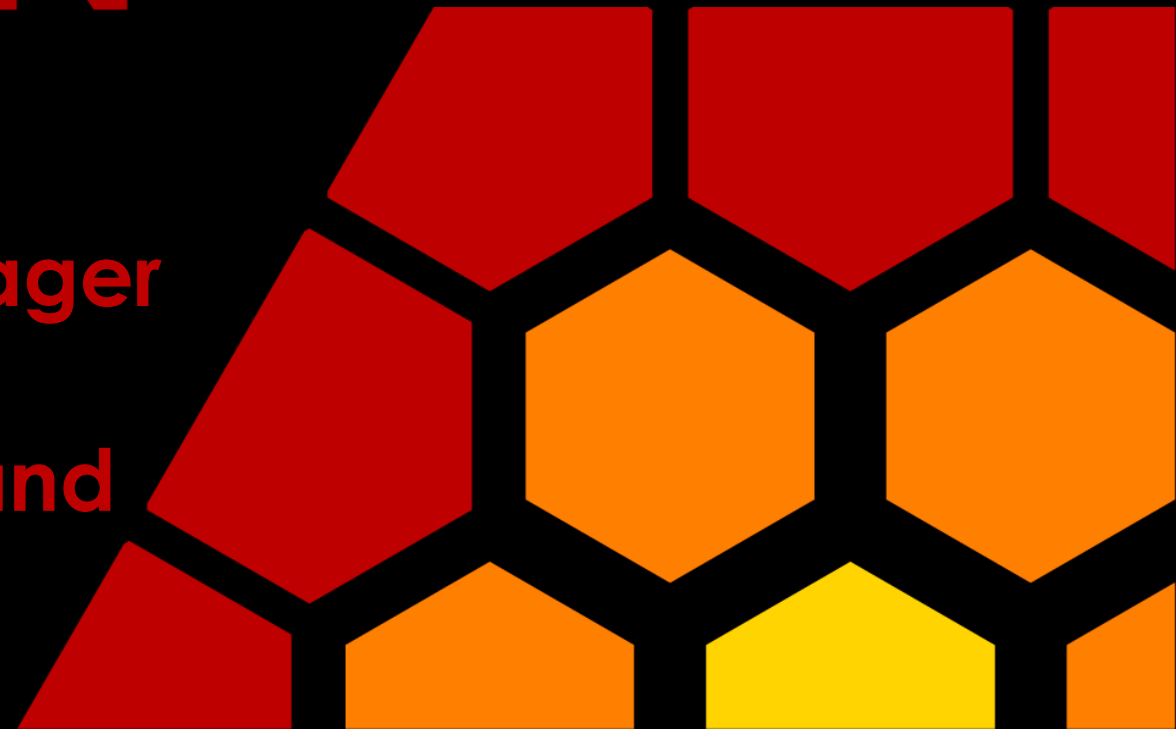


# EMBERION

**Bruce Barnett**  
**EMEA Regional Sales Manager**

**Developments in Broad-Band  
Quantum Dot Cameras.**



# Emberion

Emberion produces visible-to-eSWIR cameras and image sensors and offer imaging solutions at affordable cost



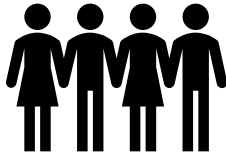
Two sites:

**Cambridge, UK:** photosensitive layer manufacturing

**Espoo, Finland:** ROIC, electronics and SW design;  
camera assembly, testing and calibration

**EMBERION**

Established  
in 2016  
(spin-off from Nokia)



38 employees



2 locations  
(Finland & UK)



