出國報告(出國類別：其他(開會))

國防專技計畫-紅外線成像尋標器次像素目標檢知關鍵技術出國報告

服務機關：國防部軍備局中山科學研究院
姓名職稱：古建德 聘用技士
派赴國家：美國
出國時間：101 年 4 月 22 日至 101 年 4 月 28 日
報告日期：101 年 5 月 25 日

<table>
<tr><th colspan="4">國防部軍備局中山科學研究院出國報告建議事項處理表</th></tr>
<tr><td>報告名稱</td><td colspan="3">國防專技計畫-紅外線成像尋標器次像素目標檢知關鍵技術
出國報告</td></tr>
<tr><td>出國單位</td><td>第五研究所</td><td>出國人員級職/姓名</td><td>聘用技士 / 古建德</td></tr>
<tr><td>公差地點</td><td>美國</td><td>出/返國日期</td><td>101.4.22 / 101.4.28</td></tr>
<tr><td>建議事項</td><td colspan="3">一、紅外線熱像儀及其相關元件、模組、系統等技術是本院發展多年的重要技術能量，包含了材料、光電子、機構、影像電路、系統整合等，培育了無數優秀的研究人力。紅外線技術與應用研討會至今已舉辦第 38 屆，由參與人數、發表文章數目、產品展出等，均可說明這是紅外線領域最悠久且重要的技術論壇。本院身爲紅外線科技的一份子，若可在類似場合或機會與國際間技術領先的團隊們相互切磋學習，刺激研發靈感，必可收事半功倍之效。

二、由本次研討會所發表的技術文章與展覽會中所展出的產品，可發覺 FPA 偵檢元件已明顯地往高畫素規格邁進，主流量產產品至少要有 640×480 畫素以上的規格才有吸引力，而仍在研發階段的元件也有 1024×768 畫素以上規格出現。本院目前雖仍以 320 格式爲主，然而主事長官早已洞燭機先進行規劃，開始 640 格式元件製作的任務已是箭在弦上，相關工作刻不容緩。未來推出與目前主流規格相當的產品，將可創造更大的技術能量與商機。

三、爲了組織的永續生存，科技機構投入新技術的研發永遠是必要的投資。除了固守 InSb 材料系列的紅外線熱像技術並力求精進外，對於高操作溫度與室溫熱像等新領域亦應投入部分資源，提早佈局建立技術能量，待將來機會來時可順勢切入，在該領域佔有一席之地。

四、本次研討會已看到許多研究成果是由許多單位共同發表，在公平、信任的原則下，多方單位合作可互取對方長處並彌補本身短缺，因本院組織功能特殊，也許無法採類似模式運作。惟關鍵零組件或材料取得有其困難性，加速提升系統零組件或材料的自製率，或是另尋第二穩定商源，均可避免缺料或採購成本異常上揚問題發生。</td></tr>
</table>

處理意見	一、紅外線技術發展歷史悠久，藉由參與國際研討會吸取新知，熟悉相關技術的最新發展與產品技術商情，是最快速有效的管道。依計畫需求適時安排同仁參與，除了能讓對本院了解自有技術能量與世界上其他團隊的差異，對增廣參與同仁視野亦有助益，值得繼續支持。 二、640 格式以上之紅外線熱像儀已是軍用產品的主流趨勢，在全力達成現有 320 格式產品生產任務的同時，一併規劃 640 格式產品設計、製作與後續驗證，相關工作已陸續進行。將來推出與目前主流規格相當的產品後，可創造更堅實的技術能量甚至商機。 三、相關新技術領域的運作模式可利用學合案、科專計畫、或國防專技等機會提案辦理，逐步建立自有的技術能量。 四、關鍵零組件或材料常受出口管制不易取得，院內單位也許有設備或技術能量，在政策及經費的許可下，可考慮整合院內具相關技術能量單位，增加部分零組件或材料自製的比例，並評估其效果，達成國防自主的目的。

<table>
<tr><td colspan="4">報　告　資　料　頁</td></tr>
<tr><td>1.報告編號：
CSIPW-101Z-H0001</td><td>2.出國類別：
其他(開會)</td><td>3.完成日期：
101 年 5 月 25 日</td><td>4.總頁數：
61</td></tr>
<tr><td colspan="4">5.報告名稱：國防專技計畫-紅外線成像尋標器次像素目標檢知關鍵技術出國報告</td></tr>
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<tr><td rowspan="2">6.核准文號</td><td>人令文號</td><td>101.04.13 國人管理字第 1010004680 號</td></tr>
<tr><td>部令文號</td><td>101.04.05 國備獲管字第 1010004940 號</td></tr>
<tr><td colspan="2">7.經　費</td><td>新台幣：　100,652　元</td></tr>
<tr><td colspan="2">8.出(返)國日期</td><td>101 年 4 月 22 日至 101 年 4 月 28 日</td></tr>
<tr><td colspan="2">9.公 差 地 點</td><td>美國</td></tr>
<tr><td colspan="2">10.公 差 機 構</td><td>2012 年防禦、安全、感測國際研討會暨展覽會</td></tr>
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系統識別號

行政院及所屬各機關出國報告提要

出國報告名稱：國防專技計畫-紅外線成像尋標器次像素目標檢知關鍵技術出國報告

頁數 61　含附件：■是 □否

出國計畫主辦機關/聯絡人/電話

國防部軍備局中山科學研究院/古建德/357088

出國人員姓名/服務機關/單位/職稱/電話

古建德/國防部軍備局中山科學研究院/第五研究所/聘用技士/357088

出國類別：□1 考察□2 進修□3 研究□4 實習■5 其他(開會)

出國期間：	出國地區：
101 年 4 月 22 日至 101 年 4 月 28 日	美國

報告日期：

101 年 5 月 25 日

分類號/目

關鍵詞：

紅外線、焦平面陣列、偵檢元件、影像感測

內容摘要：（二百至三百字）

爲執行國防專技計畫-紅外線成像尋標器次像素目標檢知關鍵技術，本案派員赴美國參加 2012 年防禦、安全、感測國際研討會暨展覽會，其中單項研討會「紅外線技術與應用研討會」之重點在紅外線偵檢元件、模組、系統、與影像感測技術等，是世界上最重要的紅外線技術研討會之一。

針對計畫任務需求，參與包括各式焦平面陣列偵檢元件與應用等研討主題議程，研討紅外線偵檢元件與模組技術最新發展趨勢。同時參觀展覽會，蒐集參展廠商關於其紅外線偵檢元件、模組、系統應用等之技術與商情等相關資料，對於本院紅外線焦平面陣列偵檢元件未來朝向高解析度(如 640×512 畫素以上格式)、縮小畫素間距、模組混成封裝等技術發展均有明顯助益，俾利計畫遂行。

目　　　　次

國防專技計畫-紅外線成像尋標器次像素目標檢知關鍵技術出國報告

壹、 目的

爲執行國防專技計畫-紅外線成像尋標器次像素目標檢知關鍵技術，本案派員赴美國參加 2012 年防禦、安全、感測國際研討會暨展覽會，其中單項研討會「紅外線技術與應用研討會」之重點在紅外線偵檢元件、模組、系統、與影像感測技術等，是世界上最重要的紅外線技術研討會之一，對於本院紅外線焦平面陣列偵檢元件未來技術發展有明顯助益。

針對計畫任務需求，主要參與包括近紅外(NIR)/短波長紅外(SWIR)焦平面陣列偵檢元件與應用、第二型超晶格(Type II Superlattice, T2SL)材料焦平面陣列偵檢元件、新式非致冷技術、非致冷焦平面陣列元件與應用、紅外線光學、汞鎘銻(HgCdTe, MCT)材料、高操作溫度(High Operating Temperature, HOT)焦平面陣列元件等研討主題議程，研討紅外線偵檢元件與模組技術最新發展趨勢。本案另一任務則是參觀展覽會，蒐集參展廠商關於其紅外線偵檢元件、模組、系統應用等之技術與商情等相關資料。

藉由所蒐集之研討會發表論文集與參展廠商之技術商情資料，了解紅外線偵檢元件與模組技術目前最新發展趨勢，除可滿足計畫需求外，對於本院目前 320*256 格式之紅外線焦平面陣列偵檢元件未來朝向高解析度如 640×512 畫素以上格式、縮小畫素間距、模組混成封裝等技術，亦提供更爲廣泛與前瞻之參考方向。

貳、 過程

本案所參加之研討會暨展覽會乃是集合防禦科技、安全防衛、感測技術三大領域之綜合型國際會議，由國際光學工程學會 SPIE(The International Society for Optical Engineering)所舉辦，對於工業界、軍事、科學研究等領域的工程師與科學家而言，這是一年一度最重要且最大型的論壇。SPIE 是致力於光學、光子學和電子學領域的研究、工程和應用的著名專業學會，每年舉辦國際性技術研討會以及各種短期課程，所發表的會議論文均是各專業領域的最新進展和動態，具有極高的學術價值。根據主辦單位所揭示的資料，本次會

議報名註冊人數超過 6700 人，共發表了 2450 篇專業論文，而展覽會參展廠商超過 540 家，整體而言，較去年成長了 18%以上，足見此綜合型國際會議之重要性。本次會議更包含了產品展覽，所有在相關領域的廠商無不藉此機會大力推銷其最新產品，從材料、元件、模組、一直到系統，均有不同的產品展出。

本案規劃行程如下。

日　　期	星期	工　　　作　　　項　　　目
101.04.22	日	去程
101.04.23	一	1. 研討會報到。 2. 研討近紅外(NIR)/短波長紅外(SWIR)焦平面陣列偵檢元件技術發展，如大尺寸化、高解析度、新型材料等，與其影像感測應用。 3. 研討空軍紅外線研究與發展現況及應用。
101.04.24	二	1. 參觀展覽會，蒐集參展廠商之紅外線偵檢元件、模組、系統等技術與商情資料。 2. 研討超晶格焦平面陣列偵檢元件技術發展。
101.04.25	三	1. 研討如微型熱輻射感測器等新式非致冷技術與非致冷焦平面陣列元件與應用。 2. 研討紅外線光學技術發展。
101.04.26	四	1. 參觀展覽會，蒐集參展廠商之奈米科技應用等技術與商情資料。 2. 研討汞鎘銻(HgCdTe)材料紅外線偵檢元件之新結構、製程方法、元件特性等技術發展現況。 3. 研討砷銻化銦(InAsSb)、汞鎘銻(HgCdTe)等材料之高操作溫度(HOT)焦平面陣列元件與應用。 4. 返程。
101.04.27	五	返程
101.04.28	六	返程

一、研討會簡介

2012 防禦、安全、感測國際研討會依相關技術主題予以分類，每項技術主題再細分爲各個專門主題之單項研討會，總共有 58 個單項研討會，而各研討會的期程則從 2 天到 5 天不一。計有以下幾項技術主題：

- 紅外線感測與系統 (IR Sensors and Systems)
    - 第 38 屆紅外線技術與應用 (Infrared Technologies and Applications XXXVIII)
    - 第 34 屆熱感測:熱紅外線應用 (Thermosense: Thermal Infrared Applications XXXIV)
    - 第 23 屆紅外線影像系統：設計、分析、模型、測試 (Infrared Imaging System: Design, Analysis, Modeling, and Testing XXIII)
- 防禦、國家安全、與法律執行 (Defense, Homeland Security and Law Enforcement)
- 影像與感測 (Imaging and Sensing)
- 工業、環境、與健康用之感測 (Sensing for Industry, Environment, and Health)
- 新興技術 (Emerging Technologies)
- 雷射感測與系統 (Laser Sensing and System)
- 顯示器用之創新防禦與安全應用 (Innovative Defense and Security Applications for Displays)
- 其他…

其中，本案所規劃參加的「**紅外線技術與應用研討會**」是本次會議中規模最大的單項研討會(期程 5 天，報名人數最多)，從這次參與會議的經驗推估，實際參加人數應該超過 400 人，即使傍晚場次仍有超過 50 人參與，會議過程中可以很明顯地感受到提問討論的熱絡。

本次會議舉辦地點巴爾的摩(Baltimore)市是美國馬里蘭(Maryland)州最大的城市，是美國最大獨立城市和主要海港之一。而巴爾的摩會議中心是美國東岸在中大西洋地區用於大型會議、商業展示和展覽會等的首選地，坐落在市中心，公共交通條件便利，可乘火車和輕軌捷運去鄰近的華盛頓或者巴爾的摩-華盛頓國際機場(BWI)。

擬參加研討會議程如下。

4 月 23 日	
08:00AM ~ 08:10AM	開幕式
08:10AM ~ 12:05PM	主題 1：近紅外線/短波長紅外線焦平面陣列偵檢元件與應用
13:05PM ~ 16:35PM	主題 2：空軍紅外線研發
4 月 24 日	
10:50AM ~ 11:30AM	主題 4：第二型超晶格焦平面陣列偵檢元件(I)
13:30PM ~ 18:20PM	主題 6：第二型超晶格焦平面陣列偵檢元件(II)
4 月 25 日	
08:00AM ~ 09:40AM	主題 7：新式非致冷技術
09:40AM ~ :12:10PM	主題 8：非致冷型焦平面陣列偵檢元件與應用
13:30PM ~ 17:50PM	主題 12：紅外線光學(II)
4 月 26 日	
09:20AM ~ 11:50AM	主題 14：汞鎘銻材料(I)
13:30PM ~ 14:30PM	主題 15：汞鎘銻材料(II)
14:30PM ~ 18:20PM	主題 16：高操作溫度焦平面陣列元件

依出國行程規劃，抵達時間約爲巴爾的摩當地 0423 早上 7 點左右，有機會趕上 0800 研討會開幕典禮。實際上，因去程時班機延誤與洛杉磯機場地勤人員疏失，加上轉機過程出了點小插曲，導致抵達巴爾的摩時已是 0424 凌晨近 2 點，原訂 0423 第一天的會議行程被迫無法參加。0424 ~ 0426 依規劃行程參與研討會與展覽會(僅 0424 ~ 0426 三天)。返程部分亦依規劃於 0426 晚間啓程返回台灣，旅程順利，按原訂時程於 0428 抵達台灣，結束本次公差。

研討會主辦場地：巴爾的摩國際會議中心

4 月 24 日展覽會開幕式(主辦單位致詞)

二、研討會議程摘要

此次參加的**紅外線技術與應用**研討會，包括 13 項主題共 20 場議程，總共發表超過 120 篇論文。雖分多項主題，但仍有某些主題分別有將近一天的議程，可見其前瞻性或重要性。因個人專長在於偵檢元件製程部分，其餘如自動處理(smart processing)、主動式影像感測(active imaging)等主題所簡報的內容大多無法有效吸收。本研討會所發表的論文清單，檢附於附件一中。據研討會主辦單位表示會議論文集(proceeding)將於會議結束後 4 至 6 週左右寄給所有註冊參加人員，未來有興趣的同仁將可利用此第一手資料，獲取相關技術最新的進展，充實新知。

以下僅就上述較前瞻與重要的主題擇要簡述幾篇代表性技術文件。

1. <u>第二型超晶格焦平面陣列偵檢元件(Type II Superlattice FPA, T2SL FPA)。</u>

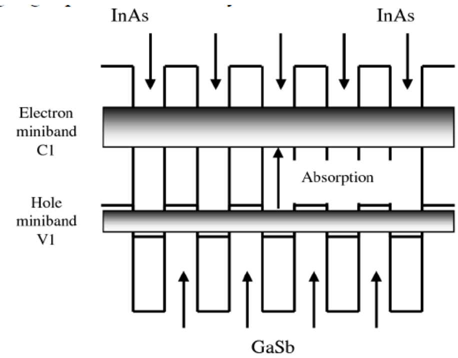
   在理論上，T2SL 有比 HgCdTe FPA 更好的元件特性與較高的操作溫度，主要是在 GaSb 基板上以分子束磊晶法(MBE)製作 InAs/Ga(In)Sb 或 InAs/InAsSb 超晶格結構，元件可調變其偵測波段，並製成中波、長波甚或是雙波段的 FPA。此項議題是目前最熱門的 IRFPA 研究題目之一。

♦ 第二型 InAs/GaSb 超晶格光偵檢器之成長與其特性

(Growth and characteristics of type-II InAs/GaSb superlattice-based detectors)

摘要：

美國噴射推進實驗室(Jet Propusion Laboratory, JPL)研究人員以互補式能障紅外線偵檢器 (Complementary Barrier Infrared Detector, CBIRD)設計法，發展第二型 InAs/Ga(In)Sb 超晶格(Type-II Superlattice, T2SL)光偵檢器。超晶格結構中，電子能隙的定義為在布里淵區中心電洞的第一能階與電子迷你能帶(miniband)之間的能量差，示意圖如下圖。利用此特性可以藉由調整超晶格結構中兩種材料的厚度，達到改變偵檢器偵測波長位置的效果。因此，改變 InAs 與 GaSb 的厚度，InAs/Ga(In)Sb T2SL 光偵檢器偵測波長可由中波段(MWIR)調變到遠紅外(VLIR)波段(3 ~ 30 μm)。



Band edge diagram illustrating the confined electron and hole minibands which form the energy band gap.

JPL 製作之 LWIR InAs/Ga(In)Sb T2SL 光偵檢器，其設備為 Veeco 製造之 MBE 系統，而超晶格結構乃成長於摻雜 Te 之 N 型 GaSb 基板上，利用反射式高能電子繞射光譜資訊控制 Indium 和 Gallium 的成長速率。由光激螢光(Photoluminescence, PL)光譜可驗證，其偵測波段為 10 μm，半高寬為 18.7 meV。

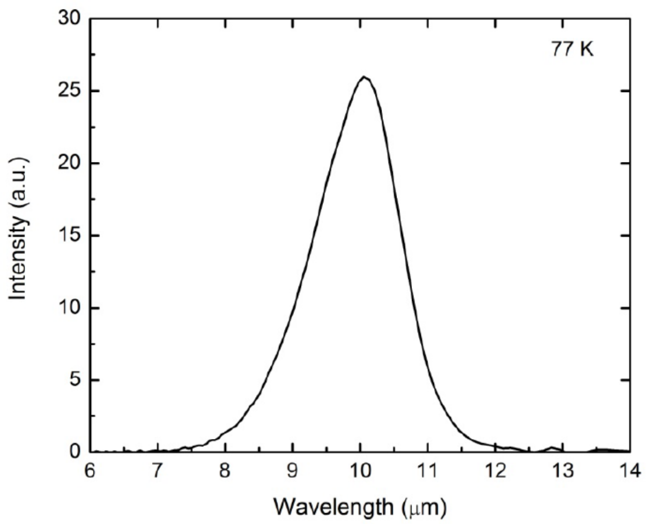


Figure 5: PL of the CBIRD structure at 77 K.

利用此技術製作而成的 320x256 格式 CBIRD T2SL FPA，在冷卻至 77 K 時，其元件操作率為 98%、雜訊等效溫度差(NEΔT，或 NETD)則為 26 mK，偵測影像如下圖。

Figure 7: Images taken by the LWIR SLS based FPA (77 K).

◆ 日本 JAXA 在未來太空應用之第二型超晶格光偵檢器發展現況

(Development of type II superlattice detector for future space applications at JAXA)

摘要：

日本航空探勘局(Japan Aerospace Exploration Agency, JAXA)發展專爲太空應用之高靈敏度、高解析度紅外線光偵測器，選擇先以中波段(~ 6 μm)偵測之 T2SL 光偵檢器爲研究對象。實驗系統爲 Veeco MBE 系統，元件設計成 9 個 monolayer 的 InAs 與 7 個 monolayer 的 GaSb 所組成的 pin 結構，爲消除 InAs 與 GaSb 之間晶格不匹配所導致的材料應力，在 InAs 與 GaSb 之間再成長了 0.9 個 monolayer 的 InSb 作爲補償。結構示意圖與超晶格層之 TEM 照片如下圖。實際量測結果顯示截止波長爲 5.5 μm，相當接近原先 6 μm 的設計。

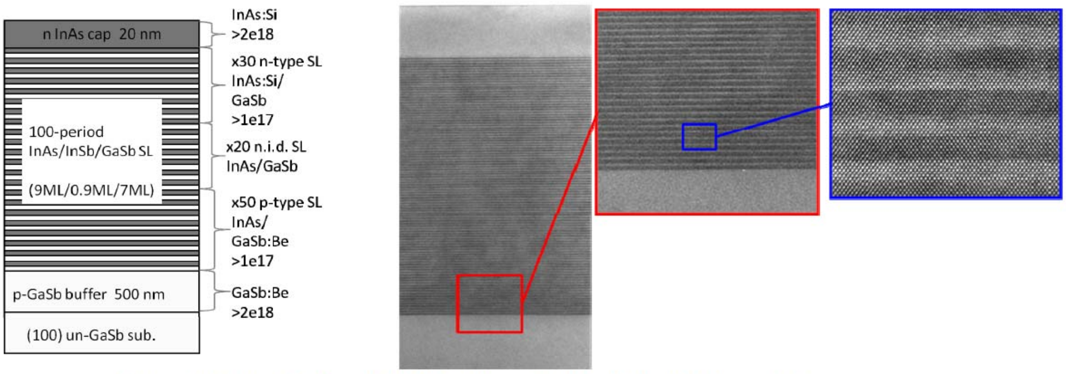


Figure 1. Design (left) and TEM pictures (right) of the T2SL crystal.

