

# 行政院所屬各機關因公出國人員出國報告書

(出國類別： 考 察)

## 赴美國參加國際遙測技術研討會

### 出國報告

服務機關：行政院國家科學委員會精密儀器發展中心

出 國 人：陳怡呈 專案副研究員

出國地點：美國

出國日期：九十二年八月二日至八月十三日

報告日期：九十二年十月七日

|                |
|----------------|
| 行政院研考會/省（市）研考會 |
| 編號欄            |
|                |

## 考察行程表

| 日 期              | 工 作 內 容      | 地 點      |
|------------------|--------------|----------|
| 8/2(六)~8/2(六)    | 搭機前往、抵達並安排住宿 | 台北-聖地牙哥  |
| 8/3(日)~8/8(五)    | 參加研討會、儀器展示   | 聖地牙哥     |
| 8/9(六)           | 前往洛杉磯、安排住宿   | 聖地牙哥-洛杉磯 |
| 8/10(日)          | 整理資料、聯繫廠商    | 洛杉磯      |
| 8/11(一)          | 拜訪Newport公司  | 洛杉磯      |
| 8/12(二) ~8/13(三) | 搭機返國         | 洛杉磯-台北   |

# 摘要

近年來精密儀器發展中心以累積多年之光、機、電及儀器整合技術為基礎，已於衛星之遙測酬載系統領域中獲取相當之技術經驗，以此基礎並於2003年開發出國內第一套多光譜機載取像儀器VCDi，跨出國人自製遙測儀器的第一步。2003年SPIE(國際光學工程學會)於八月三日至八月八日在美國加州聖地牙哥舉行第四十八屆年會，遙測與太空技術及其他光學與光電技術均列為研討主題，並同時舉辦相關產品技術展覽與發表，其研討與展覽之主題內容與本中心發展光學遙測酬載意旨頗為契合。此行任務為進一步掌握國際遙測技術研究現況與發展趨勢，並蒐集相關廠商資料與尋求可能合作對象，以作為中心遙測計畫執行基礎及我國未來精密儀器產業技術發展之依據。

本屆 SPIE 研討會規模盛大，參加發表的論文與參展的廠商十分眾多。此次行程中除了參與各項遙測技術議程，蒐集遙測領域最新發表之研究論文，作為中心未來遙測系統儀器研發計畫的參考之外，也訪談了一些參加研討會技術展覽之廠商，蒐集遙測儀器與相關零組件的資料，並透過交流相互了解彼此相關之技術與合作空間，為未來中心遙測系統發展提供國際合作之參考。在研討會後也順道拜訪 Newport 公司，參觀光學工廠與機械工廠，討論大口徑鏡片之減重設計、加工程序與檢測方法。

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# 一、前言

遙測技術的應用可分為兩方面，一方面從大氣、海洋、土壤、冰層、雪等等自然現象的觀測研究天氣與氣候的影像，另一方面則由土地開發與農作物的生長分佈了解土地資源的利用與城鄉人口的分佈及變異。這些資訊對於國家安全、國土規劃、生態保育、自然資源管理保護以及災害防治等等議題都十分的重要。近年來人類意識到地球資源有限，加上環境保護的意識抬頭，在 21 世紀的科技發展中，世界各國對於遙測技術的建立均投下了大量人力與財力，期待能在區域安全、防災、生態環保、資源規劃及地球科學研究等議題佔有一席之地。而遙測儀器正是執行這些任務所不可或缺的利器，透過衛星或飛機在高空對大地做影像擷取，不但可收集到觀測區域內所需要的資訊以供研究分析，亦可傳遞即時訊息予以緊急救災系統。

台灣地狹人稠，人口膨脹快速，山坡地的急速開墾以及都市的擴增，使得土地過度開發的問題擴及到山林地。且台灣處於地震發生頻繁之地域，夏秋之際又有颱風肆虐，往往造成人民生命財產的重大損失。有鑑於此，政府致力於土地的規劃管理、森林與農地資源應用、災害防治與監控、以及環保監測。國內應用與研究遙測技術單位眾多，主要有中央氣象局、農委會、內政部、水資局、民間顧問公司、

中央大學太空及遙測研究中心、工研院能資所、成大航測所、海洋大學海洋研究所等，各單位現已廣泛應用遙測影像於相關領域。由於效果良好，遙測影像需求日漸頻繁，然而所使用之影像資訊均仰賴國外衛星與空載遙測儀器系統，不僅影像取得之時程受限，且費用極高。以遙測影像資訊需求的殷切及國家長遠發展思考，實有必要自行研製高解析度遙測酬載。

有鑑於此，精密儀器發展中心這幾年來在遙測儀器的研發與整合不遺餘力。除了參與中華衛星二號計畫之遙測酬載整測工作，吸收國外發展衛星遙測酬載發展經驗，同時也研提長程計畫，開發機載及陸地使用遙測系統。近期成功研製在六百公里軌道高度時地面解析力為八米之光學遙測模組，並以此光機系統為核心，發展地面遙測應用之全景觀測系統，拍攝淡水、日月潭等地之三百六十度影像，為國內遙測儀器開發奠下基礎。同時成功開發蕃薯號衛星 YAMSAT 微型光學酬載，交付太空計畫室微微衛星團隊。在今年中更成功完成國人第一套自製機載多光譜遙測影像儀之取像，已陸續成功取得台中太平地區、竹科以及南科影像，並發表記者會受到各界的肯定與支持。在這些儀器的研製過程中，亦開發了許多光機設計製造之能力，對國內新興之精密光學產業有相當之助益。植基於這些技術與儀器發展經驗，精密儀器發展中心將逐步達成光機電遙測酬載自製目標，未來將更朝

大口徑、高解析力與高光譜解析度遙測儀器的目標發展。

然而發展遙測儀器技術並不能閉門造車，了解目前國際上遙測技術的發展現況與未來趨勢才能有效提昇國內自製的能力與國際競爭力，因此派員參加今年度 SPIE 的第 48 屆年會，以汲取國際遙測儀器發展經驗與技術現況，了解未來發展趨勢，並且蒐集最新廠商資料與產品資訊，以尋求可能之國際合作交流機會並作為未來發展之參考。

## 二、出國目的

本中心為配合國家太空科技發展，建立國內自主遙測酬載技術，於國內太空計畫發軔初期，即結合精密光學、機械、真空與電子技術，規劃遙測儀器技術為本中心長期發展主軸計畫之一，除積極參與中華衛星一號與二號遙測酬載儀器之規劃研製與整測工作，並於內部執行相關年度計畫，逐年完成 8m、16m 解析度影像模組、全景觀測系統與高空閃電影像地面觀測儀及光度計，今年更完成國內首套自製「植被及國土變遷觀測儀」研製，成功展示機載飛航取像測試成果，深獲各界好評。

拜電子、材料、精密控制、影像感測器等相關科技進步之賜，衛星發展朝向單純用途、快速時程與微小衛星化趨勢，同時光學遙測酬載亦朝高影像解析度、高光譜解析度方向發展。近年來國際上陸續有 IKONOS、QuickBird、SPOT V 等多顆一米/二米解析度影像衛星發射升空；高解析度影像衛星與酬載儀器技術一直在國際間維持高度競爭，每年均有長足進步。SPIE(國際光學工程學會)於每年七、八月舉行年會，遙測與太空技術及其他光學與光電技術均列為研討主題，並同時舉辦相關產品技術展覽發表，其研討與展覽主題內容與本中心發展光學遙測酬載意旨頗為契合。今年的第 48 屆年會於 8 月 3 日至 8 日於美國加州聖地牙哥舉行，其中遙測技術研討主題概要如下：

- Earth Observing Systems
- Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research
- Imaging Spectrometry



- Infrared Spaceborne Remote Sensing
- Ocean Remote Sensing and Imaging
- Ecosystems Dynamics, Agricultural Remote Sensing and Modeling, and Site-Specific Agriculture

遙測系統技術是本中心發展的主軸方向之一，為進一步掌握國際上遙測技術之發展趨勢，故派員赴美國參加國際遙測技術研討會，藉此掌握此領域目前發展的現況並蒐集相關廠商資料，以作為中心遙測計畫執行基礎及我國未來精密儀器產業技術發展之依據。同時也藉此機會與其他各國先進交流相關技術與經驗，作為未來國際合作之參考。

本次出國也順道拜訪 Newport 公司，Newport 公司位在 Los Angeles 南方的 Irvine，今年度遙測研究室也正在致力規劃 30 公分口徑遙測模組的研製，並已在今年六月完成初步設計審查，預計在年底完成細部設計審查。今年的 Zerodur 鏡片毛胚購案是由 Newport 公司所得標，並將於 Irvine 的光學工廠設計、製作，包含主鏡的減重加工與非球面曲面的研磨。此次拜訪 Newport 公司與該公司的光學部門人員就大尺寸非球面鏡的減重設計、加工、研磨與光學品質檢驗進行技術討論與交流。

### 三、參訪過程

#### A. 研討會論文發表

2003 年國際光學工程學會(SPIE, The International Society for Optical Engineering)舉辦的國際光學科學與技術研討會暨第48屆年會於八月三日至八月八日在美國加州聖地牙哥一連舉行六天, 研討會的內容十分充實且廣泛, 主要的討論議題分為下列六大項:

- 遙測與太空科技(Remote Sensing and Space Technology)、
- 天文學(Astronomy)、
- 光學系統工程(Optical Systems Engineering)、
- 輻射科技(Radiation Technologies)、
- 訊號及影像處理與感測器(Signal and Image Processing)、
- 有機材料與奈米科技(Organic Materials and Nanotechnology)

其中每一大項議題又再細分為二至三個次議題與數個子議題, 會場共有四十多個會議室同時進行論文發表, 規模可見一斑, 詳細的研討會議程參見附錄一。

此行的主要目的是參加遙測與在地感測技術(Remote and In-situ Sensing)的論文研討, 在此主題下的子議題眾多, 臚列如下:

- 地球觀測系統(Earth Observing Systems)、
- 偏極科學與遙測(Polarization Science and Remote Sensing)、
- Lidar 遙測與環境監測(Lidar Remote Sensing for Environmental Monitoring)、
- 紫外光地面與太空量測、模型與影響(Ultraviolet Ground- and

Space-based Measurements, Models, and Effects)、

- 海洋遙測與影像(Ocean Remote Sensing and Imaging)、
- 影像光譜(Imaging Spectrometry)、
- 衛星紅外光遙測(Infrared Spaceborne Remote Sensing)、
- 生態與農業的太空遙測技術 (Ecosystems Dynamics, Agricultural Remote Sensing and Modeling, and Site-Specific Agriculture)
- 大氣與太空研究儀器(Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research)。

在本研討會中有來自大陸浙江杭州大學所發表的論文，是以 MODIS 遙測影像結合 GPS 與 GIS 來觀測浙江省的水稻種植面積，MODIS (Moderate Resolution Imaging Spectroradiometer) 是美國 NASA 在地球觀測衛星 Terra 及 Aqua 所取得的中等解析度影像，最多可有 36 個波段，解析度約為 250 公尺至 1000 公尺。有關 MODIS 資料可由下列網址查詢：<http://modis.gsfc.nasa.gov>。

另外，來自俄羅斯的學者 Kopilevich 發展出特別的演算法可以有效消去海面水波的反射以得到較佳的水底影像，他們並舉例以機載取像觀測沿海的珊瑚礁情形。本中心若要以 VCDi 與農航所合作拍攝水稻種植面積，則需選用較大型 CCD 以減少航道數目與飛行取像時間，CCD 的快門速度也需加快以避免曝光過度情況發生，同時光機設計也需配合修改。假設未來要以 VCDi 觀測墾丁珊瑚礁的生長變化情況，類似的消除水波反射的演算法似乎也值得參考嘗試。

此行除了參加遙測方面的論文研討外，光機設計(Optomechanical Design)也是筆者感興趣的題目，在 Optomechanics 中，鏡面變形結果對光學成像品質的影響也是值得研究的課題之一，但此方面技術由於

