Short-wave Infrared: The Dawn of a New Imaging Age?

Edge-AI and Vision Alliance

-

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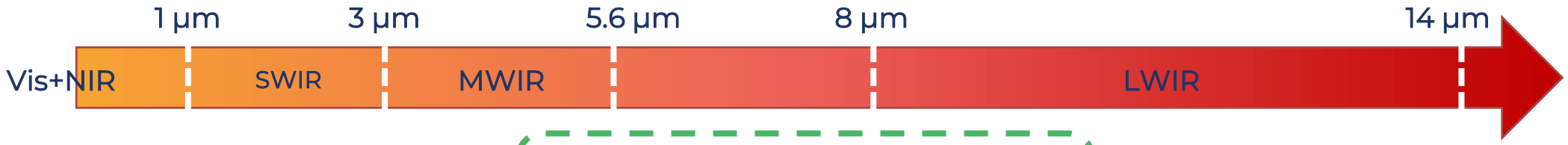
Yole Intelligence

AGENDA

- Introduction
- Existing markets: defense & industry
  - Driving applications
  - Ecosystem
  - Technology
- Emerging markets: consumer & automotive
  - Driving applications
  - Ecosystem
  - Technology
- Conclusion
  - Market forecast

Introduction

SWIR IN THE INFRARED SPECTRUM



Reflective

Emissive

Source: N.Pinchon & al., All-weather vision for automotive safety: which spectral band, VISION SIA, 2016

