A LWIR polarimetric imager

Following the successful development of the UK's megapixel 3rd gen LWIR camera based on Thales LWIR QWIP Technology, the diffraction grating coupling mechanism for the detectors has been used to advantage to allow the resolving of LWIR polarisation parameters. A LWIR polarisation-sensitive camera has been built, tested and trialled. Work is underway on another camera incorporating simultaneous polarisation and wavelength discrimination in the LWIR.

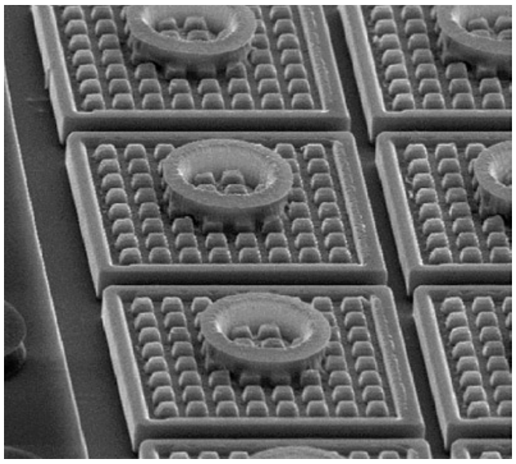
By
John Parsons and Robert Craig
Thales Optronics Limited, 1 Linthouse Road, Glasgow, G51 4BZ

Keywords: LWIR; Polarimeter; QWIP; IR Camera

Introduction

This programme was made possible by the previous successful development of a Megapixel (1280x1024 pixels) LWIR camera based on Thales QWIP technology. A conventional QWIP detector has a diffraction grating on the surface (the quantum wells are not sensitive to radiation at normal incidence, and the diffraction deviates the radiation into angles where the quantum wells are sensitive). Usually, a 2-dimensional grating is used, as shown in Figure 1, as this eliminates polarisation sensitivity.

1



Electron micrograph of a conventional QWIP array.

For this project, linear instead of 2-D gratings are used, which provides polarisation sensitivity. The use of a microscanner in the camera and the grating coupling method used on the QWIPs makes possible the design of camera which will resolve the polarimetric components of the scene radiation. A study undertaken at Thales indicated that such a discriminating imager might be beneficial in locating difficult targets. The benefit of QWIP technology is that this discrimination can be added without significant loss of sensitivity or increased cost.

The detectors

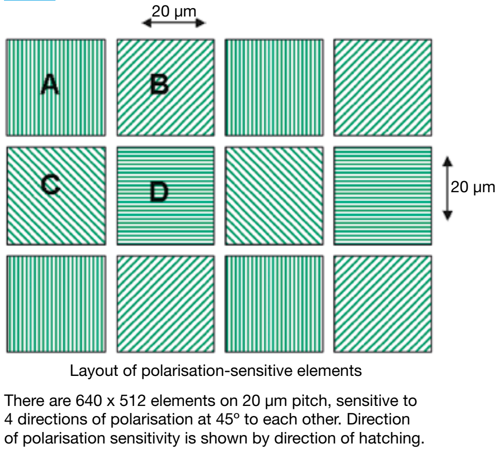
The design, development, and manufacture of the processed GaAs wafers was undertaken by Thales Research and Technology at the Thales III–V facility in France (reference 1). For the original MLA QWIP development, two suppliers were used to dice the wafers, assemble the die to Read Out Integrated Circuits (ROICs), vacuum dewars and cooling engines, and fabricate complete Integrated Detector Cooler Assemblies (IDCA). An IDCA is shown as Figure 2. For the current programme Sofradir were selected as the supplier for the IDCA.

2

IDCA.

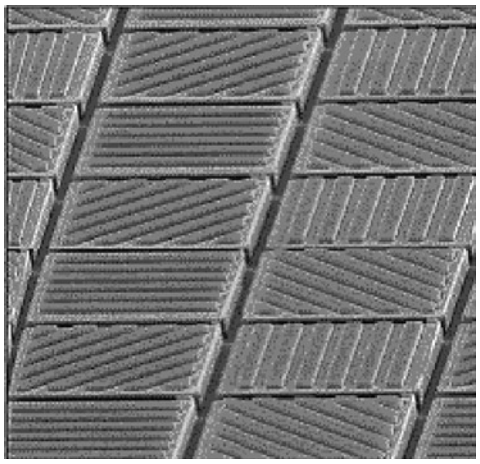
To provide the polarisation sensitivity, four linear gratings rotated by 45 degrees to each other are formed on a set of four detector elements. This pattern is then replicated across the whole array. The layout and an electron micrograph from an actual array are shown as Figures 3 and 4. Note that the circular read-out connection shown in Figure 1 has not yet been implemented on the wafer shown in Figure 4.

3



Element layout.

