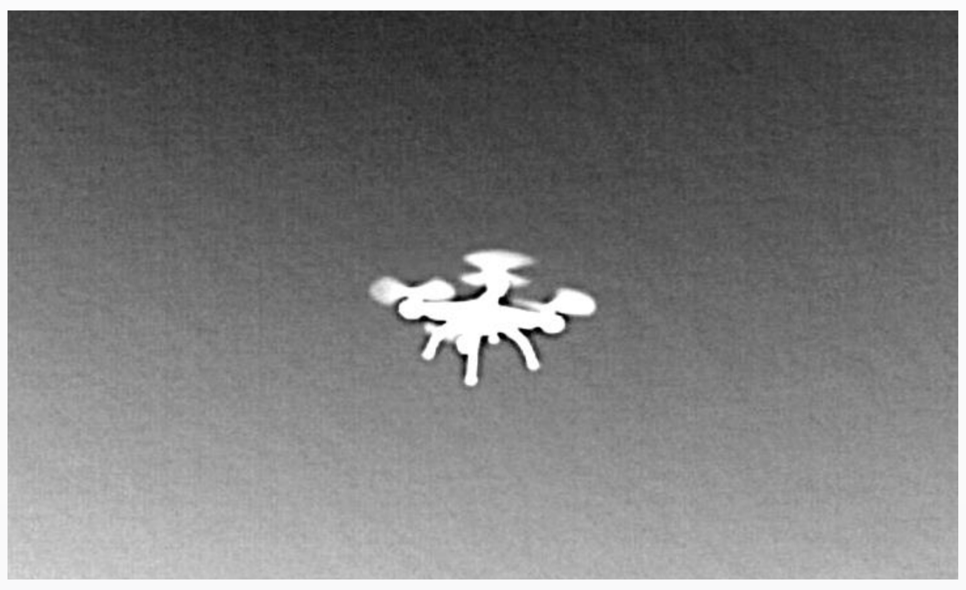
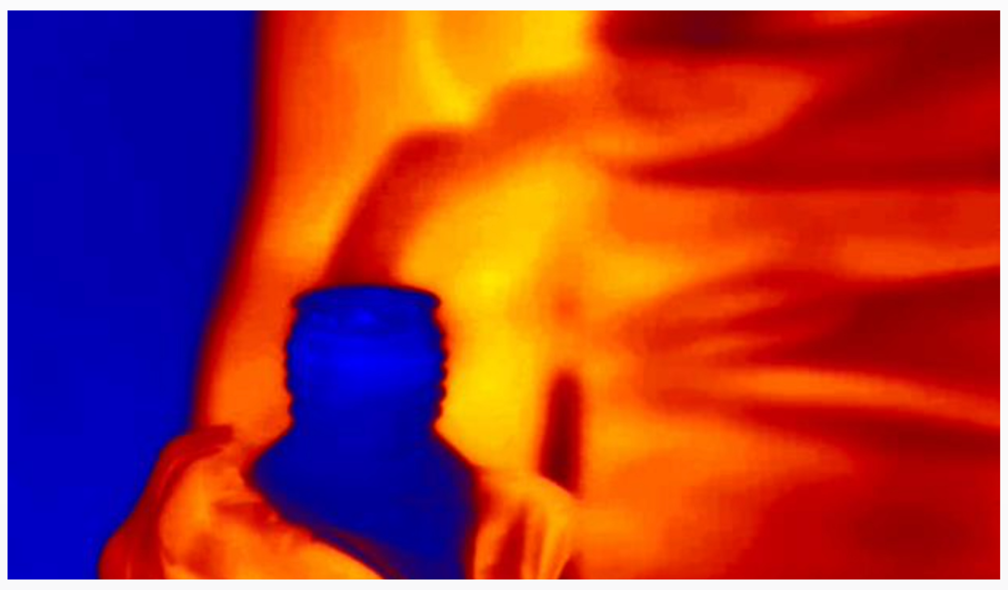
LWIR & VLWIR QWIP

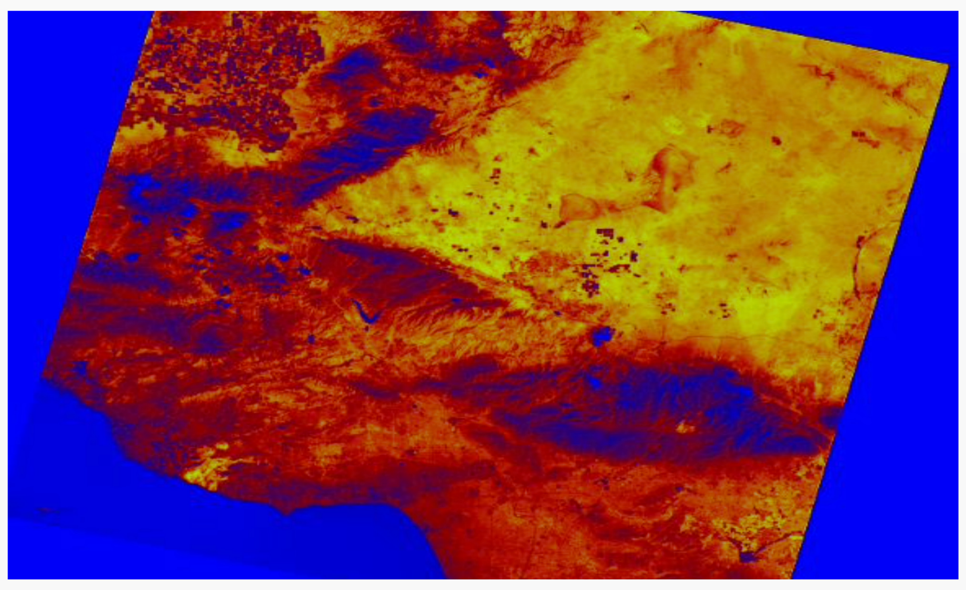
Field-proven and fast time to market IR detectors



Ground to air detection and tracking.



Industrial monitoring.



Earth satellite imagery.

Land surveillance and sighting.

LWIR - VLWIR spectral band advantages

Many imaging applications requires the use of cooled (vs. uncooled) infrared cameras, relating to their superior sensitivity, spectral behaviour, response time, frame rate or any combination of these parameters. Selecting the optimum infrared spectral band can turn out to be very difficult as the final choice is dependent on the final application. Although some applications will strongly dictate the spectral band, many others will need a trade-off decision, to be evaluated at the system level: compromising overall system performances vs. different scenarios vs. system cost (recurring and non-recurring) vs. time to market. Below are a few short examples of technical use cases were selecting the LWIR or VLWIR spectral band would be obvious:

Imaging phenomena, by nature only happening in certain wavelengths:

- Optical gas imaging for gases with absorption in the LWIR, or VLWIR part of the spectrum (SF_6 absorption at 10.55 µm etc.)
- Temperature measurement (thermography) depending on material, surface finish, absolute temperature, and scene temperature span.