FEW WORDS ON ACTIVE 3D SENSING

Camera

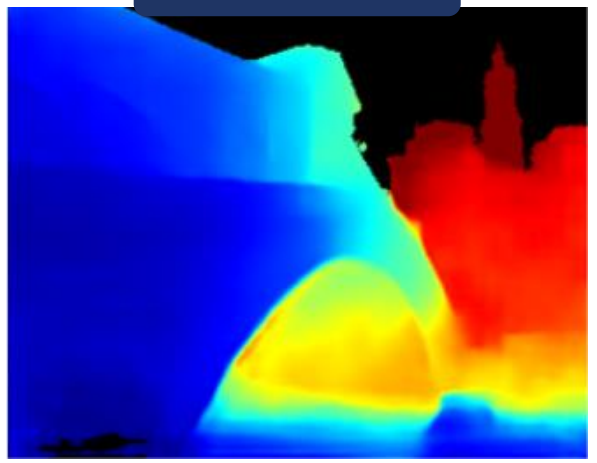
2D image

3D module

IR light source

IR Camera

3D image

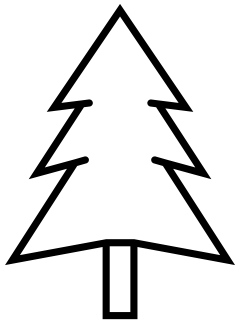


Time-of-Flight

3D module

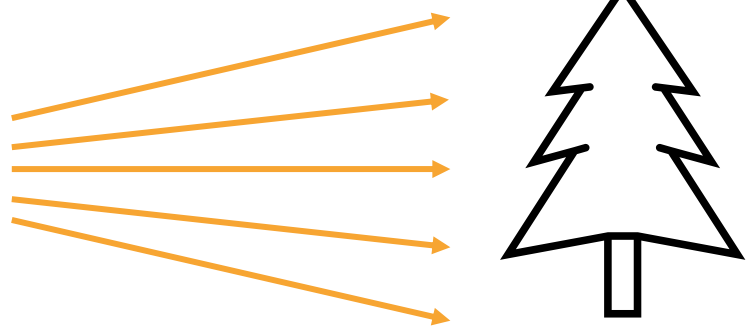
Light beam

Reflected light



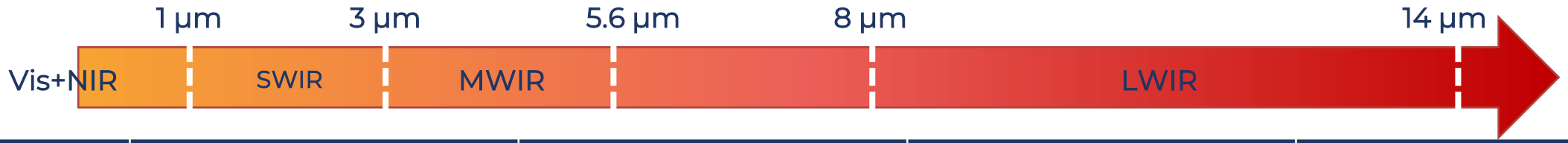
Structured light

3D module



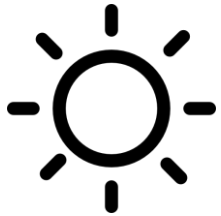
THE INFRARED WORLD

Advantage of SWIR

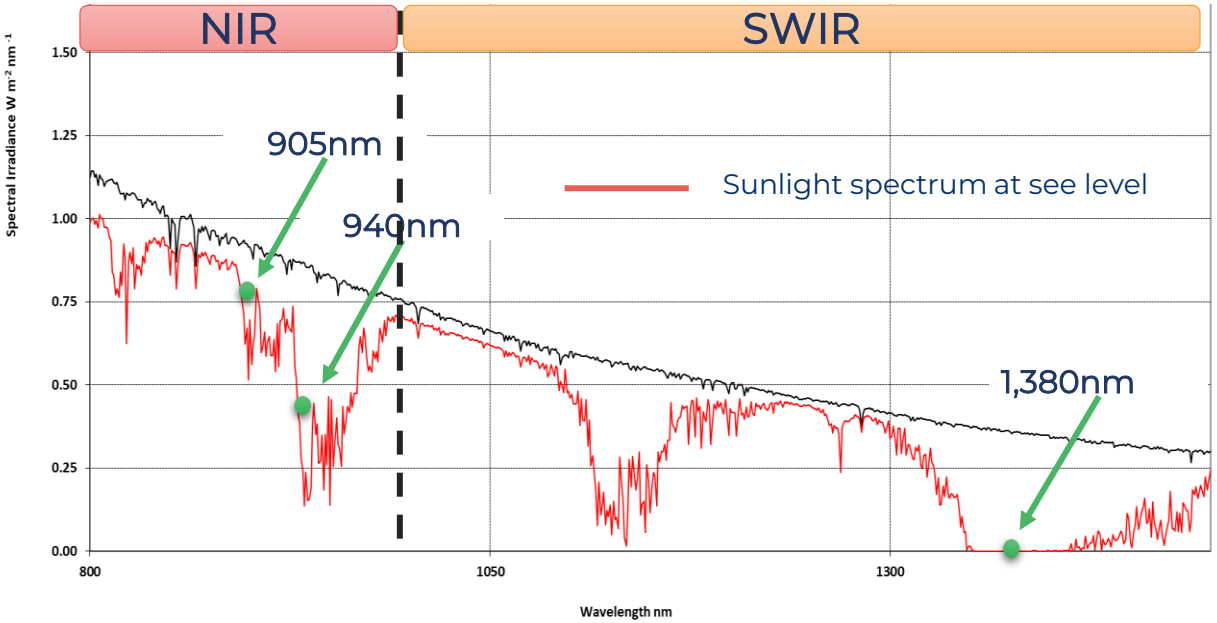


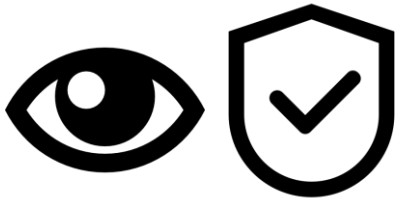
	VIS	NIR	SWIR	LWIR
Strength	• Comprehensive images • Uses silicon sensors	• Comprehensive images • Uses silicon sensors • Active 3D sensing	• Long range active 3D sensing • “See through” capability • Spectral signature of objects	• No need for light source • “See through” capability • Highlight heat sources
Weakness	• No active 3D sensing	• No color • Moderate detection range	• No low-cost technology	• Less comprehensive image • No low-cost technology

WHY SWIR IS BETTER FOR ACTIVE 3D

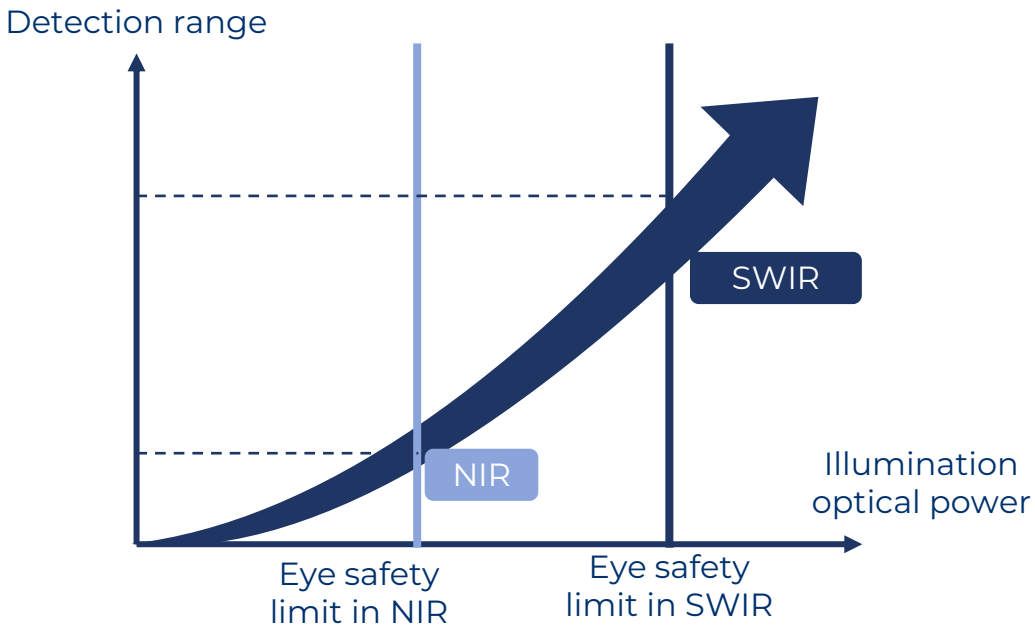


Less parasitic ambient light





More powerful active illumination



TYPES OF SWIR PHOTODETECTORS

"Sensing"

Single pixel photodetector

1x1

Optical communication

LiDAR

Since 2021:

AirPods 3

iPhone 14 Pro

Linear detector

1x128 → >1x2480

Spectrophotometers

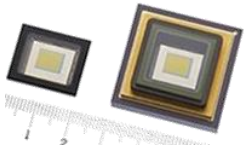
Line-scan cameras

Main scope of this presentation

"Imaging"

Area scan imager

>50x50

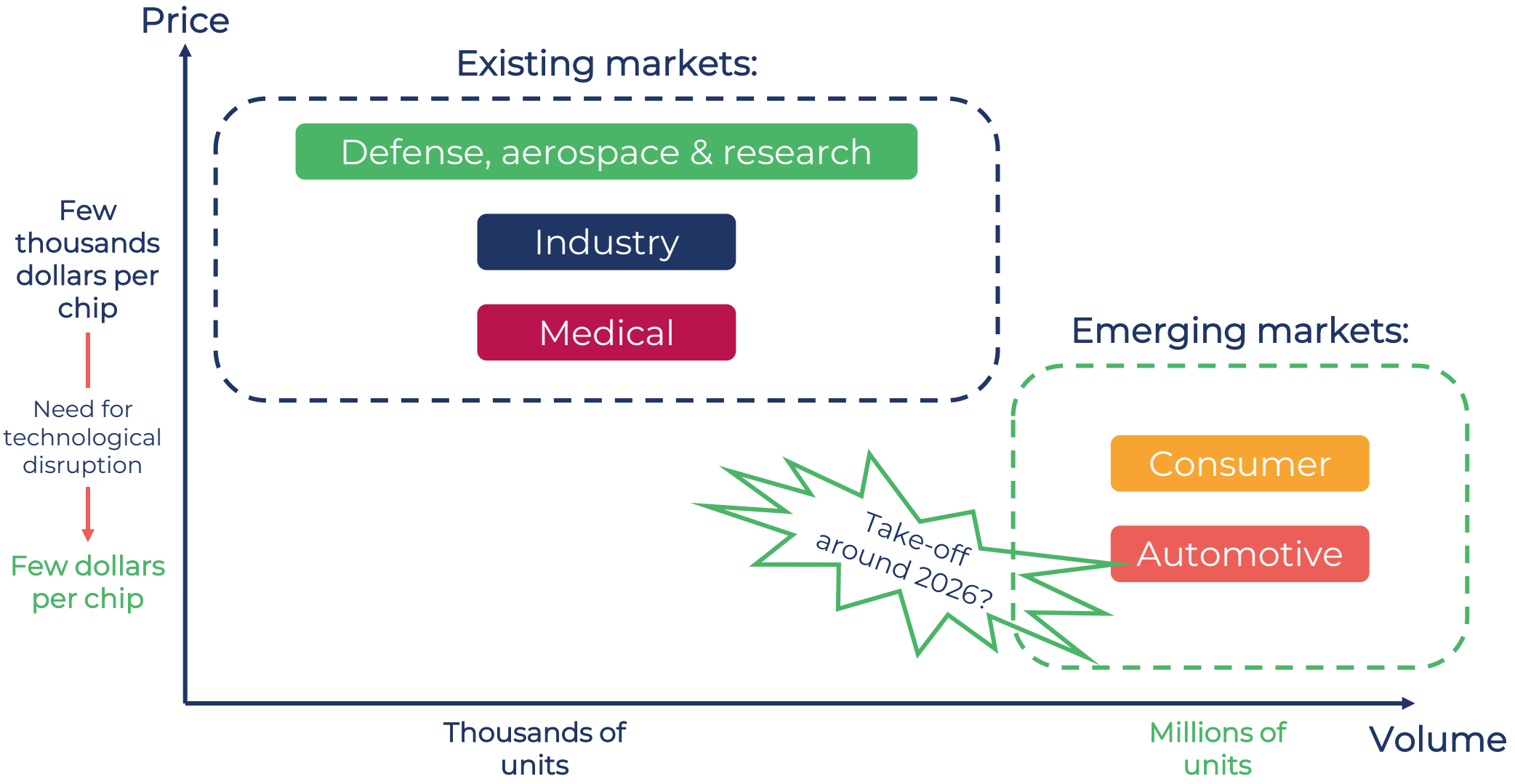


Snapshot cameras

From 2026?:

EXISTING AND EMERGING MARKETS

The two-speeds of SWIR imaging industry



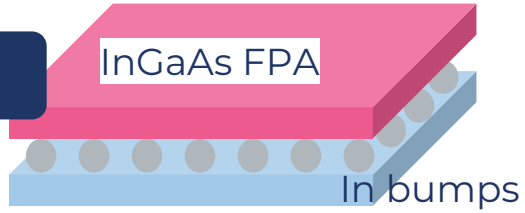
SWIR TECHNOLOGY COMPARISON

From legacy to disruptive technologies

Legacy technology

$5,000-$10,000

InGaAS



Existing markets

Disruptive technologies

Target

$5-$100

Ge-on-Si

Quantum dots

Organic

Existing markets & emerging markets

Existing markets: defense & industry

EXISTING MARKETS

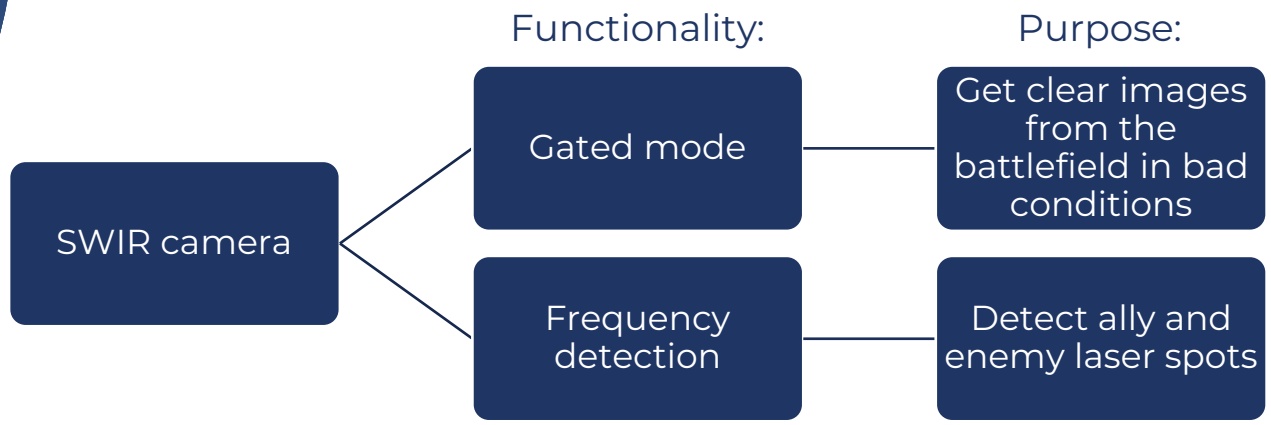
Defense: laser target designation

SWIR imaging is used for laser target designation in pods (vehicle), and soldier equipment.

Source: Sensors unlimited

Rafael Litening pod

Elbit CLRF-IC

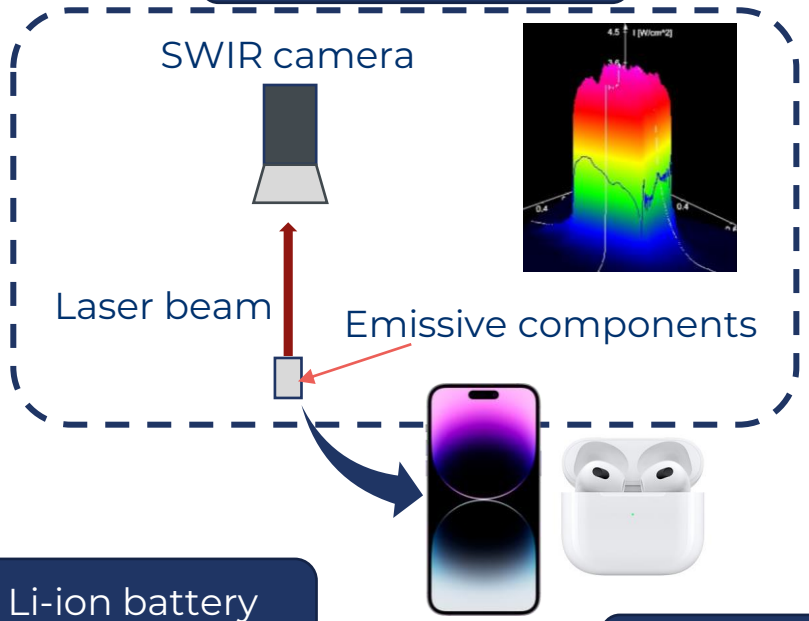


Advantage of SWIR over NIR:

- Longer range detection:
  - See through smoke & dust
  - Higher light source power (eye safety)
- Higher stealth:
  - Fewer countries or armed groups are equipped with SWIR technologies

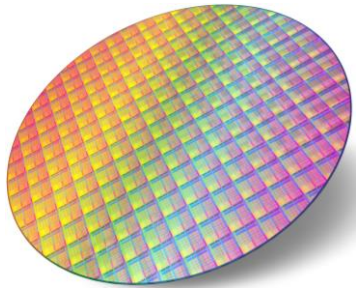
EXISTING MARKETS
Industry: driving applications

Laser beam inspection:

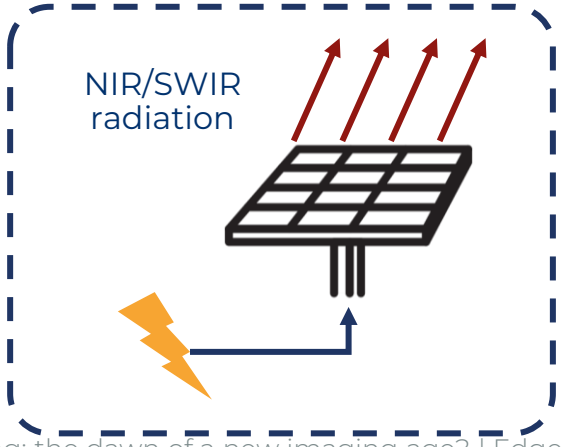


Li-ion battery inspection

Wafer inspection:



Solar cells inspection



Optical sorting:

- Linescan cameras
- Multispectral
- Extended sensitivity (>1.7µm)

Content inspection:

Source: SWIR Vision System

EXISTING MARKETS

SWIR image sensor makers

Most of players focus on InGaAs.

