Imaging Overview

dToF module	3D ToF sensor	Global shutter	ALS & combo
direct ToF	indirect ToF	2D camera sensor	ambient light sensing
Single point to multizone	High resolution	High sensitivity	ALS & proximity sensor
All-in-one module	Indirect & direct ToF	Smallest size	High sensitivity
SPAD 40 nm process	3D stacked BSI 40 nm	Ultra low power	Under OLED operation
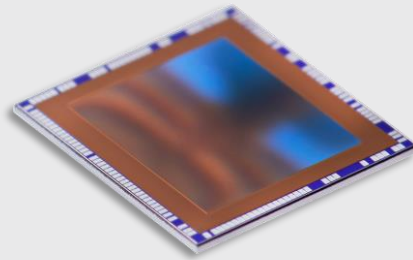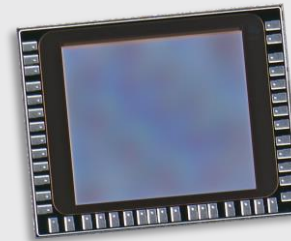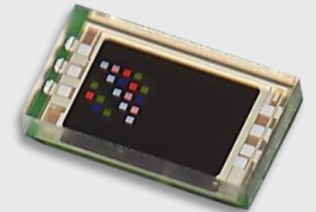
> 2 Bu n°1		> 1 Bu n°1	> 500 Mu
Time-of-Flight sensors		Global Shutter sensors	ALS sensors

Today's Focus: 2D Cameras

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Specialized Camera Sensors:

Resolutions, Ultra-low power, Embedded computing, Read-out modes, etc...

- ## Smallest Global Shutter pixel
  - ✓ Smaller sensor size for higher resolution than competition
  - ✓ Very high-performance sensing both Visible & Near-IR

- ## Disruptive Embedded Features
  Enabling new computer vision paradigms

- ## Very & Ultra Low-Power
  for always-on sensing

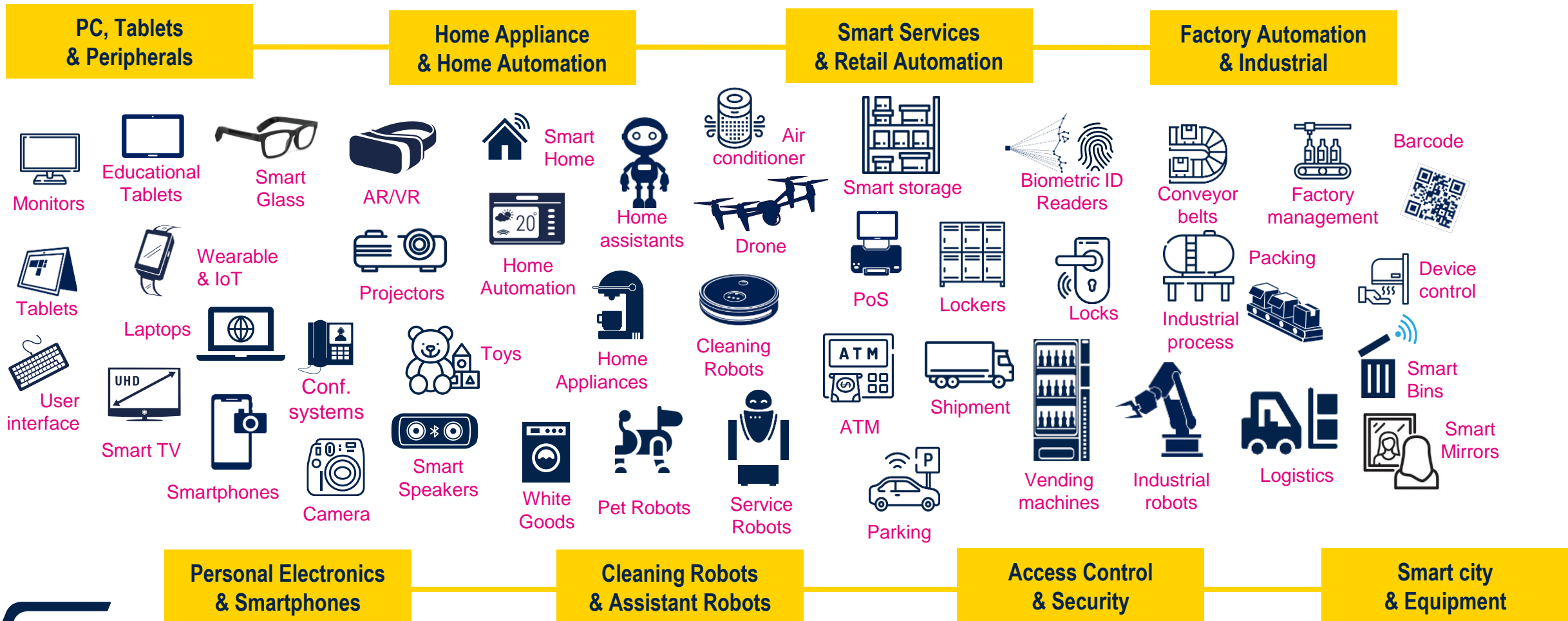- ## Low latency, fast frame-rates
  For ultra-reactive devices
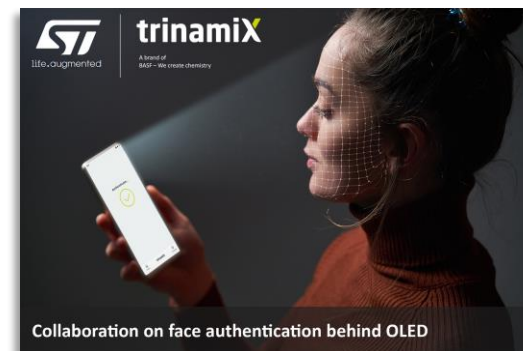
➡ **Specialized sensors for computer vision**
both for consumer & high-end

Collaboration on face authentication behind OLED

Hello

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Unlimited Market & Applications
Smart Computer Vision growing everywhere