**GRAPHENE  
FLAGSHIP**

Member of the  
EU FET Graphene  
Flagship Project

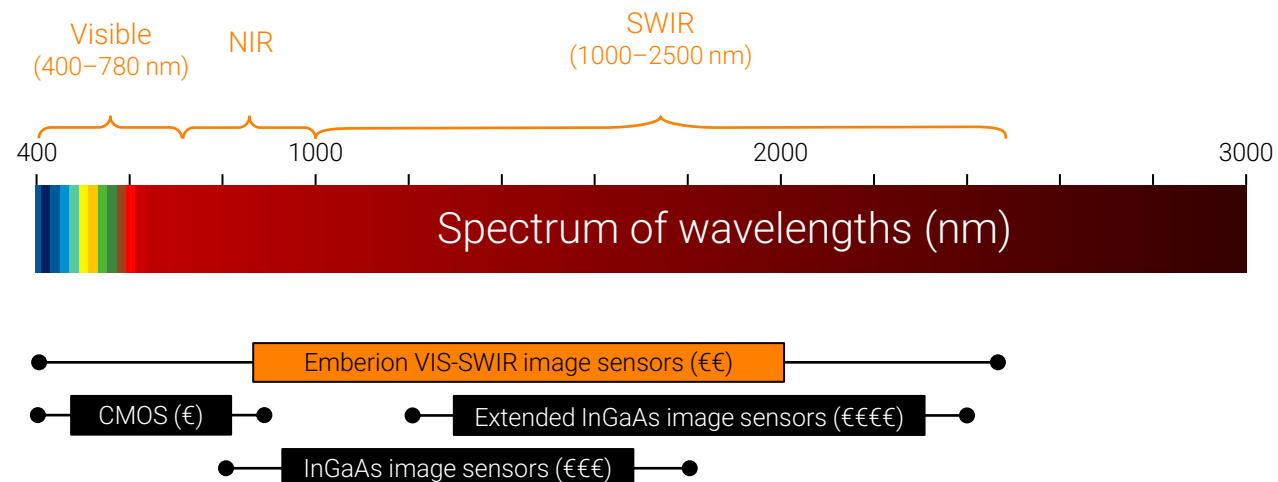
# Customer Benefits

Wide spectral range camera from visible to shortwave infrared (**VIS-SWIR**) up to 2000 nm with one image sensor from Emberion

**Integrated** camera solutions to provide optimal images beyond human vision

**High Dynamic Range** (HDR) without saturation and capability of **linear output** for optical measurement targeted for a variety of imaging application needs

**Scalability, affordability** and **customizability** is enabled by monolithic integration of colloidal quantum dots (CQD) with inhouse CMOS readout IC

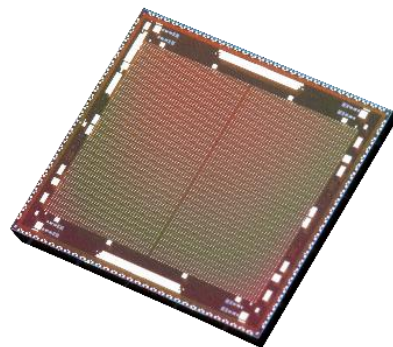
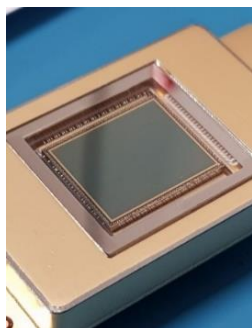


# Emberion Image sensor Technology



## Emberion VIS-SWIR image sensor

- Monochromatic wide-spectrum (400-2000 nm) VGA sensor with tunable spectral response
- Detector array integrated monolithically on a tailor-made CMOS readout integrated circuit (ROIC)
- Novel ROIC solution that enables measurement in different modes for optimal imaging operations

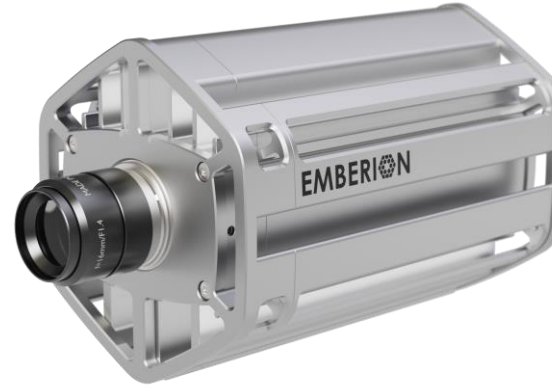


Technical Data	
Spectral range:	400 – 2000 nm
Array size:	640 × 512
Pixel size:	20 × 20 μm as primary option
Image size:	12.8 × 10.24 mm
Frame rate:	max 400 fps
NEI (@0°C, 10ms exposure time, 1850nm wavelength):	$3 \times 10^{-4} \text{ W/m}^2$
Saturation current density (@0°C):	$1 \times 10^{-4} \text{ mA/cm}^2$
Responsivity (@10ms exposure time, 1850nm wavelength)	$1.5 \times 10^9 \text{ V/W}$
Readout noise (@0°C):	200 μV
Dynamic range:	>120 dB
Shutter:	Global electronic
Timing:	Internal and external trigger, with < 1μs accuracy
Exposure time:	Min 0.1 ms, adjustable with 1μs resolution
Package:	28-pin metal package
Cooling:	2-stage TEC
ROIC I/O (data/control):	4-ch. diff. analog LVDS / SPI