涉及機械變形分析與光學成像分析兩種領域的軟體之間互相整合與資料交換，困難度較高，在國內相關之研究資料相當缺乏，在本次研討會中美國 Raytheon 公司有發表相關的研究。Raytheon 公司的 Coronato 先生介紹三種他們所發展的演算法，利用有限元素法計算得到的光學元件變形結果，將其轉換至光學公式 Zernike Polynomial 並匯入光學分析軟體中以推導出波前誤差，也比較三種演算法的相互優劣，他並且強調要得到精確的結果則在建立有限元素分析模型時鏡面上的網格必須是均勻且夠密。此外，同樣來自 Raytheon 公司的 Kremer 先生報告的主題是在線性的溫度梯度下，對拋物面鏡面的變形影響，他主要是對光學手冊書中基本的溫度變化對曲率半徑影響的公式提出一些修正式，以得到較精準的變形估算，藉由了解這些公式的推導過程對於遙測室目前進行的 30 公分口徑遙測模組的熱變形分析將甚有助益。

有關 Raytheon 公司的資料，可上網：<http://www.raytheon.com> 查詢，筆者在回國後上網查詢才得知 Raytheon 是一家規模龐大的國防及航太系統製造與設計公司，本次發表論文的兩位研究員是在飛彈系統部門工作；此外，巧合的是本中心 VCDi 飛行取像合作的農航所飛機 Beech350 正是由該公司旗下的飛機事業部門所製造，去年委託亞航公司承製的通過飛航認證的儀器架也是經由該公司所認可，難怪筆者在研討會時一直覺得這公司名稱似曾相識。

除了論文發表外，本次研討會也有部分論文是以海報張貼的方式發表，也吸引許多人駐足研究，並與作者熱烈討論。



## B. 展覽會場

在研討會進行的同時，在八月五日至八月七日也有舉辦廠商展覽，今年共有兩百多家廠商參展，展出產品包含各種光學材料與鏡片、CCD 與 CMOS 感測器、光通訊元件、太空科技、紅外線感測器、雷射系統與元件、鍍膜技術、光學檢測設備等。大尺寸輕型鏡片設計與加工是發展太空遙測的必備技術，CNC 的鑽石車削(Diamond Turning)也是熱門的精密光學鏡片加工技術，還有更精密的磁性流變加工(MagnetoRheological Finishing, MRF)，精度可達  $\lambda/20$ 。



### Corning 公司：

在會場中美國 Corning 公司展示一種命名為 ULE 的鏡片材料，此材料主要是跟德國 Schott 公司的 Zerodur 材料競爭，這兩種材料的共同特性是熱膨脹係數幾乎為零，不易因為溫度變化而產生變形，故適用於需要穩定尺寸的應用。ULE 主打的市場是天文望遠鏡與太空衛星以及半導體製程設備元件的應用，但據了解到目前為止 ULE 還沒有被使用在太空中。Corning 公司除了提供的 ULE 材料外，還可提供包含 ULE 鏡片研磨與減重設計和加工等服務，但並不提供鏡面拋光。會場中並展示一些 ULE 的減重鏡片，如圖一與圖二所示，可提供的 ULE 材料大小可達直徑八公尺，茲將 ULE 的材料性質列於表一，與 Zerodur 比較，ULE 的材料強度較低。

表一 ULE 材料性質

| Properties: Unless otherwise stated, all values @ 25°C    |                                                            |                                 |                                                                                    |
|-----------------------------------------------------------|------------------------------------------------------------|---------------------------------|------------------------------------------------------------------------------------|
| Thermal Properties:                                       |                                                            |                                 |                                                                                    |
| Mean Coefficient of Thermal expansion ( $\alpha$ )        | $0 \times 10^{-6}/K$<br>[0 ppb/ $^{\circ}C$ ]              | Mean Specific Heat ( $C_p$ )    | 767 J/(kg $\cdot$ $^{\circ}C$ )<br>[0.183 cal/(g $\cdot$ $^{\circ}C$ )]            |
| CTE Maximum Variation 5-35 $^{\circ}C$ ( $\Delta\alpha$ ) | $\pm 30 \times 10^{-6}/K$<br>[ $\pm 30$ ppb/ $^{\circ}C$ ] | Thermal Conductivity (K)        | 1.31 W/(m $\cdot$ $^{\circ}C$ )<br>[1.13 kcal/(m $\cdot$ hr $\cdot$ $^{\circ}C$ )] |
| Thermal Diffusivity (D)                                   | 0.0079 cm $^2$ /s                                          | Strain Point                    | 800 $^{\circ}C$ [1434 $^{\circ}F$ ]                                                |
| D.C. Volume Resistivity, 200 $^{\circ}C$ , 100Hz (R)      | $10^{11.5}$ ohm $\cdot$ cm                                 | Annealing Point                 | 1000 $^{\circ}C$ [1832 $^{\circ}F$ ]                                               |
|                                                           |                                                            | Softening Point (Estimated)     | 1490 $^{\circ}C$ [2714 $^{\circ}F$ ]                                               |
| Mechanical Properties:                                    |                                                            |                                 |                                                                                    |
| Poisson's Ratio ( $\nu$ )                                 | 0.17                                                       | Specific Stiffness (E/ $\rho$ ) | $3.12 \times 10^6$ m [1.23 $\times 10^6$ in]                                       |
| Ultimate Tensile Stress (MOR)                             | 49.8 MPa [7220 psi]                                        | Shear modulus (G)               | 29.0 GPa [4.20 $\times 10^6$ psi]                                                  |
| Knoop Hardness, 200 g load                                | 460 kg/mm $^2$                                             | Bulk Modulus (K)                | 34.1 GPa [4.95 $\times 10^6$ psi]                                                  |
| Density ( $\rho$ )                                        | 2.21 g/cm $^3$ [0.07966 lb/in $^3$ ]                       | Elastic Modulus (E)             | 67.5 GPa [9.80 $\times 10^6$ psi]                                                  |
| Optical Properties:                                       |                                                            |                                 |                                                                                    |
| Stress Optical Coefficient                                | 4.15 (nm/cm)/(kg/cm $^2$ )<br>[0.292 (nm/cm)/psi]          | Abbe' Number ( $v_d$ )          | 53.1                                                                               |
| Refractive Index (nominal CTE material)                   |                                                            | $dn/dt$ 20-40 $^{\circ}C$       | $10.68 \times 10^{-6}/^{\circ}C$                                                   |
| $n_d(486\text{ nm})$                                      | 1.4882                                                     | $dn/dt$ 40-60 $^{\circ}C$       | $11.24 \times 10^{-6}/^{\circ}C$                                                   |
| $n_d(589\text{ nm})$                                      | 1.4828                                                     |                                 |                                                                                    |
| $n_d(656\text{ nm})$                                      | 1.4801                                                     |                                 |                                                                                    |



圖一 Corning 公司 ULE 鏡片

同時，Corning 公司也展示一個半導體製程曝光用的鏡頭(見圖三)，此鏡頭的高度約 1.2 公尺，共有十七片鏡片，在組裝上是採一片一片的組裝對心方式，也就是一個金屬環先和一個鏡片組裝完成後，再依順序由下而上的一片一片的組合整個鏡筒，並以研磨金屬環的方式來



調整各個鏡片之間的間距，再以螺絲固定每個金屬環；筆者也很好奇的詢問這個鏡頭是以何種加工方法剖半，得到的答案是金屬鏡筒是用水刀(Abrasive Water Jet)加工，鏡片是另外切半再放進鏡筒內，但因為水刀切割時會有一個放射角度且切割面並不十分平滑，所以鏡筒的切面需再研磨過，才會得到如照片中所示光亮的切割面。



圖二 Corning 公司 ULE 鏡片各種減重設計



圖三 Corning 公司展示之半導體製程鏡頭

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### **Hextek 公司**

在大尺寸鏡片減重設計加工方面，一般是以 CNC 銑床加工，若需得到較高的減重比則需採用融接方式(Fusion Bonding)，在會場中 Hextek 公司就是專精融接各種形狀的鏡片(見圖四)，融接後的鏡片依然可以進行研磨與拋光，就平面鏡而言精度可達  $\lambda/20$ ，但所使用的材料限制為 Schott 公司出品的 Borosilicate，訪談中得知 Zerodur 材料因為強度與硬度太高，並無法使用融接加工。



圖四 Hextek 公司的融接光學鏡片

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## 行動觀測系統

會場中另一個有趣的發現是 Instrumentation Marketing Corporation 公司的行動觀測系統 (Photo-Sonics Mobile Optical Tracking System)，如圖五所示，此觀測系統的控制器可為有線或是無線控制，在望遠鏡外圍可加上保護罩以防塵，整個觀測系統可架在拖車後方載至欲觀測地點，固定後開始進行觀測，經訪談後廠商表示若是我們自備有遙測鏡頭模組，也可為我們量身定做一組類似的行動觀測系統，可做為 30 公分口徑遙測模組未來應用的一個參考。



圖五 行動觀測系統

在會場中同時也蒐集有關 CCD 與 CMOS 感測器、紅外線感測器、第三代影像加強型 CCD、金屬鍍膜技術與光學檢測設備等廠商資料，筆者將廠商資料整理彙列於附錄二，以供中心未來執行及規劃遙測儀器發展之參考。

### **C. Newport 公司參觀**

本中心遙測研究室今年度向美商理寶公司購買已研磨成型的 300mm 口徑的 Zerodur 鏡片毛胚，在為期六天的研討會結束後筆者順道至洛杉磯南方的 Irvine 拜訪 Newport 公司，與 Newport 公司的光學部門人員就鏡片規格與減重設計進行討論，並參觀光學工廠與機械工廠。

#### **拜訪人員：**

Mark Mailberger, Director of Operations, Newport Precision Optics

Patrick Frank, Sr. Engineer, Newport Precision Optics

Ronald C. Stearns, Sr. Staff Applications Engineering, International Sales

Chang H. Sun, Regional Sales Manager, International Sales

#### **Zerodur 鏡片加工與檢測討論：**

問：可否簡介 Newport 公司與光學工廠？

答：Newport 公司在加州 Irvine 共有員工約 500 人，除了銷售一般的型錄商品如定位平台與各式光學元件外，也為客戶量身訂做委製產品，另外也製作 OEM 產品，以上三類商品各約佔商品銷售金額的三分之一。Newport 公司的光學工廠是在 1999 年從 Corning 公司旗下的一個航太光學部門買下來的，對於太空規格的大尺寸鏡片加工有相當的經驗與技術。

問：在貴公司的減重設計圖面上有些地方如圓角(fillet)與倒角(chamfer)並沒有全部標示，在加工時候該不該省略？

答：沒有標示到的圓角半徑為 3mm，因為很小所以在圖面上就算標示出來也看不清楚所以沒有標示，但是在加工時是一定會有圓角的；此外在鏡片的邊緣部分都會有倒角以保護鏡片，這部分雖然

很花時間但是基於保護鏡片還是不能省略。

問：貴公司對於有中央開孔之大口徑非球面鏡片標準製造程序為何？

若有中央開孔則拋光或研磨後的表面精度要如何量測？

答：依照我們的經驗所建議的加工程序為先減重加工、酸洗(acid bath)以去除減重加工造成的殘留應力、鏡面成型、研磨、拋光、再小心去除中央開孔、鍍膜。一般若無中央開孔則在研磨後可用輪廓儀量測鏡面精度；但是在有中央開孔情況下則需設計一個輔助鏡頭(null lens)以干涉儀量測非球面鏡片的精度，若有需要本公司也可代為設計 null lens。此次 PIDC 訂購的鏡片毛坯中央開孔已經在本公司挖除，若 PIDC 有需要，我們可以製作一個輔助拋光用的 central core，因為是與主鏡使用同一個機器設定下研磨，兩者在曲率與厚度的精度上會較吻合，但是需要特別的刀具與夾治具，故需要的經費較多。補充說明一點，一般酸洗程序必須在減重加工後 48 小時內處理，否則無法達到預期的去除加工殘留應力效果。酸洗因有毒性且高污染，Newport 是送到外面合作廠商處理。