PC, Tablets & Peripherals

Home Appliance & Home Automation

Smart Services & Retail Automation

Factory Automation & Industrial

Monitors

Educational Tablets

Smart Glass

AR/VR

Smart Home

Air conditioner

Smart storage

Biometric ID Readers

Conveyor belts

Factory management

Barcode

Tablets

Wearable & IoT

Home Automation

Home assistants

Drone

PoS

Lockers

Locks

Industrial process

Packing

Device control

Laptops

Projectors

Home Appliances

Cleaning Robots

ATM

Shipment

Smart Bins

User interface

Smart TV

Smartphones

Conf. systems

Camera

Toys

Smart Speakers

White Goods

Pet Robots

Service Robots

Parking

Vending machines

Industrial robots

Logistics

Smart Mirrors

Personal Electronics & Smartphones

Cleaning Robots & Assistant Robots

Access Control & Security

Smart city & Equipment

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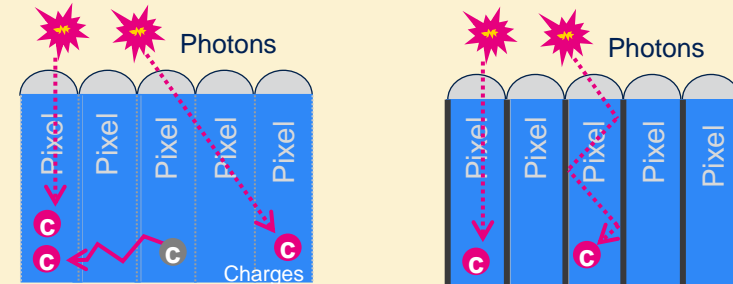
Global Shutter | Specialized Technology

C-DTI pixels
Capacitive Deep Trench Isolation

Advanced Global Shutter

- BSI with deep photodiode
- Full pixel isolation

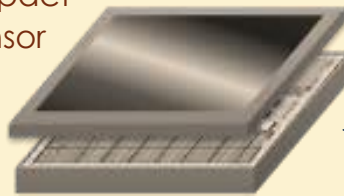➡ High sensitivity & sharpness, up to near-IR wavelength

No pixel isolation

C-DTI
Capacitive Deep Trench Isolation

3D Stacking
Small Size & Higher Resolution

Ultra Compact Imaging Sensor

65nm

40nm

Top layer 65nm => Optimized for pixel
- Full pixel encapsulation C-DTI & Deep photodiode
- High density unique in-pixel storage nodes

Bottom layer 40nm => No pixel circuitry !
- Full layer available for analogue/digital circuitry
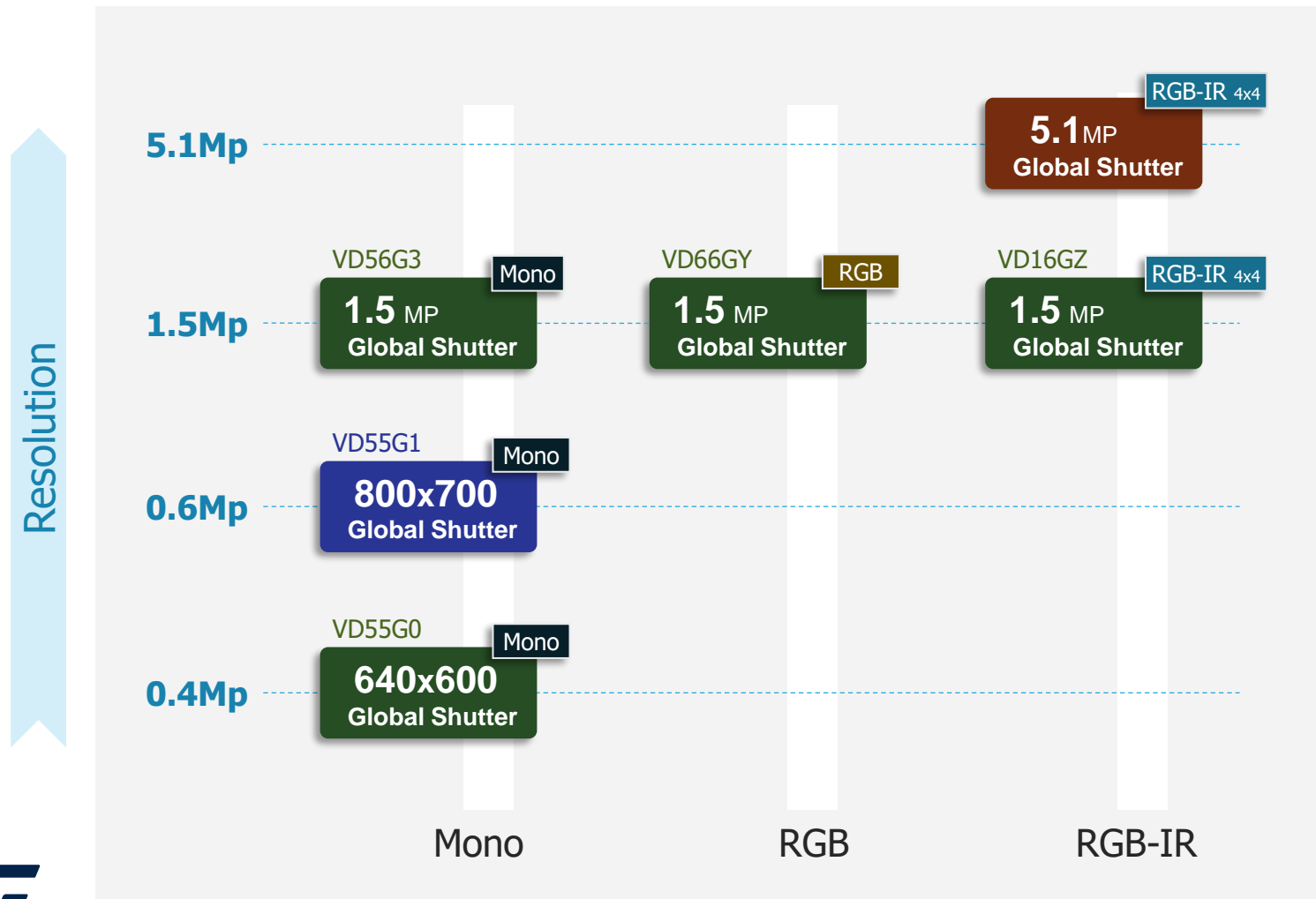- Feature full & very low power