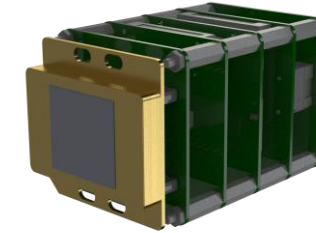
# Emberion VS20 camera offerings



Emberion VS20 Camera link  
Up to 86 fps



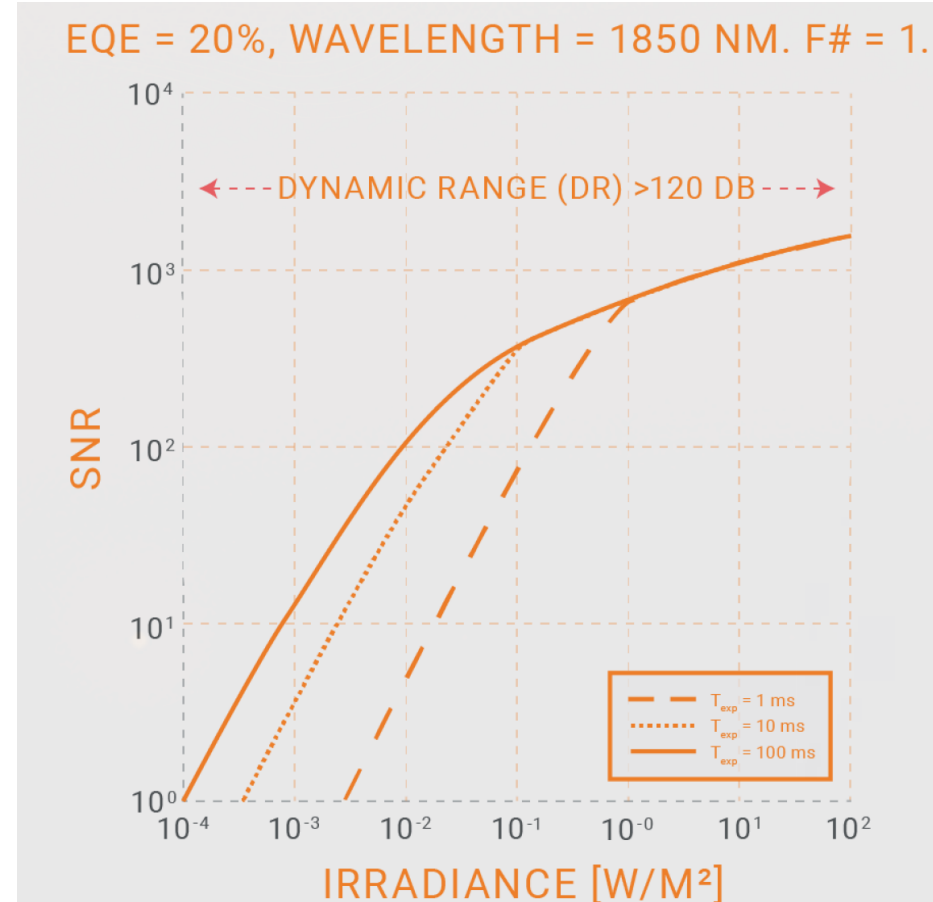
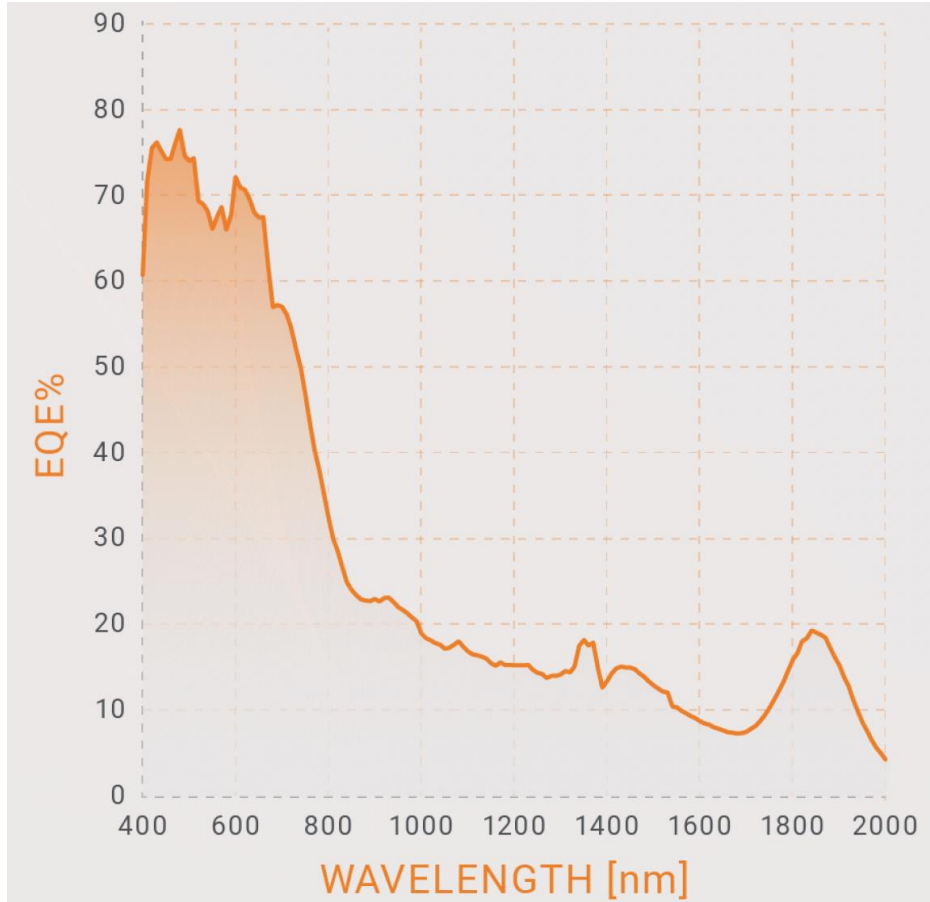
Emberion VS20 GigE  
Up to 400 fps