◆ 大尺寸 GaSb 晶圓成長與其特性

(Growth and characterisation of large diameter GaSb substrates)

摘要：

GaSb 對於發展偵測中波段(3 ~ 5 μm)至長波段(8 ~ 12 μm)光偵檢器而言，是非常重要的 III-V 半導體材料。跟 4 吋的 GaAs 或是 InP 晶圓材料相比，Sb 系列的材料晶圓尺寸大多僅有2吋，使其發展受限。近年由於可偵測中波段至長波段的 InAs/Ga(In)Sb T2SL 光偵檢器發展快速，使得 4 吋 GaSb 晶圓的需求大增。

Galaxy 公司以液態壓縮柴氏長晶技術(Liquid Encapsulated Czochralski, LEC)與材料分析技術，發展了適合磊晶的 4 吋 GaSb 晶圓，同時定義了量產晶圓的品質判斷標準，亦爲將來發展 5 吋甚至 6 吋 GaSb 晶圓奠下基礎。

- 美國量子元件中心發展長波段第二型 InAs/GaSb 超晶格光偵檢器與焦平面陣列偵檢元件現況

(Recent advances in LWIR Type-II InAs/GaSb superlattice photodetectors and focal plane arrays at the Center for Quantum Devices)

摘要：

近年來，第二型 InAs/GaSb 超晶格光偵檢器因其偵測波段寬廣，尤其是遠紅外光波段，而被視爲汞鎘銻(HgCdTe)光偵檢器的另一選擇。在量子元件中心，InAs/GaSb T2SL 光偵檢器完全是由實驗室自有設備製作出來，藉由 MBE 系統精確地調整超晶格層的厚度，可完成偵測波段爲 3.7 ~ 32 μm 的光偵檢器製作。利用如下方圖顯示之 PL 光譜，在不同位置所得到的 PL 光譜波峰位置接近，說明其偵測波段相當接近，故可驗證其超晶格材料厚度的均勻性。

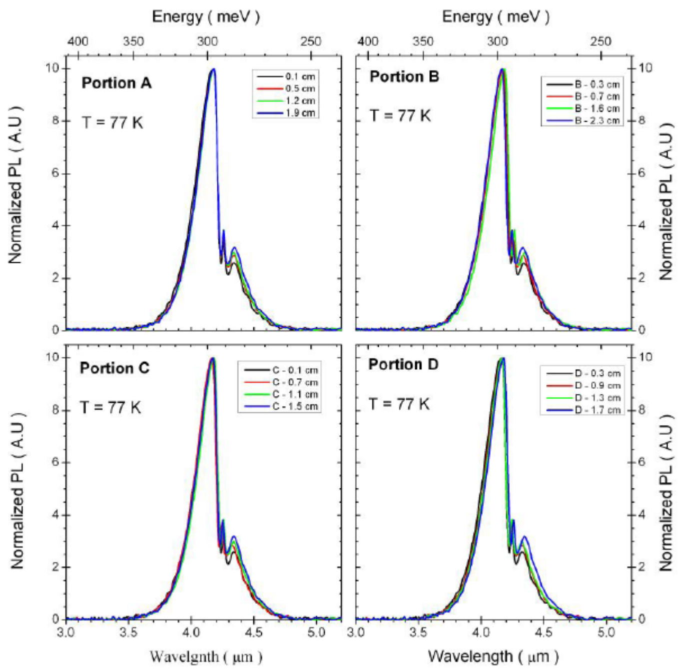


Figure 1: Spatially dependence PL of MWIR Type – II SL

由下圖可知其 InAs/GaSb T2SL 結構爲 p-π-M-n 結構，而超晶格結構爲 13 個 monolayer 的 InAs 與 7 個 monolayer 的 GaSb，其中 M 結構由週期性 AlSb/GaSb/InAs/GaSb/AlSb 所構成。

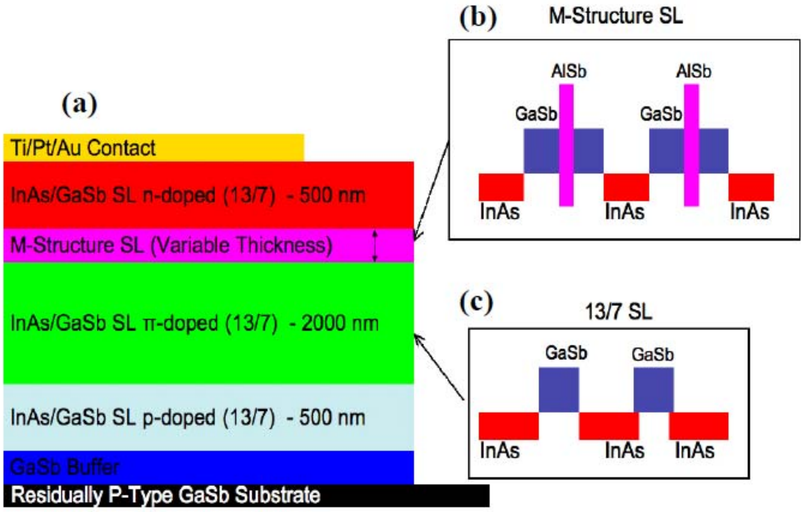


Figure 5: (a) Schematic diagram of a new p-π-M-n superlattice photodiode design. (b) The band alignments of M-superlattice structure, the dash line shows the letter M – shape of the band alignment. C) Band alignment of standard Type II superlattice.

下圖爲此中心自行發展之 FPA 偵檢模組影像圖。在 81 K 操作溫度下，其 NEΔT 爲 26 mK，而積分時間爲 0.08 ms；若在 67 K 操作溫度下，其 NEΔT 則爲 19 mK，而積分時間爲 0.11 ms。

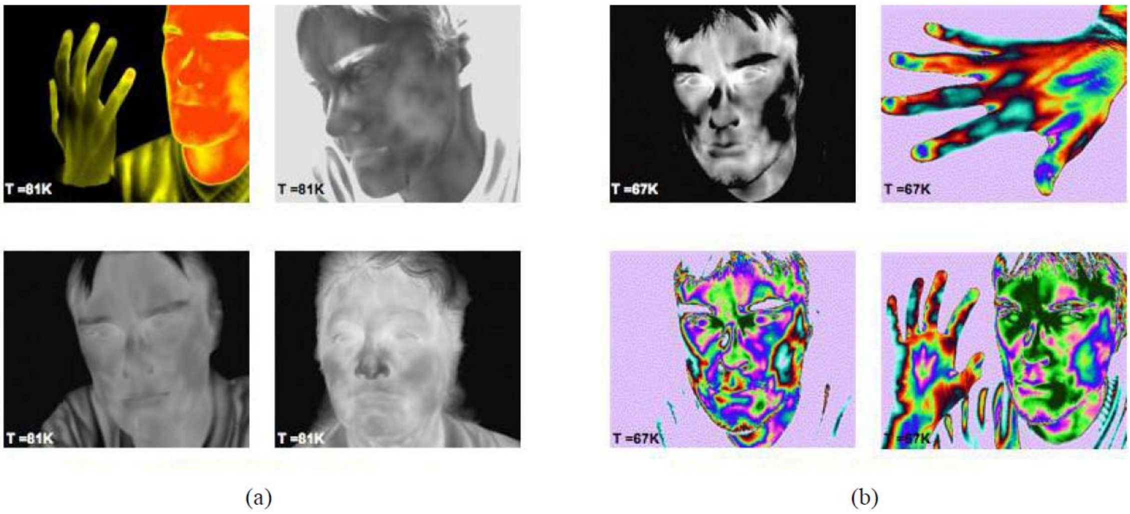


Figure 10: FPA images from a LWIR T2SL with a cutoff of ~ 11 μm with detectors at 81 K (a) and 67 K (b). The ROIC used was an Indigo ISC9705 320 x 256.

◆ 在 GaSb 基板上製作 InAs/$InAs_{1-x}Sb_x$ 超晶格結構-第二型超晶格紅外線光偵測另一種有前景的材料系統

(InAs/$InAs_{1-x}Sb_x$ superlattices on GaSb substrates: a promising alternative type-II superlattice infrared material system)

摘要：

InAs/$InAs_{1-x}Sb_x$ T2SL 是一種非常有前景的紅外線材料結構，可適用於中波段至長波段紅外線範圍的發光二極體、雷射、光偵檢器應用。雖然成長在 InAs 或是 GaSb 基板上的 InAs/$InAs_{1-x}Sb_x$ T2SL 研究結果早在 1990 年代即被提出，但仍不及 InAs/Ga(In)Sb 系列的 T2SL 來得受注目。目前 InAs/Ga(In)Sb 系列的 T2SL 光偵檢器受到其少數載子生命期(~ 30 ns)限制，使得元件特性亦受限。美國空軍研究實驗室(Air Force Research Laboratory)與亞利桑那州立大學(ASU)合作團隊製作偵測波段在 8 μm 之長波段 InAs/$InAs_{1-x}Sb_x$ T2SL 光偵檢器，利用時間解析式光激瑩光光譜(Time-resolved PL)分析發現，其少數載子生命期達 412 ns，是一般 InAs/Ga(In)Sb T2SL 的 10 倍以上。經由高解析 XRD、TEM、PL、變溫霍爾效應量測等分析方法，推測原因應是結構中未含有 Ga 元素，使得電子電洞對發生 Shockley-Read-Hall 非輻射復合機率降低，故載子生命期可以增加。此研究結果再驗證了 InAs/$InAs_{1-x}Sb_x$ T2SL 作爲紅外光偵檢材料的好處。

2. 汞鎘銻(HgCdTe, MCT)、高溫操作(High Operating Temperature, HOT)偵檢元件。

MCT FPA 有較低的暗電流、操作溫度高、偵測度高等優點，且藉由調變材料能帶方式，使得其 FPA 偵測波段可由短波長(SW)延伸至長波長(LW)範圍的特性，在目前商業化 IRFPA 領域仍佔有一席重要的地位。德國 AIM 公司、法國 SOFRADIR 公司、英國 SELEX 公司、美國軍方研究單位等均投入研究。HOT FPA 操作溫度高於 80 K，可降低元件冷卻需求，此主題在本次會議中發表的論文，以應用在中波段 FPA 元件的 InAsSb、AlAsSb 材料爲主。此類元件雖稱爲高溫操作元件，但實則是與傳統需冷卻至 77 K 以下的偵檢元件相比，其操作溫度仍無法像室溫熱像那麼高。

- **以有機金屬氣相磊晶法製作中波/長波雙波段汞鎘銻紅外線焦平面陣列偵檢元件**

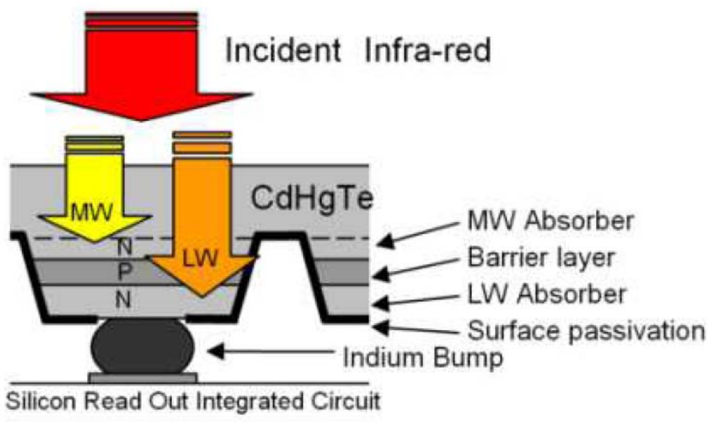
(Dual-band MW/LW IRFPAs from HgCdTe grown by MOVPE)

摘要：

中波/長波雙波段偵測的好處在於同時提供兩波段的紅外線影像資訊，可增強目標偵測能力與辨識能力，另一方面，針對被測物體對不同波段光的反應性，隨時調整偵測波段也可以應用在不同領域中。英國 SELEX 公司幾年前發表在 3 吋 GaAs 晶圓上成長 HgCdTe 紅外線偵檢元件的成果，近年來，其磊晶設備已朝 6 吋 GaAs 晶圓發展。Condor-I 是第一代 SELEX 雙波段紅外線熱像儀，其陣列格式爲 320×256(30 μm pitch)，操作率大於 99.7%，中波段偵測波長爲 3.7 ~ 4.95 μm；而長波段偵測波長爲 8 ~ 9.4 μm。其熱影像如下圖所示。

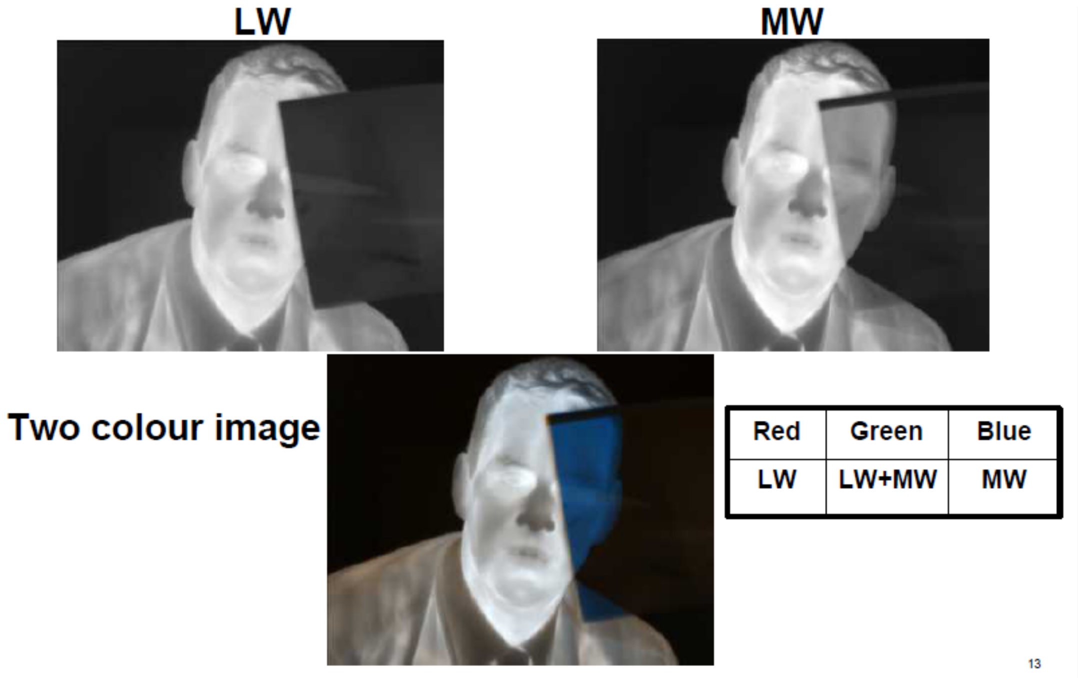
Images through acetate sheet taken with Condor-I device

Condor-II 是第二代產品，其陣列格式精進爲 640×512(24 μm pitch)，操作率大於 99.9%。其 HgCdTe 元件結構採背靠背(back-to-back)二極體架構，對入射紅外光而言等同於入射在同一個畫素，示意圖如下圖。



此外同一畫素上設計有兩個電容，可分別處理積分與信號讀出。熱像儀操作在單波段偵測時，畫面更新頻率達 120 Hz；若操作在雙波段偵測時，則為 60 Hz。

其熱影像如下圖所示。



Red	Green	Blue
LW	LW+MW	MW

- 高操作溫度 XBn-InAsSb 系列 Bariode 偵檢器

(High operating temperature XB_n-InAsSb Bariode detectors)

摘要：

以色列 SCD 公司在高操作溫度(High Operating Tempareture, HOT)紅外線偵檢元件方面發表了一項新的技術，稱之為 Bariode。Bariode 是一種類似 diode 結構的元件，其原理為元件內多數載子的傳輸在空乏區會被一高位能障礙給擋住，而少數載子(因材料吸收紅外光所產生)卻不會被擋可順利通過。本篇文章發表了 SCD 分別在兩種不同基板(GaSb 和 GaAs)上成長 InAsSb 主動層與 AlSbAs 阻障層，並製作程中波段(4.1 μm)N 型 Bariode 偵檢器的成果。Bariode 元件結構以 XB_nn 表示，”X”代表 N 型或 P 型 $InAs_{1-x}Sb_x$ 或是 GaSb 接觸金屬層；”B_n”代表 N 型 $AlSb_{1-y}As_y$ 阻障層；”n”則代表 N 型 $InAs_{1-x}Sb_x$ 主動層。

元件製程使用 Veeco MBE 設備在 GaSb 基板上成長晶格匹配的 N 型 InAsSb 光吸收層、AlSbAs 阻障層、N 型 InAsSb 或 P 型 GaSb 接觸層。若是在 GaAs 基板上成長晶格不匹配結構，則需先在 GaAs 基板上先成長一層 GaSb 作為緩衝層，再製作後續 InAsSb 光吸收層等結構。成長好的磊晶結構將製作成 640×512(15 μm pitch)與 320×256(30 μm pitch)偵檢元件，各自搭配所需格式的 ROIC(如 640 格式使用 Pelican/Pelican-D 系

列ROIC、320格式使用Blue Fairy系列ROIC)進行混成，基板材料再以蝕刻方式去除之，即可完成偵檢模組。下圖所示爲不同格式之N型InAsSb Bariode偵檢器之紅外線影像照片，其中640格式(左圖)操作在150 K，其NETD與積分時間分別爲20 mK與22 ms，元件操作率可達99.5%，圖中小黑點實際上是1~2公里以外樹林區有牛群在吃草的影像；而320格式(右圖)操作在180 K，其NETD則爲43 mK。

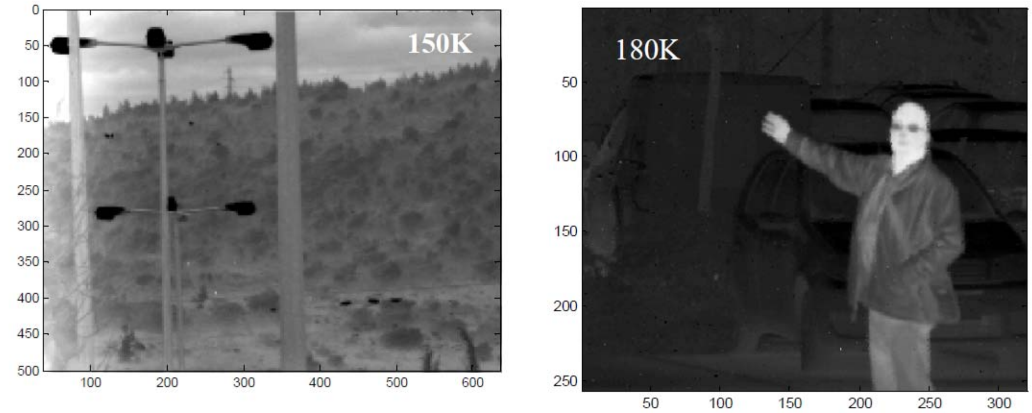


Figure 6
Images registered with F/3 optics on InAsSb n-type bariode FPAs:
(a) at 150K on a 15μm pitch Pelican FPA with 640×512 pixels (NETD=20mK)
(b) at 180K on a 30μm pitch Blue Fairy FPA with 320×256 pixels (NETD = 43mK)

- 應用於高操作溫度紅外線偵檢器之線性致冷器

(Linear cyrogenic coolers for HOT infrared detectors)

摘要：

無論非致冷型夜視技術進展如何快速，致冷型系統仍因其偵測範圍、解析度、辨認追蹤快速移動物體等特性，使得致冷型系統仍較具有優勢。近年技術進步，~ 200 K高溫操作的紅外線偵檢器其特性已接近77 K操作溫度的致冷型元件特性。使用此類HOT偵檢器，最直接的好處則是突破了冷卻與封裝的尺寸限制，發展出在光、電、機械方面更小、更便宜的新式致冷器。

一般使用在致冷型FPA(77 K)上的致冷器是屬於旋轉式(rotary)設計，但有某些缺點使得其不易應用在HOT偵檢元件上。比較起來，線性致冷器在機械磨耗、銅線圈損耗、封裝與散熱的設計靈活性、較低噪音…等等有較佳表現，使得線性致冷器在HOT偵檢元件應用上有較大優勢。

以色列RICOR公司在致冷器領域居世界領導地位，近年發表了專供可攜式手持紅外線熱像機使用，代號K527的微型分離式史特靈(stirling)線性致冷器，技術資料顯示此微型致冷器是目前市面上1 W等級致冷器中體積最小、最輕、與效率最好的產

品。

下圖顯示 RICOR K527 系列致冷器的外觀設計與實體照片，除了 42 mm 標準型冷指管(cold finger)產品，另有 19 mm 較短冷指管產品”shorty”。此型產品適用於操作溫度 130 K 的 HOT 偵檢器。

