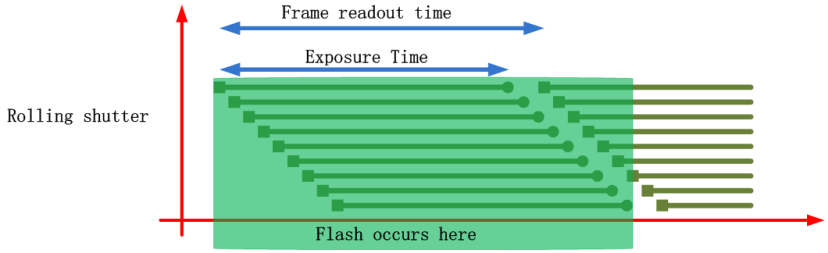
Global Shutter

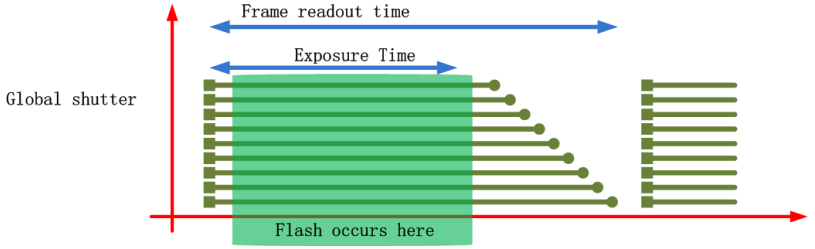


4T pixel



5T pixel

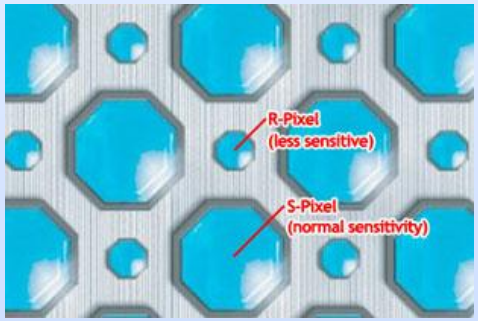




- All pixels experience the same exposure, transfer the signals to individual storages for sequential readout
- Global shutter solves the problem of image tilting of moving objects by rolling shutter imagers
- Smaller fill factors in the pixel due to one or more transistors inside

High Dynamic Range

large pixel and small pixel



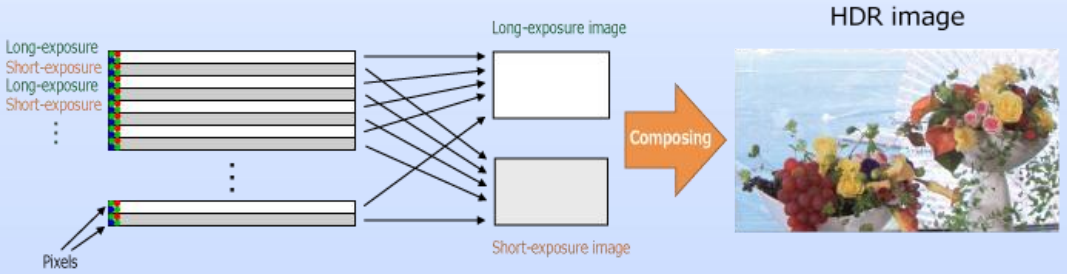
Fujifilm FinePix S3 Pro
(CCD, 2004)

HDR on

HDR off

Intral frame & Inter frame

Single-frame HDR: Captures lines of an image with different exposure times simultaneously and composes them into a single HDR image



Advantage: Support of video and little cost overhead
Disadvantage: Limited improvement

Multi-frame HDR: Composes multiple frames captured with different exposure times into a single HDR image.

Advantage: Unlimited frames with better result
Disadvantage: Motion blur, limited to still imaging

Summary

- CMOS image sensors for cellphones and automobiles/ surveillance present exciting but different types of challenges
- Collective efforts in wafer processing, imager design and system applications are providing end users better solutions
- There are areas that need technical solutions, especially for the automotive applications.

Questions?

Build Your Dreams

Thanks

Build Your Dreams