Electro optical artefacts generated by the scene:

- System disturbance due to Solar reflections.
- Non-transparency of certain material.
- High intra scene dynamic range required.
- Battlefield obscurant (dust/smoke).

For uses cases where compromises must be considered, selecting the proper waveband can be difficult as it involves many other parameters, technical as well as non-technical, and every application/business case will weight differently each of these parameters.

Some technical parameters that should be considered:

- System performance requirements:
  - detection, recognition, and identification range for surveillance systems.
  - detection probability and false alarm rates for defence systems.
- Final system size and weight.
- Final system power consumption.
- Tolerance to scene artefacts or unexpected events.
- Optimum performance coverage for one system over different operational scenarios.

Some non-technical parameters:

- Overall system cost (design, serial production, etc.)
- System servicing and maintenance tasks and cost.
- Time to market

In conclusion, no spectral band could claim to be the best choice whatever the application:

- Some applications will strongly dictate the spectral band.
- Most applications would need to evaluate the best compromise with weighted parameters as per the application needs.
- Some applications require a combination of several spectral band or other infrared light properties (polarization for example) to reach the desired performance.

Below is a non-exhaustive attempt to list some great LWIR and VLWIR use cases.

LWIR and VLWIR use cases

Typical application	Rationale
Detection on water surface	Search and rescue at sea, oil spill detection will not be perturbed by solar reflections
High-contrast scenes (Planes, UAV with clear sky background) or high-energy object tracking (rockets etc.)	Benefit from Planck's Law. LWIR flux variation over a wide spectrum would be lower, thus allowing higher intra-scene dynamic range (hot and cold objects in the same scene) and preventing Wide/full detector saturation when steering the camera to the sun (quite often non- evitable in land to air imagery) in the field of view, therefore exceeding detectors operating in MWIR
Imaging cold objects	Benefit from higher IR flux emission in LWIR spectrum at low temperature
Imaging through smoke and dust (battlefield, fire fighting)	Benefit from low air transmission loss by these obscurants in LWIR spectrum
Optical Gas Imaging	Benefit from specific absorption band for gases like SF6, etc.
Optical Gas Imaging	Earth ground or weather observation from satellites due to intrinsic absorption from atmosphere

QWIP for LWIR and VLWIR detectors

There are some solutions on the market for producing LWIR and VLWIR detectors: cooled QWIP, Cooled MCT, uncooled bolometers, and the most promising cooled T2SL.

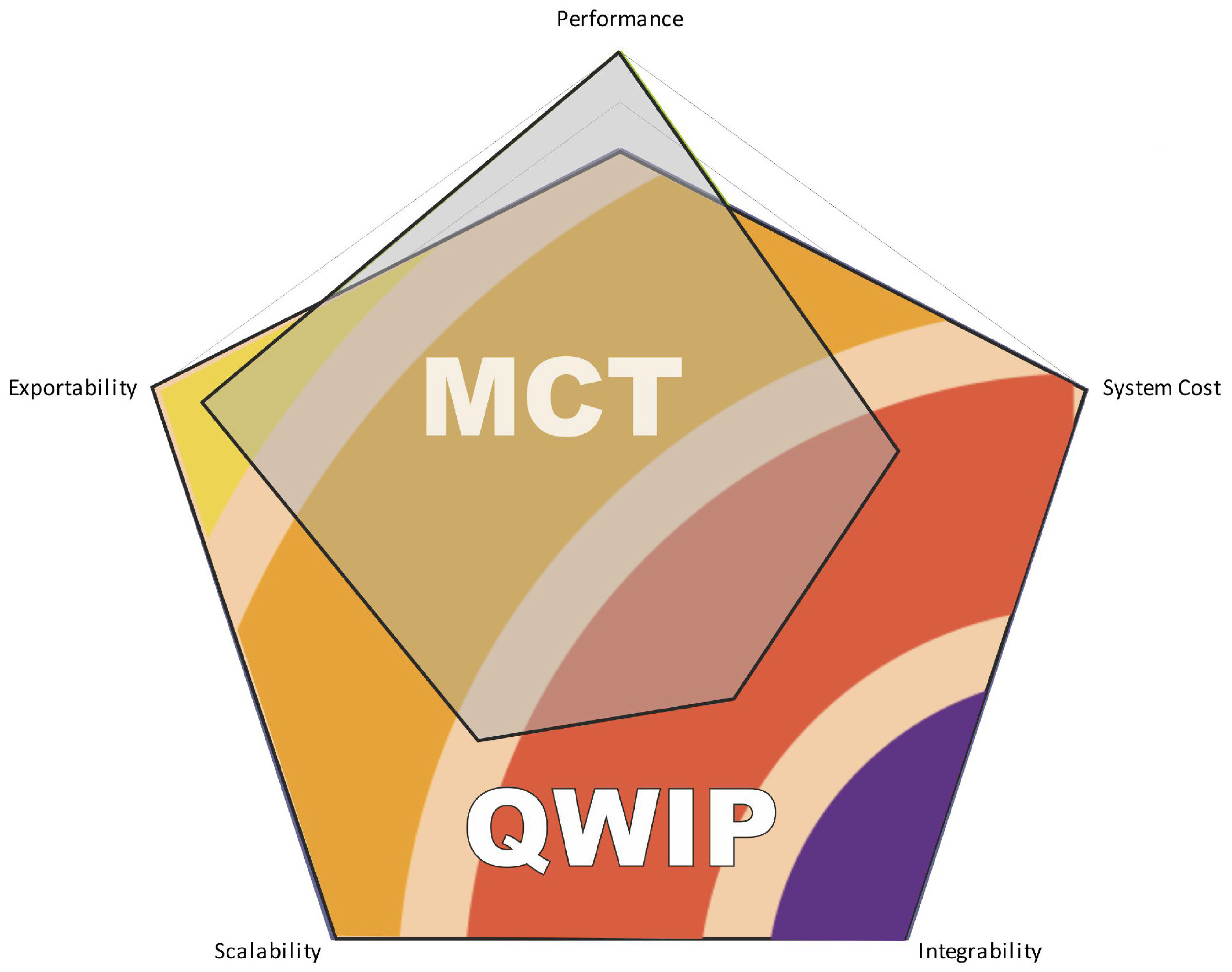
This application note does not deal with LWIR uncooled detectors (commonly named bolometers), but instead focus on comparing cooled detectors solutions. Bolometers can provide a good solution for applications looking for LWIR spectral band (or more general thermal imagery) as bolometers are broadly available and well suited for less demanding or cost constrained applications.
LWIR QWIP detectors have been manufactured since the late 1980s and have been the most deployed 2D detector technology for LWIR applications ever since. Especially in tactical defence and surveillance applications, where QWIP is still the most mature and preferred solution, massively deployed in the field.