Emberion VS20 GigE Camera Core  
Up to 400 fps

Emberion VS20 variants	Sensor readout & control	ADC conversion	Calibration	Image processing	Interface included	Power management	Thermal control	Housing enclosure	Lens mount included
Complete Cameras	✓	✓	✓	✓	✓	✓	✓	✓	✓
Camera core	✓	✓	✓	✓	✓	✓	optional	✗	optional

# Key Performance



$J_s = 10^{-3} \text{ A/m}^2$   
 $R_{leakage} = 300 \text{ G}\Omega$   
 $C_{tot} = 450 \text{ pF}$   
 $A_{pixel} = 20 \times 20 \mu\text{m}^2$   
 $EQE = 0.2$   
 $\lambda = 1850 \text{ nm}$   
 $F\# = 1$

EQE  
SNR

External Quantum Efficiency, taking losses, reflection and recombination into account  
Signal to Noise Ratio

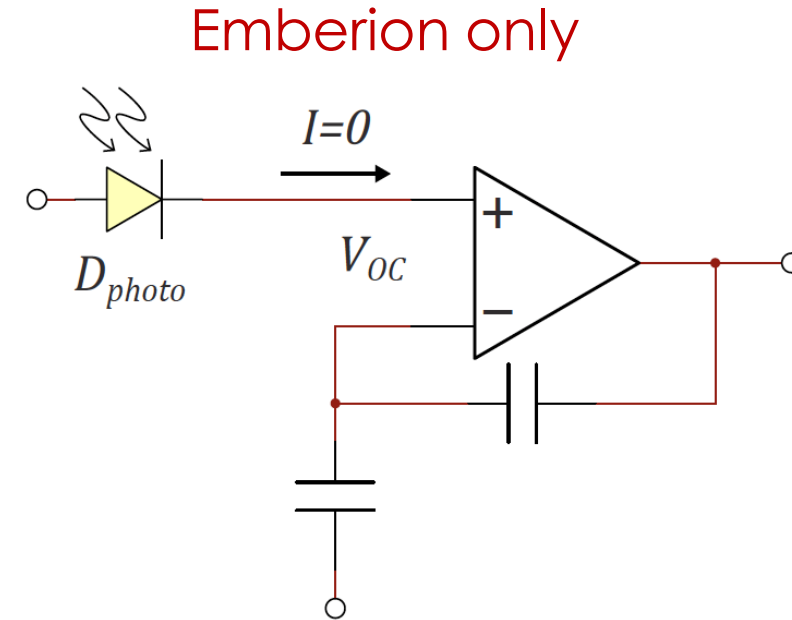
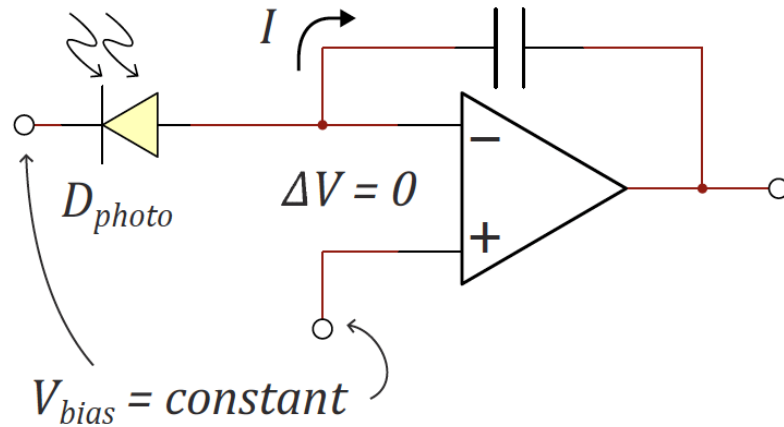
# Outdoor imaging - HDR advantage