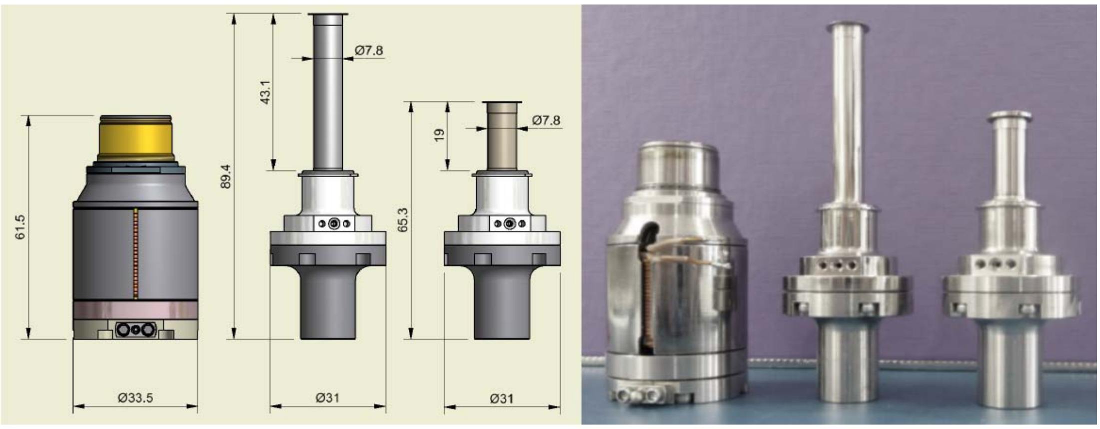
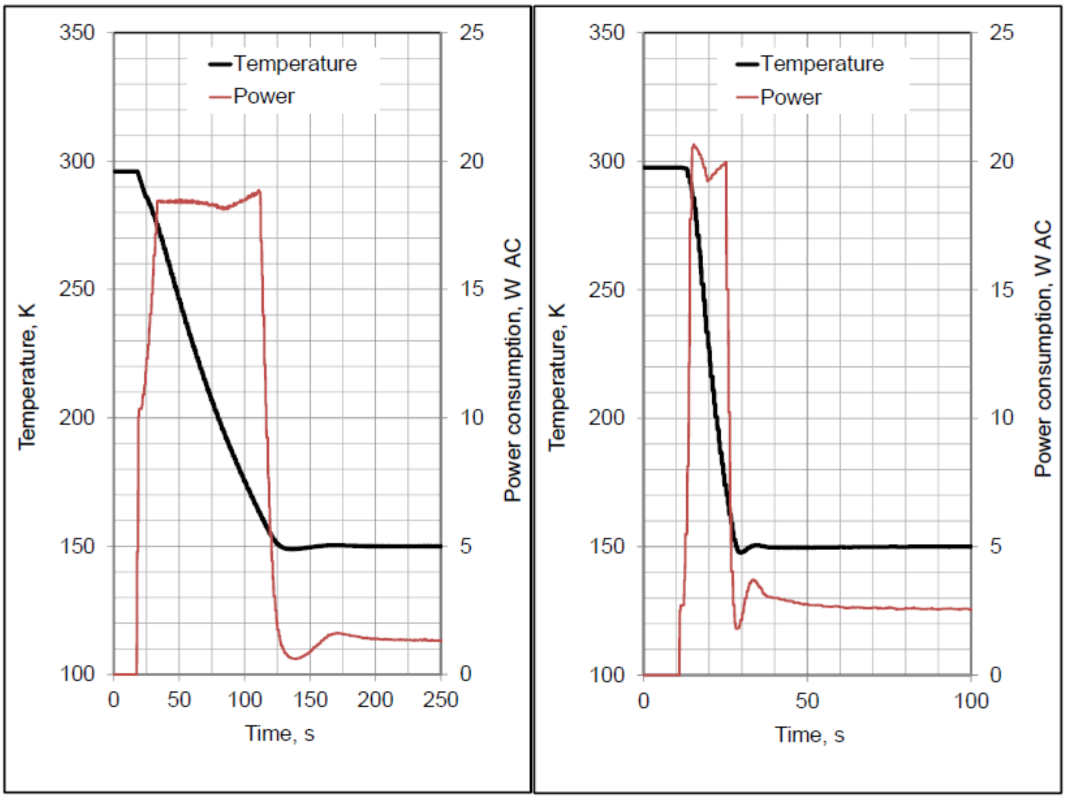


Figure 3. External layout and pictures of the linear K527 compressor, regular and shortened cold fingers

標準型與 Shorty K527 之冷卻曲線(cooldown curve)如下圖。對標準型而言，冷卻至 150 K 所需時間約為 125 秒；而對 Shorty 而言，則約為 30 秒。



(a) (b)

Figure 6. Cooldown curves in cases of regular (a) and shortened cold finger (b)

3. <u>非致冷(uncooled)技術偵檢元件。</u>

即所謂室溫熱像技術，利用元件吸收紅外線輻射，依不同物質對熱的反應特性，造成元件本身電特性的變化。此類元件因不使用致冷技術將元件冷卻至極低溫，可大幅減少致冷系統成本。又經過多年來世界各國研究團隊的努力，其元件光電特性都精進至可與低溫熱像元件比擬，故產品商業化前景可期。此主題所發表的論文以 GaN、$Si_xGe_{1-x}O_y$、VO_x 為主，主要是以微機電(MEMS)技術在矽基板上製作懸浮結構元件，通常都使用於 8 ~ 12 μm 波段。

♦ 紅外線偵檢用之 GaN 微機械共振器

(Gallium nitride micromechanical resonators for IR detection)

摘要：

美國密西根大學研究團隊結合材料壓電、熱電、共振等技術，提出一個創新的低雜訊、非致冷式紅外線光偵檢技術。其結構由 GaN 微機械共振器陣列組成，共振器上並鍍製了一層可吸收紅外線的複合材料。GaN 共振陣列材料吸收紅外線後因受熱改變共振腔的共振頻率，並比對原先設計好的參考共振腔頻率，藉由量測此一參數的變化量，即可完成紅外線偵測。下圖即為此共振腔元件設計示意圖。

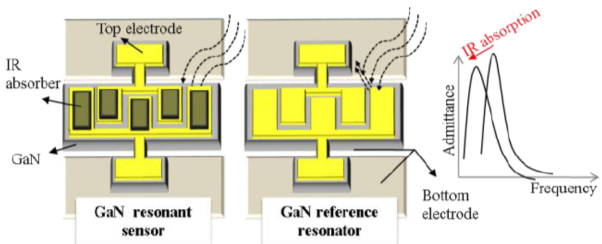


Figure 1. A schematic view showing the GaN IR sensor architecture. A reference resonator is used to reduce noise and cancel the frequency shift because of other changes such as increase in the ambient temperature. The detector response time is governed by the thermal time constant ($\tau_{th} = R_{th}C_{th}$), where R_{th} and C_{th} are the thermal resistance of the tethers and the thermal capacity of the resonator, respectively.

元件製程方面如下方示意圖所示，使用 MOCVD 或 MBE 系統在 Si 基板上成長 AlN/AlGaN 薄膜作為緩衝層，在於其上磊晶成長 GaN 薄膜，一般而言厚度約 0.5 ~ 3 μm。共振腔結構與金屬電極均以一般半導體製程完成，元件背面再以蝕刻方式將 Si 基板蝕刻去除，並鍍上背面電極，完成懸浮式共振腔元件製作。

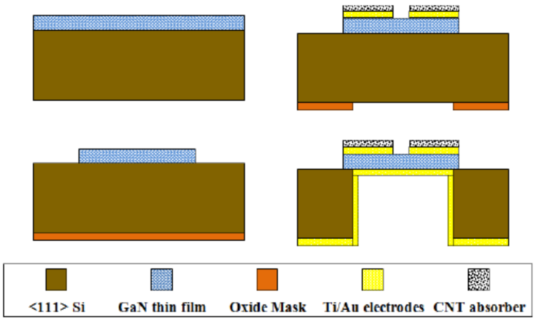


Figure 3. Process flow schematic for making resonant IR detectors augmented by thin film IR absorbers.

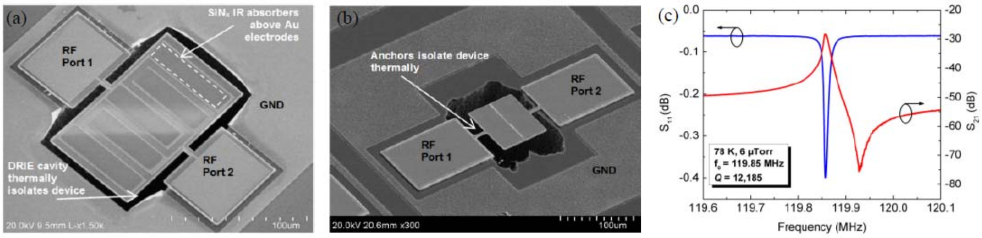


Figure 4. Scanning micrograph images of fabricated GaN resonators with dimensions (a) 120μm × 80μm and (b) 80μm × 60μm. Reducing area will improve the resolution of the proposed IR focal plane array. (c) RF performance of a 40μm × 80μm resonator with a Q of 12,185 (Q =8,000 at 300 K). This device demonstrated the highest $f \times Q$ for GaN so far.

- SCD 非致冷型光偵檢器特色

(Advanced features of SCD’s uncooled detectors)

摘要：

SCD 近年發展以氧化釩(VO_x)室溫熱感測(microbolometer)技術爲主的非致冷型光偵檢器生產線。Microbolometer 是在 6” ROIC 上以微機電技術製作，在每個畫素(pixel)上都有 SiN_x 薄膜片懸浮於基板上方，而此膜片則利用兩隻腳作爲絕熱與支撐之用，均勻的 VO_x 薄膜爲溫度敏感材料，具有極高的熱係數。

最先發表的 FPA 爲 384x288 格式(25 μm pitch)，技術規格如下表(測試條件爲 F/1、20/50Hz、FPA 與背景溫度爲 300 K)。

Table 1. Performance characteristics of the 25-μm detector.

Parameter	Performance
Array size	384×288 (320×240, 160×120 configurable)
Pitch	25 μm
Spectral band	8–14 μm
Thermal time-constant	5 or 12 ms (typically 10) for “fast” and “slow” pixels
Temporal *NETD* (*F*/1, 30Hz)	< 35 mK @ 12 ms (50 mK at 60 Hz) < 50 mK @ 5 ms (70 mK at 60 Hz)
Intra-scene DR	> 100 K
Coarse non uniformity (after compensation)	< 200 mV (p-t-p)
Power dissipation	< 200 mW (excluding TEC)
Package weight	< 20 gram
Pixel operability	> 99%
Nominal operating temperature	25°C
Ambient range	−40°C – 70°C

♦ BIRD640：SCD 高靈敏度 VGA 格式氧化釩微型輻射熱感測器

(BIRD640: SCD's high sensitivity VGA VO_x μ-bolometer detector)

摘要：

以色列 SCD 公司自 2005 年起發展 BIRD 系列 VO_x 材料之非致冷型紅外光偵檢元件，初期產品為 384 格式(如上篇技術論文摘要)，目前已發展至 640 格式。利用 SCD 自有"power-save"技術，搭配 ROIC 設計，改善偵檢元件本身靈敏度，也達到減低耗能、縮小尺寸、提高空間均勻性等。

BIRD640 另一特色即是其可操作在增強型動態範圍(enhanced dynamic range)，稱之為 fire-man mode。目前 SCD 發表新的操作模式，稱之為聯合模式(combined mode)，其主要目標即是要同時達到高動態範圍與低雜訊等效溫差(NETD)(在 F/1 時，NETD 低於 50 mK)。另一方面，操作模式亦包含了另兩種模式：一為高動態範圍同時高 NETD、另一為低動態範圍同時低 NETD。將這兩種模式的畫面加以處理變成一個畫面，原來個別模式的畫面缺點可互相取代，形成一個較佳的畫面。下圖顯示操作在 combined mode 下的 BIRD384 影像畫面，在 F/1 時，NETD 低於 40 mK。

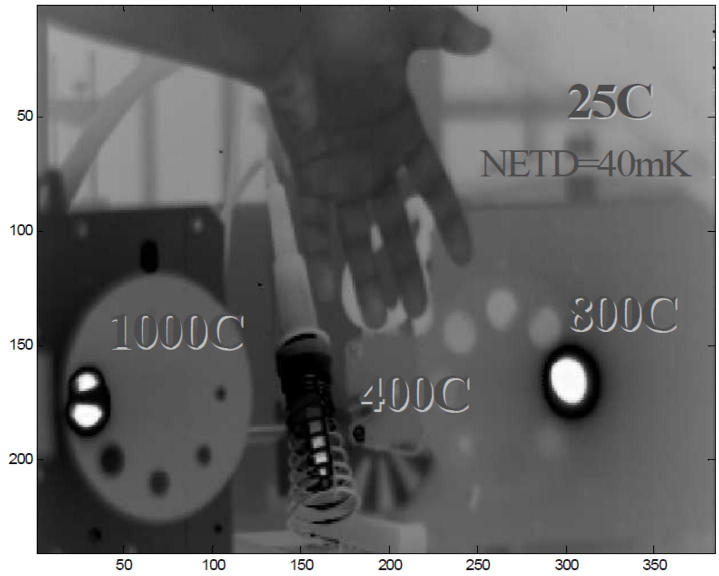


Figure 3: High Dynamic Range and low NETD with the "Combined" Mode

使用 50 mm F/1 鏡頭時，操作在 fire-man 模式的 BIRD640 產品，其紅外線影像如下圖所示。

Figure 7: *BIRD640* Image Captured with an F/1 50mm Lens

4. 量子井紅外線偵檢元件(Quantum Well Infrared Photodetector, QWIP)。

此類元件結構主要以 GaAs/AlGaAs 量子井結構爲主，由於此兩層材料爲爲晶格匹配(Lattice-matched)物質，故不論是以 MBE 或 MOCVD 成長都能得到高品質的磊晶片。利用能隙調變工程，可製作成偵測波段由 6 μm 擴展到 25 μm 各式的 GaAs/AlGaAs 量子井紅外線偵測器。其中本人雖然無法參加此議程，但參考研討會所檢附的會議手冊，法國 Sofradir 公司與 Thales 公司、III-V 實驗室(屬 Alcatel 與 Thales 合作單位)合作開發了可操作在 73 K 的 QWIP 偵檢元件，並已批量製作成 384*288(25 μm)與 640*512(25 μm)的 IDDCA。其合作模式大致爲 III-V 實驗室負責磊晶材料與偵檢元件、Sofradir 公司發展適用的 ROIC、Thales 公司利用其致冷器在將全體整合成 IDDCA，同時將產品特性回饋給 III-V 與 Sofradir，供改善精進之參考。如此良性循環可大幅減少投入重覆的研發資源，共創三贏。

- 先進量子井與量子點光偵檢器與焦平面陣列元件

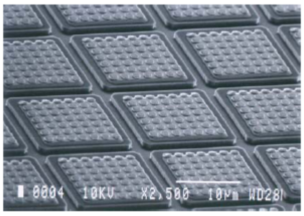
(Quantum well and quantum dotmodeling for advanced infrared detectors and focal plane arrays)

摘要：

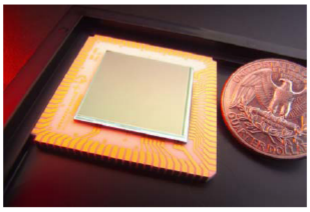
量子井紅外線光偵檢元件(Quantum Well Infrared Photodetector, QWIP)採用先進且成熟的 MBE 製程，將不同能隙的 GaAs/AlGaAs 材料有週期性地製作在 GaAs 基板上，元件具有高度均勻性、高操作率、高可靠度等優點，藉由調變磊晶材料厚度與其週期，

偵測波段可從中波段延伸至長波段(3 ~ 16 μm)。

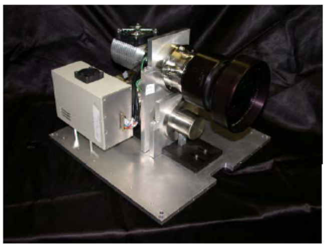
美國噴射推進實驗室(Jet Propulsion Laboratory, JPL)是世界上發展 QWIP 元件最先進的團隊，目前已發表 1024×1024 格式之 QWIP FPA，而 2048×2048 格式的研發工作也已經開始。其 1024×1024(19.5 μm pitch)格式之中波段(4.4 ~ 5.1 μm)QWIP FPA 熱像產品與熱影像如下圖所示。



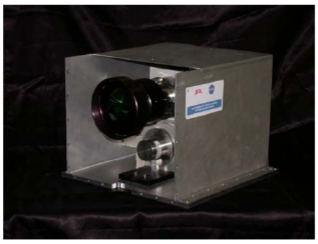
Detector pixel with light coupling gratings



1024 x 1024 pixel QWIP focal plane array



1Kx1K MWIR sensor engine



1Kx1K MWIR QWIP camera

➤ NEΔT OF 19 mK WAS ACHIEVED.

長波段 QWIP FPA 方面，偵測波段為 8 ~ 9 μm、元件操作率 ~ 99.98%、雜訊等效溫度差為 16 mK。

另一方面，JPL 亦發展雙波段 QWIP 元件，其採用中波/長波共結構設計，對入射紅外光而言亦等同於入射在同一個畫素，不同波段結構的電極與共同對地電極(Det Com)均製作在同一個畫素結構上，製程困難度極高，示意圖如下圖。

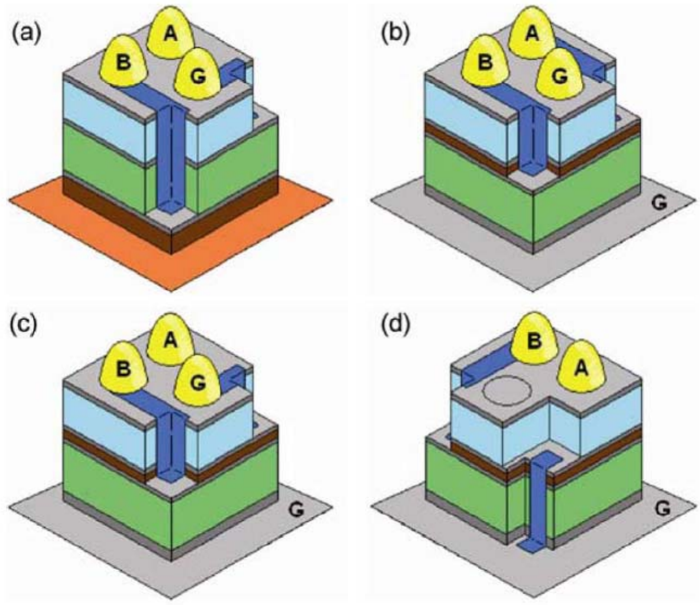


Fig. 1. 3-D view of four possible dual-band QWIP device structure showing via connects for independent access of MWIR and LWIR devices. The color code is as follows, orange—isolation layer; green—LWIR QWIP; light blue—MWIR QWIP; grey—contact layer; brown—undoped AlGaAs insulation layer; dark blue—metal bridges between MQW regions; yellow—indium bumps.

其 1024×1024(30 μm pitch)格式之雙波段 QWIP FPA，在 68 K 操作溫度下，中波段(4.4 ~ 5.1 μm)與長波段(7.8 ~ 8.8 μm)之雜訊等效溫度差分別為 27 mK 與 40 mK。熱影像如下圖所示。

Fig. 10. An image taken with the first megapixel simultaneous pixel co-registered MWIR:LWIR dual-band QWIP camera. The flame in the MWIR image (left) looks broader due to the detection of heated CO2 (from cigarette lighter) re-emission in 4.1–4.3-micron band, whereas the heated CO2 gas does not have any emission line in the LWIR (8–9 microns) band. Thus, the LWIR image shows only thermal signatures of the flame.

三、展覽會摘要

本展覽會有超過 540 家公司參展，會中將展出以下最新技術的產品。

- 化學與生物感測 (Chemical and biological sensing)
- **紅外線偵檢器與系統 (Infrared sources, detectors, and systems)**
- 雷射與其他光源、雷射附屬配件、雷射系統 (Laser and other light sources, laser accessories, and laser systems)
- 照相機與 CCD 零組件 (Cameras and CCD components)
- 電子成像、光纖零組件、光纖設備與系統 (Electronic imaging and fiber optic components, equipment, and systems)
- 高速成像與感測 (High-speed imaging and sensing)
- 高精度光學製造 (High-precision optics manufacturing)
- 奈米科技應用 (Nanotechnology applicatons)
- 其他…

其中，本案將參觀重點放在**紅外線偵檢器與系統**的參展廠商，利用機會與其討論偵檢器材料、製程方法等議題，並當場蒐集了多家相關廠商的產品資料。除瀏覽式的參觀各家展出產品，亦專程與知名致冷器(cooler)原廠 Ricor 美國分公司人員洽談，表明我方採購價格有逐年上升趨勢，且不易獲得較高規格的產品。對方回應若是採購較高規格產品將受限於出口管制，本來就較困難；至於價格是由地區性代理商決定，若我方希望有第二管道，可直接向美國分公司洽詢，現場並給了美國分公司窗口的名片以供參考。以上資訊均於回國後利用知識分享機會給長官、同仁知悉，對未來計畫執行，應有潛在的幫助。

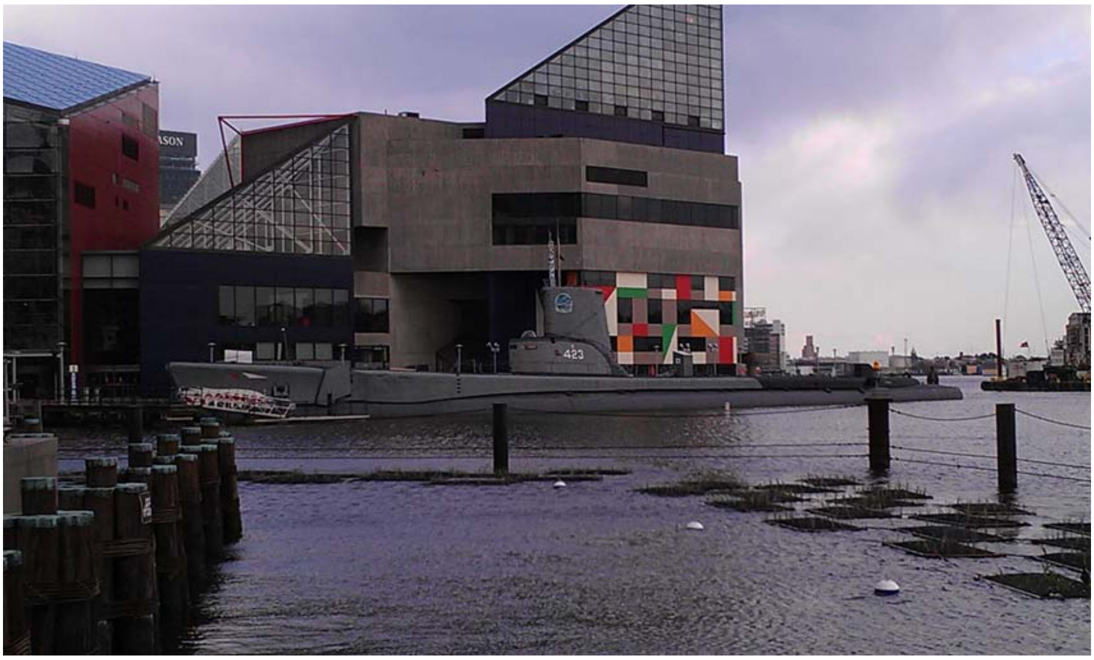
因本案重點在蒐集關於紅外線偵檢元件、模組、系統之技術商情資料，相關廠商重點宣傳資料擇要檢附如附件二。

參、 心得

一、本次紅外線研討會雖分多項主題，仍有極具前瞻性或重要性的研究領域，如 T2SL、HOT、QWIP 等類型的偵檢元件，共同特色即是操作溫度較以往 InSb 系列偵檢元件爲高、耗能較小。目前爲止，此類偵檢元件距可商品化階段仍有一段距離。從這次會議中此類論文佔總體近 1/2 的比例即可得知其未來的發展性不容小覷。