The genuine intrinsic capabilities of QWIP have been more recently introduced for emerging applications, such as optical gas imaging and polarization detection.

Cooled LWIR MCT detectors (mercury-cadmium-telluride, HgCdTe) have been offered as alternatives. Although some intrinsic features (High Qe and broader spectral response) are obvious advantages, several significant drawbacks are still preventing this solution from taking any LWIR leadership.
Finally, cooled T2SL-based (Type II Super Lattice) detectors sound very promising, although technical maturity and high production capabilities will require some more time to realise. IRnova, as a world leader in MWIR T2SL, is at the forefront of developing T2SL materials suited to the LWIR spectrum. These are planned to become available in mid-long term for future LWIR large arrays (HD formats) and multiple-band detectors.

As this application note is focussed on mature, field-deployed, fast time to market solutions, we will narrow down to QWIP versus MCT comparisons.

Comparison to other technologies



Criteria	MCT	QWIP	Parameters
Performance	✓	✓	Temporal Netd, Spatial Netd
System cost		✓	Volume manufacturing capacity
Array uniformity and operability		✓	Reduced NUC complexity, low number of defective pixels
Detector stability		✓	No deviation over time
Scalability		✓	Large arrays, spectral band agility
Exportability	✓	✓	Original source, supplier independence

MCT (mercury-cadmium-telluride or HgCdTe) detectors can be tuned for LWIR. But the notorious challenge to produce such material increases in LWIR spectral band as the extremely low Cadmium fraction and high Mercury concentration makes it even more difficult (thus expensive) to manufacture with appropriate uniformity and stability.

Performance

Quantifying (and moreover comparing) infrared detector performance, especially when the comparison involves different materials, includes several parameters, each of them weighted against the final application: surveillance, thermography, optical gas imaging, space, etc.

Overall detector performance is a combination between the intrinsic material benefits (the purpose of this note) combined with detector specific embedded features and additional capabilities (not investigated here).

A first attempt to assess detector intrinsic performance would be to quantify "sensitivity". This would involve a combination of several parameters like material absorption capability, quantum efficiency and spectral response. As far as these three parameters are considered, MCT would have an advantage over QWIP, but the key here is to envisage if and how this would translate at the camera level, as the detector integration time can be freely set.

A synthetic and commonly adopted parameter to try to gauge performance is the Netd parameter (Noise Equivalent Temperature Difference). Although not exhaustive, compared to the absolute "sensitivity" assessment, Netd has the advantage of combining several parameters (absorption, quantum efficiency, intrinsic detector noise, integration time, etc.) as an ultimate attempt to quantify the performance benefits for a given application.

As stated in the above sections, LWIR spectrum is characterized by high photon flux, and therefore, unless extremely low integration times are required, QWIP based detector's Netd will nicely compare to MCT, considering that for a given configuration, QWIP detector will simply require higher integration time, without compromising it suitability for almost any known field application.

LWIR - VLWIR spectral band advantages

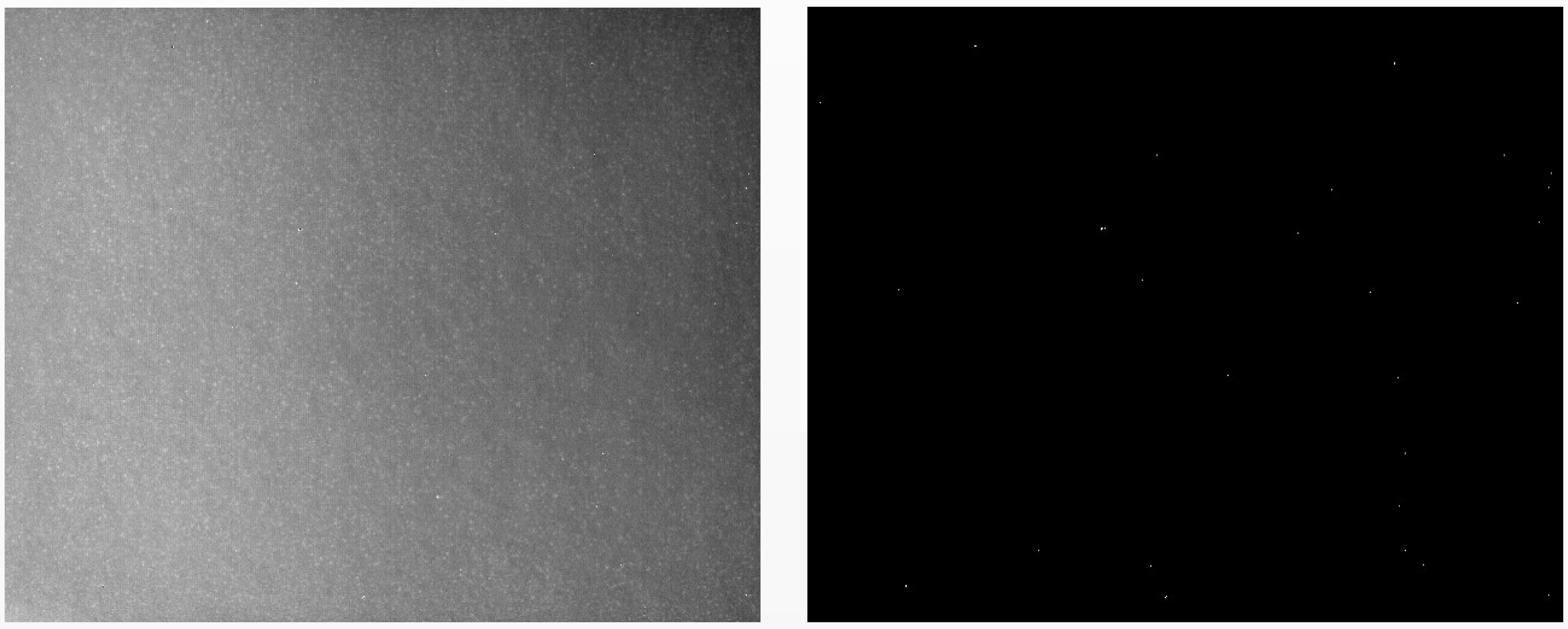
All detector technologies (not only infrared) suffer from imperfections, caused either by the materials themselves or tiny variations or defects resulting from numerous and challenging detector production steps. The so-called uniformity and operability cause some pixels to respond irregularly to incoming photons flux. They might show an output signal that is higher or lower than the average of the array, or intermittent behaviour, or just no signal at all.