Newcomers provide newer technologies.

InGaAs imagers

- SemiConductor Devices
- SONY
- TELEDYNE FLIR Everywhereyoulook™
- HAMAMATSU
- TELEDYNE DALSA Everywhereyoulook™ Part of the Teledyne Imaging Group
- Xenics Infrared Solutions
- i3system
- GHOPTO
- SENSORS UNLIMITED
- CHUNGHWA LEADING PHOTONICS TECH
- LYNRED
- ATTOLLO Engineering
- Princeton Infrared Technologies
- NIT

QD imagers

- SWIR VISION SYSTEMS
- imec R&D
- EMBERION

Ge imagers

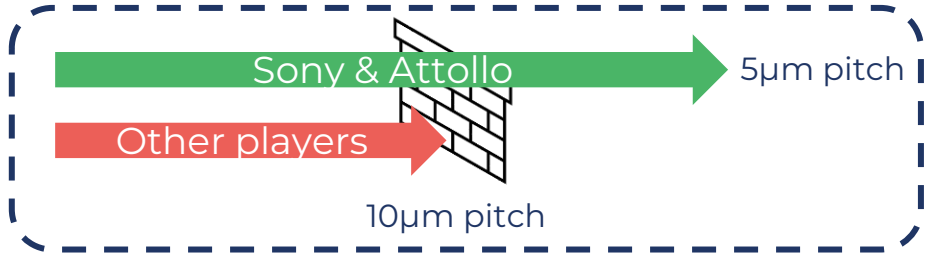
- Stratio, Inc.

Newcomers

EXISTING MARKETS
InGaAs imagers

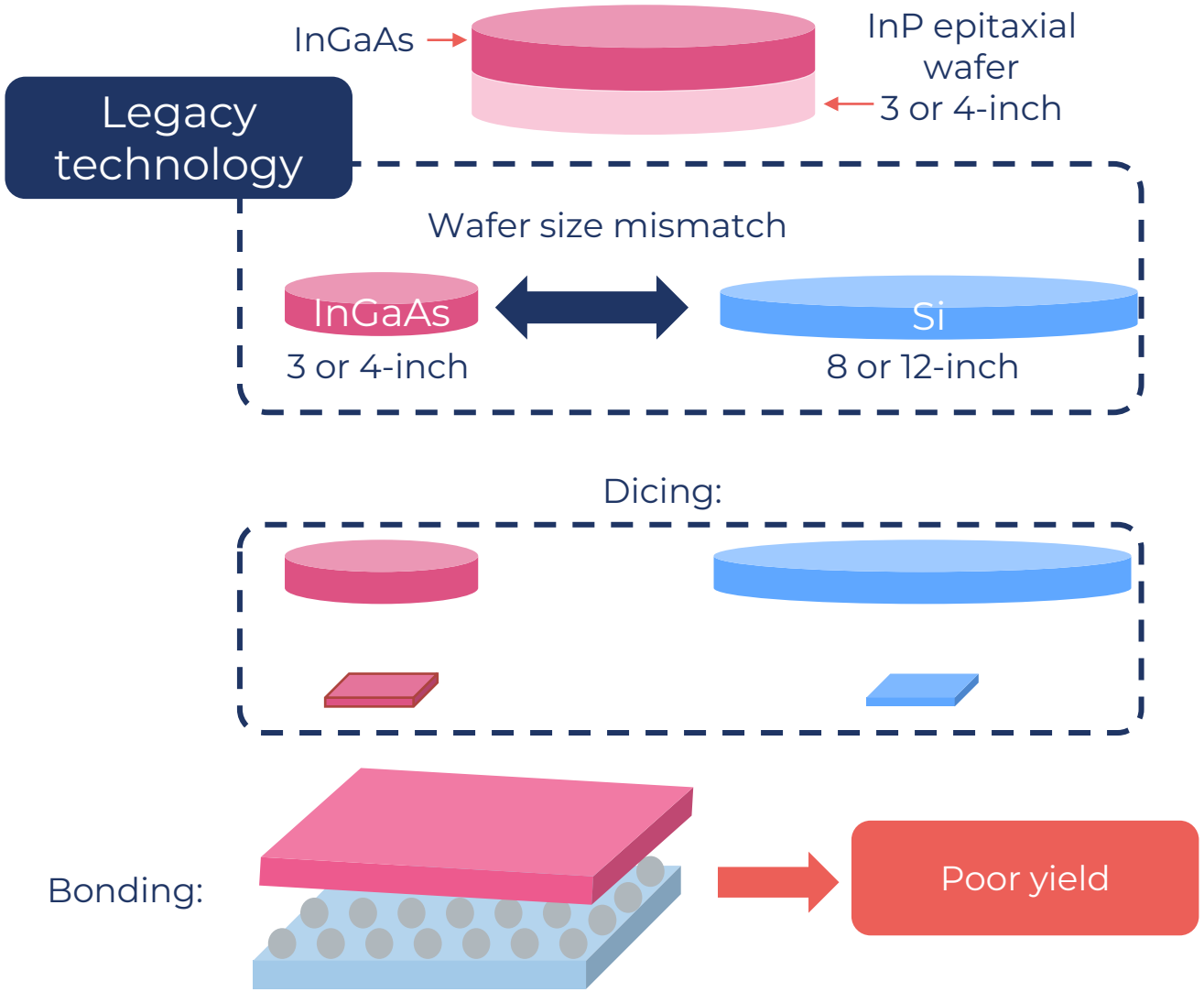
- Average resolution: VGA
- Average pitch: 15µm