問：貴公司在 30 公分主鏡的研磨可否達到 Form-Error P-V 值在  $5\mu m$  內的精度？

答：在技術方面沒問題，若要達到  $5\mu m$  內的精度則需要人工的經驗與更多的加工時間，當然費用也就較高了。這次 PIDC 所提出的 Form-Error P-V 值在  $200\mu m$ ，本公司在交貨前除了研磨外，為了檢測方便也會稍加拋光，所以精度一定會在  $200\mu m$  內，甚至應該會在  $25\mu m$  內。

問：主鏡在背面有減重設計，在研磨或是拋光時是否需要用特殊材料將這些孔暫時填補起來，以提高強度，避免研磨施加壓力造成變

形？

答：應該是不用，主鏡雖有減重，但依照我們的經驗判斷鏡片強度仍然足夠應付加工時的負荷，所以不需要另外填補材料；依照我們的經驗判斷，此次的減重設計對於研磨與拋光並不會造成太大影響。

問：貴公司是否有關將有限元素分析(FEA)所得結果轉換至光學分析軟體以得到波前誤差(WFE)的技術與經驗？

答：將 FEA 轉換至 WFE 是個很難的題目，本公司最近也有人力在進行這方面研究，但還沒有進一步結果。

問：貴公司有無加工 Corning 公司的 ULE 材料經驗，該材料與 Schott 的 Zerodur 比較又是如何？

答：ULE 是 Corning 公司推出與 Schott 公司的 Zerodur 競爭之材料，通常鏡片材料都是由客戶指定，我們只負責加工，本公司的光學工廠對 Zerodur 與 ULE 都具有加工經驗。

#### 參觀光學工廠：



圖六 一公尺非球面鏡拋光機台



圖七 CNC 鑽石車削

表二 Newport 公司光學工廠產品一覽表

| Typical Optical Components                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• <b>Lenses</b> <ul style="list-style-type: none"> <li>- Plano-Convex/Concave</li> <li>- Bi-Convex/Concave</li> <li>- Achromatic Doublet</li> <li>- Cylindrical Plano-Convex/Concave</li> <li>- Aspheres</li> </ul> </li> <li>• <b>Mirrors</b> <ul style="list-style-type: none"> <li>- Flat</li> <li>- Concave/Convex</li> <li>- Superpolished</li> </ul> </li> <li>• <b>Prisms</b> <ul style="list-style-type: none"> <li>- Right Angle</li> <li>- Dispersing</li> <li>- Retroreflectors</li> <li>- Penta</li> </ul> </li> </ul> | <ul style="list-style-type: none"> <li>• <b>Beamsplitters</b> <ul style="list-style-type: none"> <li>- Cube</li> <li>- Plate</li> <li>- Polarizing</li> <li>- Non-Polarizing</li> </ul> </li> <li>• <b>Windows</b> <ul style="list-style-type: none"> <li>- Wedged</li> <li>- Parallel</li> </ul> </li> <li>• <b>Filters</b> <ul style="list-style-type: none"> <li>- Neutral Density</li> <li>- Colored Glass</li> <li>- Bandpass</li> <li>- Short and Long-Wave Pass</li> </ul> </li> <li>• <b>Polarization Optics</b> <ul style="list-style-type: none"> <li>- Polarizers</li> <li>- Waveplates</li> </ul> </li> </ul> |

Newport 公司的光學工廠是在 1999 年買下 Corning 公司的 OCA

部門，該部門專長於航太用大口徑鏡片精密加工技術，其光學產品種類整理於表二，目前設備包含有一公尺非球面拋光機台(見圖六)，CNC 鑽石車削(Diamond Turning, 見圖七)、CNC Fly cutter 等；另外，更精密的磁性流變加工(MagnetoReological Finishing, MRF)系統(見圖八)，利用獨特的干涉儀精密控制，使得非球面鏡的加工精度可達  $\lambda/20$ ；適用在可見光及紫外光波段的光學鏡片的最後表面加工，紅外波段的鏡片經 CNC 鑽石車削後即可直接使用，不需再以 MRF 進一步處理。在鍍膜方面，Dielectric coating 等污染性較低的處理在 Newport 公司內部自行加工，但是污染性較高的金屬鍍膜、表面陽極處理以及去除鏡面減重加工的酸洗等製程則是交由其他廠商處理。Newport 公司光學工廠所能加工的材料如表三所示，常用的加工精度則列於表四。

表三 Newport 公司光學工廠常用加工材料

| Common Optical Materials |        |                           |         |        |         |            |
|--------------------------|--------|---------------------------|---------|--------|---------|------------|
| Material                 | Lenses | Beamsplitters/<br>Mirrors | Windows | Prisms | Filters | Polarizers |
| BK 7                     | ✓      | ✓                         | ✓       | ✓      | ✓       | ✓          |
| CaF <sub>2</sub>         | ✓      | ✓                         | ✓       |        |         |            |
| MgF <sub>2</sub>         | ✓      |                           | ✓       |        |         |            |
| Gladium®                 | ✓      |                           |         |        |         |            |
| UV Fused Silica          | ✓      | ✓                         | ✓       | ✓      | ✓       | ✓          |
| Pyrex®                   |        | ✓                         |         |        |         |            |
| Zerodur®                 |        | ✓                         |         |        |         |            |
| ULE®                     |        | ✓                         |         |        |         |            |
| Colored Glass            |        |                           |         |        | ✓       |            |
| Crystal Quartz           |        |                           |         |        |         | ✓          |

表四 Newport 公司光學工廠加工精度分類

| Fabrication Tolerances |              |                            |                 |
|------------------------|--------------|----------------------------|-----------------|
| Spherical Lenses       | Focal Length | Surface Irregularity       | Surface Quality |
| Commercial             | $\pm 2\%$    | $\leq \lambda/2$           | 60-40           |
| Precision              | $\pm 1\%$    | $\leq \lambda/4-\lambda/8$ | 40-20           |
| Ultra-Precision        | $\pm 0.1\%$  | $\leq \lambda/20$          | 0-0             |

| Plano Surfaces  | Surface Flatness             | Surface Quality |
|-----------------|------------------------------|-----------------|
| Commercial      | $\leq 5\lambda-\lambda/5$    | 60-40           |
| Precision       | $\leq \lambda/10-\lambda/20$ | 10-5            |
| Ultra-Precision | $\leq \lambda/40$            | 0-0             |



圖八 MRF 加工機台

此外，Newport 公司對於產品的檢測是採取每樣出廠的產品都必需通過產品測試並附有測試報告，圖九所示就是以干涉儀檢測六個自由度(對 X、Y、Z 三軸的平移與旋轉)的定位精度與行程的測試平台，這也是 Newport 的定位平台價格較高，但是相對的精度也是較佳的主



要原因。



圖九 定位平台之干涉儀檢驗

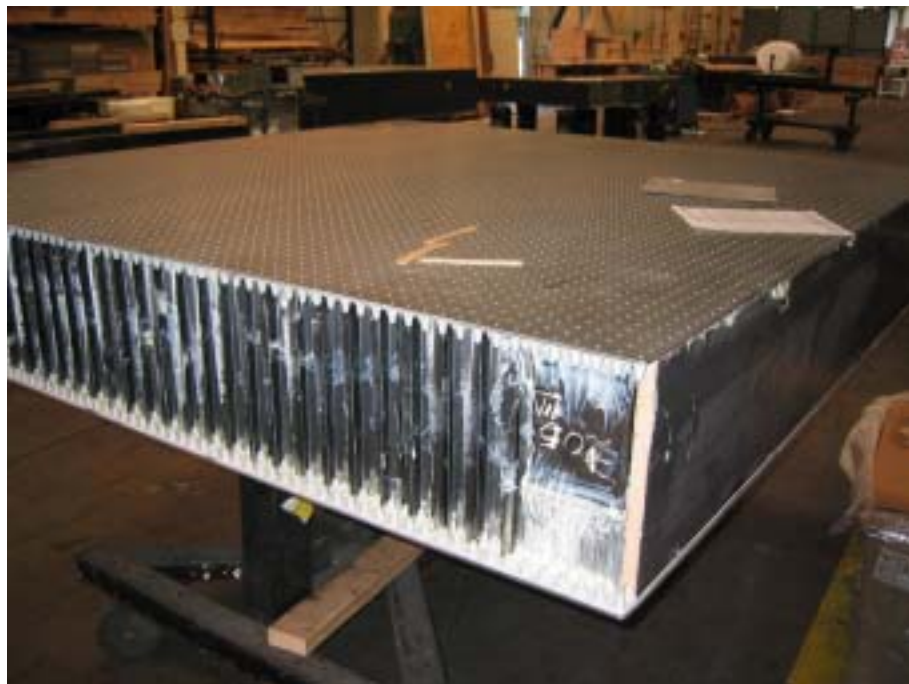
### 參觀機械工廠：

Newport 公司是以製造光學桌起家，在機械工廠中參觀整個光學桌的製作流程，首先由不鏽鋼片的裁切與鑽孔開始(見圖十)，光學桌不鏽鋼表面的霧面處理是以人工加工達到類似鏟花的效果，以減少鏡面的反射；接著組裝外圍的木框、防水橡皮、蜂槽結構與阻尼器等(見圖十一)，接合膠是以人工塗佈(見圖十二)，這裡所用的膠為特別調配，是 Newport 的商業機密，需要 24 小時固化。另外，阻尼器的調配是有二十年以上經驗的師傅，依照經驗針對各個光學桌量測出來的自然頻率來各別配置(見圖十三)；可見經驗與人力在精密機械中還是扮演重要的角色。整體而言，機械工廠雖免不了有噪音與油味，但該公司整個廠房還是維持得相當整潔，工具與庫房管理井然有序。





圖十 不鏽鋼鋼板鑽孔與攻牙



圖十一 光學桌粘著組合



圖十二 光學桌製程之膠的塗佈



圖十三 光學桌阻尼器的調配

## 四、達成之任務

1. 參加 SPIE 在美國舉辦之國際遙測應用研討會，瞭解目前遙測領域上最新的資訊與技術發展。由於此次參加研討會的各國研究人員相當踴躍，論文發表主題廣泛而內容深入，許多感測技術、儀器系統與資料處理等技術議題與文章可供本中心相關研究作為參考。
2. 訪問參展之廠商，蒐集相關廠商資料，以了解其產品開發能力及所能提供之服務。目前本中心遙測計畫在光學鏡頭上的製造組裝已有累積相當之經驗，太空遙測鏡頭目標為大尺寸及輕量化，透過與廠商的訪談了解目前使用的鏡片材料與加工技術，並透過相互交流認識增進合作機會。次外，本中心在後端遙測電子電路與相關應用硬體設備仍有賴於外界之支援。因此透過對 CCD、CMOS 與影像加強型 CCD 影像感測器、遙測儀器系統軟硬體整合具經驗之廠商進行了解，吸取相關經驗。
3. 拜訪 Newport 公司，了解該公司光學部門的加工能力與機械設施，以及所能提供的服務，並就大口徑非球面光學鏡片之設計、工與檢測進行討論與經驗交流。

## 五、心得與建議

本次出國參加研討會帶回許多豐富資料以供參考，在此提出幾點個人心得與建議供大家分享：

1. 在展覽會場有美國太空總署的火星探測號 (Mars Rover) 模型並播放相關之介紹影片，也有歐、美各國研究機構的遙測影像展示，台灣廠商與研究機構在此次展覽會場缺席，十分可惜。台灣在遙測儀器發展雖然起步較晚，然而中心自行研發的多光譜機載取像系統已於今年成功取像，未來希望可以見到將 VCDi 的遙測影像、或是利用所拍得影像進行後續研究的成果送至國際大型研討會展示，宣傳中心研發成果並與各國先進技術互相切磋、交流，並增進國際合作機會。畢竟高科技的星載或機載遙測所需要的金錢與技術已非單一機構所能承擔，多派員出席參加國際研討會與展覽，吸取經驗與並尋求國際合作機會，才能快速突破技術瓶頸。
2. 在參觀 Newport 公司時，體會該公司對於門禁管理與工安相當嚴格，在大廳就得輸入密碼才能進入辦公室，進入機械工廠一率佩帶護目鏡，工廠內部的工具庫房排列整齊，雖有噪音與油味，但還是相當整潔明亮。此外，該公司在光學工廠與機械光廠的加工技術方面還是得倚賴有經驗的員工，例如非球面鏡的減重設計與整個製造、檢測流程都是由一位具有 20 年以上經驗的工程師在負責規劃，筆者認為中心的工廠也是有相當多具有豐富實務經驗的員工，如何對新進員工有計畫的加以訓練並將經驗傳承給新進員工，如此承先啟後才能保持一間公司的永續經營。

## 六、附錄

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# 附錄一

## **Remote Sensing and Space Technology**

Program on

### **Remote and In-situ Sensing**

*Program Chair:* **William L. Barnes**, NASA Goddard Space Flight Ctr.