Each application might have different allowance criteria for both uniformity and operability, but these must always be compensated with post processing algorithms. The severity of these defects and variations can impact:

- The system overall complexity, as these may need sophisticated algorithms, processing power and development time to compensate for the variations and hide the defects.
- System overall performance, as large variations reduce overall intra-scene ranges and can generate video artefacts.
- Detection systems inability to execute, as hidden, non-working pixels can lead to fail at detecting threats or generate false alarms.
- Higher engineering and production costs, as more sophisticated processing would increase development cost and hardware video platform cost.

Uniformity and operability of QWIP detectors are known to be the best one over any technologies and clearly not reachable with LWIR MCT-based detectors. This root from the genuine benefits of QWIP material design, backed by IRnova's manufacturing excellence, allowing for very uniform wafer production.

IRnova's QWIP detectors, including VGA format arrays, are all above 99.95 % operability. Many even show manufacturing records, having zero dead pixels.



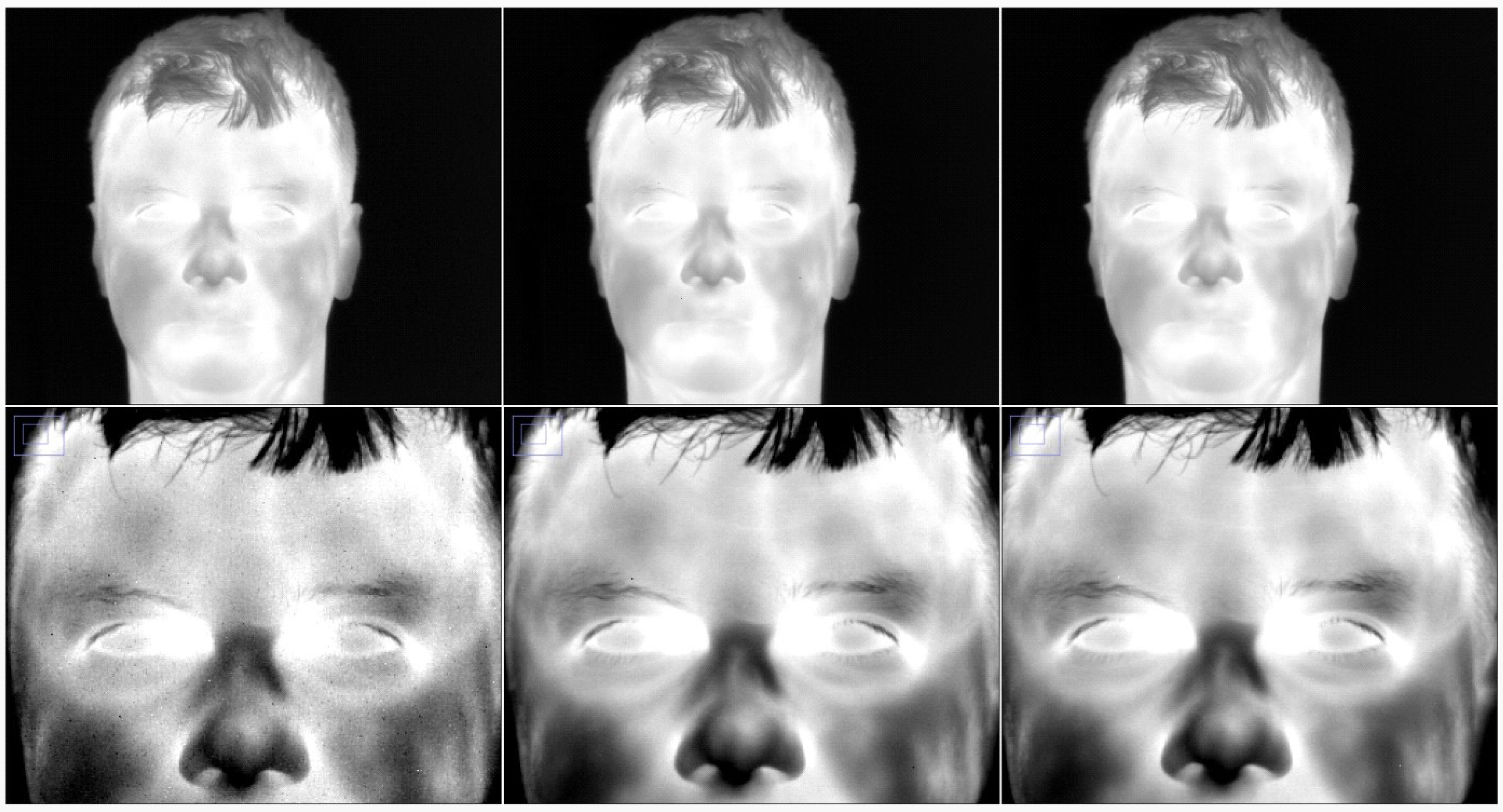
Example: Tor LW detector, VGA format, 15 µm pitch. Left image: ±10 % gain map.
Right image: non-operating pixel map. Total operability is 99.99 %.

Detector stability

Another key advantage of QWIP is the excellent image stability over the time. Several other materials (especially bulk ones) can vary over the time due to intrinsic material recombination. Lower stability would mean that uniformity (and operability) may vary over the time. This may require regular recalibration of the system or real-time detector drift detection and compensation which means more complex and expensive systems.

The below example illustrates the incredibly stable behaviour of IRnova's QWIP detectors. There is no difference between the three sets of images.

The left image was made with a Tor LW detector, recently switched on, using a 6 months old gain and offset correction map, using nor live shutter correction or live correction algorithms. It's a stunning image, made straight after cooling down time.



Gain map: 6 months old
Offset map: 6 months old

Gain map: 6 months old
Offset map: same cool down

Gain map: same cool down
Offset map: same cool down

The centre image was made after an offset update (one point non uniformity correction update with uniform reference). The bottom image is not just a zoomed image it also applies updated AGC values. (top images having a grey scale span of 7K, while bottom view images are narrowed to 2.5K span.