A wide-spectrum VIS-SWIR image resembles a VIS image but there are some prominent dissimilarities in the contrast differences, e.g. tree leaves appear much lighter IR than in VIS light.

The non-linear response characteristic and the wider spectral sensitivity range of Emberion cQD sensor offer a wider dynamic range, see the contrast differences in the clouds, balconies and car windows.

# Unique operating mode



In reverse bias mode, the photodiode is reverse biased, which causes a small reverse current (dark current) to flow. Light will generate current on this photodiode.

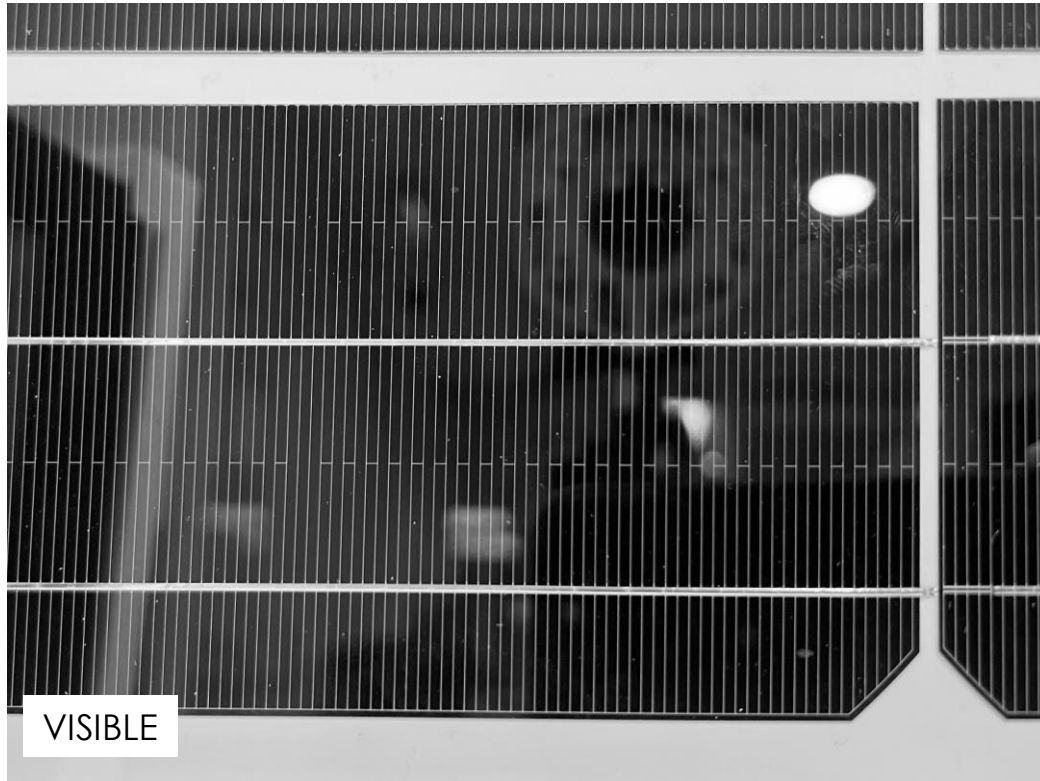
Dark current and readout noise are the two important noise sources; SNR is roughly the ratio of signal and dark currents

In Open-circuit voltage mode **OCVM** (Emberion Only), the photodiode is forward biased, and circuit is left open. There is no dark current. When exposed to light, the photodiode generates a voltage charge.