Sun-Wed [5151 - Earth Observing Systems VIII](#) (Barnes)

Sun-Tues [5158 - Polarization Science and Remote Sensing](#) (Shaw, Tyo)

Sun-Mon [5154 - Lidar Remote Sensing for Environmental Monitoring IV](#) (Singh)

Mon-Wed [5156 - Ultraviolet Ground- and Space-based Measurements, Models, and Effects III](#) (Slusser, Herman, Gao)

Tues-Wed [5155 - Ocean Remote Sensing and Imaging II](#) (Frouin, Gilbert, Pan)

Wed-Thurs [5159 - Imaging Spectrometry IX](#) (Shen, Lewis)

Wed-Fri [5152 - Infrared Spaceborne Remote Sensing XI](#) (Strojnik)

Thurs [5153 - Ecosystems Dynamics, Agricultural Remote Sensing and Modeling, and Site-Specific Agriculture](#) (Shaw, Gao)

Thurs-Fri [5157 - Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research V](#) (Larar, Shaw)

Program on

### **Atmospheric and Space Optical Systems**

*Program Chair:* **Jennifer C. Ricklin**, Army Research Lab.

Mon-Wed [5160 - Free-Space Laser Communication and Active Laser Illumination III](#)  
(Voelz, Ricklin)

Wed-Fri [5161 - Quantum Communications and Quantum Imaging](#) (Meyers, Shih)

Wed-Thurs [5162 - Advanced Wavefront Control: Methods, Devices, and Applications](#)  
(Gonglewski, Vorontsov, Gruneisen)

## **Astronomy**

Program on

### **Astronomical Optics and Instrumentation**

Program Chair: **Oswald H. W. Siegmund**, Univ. of California/Berkeley

Sun-Mon [5169 - Astronomical Adaptive Optics Systems and Applications](#) (Tyson, Lloyd-Hart)

Sun-Tues [5166 - UV/Optical/IR Space Telescopes: Innovative Technologies and Concepts](#) (MacEwen)

Sun-Tues [5165 - X-Ray and Gamma-Ray Instrumentation for Astronomy XIII](#) (Flanagan, Siegmund)

Sun-Mon [5163 - Instruments, Methods, and Missions for Astrobiology VII](#) (Hoover, Rozanov, Paepe)

Tues-Wed [5167 - Focal Plane Arrays for Space Telescopes](#) (Grycewicz, McCreight)

Tues-Wed [5170 - Techniques and Instrumentation for Detection of Exo-Planets](#) (Coulter)

Tues-Thurs [5168 - Optics for EUV, X-Ray, and Gamma-Ray Astronomy](#) (Citterio, O'Dell)

Wed [5172 - Cryogenic Optical Systems and Instrumentation X](#) (Heaney, Burrieschi)

Thurs-Fri [5171 - Telescopes and Instrumentation for Solar Astrophysics](#) (Fineschi, Gummin)

Thurs-Fri [5164 - UV/EUV and Visible Space Instrumentation for Astronomy II](#) (Siegmund)

## **Optical Systems Engineering**

Program on

### **Optical and Optomechanical Design**

Program Chair: **José M. Sasián**, Optical Sciences Ctr./Univ. of Arizona

Sun [5173 - Current Developments in Lens Design and Optical Engineering IV](#) (Mouroulis, Smith, Johnson)

Mon [5174 - Novel Optical Systems Design and Optimization VI](#) (Sasián, Koshel, Manhart)



Mon-Tues [AM100 - Tribute to Emil Wolf: Engineering Legacy of Physical Optics](#) (Jannson)

Wed [5175 - Laser Beam Shaping IV](#) (Dickey, Shealy)

Thurs-Fri [5176 - Optomechanics 2003](#) (Hatheway)

Program on

### **Optical Components and Systems Engineering**

Program Chair: H. Philip Stahl, NASA Marshall Space Flight Ctr.

Sun-Tues [5180 - Optical Manufacturing and Testing V](#) (Stahl)

Mon-Thurs [5179 - Optical Materials and Structures Technologies](#) (Goodman)

Wed-Thurs [5178 - Optical Modeling and Performance Predictions](#) (Kahan)

Wed [5177 - Gradient Index, Miniature, and Diffractive Optical Systems III](#) (Suleski)

Program on

### **Wave Optical Engineering**

Program Chair: **Frank Wyrowski**, Friedrich-Schiller-Univ. Jena (Germany)

Sun-Mon [5182 - Wave-Optical Systems Engineering II](#) (Wyrowski)

Sun-Mon [5183 - Lithographic and Micromachining Techniques for Optical Component Fabrication II](#) (Kley, Herzig)

Tues-Wed [5184 - Physics, Theory, and Applications of Periodic Structures in Optics II](#)  
(Lalanne)

Thurs-Fri [5181 - Wave Optics and Photonic Devices for Optical Information Processing II](#) (Ambs, Beyette)

Program on

### **Illumination Engineering**

Program Chair: **Ian T. Ferguson**, Georgia Institute of Technology

Sun [5185 - Nonimaging Optics: Maximum Efficiency Light Transfer VII](#) (Winston)

Mon-Tues [5186 - Design of Efficient Illumination Systems](#) (Koshel)

Tues-Thurs [5187 - Third International Conference on Solid State Lighting](#) (Ferguson,  
Narendran, DenBaars, Carrano)



Program on

### **Advanced Metrology**

Program Chair: **Katherine Creath**, Optinengineering

Sun-Tues [5188 - Advanced Characterization Techniques for Optics, Semiconductors, and Nanotechnologies](#) (Duparré, Singh)

Sun-Mon [5191 - Optical Diagnostics for Fluids, Solids, and Combustion II](#) (Farrell, Chiang, Mercer, Shen)

Mon-Wed [5190 - Recent Developments in Traceable Dimensional Measurements II](#) (Decker, Brown)

Tues-Wed [5189 - Surface Scattering and Diffraction III](#) (Gu, Maradudin)

Wed [5192 - Optical Diagnostic Methods for Inorganic Materials III](#) (Hanssen)

## **Radiation Technologies**

Program on

### **X-Ray Systems and Technologies**

Program Chair: **Ali M. Khounsary**, Argonne National Lab.

Mon-Wed [5196 - Laser-Generated and Other Laboratory X-Ray and EUV Sources, Optics, and Applications](#) (Kyrala, Gauthier, MacDonald, Khounsary)

Mon-Tues [5194A - Optics for Fourth Generation X-Ray Sources](#) (Tatchyn)

Tues [5195 - Crystals, Multilayers, and Other Synchrotron Optics](#) (Ishikawa, Macrander, Wood)

Wed-Thurs [5197 - Soft X-Ray Lasers and Applications V](#) (Fill)

Wed [5194B - Ultrafast X-Ray Detectors and Applications](#) (Chang, Kieffer, Hastings)

Thurs-Fri [5193 - Advances in Mirror Technology for X-Ray, EUV Lithography, Laser, and Other Applications](#) (Khounsary, Dinger, Ota)

Program on

### **Hard X-Ray, Gamma-Ray, and Particles**

Program Chair: **F. Patrick Doty**, Sandia National Labs.

Wed [5199B - Medical Applications of Penetrating Radiation III](#) (Barber, Roehrig)

Mon-Tues [5198 - Hard X-Ray and Gamma-Ray Detector Physics V](#) (Franks, Burger, James, Hink)

Thurs-Fri [5199A - Penetrating Radiation Systems and Applications V](#) (Doty)

## **Signal and Image Processing**

Program on

### **Algorithms, Architectures, and Devices**

Program Chair: **Bahram Javidi**, Univ. of Connecticut

Sun-Mon [5206 - Photorefractive Fiber and Crystal Devices: Materials, Optical Properties, and Applications IX](#) (Yu, Guo, Yin)

Mon-Tues [5202 - Optical Information Systems](#) (Javidi, Psaltis)

Tues-Wed [5200 - Applications and Science of Neural Networks, Fuzzy Systems, and Evolutionary Computation VI](#) (Bosacchi, Fogel, Bezdek)

Tues-Fri [5203 - Applications of Digital Image Processing XXVI](#) (Tescher)

Tues-Thurs [5204 - Signal and Data Processing of Small Targets 2003](#) (Drummond)

Wed-Fri [5205 - Advanced Signal Processing Algorithms, Architectures, and Implementations XIII](#) (Luk)

Wed-Thurs [5201 - Photonic Devices and Algorithms for Computing V](#) (Iftekharuddin, Awwal)

Program on

### **Mathematical Methods**

Program Chairs: **Gerhard X. Ritter**, Univ. of Florida; **Mark S. Schmalz**, Univ. of Florida

Mon-Fri [5207 - Wavelets X](#) (Unser, Aldroubi, Laine)

Tues [5208 - Mathematics of Data / Image Coding, Compression, and Encryption VI, with Applications](#) (Schmalz)

Program on

### **Detectors and Imaging Devices**

Program Chair: **Randolph E. Longshore**, Raytheon Systems Co.

Thurs-Fri [5210 - High Speed and Ultra High Speed Photography, Photonics, and Videography](#) (Snyder)

Fri [5209 - Materials for Infrared Detectors III](#) (Longshore, Sivananthan)

## **Organic Materials and Nanotechnology**

Program on

### **Organic Photonics and Electronics**

Program Chair: **Zakya H. Kafafi**, Naval Research Lab.

Sun-Mon [5211 - Nonlinear Optical Transmission and Multiphoton Processes in Organics](#) (Yeates)

Sun-Mon [5217 - Organic Field Effect Transistors II](#) (Dimitrakopoulos)

Mon-Wed [5212 - Linear and Nonlinear Optics of Organic Materials III](#) (Kuzyk)

Mon-Wed [5214 - Organic Light-Emitting Materials and Devices VII](#) (Kafafi)

Tues-Wed [5213 - Liquid Crystals VII](#) (Khoo)

Thurs-Fri [5216 - Organic Holographic Materials and Applications](#) (Meerholz)

Thurs-Fri [5215 - Organic Photovoltaics IV](#) (Kafafi)

Program on

### **Nanotechnology**

Program Chairs: **Ghassan E. Jabbour**, Univ. of Arizona; **Vicki L. Colvin**, Rice Univ.