二、本次研討會中所發表的偵檢元件技術，無論是 T2SL、MCT 或是 QWIP FPA，雖然大部分仍在研發階段，但其格式亦以 640 爲主，甚至達 1024 以上。另一方面，許多論文的作者分別來自學術單位、民間公司甚或是軍事單位，這種學術合作的模式，利用雙方甚至三方的優勢，應可加速技術產品化的腳步，縮短產品商業化的時程。

三、本次展覽會參展產品包羅萬象，從紅外線偵檢系統、雷射應用、光纖技術、精密光學製造、半導體設備等較高階產品到 LED、消費型照相機等低階產品均可在會場看到，但以紅外線熱像機產品最多，幾個較有名的廠商如 SCD、SOFRADIR、SELEX、FLIR 等均展示其最新產品。仔細觀察發現，所有熱像機的偵檢元件規格均是 640×480 畫素以上的格式，已看不到任何 320 格式的產品，高解析度的產品趨勢已非常明顯。



巴爾的摩-內港(Inner Habor)

巴爾的摩市區街景(Gay Street)

肆、 建議事項

一、紅外線熱像儀及其相關元件、模組、系統等技術是本院發展多年的重要技術能量，包含了材料、光電子、機構、影像電路、系統整合等，培育了無數優秀的研究人力。紅外線技術與應用研討會至今已舉辦第 38 屆，由參與人數、發表文章數目、產品展出等，均可說明這是紅外線領域最悠久且重要的技術論壇。本院身爲紅外線科技的一份子，若可在類似場合或機會與國際間技術領先的團隊們相互切磋學習，刺激研發靈感，必可收事半功倍之效。

二、由本次研討會所發表的技術文章與展覽會中所展出的產品，可發覺 FPA 偵檢元件已明顯地往高畫素規格邁進，主流量產產品至少要有 640×480 畫素以上規格才有吸引力，而仍在研發階段的元件也有 1024×768 畫素以上規格出現。本院目前雖仍以 320 格式爲主，然而主事長官早已洞燭機先進行規劃，開始 640 格式元件製作的任務已是箭在弦上，相關工作刻不容緩。未來推出與目前主流規格相當的產品，將可創造更大的技術能量與商機。

三、爲了組織的永續生存，科技機構投入新技術的研發永遠是必要的投資。除了固守 InSb 材料系列的紅外線熱像技術並力求精進外，對於高操作溫度與室溫熱像等新領域亦應投入部分資源，提早佈局建立技術能量，待將來機會來時可順勢切入，在該領域佔有一席之地。

四、本次研討會已看到許多研究成果是由許多單位共同發表，在公平、信任的原則下，多方單位合作可互取對方長處並彌補本身短缺，因本院組織功能特殊，也許無法採類似模式運作。惟關鍵零組件或材料取得有其困難性，加速提升系統零組件或材料的自製率，或是另尋第二穩定商源，均可避免缺料或採購成本異常上揚問題發生。

Conference 8353 · Room: Conv. Ctr. 307

Monday-Friday 23-27 April 2012 • Proceedings of SPIE Vol. 8353

Infrared Technology and Applications XXXVIII

Conference Chairs: **Bjørn F. Andresen,** Israel Aerospace Industries-ELTA (Israel); **Gabor F. Fulop,** Maxtech International, Inc. (USA); **Paul R. Norton,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

Program Committee: **Christopher C. Alexay,** StingRay Optics, LLC (USA); **Jagmohan Bajaj,** Teledyne Imaging Sensors (USA); **Stefan T. Baur,** Raytheon Co. (USA); **Philippe F. Bois,** Alcatel-Thales III-V Lab. (France); **Wolfgang A. Cabanski,** AIM INFRAROT-MODULE GmbH (Germany); **John T. Caulfield,** Cyan Systems (USA); **John W. Devitt,** Georgia Tech Research Institute (USA); **Nibir K. Dhar,** Defense Advanced Research Projects Agency (USA); **Michael T. Eismann,** Air Force Research Lab. (USA); **Mark E. Greiner,** L-3 Communications Cincinnati Electronics (USA); **Sarath D. Gunapala,** Jet Propulsion Lab. (USA); **Charles M. Hanson,** Consultant in Infrared (USA); **Masafumi Kimata,** Ritsumeikan Univ. (Japan); **Hee Chul Lee,** KAIST (Korea, Republic of); **Paul D. LeVan,** Air Force Research Lab. (USA); **Chuan C. Li,** DRS Technologies, Inc. (USA); **Wei Lu,** Shanghai Institute of Technical Physics (China); **Michael H. MacDougal,** FLIR Electro-Optical Components (USA); **Tara J. Martin,** Sensors Unlimited, Inc., part of Goodrich Corp. (USA); **Paul L. McCarley,** Air Force Research Lab. (USA); **R. Kennedy McEwen,** SELEX Galileo Infrared Ltd. (United Kingdom); **John L. Miller,** FLIR Systems, Inc. (USA); **A. Fenner Milton,** U.S. Army RDECOM CERDEC NVESD (USA); **Mario O. Münzberg,** Carl Zeiss Optronics GmbH (Germany); **Peter W. Norton,** BAE Systems (USA); **Robert A. Owen,** L-3 Communications Infrared Products (USA); **Joseph G. Pellegrino,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Ray Radebaugh,** National Institute of Standards and Technology (USA); **Manijeh Razeghi,** Northwestern Univ. (USA); **Colin E. Reese,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Ingmar G. Renhorn,** Swedish Defence Research Agency (Sweden); **Antoni Rogalski,** Military Univ. of Technology (Poland); **Ingo Rühlich,** AIM INFRAROT-MODULE GmbH (Germany); **Piet B. W. Schwering,** TNO Defence, Security and Safety (Netherlands); **Itay Shtrichman,** SCD Semiconductor Devices (Israel); **Rengarajan Sudharsanan,** Spectrolab, Inc., A Boeing Co. (USA); **Stefan P. Svensson,** U.S. Army Research Lab. (USA); **Venkataraman S. Swaminathan,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Simon Thibault,** Univ. Laval (Canada); **Gil A. Tidhar,** IAI-Elta (Israel); **Meimei Z. Tidrow,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Jean-Luc M. Tissot,** ULIS (France); **Alexander Veprik,** RICOR-Cryogenic & Vacuum Systems (Israel); **Jay N. Vizgaitis,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Michel Vuillermet,** SOFRADIR (France); **James R. Waterman,** U.S. Naval Research Lab. (USA); **Lucy Zheng,** Institute for Defense Analyses (USA)

Monday 23 April

Room: Conv. Ctr. 307 . . . . .Mon. 8:00 to 8:10 am

Opening Remarks

Session Chair: **Bjørn F. Andresen,** Israel Aerospace Industries-ELTA (Israel)

SESSION 1

Room: Conv. Ctr. 307 . . . . Mon. 8:10 am to 12:05 pm

NIR/SWIR FPAs and Applications

Session Chairs: **Tara J. Martin,** Sensors Unlimited, Inc., part of Goodrich Corp. (USA); **Michael H. MacDougal,** FLIR Electro-Optical Components (USA)

8:10 am: **A high-resolution SWIR camera via compressed sensing**, Lenore McMackin, Matt Herman, Bill Chatterjee, Matt S. Weldon, InView Technology Corp. (USA) . . . . [8353-01]

8:30 am: **Shortwave infrared camera with extended spectral sensitivity**, Martin Gerken, Bertram Achtner, Michael Kraus, Tanja Neumann, Mario O. Münzberg, Carl Zeiss Optronics GmbH (Germany). . . . . [8353-02]

8:50 am: **SCD's cooled and uncooled photo detectors for NIR SWIR** *(Igor Szafranek Memorial presentation)*, Avraham Fraenkel, Daniel Aronov, Yael Beny, Leonid Bikov, Zipora Calahorra, Tal Fishman, Aviho Giladi, Elad Ilan, Philip Klipstein, Lidia Langof, Inna Lukomsky, Udi Mizrahi, Avi Tuito, Michael Yassen, Ami Zemel, SCD Semiconductor Devices (Israel) . . . . [8353-03]

9:15 am: **Flexible wide dynamic range VGA ROIC for InGaAs SWIR imaging**, Yang Ni, Bogdan Arion, Yiming Zhu, Pierre Potet, New Imaging Technologies SAS (France) . . . . [8353-04]

9:35 am: **High-performance 640 × 512 pixel hybrid InGaAs image sensor for night vision**, Eric De Borniol, Fabrice Guellec, Pierre Castelein, Michaël Tchagaspanian, CEA-LETI (France); Anne Rouvié, Jean-Alexandre Robo, Alcatel-Thales III-V Lab. (France); Philippe F. Bois, Thales Research & Technology (France) . . . . [8353-05]

9:55 am: **InGaAs focal plane array developments at III-V Lab.**, Anne Rouvié, Jean-Luc Reverchon, Odile Huet, Jean-Alexandre Robo, Jean-Patrick Truffer, Toufiq Bria, Jean Decobert, Philippe F. Bois, Eric M. Costard, Alcatel-Thales III-V Lab. (France) . . . . [8353-06]

Coffee Break . . . . 10:15 to 10:45 am

10:45 am: **Low dark current small pixel large format InGaAs 2D photodetector array development at Teledyne Judson Technologies**, Henry H. Yuan, Joseph Kimchi, Louis C. Kilmer, Teledyne Judson Technologies (USA) . . . . [8353-07]

11:05 am: **Large-format InGaAs focal plane arrays for SWIR imaging**, Michael H. MacDougal, Andrew D. Hood, Juan Manzo, Jonathan C. Geske, David Follman, FLIR Electro-Optical Components (USA) . . . . [8353-08]

11:25 am: **A low-power, TEC-less, 1280×1024, compact SWIR camera with temperature-dependent, non-uniformity corrections**, Jonathan Nazemi, Michael Delamere, Jesse Battaglia, Christopher Martin, Goodrich ISR Systems (USA) . . . . [8353-09]

11:45 am: **Ultralow flux SWIR detection issues using HgCdTe planar p-on-n photodiode arrays**, Olivier Gravrand, CEA-LETI-Minatec (France); Olivier Boulade, Vincent Moreau, Commissariat à l'Énergie Atomique (France); Eric Sanson, SOFRADIR (France); Gérard L. Destefanis, CEA-LETI-Minatec (France) . . . . [8353-10]

Standby Oral/Poster Presentation

This poster may also be given as an oral presentation in this session.

MT6425CA: a 640 X 512-25 µm CTIA ROCI for SWIR InGaAs detector arrays, Selim Eminoglu, Yigit Uygar Mahsereci, Caglar Altiner, Tayfun Akin, Mikro-Tasarim Ltd. (Turkey) . . . . [8353 147]

Lunch Break . . . . 12:05 to 1:05 pm

SESSION 2

Room: Conv. Ctr. 307 . . . . Mon. 1:05 to 4:35 pm

Air Force Infrared Research and Development

Session Chairs: **Paul D. LeVan,** Air Force Research Lab. (USA); **R. Kennedy McEwen,** SELEX Galileo (United Kingdom)

1:05 pm: **Multispectral imaging with Type II superlattice detectors** *(Invited Paper)*, Gamini Ariyawansa, Joshua M. Duran, Matthew Grupen, John E. Scheihing, Thomas R. Nelson, Jr., Michael T. Eismann, Air Force Research Lab. (USA) . . . . [8353-11]

1:25 pm: **Radiation tolerance of a dual-band IR detector based on a pBp architecture** *(Invited Paper)*, Vincent M. Cowan, Christian P. Morath, Air Force Research Lab. (USA); Stephen A. Myers, Elena Plis, Sanjay Krishna, Ctr. for High Technology Materials, Univ. of New Mexico (USA). . . . . [8353-141]

1:45 pm: **Space-based hyperspectral technologies for the thermal infrared** *(Invited Paper)*, Paul D. LeVan, Air Force Research Lab. (USA) . . . . [8353-13]

2:05 pm: **Hybrid dual-color MWIR detector for airborne missile warning systems** *(Invited Paper)*, Itay Hirsh, Lior Shkedy, Dan Chen, Nir Fishler, Yonatan Hagbi, Alina Koifman, Yaki Openhaim, Ilan Vaserman, Michael T. Singer, SCD Semiconductor Devices (Israel). . . . . [8353-14]

2:25 pm: **Detection in urban scenario using combined airborne imaging sensors** *(Invited Paper)*, Ingmar G. Renhorn, Swedish Defence Research Agency (Sweden); Michal Shimoni, Royal Belgian Military Academy (Belgium); Xavier Briottet, Yannic Boucher, ONERA (France); Alwin Dimmeler, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany); Sergio U. de Ceglie, CISAM (Italy); Salvatore Resta, Univ. degli Studi di Pisa (Italy); Piet B. W. Schwering, Koen W. Benoist, Rob J. Dekker, TNO Defence, Security and Safety (Netherlands); Remco Dost, Mark van Persie, National Aerospace Lab. NLR (Netherlands); Ingebjörg Kåsen, Trym V. Haavardsholm, Norwegian Defence Research Establishment (Norway); Ola Friman, Swedish Defence Research Agency (Sweden). . . . . [8353-15]

2:45 pm: **IR-CENTRIC®: a force multiplier for fixed and rotary wing aircraft** *(Invited Paper)*, Tsvi Rozen, Shavit Nadav, Meir Danino, Elbit Systems EW & SIGINT - ELISRA Ltd. (Israel). . . . . [8353-16]

Coffee Break . . . . 3:05 to 3:35 pm

3:35 pm: **Half TV format MWIR sensor incorporating proximity electronics** *(Invited Paper)*, Andrew P. Ashcroft, SELEX Galileo Infrared Ltd. (United Kingdom) . . . . [8353-17]

3:55 pm: **Comparison of the strapdown and gimballed seekers** *(Invited Paper)*, Bülent Özkan, Altug Uçar, TÜBITAK SAGE (Turkey). . . . . [8353-18]

4:15 pm: **Anti-dazzling protection for Air Force pilots** *(Invited Paper)*, Ariela Donval, Tali Fisher, Ofir Lipman, Moshe Oron, KiloLambda Technologies, Ltd. (Israel) . . . . [8353-19]

Symposium-Wide Plenary Session

Monday • 5:00 to 6:00 pm • Conv. Ctr. (Level 400), Ballroom I-II

Bruce Carlson, Director, National Reconnaissance Office

See p. 11 for details • Open to All Attendees

Tuesday 24 April

SESSION 3

Room: Conv. Ctr. 307 . . . . Tues. 8:00 to 10:00 am

Threat Acquisition

Session Chairs: **Mario O. Münzberg,** Carl Zeiss Optronics GmbH (Germany); **Gil A. Tidhar,** IAI-Elta Systems Ltd. (Israel)

8:00 am: **Stereoscopic uncooled thermal imaging with autostereoscopic 3D-flat screen display in military driving enhancement systems**, Hubertus A. Haan, Mario O. Münzberg, Uwe Schwarzkopf, Carl Zeiss Optronics GmbH (Germany); Rene De la Barre, Silvio Jurk, Bernd Duckstein, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany) . . . . [8353-20]

8:20 am: **Infrared stereo camera for human machine interface**, Richard Edmondson, David B. Chenault, Justin P. Vaden, Polaris Sensor Technologies, Inc. (USA). . . . . [8353-21]

8:40 am: **A compact deployable mid-wave infrared imaging system for wide-area persistence surveillance in maritime environments**, K. Peter Judd, U.S. Naval Research Lab. (USA); Costa Colbert, Russ Smith, Smart Logic, Inc. (USA); Kenneth M. Vilardebo, V Systems, Inc. (USA); James R. Waterman, U.S. Naval Research Lab. (USA); Gregory J. Petty, Joel Kilzer, Naval Surface Warfare Ctr. Crane Div. (USA) . . . . [8353-23]

9:00 am: **OTHELLO: a novel SWIR dual-band detection system and its applications**, Gil A. Tidhar, Ori Aphek, Israel Aerospace Industries Ltd., Elta Group (Israel) . . . . [8353-24]

9:20 am: **Quantification of nitromethane with complementary super clip apodization and an iterative spectral comparison routine**, Kathryn J. Conroy, The Univ. of New South Wales (Australia); K. Paul Kirkbride, Australian Federal Police (Australia); Charles C. Harb, The Univ. of New South Wales (Australia). . . . . [8353-25]

9:40 am: **On designing a SWIR multiwavelength facial-based acquisition system**, Thirimachos Bourlai, Neeru Narang, Bojan Cukic, Lawrence A. Hornak, West Virginia Univ. (USA) . . . . [8353-26]

Coffee Break . . . . 10:00 to 10:30 am

SESSION 4

Room: Conv. Ctr. 307 . . . . Tues. 10:30 to 11:30 am

Type II Superlattice FPAs I

Session Chairs: **Meimei Z. Tidrow,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Manijeh Razeghi,** Northwestern Univ. (USA); **Lucy Zheng,** Institute for Defense Analyses (USA)

10:30 am: **Recent developments in type-II superlattice detectors at IRnova AB**, Hedda Malm, Rickard Marcks von Würtemberg, Carl Asplund, Dan Haga, Henk H. Martijn, IRnova AB (Sweden); Amir Karim, Acreo AB (Sweden); Elena Plis, Sanjay Krishna, Ctr. for High Technology Materials, Univ. of New Mexico (USA) . . . . [8353-27]

10:50 am: **Long-wavelength infrared superlattice detectors and FPA based on CBIRD design**, Alexander Soibel, Sir B. Rafol, Jean Nguyen, Arezou Khoshakhlagh, Linda Höglund, Sam A. Keo, Jason M. Mumolo, John K. Liu, Anna Liao, David Z. Y. Ting, Sarath D. Gunapala, Jet Propulsion Lab. (USA) . . [8353-28]

11:10 am: **Development of type II superlattice detector for future space applications at JAXA**, Haruyoshi Katayama, Jyunpei Murooka, Masataka Naitoh, Tadashi Imai, Ryota Sato, Eichi Tomita, Munetaka Ueno, Hiroshi Murakami, Japan Aerospace Exploration Agency (Japan); Kunihiko Bito, Satoshi Kawasaki, Masafumi Kimata, Ritsumeikan Univ. (Japan); Takahiro Kitada, Toshiro Isu, Univ. of Tokushima (Japan); Mikhail A. Patrashin, Iwao Hosako, National Institute of Information and Communications Technology (Japan). . . . . [8353-32]

Standby Oral/Poster Presentation

This poster may also be given as an oral presentation in this session.

MWIR and LWIR photodetectors made of InAs/InAsSb Type-II superlattices, Oray O. Cellek, Ha Sul Kim, Elizabeth H. Steenbergen, Hua Li, Zhiyuan Lin, Shi Liu, Yong-Hang Zhang, Arizona State Univ. (USA) [8353-143]

SESSION 5

Room: Conv. Ctr. 307 . . . . Tues. 11:30 am to 12:00 pm

Keynote Session

Session Chair: **Gabor F. Fulop,** Maxtech International, Inc. (USA)

11:30 am: **Advanced imaging R&D at DARPA-MTO** *(Keynote Presentation)*, Nibir K. Dhar, Defense Advanced Research Projects Agency (USA). [8353-29]

Lunch/Exhibition Break . . . . 12:00 to 1:30 pm

SESSION 6

Room: Conv. Ctr. 307 . . . . Tues. 1:30 to 6:20 pm

Type II Superlattice FPAs II

Session Chairs: **Meimei Z. Tidrow,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Manijeh Razeghi,** Northwestern Univ. (USA); **Lucy Zheng,** Institute for Defense Analyses (USA)

1:30 pm: **Performance enhancement of III-V superlattice infrared detectors by solving material and fabrication issues** *(Invited Paper)*, Meimei Z. Tidrow, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Lucy Zheng, Institute for Defense Analyses (USA). . . . . [8353-30]

2:00 pm: **1024 x 1024 LWIR SLS FPAs: status and characterization**, Mani Sundaram, Axel Reisinger, Richard Dennis, Kelly Patnaude, Douglas Burrows, Jason Bundas, Kim E. Beech, Ross Faska, Daniel Manitakos, QmagiQ, LLC (USA) . . . . [8353-35]

2:20 pm: **Temperature-dependent absorption derivative on InAs/GaSb Type II superlattices**, Brianna Klein, Nutan Gautam, Stephen A. Myers, Sanjay Krishna, Ctr. for High Technology Materials, Univ. of New Mexico (USA) . . . . [8353-33]

2:40 pm: **Electronic transport in InAs/GaSb type-II superlattices for infrared detector applications**, Gilberto A. Umana-Membreno, Hemendra Kala, Jarek Antoszewski, Lorenzo Faraone, The Univ. of Western Australia (Australia); Brianna Klein, Nutan Gautam, Maya Narayanan Kutty, Elena Plis, Sanjay Krishna, The Univ. of New Mexico (USA) . . . . [8353-34]

Coffee Break . . . . 3:00 to 3:30 pm

3:30 pm: **Passivation of type II InAs/GaSb superlattice photodetectors with atomic layer deposited Al_2O_3**, Omer Salihoglu, Abdullah Muti, Bilkent Univ. (Turkey); Kutlu Kutluer, Tunay Tansel, Rasit Turan, Middle East Technical Univ. (Turkey); Atilla Aydinli, Bilkent Univ. (Turkey) . . . . [8353-36]

3:50 pm: **Recent advances in 2 colors FPAs based on T2SL; InAs/GaSb** *(Invited Paper)*, Manijeh Razeghi, Northwestern Univ. (USA) . . . . [8353-31]

4:20 pm: **Analysis surface oxides on narrow band III-V semiconductors toward surface-leakage-free IR photodetectors**, Qin Wang, Acreo AB (Sweden); Mats Göthelid, Kista Photonics Research Ctr. (Sweden); Emmanuelle Göthelid, Uppsala Univ. (Sweden); Susanne Almqvist, Amir Karim, Acreo AB (Sweden); Oscar Gustafsson, Mattias Hammar, Kista Photonics Research Ctr. (Sweden); Jan Y. Andersson, Acreo AB (Sweden) . . . . [8353-37]

4:40 pm: **Unrelaxed InAsSb with novel absorption, carrier transport, and recombination properties for MWIR and LWIR photodetectors**, Dmitry Donetsky, Gregory Belenky, Ding Wang, Youxi Lin, Leon Shterengas, Gela Kipshidze, Stony Brook Univ. (USA); Wendy L. Sarney, Stefan P. Svensson, Harry Hier, U.S. Army Research Lab. (USA) . . . . [8353-38]

5:00 pm: **100mm GaSb substrate manufacturing for IRFPA epi growth**, Lisa P. Allen, J. Patrick Flint, Gregory Meshew, Gordon Dallas, John Trevethan, Galaxy Compound Semiconductors, Inc. (USA); Dmitri Lubyshev, Yueming Qiu, Amy W. Liu, Joel M. Fastenau, IQE Inc. (USA) . . . . [8353-39]

5:20 pm: **Large diameter ultra-flat epitaxy ready GaSb substrates: requirements for MBE grown advanced infrared detectors**, Mark J. Furlong, Rebecca J. Martinez, Sasson Amirhaghi, Brian Smith, Andrew Mowbray, Wafer Technology Ltd. (United Kingdom) . . . . [8353-40]

5:40 pm: **Competing technology for high-speed HOT-IR-FPAs** *(Invited Paper)*, Manijeh Razeghi, Northwestern Univ. (USA) . . . . [8353-91]

6:00 pm: **Dark current modeling of Type II superlattice diodes**, Antoni Rogalski, Military Univ. of Technology (Poland) . . . . [8353-41]

Standby Oral/Poster Presentation

This poster may also be given as an oral presentation in this session.