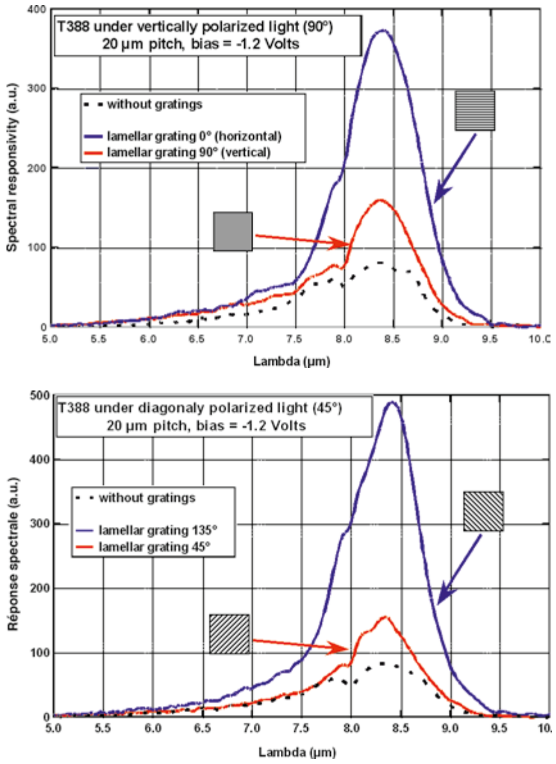
4



Electron micrograph of polarimetric array.

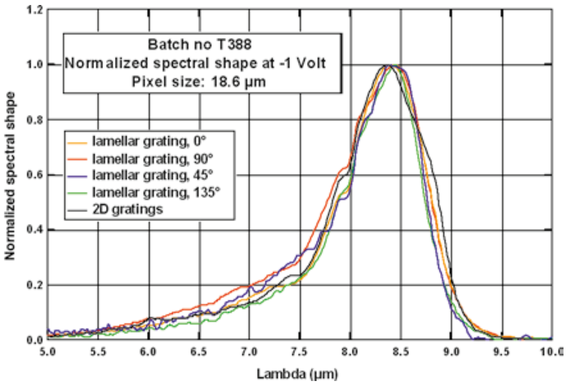
Test cells of the array have been characterised. The spectral response is shown in Figure 5, which shows that the spectral response is almost independent of polarisation direction.

5



Polarisation sensitivity.

6



Spectral response of test cells.

The polarisation sensitivities are shown in Figure 6. It will be seen that useful polarisation sensitivity has been achieved. Note the slightly better polarisation contrast for the diagonal gratings. This is a consequence of the larger number of grating periods in this diagonal case.

The camera

The camera was based on the Thales Catherine MP camera (reference 3 and Figure 7) which is itself a development from a Thales/MOD joint funded Technology Demonstrator Programme (TDP) called the Microscanned Large Array QWIP camera (MLA QWIP). This project took the Thales developed 640x512 pixel LWIR QWIP detector and added microscanning to provide a resolution of 1280x1024 pixels.

7

Thales Catherine MP.

8

Additional parts.

The original plan for the Polarimeter was to use an existing bench top assembly to demonstrate the cameras. However, additional DTC funding allowed the purchase of new electronics, optics and a housing, as illustrated in Figure 8. This allowed the camera be housed in a manner suitable for field trials.

Processing

Processing to extract the polarimetric data is performed on a PC external to the camera. Uniformity-corrected digital data is transferred from the camera via a Gigabit Ethernet fibre-optic link to an external PC. The processing provides:

- either of four polarised images separately
- either of the first three Stokes parameters I, Q, U, or the amount of polarisation P separately.
- a combination of the images into a single colour image. This combination is configurable to allow user-selectable mappings between the four polarisation directions and the colour of the image.

In addition to the Catherine MP camera processing functions, providing the Non Uniformity Correction (NUC), gain and offset, and reformatting, a study has shown that the additional processing required to extract the basic polarimetric information should fit within the existing FPGA on the processing electronics board, and without conflicting with the existing functions. Both camera modes (high resolution imagery, and polarimetry) would be available, though not simultaneously.

Camera build

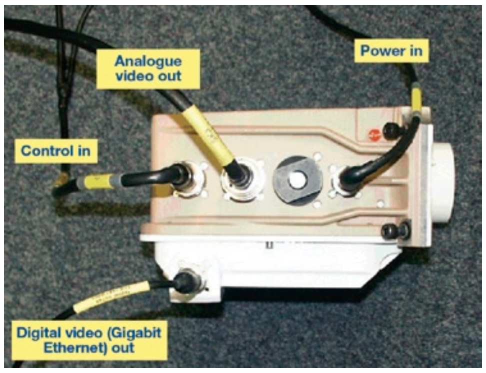
The completed Polarimeter is shown in Figure 9.