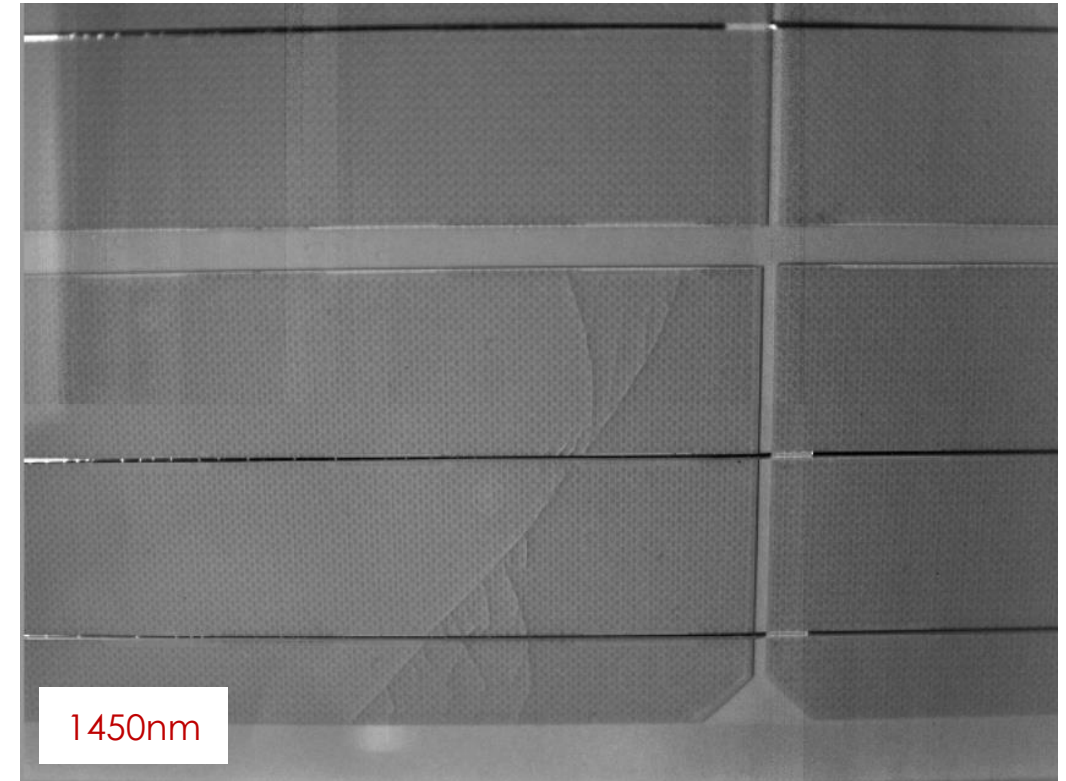
Thermal  $kT/C$  noise and the readout voltage noise are the two important noise sources (the dark current is not present)



# Solar panel inspection



Raw material can be easily damaged during solar panel production. Under visible light, cracks cannot be detected.

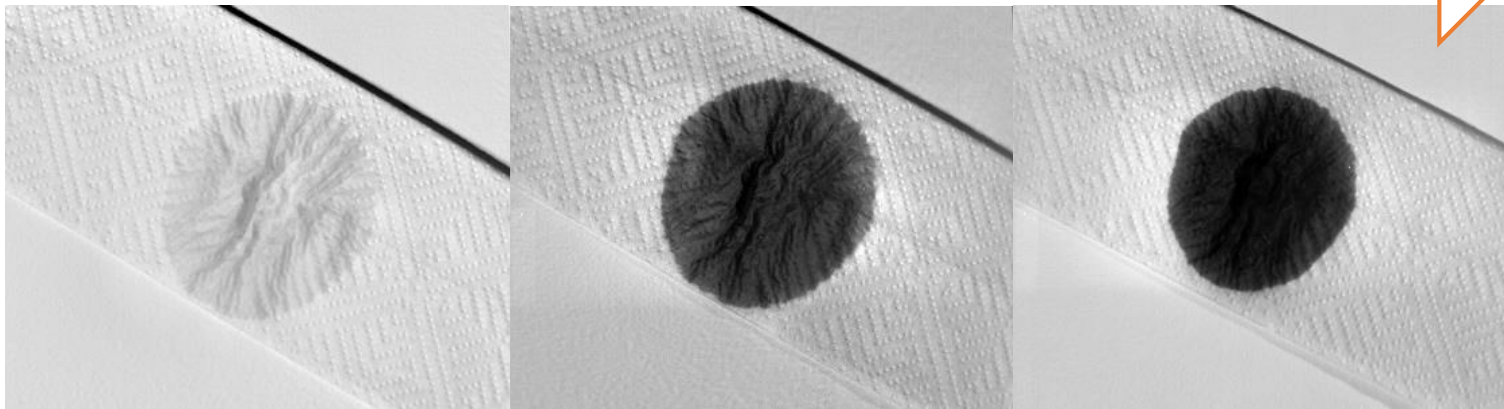


At SWIR wavelength crack starts to become visible, and can be detected by Emberion VS20 SWIR camera. The same solar panel can be observed using 1200nm filter to identify the cracks.