Sun-Mon [5225 - Nano- and Micro-Optics for Information Systems](#) (Eldada)

Sun [5220 - Nanofabrication Technologies](#) (Dobisz)

Sun [5219 - Nanotubes and Nanowires](#) (Lakhtakia, Maksimenko)

Sun-Tues [5221 - Plasmonics: Metallic Nanostructures and Their Optical Properties](#) (Halas)

Mon [5222B - Organic and Hybrid Materials for Nanophotonics](#) (Cartwright, Lee)

Mon-Tues [5218 - Complex Mediums IV: Beyond Linear Isotropic Dielectrics](#) (McCall,

|            |                                                                                                                                      |
|------------|--------------------------------------------------------------------------------------------------------------------------------------|
|            | Dewar)                                                                                                                               |
| Tues-Thurs | <a href="#"><u>5224 - Nanomaterials and Their Optical Applications</u></a> (Cao, Xia, Braun)                                         |
| Wed-Fri    | <a href="#"><u>5223 - Physical Chemistry of Interfaces and Nanomaterials II</u></a> (Lian, Dai)                                      |
| Thurs-Fri  | <a href="#"><u>5222A - Linear and Nonlinear Optics of Nanocrystals</u></a> (Andrews, Gaburro)                                        |
| Sun-Tues   | <a href="#"><u>5188 - Advanced Characterization Techniques for Optics, Semiconductors, and Nanotechnologies</u></a> (Duparré, Singh) |

## 附錄二

1. 4D 公司干涉儀
2. AEH 光機顧問公司
3. Corning 公司 ULE 鏡片材料
4. Hextek 公司資料
5. IR\_Intensifier 資料
6. Kodak 公司 CCD 資料
7. Ohara 公司 CCZ 材料資料
8. SBSI 公司小型干涉儀資料
9. Tinsley 公司資料
10. 行動觀測系統資料

## 1. 4D 公司干涉儀

# PhaseCam 4000

## Dynamic Interferometer System

Vibration can't shake the accuracy and speed of 4D Technology's PhaseCam™ dynamic interferometer system. Nor will long paths, poor isolation, air turbulence, or moving parts. Compact and reliable, only the PhaseCam 4000 delivers high resolution accuracy in the most challenging environments. This patented system incorporates an innovative technique to acquire high spatial resolution phase data in as little as 30μsec!





### Vibration Insensitive

Rapid data acquisition permits conventional optical testing in production environments, as well as large optical component or system testing in configurations where vibration isolation is impractical. Phase measurement over long optical paths and in vacuum and environmental chambers can now be performed with unprecedented precision.

### Dynamic Surface Analysis

The PhaseCam 4000's unique ability to acquire data quickly enables modal analysis of dynamic surface shape at interferometric resolution. Phase data can be transformed into movies to visualize and characterize moving surfaces and verify finite element models.

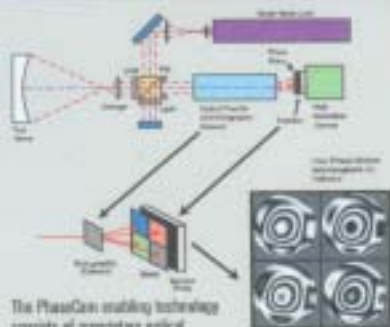
### 4Sight Software

This intuitive Windows™ software/ interface provides control of the system configuration, data acquisition, and on-the-fly display of processed data at 3 frames/sec. Burst mode acquires and stores data at over 20 frames/sec for post processing and analysis. 4Sight™ allows the user to mask data and generate reference files, fit Zernikes and calculate Seidel terms, perform geometric and diffraction analysis, and save, print and export data.



**4D Technology**  
Measurement at the Speed of Light

# PhaseCam 4000 Specifications



The PhaseCam enabling technology consists of proprietary optical elements that modify image formation to simultaneously image multiple phase shifted interferograms.



PhaseCam 4000 dimensions

## System Configuration

### Optical Configuration Acquisition Source

Turn key, includes optical head, computer and software  
Twyman Green interferometer  
Instantaneous phase shifting  
Stabilized HeNe laser at 632.8 nm



WARNING: LASER RADIATION  
AVOID EXPOSURE TO BEAM  
CLASS II LASER PRODUCT  
SEE USER MANUAL

### Beam Diameter Polarization Sample Reflectivity Pupil Focus Range Camera Data Array Computer System

7.0 mm collimated  
Circular  
1 to 100%  
 $\pm 12.5$  mm  
1024 x 1024 pixels, 10 bit  
470 x 470 data array  
2.66 GHz Pentium® IV, 1 GB RAM,  
80 GB hard drive, CDRW, 17" SVGA,  
Windows XP® (min. configuration)

### Software

Instantaneous phase shifting  
Fringe display / exposure control  
Data acquisition and analysis  
On the fly phase processing,  
data masking and terms removal  
Reference generation, subtraction,  
data averaging  
2D and 3D surface maps  
Zernike / Seidel analysis

### Data Format Compatibility

Intellwave™ and Duraango™ software

### Physical Envelope

< 15 cm x 75 cm x 20 cm (H x W x D)

### Weight

< 15 Kg

### Power consumption

< 500 Watts

### Warranty

1 year, limited

## Configuration Options

### Vacuum Operation

Pressure vessel enclosure  
(must be ordered with system)

### 4 MegaPixel Camera

2048 x 2048 pixels / 575 x 975  
data array

### Aperture Converters

25, 50, 100 mm

### Diverging Optics

f/1, 2, 4, 8, 12

### Special Analysis

Modal analysis

## System Performance

### Display Rate

Up to 15 frames/sec:  
4 interferograms/frame

### Minimum Exposure

30 micro-sec

### Acquisition Rate

Up to 3 processed frames/sec

### RMS Repeatability

< 0.001  $\lambda$ , (1  $\sigma$  of rms for 10 data sets,  
each an average of 10 measurements)

### RMS Precision

< 0.002  $\lambda$ , (Average rms of 10 data sets  
with reference subtracted, each data set  
an average of 10 measurements;  
reference is a pixel-by-pixel average of  
10 measurements)



3280 E. Hemisphere Loop, Suite #112 • Tucson, AZ 85706

Phone (520) 294-5600 • Fax (520) 294-5601

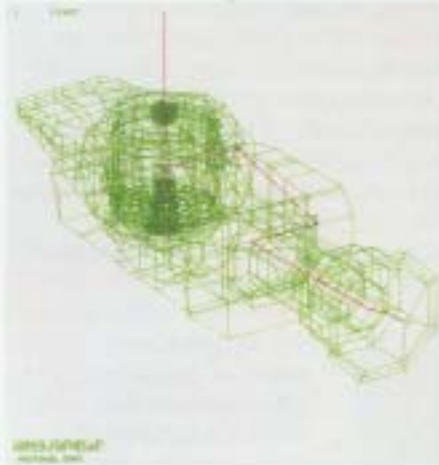
www.4DTechnology.com • info@4DTechnology.com

Specifications are subject to change without notice.  
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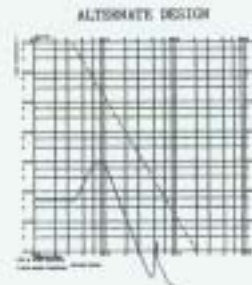
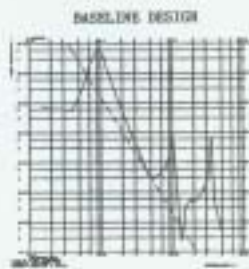
## 2. AEH 光機顧問公司

### Gimbal Stabilized Laser Beam Expander



**Optical Analog<sup>™</sup>** modeling methods were used to incorporate the axial chief ray of a laser beam into the finite element model of the beam expander and its stabilizing gimbal system. The chief ray is shown in red in a plot of the "undeformed" model. The gimbal and the telescope/beam expander is plotted in green. The two-axis gimbal was subject to a random vibration at its mounting base at the lower right side of the plot.

Performance of the system required sub-microradian rms pointing stability of the laser beam. Incorporating the laser's chief ray directly in the finite element model using **Optical Analog** methods permitted rapid evaluation of the suitability of the structural design and it was possible to improve the beam stability by two orders of magnitude (Alternate Design compared to Baseline Design).



**Optical Analog** methods have been used to evaluate both image motion and image deterioration due to the motion and deformation of the optical elements.

### Alson E. Hatheway Incorporated

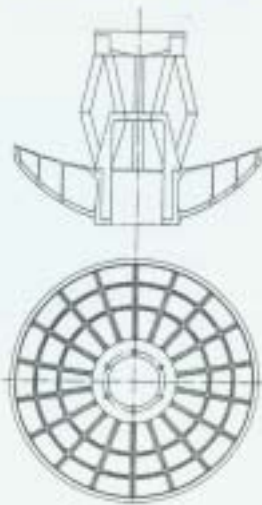
Suite 400, 595 East Colorado Boulevard, Pasadena, California 91101

v: (626)795-0514, f: (626)795-0781, e: aeh@aehinc.com

"Optical Analog" is a trademark of Alson E. Hatheway Inc.



# Optically Guided Ordnance



Telescope design

**Optical Analog™** modeling techniques were used in a **Unified Analysis™** of an all-beryllium telescope designed for use in guided munitions. The telescope was required to operate after exposure to 100,000 gs initial acceleration (launch). Plastic yielding of the beryllium had to be sufficiently small that the after-launch spot size was small with respect to the detector elements on the focal plane assembly.

Cylindrical symmetry permitted the finite element model to be a 20° sector of the telescope. **The Optical**

**Analog** was used to incorporate 44 optical rays into the sector, all controlled by the optical law of reflection at the mirror surfaces. The **Optical Analog** was used to calculate the after-launch radius of the blur circle on the detector element at the optical axis.

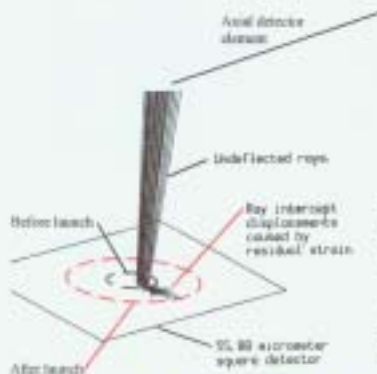


Unified analysis model

The rms radius of the blur circle was used with the Design Sensitivity Analysis (DSA) routines of the finite element code to minimize the

mass of the primary mirror. Nonlinear finite element methods were used to predict the residual strains after launch.

**Optical Analog** techniques in a **Unified Analysis** environment provided reliable prediction of the after-launch image quality (spot size).



## Alson E. Hatheway Incorporated

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"Optical Analog" and "Unified Analysis" are trademarks Alson E. Hatheway Inc.

## Airborne Spectrometer

AEH repackaged a laboratory spectrometer and ruggedized it for airborne research over the polar ice during winter. The spectrometer's components were mounted in an environmentally sealed enclosure, insulated from the extreme cold and heated to assure stable operating temperatures. The entire instrument package was mounted on a two-axis gimbal. The gimbal was, in turn, mounted to the outside of the helicopter's airframe on specially selected "hard points." A low light level video camera was boresighted to the spectrometer in the instrument package and permitted the operator to direct the spectrometer toward selected objects in the environment.



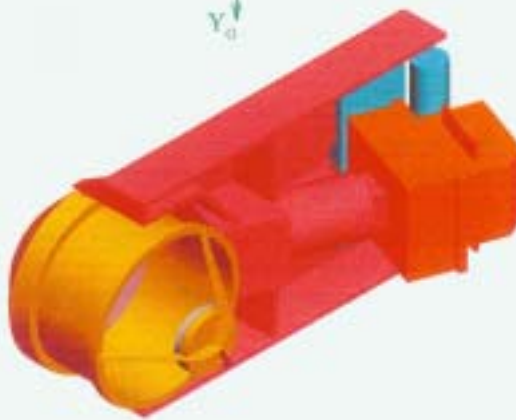
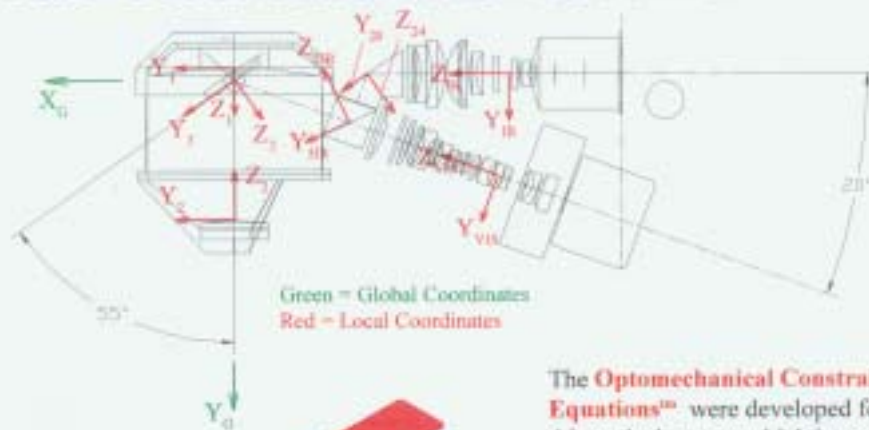
The project activity included design, analysis, **manufacturing, assembly, integration into the helicopter and acquiring FAA certification for flight.** The system survived the winter's service and was later deployed to tropical climates for additional research.