MWIR and LWIR photodetectors made of InAs/InAsSb Type-II superlattices, Oray O. Cellek, Ha Sul Kim, Elizabeth H. Steenbergen, Hua Li, Zhiyuan Lin, Shi Liu, Yong-Hang Zhang, Arizona State Univ. (USA) [8353-143]

Wednesday 25 April

Sessions 7, 8, 9 run concurrently with sessions 10,11,12.

SESSION 7

Room: Conv. Ctr. 307 . . . . Wed. 8:00 to 9:40 am

Emerging Uncooled Technologies

Session Chairs: **Colin E. Reese,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Charles M. Hanson,** Consultant in Infrared (USA)

8:00 am: **Uncooled silicon germanium oxide ($Si_xGe_{1-x}O_y$) thin films for infrared detection**, Muhammad L. Hai, Muhammad Hesan, Qi Cheng, Univ. of Missouri-Columbia (USA); Athanasios J. Syllaios, Sameer K. Ajmera, L-3 Electro-Optical Systems (USA); Mahmoud F. Almasri, Univ. of Missouri-Columbia (USA) . . . . [8353-105]

8:20 am: **Formation of GaN film on Si for microbolometer**, Yong Soo Lee, Dong-Seok Kim, Jong-Hoon Kim, Kyungpook National Univ. (Korea, Republic of); Young-Chul Jung, Kyungju Univ. (Korea, Republic of); Jung-Hee Lee, Kyungpook National Univ. (Korea, Republic of) . . . . [8353-43]

8:40 am: **Novel uncooled detector based on gallium nitride micromechanical resonators**, Mina Rais-Zadeh, Vikrant J. Gokhale, Sui Yu, Univ. of Michigan (USA) . . . . [8353-44]

9:00 am: **Silicon-based nanobolometer for multispectral room temperature IR detection**, Hyesog Lee, Tanner Research, Inc. (USA) . . . . [8353-45]

9:20 am: **Development of microbolometer with high fill factor and high mechanical stability by shared-anchor structure**, Taehyun Kim, Kimyung Kyung, Jae Hong Park, Young Su Kim, Sung Kyu Lim, Kyungmin Kim, Taejoong Lee, Kwyro Lee, National Nanofab Ctr. (Korea, Republic of); Christopher Welham, COVENTOR Europe (France); Hee Yeoun Kim, National Nanofab Ctr. (Korea, Republic of) . . . . [8353-46]

SESSION 10

Room: Conv. Ctr. 316 . . . . Wed. 8:00 to 10:00 am

Cryocoolers for IR Focal Plane Arrays

Session Chairs: **Alexander Veprik,** RICOR-Cryogenic & Vacuum Systems (Israel); **Ingo Rühlich,** AIM INFRAROT-MODULE GmbH (Germany); **Ray Radebaugh,** National Institute of Standards and Technology (USA)

8:00 am: **Thales cryogenics rotary cryocoolers for HOT applications**, Jean-Yves Martin, Jean-Marc Cauquil, Thales Cryogénie S.A. (France); Tonny Benschop, Thales Cryogenics B.V. (Netherlands); René J. Griot, Sébastien Freche, Thales Cryogénie S.A. (France) . . . . [8353-56]

8:20 am: **Update on MTTF figures for linear and rotary coolers of Thales cryogenics**, Willem van de Groep, Thales Cryogenics B.V. (Netherlands)[8353-57]

8:40 am: **Compact high-efficiency linear cryocooler in single-piston moving magnet design for HOT detectors**, Ingo Rühlich, Markus Mai, Carsten Rosenhagen, AIM INFRAROT-MODULE GmbH (Germany) . . . . [8353-58]

9:00 am: **RICOR's rotary cryocoolers development and optimization for HOT IR detectors**, Avishai Filis, Zvi Bar-Haim, Tomer Havatzelet, Moshe Barak, RICOR-Cryogenic & Vacuum Systems (Israel) . . . . [8353-59]

9:20 am: **Linear cryogenic coolers for HOT infrared detectors**, Alexander Veprik, Sergey V. Riabzev, RICOR-Cryogenic & Vacuum Systems (Israel) . . . . [8353-60]

9:40 am: **Experimental demonstration of cryocooler electronics with multiple mechanical cryocooler types**, Jeremy J. Freeman, Carl S. Kirkconnell, J. Brian Murphy, Robert K. Ito, Iris Technology Corp. (USA) . . . . [8353-61]

Coffee Break . . . . 10:00 to 10:30 am

Sessions 7, 8, 9 run concurrently with sessions 10,11,12.

SESSION 8

Room: Conv. Ctr. 307 . . . . .Wed. 9:40 to 11:50 am

Uncooled FPAs and Applications

Session Chairs: **Jean-Luc M. Tissot,** ULIS (France); **Masafumi Kimata,** Ritsumeikan Univ. (Japan); **Avraham Fraenkel,** SCD Semiconductor Devices (Israel)

9:40 am: **Uncooled detector development at Raytheon**, Stephen H. Black, Raytheon Co. (USA) . . . . [8353-47]

Coffee Break . . . . 10:00 to 10:30 am

10:30 am: **Easy to use uncooled ¼ VGA 17 µm FPA development for compact and low-power systems**, Jean-Luc M. Tissot, Patrick Robert, ULIS (France) . . . . [8353-49]

10:50 am: **2-million-pixel SOI diode uncooled IRFPA with 15µm pixel pitch**, Daisuke Takamuro, Tomohiro Maegawa, Yasuaki Ohta, Takaki Sugino, Yasuhiro Kosasayama, Takahiro Ohnakado, Hisatoshi Hata, Masashi Ueno, Hiroshi Ohji, Mitsubishi Electric Corp. (Japan); Ryota Sato, Haruyoshi Katayama, Tadashi Imai, Munetaka Ueno, Japan Aerospace Exploration Agency (Japan) . . . . [8353-50]

11:10 am: **SCD µ-Bolometer VOx infrared high-end detector development**, Udi Mizrahi, Fabian Schapiro, Leonid Bikov, Aviho Giladi, Niv Shiloah, Igor Pivnik, Shimon Elkind, Shay Maayani, Emanuel Mordechai, Asaf Amsterdam, Ilan Vaserman, Oran Farbman, Yoav Hirsh, SCD Semiconductor Devices (Israel); Avi Tuito, Israel Ministry of Defense (Israel); Michael Ben-Ezra, SCD Semiconductor Devices (Israel) . . . . [8353-51]

11:30 am: **Current progress on pixel level packaging for uncooled IRFPA**, Geoffroy Dumont, Wilfried Rabaud, Jean-Jacques Yon, Laurent Carle, Valérie Goudon, Claire Vialle, Agnès Arnaud, CEA-LETI-Minatec (France) . . . . . [8353-52]

Oral Standby Presentation

This presentation may be given in this session, and will also be given in Session 18 on Friday.

An uncooled microbolometer focal plane array using bias heating for resistance nonuniformity compensation, Murat Tepegoz, Alperen Toprak, Alp Oguz, Sukru Senveli, Eren Canga, Yusuf Tanrikulu, Tayfun Akin, Middle East Technical Univ. (Turkey) . . . . [8353-146]

Lunch/Exhibition Break . . . . 11:50 am to 1:30 pm

SESSION 11

Room: Conv. Ctr. 316 . . . . .Wed. 10:30 to 11:50 am

IR Optics I

Session Chairs: **Jay N. Vizgaitis,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Christopher C. Alexay,** StingRay Optics, LLC (USA)

10:30 am: **Common aperture multispectral optics for military applications**, Nicholas A. Thompson, Qioptiq Ltd. (United Kingdom) . . . . [8353-62]

10:50 am: **Multi-field of view see-spot optics**, Scott Lilley, Jay N. Vizgaitis, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Jonathan E. Everett, Robert Spinazzola, General Dynamics-Global Imaging Technologies (USA) . . . . [8353-66]

11:10 am: **Tailored thermal emission from sub-wavelength diffractive optical elements**, Adam M. Jones, College of Optical Sciences, The Univ. of Arizona (USA) and Sandia National Labs. (USA); Shanalyn A. Kemme, David A. Scrymgeour, Michael J. Cich, Sally Samora, Sandia National Labs. (USA); Robert A. Norwood, College of Optical Sciences, The Univ. of Arizona (USA) . . [8353-64]

11:30 am: **Low-reflecting DLC coating on IR substrates**, Mordechai Gilo, Ophir Optronics Ltd. (Israel) . . . . [8353-65]

Lunch/Exhibition Break . . . . 11:50 am to 1:30 pm

Defense, Security, and Sensing Facility Maps:

Baltimore Convention Center pp. 3–4
Hilton Baltimore p. 5

Sessions 7, 8, 9 run concurrently with sessions 10,11,12.

SESSION 9

Room: Conv. Ctr. 307 . . . . Wed. 1:30 to 5:40 pm

Smart Processing

Joint Session with Conference 8355

Session Chairs: **Richard L. Espinola,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Endre Repasi,** Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany); **Paul L. McCarley,** Air Force Research Lab. (USA); **John T. Caulfield,** Cyan Systems (USA)

1:30 pm: **Infrared detector size: how low should you go?**, Ronald G. Driggers, U.S. Naval Research Lab. (USA); Richard H. Vollmerhausen, Univ. of Delaware (USA); Joseph Reynolds, U.S. Army RDECOM CERDEC Night Vision & Electronic Sensors Directorate (USA); Gerald C. Holst, Consultant (USA) . . . . [8355-23]

1:50 pm: **An information-theoretic perspective on the challenges and advances in the race toward 12µm pixel pitch for megapixel uncooled infrared imaging**, Christel-Loic Tisse, MTech Imaging Pte. Ltd. (Singapore); Arnaud A. Crastes, Jean-Luc M. Tissot, ULIS (France). . . . . [8353-53]

2:10 pm: **Implementation of intensity ratio change and LOS rate change algorithms for imaging infrared trackers**, Claude R. Viau, Tactical Technologies Inc. (Canada) . . . . [8355-25]

2:30 pm: **Flexible readout and integration sensor (FRIS): a bio-inspired, system-on-chip, event-based readout architecture**, Joseph H. Lin, Philippe O. Pouliquen, Andreas G. Andreou, The Johns Hopkins Univ. (USA); Charbel G. Rizk, Arnold C. Goldberg, The Johns Hopkins Univ. Applied Physics Lab. (USA) . . . . [8353-54]

Coffee/Exhibition Break. . . . . 2:50 to 4:00 pm

4:00 pm: **ADMIRE: a locally adaptive single-image, non-uniformity correction and denoising algorithm: application to uncooled IR camera**, Yohann Tendero, École Normale Supérieure de Cachan (France); Jerome Gilles, Univ. of California, Los Angeles (USA) . . . . [8353-55]

4:20 pm: **Turbulence compensation: an overview**, Adam W. M. van Eekeren, Klamer Schutte, Judith Dijk, Piet B. W. Schwering, Miranda van Iersel, TNO Defence, Security and Safety (Netherlands) . . . . [8355-26]

4:40 pm: **A real-time atmospheric turbulence mitigation and superresolution solution for infrared imaging systems**, Douglas R. Droege, L-3 Communications Cincinnati Electronics (USA); Russell C. Hardie, L-3 Communications Cincinnati Electronics (USA) and Univ. of Dayton (USA); Brian S. Allen, Alexander J. Dapore, Jon C. Blevins, L-3 Communications Cincinnati Electronics (USA) . . . . . [8355-27]

5:00 pm: **Turbulence degradation and mitigation performance for handheld weapon ID**, Richard L. Espinola, Sameer Aghera, Jason Miller, U.S. Army RDECOM CERDEC Night Vision & Electronic Sensors Directorate (USA) [8355-28]

5:20 pm: **Patch-based local turbulence compensation in anisoplanatic conditions**, Adam W. M. van Eekeren, Maarten Kruithof, Klamer Schutte, Judith Dijk, Miranda van Iersel, Piet B. W. Schwering, TNO Defence, Security and Safety (Netherlands) . . . . [8355-29]

SESSION 12

Room: Conv. Ctr. 316 . . . . Wed. 1:30 to 5:50 pm

IR Optics II

Session Chairs: **Christopher C. Alexay,** StingRay Optics, LLC (USA); **Jay N. Vizgaitis,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

1:30 pm: **Planar integrated plasmonic mid-IR spectrometer**, Christopher J. Fredricksen, LRC Engineering, Inc. (USA); Justin W. Cleary, Air Force Research Lab. (USA); Walter R. Buchwald, Solid State Scientific Corp. (USA); Pedro Figueiredo, Janardan Nath, Gautam Medhi, Imen Rezadad, Javaneh Boroumand, Robert E. Peale, Univ. of Central Florida (USA) . . . . [8353-63]

1:50 pm: **Integration of wide field-of-view imagery functions in a detector dewar cooler assembly**, Guillaume Druart, Florence de la Barrière, Nicolas Guérineau, ONERA (France); Gilles Lafargues, Manuel Fendler, Nicolas Lhermet, CEA-LETI (France); Jean Taboury, Institut d'Optique Graduate School (France); Yann Reibel, SOFRADIR (France); Jean-Baptiste Moullec, Direction Générale de L'armement (France) . . . . [8353-67]

2:10 pm: **Infrared focal plane array with a built-in stationary Fourier-transform spectrometer: recent technological advances**, Nicolas Guérineau, Yann Ferrec, Sylvain Rommeluère, Frédéric Gillard, Florence de la Barrière, Sidonie Lefebvre, ONERA (France); Gilles Lasfargues, Manuel Fendler, Commissariat à l'Énergie Atomique (France) . . . . [8353-68]

2:30 pm: **Laser designator protection filter for see-spot thermal imaging systems**, Ariela Donval, Tali Fisher, Ofir Lipman, Moshe Oron, KiloLambda Technologies, Ltd. (Israel) . . . . [8353-70]

Coffee/Exhibition Break. . . . . 2:50 to 3:50 pm

3:50 pm: **Passive athermalization of two-lens designs in 8-12micron waveband**, Norbert Schuster, Umicore Electro-Optic Materials (Belgium); John Franks, Umicore Coating Services (United Kingdom) . . . . [8353-71]

4:10 pm: **Advantages of using engineered chalcogenide glass for color corrected, passively athermalized LWIR imaging systems**, Scott W. Sparrold, Katie Schwertz, Adam Bublitz, Edmund Optics Inc. (USA). . . . . [8353-72]

4:30 pm: **Qualification and metrology for US-produced chalcogenides**, Nathan Carlie, SCHOTT North America, Inc. (USA) . . . . [8353-73]

4:50 pm: **Material trades between Be, SiC, and VQ aluminum for tactical systems: update referencing the current state-of-the-art**, Christopher J. Duston, Tony Hull, L-3 Integrated Optical Systems Division (USA) . . . . . [8353-74]

5:10 pm: **Mid-spatial frequency matters: examples of the control of the power spectral density and what that means to the performance of imaging systems**, Tony Hull, L-3 Integrated Optical Systems Division (USA) and The Univ. of New Mexico (USA); Michael J. Riso, John M. Barentine, L-3 Integrated Optical Systems Division (USA). . . . . [8353-75]

5:30 pm: **Advanced in shutter drive technology to enhance man-portable IR cameras**, David W. Durfee, CVI Melles Griot (USA) . . . . [8353-142]

Thursday 26 April

SESSION 13

Room: Conv. Ctr. 307 . . . . Thurs. 8:00 to 9:20 am

Active Imaging

Session Chairs: **Stefan T. Baur,** Raytheon Co. (USA); **Ingmar G. Renhorn,** Swedish Defence Research Agency (Sweden)

8:00 am: **Low-noise GHz bandwidth 16-channel photoreceivers for lidar imaging applications**, Xiaogang Bai, Ping Yuan, Paul A. McDonald, Joseph C. Boisvert, James J. Chang, Robyn L. Woo, Eduardo L. Labios, Rengarajan Sudharsanan, Spectrolab, Inc., A Boeing Co. (USA); Michael A. Krainak, Guangning Yang, Xiaoli Sun, Wei Lu, NASA Goddard Space Flight Ctr. (USA) . . . . [8353-76]

8:20 am: **Advances in ladar components and subsystems at Raytheon**, Michael D. Jack, Raytheon Co. (USA). . . . . [8353-77]

8:40 am: **Small pixel pitch APD solutions for active and passive imaging**, Yann Reibel, Alexandre Kerlain, Gwladys Bonnouvrier, David Billon-Lanfrey, SOFRADIR (France); Johan Rothman, Laurent R. Mollard, Eric De Borniol, Gérard L. Destefanis, CEA-LETI (France) . . . . [8353-78]

9:00 am: **Development of low-excess noise SWIR APDs**, Xiaogang Bai, Ping Yuan, Paul A. McDonald, Joseph C. Boisvert, James J. Chang, Rengarajan Sudharsanan, Spectrolab, Inc., A Boeing Co. (USA) . . . . [8353-79]

SESSION 14

Room: Conv. Ctr. 307 . . . . Thurs. 9:20 am to 12:05 pm

HgCdTe I

Session Chairs: **Joseph G. Pellegrino,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Michel Vuillermet,** SOFRADIR (France)

9:20 am: **Mercury cadmium telluride (HgCdTe) passivation by advanced thin conformal Al_2O_3 films**, Richard Fu, James Pattison, Andrew Chen, Osama Nayfeh, U.S. Army Research Lab. (USA). . . . . [8353-80]

9:40 am: **12µm pixel pitch development for 3-side buttable megapixel MW FPAs**, Peter Thorne, Harald J. Weller, Les G. Hipwood, SELEX Galileo Infrared Ltd. (United Kingdom) . . . . [8353-81]

Coffee Break . . . . 10:00 to 10:30 am

10:30 am: **Status of MCT focal plane arrays in France**, Michel Vuillermet, David Billon-Lanfrey, SOFRADIR (France); Gérard L. Destefanis, CEA-LETI (France) . . . . [8353-82]

10:50 am: **State-of-the-art MCT IR-modules with enhanced long-term and cycle stability**, Rainer Breiter, Joachim C. Wendler, Holger Lutz, Stefan Rutzinger, Timo Schallenberg, Johann Ziegler, AIM INFRAROT-MODULE GmbH (Germany) . . . . [8353-83]

11:10 am: **SWIR and NIR MCT arrays grown by MOVPE for astronomy applications**, Les G. Hipwood, Ian M. Baker, Paul Abbott, Nick Shorrocks, Chris D. Maxey, SELEX Galileo Infrared Ltd. (United Kingdom); Naidu Bezawada, David C. Atkinson, UK Astronomy Technology Ctr. (United Kingdom). . . . . [8353-84]

11:30 am: **Very long wavelength infrared detection with p-on-n LPE HgCdTe**, Nicolas Baier, Laurent R. Mollard, Olivier Gravrand, Gérard L. Destefanis, Guillaume Bourgeois, Jean-Paul Zanatta, Commissariat à l'Énergie Atomique (France); Patricia Pidancier, SOFRADIR (France); Laurie Tauziède, Centre National d'Etudes Spatiales (France). . . . . [8353-85]

11:50 am: **LWIR and VLWIR MCT technologies and detectors development at Sofradir for space applications**, Cedric Leroy, Patricia Pidancier, Philippe Chorier, SOFRADIR (France); Gérard L. Destefanis, CEA-LETI (France) [8353-115]

Lunch/Exhibition Break . . . . 12:05 to 1:30 pm

SESSION 15

Room: Conv. Ctr. 307 . . . . Thurs. 1:30 to 2:30 pm

HgCdTe II

Session Chairs: **Michel Vuillermet,** SOFRADIR (France); **Joseph G. Pellegrino,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

1:30 pm: **Electrical characterisitcs of a MOVPE grown MWIR N+p(As)HgCdTe heterostructure photodiode build on a GaAs substrate**, Roger E. DeWames, U.S. Army Night Vision & Electronic Sensors Directorate (USA). . . . . [8353-86]

1:50 pm: **State of MBE technology at AIM**, Johann Ziegler, Jan Wenisch, Detlef Eich, Holger Lutz, Timo Schallenberg, Richard Wollrab, AIM INFRAROT-MODULE GmbH (Germany). . . . . [8353-87]

2:10 pm: **HgCdTe photon trapping detectors for mid-wavelength infrared (MWIR) high operating temperature (HOT) focal plane arrays**, Kasey D. Smith, Justin G. A. Wehner, Aaron M. Ramirez, Edward P. Smith, Raytheon Co. (USA) . . . . [8353-88]

Standby Oral/Poster Presentation

This poster may also be given as an oral presentation in this session.