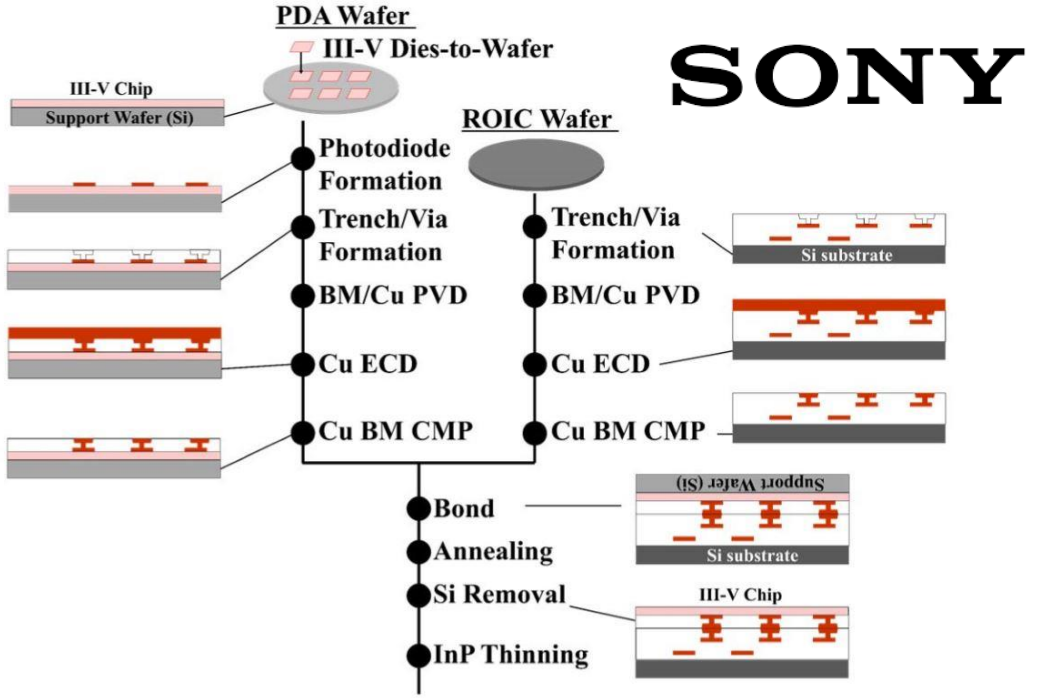
Resolution	SUI	SCD	Teledyne FLIR	Lynred	NIT	Xenics	Sony	Attollo	Hamamatsu	I3system	Chunghwa	Teledyne Dalsa	Princeton infrared	Ghopto
QVGA	12.5µm				15µm 25µm	20µm 30µm			20µm	15µm 25µm	30µm			15µm
VGA	12.5µm 15µm	15µm	15µm	15µm	15µm	20µm	5µm	5µm	20µm		15µm			15µm
SXGA/XGA	12.5µm	10µm			10µm		5µm	5µm					12µm	15µm
1980x1080														



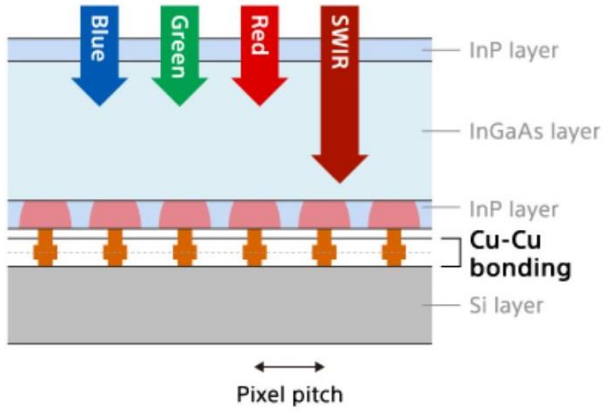
EXISTING MARKETS

InGaAs imager manufacturing





SONY



EXISTING MARKETS
Newcomers' value proposition

Lower cost:

SONY — Sensor

SWIR VISION SYSTEMS EMBERION — Camera

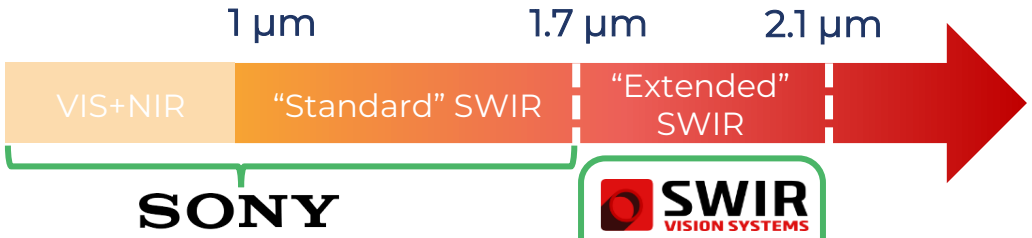
Higher resolution:

320x180p — 1.3Mp — 2.1Mp

Average

SWIR VISION SYSTEMS EMBERION — Quantum dots

Extended spectral range:



Quantum dots

Integrability:

As a tradeoff, these devices have lower quantum efficiency and higher noise than legacy technologies

EXISTING MARKETS

Key takeaways

- ~11,000 units have been shipped in 2021 to serve existing applications (SWIR imaging is a niche industry).
- The driving applications are: laser target designation in defense, electronic component and optical sorting in industry.
- Leading players make InGaAs imagers. Two companies making quantum dots cameras entered the market in the last years.
- Most of products have VGA resolution and 15µm pixel pitch.
- Newcomers bring lower-cost technologies and new characteristics (extended spectral sensitivity) at cost image quality.

Emerging market: consumer and automotive

EMERGING MARKETS

Consumer: initial SWIR adoption in 2021/2022

Apple starts integrating SWIR sensing in consumer devices.

Will SWIR imaging follow?

Today sensing: → ?? → Tomorrow imaging?:

2021:

AirPods 3

SWIR Skin detection

2022:

Under-display integration

SWIR Proximity sensing

iPhone 14 Pro

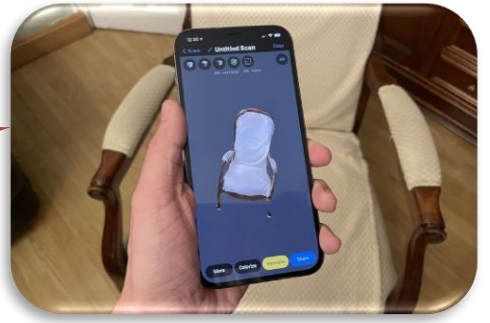
Smartphones:

Front:

Under-display integration

Rear:

"World facing" 3D sensing



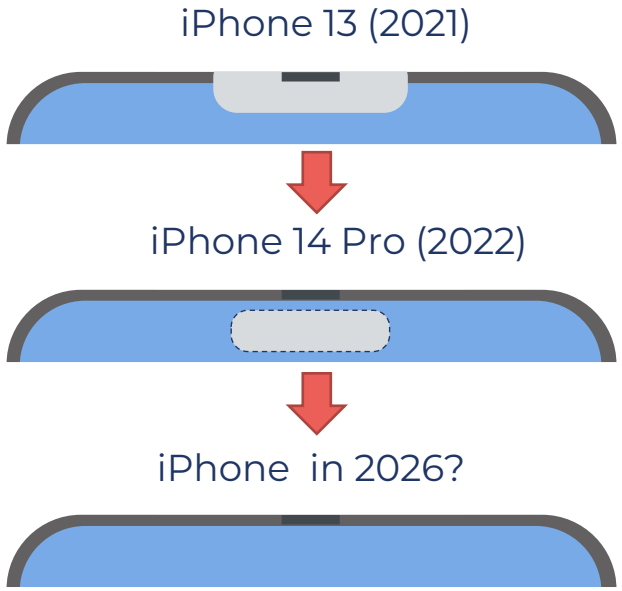
AR & MR headsets:

"World facing" 3D sensing?