# Extended Wavelength Range



CONTRAST LEVEL INCREASING WITH DISTICT WATER ABSORPTION PEAKS



VISIBLE

SWIR at 1450nm

SWIR at 1920nm

*Water absorption peak shows highest contrast at 1920nm enabling contrast differentiation and improve on false defect count*



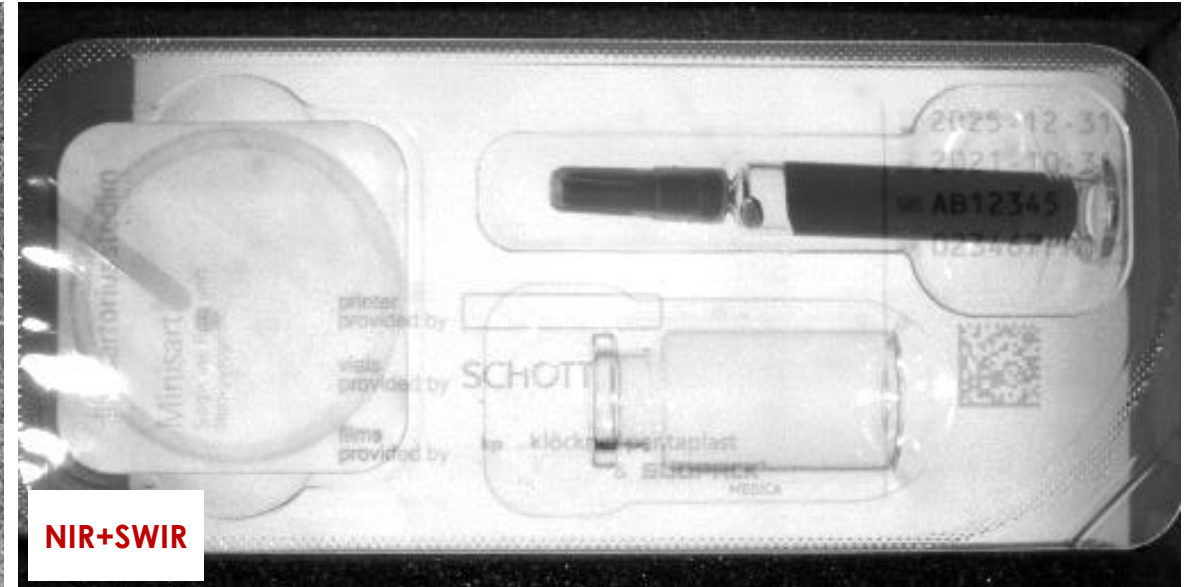
*SWIR 1920nm image shows water contrast on coffee beans*

Potential applications: machine vision, optical sorting, multispectral and hyperspectral imaging, night vision

# Medical plastic package inspection



Full VIS-SWIR spectrum image shows the printing on the packaging and the vials underneath the opaque package are barely visible. The visual features dominate in the image as the sensor is more sensitive to VIS light than to IR light.



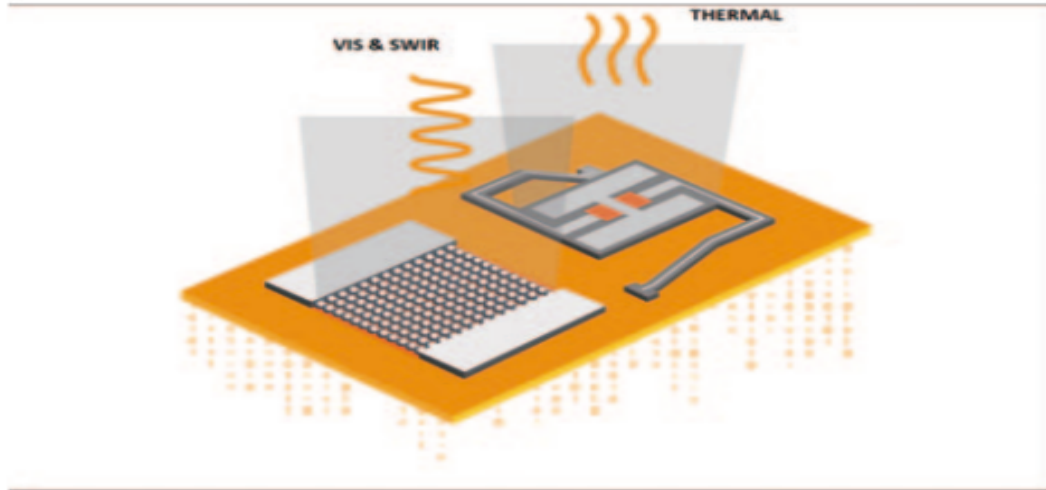
IR image shows the vials very clearly underneath the opaque package. Some of the printed package labels are not visible in IR light. However, the printings on the left-most vial are visible. The fill-up level of the transparent liquid in the vial is very visible due to the water's high light absorption factor at 1450 nm and 1950 nm.

