# Detector for LWIR Hyperspectral Imagers.

D. J. Lees[*], D. Barron[+], J. W. Cairns[*], P. C. Haynes[*] and C. J. Hollier[*]
[*]QinetiQ Ltd, St Andrews Road, Malvern, Worcs. WR14 3PS
[+]Thales Optronics, Thorpe Road, Staines, Middlesex. TW18 3HP

## Abstract

*This project is aimed at supporting UK industry to produce a low Noise Equivalent Temperature Difference (NETD) hyperspectral long waveband IR camera for the UK MoD that does not require cryogenically cooled optics, is compact and relatively low in cost. Over the last year this project has completed the design and fabrication of a linearly variable (LVF) which is designed to minimise stray radiation. High efficiency cold shield designs have been supplied to companies for manufacture. ROICs designed during the first year of this project have been fabricated and assessed. The measured yield is 56.8% which is typical for ROICs of this size and complexity. A proximity electronics unit (PEU) suitable for use with the hyperspectral focal plane array (FPA) has been identified. This will be mounted in close proximity to the integrated detector cooler assembly (IDCA). The PEU will interface with a camera link frame grabber card mounted in a PC. This PC will be used to control the hyperspectral camera head and analyse data. It is planned that the above system components will be integrated with fabricated CMT focal plane arrays to build the LWIR hyperspectral camera, with the system performance initially being assessed under laboratory conditions before undertaking a limited field trial.*

Keywords: hyperspectral, long waveband infrared,

## Introduction

This EMRS DTC project on ‘Detectors for long waveband infrared (LWIR) hyperspectral imagers’ started during April 2006. The project aims to develop a new long waveband focal plane array (FPA) which is compatible with an optical system built as part of the UK MoD funded Hyperion programme. The imager will enable the acquisition of hyperspectral data using a practical sensor which is suitable for military applications.

## Hyperspectral camera system

Figure 1 shows the key components of the hyperspectral camera system. The optical system, which was designed and built under the UK MoD Hyperion project, contains a novel optical component known as a grism. The grism diffracts the spectral content of each point in the scene and spreads it out along one dimension of the focal plane.

Two grisms will be available with diffraction wavelength shifts of 1nm and 2nm per 1μm on the focal plane. Both grisms cover a wavelength band of 8.0μm to 10.4μm. For a 50μm pixel pitch FPA this results in a camera with either 48 50nm wide bands or 24 100nm wide bands.

The second dimension on the FPA contains spatial information from one line in the scene. Multiple lines are acquired using a scanning mirror to build up a two dimensional image. Stray radiation is minimised by the use of a linearly variable filter (LVF) and baffled cold shield as described in the following sections. A

Stirling cycle engine is used to cool the custom built long waveband LWIR FPA.

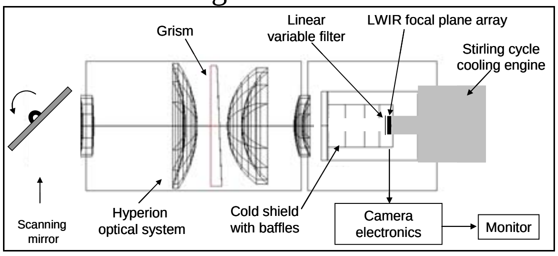


**Figure 1** *Hyperspectral camera system*

The thermal performance of the hyperspectral camera has been modelled with an optimised cold shield and a linearly variable filter (LVF). Results show that thermal sensitivities of 78mK (48 band system) and 43mK (24 band system) can be achieved. The hyperspectral cube update rate for both systems is approximately 2.5Hz.

## Linear Variable Filter

The LVF is designed to transmit radiation from the target and attenuate flux from other sources such as the optical system, dewar component, and Stirling engine. By reducing flux from these sources the FPA stare time can be increased resulting in lower NETD.

Figure 2 shows the measured transmission of the LVF over the waveband 5-13µm. An improved LVF which is expected to have higher transmission and better out of band blocking is currently being manufactured.

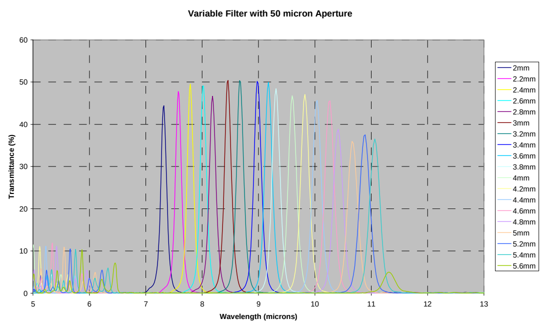


**Figure 2** *LVF transmission verses wavelength*

The LVF is designed to transmit the radiation pattern from the grism (and therefore the target) and attenuate all other wavelengths.

## Infrared long waveband focal plane arrays

IR LWIR FPAs for the hyperspectral camera will be fabricated at QinetiQ Malvern. Each FPA consists of two main components, an array of IR detectors and a custom silicon readout integrated circuit (ROIC). FPAs are fabricated by bump bond hybridising detector arrays to ROICs.

The IR detector arrays are based on cadmium mercury telluride (CMT) grown on silicon substrates, a technology pioneered by QinetiQ. Arrays are fabricated using dry and wet etching technology to form mesa devices.