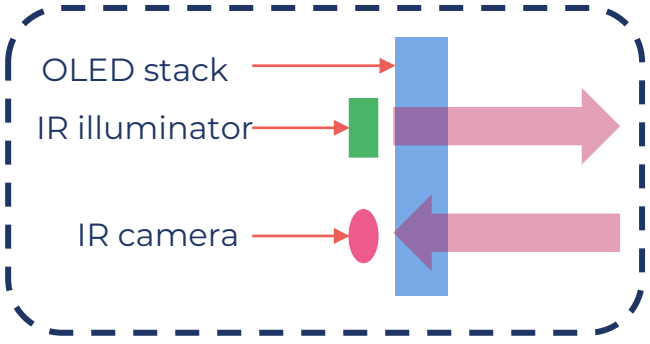
EMERGING MARKETS

Towards under-display 3D modules?

Under-display proximity sensor: → **Under-display facial recognition?**



Going through the OLED:

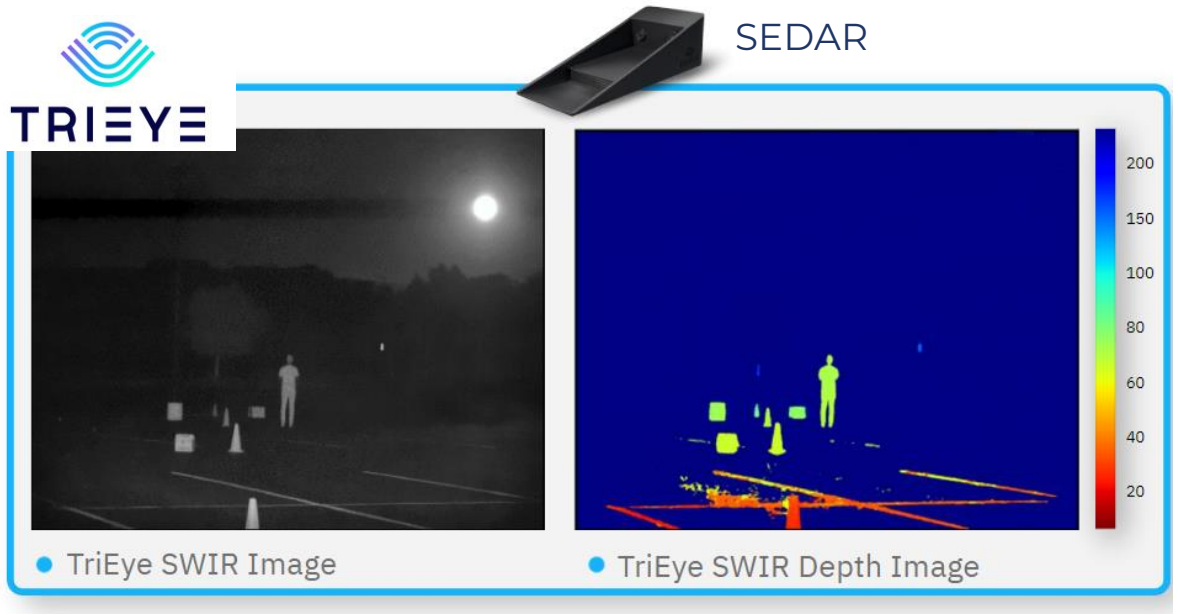


Why SWIR?

- Transparency of OLED
- Higher SNR
- Lower risk of damage on OLED

EMERGING MARKETS
SWIR in automotive

SWIR Imaging:

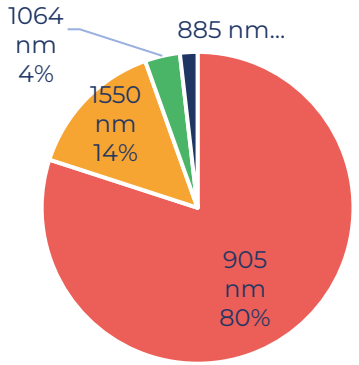


For ADAS:

- Get 2D & 3D information at the same time
- Immune to parasitic sunlight, low-light conditions, dust, fog, rain.
- Longer range imaging

SWIR LiDAR:

Design win split by wavelength in 2022



Interest from the LiDAR ecosystem:

EMERGING MARKETS

SWIR imaging for ADAS (automotive)

	Visible cameras	Thermal cameras	SWIR gated cameras	LiDAR
Resolution	1.3Mp → 6Mp	0.3Mp	1.3Mp	/
Supports night vision and bad weather	No	Yes	Yes	Yes
Needs light source	No	No	Yes	Yes
Depth sensing capability	No	No	Yes	Yes

Redundancy

EMERGING MARKETS

Who paves the way?

SWIR sensor makers

InGaAs

COHERENT
USHIO
GHOPTO
CHUNGHWA LEADING PHOTONICS TECH
HAMAMATSU
EXCELITAS TECHNOLOGIES

single pixel

Germanium-based

Yole's assumption

TRIEYE
ARTILUX
tsmc

Quantum dots

qurv
life.augmented
imec

Organic photodiodes

isorg
SAMSUNG

??

CMOS image sensors for consumer leaders

Already have SWIR technology:

life.augmented
SONY

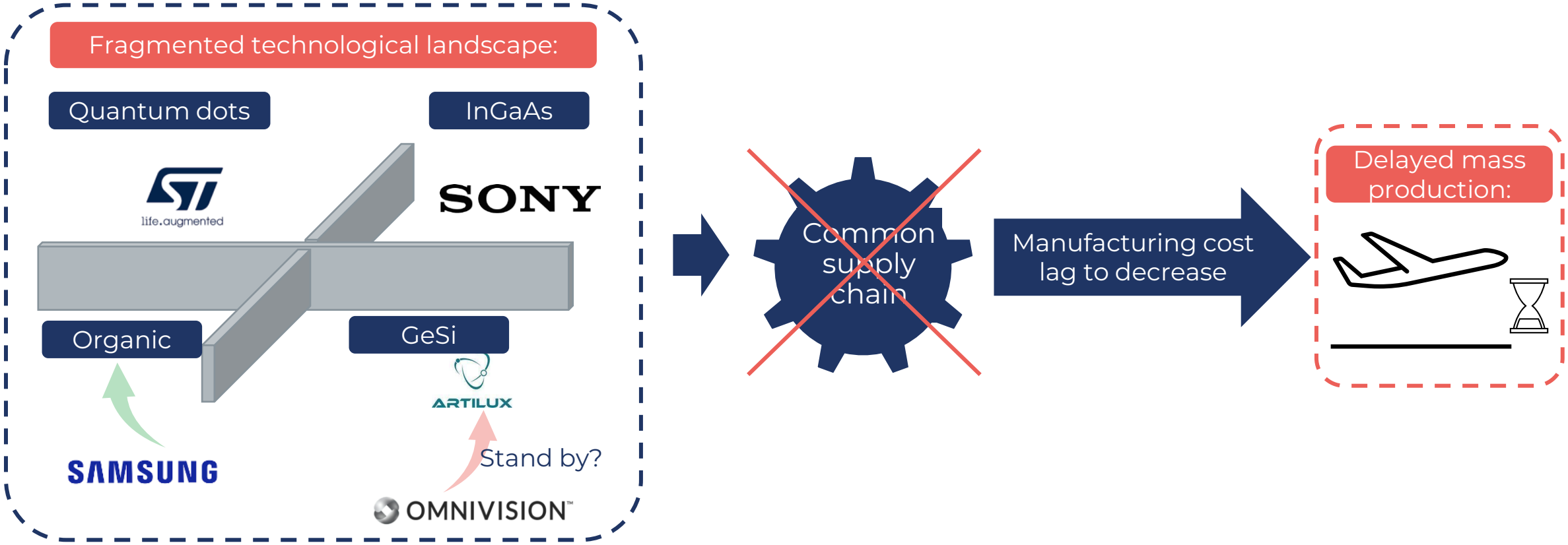
Signs of interest for SWIR range:

OMNIVISION
SAMSUNG

Other CIS suppliers:

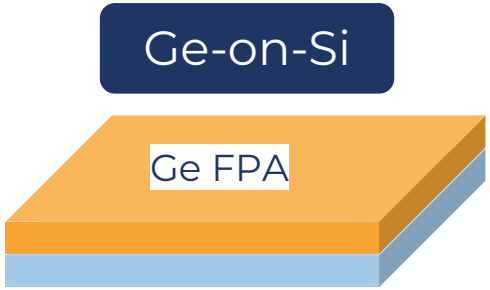
onsemi
SMARTSENS
GALAXYCORE
SK hynix
Himax
Canon
Panasonic

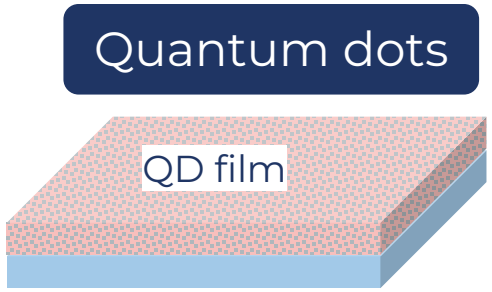
EMERGING MARKETS
Fragmented technological landscape