**AEH.**

[ach@aehtec.com](mailto:ach@aehtec.com)

## Two-color Airborne Receiver



The **Optomechanical Constraint Equations™** were developed for this optical system which is comprised of thirty-four optical elements including two focal plane arrays (one cryogenically cooled) and a shared all-reflective objective lens. The equations were derived from the physical prescription of the optical design (CodeV) and read into a spreadsheet (Excel) for use. There were 238 independent degrees of freedom (lens motions) controlling the seven registration variables at the detectors.

A complementary finite element model was used to calculate the independent degrees of freedom that were then copied into the spreadsheet. This technique permitted the rapid and repeated evaluation of the registration errors (between the images and the detectors) caused by environmental variables such as vibration, gravity and heating.

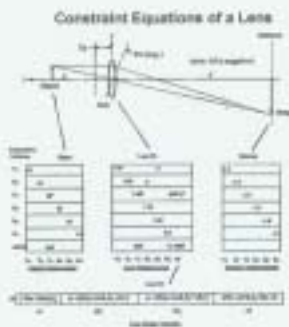
The **Optomechanical Constraint Equations** were used during the design to,

- Optimize mass and stiffness of the optical bench
- Devise alignment plans and size alignment mechanisms
- Stabilize the images on the detectors

"Optomechanical Constraint Equations" is a trademark of Alison E. Hatheway Inc.

**AEH.**  
aeh@aehtec.com

Figure 1 consists of two parts. Part (a) is a 3D perspective view of a rectangular environment containing several obstacles, including a tall rectangular block and several smaller blocks. Two robots are shown: one is a small cube, and the other is a more complex, multi-segmented robot. Part (b) is a 2D grid map of the same environment. The grid is divided into cells. A red path is shown, starting from the top left and ending at the bottom right. A blue path is also shown, starting from the top left and ending at the bottom right. A small coordinate system is shown at the bottom left of the grid.



The mechanical design was simulated in a simple finite element thermal and elastic model. The **optomechanical constraint equations** were used to couple 96 elastic displacements

| Temperature (°C) | Coating Efficiency (%) |
|------------------|------------------------|
| 25               | 100                    |
| 35               | 95                     |
| 45               | 65                     |
| 50               | 42                     |

Suite 400, 595 East Colorado Boulevard, Pasadena, California 91101  
v: (626)795-0514, f: (626)795-0781, e: aeh@aehinc.com



### 3. Corning 公司 ULE 鏡片材料

**ULE<sup>®</sup>**, Corning Code 7972 Ultra Low Expansion glass is a titanium silicate glass with unique characteristics that has made it the material of choice in applications ranging from machine tool reference blocks to solid and lightweight mirror blanks for large astronomical telescopes and space satellite applications.

Leading industry experts in the semiconductor integrated circuits manufacturing industry have identified ULE as a "material of choice" for EUV applications.

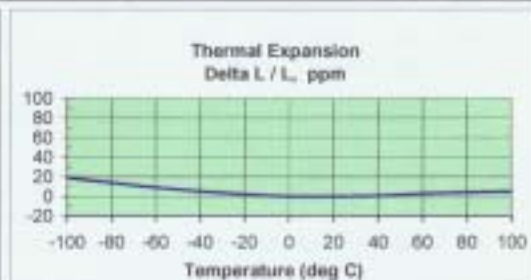
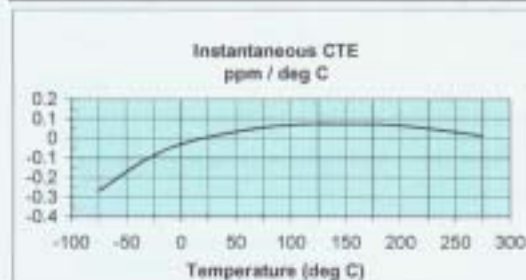
**LINEAR COEFFICIENT OF THERMAL EXPANSION (CTE)** - The guaranteed maximum limits for CTE and Optical Retardation are as follows:

- For all grades, CTE shall be  $0 \pm 30$  ppb/ $^{\circ}\text{C}$  over a temperature range of 5 to  $35^{\circ}\text{C}$ , with a 95% confidence level.
- Delta CTE = Variation of CTE measurements within a part as measured in the radial and axial direction.

**INCLUSION QUALITY** - The guaranteed maximum limits for seeds, bubbles, and opaque inclusions are as follows:

**Quality Grade Selection Chart**

| GRADE    | Delta CTE (ppb/ $^{\circ}\text{C}$ )                      |             | Birefringence (nm/cm)<br>Optical Retardation | Inclusion Quality Information                                                       |                       |                  |
|----------|-----------------------------------------------------------|-------------|----------------------------------------------|-------------------------------------------------------------------------------------|-----------------------|------------------|
|          | Radial Range                                              | Axial Range |                                              | Inclusion Definition                                                                | Diameter or Diagonal: |                  |
|          |                                                           |             |                                              |                                                                                     | $\leq 20''$           | $20''$ to $58''$ |
| Premium  | 10                                                        | 10          | 10                                           | Mean Diameter<br>Inclusions per cubic inch<br>Avg. no. of inclusions per cubic inch | 0.040"<br>4<br>0.1    | N/A              |
| Mirror   | 15                                                        | 15          | 20                                           | <b>Critical Zone - See Notes Below</b>                                              |                       |                  |
|          |                                                           |             |                                              | Mean Diameter                                                                       | 0.040"                | 0.080"           |
|          |                                                           |             |                                              | Inclusions per cubic inch                                                           | 4                     | 6                |
|          |                                                           |             |                                              | Avg. no. of inclusions per cubic inch                                               | 0.1                   | 0.2              |
|          |                                                           |             |                                              | <b>Non-Critical Zone - See Notes Below</b>                                          |                       |                  |
|          |                                                           |             |                                              | Mean Diameter                                                                       | 0.100"                | 0.250"           |
|          |                                                           |             |                                              | Avg. no. of inclusions per cubic inch                                               | 0.2                   | 0.6              |
| Standard | 15                                                        | 15          | 20                                           | Mean Diameter<br>Avg. no. of inclusions per cubic inch                              | 0.100"<br>0.2         | 0.250"<br>0.6    |
| Tooling  | Delta CTE not specified. Delta CTE data is not available. |             |                                              | No guaranteed maximum limits on inclusions.                                         |                       |                  |



- **No measurable hysteresis** results from thermal cycling of ULE regardless of the rate of temperature change.
- **Full characterization** of CTE is achieved through a rapid, non destructive ultrasonic method.
- **Stability:**
  - Excellent long term dimensional stability at room temperature.
  - No residual figure change when taking a mirror from  $350^{\circ}\text{C}$  to a water quench.
- **Delayed Elastic Effect** - There has been no measurable delayed elastic effect in ULE. This is an important consideration when large strain is present during fabrication or when environmental loading is present, such as during gravity release or dynamic control of active optics.

**Properties:** Unless otherwise stated, all values @ 25°C

**Thermal Properties:**

|                                                                  |                                                                                  |                              |                                                                                                  |
|------------------------------------------------------------------|----------------------------------------------------------------------------------|------------------------------|--------------------------------------------------------------------------------------------------|
| Mean Coefficient of Thermal expansion ( $\alpha$ )               | $0 \times 10^{-6}/^{\circ}\text{K}$<br>[0 ppb/ $^{\circ}\text{C}$ ]              | Mean Specific Heat ( $C_p$ ) | 767 J/(kg $\cdot$ $^{\circ}\text{C}$ )<br>[0.183 cal/(g $\cdot$ $^{\circ}\text{C}$ )]            |
| CTE Maximum Variation 5-35 $^{\circ}\text{C}$ ( $\Delta\alpha$ ) | $\pm 30 \times 10^{-6}/^{\circ}\text{K}$<br>[ $\pm 30$ ppb/ $^{\circ}\text{C}$ ] | Thermal Conductivity (K)     | 1.31 W/(m $\cdot$ $^{\circ}\text{C}$ )<br>[1.13 kcal/(m $\cdot$ hr $\cdot$ $^{\circ}\text{C}$ )] |
| Thermal Diffusivity (D)                                          | 0.0079 cm <sup>2</sup> /s                                                        | Strain Point                 | 890 $^{\circ}\text{C}$ [1634 $^{\circ}\text{F}$ ]                                                |
| D.C. Volume Resistivity, 200 $^{\circ}\text{C}$ , 100Hz (R)      | $10^{14}$ ohm $\cdot$ cm                                                         | Annealing Point              | 1000 $^{\circ}\text{C}$ [1832 $^{\circ}\text{F}$ ]                                               |
|                                                                  |                                                                                  | Softening Point (Estimated)  | 1490 $^{\circ}\text{C}$ [2714 $^{\circ}\text{F}$ ]                                               |

**Mechanical Properties:**

|                               |                                                      |                                 |                                              |
|-------------------------------|------------------------------------------------------|---------------------------------|----------------------------------------------|
| Poisson's Ratio ( $\nu$ )     | 0.17                                                 | Specific Stiffness ( $E/\rho$ ) | $3.12 \times 10^6$ m [1.23 $\times 10^6$ in] |
| Ultimate Tensile Stress (MOR) | 49.8 MPa [7220 psi]                                  | Shear modulus (G)               | 29.0 GPa [4.20 $\times 10^6$ psi]            |
| Knoop Hardness, 200 g load    | 400 kg/mm <sup>2</sup>                               | Bulk Modulus (K)                | 34.1 GPa [4.95 $\times 10^6$ psi]            |
| Density ( $\rho$ )            | 2.21 g/cm <sup>3</sup> [0.07965 lb/in <sup>3</sup> ] | Elastic Modulus (E)             | 67.8 GPa [9.80 $\times 10^6$ psi]            |

**Optical Properties:**

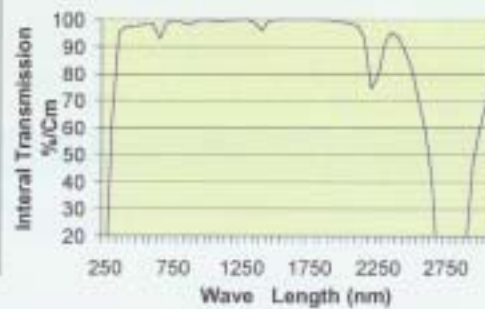
|                                         |                                                           |                                  |                                         |
|-----------------------------------------|-----------------------------------------------------------|----------------------------------|-----------------------------------------|
| Stress Optical Coefficient              | 4.15 (nm/cm)/(kg/cm <sup>2</sup> )<br>[0.292 (nm/cm) psi] | Abbe' Number ( $v_d$ )           | 53.1                                    |
| Refractive Index (nominal CTE material) |                                                           | $dn/dt$ 20-40 $^{\circ}\text{C}$ | $10.68 \times 10^{-6}/^{\circ}\text{C}$ |
| $n_d(486 \text{ nm})$                   | 1.4892                                                    | 40-60 $^{\circ}\text{C}$         | $11.24 \times 10^{-6}/^{\circ}\text{C}$ |
| $n_d(589 \text{ nm})$                   | 1.4828                                                    |                                  |                                         |
| $n_d(656 \text{ nm})$                   | 1.4801                                                    |                                  |                                         |

**Chemical Durability:**

- Excellent resistance to weathering.
- Exhibits virtually no surface clouding or electrical surface leakage when subject to attack by water, sulfur dioxide, and atmospheric gases.
- High resistance to attack by nearly all chemical agents.

| Solution @ 95 $^{\circ}\text{C}$     | Test Duration | Wet Loss                 |
|--------------------------------------|---------------|--------------------------|
| 5% HCl                               | 24 hrs        | <0.01 mg/cm <sup>2</sup> |
| 5% NaOH                              | 6 hrs         | 0.9 mg/cm <sup>2</sup>   |
| .02N Na <sub>2</sub> CO <sub>3</sub> | 6 hrs         | 0.02 mg/cm <sup>2</sup>  |
| 5% H <sub>2</sub> SO <sub>4</sub>    | 24 hrs        | <0.01 mg/cm <sup>2</sup> |
| H <sub>2</sub> O                     | 24 hrs        | <0.01 mg/cm <sup>2</sup> |

**ULE Internal Transmission**



**NOTES:**

- **Critical Zone** - a quality layer typically extending to a depth of 0.200" below the surface specified by the customer for finishing.
- **Non-Critical Zone** - all glass outside the Critical Zone.
- Inclusions with 0.005" or smaller mean diameter are disregarded.
- Premium Grade available in sizes up to 20" diameter or diagonal by 3" thick.
- Mirror and Standard Grades available in sizes up to 58" diameter or diagonal by 5" thick. Corning would be pleased to quote larger sizes to customer specs.
- Tooling Grade available. Please contact Corning for availability.

