

Detector for LWIR Hyperspectral Imagers

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Abstract

This report describes the final build and assessment of the EMRS DTC hyperspectral camera system. Initial measurements show that the camera has a NETD of 460mK which is more than a factor of two better than the original Hyperion system. Placing a gold mirror and cold black body at the dewar window has shown that stray radiation in the FPA/cold shield/dewar assembly is negligible. Measurements with reference sources at the slit aperture have demonstrated that stray radiation generated in the optical system is being reflected by the slit mirror onto the detector. Experiments with a 77K black body slit assembly have shown a significant reduction in NETD to 198mK. With a linearly variable filter fitted into the cold shield to attenuate stray radiation the NETD is reduced to 157mK. Under these conditions the detector dark current becomes significant compared to the stray light. A reduction in this dark current can be realised by reducing the FPA operating temperature below 80K. It is recommended that stray light paths in the optical system are re-evaluated which may result in the need for improved optical components. In addition, the demountable FPA dewar should be replaced with a sealed for life encapsulation to allow more extensive field trials to be undertaken.

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 previously 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

The new DTC hyperspectral camera system is shown in figure 1. The optical system, scanning mirror and scanning mirror drive electronics from the original Hyperion camera have been reused. Components,

such as the LWIR focal plane array (FPA) cold shield, grism and linear variable filter (LVF), have each been designed and manufactured specifically for the DTC camera system.

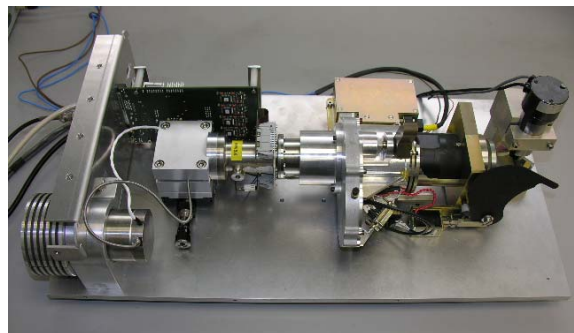


Figure 1 Photograph of the DTC hyperspectral camera system

Figure 2 shows a schematic of the radiation paths within the camera. The objective lens is used to focus the image of the target at

the slit plane. The vertical slit selects a single column from the image which is passed to the grism. The grism is designed to disperse radiation in the horizontal plane with zero deviation set to correspond to the band centre of 9.2 μm . The total band coverage is 8 μm to 10.4 μm with each pixel corresponding to a 60nm bandwidth.

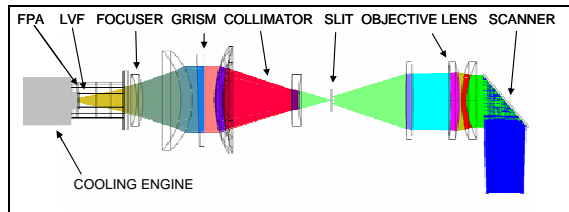


Figure 2 Hyperspectral camera system

Spectral data is focused onto a 128x128 pixel FPA. Each output frame from the FPA consists of spatial information from one vertical column of the image together with 40 spectral bands, each with a 60nm bandwidth. To form a two dimensional image the second (horizontal) spatial dimension is acquired using a scanning mirror.

The FPA cold shield has been designed by Thales Optronics to minimise stray radiation. In addition, the redesigned camera system enables a linearly variable filter (LVF) to be fitted into the cold shield to further reduce stray radiation. A Stirling cycle engine is used to cool the custom built long waveband LWIR FPA.

Analogue data from the FPA is digitised using 8 analogue to digital converters fitted to the proximity electronics board (PEU). The PEU outputs digital data to a frame grabber card in the system PC using a high speed camera link interface. A field programmable gate array (FPGA) fitted to the PEU is used to supply clock waveforms to the FPA.

Labview software running on the system PC processes data from the frame grabber

and displays both spectral information and spatial images as shown in figure 3. The software can also store raw data cubes, consisting of a 128x128 pixel spatial image and 40 spectral channels, for off line analysis. The cube update rate is approximately 2Hz.

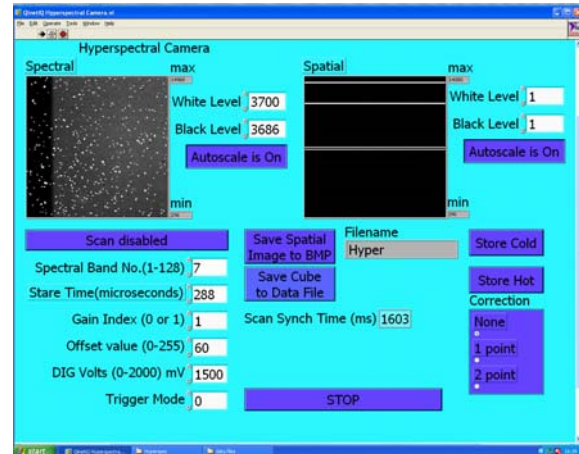


Figure 3 Labview graphical user interface

Camera Performance measurements

Figure 4 shows the array output without the grism in place. The vertical slit can be seen in the centre of the image. The dark region on the left of the image corresponds to pixels which are in close proximity to a cold shield metal surface. Detectors in this region of the array will only output dark current levels as they are not exposed to any external radiation.