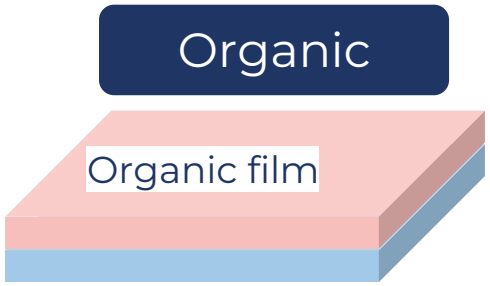


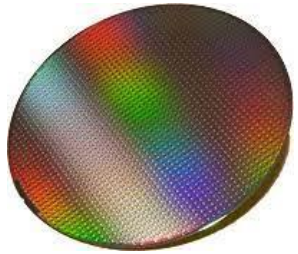
EMERGING MARKETS

Technology comparison: manufacturing

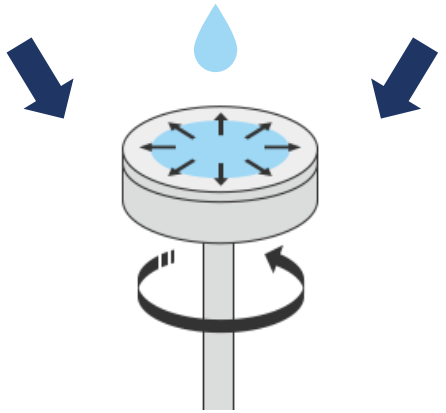








Standard CMOS process

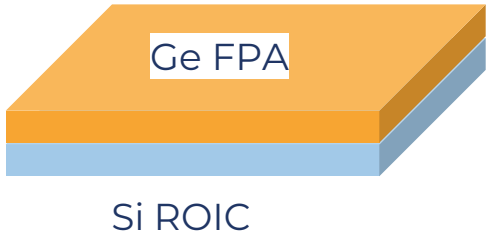


Films deposited by spin coating

Compatible with 12-inch wafer! → Mass production

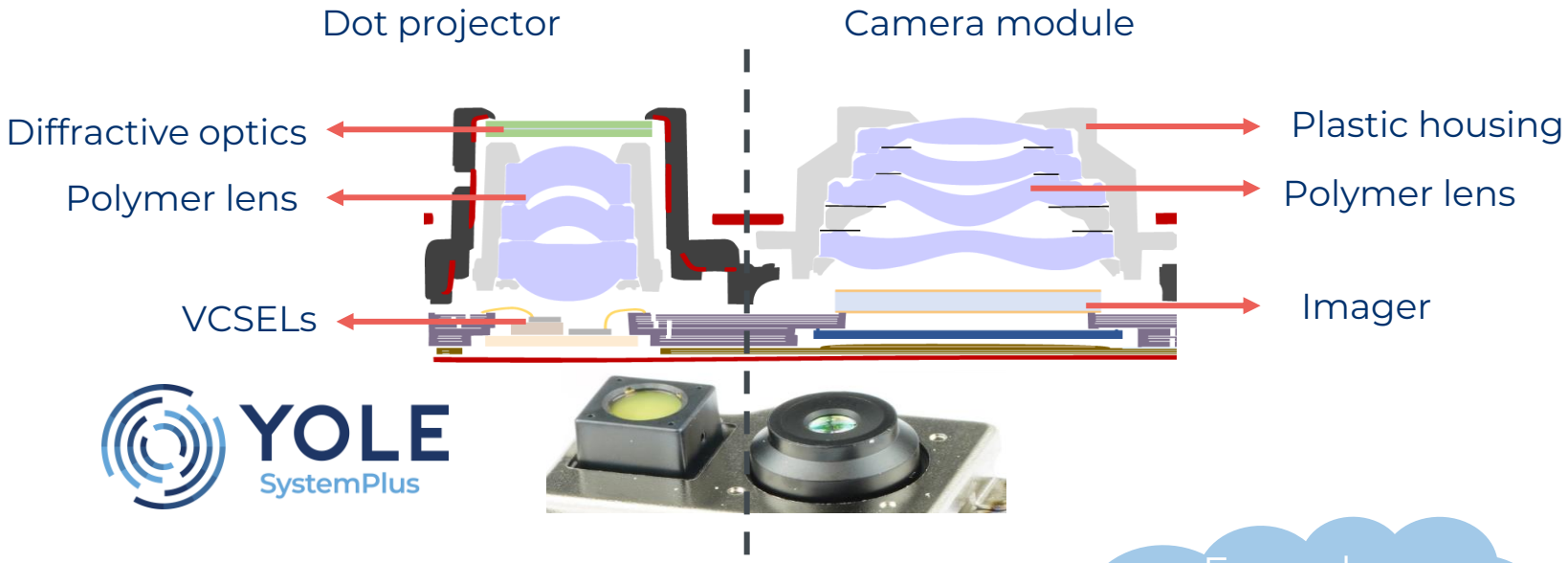
EMERGING MARKETS

Technology comparison: characteristics

	Ge-on-Si	Quantum dots	Organic
			
Minimum pixel size	1-2 µm	1-2 µm	1-2 µm
Spectral limit	~1,600nm	>2,000nm	~1,350nm?
QE profile	Broad band	Peak	Broadband
Dark current	High (!!)	Low	Low
Robustness	High	Low	Low
ToF compatibility	Yes	Not yet	Not yet

EMERGING MARKETS

Around the image sensor: a few words on optics



SWIR glass lenses

NIR polymer lenses

SWIR polymer lenses?

Fresnel polymer lens in iPhone 14 Pro proximity sensor

EMERGING MARKETS

Around the image sensor: a few words on software

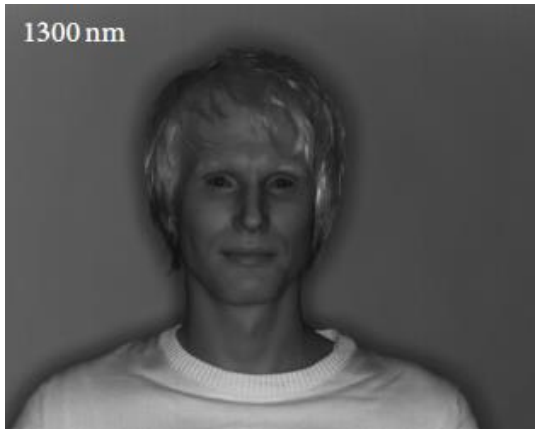
Unusual image processing methods

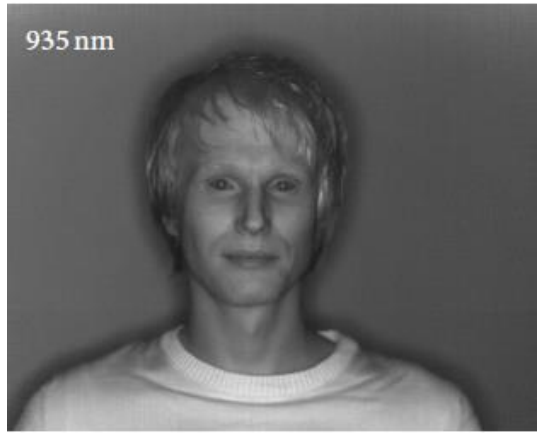
- Emissive
- MWIR
- LWIR

Standard image processing methods

- Reflective
- Visible
- NIR
- SWIR

Requires adjustment, but still reflective images





Source: H.Steiner & al. Design of an Active Multispectral SWIR Camera System for Skin Detection and Face Verification, MDPI Sensors, 2016

EMERGING MARKETS

Key takeaways

- Apple integrated SWIR single pixel sensors in its latest products.
- In consumer, SWIR could replace NIR in 3D sensing for under-display integration of facial recognition modules. It could also help improving performance 3D sensing in outdoor conditions.
- In automotive, Trieye works on a gated imaging system which promises to achieve 2D and 3D imaging within a single module. A large number of LiDAR players are interested in 1,550nm wavelength.
- CMOS image sensor suppliers are not really involved yet in SWIR (except STMicroelectronics and Sony). Will they help SWIR imaging industry to take-off?
- A technology disruption is required to address these markets. The candidates are Ge-on-Si, Quantum dots and Organic image sensors.
- Optics and software parts of SWIR imaging systems will require few adjustments.

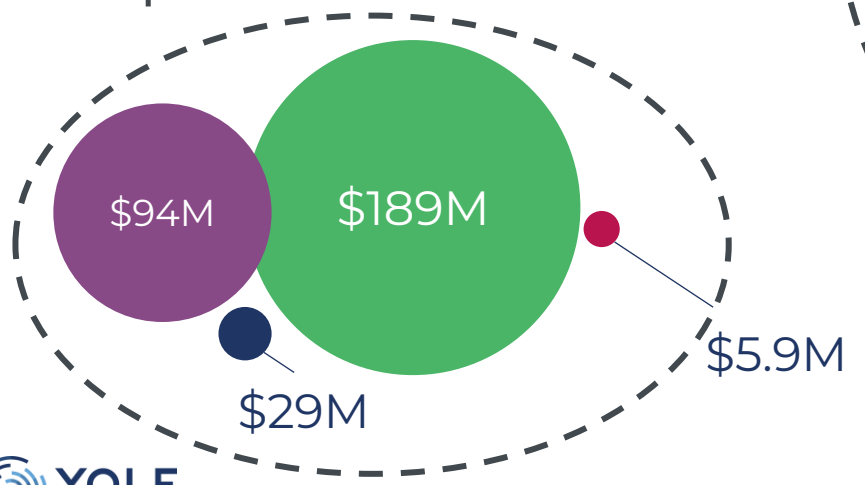
Conclusion

CONCLUSION

From a niche to mass market?

- Defense
- Industry
- Other
- Medical
- Consumer
- Automotive

2021
$317M



2027
$ X B

Forecast to be updated soon...

$360M
+25.1% $CAGR_{21-27}$

$224M
+2.9%
$CAGR_{21-27}$

3D sensing modules:
$ X B

$20.5M
+26.8% $CAGR_{21-27}$

Imaging platform (camera + lighting):
$20.8M
+28.9% $CAGR_{24-27}$

CONCLUSION

- SWIR wavelength offers new information and more efficient 3D sensing solutions.

- There are two worlds in the SWIR imaging industry universe. On the one hand, there is the existing markets driving small volumes but high value technologies. On the other hand, there is the emerging markets that could drive larger volumes.

- The rise SWIR imaging mass market will require important technological disruption and supply chain efforts.

- While the penetration of SWIR imaging in consumer is an optimistic scenario, it could happen. Recent integration of SWIR sensors in smartphones and wearables shows the interest of major consumer electronics integrators in this wavelength. The first SWIR imagers could be integrated starting in 2025/2026.

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