**For additional information or quotes, please contact us:**

|                            |                       |                       |                             |
|----------------------------|-----------------------|-----------------------|-----------------------------|
| <b>Customer Service</b>    | Tel: (315) 379 - 3670 | Fax: (315) 379 - 3317 | <b>Corning Incorporated</b> |
| <b>Product Engineering</b> | Tel: (315) 379 - 3381 | Fax: (315) 379 - 3317 | 334 County Rt 16            |
|                            |                       |                       | Canton, New York 13617      |

**ULE™**

Corning's Code 7971  
Ultra Low Expansion  
Titanium Silicate Glass...

ULE's unique characteristics  
have made it the material  
of choice in applications  
ranging from machine  
tool reference blocks to  
solid and lightweight  
mirror blanks for large  
astronomical telescopes and  
space satellite applications.



*The first 8.2 meter ULE mirror blank for the Gemini II-A Telescope Project was completed in October 1995 and will be delivered to the Gemini Observatory in 1998.*

## Characteristics of ULE™

ULE is an Ultra Low Expansion (ULE) ultra-pure glass from Corning, manufactured by flame hydrolysis. This glass is formed as large boules, typically 1.5 meters in diameter by 15 cm thick, from which virtually any size product can be made.

### Coefficient of Thermal Expansion (CTE)

Corning ULE offers superior dimensional stability due to essentially zero expansion at room temperature...

- Average coefficient of thermal expansion is zero at room temperature.
- There is high homogeneity of CTE within each boule, typically less than 15 ppb/°C radially and axially.
- Measurement of CTE is performed non-destructively (by interferometry) on boules, and can be performed on products as well.
- No noticeable hysteresis is exhibited after thermal cycling. ULE has been heated to 150°C, then water quenched with no residual figure change.

### Fabrication Flexibility is Design Freedom

Several key manufacturing processes used by Corning offer extensive design freedom in terms of size, shape, and weight...

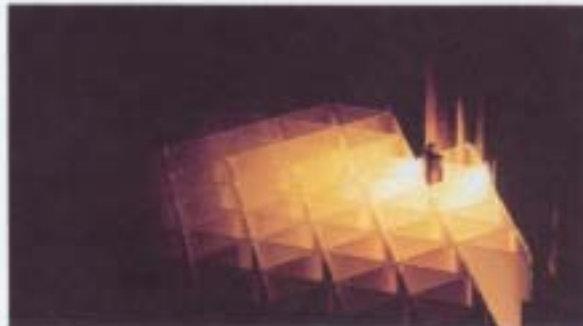
- Monolithic solids can be made from a few centimeters to over 10 meters in diameter.
- Lightweight fused bonded structures offer up to 80% weight reduction over the same sized solids.
- Ultra-lightweight frit bonded structures with up to 95% weight reduction are possible using a glass fritting frit which closely matches the expansion of the ULE glass.



The 8.1 meter ULE mirror blank for the future telescope is the largest monolithic mirror in the world.



The CTE of ULE can be measured non-destructively because both ultrasonic velocity and expansion correlate directly with density content. A single measurement of ultrasonic transit time through ULE corrects for the CTE with an accuracy of  $\pm 2$  ppb/°C.



Triangles which have already been formed by fusing struts together are then fused to form a lightweight optical wave structure.



## Applications for Zero Expansion ULE™ Material for engineering and design

Zero coefficient of thermal expansion (ZTE) is a material property performance feature that is valuable to the designer.

- Low CTE guarantees dimensional stability under thermally variable conditions. ULE is used in critical applications where dimensional stability is a requirement.
  - in an application such as a resonant cavity ULE will maintain the critical dimensions of the cavity.
  - Machine tools, such as computer numerically controlled (CNC) devices use ULE as a reference standard to insure precision.
  - Key components made from ULE in microphotography machines meet the reproducibility required in that demanding application.

- Low CTE also provides a high degree of thermal shock resistance. ULE's outstanding thermal shock resistance enabled breakthrough technology in optical fiber techniques for medical applications.

- ULE has the excellent chemical resistance and the optical clarity you expect from glass.



A 3.3 meter diameter ULE total mirror blank for a microwave probe



Zero expansion components of precise size and shape can be fabricated from ULE by standard manufacturing processes

## Mirror Applications

Ure<sup>TM</sup> is the material of choice for mirror substrates for many applications:

- Zero thermal expansion ensures mirror faces with temperature changes. Ure is fully characterized for CTE. Since the actual small variations of CTE within any blank are known in advance, finite element modeling can be used to predict the performance of the blank due to temperature changes.
- Lower density allows mirrors to have less mass, which speeds thermal equilibration and reduces support mechanism cost.
- High specific surface results in rigid surfaces.
- Ure can easily be polished to specular finishes better than 10 angstroms, which results in great coatings.

## Solids

Solid mirror blanks of virtually any diameter, thickness and shape can be manufactured of Ure using Goring's fusion casting processes.

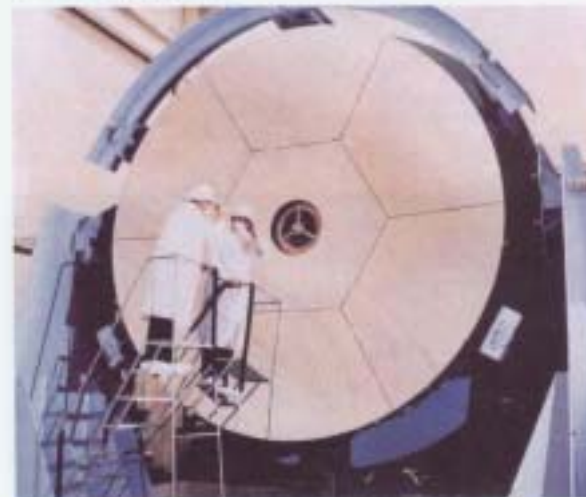
- A single boule can be made into blanks up to 1.4 meters in diameter.
- Single or multiple boules can be flowed out to produce blanks from 1.4 to 2.3 meters in diameter.
- Multiple boules can be hot welded into monolithic blanks greater than 8 meters in diameter. Strength of fusion bonds is equal to that of the parent glass.
- Desired contours can be ground directly into the blank, or the blank can be sagged to a near free shape contour and then finish ground.



The 8.1 meter (center mirror) blank was fabricated using the hot casting process. Both surfaces, the center hole, and outside diameter were generated by sagging to a near net shape.



The Large Mirror Segment (LMS) mirror for the 4.5 meter (in diameter) and was finished to a thickness of only 17 mm, an aspect ratio of 215:1.



The LMS (Large Advanced Mirror Segment) mirror fabricated from seven segments of Ure.

## Lightweights

Lightweight structures for aerospace applications must be capable of withstanding stresses imposed by launch and the space environment, including extreme and rapid temperature variations, high vacuum, zero gravity, vibration and shock. The EET™ properties that make it the preferred material for such applications are:

- Zero thermal expansion
- Relatively low density
- High modulus of elasticity

### Machined Lightweight Blanks

Using CNC machining techniques, complex lightweight mirror blanks ranging from 50% to 80% weight reduction can be made from EET.

### Fusion Bonded Lightweight Blanks

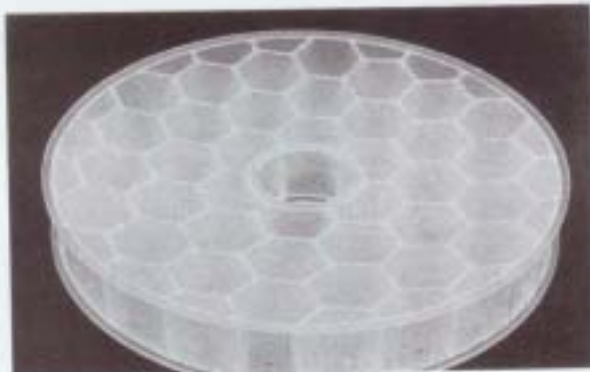
Fusion bonding techniques can be used to obtain up to 80% weight reduction. A lightweight core is produced using one of a number of techniques, and then front and back plates are fused to the core. Structurally superior and dimensionally stable lightweight monolithic mirror blanks are the result.

- Tensile core structures can take many forms: square, rectangular or triangular, as well as custom designed structures. They are made by fusion bonding small pieces of EET at room temperature.
- Bucklewell core structures can also be made using different methods: simple interlocking, machining, and abrasive waterjet cutting offer maximum design flexibility.

### Frit Bonded Ultralightweight Blanks

A frit bonding process developed by Corning produces mirror blanks in excess of 90% weight reduction. Extremely thin, rigid lightweight cores can be frit bonded to front and back plates at a relatively low temperature, maintaining tight dimensional tolerances with no distortion of the structure.

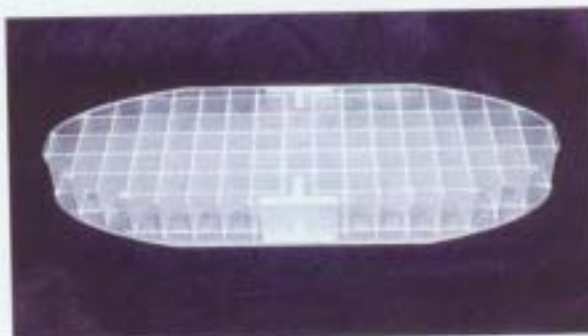
- Both bond core and abrasive waterjet cut structures with cell walls as thin as 1.5 mm, with core densities as low as 5%.
- Ultralightweight cores and film reinforced plates frit bonded together produce a mirror shape mirror blank requiring minimal processing by the optical fabricator.



The 0.7 meter diameter EET lightweight primary mirror blank for the Space Imaging satellite weighs only 1.1 kg. Mirror core developed at CNRS.



EET can be lightweighted by using standard CNC machining techniques.



The 700 mm long x 250 mm wide elliptical shaped frit bonded ultralightweight mirror blank weighs only 0.5 kg.

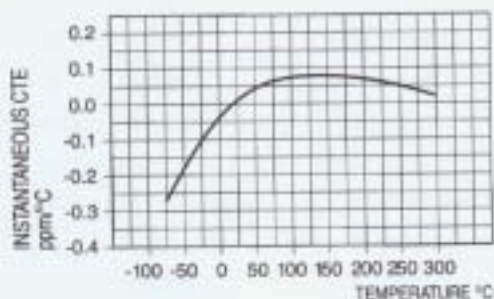
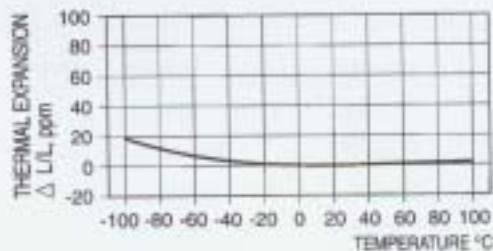
## ULE™ Zero Expansion Glass

### Coefficient of Thermal Expansion (CTE)

Corning ULE offers superior dimensional stability due to essentially zero expansion at room temperature...