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Secured Supply chain ➡
- No dependency from a 3rd party foundry
- Made in ST European 300mm fabs
- ST proprietary technologies

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Image Sensor Offerings

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Camera Sensors
Global Shutter technologies

Resolution

5.1Mp .... 5.1 MP **Global Shutter** — RGB-IR 4x4

VD56G3 — Mono
1.5Mp — 1.5 MP **Global Shutter** (Mono)

VD66GY — RGB
1.5 MP **Global Shutter** (RGB)

VD16GZ — RGB-IR 4x4
1.5 MP **Global Shutter** (RGB-IR 4x4)

VD55G1 — Mono
0.6Mp — 800x700 **Global Shutter** (Mono)

VD55G0 — Mono
0.4Mp — 640x600 **Global Shutter** (Mono)

Mono   **RGB**   **RGB-IR**

BSI with CDTI Stacked 40nm — 2.6µm GS

BSI with CDTI Stacked 40nm — 2.16µm GS

BSI with CDTI Stacked 40nm — 2.25um GS

Engineered to enable Computer Vision everywhere

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Deep Dive

1.5 Mpixels   VD56G3

1.5 Mpixels
Global Shutter High performance

VD56G3 Monochrome
**VD16GY** RGB-IR 4x4
VD66GZ Bayer RGB

Sensor Characteristics

- 1.5 MP (1124 x 1364 pixels array)
- 2.6 µm BSI Global Shutter
  High Sensitivity & Sharpness, from visible to near-IR
- Auto-exposure, Defect correction, Temperature sensor
- 4 contexts, sequence-able with immediate switch
- Flexible illumination controls

Embedded Optical Flow

- Embedded Motion Vectors,
  fully hardware for best power/perf ratio
- Detects automatically point of interest,
  and track their position change
- Up to 2000 vectors/image @60fps
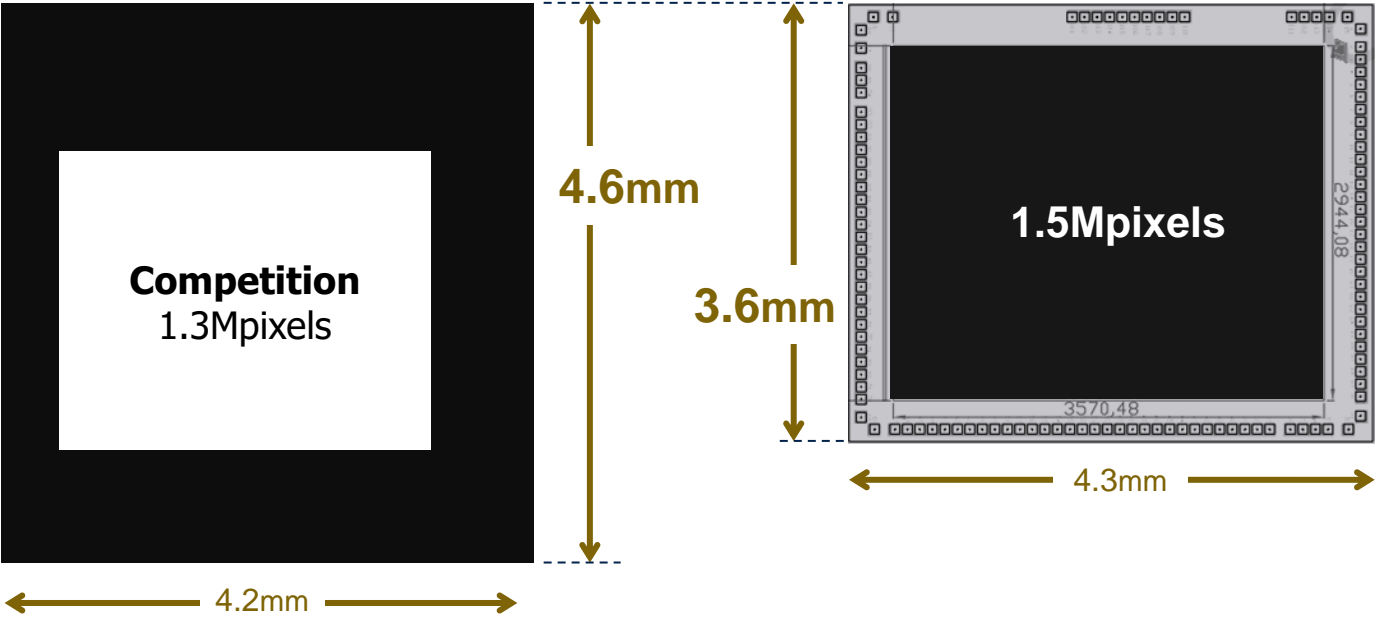 or 300fps with lower number of vectors
- Feature consuming only 20mW

FoV of +15%
1.5Mp vs 1.3Mp

1124

4.6 mm

1364
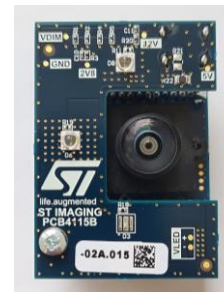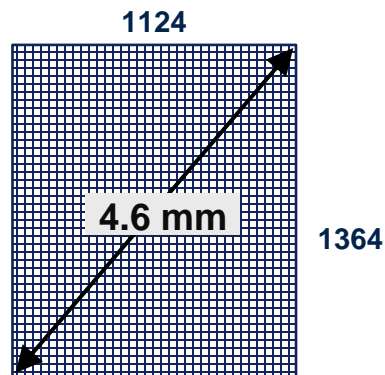
Development Tools