In the right-hand image, a newly created gain correction table has been applied. There is no difference from the centre image. This shows that gain correction has not changed at all after a six-month period. There is no need for real time drift detection and correction algorithms. System performance and ability to execute the task, as well as end user satisfaction will be stable over the full lifetime of the system.

System cost

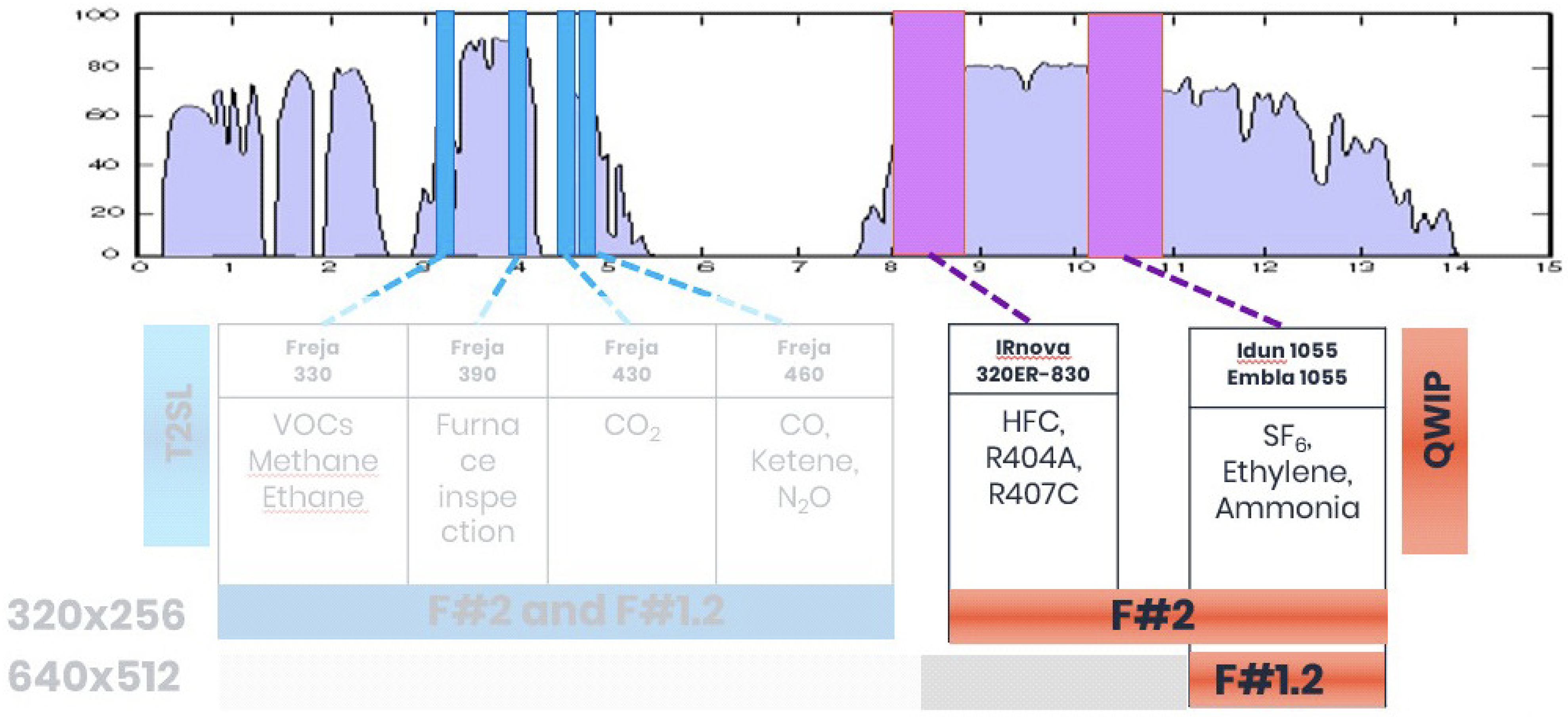
As with many other applications, infrared detector cost, and more importantly, customer price, depends heavily on the industrialization techniques used in volume production.

As discussed above, QWIP material intrinsic benefits (uniformity, operability, and stability) combined with III-V material growth benefits, have positioned QWIP as the best currently available material, capable of sustaining high production volume ramp-up by enabling cost-scale benefits.
Whenever complex electro-optical systems are considered, there is no point in comparing only the detector overall system ownership cost, without including the design effort, serial production (assembly, test recurring cost) and lifetime servicing and maintenance costs.

At the R&D stage, QWIP uniformity and operability will enable the electro-optical system designer to focus on final user features and capabilities (video enhancements, application specific capabilities) rather than spending time compensating for the difficult, ever-evolving detector flaws, thus saving R&D time and resources. Electro-optical system onboard computing resources could either reduce or reallocated to implement more sophisticated customer mission added value.

On the assembly and production side, QWIP uniformity and operability will save time in the calibration procedure. The same goes for servicing and maintenance.

Optical gas imaging



Detecting gas leaks though imaging has seen a tremendous adoption during the past decade. This is a combination of the world's increased focus on the environmental effects of unmanaged harmful gas leaks into the atmosphere, as well as some unfortunate industrial catastrophes (refinery and pipeline explosions) that has led to many injuries and loss of lives. As the world's monitoring standards increases, optical gas detection using infrared cameras means has proved to be a key asset on fighting against these threats.

Optical gas imaging relies on atmospheric absorption for each gas. Air transmission gaps on one specific wavelength indicate the presence of the gas (each gas having its own absorption signatures). As this application is not "seeing the gas", but rather detecting their influence on air transmission. This requires an ultimate sensitivity and focused spectral response to be able to distinguish even very tiny variations.

The ability to tune QWIP spectral response at the manufacturing stage, as well as the resonant behaviour (maximum sensitivity reached at peak wavelength), along with its excellent uniformity is instrumental in offering optical imaging detectors that can detect gases having absorption bands in the LWIR and VLWIR spectrum.