# See through smoke – adverse condition

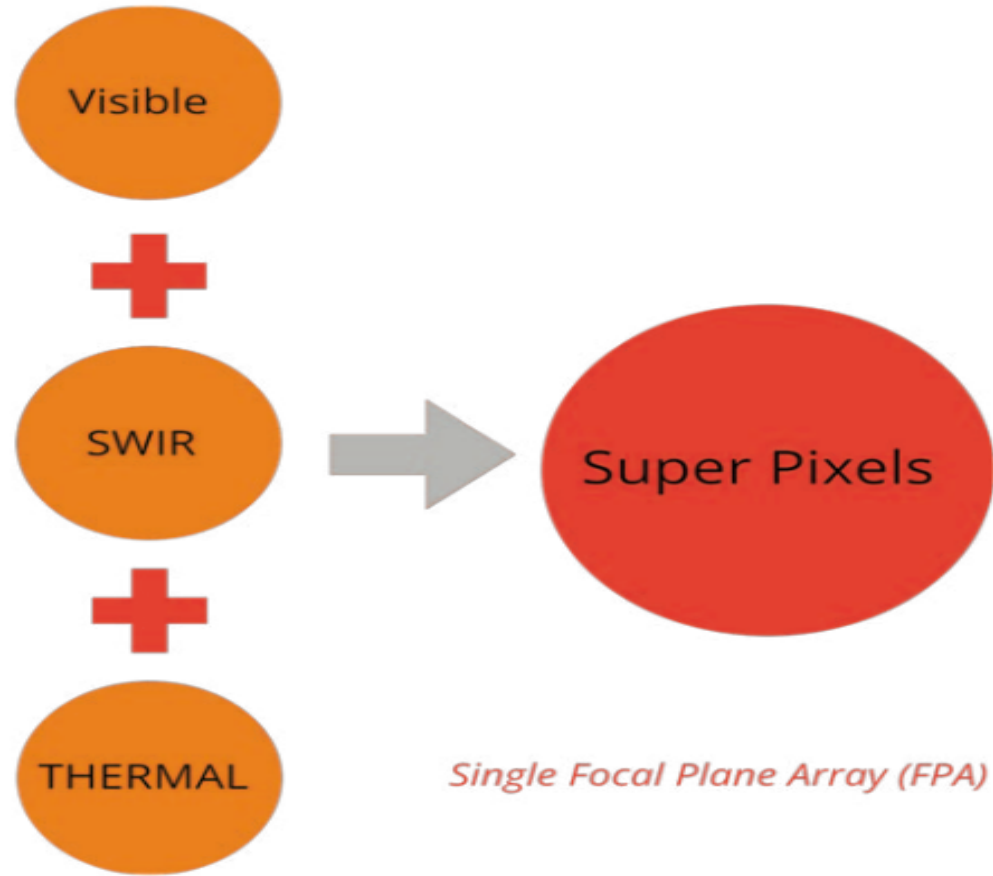


Image on the left showing visible smoke from campfire blocking the scene. The same image can be seen through the smoke using Emberion VS20 SWIR camera using 1550nm filter. **SWIR penetrates through smoke particles allowing adverse condition surveillance** (defence, night vision, firefighting, automotive)

# Tri-Band Quantum Dot Camera



**Image 1** | Emberion designed a new CMOS ROIC with a unique nanomaterial stack and pixel-geometries of each band (VIS-SWIR-Thermal), which are termed as super-pixels, enabling the development of simultaneous imaging of three bands under one focal plane array



*Single Focal Plane Array (FPA)*

# EMBERION

[WWW.Emberion.com](http://WWW.Emberion.com)

Any Questions?

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