- Evaluation Kit (GUI + SDK)
- Linux Driver & 96boards plugin
- Raspberry plugin
- STM32 board & driver

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Size: ST vs Competition

Competition
1.3Mpixels

4.6mm

3.6mm

1.5Mpixels

2944.08

3570.48

4.3mm

4.2mm

ST sensor with both
- higher resolution
- & smaller sensor size

Competition $\begin{bmatrix} \bullet\ \text{1.3Mp} \\ \bullet\ \text{18mm}^2 \end{bmatrix}$ vs $\begin{bmatrix} \bullet\ \text{1.5Mp} \\ \bullet\ \text{16mm}^2 \end{bmatrix}$ ST VD56G3

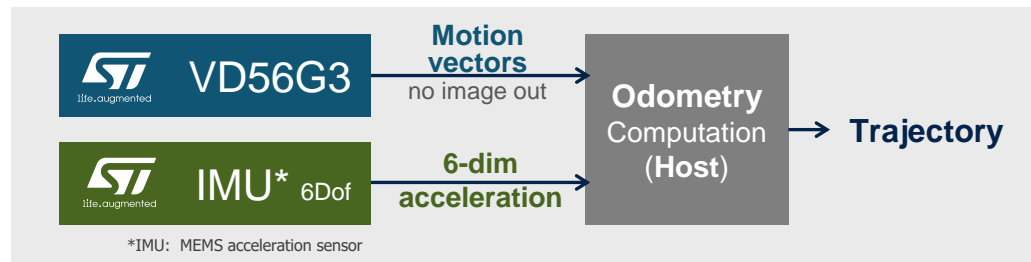life.augmented

VD56G3 : Optical Flow

Outputs

- **Points of Interests**
  as automatically detected
  by the sensor on each frames,
  Up to 2000 points per frame

- **Movement vectors**
  indicates points position change
  - Up to 2000 vectors per frame at 60 fps
  - or 300fps with lower number of vectors

- **Quality estimation**
  of vector relevance

VD56G3 sensor

Pixel Array
ADC
Vtiming
Power

Raw ISP

Optical Flow

Output interface

CSI2
2 lanes
at 1.5Gbps
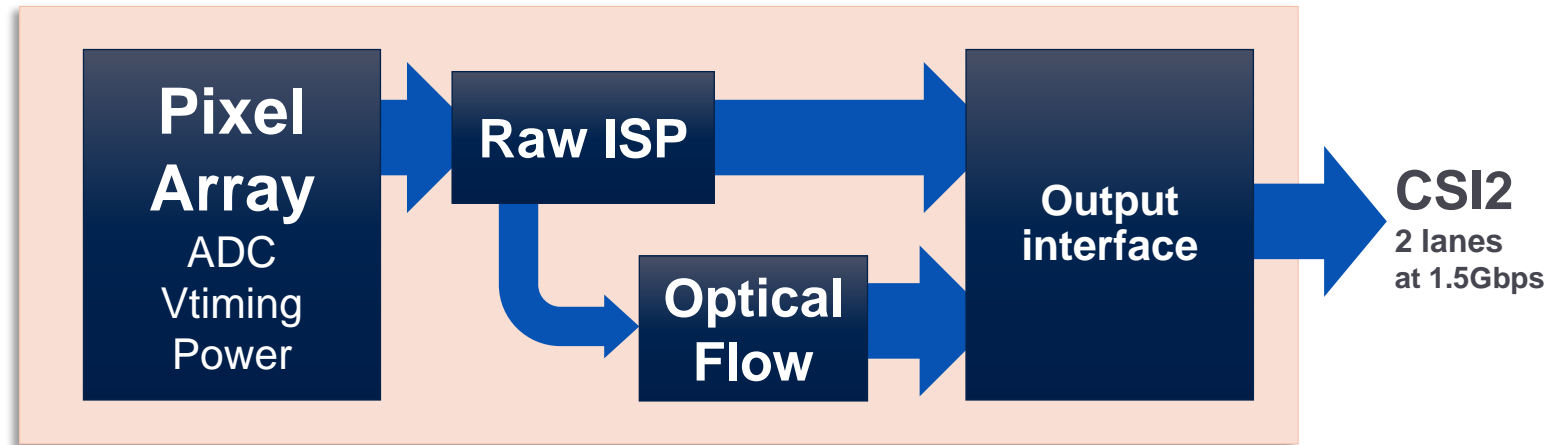
SLAM ➡ Enabling odometry only with Optical Flow + IMU

VD56G3 — Motion vectors (no image out) → Odometry Computation (**Host**) → **Trajectory**

IMU* 6Dof — 6-dim acceleration →

*IMU: MEMS acceleration sensor

Optical Flow
Embedded and 100% Autonomous

- Lower external processing usage
- Much lower host power consumption
- Only 20mW feature
- Preserved people privacy