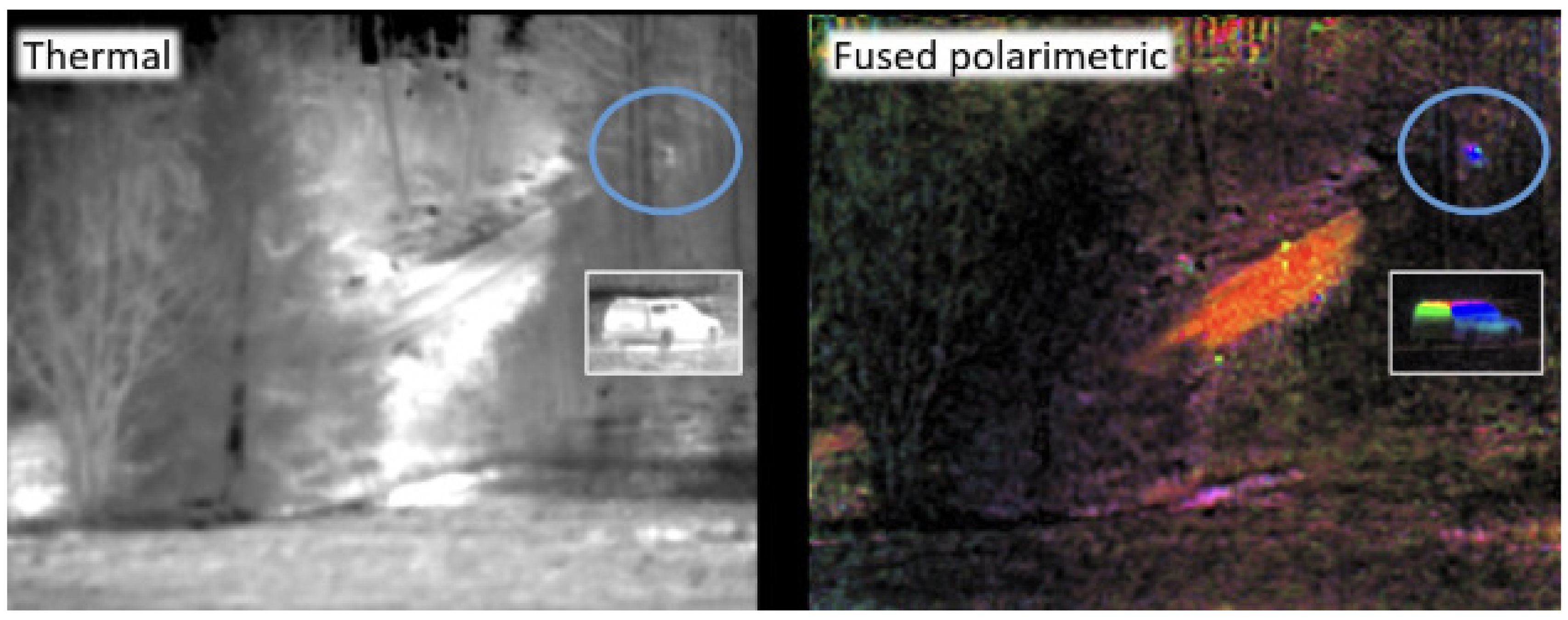
Polarimetric capability

QWIP can be easily customized to detect the polarity of incoming IR flux at the pixel level.

This opens great new possibilities, increasing system performance as well as new applications. Please see our dedicated application notes on polarimetric detectors to know more about IR face identification, increased UAV and mine detection and oil spills detection capabilities.

Example of polarimetric applications:

- Camoflauge denial.



- UAV detection

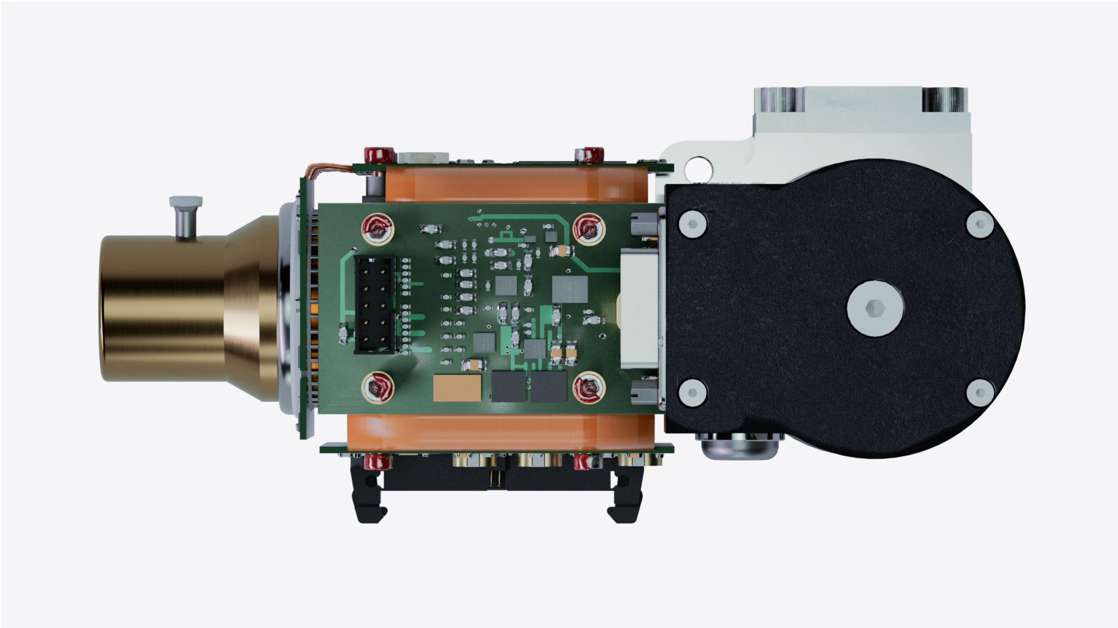
IRnova's QWIP detectors at a glance

QWIP detectors currently available from IRnova includes the detector, dewar and cooler assembly all packaged with an optimized proximity electronics. These proximity electronic standard digital interfaces helps customer to focus solely on their dedicated applications algorithms.

Many custom detectors were derived from the off-shelf configuration to meet special demands.