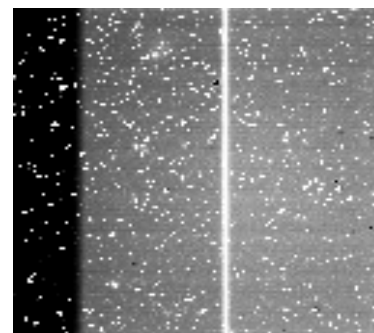


Figure 4 Image of slit without the grism in position

Figure 5 shows the output from the FPA with the grism in place. The radiation which

passes through the slit is horizontally dispersed by the grism with the highest deviation for radiation at the extreme ends of the operational waveband (i.e. 8 μ m and 10.4 μ m).

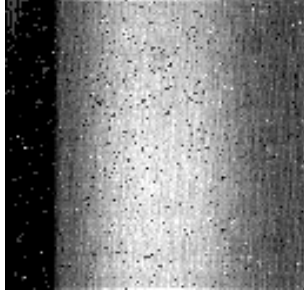


Figure 5 FPA output with grism in place

Noise equivalent temperature difference (NETD) measurements were made using a blackbody source set to 20°C and 30°C. For these measurements the scanning mirror was removed and raw data cubes were acquired with the stare time set to half well in all cases. Measurements were carried at half well fill to avoid any non-linearity issues.

Table 1 shows the original Hyperion camera performance compared with the new DTC camera and the modelled values. For these initial measurements the LVF was not fitted.

	Original Hyperion camera	DTC camera	Modelled values
Stare time (half well)	300 μ s	420 μ s	2ms
NETD	940mK	460mK	70mK

Table 1 Initial performance measurements.

Whilst the NETD has been improved by a factor of two compared with the original Hyperion camera the performance is around six times poorer than expected from the system modelling. A number of experiments have consequently been undertaken to determine the cause of this poor performance.

The lower than expected half well stare time is due to stray radiation from either the

dewar assembly or the Hyperion optical system. To determine the source of this stray radiation a gold mirror and a 77K black body source were placed at the dewar window and at the slit plane (with the slit mirror removed). A summary of the half well stare times measured using these reference sources is shown in table 2.

Stare time (half well)	300K	77K	Mirror
Dewar window	160 μ s	4ms	3ms
Slit plane, grism in (no slit)	192 μ s	1.3ms	420 μ s

Table 2 Stare times with reference sources

These measurements identify that the stray radiation inside the dewar has been reduced to negligible levels by the high efficiency cold shield. The low stray radiation levels enable the FPA to operate at stare times in excess of the 2ms required for the target sensitivity of 70mK. The long stare time achieved with the mirror in place also shows that there is negligible radiation being emitted from the dewar into the optical system.

With the reference sources at the slit plane, stare times are significantly reduced compared with the detector alone. Replacing the slit mirror with a 77K black body results in a half well stare time of 1.3ms. As expected the planar gold mirror gives the same stare time as the slit mirror, 420 μ s. The longer stare time achieved with the 77K black body indicates that stray radiation from within the optical system is reaching the slit plane and is being absorbed. When the black body is replaced with a mirror, this stray radiation is reflected back to the detector resulting in a reduction in stare time.

To investigate this further a 77K black body slit assembly, developed as part of the original Hyperion project, was fitted to the camera. With this cold slit in place, the half well stare time was measured at 1.2ms and the NETD is significantly reduced to 198mK.

A reduction in out of band stray radiation can also be achieved by using the LVF. For this project, LVFs that match the spectral dispersion of the grism have been manufactured by Barr Associates. An LVF has been fitted to a second cold shield and installed in the dewar. Alignment of the LVF with the grism is achieved by translating the dewar assembly in the horizontal plane.

With a linearly variable filter fitted into the cold shield to reduce stray radiation at the detector the half well stare time is increased to 4ms and the NETD is reduced to 157mK. Under these conditions the detector dark current becomes significant compared to the stray light. A reduction in this dark current can be realised by reducing the FPA operating temperature below 80K. The improvement in performance is summarised in Table 3.

	Mirror slit, no LVF	Cold slit, no LVF	Cold slit + LVF
Stare time	420µs	1.2ms	4ms
Median NETD	460mK	198mK	157mK

Table 3 Performance improvement summary

Conclusions

The DTC hyperspectral camera build has been completed. The camera consists of a QinetiQ 128x128 pixel FPA with a high performance cold shield designed by Thales Optronics. This is used together with an optical system which was designed and manufactured with funding from the MoD Hyperion project.

Initial measurements show that the camera has a NETD of 460mK which is more than a factor of two better than the original Hyperion system. However, the NETD is six times poor than the modelled values.

Measurements using a gold mirror and cold black body reference sources have shown

that stray radiation in the FPA/cold shield/dewar assembly is negligible.

Measurements with reference sources at the slit aperture have demonstrated that stray radiation generated in the optical system is being reflected by the slit mirror onto the detector. This excess radiation is limiting the FPA stare time to 420µs resulting in an NETD of 460mK.

Experiments with a 77K black body slit assembly have shown that a stare time of 1.2ms can be achieved resulting in a significant reduction in NETD to 198mK.

With a linearly variable filter fitted into the cold shield to reduce stray radiation at the detector, the half well stare time is increased to 4ms and the NETD is reduced to 157mK.

Under these conditions the detector dark current becomes significant compared to the stray light. A reduction in this dark current can be realised by reducing the FPA operating temperature below 80K.

It is recommended that stray light paths in the optical system are re-evaluated which may result in the need for improved optical components. In addition, the demountable FPA dewar should be replaced with a sealed for life encapsulation to enable field trials to be undertaken.

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