Optical Flow

Example of video with both **Optical Flow** output & **Image**

VD56G3, V66GY & V16GZ
Compatible with all Mono/Color versions
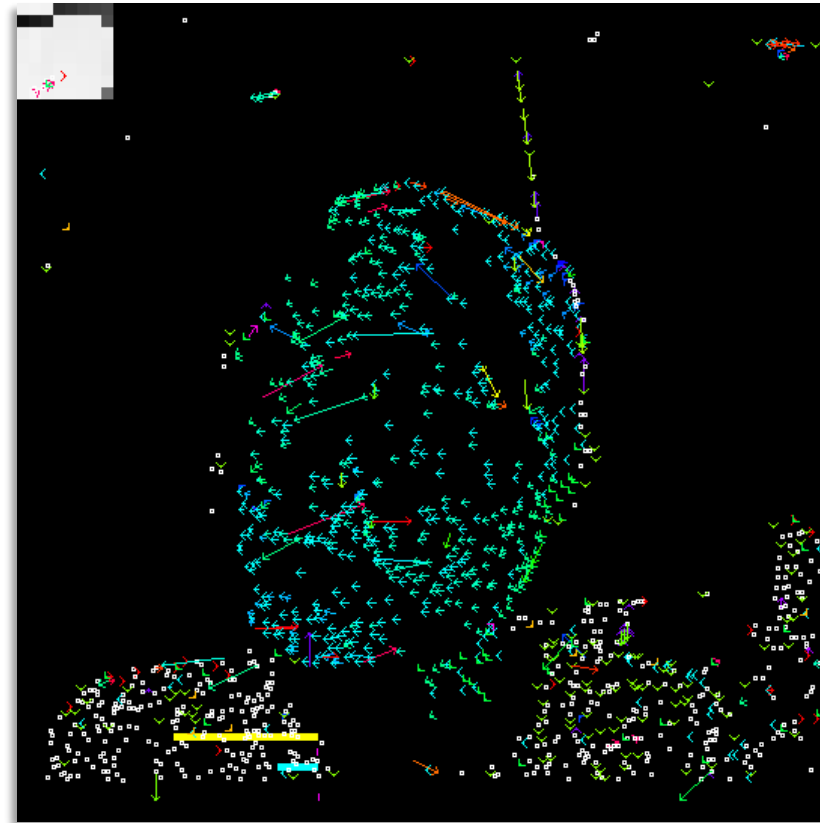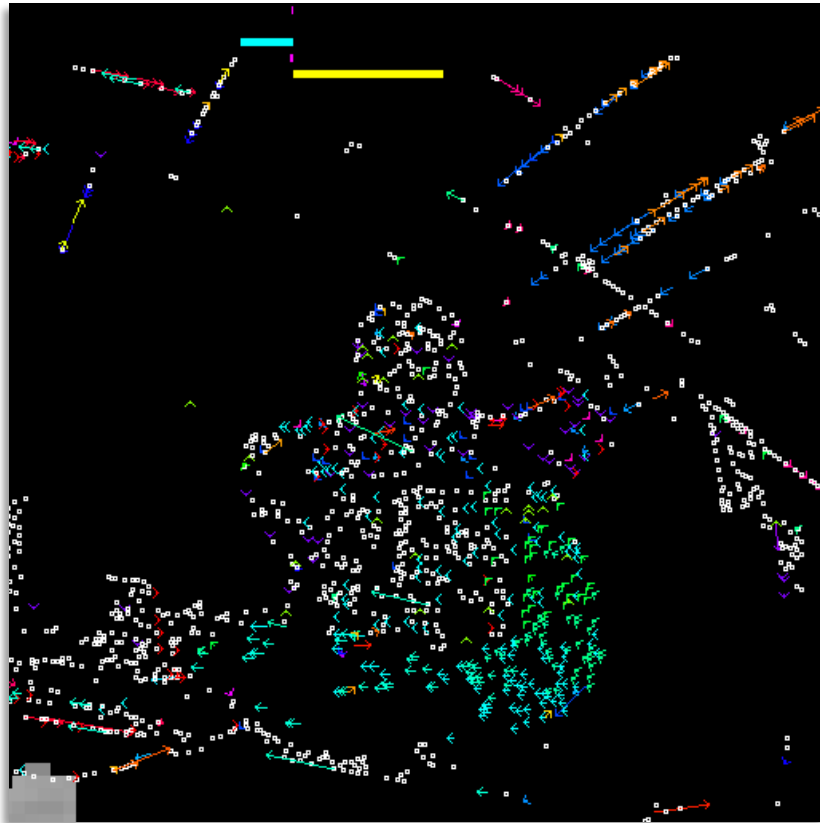
Embedded Optical Flow
- Privacy with no image out mode
- Fully autonomous

Enabling SLAM (odometry)
Without image output but motion vectors

Up to 2000 features & vectors per frame
at 60 frames/sec
or up to 300fps with 512 vectors

VD56G3 : Optical Flow

- Low host processing
- Privacy

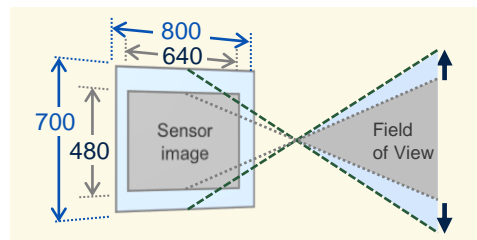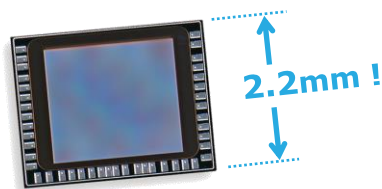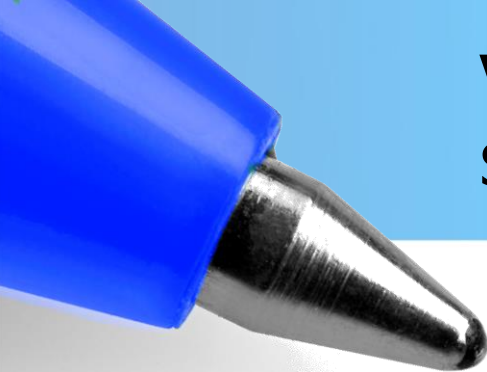## no image output, only vectors !
User Interaction & Object tracking

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Deep Dive

800 x 700 VD55G1

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VD55G1 : 800 x 700
Smaller sensor than existing 640x480 global shutter !

2.2mm !