Laser power and temperature dependence on laser beam induced current signal in As-doped p-type HgCdTe, Y. Chen, W. Hu, X. Chen, Z. Ye, Shanghai Institute of Technical Physics (China); J. Wang, Univ. of Science and Technology of China (China); C. Lin, X. Hu, W. Lu, Shanghai Institute of Technical Physics (China) . . . . [8353-137]

SESSION 16

Room: Conv. Ctr. 307 . . . . Thurs. 2:30 to 6:00 pm

HOT: High-Operating Temperature FPAs

Session Chairs: **Michael T. Eismann,** Air Force Research Lab. (USA); **Stuart B. Horn,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

2:30 pm: **MWIR mercury cadmium telluride detectors for high operating temperatures** *(Invited Paper)*, Les G. Hipwood, Peter Knowles, Luke Pillans, Richard Ash, Nick Shorrocks, Darren Vincent, SELEX Galileo Infrared Ltd. (United Kingdom) . . . . [8353-89]

2:50 pm: **HOT MWIR HgCdTe performance on CZT and alternative substrates** *(Invited Paper)*, Joseph G. Pellegrino, Roger E. DeWames, Patrick G. Maloney, Curtis Billman, U.S. Army Night Vision & Electronic Sensors Directorate (USA) . . . . [8353-90]

3:10 pm: **High operating temperature $InAs_{1-x}Sb_x$ diode and bariode photodetectors** *(Invited Paper)*, Philip Klipstein, Daniel Aronov, Eyal Berkowicz, Maya Brumer, Avraham Fraenkel, Alexander Glozman, Steve Grossman, Olga Klin, Inna Lukomsky, Osnat Magen, Itay Shtrichman, Noam Snapi, Michael Yassen, Eliezer Weiss, SCD Semiconductor Devices (Israel) . . . . [8353-92]

Coffee Break . . . . 3:30 to 4:00 pm

4:00 pm: **Photoconductive gain in barrier heterostructure infrared detectors**, Stephen A. Myers, Nutan Gautam, Elena Plis, Ctr. for High Technology Materials, Univ. of New Mexico (USA); Christian P. Morath, Vincent M. Cowan, Air Force Research Lab. (USA); Sanjay Krishna, Ctr. for High Technology Materials, Univ. of New Mexico (USA) . . . . [8353-93]

4:20 pm: **Numerical simulation of InAsSb/AlAsSb nBn detector arrays**, Jonathan Schuster, Craig A. Keasler, Boston Univ. (USA); Marion B. Reine, Consultant in Infrared Detectors (USA); Enrico Bellotti, Boston Univ. (USA) . . . . [8353-94]

4:40 pm: **320 × 256 complementary barrier infrared detector focal plane array for longwave infrared imaging**, Jean Nguyen, Sir B. Rafol, Alexander Soibel, Arezou Khoshakhlagh, David Z. Y. Ting, John K. Liu, Jason M. Mumolo, Sarath D. Gunapala, Jet Propulsion Lab. (USA) . . . . [8353-95]

5:00 pm: **High operating temperature midwave quantum dot barrier infrared detector (QD-BIRD)**, David Z. Y. Ting, Alexander Soibel, Cory J. Hill, Sam A. Keo, Jason M. Mumolo, Sarath D. Gunapala, Jet Propulsion Lab. (USA). . . . . [8353-96]

5:20 pm: **MWIR $InAs_{1-x}Sb_x$ nCBn detectors data and analysis**, Arvind I. D'Souza, Ernest W. Robinson, Adrian C. Ionescu, Daniel Okerlund, DRS Sensors & Targeting Systems, Inc. (USA); Terrence J. deLyon, Rajesh D. Rajavel, Hasan Sharifi, Daniel Yap, HRL Labs., LLC (USA); Nibir K. Dhar, Defense Advanced Research Projects Agency (USA); Priyalal S. Wijewarnasuriya, U.S. Army Research Lab. (USA); Christoph H. Grein, Univ. of Illinois at Chicago (USA) . . . . [8353-97]

5:40 pm: **Improved IR detectors to swap heavy systems for SWaP,** Alain Manissadjian, Yann Reibel, Laurent Rubaldo, SOFRADIR (France); Laurent R. Mollard, Delphine Brelier, CEA-LETI (France) . . . . [8353-98]

POSTERS–THURSDAY

Room: Conv. Ctr. Hall A . . . . Thurs. 6:00 to 7:30 pm

All symposium attendees are invited to attend the poster sessions. Come view the high-quality papers that are presented in this alternative format, and interact with the poster author who will be available for discussion. Enjoy light refreshments while networking with colleagues in your field. Attendees are required to wear their conference registration badges to the poster sessions.

Authors may set-up their posters between 10:00 am and 5:00 pm the day of their poster. Posters that are not set-up by the 5:00 pm cut-off time will be considered no-shows and their manuscripts may not be published. Poster authors should be at their papers from 6:00 pm to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any papers left on the boards at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Multispectral detection of small vessels in infrared, Rafal Dulski, Military Univ. of Technology (Poland); Stanislaw Milewski, Polish Naval Academy (Poland); Mariusz Kastek, Piotr Trzaskawka, Marek Zyczkowski, Military Univ. of Technology (Poland) . . . . [8353-22]

Thermoelectric sensors for analytical measurement applications, Frank Hänschke, Ernst Kessler, Ulrich Dillner, Uwe Schinkel, Andreas Ihring, Hans-Georg Meyer, Institut für Photonische Technologien e.V. (Germany) . . . [8353-110]

Passivation effect on the noise characteristics of midwave infrared InAs/GaSb superlattice photodiodes, Tunay Tansel, Kutlu Kutluer, Rasit Turan, Middle East Technical Univ. (Turkey) . . . . [8353-117]

Studies on a novel mask technique to depress side-wall processing damage of ICP-etched HgCdTe trenches, Zhenhua Ye, Weida Hu, Wenting Yin, Jingguo Huang, Chun Lin, Xiaoning Hu, Xiaoshuang Chen, Wei Lu, Li He, Shanghai Institute of Technical Physics (China) . . . . [8353-119]

Study on optimizing the thickness of silicon window of WLP for IR sensor, Myeongho Song, National Nanofab Ctr. (Korea, Republic of) . . . . [8353-121]

SWIR imaging for facial image capture through tinted materials, Jason Ice, Neeru Narang, Cameron Whitelam, Nathan D. Kalka, Lawrence A. Hornak, Jeremy M. Dawson, Thirimachos Bourlai, West Virginia Univ. (USA) . . . . [8353-122]

Electrical characterization of (GaIn)Sb/InAs T2SLS detector materials using CV, hall effect, and capacitance transient measurements, Frederick J. Towner, Richard P. Leavitt, John T. Pham, John D. Bruno, Maxion Technologies, Inc. (USA); John W. Little, U.S. Army Research Lab. (USA). . . . . [8353-123]

Infrared detection module for optoelectronic sensors, Waldemar Gawron, Zbigniew Bielecki, Jacek Wojtas, Military Univ. of Technology (Poland); Dariusz Stanaszek, Jerzy Lach, Maciej Fimiarz, VIGO Systems S.A. (Poland) . . [8353-125]

Initial testing of a Si:As blocked-impurity-band (BIB) trap detector, Solomon I. Woods, Simon G. Kaplan, National Institute of Standards and Technology (USA); Timothy M. Jung, Jung Research and Development Corp. (USA); Adriaan C. Carter, Booz Allen Hamilton Inc. (USA); James E. Proctor, Jeptech Inc. (USA). . . . . [8353-126]

Commercially developed, mixed-signal CMOS process features for advanced ROICs and image sensor products in 0.18µm technology node, Arjun Kar-Roy, Paul Hurwitz, Richard Mann, Yasir Qamar, Li Dong, Samir Chaudhry, Robert Zwingman, David Howard, Marco Racanelli, TowerJazz (USA) . . . . [8353-127]

The estimation of thermal conductance values of µ-bolometers in a FPA with some selected structures and pitches, Seung-Man Park, Seungoh Han, Chang Suk Han, Hoseo Univ. (Korea, Republic of); Hee Chul Lee, KAIST (Korea, Republic of) . . . . [8353-128]

Design and realization of 144 x 7 TDI ROIC with hybrid integrated test structure, Huseyin Kayahan, Omer Ceylan, Melik Yazici, Muhammet B. Baran, Yasar Gurbuz, Sabanci Univ. (Turkey). . . . . [8353-129]

Adaptive bias voltage technique of IRFPA, Xiubao Sui, Qian Chen, Guohua Gu, Nanjing Univ. of Science & Technology (China) . . . . [8353-130]

Parylene supported 20µm*20µm uncooled thermoelectric infrared detector with high fill factor, Mohammad J. Modarres-Zadeh, Zachary Carpenter, Mark G. Rockley, Reza Abdolvand, Oklahoma State Univ. (USA) . . . . [8353-131]

Update on Tinsley Visible Guality (VQ) aluminum optics, Ankit Patel, L-3 Communications Tinsley Labs. Inc. (USA); Keith G. Carrigan, L-3 Integrated Optical Systems (USA) . . . . [8353-132]

Manufacturing status of Tinsley Visible Quality (VQ) bare aluminum, and an example of snap together assembly, Keith G. Carrigan, L-3 Integrated Optical Systems (USA). . . . . [8353-133]

Precise optomechanical characterization of assembled IR optics, Patrik Langehanenberg, Bernd Lueerss, Josef Heinisch, TRIOPTICS GmbH (Germany) . . . . [8353-134]

Evaluation of the effect of optical manufacturing tolerances on the performance of an infrared imager, Altug Uçar, Göktug G. Artan, Turgay Karakas, TÜBITAK SAGE (Turkey) . . . . [8353-135]

Modeling of dark current suppression in unipolar barrier infrared detectors, Jun Wang, Univ. of Science and Technology of China (China); Xiaoshuang Chen, Weida Hu, Yongguo Chen, Lin Wang, Wei Lu, Shanghai Institute of Technical Physics (China); Faqiang Xu, Univ. of Science and Technology of China (China) . . . . [8353-138]

The first fabricated dual-band uncooled infrared microbolometer detector with a tunable micro-mirror structure, Selcuk Keskin, Tayfun Akin, Middle East Technical Univ. (Turkey) . . . . [8353-144]

An analysis for the absorption enhancement using plasmonic structures on uncooled infrared detector pixels, Sevil Zeynep Lulec, Seniz E. Kucuk, Middle East Technical Univ. (Turkey); Enes Battal, Ali K. Okyay, Bilkent Univ. (Turkey); Yusuf Tanrikulu, Tayfun Akin, Middle East Technical Univ. (Turkey). . . . [8353-145]

Standby Oral/Poster Presentations

Room: Conv. Ctr. Hall A . . . . Thurs. 6:00 to 7:30 pm

Laser power and temperature dependence on laser beam induced current signal in As-doped p-type HgCdTe, Yongguo Chen, Weida Hu, Xiaoshuang Chen, Zhenhua Ye, Shanghai Institute of Technical Physics (China); Jun Wang, Univ. of Science and Technology of China (China); Chun Lin, Xiaoning Hu, Wei Lu, Shanghai Institute of Technical Physics (China) . . . . [8353-137]

MWIR and LWIR photodetectors made of InAs/InAsSb Type-II superlattices, Oray O. Cellek, Ha Sul Kim, Elizabeth H. Steenbergen, Hua Li, Zhiyuan Lin, Shi Liu, Yong-Hang Zhang, Arizona State Univ. (USA) . . . . [8353-143]

MT6425CA: a 640 X 512-25 µm CTIA ROCI for SWIR InGaAs detector arrays, Selim Eminoglu, Yigit Uygar Mahsereci, Caglar Altiner, Tayfun Akin, Mikro-Tasarim Ltd. (Turkey). . . . . [8353-147]

Friday 27 April

SESSION 17

Room: Conv. Ctr. 307 . . . . Fri. 8:00 to 9:20 am

QWIP and Q-DOT

Session Chair: **Eric M. Costard,** Alcatel-Thales III-V Lab. (France)

8:00 am: **Sub-monolayer InAs/InGaAs quantum dot infrared photodetectors**, Jun Oh Kim, Saumya Sengupta, Yagya D. Sharma, Ajit V. Barve, Ctr. for High Technology Materials, Univ. of New Mexico (USA); Sang Jun Lee, Sam Kyu Noh, Korea Research Institute of Standards and Science (Korea, Republic of); Sanjay Krishna, Ctr. for High Technology Materials, Univ. of New Mexico (USA) [8353-99]

8:20 am: **Solution-processed colloidal quantum dot photodiodes for low-cost SWIR imaging**, Ethan J. Klem, Jay S. Lewis, Chris Gregory, Garry Cunningham, Dorota Temple, RTI International (USA) . . . . [8353-100]

8:40 am: **Demonstration of high responsivity (~2.2 A/W) and detectivity (~10^{11} Jones) in the long wavelength (~10.2µm) from InGaAs/GaAs quantum dot infrared photodetector with quaternary $In_{0.21}Al_{0.21}Ga_{0.58}As$ capping**, Subhananda Chakrabarti, Sourav Adhikary, Indian Institute of Technology Bombay (India); Yigit Aytac, A. G. Unil Perera, Georgia State Univ. (USA) . . . . [8353-101]

9:00 am: **QWIP infrared detector production line results**, Michel Runtz, Yann Reibel, SOFRADIR (France); Nadia Brière de l'Isle, Alexandru Nedelcu, Hugues Facoetti, Eric M. Costard, Alcatel-Thales III-V Lab. (France); Vincent Guériaux, Véronique Besnard, Arnaud Mouette, Thales Optronique S.A. (France); William Johnston, Robert Craig, Thales Optronics Ltd. (United Kingdom) . . . . . [8353-102]

SESSION 18

Room: Conv. Ctr. 307 . . . . Fri. 9:20 to 12:10 am

Selected Detector Technologies

Session Chair: **John W. Devitt,** Georgia Tech Research Institute (USA)

9:20 am: **Design and development of carbon nanotube-based microbolometer for IR imaging applications**, Ashok K. Sood, Magnolia Optical Technologies, Inc. (USA); Jimmy Xu, Gustavo E. Fernandes, Brown Univ. (USA); Neil Goldsman, Univ. of Maryland, College Park (USA); Nibir K. Dhar, Defense Advanced Research Projects Agency (USA); Priyalal S. Wijewarnasuriya, U.S. Army Research Lab. (USA) . . . . [8353-103]

9:40 am: **Nano-antenna-enabled MWIR FPAs**, David W. Peters, Paul Davids, John F. Klem, Sandia National Labs. (USA) . . . . [8353-104]

10:00 am: **Lifetime prediction in vacuum packaged MEMS provided with integrated getter film**, Fabrizio Siviero, Antonio Bonucci, Andrea Conte, Marco Moraja, SAES Getters S.p.A. (Italy); Olivier Gigan, TRONICS Microsystems (France); Isabelle Thomas, Thales Avionics S.A. (France). . . . . [8353-106]

Coffee Break . . . . 10:20 to 10:50 am

10:50 am: **High-speed, large-area, p-i-n InGaAs photodiode linear array at 2-micron wavelength**, Abhay Joshi, Shubhashish Datta, Discovery Semiconductors, Inc. (USA) . . . . [8353-107]

11:10 am: **NIR/LWIR dual-band infrared photodetector with optical addressing**, Oray O. Cellek, Ha Sul Kim, Arizona State Univ. (USA); John L. Reno, Sandia National Labs. (USA); Yong-Hang Zhang, Arizona State Univ. (USA) . . . . [8353-109]

11:30 am: **InAs/InAsSb Type-II superlattice: a promising material for middle-wavelength and long-wavelength infrared applications**, Elizabeth H. Steenbergen, Oray O. Cellek, Hua Li, Xiaomeng Shen, Zhiyuan Lin, Ding Ding, Shi Liu, Qiang Zhang, Ha Sul Kim, Lu Ouyang, Jin Fan, Zhaoyu He, Preston Webster, Shane R. Johnson, David J. Smith, Yong-Hang Zhang, Arizona State Univ. (USA) . . . . [8353-136]

11:50 am: **An uncooled microbolometer focal plane array using bias heating for resistance nonuniformity compensation,** Murat Tepegoz, Alperen Toprak, Alp Oguz, Sukru Senveli, Eren Canga, Yusuf Tanrikulu, Tayfun Akin, Middle East Technical Univ. (Turkey) . . . . [8353-146]

Lunch Break . . . . 12:10 am to 1:10 pm

SESSION 19

Room: Conv. Ctr. 307 . . . . Fri. 1:10 to 2:50 pm

Various Applications of Selected Detector Technologies

Session Chairs: **Bjørn F. Andresen,** Israel Aerospace Industries-ELTA (Israel); **Paul R. Norton,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

1:10 pm: **IR CMOS: infrared enhanced silicon imager**, Martin U. Pralle, James E. Carey, Homayoon Haddad, SiOnyx Inc. (USA) . . . . [8353-111]

1:30 pm: **Development of low-flux SWIR radio-imaging systems to study nightglow emission**, Sophie Derelle, Pierre Simoneau, Joël R. Deschamps, Sylvain Rommeluère, ONERA (France); Michel Hersé, Guy Moreels, Observatoire de Besançon (France); Eric De Borniol, CEA-LETI (France); Olivier Pacaud, SOFRADIR (France). . . . . [8353-112]

1:50 pm: **Location precision analysis of stereo thermal anti-sniper detection system**, Yuqing He, Ya Lu, Yushi Hou, Weiqi Jin, Xiaoyan Zhang, Beijing Institute of Technology (China) . . . . [8353-140]

2:10 pm: **Development of the Compact InfraRed Camera (CIRC) for earth observation**, Eri Kato, Haruyoshi Katayama, Masataka Naitoh, Masatomo Harada, Ryoko Nakamura, Ryota Sato, Japan Aerospace Exploration Agency (Japan). . . . . [8353-114]

2:30 pm: **Application of advanced IR-FPA in high-sensitivity pushbroom SWIR hyperspectral imager**, Yueming Wang, Jian-yu Wang, Xiao-qiong Zhuang, Sheng-wei Wang, Shanghai Institute of Technical Physics (China) . . . . [8353-139]

Courses of Related Interest

SC1076 **Analog-to-Digital Converters for Digital ROICs** (Veeder) Tuesday, 8:30 am to 12:30 pm

SC152 **Infrared Focal Plane Arrays** (Dereniak, Hubbs) Monday, 1:30 to 5:30 pm

SC278 **Infrared Detectors** (Dereniak) Monday, 8:30 am to 12:30 pm

SC835 **Infrared Systems - Technology & Design** (Daniels) Monday, 8:30 am to 5:30 pm

SC892 **Infrared Search and Track Systems** (Schwering) Thursday, 8:30 am to 5:30 pm

SC900 **Uncooled Thermal Imaging Detectors and Systems** (Hanson) Monday, 8:30 am to 5:30 pm

SC067 **Testing and Evaluation of E-O Imaging Systems** (Holst) Tuesday, 8:30 am to 5:30 pm

SC1000 **Introduction to Infrared and Ultraviolet Imaging Technology** (Richards) Wednesday, 1:30 to 5:30 pm

SC789 **Introduction to Optical and Infrared Sensor Systems** (Shaw) Wednesday, 8:30 am to 5:30 pm

SC154 **Electro-Optical Imaging System Performance** (Holst) Friday, 8:30 am to 5:30 pm

SC713 **Engineering Approach to Imaging System Design** (Holst) Monday, 8:30 am to 5:30 pm

SC950 **Infrared Imaging Radiometry** (Richards) Tuesday, 8:30 am to 5:30 pm

SC1073 **Radiometry and its Practical Applications** (Grant) Monday, 8:30 am to 5:30 pm

SC720 **Cost-Conscious Tolerancing of Optical Systems** (Youngworth) Tuesday, 8:30 am to 12:30 pm

SC181 **Predicting Target Acquisition Performance of Electro-Optical Imagers** (Vollmerhausen) Wednesday, 8:30 am to 5:30 pm

See Course Materials Desk, located near the SPIE Registration Area, Pratt St. Lobby, Open during Registration Hours

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附件二、展覽會廠商宣傳資料摘要

以色列 SCD 公司-美國分公司熱像產品

- 偵檢元件：640*512(15 μm) InSb photodector
- 操作率：> 99.5%
- 波長範圍：3.6 ~ 4.9 μm(標準濾光片)、1.5 ~ 5.5 μm(無濾光片)
- 致冷器型式：Rotary Stirling Cooler

SCD USA
SEMI CONDUCTOR DEVICES USA

SCD.USA LLC
1901 S Harbor City Blvd. Suite #806,
Melbourne, FL 32901
Phone: (321) 724-6146 • Toll-free: (866) 9SCDUSA (972-3872) • Fax: (321) 724-6267
Email: contactus@scdusa.com

Imaging Sensor	
Detector Type	Photovoltaic Indium Antimonide (InSb)
Spectral Range	3.6 - 4.9μm with Standard Cold Filter 1.5 - 5.5μm Broadband Custom Options Available
Resolution	640 x 512 (328K Pixel - Windowable)
Pitch	15 x 15μm
Optical Format	1/2"
Operability	≥99.5%
Dynamic Range	75dB (as per Video ADC)
Responsivity (NEdT)	< 15mK Typical
Readout	Snapshot w/ Integrate while Read Mode or Integrate then Read Mode
Well Capacity	6.5 Me-
Integration Time	>0.5μsec, <33msec Adjustable

Dewar / Cooler	
Cooler Type	Closed Cycle Integral or Split Rotary Stirling
Detector Operating Temperature	77°K or 95°K Depending on InSb Material
Cooling Capacity	1/4W, 1/2W, 3/4W or 1W
Cooldown Time	<6 Minutes @ 23°C Ambient Typical <8 Minutes @ 60°C Ambient Typical
Cooler MTTF	>10,000 Hours Typical
Cold Shield F#	f/4.0 or f/5.5 Typical, Others Available
Cold Shield Height	19.7mm Typical, Others Available