Detector	Application	Format
Tor LW	General purpose	640x512 , 15µm
Brage LW	General purpose	320x256 , 30µm
Idun 1055	Gas detection	640x512 , 15µm
Embla 1055	Gas detection	320x256 pixels
Garm LW Pol	Extended detection polarimetric	320x256 pixels

Tor LW

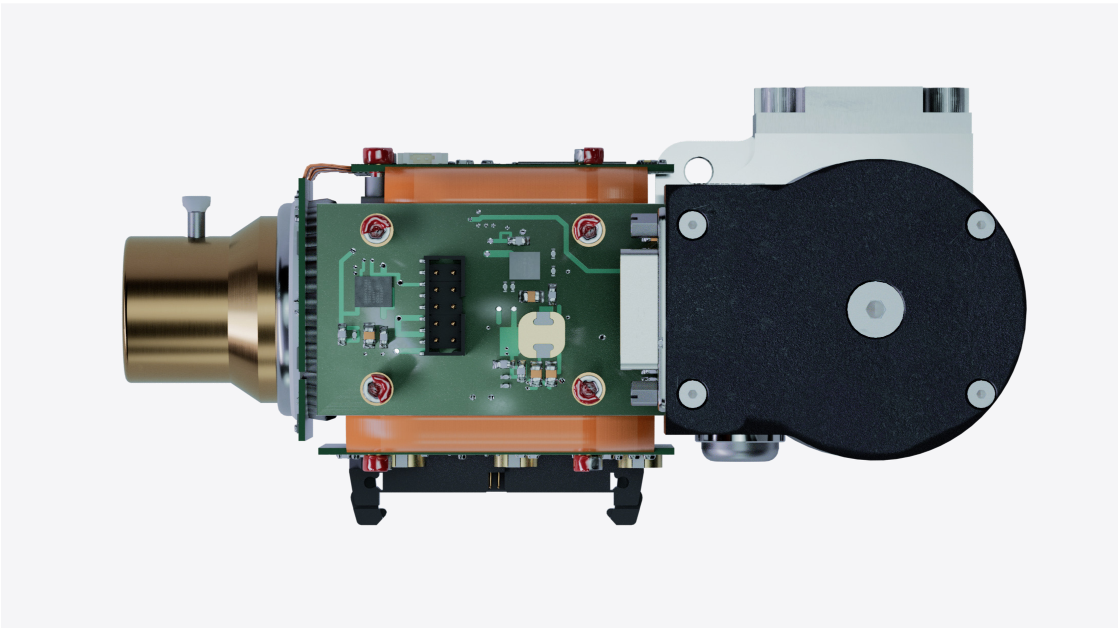


The Tor LW is a 15 µm pitch QWIP detector serving high-end cooled LWIR applications. IRnova's mastered QWIP technology is the world's most proven material. The Tor LW's unique 15 µm pitch array combines inherent QWIP benefits (high uniformity, stability, and operability) with state-of-the-art LWIR array size and performance.

Applications:

- Border security and surveillance cameras.
- Air defence target tracking (including UAVs).
- Industrial applications (thermography, NDT...).
- Airborne / space earth imagery.

Idun 1055

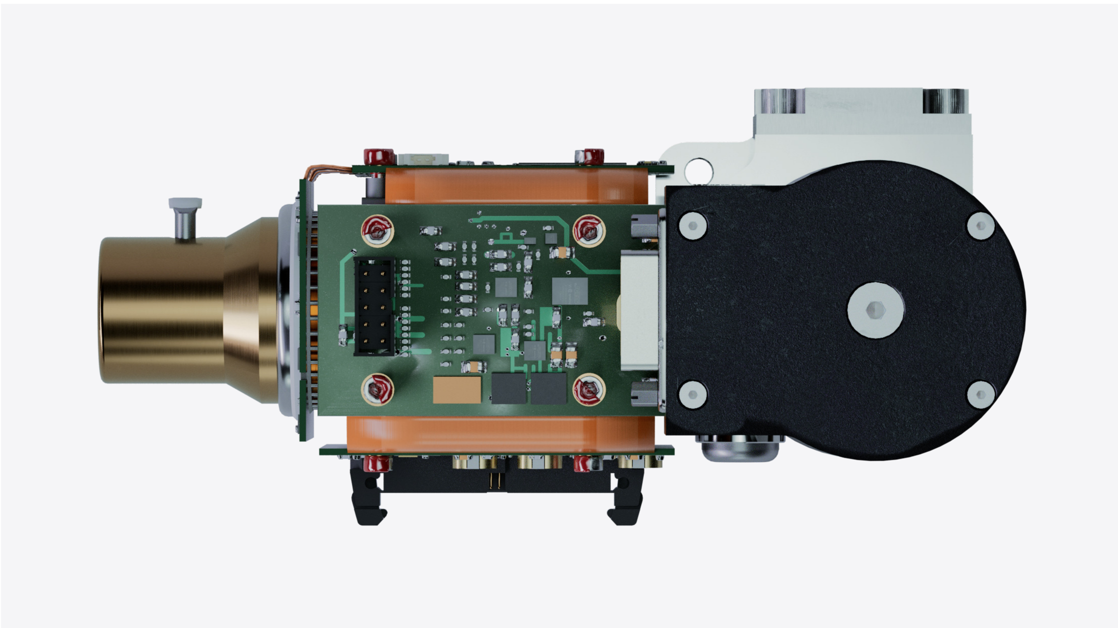


The Idun 1055 is a state-of-the art optical gas imaging (OGI) detector for sulphur hexafluoride (SF6), ammonia, ethylene, and numerous other gases with absorption around 10.55 µm. This next generation 640x512 detector is a world first and it is quickly becoming the obvious choice for systems manufacturers willing to set new performance standards in the OGI market. Relying on high resolution and an optimized F number, the Idun addresses the most stringent requirements and regulations posed by industry for leak detection systems.

Applications:

- Optical gas imaging for any gas with absorption in the 10.55 µm range.
- Optimized for sulphur hexafluoride, ammonia, and ethylene detection.
- Handheld and battery powered cameras.
- Mobile and stationary platforms.