800
640
700
480
Sensor image
Field of View

800x700 resolution

↓

+26% hor FoV
+47% ver FoV
vs VGA sensor

800
2.3 mm
700

Sensor Characteristics
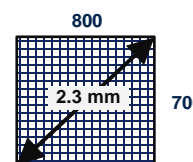
- Smallest 2.16 µm BSI Global Shutter
- 804 x 704 pixels array

Smaller GS sensor vs VGA, for higher resolution

- High Sensitivity & Sharpness, from visible to near-IR
- Fully encapsulated CDTI pixel for ultra-low crosstalk
- Low noise GS pixel + embedded smart denoising
- 260fps (VGA), 460fps (QVGA) & 185fps (800x700)
- Temperature sensor

➡ **Smallest high performance Global Shutter pixel & sensor**

Embedded Features

- **Auto wake-up Always-on**
  Scene change detection, ultra-low power
- **Auto Background & Ambient removal**
  In-pixel & no host processing required
- **Innovative Differential image mode**
  Single frame signed pixel change events !
- **Spatial HDR**
  No latency, perfect for SLAM & motion
- **Multiple Auto-exposures**
  Several concurrent AE loops
- **I3C image output** Dual image output
- **10x faster control with I3C**
- **Flexible tone mapping**
- **4 sequence-able contexts fast switch**
  Modes, tone mapping, AE, illumination ctrl…
- **Raw ISP** Dark Calibration, Smart denoising, Adaptive Defect correction …

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Size : ST vs Competition

2.6mm

2.7mm

Competition
640x480

800 x 700

640 x 480

VD55G1
800x700

Pixel 2.16µm

3.0mm
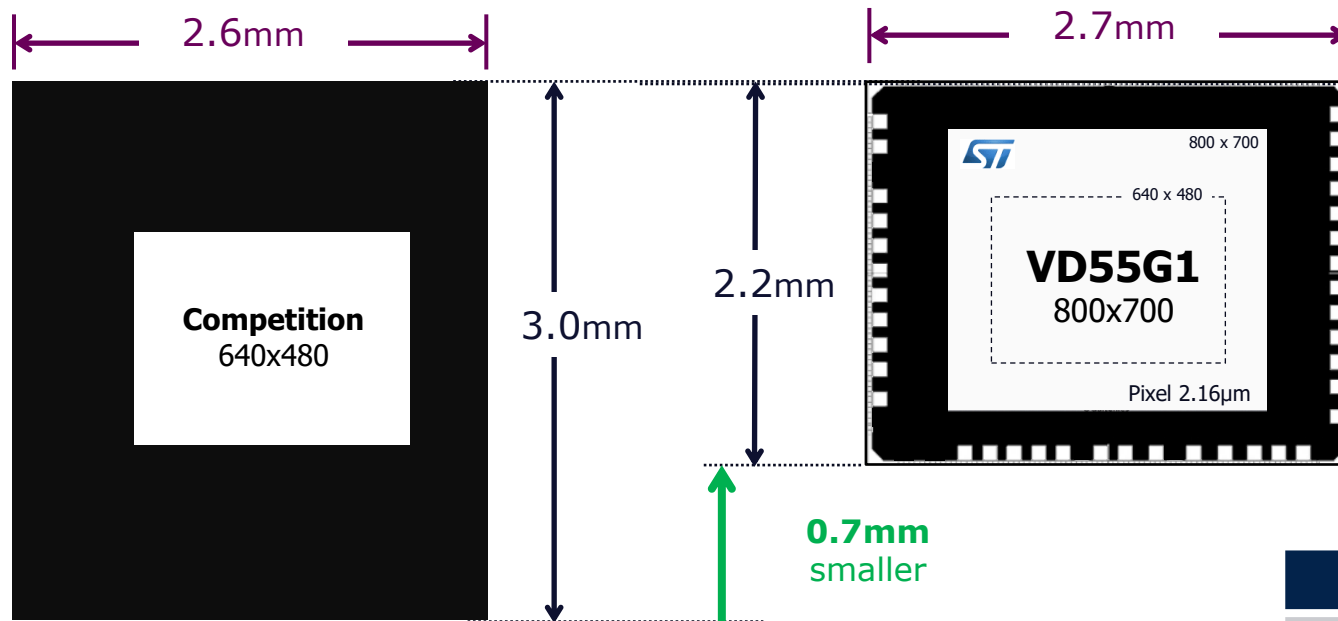
2.2mm

0.7mm smaller

ST proposes a higher resolution on a smaller size !
especially on the Y direction

	Competition	STMicroelectronics	
Resolution	640x480	Higher ➤ 800x700	**+ 82%**
Die Size	8.1 mm²	Smaller ➤ 5.5 mm²	**- 42%**
Y Size	3.0 mm	Smaller ➤ 2.2mm	**- 30%**

- **Smaller sensor** ➡ no penalty when replacing a VGA sensor

- **Higher resolution** ➡ enabling wider FoV

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VD55G1 : In-pixel Background Removal
Single frame, no impact on host, power or latency

Scene
Ambient light + illuminated NIR

Sensor output
illuminated NIR data only

<u>Single</u> frame background removal
- Autonomous
- Without need for host computing
- No latency drawback
- No impact on power consumption !

Sensor outputs simpler image for analysis
- Background is black in the output image

Only the foreground is sent to the host
- Only the user near surrounding is sensed
- Easy the privacy control

- **Easing user detection & effortless foreground isolation**
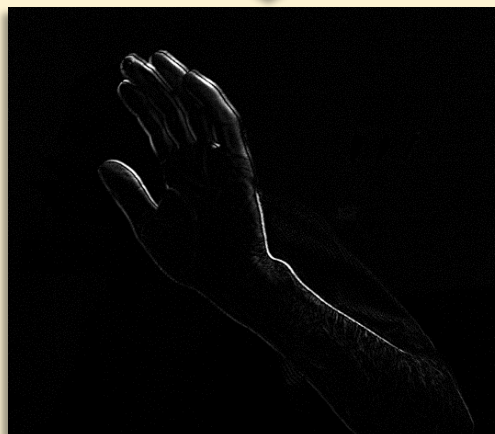- **Possibly assisting the background blurring**

VD55G1 : Differential mode
Single frame with only pixel changes !

Scene

Differential image

Innovative event-like image

- **Only pixel with motion remaining**
- Difference is signed & proportional
- Flexible delay between the 2 exposures
- Ultra-short delay possible to catch motion
- Preserving privacy !

<u>Single</u> frame Differential Mode

- Autonomous
- No need for host computing
- Ultra-low latency motion capture
- No impact on power consumption !

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VD55G1 : Differential mode
Single frame with only pixel changes !