Electronics		
Display Formats	480i29.97	480p59.94
Digital Display Video	Parallel BT.656 or Serial SMPTE 259M SD-SDI	Consult Factory
Analog Display Video	NTSC (with S-VIDEO Option)	Component RGB or YPbPr
KLV Metadata Insertion	SMPTE 334M, 335M, 336M Compatible on Serial Digital Display Video	
Digital Data Streaming	Camera Link Base or CoaXPress (Options)	
Video Compression	H.264 Baseline Profile via Ethernet (Optional)	NA
Command and Control	RS-232C, RS-422, Camera Link COM or Ethernet	
Synchronization Modes	Internal / External Sync and Clock	
Maximum Frame Rate - Full Frame	29.97Hz on Digital Data Stream Interface (Faster Available - Consult Factory)	
Non-Uniformity Correction Tables	Up to 4 Available	
Processing Expansion	Coprocessor w/ FPGA for Video Tracking or DSP for Analytics (Optional)	
Lens-Direct Technology	Native Support for Motorized Focus and Continuous Zoom Lenses	

Image Presentation	
Edge Enhancement	"Optimal" Process / User Adjustable Threshold and Boost
AGC/ALC	Full Manual, ROI Linear (with Manual Adjust) or ROI Histogram (with Manual Adjust)
Electronic Zoom	2X or 4X Edge Preserving
Display Color Formats	Monochrome, False Color w/ Normal or Inverted Polarity
Color Palettes	8 Monochrome and False Color
Symbology Overlay	76x2 Character Upper / 76x1 Character Lower Alphanumeric Text Display
Reticle	128x128 Dot Bit-Mapped / Central FOV

Special Features	
Calibration Flag	Open / Closed (Optional)
Low-Level Mode Operation	Integration Time Switch

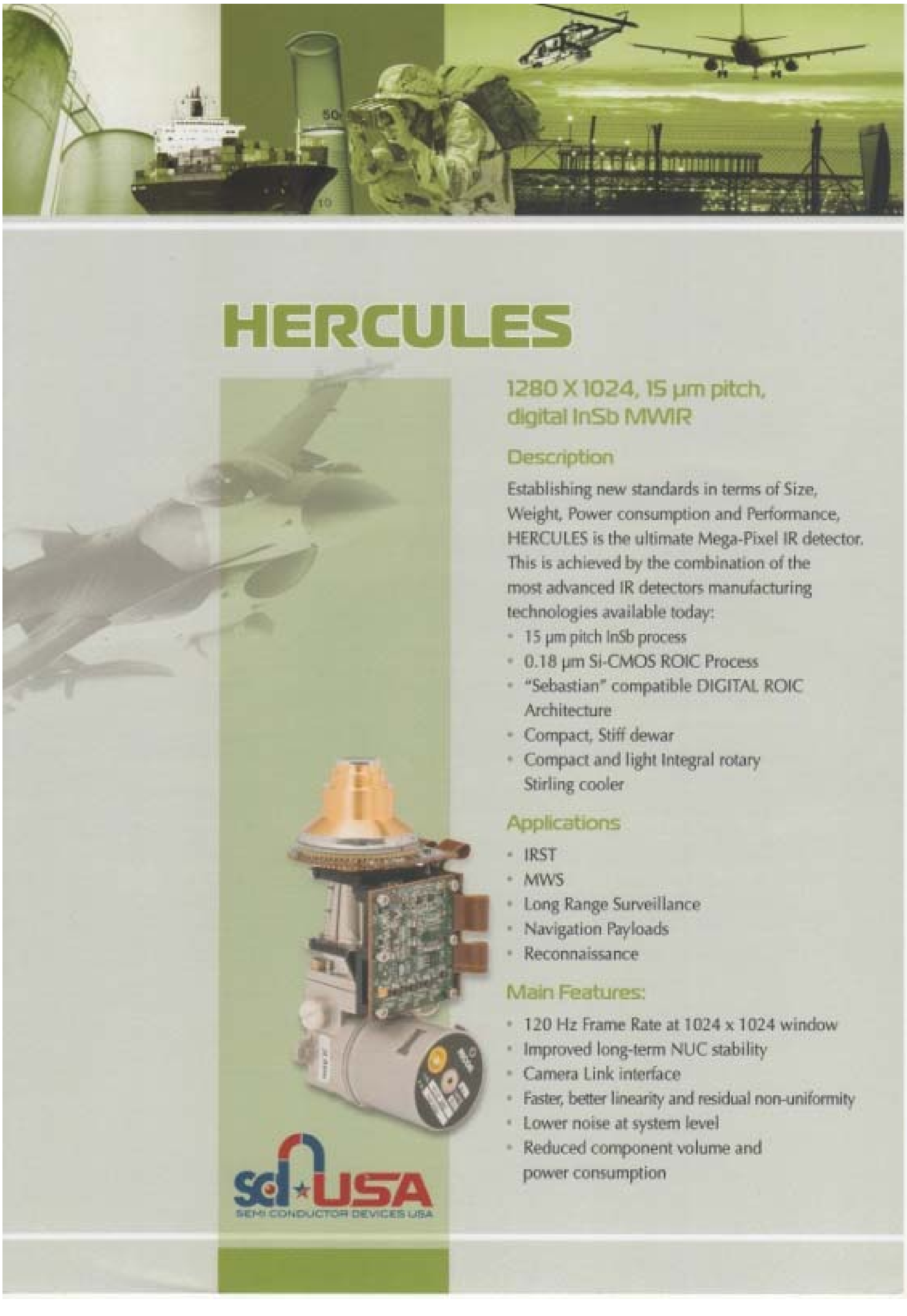
Optics	
Available f/4.0 Lenses	15 - 250mm, Continuous Zoom (optional 2.4x Extender) 15 - 300mm, Continuous Zoom (optional 2.0x Extender) 15 - 330mm, Continuous Zoom (optional 2.0x, 2.3x, 2.5x Extender)
Available f/5.5 Lenses	19 - 275mm, Continuous Zoom (optional 1.5x, 2.0x, 2.55x Extender) 20 - 320mm, Continuous Zoom (optional 2.0x, 2.3x Extender) 15 - 435mm, Continuous Zoom (optional 2.0x, 2.3x, 2.5x Extender)
Custom Lens Options	Consult Factory

General	
Power Input	+12VDC Nominal
Power Consumption	< 8W Capable @ 23°C Ambient Steady State (w/o Lens) < 12W Capable @ 23°C Ambient During Cooldown (w/o lens)
Weight	< 2 lbs. (w/o Lens)
Size	5.50 in L x 2.85 in H x 2.50 in W (Typical w/o lens)
Operating Temperature	-40°C to +65°C
Storage Temperature	-50°C to +70°C
Interface Connections	Quantity and Type Determined by Customer
Mounting	As needed, 2X 1/4 in - 20 with Enclosure, 4x Mounting Holes for Open Frame

The equipment described above may require US government authorization for export and diversion contrary to US Law is prohibited.
These features and specifications are subject to change without notice.

以色列 SCD 公司-美國分公司 IDDCA 產品- HERCULES

- 在尺寸、重量、消耗功率、元件特性等方面建立新典範，是最先進的百萬畫素等級的紅外線偵檢器。
- 偵檢元件：1280*1024(15 μm) InSb 2D array
- 致冷器型式：0.75W Ricor K548 或 K549 或 JT Cooler



以色列 SCD 公司-美國分公司偵檢元件產品- BIRD 640 WB

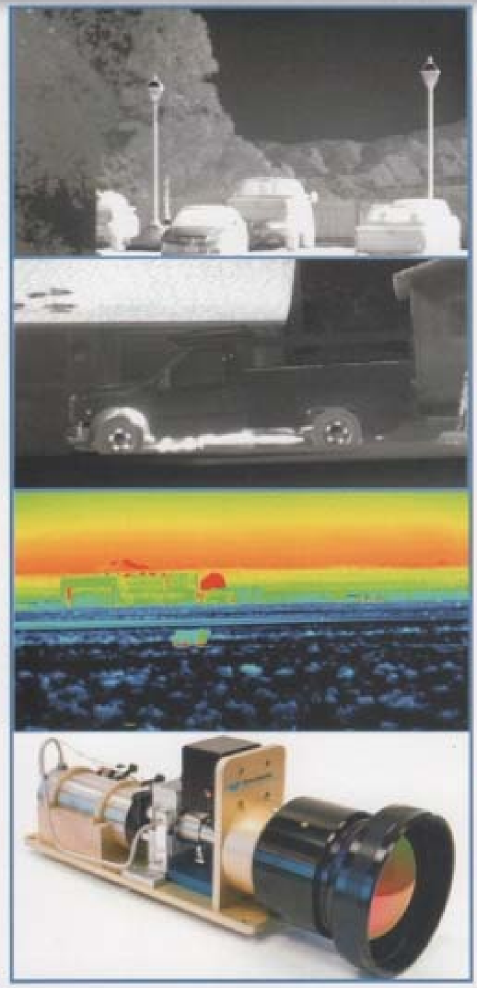
- 以標準型 Barrier IR Detector(BIRD) 640*480 非致冷型偵檢元件為基礎，可提供同時偵測中波段(3 ~ 5 μm)與長波段(8 ~ 14 μm)訊號。
- 偵檢元件：640*480(25 μm) VO_x microbolometer
- 操作率：> 99%

美國 NOVA SENSOR 公司熱像產品- Cruz MWIR 1280A

- 偵檢元件：1280*1024(12 μm)InSb
- 操作率：> 99.5%
- 波長範圍：3 ~ 5 μm
- 致冷器型式：Closed Cycle Stirling Cooler

NOVA SENSORS
A Teledyne Majority Owned Company

Cruz MWIR 1280A
Automatic Camera Exposure



Cruz MWIR 1280A
Automatic Camera Exposure

Detector

Type	InSb (SBF 207 digital FPA)
Spectral Range	<1 μm – 5.4 μm
Resolution	1280 x 1024 or 1280 x 720 (w/windowing)
Pixel Pitch	12 μm

Electronics and Data Rate

Integration Type	Snapshot
Integration Time	0 to 16 ms (8.3 ms at 120 Hz)
Dynamic Range	14 or 13 bits
Data Rate	79 megapixels per second
Max Frame Rate Full Window	>60 Hz
SubWindowing	Available upon request

Performance Specifications

NETD	<20 mK over backgrounds (-20 °C to 100 °C)
Well Capacity	2 million electrons
Operability	>99.5%

Camera Specifications

Sensor f/#	f/2.5 or f/4 (or custom)
Standard Spectral Range	3 μm - 5 μm (CO_2 notch available)
Sensor Cooling	Stirling closed cycle cooler
Lens Mount	Bayonet (custom as needed)
Power	39 watts steady state (20 °C ambient)

Communication and Data Transfer

Command, Control, Data Output	Camera Link output, RS-232 control
Meta-data	Yes – thru GUI or IRIG-B
Software	Nova IR and SDK available

Physical Characteristics

Size	10" x 3.5" x 4.5" (no lens - can be sized smaller depending on cooler)
Weight	7 lbs 10 oz
Environmental	Ruggedized to MIL-STD-810F

Optics

f/2.4: BWD = 33.1 mm
f/4: BWD = 52.0 mm

Everywhereyoulook™
CAMERAS BY TELEDYNE

For more information please contact Tony Vengel at (805) 245-9979
or go to our website at www.novasensors.com

TB-0633

美國 NOVA SENSOR 公司熱像產品- Cruz MWIR 640A

- 偵檢元件：640*480(20 μm)InSb
- 操作率：> 99.5%
- 波長範圍：3 ~ 5 μm
- 致冷器型式：Closed Cycle Stirling Cooler

NOVA SENSORS
A Teledyne Majority Owned Company

Cruz MWIR 640A

Cruz MWIR 640A

Detector

Type	InSb (SBF 191 digital FPA)
Spectral Range	<1 μm – 5.4 μm
Resolution	640 x 512 (w/windowing)
Pixel Pitch	20 μm

Electronics and Data Rate

Integration Type	Snapshot
Integration Time	<0.1 μs to full-frame time
Dynamic Range	14
Data Rate	40 megapixels/second
Max Frame Rate Full Window	60 Hz
SubWindowing	Available upon request

Performance Specifications

NETD	<20 mK
Well Capacity	7 million electrons
Operability	>99.5%

Camera Specifications

Sensor f/#	f/2.3 or f/4 (or custom)
Standard Spectral Range	3 μm - 5 μm (CO_2 notch available)
Sensor Cooling	Stirling closed cycle cooler
Lens Mount	Bayonet (custom as needed)
Power	10 watts steady state (20 °C ambient)

Communication and Data Transfer

Command, Control, Data Output	Camera Link output, RS-232 control
Meta-data	Yes – thru GUI or IRIG-B
Software	Nova IR and SDK available

Physical Characteristics

Size	5" x 3" x 3.5" (no lens)
Weight	1.175 lbs
Environmental	Ruggedized to MIL-STD-810F

Optics

f/2.3: BWD = 33.1 mm
f/4: BWD = 52.0 mm

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For more information please contact Tony Vengel at (805) 245-9979
or go to our website at www.novasensors.com

英國 SELEX Galileo 系列熱像產品- SLX Condor II

- 使用最新的第 3 代雙波段紅外線(Dual Waveband IR, DWIR)技術，提供在陸、海、空環境的最佳熱影像。
- 偵檢元件：640*512 HgCdTe detector array(配合光學掃描機制，可達 1280*1024)
- 操作波長：3 ~ 5 μm(MW)與 8 ~ 10 μm(LW)

SLX CONDOR II
HIGH PERFORMANCE DWIR THERMAL IMAGING CAMERA

SELEX Galileo's new SLX-Condor II thermal imaging camera uses the latest Dual Waveband Infra-Red (DWIR) "3rd Generation" detector technology to provide the optimum passive thermal images irrespective of environmental conditions in land, sea and airborne operations.

The DWIR camera uses the standard TV resolution "Condor-II" MCT detector array developed by SELEX Galileo under UK MOD funding. The detector is manufactured using SELEX Galileo's proprietary MOVPE on GaAs process and operates in two different spectral wavebands, at 3-5μm and 8-10μm. Coupled with SELEX Galileo's latest generation of advanced image processing electronics, the resulting camera produces near simultaneous images in both bands.

The SLX-Condor II camera enables the user to select the optimum thermal imaging waveband for the prevailing conditions at the time of operation. For the first time in a single camera, the natural resolution advantage of the MWIR waveband can be fully exploited without sacrificing any of the traditional advantages of the LWIR waveband.

Both wavebands can be displayed side-by-side on the video

KEY BENEFITS

- Affordable, high performance 3rd generation camera
- Dual waveband operating concurrently:
  - 3-5μm Midwave
  - 8-10μm Longwave
- Image resolution - 640 x 512 (1280 x 1024 with Microscan)
- Optional Microscan providing:
  - 1.3 Megapixel resolution imagery
  - and/or combined e-zoom and Microscan for enhanced narrow FoV capability: reducing lens size, complexity and cost
- Military specification
- Lightweight, compact design
- Flexible architecture enables remote location of processing electronics for small enclosures
- Ease of system integration
- Flexible video output and control interface
- Low through-life cost of ownership
- No ITAR-controlled components.

MWIR image

2-colour DWIR image (MWIR shown in blue, LWIR in red)

LWIR image

output for direct comparison of the images. The camera also enables both wavebands to be fused in real time to create a unique true two-colour thermal image of the scene, clearly showing spectral anomalies in the scene.

An integrated microscan module is optional, to provide 1.3-megapixel resolution in each waveband and enhanced range performance using digital zoom technology.

The SLX-Condor II DWIR camera has been designed as a compact, high performance unit which can be applied to a wide range of thermal imaging applications by system integrators and OEMs.

FEATURES

- Programmable configuration
- Auto or manual gain and offset, independently controlled in each waveband
- Single band MWIR or LWIR operation
- Frame Sequential Dual Waveband operation
- Simultaneous Dual Waveband operation in each frame
- User definable automatic gain and offset region
- User selectable image orientation permits camera to be mounted in any position
- User definable text displays and symbols
- Colour text and graphics
- MWIR & LWIR in camera image fusing
- Colour image mapping with user definable palette
- Freeze frame

TECHNICAL SPECIFICATIONS

Operating waveband	3 - 5μm 8 - 9.4μm
Resolution	640 x 512 (1280 x 1024 with optional Microscan)
Noise Equivalent Temperature Difference	
(Single band NETD)	15mK MWIR (typ.) 25mK LWIR (typ.)
(Simultaneous NETD)	24mK MWIR (typ.) 26mK LWIR (typ.)
Non-uniformity correction	User selectable 1, 2 or 3 point NUC
User control	RS422
Video	625 line 50 Hz 525 line 60 Hz RGB VESA
Digital video output	16 bit full dynamic range or 8 bit video. Optional DVI & HDMI
Dimensions (L x W x H)	195 x 115 x 95 mm (exc. lens)
Power supply	28V DC (Max 36V, Min 18V)
Power consumption	<40 watts operating
Weight	<4kg
Operating temperature	-40°C to +55°C
Environmental	DEFSTAN 00-35 MIL STD 810E810E

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加拿大 INO 公司熱像產品-HRXCAM 2048

- 使用最新的非致冷 microbolometer 偵檢器技術，提供高解析度/高靈敏度的最佳長波段熱影像。
- 偵檢元件：1024*768(17 μm) uncooled microbolometer
- 操作波長：7 ~ 14 μm

INO
CHALLENGING LIGHT FOR OUR PARTNERS

HRXCAM-2048

THERMAL INFRARED, HIGH RESOLUTION, MICRO-SCANNED CAMERA MODULE

INO is proud to introduce its thermal infrared, high-resolution, micro-scanned 2048 X 1536 pixel camera module. With its open architecture, this user-friendly module offers extensive flexibility with respect to integration. The HRXCAM-2048 camera module uses a state-of-the-art uncooled microbolometer detector for high-resolution/high-sensitivity imaging in the LWIR range. The 1024 X 768 pixel sensor is combined with a unique microscanned lightweight catadioptric lens.

The camera module, providing a 16-bit raw signal, is ideal for developers because it provides full access to the detector configuration parameters. TECless operation minimizes module size and power consumption. The camera module can be configured at the factory for outdoor operation over a large thermal range at maximum sensitivity. The device incorporates a catadioptric optical objective. Windowing capability provides flexibility in frame frequency, sensitivity, and field of view.

INO

CHALLENGING LIGHT
FOR OUR PARTNERS

MICROSCANNED LIGHTWEIGHT CATADIOPTRIC OPTICS

The HRXCAM-2048 is built around catadioptric optics. Catadioptric optics are based on refractive and reflective elements. Reflective elements, such as mirrors, can be made of light materials, such as aluminum, and are usually lighter than their refractive counterparts. Reflective architectures can also be intrinsically athermalized and used on wider wavebands. This requires fewer optical elements, resulting in reduced weight. By using a folded path, the optics can be made compact.

INO has designed catadioptric optics for wide field-of-view and large numerical aperture. These optics are designed to provide excellent infrared imaging performance with minimum weight. INO can also design and fabricate custom optics according to customer specifications and applications.

PRELIMINARY TECHNICAL SPECIFICATIONS

RESOLUTION	2048 x 1536 pixels
EFFECTIVE PIXEL PITCH	8.5 microns
EFFECTIVE FRAME RATE	12 fps
FPA	1024 x 768 pixel uncooled microbolometer, 17 micron pitch , 48 fps, Ulis UL05251
NETD (F/#:1.0, 300 K, 30 fps)	< 100 mK
READOUT MODE	Row per row
TECLESS OPERATION	Single detector parameter configuration for high-gain operation over a broad temperature range
OUTPUT	16-bit raw data at full frame rate on camera link
DETECTOR CONFIGURATION VIA GigE	All detector parameters can be adjusted inclu-ding input voltages, gain, and integration tiMe
TEMPERATURE	. Operating: -30 to 55 °C . Storage: -40 to 80 °C
MECHANICS	Integrated heat sink
SIZE	11.4 cm (Φ) x 27.6 cm
WEIGHT	1.6 kg
POWER SUPPLY	12 V
SOFTWARE	Control and operation software available

WAVEBAND	7 to 14 microns
FOCAL LENGTH	50.0 mm
EFFECTIVE F/#	F/1.05
FOV	24.55 degrees
RELATIVE ILLUMINA-TION	85% at 6 degrees
MICROSCAN RES-PONSE TIME	< 1.5 milliseconds
MANUAL FOCUS RANGE	10 meters to infinity
OPTICAL DIMENSIONS	72 mm diameter (78 mm with flange)
OPTICS MASS	750 grams without front window
ATHERMAL RANGE	-30 °C/60 °C

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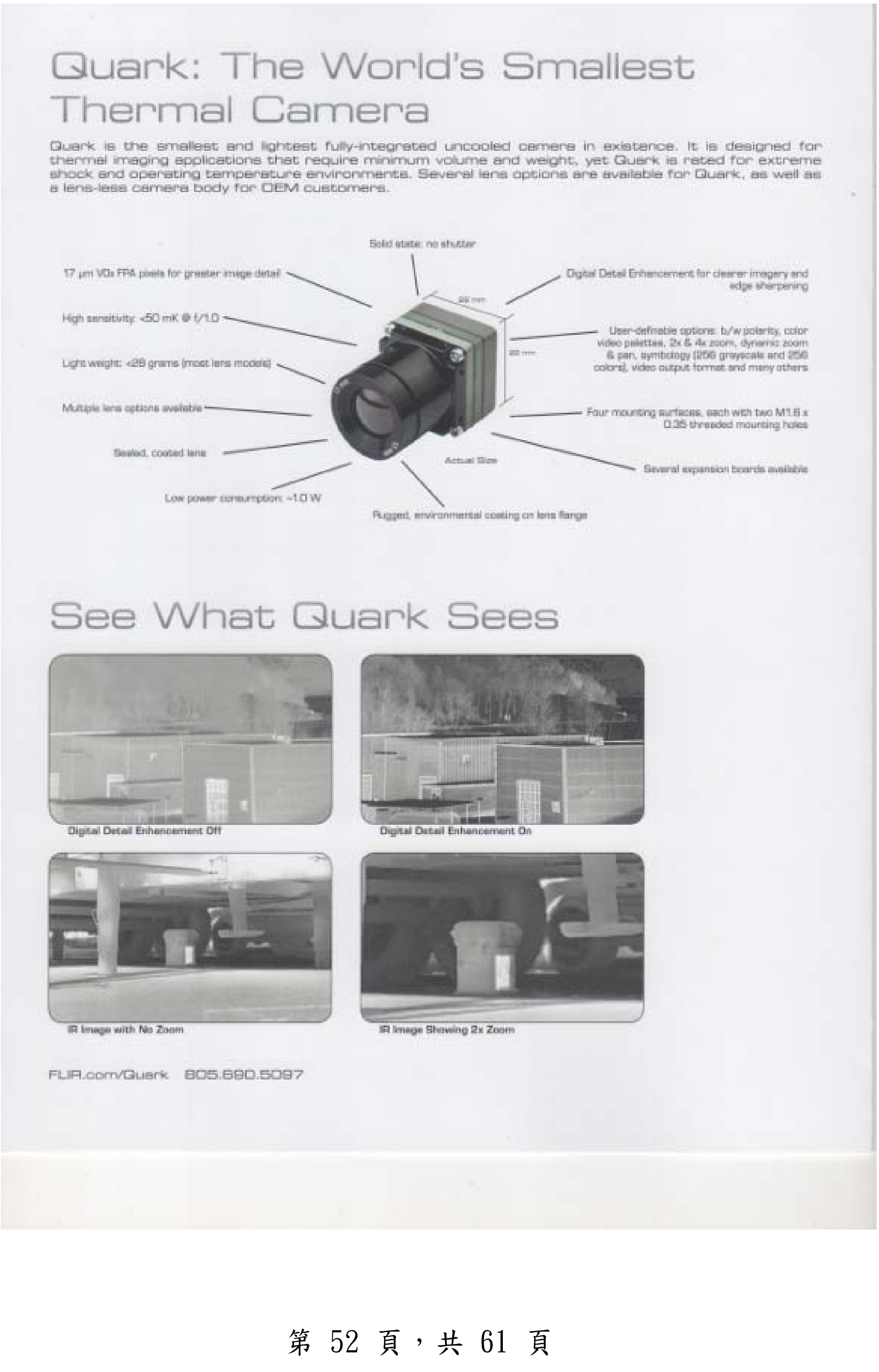
美國 FLIR 公司熱像產品- Quark

- 長波長熱像機具有小體積、重量輕、低消耗功率、耐衝擊與震動等特色，適合小型產品應用。
- 偵檢元件：640*512(17 μm) VO_x Microbolometer
- 操作波長：7.5 ~ 13.5 μm



Quark: The World's Smallest Thermal Camera

Quark is the smallest and lightest fully-integrated uncooled camera in existence. It is designed for thermal imaging applications that require minimum volume and weight, yet Quark is rated for extreme shock and operating temperature environments. Several lens options are available for Quark, as well as a lens-less camera body for OEM customers.