Embla 1055

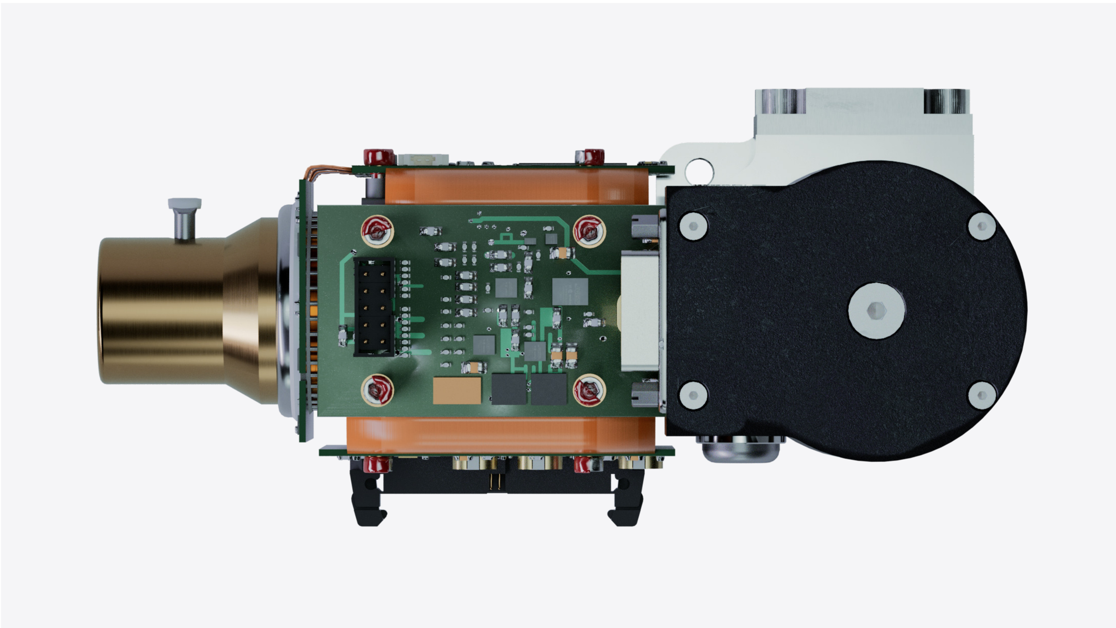


The Embla 1055 represents the industry standard when it comes to OGI detectors in the upper LWIR region. It is based on a customized QWIP design for maximum sensitivity at precisely 10.55 µm. It is a field-proven and widely adopted solution for detection of SF6 (sulphur hexafluoride) as well as ammonia, ethylene, and numerous other gases. Designing state-of-the-art industrial optical gas detection and monitoring systems has never been so easy.

Applications:

- Optical gas imaging for any gas with absorption in the 10.55 µm range.
- Optimized for sulphur hexafluoride, ammonia, and ethylene detection.
- Handheld and battery powered cameras.
- Mobile and stationary platforms.

Garm LW Pol



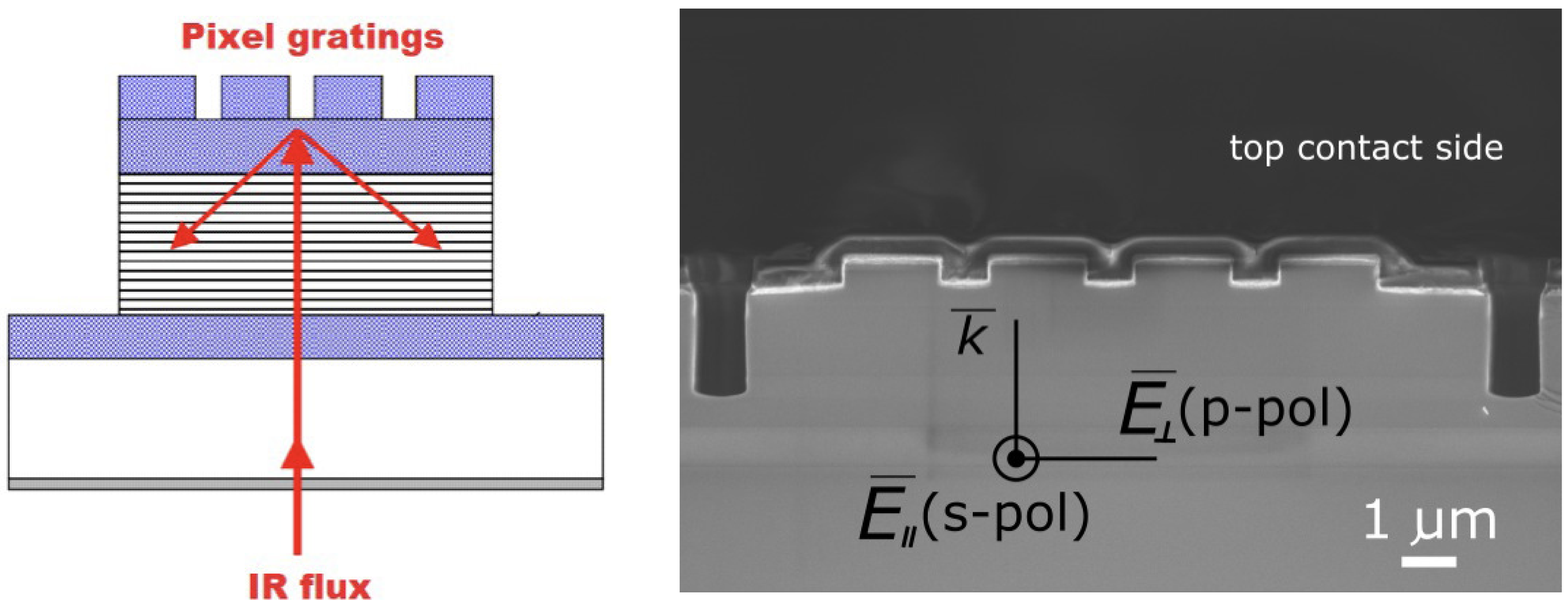
The Garm LW Pol has a built-in 2x2 pixel array structure. With each pixel sensitive to a distinct polarization angle (0°, 45°, 90°, and -45°), it can sense the smallest polarimetric information within any scene without optical parallax or frame rate constraints. This unique detector allows real-time capture of polarimetric video and images with high polarimetric contrast and freedom from filter induced transmission losses.

Applications:

- Efficient oil spill detection.
- Camouflage denial.
- Improvised Explosive Device (IED) detection.
- Human infrared face recognition.
- Industrial applications (thermography, NDT...)
- And much more...

Appendix: QWIP material details

The QWIP (Quantum Well Infrared Photodetector) technology belongs to the III-V family of materials, consisting of an artificial semiconductor structure repeating GaAs and Al GaAs layers.



QWIP detectors rely on intersubband absorption within either the conduction band (n-type) or the valence band (p-type). QWIPs are built from quantum wells of wide-bandgap materials. However, electron (hole) excitation may occur between the ground state and excited states in a conduction (valence) band quantum well making intersubband absorption possible. The quantum well structure is designed so that these photo-excited carriers can escape from the quantum well and can be collected as photocurrent.

Due to their design principles, QWIP detector enables great flexibility, because the peak and cut-off wavelength can be tailored at production stage by varying layer thickness (quantum well width) and barrier composition (barrier height). With appropriate choice of the well and barrier material, the detection wavelength of a QWIP can be tailored to any wavelength from MWIR to VLWIR.

For more information about material science, please contact IRnova.