Opportunity for a new paradigm for use cases with *event-like* image

- 6DoF
- Eyes tracking
- Gesture & hand tracking
- Scene activity detection
- Object tracking

VD55G1 : Single frame HDR
Different pixel exposures within the same frame

VD55G1 raw HDR output

Single frame with 90dB$^+$!

Host
processing

Single HDR frame

HDR frame reconstructed

VD55G1 sensor HDR mode

A	B	A	B	A	B	A	B
A	A	A	A	A	A	A	A
A	B	A	B	A	B	A	B
A	A	A	A	A	A	A	A
A	B	A	B	A	B	A	B
A	A	A	A	A	A	A	A
A	B	A	B	A	B	A	B
A	A	A	A	A	A	A	A

A Pixel with exposure A
B Pixel with exposure B
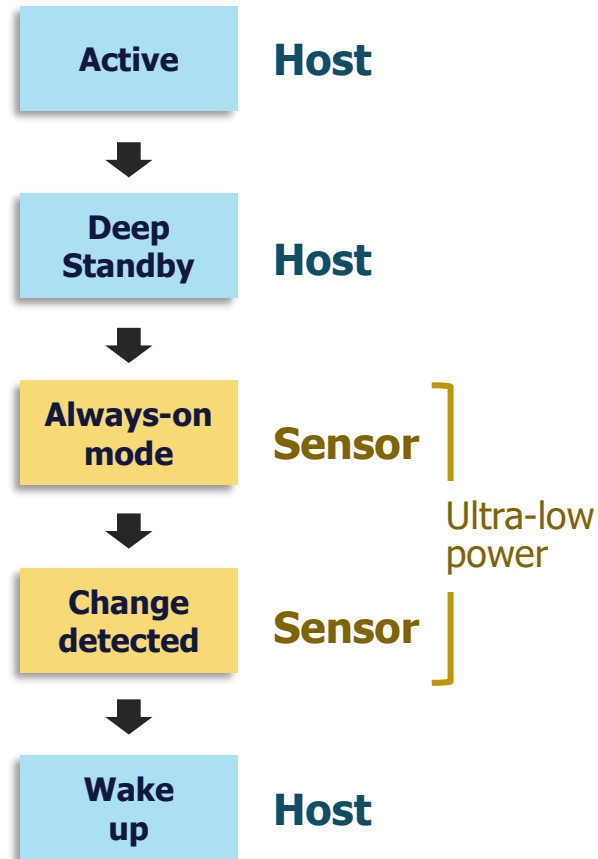
Linear HDR
with a single frame

- No impact on latency
- No impact on power consumption
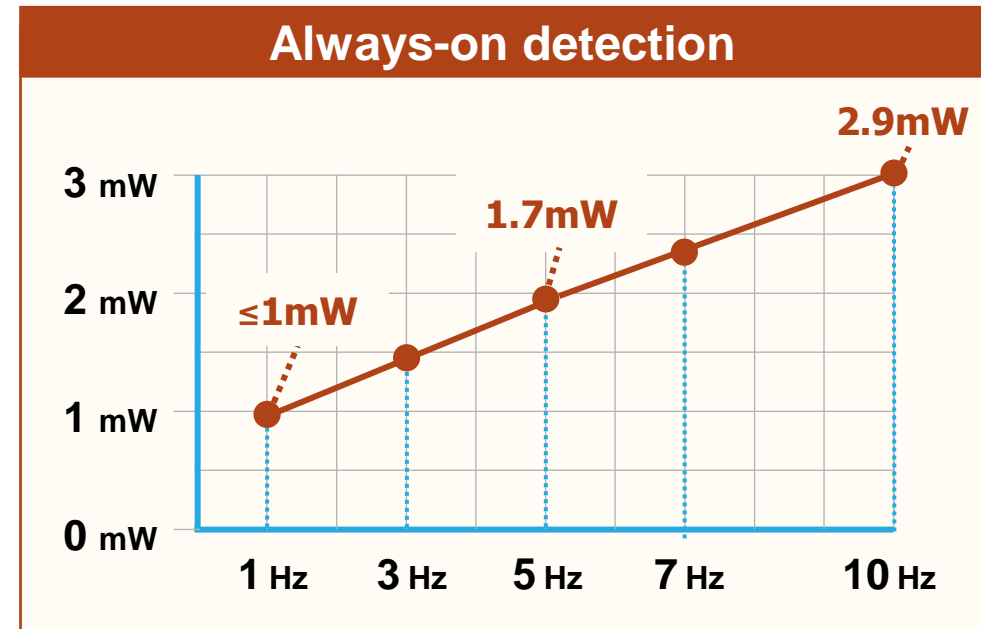- No ghosting artifacts => perfect for motion

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VD55G1 : Always-on detection
Ultra-low power scene change analysis

Sensor Always-on Detection

Active	**Host**
Deep Standby	**Host**
Always-on mode	**Sensor**
Change detected	**Sensor**
Wake up	**Host**

Ultra-low power

Auto wake-up feature

✓ Autonomous scene analysis
✓ Wake-up the host if change detected
✓ Ultra-low power for always-on sensing