The Polarimeter was tested using an external polariser and a black body set to two different temperatures. The responsivity was taken as the difference in signal divided by the difference in temperature. The measured contrasts for the four sets of detectors were (contrast being defined as max/min) are:

A 0.52
B 0.41
C 0.41
D 0.53

This is enough to give a useful signal to noise ratio for polarimetry. See Figure 3 for the definitions of A, B, C and D.

9

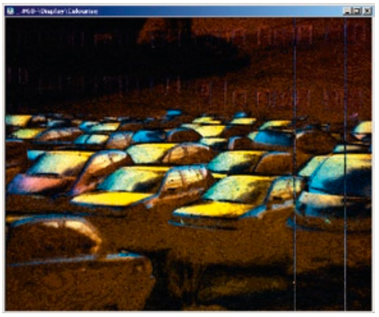


Polarimetric camera trials results.

Trials results

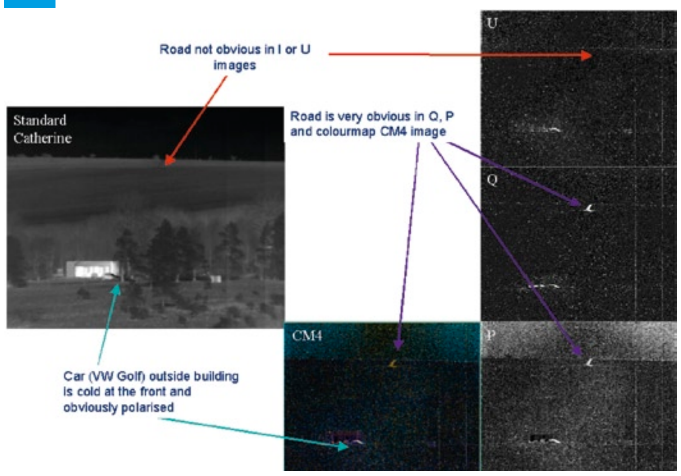
The Polarimeter was trialled at the Hydravision trial in March 2008. Some sample unclassified images from that trial (and from a previous demonstration) are shown below in Figures 10 and 11.

10



Short-range image (Red = Q, Green = P, Blue = U).

11



Long range image.

Conclusions

A Polarimetric camera, capable of being switched to high-resolution non-polarimetric mode, has been demonstrated. This Polarimeter provides good polarisation and thermal sensitivity, and useful imagery.

Successful trials have been carried out. Polarimetric signatures can be seen from targets at both short and long ranges. These signatures allow targets to be discriminated as being man-made.

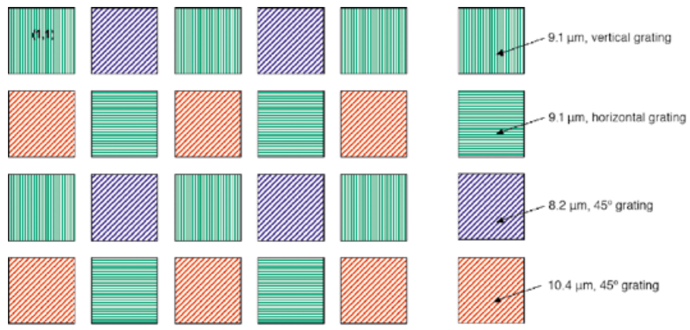
Future work

There is scope for further work in the exploitation of the polarimetric imagery. In particular, as there is a link between the angle of a surface and the polarisation, it should be possible to estimate the 3D shape of polarising objects.

The Polarimetric camera is available for further trials.

In addition, the microscanning four positions technique will be used to demonstrate a 3 band/ 3 polarisation direction LWIR imager, where again the coupling grating on the detector is being used discriminatively by adjusting the grating design to give sets of four different peak wavelengths in the 8 to 12 μm waveband as shown in Figure 12.

12



Layout of 3-colour/Polarimetric array.

This work is now covered by DTC funding. Delivery of this IDCA is expected in December 2008.

References

1. Technical report on 20 μm pitch, 640 x 512 Polarisation Sensitive QWIP Focal Plane Arrays, Report reference MAR/AT35/A06, TRT III–V lab 12/7/2006.

2. Crawford et al, Thales Long Wave Advanced IR QWIP Cameras, SPIE XXXII-6206-17 Orlando 2006.

Acknowledgements

The work reported in this paper was funded by the Electro-Magnetic Remote Sensing (EMRS) Defence Technology Centre, established by the UK Ministry of Defence and run by a consortium of SELEX Galileo, Thales UK, Roke Manor Research and Filtronic.

Thales for its investment in QWIP technology.

Thales, Land & Joint Systems for their financial support for Microscanned Large Array QWIP Camera developments, for this programme, and for the EMRS DTC.

MOD for their financial support for the Microscanned Large Array QWIP Camera development, the additional camera hardware contract and the EMRS DTC.

Porton Down and Dstl trials teams for their support during the Hydravision trial.