Two ROIC variants have been designed, fabricated and assessed. ROIC 1 and 2 have identical array layout enabling a common CMT detector array format to be used. The ROIC 1 pixel is a common gate direct injection circuit whereas the ROIC 2 pixel has a chopper stabilised amplifier to improve injection efficiency. Reference 1 describes the operation of both types of ROIC in more detail.

ROIC wafers have been fabricated at a silicon foundry using a 0.6µm minimum feature size process and delivered to QinetiQ for assessment. Each wafer contains 44 ROIC 1 and 46 ROIC 2 die.

All the ROICs on one of these wafers have been assessed using a probe card and wafer probe station. The ROIC tests are designed to identify short and open circuits on the signal and power supply lines as well as checks to confirm the correct operation of the pixel circuit and digital multiplexer.

The measured yield (% of ROICs which pass all tests) for the tested wafer is 56.8% (25/44) for ROIC 1 and 47.8% (22/46) for ROIC 2. The overall yield is 52.2% (47/90). These values are typical for ROICs of this size and complexity.

### Cold shield

The design of a cold shield for the LWIR hyperspectral focal plane array has been undertaken by Thales Optronics, Staines and was described in an earlier report[2]. Figure 3 shows CAD models of the cold shield designed for two different fabrication technologies. The model on the left is designed for electroform fabrication using a sacrificial mandrel onto which copper is electroplated. The model on the right is a hybrid construction where the baffles are made from sheet copper and held in position by an electroformed copper cylinder.

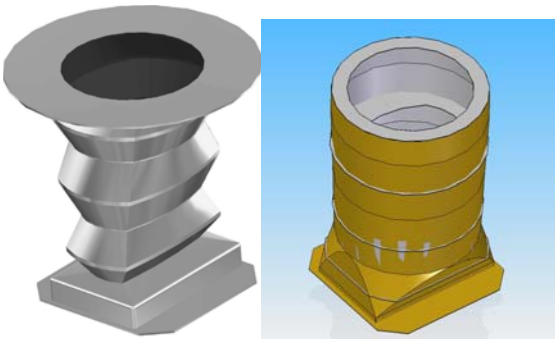

**Figure 3 CAD** *model showing two types of cold shield*

A cross section view of the cold finger assembly, incorporating the cold shield, mounted in a research dewar is shown in figure 4.

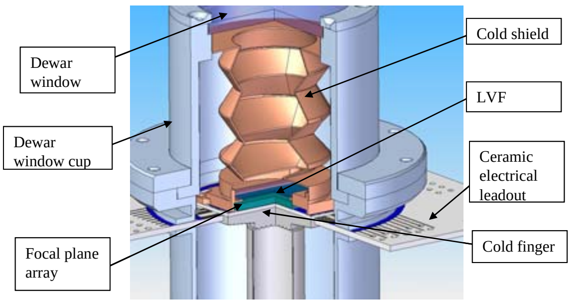


**Figure 4** *Cross sectional view of cold finger assembly*

The inner surface of the cold shield and the surface closest to the dewar window will have a high emissivity black coating which is designed to absorb stray radiation. The remaining surfaces have a high reflectivity gold coating to reduce the thermal load on the cold finger.

### Camera electronics

A QinetiQ proximity electronic unit (PEU), as shown in figure 5, will be used to interface the FPA to the system electronics unit (SEU).

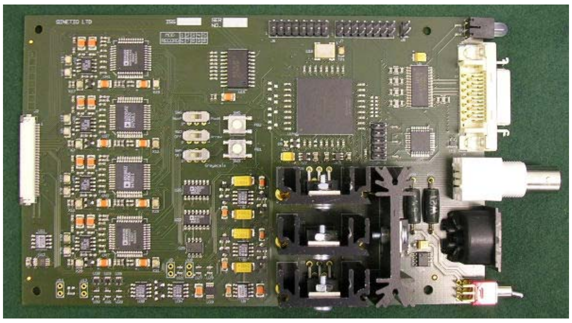

**Figure 5** *QinetiQ proximity electronics unit*

This PEU designed to interface to the integrated detector cooler assembly using a flexi cable which carries power supplies, control data and analogue FPA output data streams. The board has 8 analogue input channel each capable of supporting 10Mpixels/s. An on board FPGA is used to control the FPA including random sub-array window selection. A camera link interface is used to exchange digital data with the SEU. The compact size of this board (165mmx100mm) makes it ideal for fitting into the hyperspectral camera head in close proximity to the integrated detector cooler assembly (IDCA).

The PEU will be interfaced to a Cameralink frame grabber unit fitted into a standard PC. Software running on the PC will be used to analyse and store the hyperspectral data.

## Conclusions

Over the last year this project has completed the design and fabrication of the LVF. Final cold shield designs have been supplied to companies for manufacture. ROICs wafers have been fabricated and assessed. The measured yield is 56.8% which is typical for ROICs of this size and complexity.

A PEU suitable for use with the hyperspectral FPA has been identified. This will be mounted in close proximity to the IDCA. The PEU will interface with a camera link frame grabber card mounted in a PC. This PC will be used to control the hyperspectral camera head and analyse data. It is planned that the above system components will be integrated with fabricated CMT focal plane arrays to build the LWIR hyperspectral camera, with the system performance initially being assessed under laboratory conditions before undertaking a limited field trial.

## References


1. Detector for LWIR Hyperspectral Imagers, DJ Lees et al, Proceedings of the EMRS DTC 4th Annual Technical Conference July 2007, B13.

2. Report on Cold shield design and fabrication. DJ Lees.
   QinetiQ – Unpublished Report


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