Always-on detection

2.9mW
1.7mW
≤1mW

3 mW
2 mW
1 mW
0 mW

1 Hz 3 Hz 5 Hz 7 Hz 10 Hz

Typical - preliminary

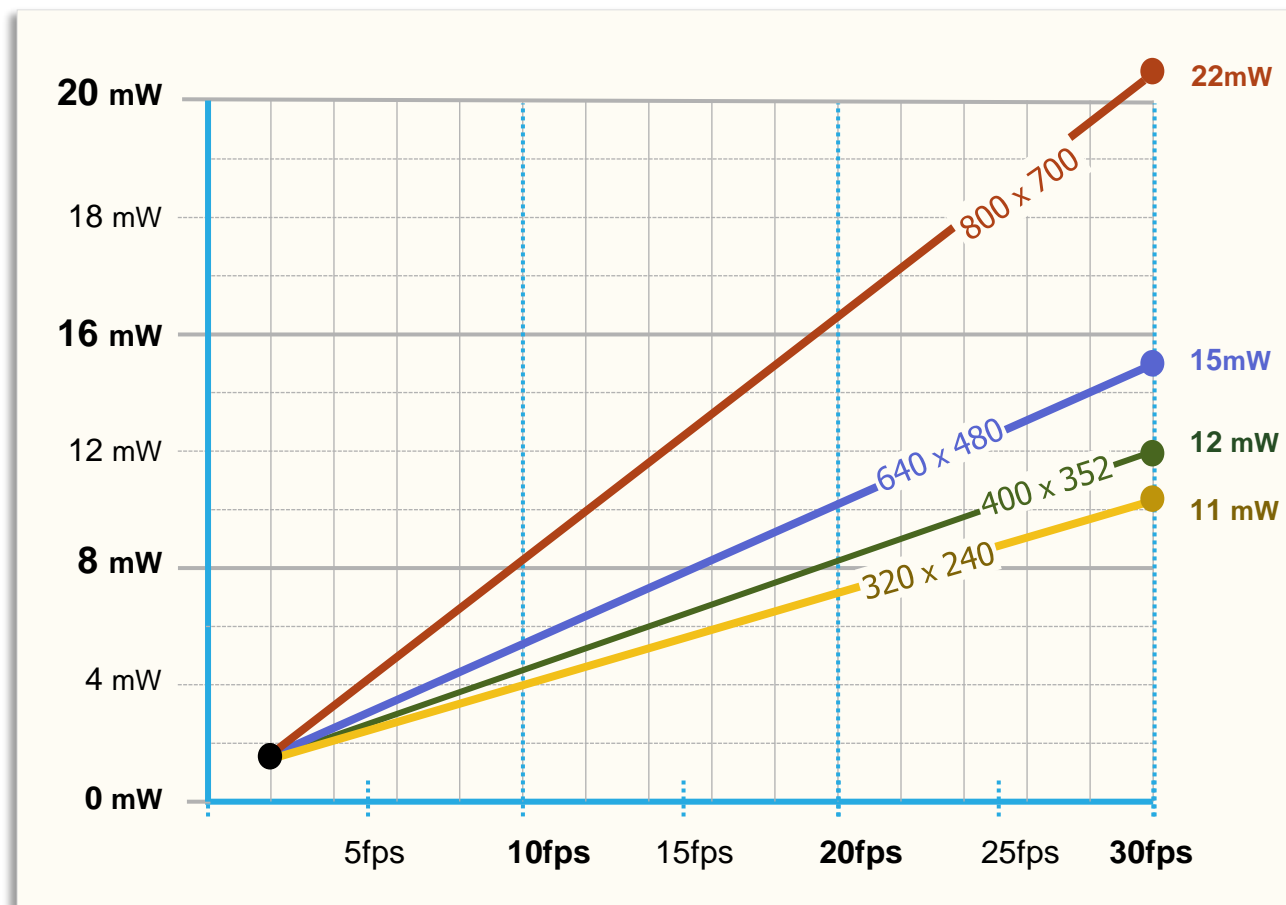© 2023 STMicroelectronics

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VD55G1 : Power Consumption
Very & Ultra low power architecture

Battery-friendly sensor

✓ None image quality decrease with ultra-low power mode

✓ **All features & modes fully functional !**
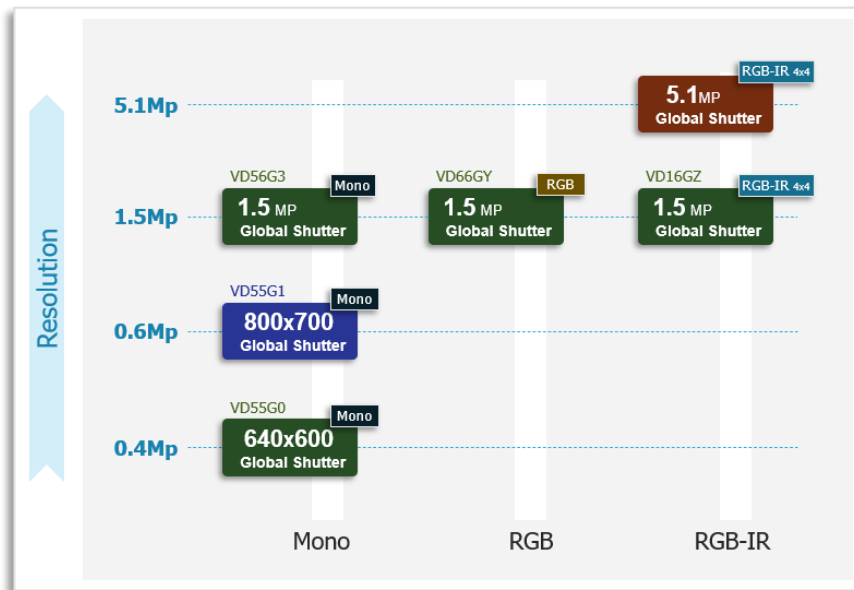
✓ VD55G1 is natively optimized for power efficiency

Typical - preliminary

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Key Take Aways

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Take away

ST supporting the growth of computer vision use cases, with a specialized sensor family

- **Smallest Global Shutter technologies**
  - ✓ Smaller sensor size for higher resolution than competition
  - ✓ Very high-performance sensing both Visible & Near-IR

- **Disruptive Embedded Features**
  Enabling new computer vision paradigms

- **Very & Ultra Low-Power**
  for always-on sensing

- **Low latency, fast frame-rates**
  For ultra-reactive devices

Resource

Resource

New camera sensors

YouTube video - Global Shutter family

Product page:

https://www.st.com/en/imaging-and-photonics-solutions/vd55g1.html

2023 Embedded Vision Summit Demos Booth:#516

Optical Solutions for Computer Vision featuring:

VD55G1 – 0.56Mp with embedded CV features
VD56G3 – 1.5Mp stereovision camera module

Thank you

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