See What Quark Sees

Digital Detail Enhancement Off

Digital Detail Enhancement On

IR Image with No Zoom

IR Image Showing 2x Zoom

FLIR.com/Quark 805.690.5097

Quark Specifications 

SYSTEM OVERVIEW	
System Type	Uncooled LWIR Thermal Imager
Quark 640:	640 x 512 VOx Microbolometer
Quark 336:	336 x 256 VOx Microbolometer
Pixel Size	17 µm
Spectral Band	7.5 - 13.5 µm
Performance	<50 mK @ f/1.0
OUTPUTS	
Analog Video	Field-switchable between NTSC and PAL
Quark 640:	30 Hz (NTSC); 25 Hz (PAL); <9Hz option for export (factory set)
Quark 336:	30/60 Hz (NTSC); 25/50 Hz (PAL) ; <9Hz export option (factory set)
Digital Video	8- or 14-bit serial LVDS; 8- or 14-bit parallel CMOS; 8-bit BT.656
OPERATION & CONTROL	
Image Control	Invert, revert, 2x & 4x digital zoom, polarity, false color or monochrome, AGC, digital detail enhancement (DDE)
Camera Control	Autonomous; Manual via GUI or serial command
Signal Interface	Connector for power, communication, video, digital data, external sync, discrete commands
Accessories	Video, Power & Communication (VPC) expansion board
PHYSICAL ATTRIBUTES	
Size	22 x 22 x 12 mm (less lens)
Weight	8 g (camera body only)
Mounting Interface	8 attach points in lens mount, M1.6 x0.35 on 4 sides, 2 per side
POWER	
Input Voltage	3.3 +/- 0.1 VDC
Power Dissipation	~1.0 W
Time to Image	~2 seconds
ENVIRONMENTAL	
Operating Temperature Range	-40° C to +80° C external temp
Storage Temperature Range	-55° C to +105° C external temp
Scene Temp Range	To 150° C standard
Shock	800 g; 10 msec shock pulse (all axes)
Temperature Shock	5°/min
Vibration	100 g, 3 Hz continuous (all axes); 1000 g, 10 kHz for 10 msec (all axes)
Humidity	5 - 95% non-condensing
Operational Altitude	+40,000 feet
EMC Radiation	FCC/CE Class B
ROHS, REACH, and WEEE	Compliant

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www.flir.com/Quark

FCC Notice. This device is a subassembly designed for incorporation into other products in order to provide thermal imaging capability. It is not an end-product fit for consumer use. When incorporated into a host device, the end-product will generate, use, and radiate radio frequency energy that may cause radio interference. As such, the end-product incorporating this subassembly must be tested and approved under the rules of the Federal Communications Commission (FCC) before the end-product may be offered for sale or lease, advertised, imported, sold, or leased in the United States. The FCC regulations are designed to provide reasonable protection against interference to radio communications. See 47 C.F.R. §§ 2.803 and 15.1 et seq.
Industry Canada Notice. This device is a subassembly designed for incorporation into other products in order to provide thermal imaging capability. It is not an end-product fit for consumer use. When incorporated into a host device, the end-product will generate, use, and radiate radio frequency energy that may cause radio interference. As such, the end-product incorporating this subassembly must be tested for compliance with the Interference-Causing Equipment Standard, Digital Apparatus, ICES-003, of Industry Canada before the product incorporating this device may be: manufactured or offered for sale or lease, imported, distributed, sold, or leased in Canada.
Avis d'Industrie Canada. Cet appareil est un sous-ensemble conçu pour être intégré à d'autres produits afin de fournir une fonction d'imagerie thermique. Ce n'est pas un produit final destiné aux consommateurs. Une fois intégré à un dispositif hôte, le produit final va générer, utiliser et émettre de l'énergie radiofréquence qui pourrait provoquer de l'interférence radio. En tant que tel, le produit final intégrant ce sous-ensemble doit être testé pour en vérifier la conformité avec la Norme sur les appareils numériques causant des interférences (ICES-003) d'Industrie Canada avant que le produit intégrant ce dispositif puisse être fabriqué, mis en vente ou en location, importé, distribué, vendu ou loué au Canada.
EU Notice. This device is a subassembly or component intended only for product evaluation, development or incorporation into other products in order to provide thermal imaging capability. It is not a finished end-product fit for general consumer use. Persons handling this device must have appropriate electronics training and observe good engineering practice standards. As such, this product does not fall within the scope of the European Union (EU) directives regarding electromagnetic compatibility (EMC). Any end-product intended for general consumer use that incorporates this device must be tested in accordance and comply with all applicable EU EMC and other relevant directives.

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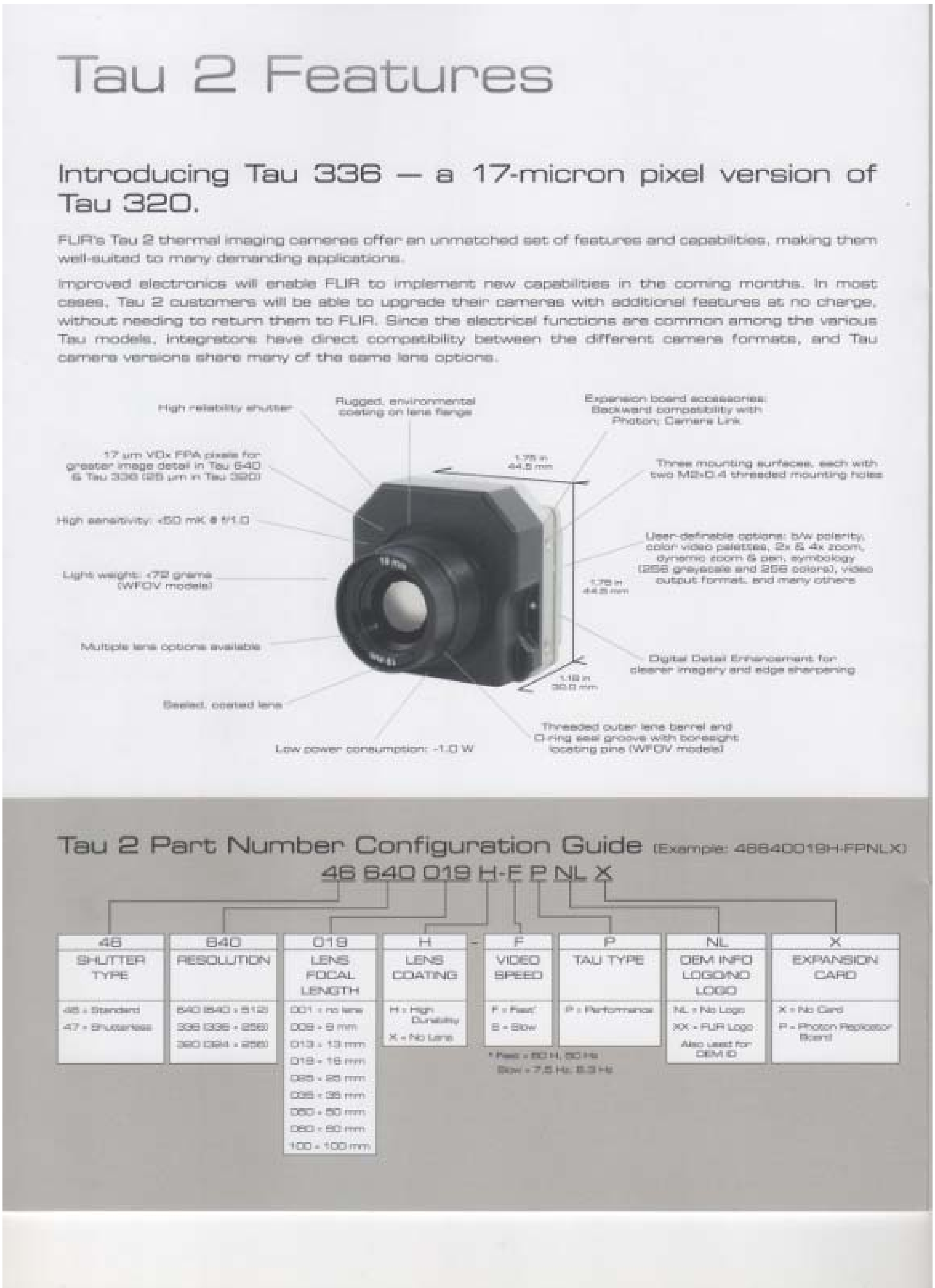
2578 04/12

美國 FLIR 公司熱像產品- Tau 2

- 依解析度分爲 640、336、320、160 共 4 種型號，適合無人飛行載具 UAV、或手持式小型產品應用。
- 偵檢元件：640*512(17 μm)或 320*256(25 μm) VO_x Microbolometer
- 操作波長：7.5 ~ 13.5 μm



Tau 2 Features

Introducing Tau 336 — a 17-micron pixel version of Tau 320.

FLIR's Tau 2 thermal imaging cameras offer an unmatched set of features and capabilities, making them well-suited to many demanding applications.

Improved electronics will enable FLIR to implement new capabilities in the coming months. In most cases, Tau 2 customers will be able to upgrade their cameras with additional features at no charge, without needing to return them to FLIR. Since the electrical functions are common among the various Tau models, integrators have direct compatibility between the different camera formats, and Tau camera versions share many of the same lens options.

Tau 2 Part Number Configuration Guide (Example: 46640019H-FPNLX)

46 640 019 H-F P NL X

46	640	019	H	F	P	NL	X
SHUTTER TYPE	RESOLUTION	LENS FOCAL LENGTH	LENS COATING	VIDEO SPEED	TAU TYPE	OEM INFO LOGO/NO LOGO	EXPANSION CARD
46 = Standard 47 = Shutterless	640 (640 x 512) 336 (336 x 256) 320 (324 x 256)	001 = no lens 009 = 9 mm 013 = 13 mm 019 = 19 mm 025 = 25 mm 035 = 35 mm 050 = 50 mm 060 = 60 mm 100 = 100 mm	H = High Durability X = No Lens	F = Fast* S = Slow	P = Performance	NL = No Logo XX = FLIR Logo Also used for OEM ID	X = No Card P = Photon Replicator Board

* Fast = 60 Hz, 50 Hz
Slow = 7.5 Hz; 8.3 Hz

Tau 2 Specifications

SYSTEM OVERVIEW	
System Type	Uncooled LWIR Thermal Imager
Tau 640	640 × 512 VOx Microbolometer
Tau 336, 320	336 × 256 VOx Microbolometer
Pixel Size	17 µm (Tau 640, 336); 25 µm (Tau 320)
Spectral Band	7.5 - 13.5 µm
Performance	<50 mK @ f/1.0
OUTPUTS	
Analog Video	Field-switchable between NTSC and PAL
Quark 640	30 Hz (NTSC); 25 Hz (PAL); <9Hz option for export (factory set)
Quark 336, 320	30/60 Hz (NTSC); 25/50 Hz (PAL) ; <9Hz option for export (factory set)
Digital Video	8- or 14-bit serial LVDS; 8- or 14-bit parallel CMOS; 8-bit BT.656
OPERATION & CONTROL	
Image Control	Invert, revert, continuous digital zoom, dynamic zoom & pan, 2x & 4x digital zoom (8x in Tau 640), polarity, false color or monochrome, AGC, digital detail enhancement (DDE), image optimization (BPR, NUC & AGC'd video), settable splash screens
Camera Control	Manual via SDK & GUI, dynamic range switching (Tau 336 & 320 only)
Signal Interface	Camera Link (Expansion Bus Accessory Module), discrete I/O controls available, RS-232 compatible (57,600 & 921,600 baud), external sync input/output, power reduction switch (removes analog video)
FFC Duration	<0.5 sec
PHYSICAL ATTRIBUTES	
Size	1.75" × 1.75" × 1.75" (less lens)
Mounting Interface	6 attach points in lens mount, M2 x 0.4 on 3 sides, 2 per side (sealable bulkhead mounting feature on lens barrel [M29 × 1.0], WFOV only)
POWER	
Input Voltage	4.0 - 6.0 VDC
Primary Electrical Connector	50-pin Hirose
Power Dissipation	~1.0 W
Time to Image	<3.5 seconds
ENVIRONMENTAL	
Operating Temperature Range	-40° C to +80° C external temp
Storage Temperature Range	-55° C to +95° C external temp
Scene Temp Range	High gain: -40°C to +160°; Low gain: -40°C to +550°
Shock	200 g shock pulse with 11 msec sawtooth
Temperature Shock	5°/min
Vibration	4.3 g 3 axes, 8 hours each
Humidity	5 - 95% non-condensing
Operational Altitude	+40,000 feet
EMC Radiation	FCC/CE Class B
ROHS, REACH, and WEEE	Compliant

德國 AIM 公司致冷器產品- SX040

- 應用面廣，包括第 3 代紅外線系統應用、高溫操作(90 ~ 160 K)偵檢元件應用、高階 IDDCA 等。
- 致冷能力：0.6 W
- MTTF：> 20000 Hr

德國 AIM 公司致冷器產品- SX070

- 使用 flexure bearing 與 moving magnet 技術
- 致冷能力：0.8 W
- MTTF：> 25000 Hr

AIM

FLEXURE BEARING STIRLING COOLER SF070

- Flexure Bearing and Moving Magnet Technology
- High MTTF (>25,000h)
- Compact and lightweight
- High cooling capacity of 0.8W (@ 80K; 23°C)
- Sleeve coldfinger, suitable for IDCA solutions

The AIM SF070 is a Stirling cryocooler based on Moving Magnet technology and Flexure Bearing suspension on both ends of the driving mechanism. A computerized alignment process combined with an optimized material composition inside the helium vessel results in lifetimes exceeding 25,000h.

The cooler is designed for high performance IR-detectors. The SF070 is compact, lightweight and provides a cooling capacity of more than 0.5W @ 80K, at 71°C ambient temperature.

The resulting performance margin allows detector temperatures down to 70K.

The SF070 can be powered by customer control electronics or by the AIM cooler electronics AM7X.

德國 AIM 公司致冷器產品- SX095

- 適合輕量且高階特性的紅外線技術產品
- 致冷能力：1.3 W(@ 80 K；23℃)
- 在操作溫度 71℃環境下仍有 0.6 W 的致冷能力，優異的致冷能力，使其適合操作溫度需冷至 60 K 的 QWIP 元件。
- MTTF：> 15000 Hr


AIM

LINEAR STIRLING COOLER SX095

- Outstanding specific performance
- High MTTF (>15,000h)
- High cooling capacity of 1.3W (@ 80K; 23°C)
- Sleeve coldfinger, suitable for IDCA solutions

The SX cryocooler-series is our latest product family targeting 3rd Gen IR-applications.

The SX095 combines small outline dimensions with outstanding specific performance and provides high reliability exceeding lifetimes of 15,000h.

The compactness and cooling power meets the demand on lightweight high performance IR-technology. The SX095 provides a cooling capacity of more than 0.6W @ 80K, at high 71°C ambient temperature.

The resulting performance margin allows detector temperatures down to 60K as required for QWIP and VLW detectors.

The SX095 can be used with AIM's cooler electronics AM7X or alternatively with the customer's electronics.

Due to the sleeve design of the coldfinger (Titanium or optional Inconel®) the expander can be integrated and exchanged by the customer.

以色列 Ricor 致冷器產品

- Ricor 提供從紅外線、X 光、加碼射線、科學研究儀器、真空冷凍幫浦…等所需之致冷設備。致冷器型態爲史特靈(Stirling)型式，又分爲旋轉式(rotary)與線性式(linear)兩種，操作溫度從 50 K 至 200 K，可提供致冷能力從不到 1 W 一直到 15 W 的各式產品。

Coolers for Electro-Optics Applications

K508

Integral Stirling 1/2W Micro Cooler

This model is in service since 1994. Over 50,000 of these coolers have been fielded and operate reliably in ground, airborne, heliborne, space borne and naval applications. The K508 Micro Cooler contains an onboard temperature controller, which offers standby, remote shutdown and over-temperature/ over-current protection options.

K508N

Integral Stirling 1/2W Micro Cooler High Reliable

The K508N is a new member of RICOR's microcoolers family. This model was developed as a high reliability K508 derivative with a goal of increasing cooler reliability above 20,000 operating hours. K508N is fully interchangeable with the standard K508 and ideal for IR systems' life cycle cost improvement especially for applications operating 24hr/7days such as border surveillance.

K543

Integral Stirling 1W Micro Cooler

Model K543 is a new member of Ricor's expanding family of highly reliable integral rotary microcoolers. This model is developed to meet the growing demand for more cooling power and extended lifespan. The cooler is designed primarily for Mega pixel format FPAs, Dual band detectors, QWIP applications and Slip-On configuration where reliability, cooling power, robustness and low acoustic signature are of concern.

K548

Integral Stirling 3/4W Micro Cooler

The ultimate microcooler solution for large format FPA detectors. This model extends the use of Ricor's microcoolers family to applications with a larger detector format and / or tougher mission profiles, where higher cooling power and reliability are required.

K561

Integral Stirling Low Power Micro Cooler

Model K561 is a member of Ricor's microcoolers family. This model was specially developed to fit handheld thermal imager applications, where low input power and bulk are the most important parameters. This cooler is based on the same design concepts as Ricor's other microcoolers and is highly reliable.

K563

Integral Stirling Low Power Micro Cooler

Model K561 is a member of Ricor's microcoolers family. This model was specially developed to fit handheld thermal imager applications, where low input power and bulk are the most important parameters. This cooler is based on the same design concepts as Ricor's other microcoolers and is highly reliable. The design based on standard (¼") cold finger.

K562S

Integral Stirling 0.2W Mini Micro Cooler

The new model K562S represents the ultimate miniaturization of Ricor's integral rotary Stirling mini micro cooler. Weighing only 185 grams this cooler was specially developed to support miniature IR systems where the IR detector operates at temperatures of 90K and above. The basic design concept is based on Ricor's famous integral rotary coolers known for their battle proven reliability and ruggedness.

K549

Split Stirling 3/4W Micro Cooler

The K549 microcooler was specially designed to meet the cooling demands of large format FPA detectors for military gimbaled systems, compactness, low acoustic noise, low vibration and longer operating life.
This model is a new member of Ricor's rotary microcoolers family, it shares the dewar / detector assembly with the model K548 integral rotary micro Stirling cooler.

K527

Linear Split Stirling Low Power Mini Micro Cooler

Model K527 micro-miniature cryogenic cooler is designed for the portable infrared imagers where, weight, size, power consumption, heat sinking, reliability, flexibility in system design, vibration export and aural stealth are of concern. Model K527 is an ultimate solution for the perspective "warm" IR detectors optimized to operate at 95K.

K529N

The K529N IDA split Stirling linear cryocooler was specifically designed to meet the demand of long life operation, high cooling power, harsh environmental conditions and compactness for robust military type systems. The cooler is based on the linear single piston compressor establishing the concept of direct detector mounting on the cooler's cold finger.
The cooler could also share the same cold finger used in K548/ K549 models. The compressor is driven by a modern digital controller unit specially designed for military environments.

K570 – Under development

Split Stirling Linear Mini Cooler

Ricor model K570 miniature split Stirling linear cryogenic cooler is designed to deliver up to 2W cooling power and withstand temperature and vibration extremes typical for the modern battlefield. Model K570 is an ultimate solution for the perspective large format IR detectors where weight, size, power consumption, reliability and flexibility in system design are of concern.