- Measurement of CTE is performed nondestructively using an ultrasonic method to characterize all bodies. Because ultrasonic velocity and expansivity both correlate linearly with titania content, simple measurement of ultrasonic transit time through a given thickness of ULE yields the CTE of the glass. When a body is being evaluated for a particular application, both radial and axial CTE data are considered. For any given size or shape, the three-dimensional CTE can be compared with the product requirements to assure CTE specifications and thermal performance requirements are met.
- No measurable hysteresis is exhibited after thermal cycling.
- The mean linear Coefficient of Thermal Expansion is zero, with guaranteed maximum limits of  $\pm 30$  ppb/°C, from 5°C to 35°C.
- High homogeneity of CTE allows selection of even tighter CTE ranges.

Please refer to the table for available CTE grades.



|                | Radial CTE Range (ppb/°C)                                                                                                                  | Axial CTE Range (ppb/°C) | Optical Retardation (nm/cm) |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-----------------------------|
| PREMIUM GRADE  | 10                                                                                                                                         | 10                       | 10                          |
| MIRROR GRADE   | 15                                                                                                                                         | 15                       | 20                          |
| STANDARD GRADE | 15                                                                                                                                         | 15                       | 20                          |
| TOOLING GRADE  | Variation of CTE and optical retardation are not specified for Tooling Grade. CTE data on actual parts is not available for Tooling Grade. |                          |                             |

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## ULE™ At A Glance

| Property                                     | Symbol               | Scientific International           | Common Use                 |
|----------------------------------------------|----------------------|------------------------------------|----------------------------|
| Mean Coefficient of Thermal Expansion 5–35°C | $\alpha$             | $0 \times 10^{-6}/K$               | 0 ppb/°C                   |
| CTE Maximum Variation (5–35°C)               | $\Delta\alpha$       | $\pm 30 \times 10^{-6}/K$          | $\pm 30$ ppb/°C            |
| Mirror grade                                 |                      | $\leq 15 \times 10^{-6}/K$         | $\leq 15$ ppb/°C           |
| Premium grade                                |                      | $\leq 10 \times 10^{-6}/K$         | $\leq 10$ ppb/°C           |
| Density, 25°C                                | $\rho$               | 2.21 g/cm <sup>3</sup>             | 0.07966 lb/in <sup>3</sup> |
| Elastic Modulus, 25°C                        | E                    | 67.6 GPa                           | $9.80 \times 10^6$ psi     |
| Shear Modulus, 25°C                          | G                    | 29.0 GPa                           | $4.20 \times 10^6$ psi     |
| Bulk Modulus, 25°C                           | K                    | 34.1 GPa                           | $4.95 \times 10^6$ psi     |
| Ultimate Tensile Stress, 25°C                | (MOR)                | 49.8 MPa                           | 7220 psi                   |
| Poisson's Ratio, 25°C                        | $\nu$                | 0.17                               | 0.17                       |
| Thermal Conductivity, 25°C                   | K                    | 1.31 w/(m·°C)                      | 1.13 kcal/(m·hr·°C)        |
| Mean Specific Heat, 25°C                     | $C_p$                | 767 J/(kg·°C)                      | 0.183 cal/(g·°C)           |
| Thermal Diffusivity, 25°C                    | D                    | 0.0079 cm <sup>2</sup> /s          | 0.0079 cm <sup>2</sup> /s  |
| Softening Point (estimated)                  |                      | 1490°C                             | 2714°F                     |
| Annealing Point                              |                      | 1000°C                             | 1832°F                     |
| Strain Point                                 |                      | 890°C                              | 1634°F                     |
| D.C. Volume Resistivity, 200°C, 100Hz        | R                    | $10^{11.6}$ ohm·cm                 | $10^{11.6}$ ohm·cm         |
| Stress Optical Coefficient                   |                      | 4.15 (nm/cm)/(kg/cm <sup>2</sup> ) | 0.292 (nm/cm)/psi          |
| Refractive Index (nominal CTE material)      | $n_D(589\text{ nm})$ | 1.4828                             | 1.4828                     |
| Abbe Number                                  | $v_d$                | 53.1                               | 53.1                       |
| Knoop Hardness, 200 g load                   |                      | 460 kg/mm <sup>2</sup>             | 460 kg/mm <sup>2</sup>     |
| Specific Stiffness                           | E/ $\rho$            | $3.12 \times 10^6$ m               | $1.23 \times 10^6$ in      |

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## ULE™ Zero Expansion Glass

**INCLUSION QUALITY:** The guaranteed maximum limits for seeds, bubbles, and opaque inclusions are as follows. Inclusions with 0.12 mm or smaller mean diameter are disregarded.

|                   |                                                                                                                                         | Diameter or Diagonal |                 |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------|----------------------|-----------------|
|                   |                                                                                                                                         | Less than 50 cm      | 50 cm to 147 cm |
| PREMIUM<br>GRADE  | Mean Diameter                                                                                                                           | 1 mm                 | N/A             |
|                   | Inclusions/cm <sup>3</sup>                                                                                                              | 0.24                 |                 |
|                   | Average number of inclusions/cm <sup>3</sup>                                                                                            | 0.006                |                 |
| MIRROR<br>GRADE   | <i>Critical Zone</i> —a quality layer typically extending to a depth of 5 mm below the surface specified by the customer for finishing: |                      |                 |
|                   | Mean Diameter                                                                                                                           | 1 mm                 | 2 mm            |
|                   | Inclusions/cm <sup>3</sup>                                                                                                              | 0.24                 | 0.36            |
|                   | Average number of inclusions/cm <sup>3</sup>                                                                                            | 0.006                | 0.012           |
|                   | <i>Non-Critical Zone</i> —all glass outside the Critical Zone:                                                                          |                      |                 |
|                   | Mean Diameter                                                                                                                           | 2.5 mm               | 6.4 mm          |
| STANDARD<br>GRADE | Average number of inclusions/cm <sup>3</sup>                                                                                            | 0.012                | 0.036           |
|                   | Mean Diameter                                                                                                                           | 2.5 mm               | 6.4 mm          |
| TOOLING<br>GRADE  | Average number of inclusions/cm <sup>3</sup>                                                                                            | 0.012                | 0.036           |
|                   | No guaranteed maximum limits on inclusions for Tooling Grade.                                                                           |                      |                 |

### STANDARD DIMENSIONAL TOLERANCES AND FINISHES:

Corning can provide a wide variety of finishes and tolerances to meet your needs. Unless otherwise requested, the following standard finishes and tolerances for sizes up to 147 cm will be used:

#### Standard Finishes

|                |                |
|----------------|----------------|
| Plane Surfaces | D151 or better |
| Edges          | D252 or better |

#### Tolerances

|                        |           |
|------------------------|-----------|
| Diameter, Length/Width | +1 mm, -0 |
| Thickness              | +1 mm, -0 |

#### Hand Bevels

|                                                                          |
|--------------------------------------------------------------------------|
| 0.5 mm-1.5 mm x 45 degrees on parts up to 50 cm diameter or diagonal     |
| 1.2 mm-2.5 mm x 45 degrees on parts 50 cm to 147 cm diameter or diagonal |

### SPECIAL FINISHES AVAILABLE UPON REQUEST:

- Tighter tolerances on dimensions
- Finer finishes
- Spherical contours
- Commercial polishes
- Machined bevels
- Centerless ground rods
- Thin wafers
- Sawcut blanks

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## ULE™ Zero Expansion Glass

### Optical Properties

#### • Birefringence

Birefringence resulting from permanent stress is specified by ULE grade:

Precision: 10 nan/cm maximum  
Mirror and Standard: 20 nan/cm maximum  
Tooling: (not specified)

#### • Stress Optical Coefficient (Birefringence Constant)

0.292 (nan/cm)/psi  
6.15 (nan/cm)/(kg/cm<sup>2</sup>)

#### • Striae normal to blank faces

Grade A per MIL-G-174

#### • Refractive Index of Nominal

(D ppb/°C) Material

$n_o$ (486 nm): 1.4892

$n_o$ (589 nm): 1.4828

$n_e$ (589 nm): 1.4801

#### • Refractive Index Change with Temperature

$\Delta n_o$ : 20-40°C:  $10.66 \times 10^{-6}/^\circ\text{C}$

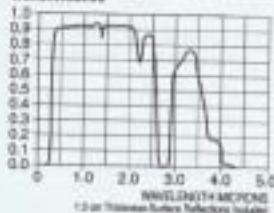
40-60°C:  $11.24 \times 10^{-6}/^\circ\text{C}$

#### • Dispersion

Abbe (V<sub>d</sub>) value:  $V_d = \frac{n_D - 1}{n_F - n_C} = 55.1$

#### • Transparency allows fast and accurate optical inspection.

#### • Transmittance



### Electrical Properties

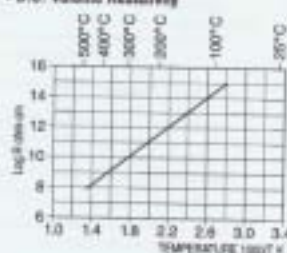
#### • Dielectric Constant

|       | @ 100Hz | @ 1kHz | @ 10kHz |
|-------|---------|--------|---------|
| 25°C  | 3.99    | 3.99   | 3.99    |
| 200°C | 4.00    | 4.00   | 4.00    |
| 300°C | 4.05    | 4.06   | 4.00    |
| 400°C | —       | 4.04   | 4.05    |

#### • Loss Tangent

|       | @ 100Hz | @ 1kHz  | @ 10kHz |
|-------|---------|---------|---------|
| 25°C  | 0.00005 | 0.00005 | 0.00002 |
| 200°C | 0.0008  | 0.00015 | 0.00005 |
| 300°C | 0.078   | 0.0078  | 0.0006  |
| 400°C | —       | 0.14    | 0.019   |

#### • D.C. Volume Resistivity



### Chemical Durability

#### • Excellent resistance to weathering

• Exhibits virtually no surface clouding or electrical surface leakage when subjected to attack by water, sulfur dioxide, and other atmospheric gases.

• High resistance to attack by nearly all chemical reagents.

| Solution @ 90°C                    | Duration of Test (hr) | Weight Loss (mg/cm <sup>2</sup> ) |
|------------------------------------|-----------------------|-----------------------------------|
| 5% HCl                             | 24                    | <0.01                             |
| 5% NaOH                            | 4                     | 0.3                               |
| 40N H <sub>2</sub> CO <sub>3</sub> | 4                     | 0.02                              |
| 5% H <sub>2</sub> SO <sub>4</sub>  | 24                    | <0.01                             |
| H <sub>2</sub> O                   | 24                    | <0.01                             |

• Rapid corrosion occurs only on exposure to hydrofluoric acid and concentrated alkaline solutions, the rate of attack increasing with temperature.

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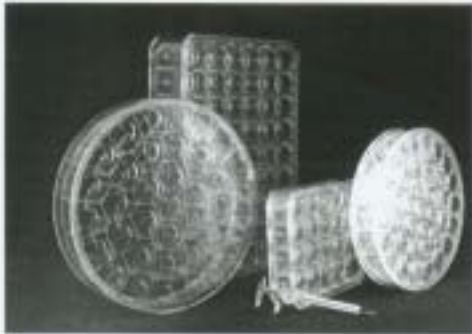


#### 4. HEXTEK 公司資料



## HEXTEK Substrates

## Gas-Fusion™ Technology



- ▶ Stiffer than a Solid
- ▶ Lightweight
- ▶ Rapid Thermal Stability
- ▶ Flexible Shape Design
- ▶ Near Net Shape Slumping
- ▶ Easy to Mount
- ▶ Robust Structural Integrity
- ▶ Guaranteed 100% Fused

|                           |                                                                                                                                                                      |
|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Experience</b>         | Over 17 years of manufacturing experience in large optics. Full range of capabilities including slumping, generating and subcontracting polishing/coating.           |
| <b>Optical Accuracy</b>   | Documented optical accuracy better than $\lambda/20$ p-v without print through.                                                                                      |
| <b>Sizes &amp; Shapes</b> | Customized geometries ranging from 8 to 55 inches (0.2 to 1.4 Meters) – Larger possible. Plano, parabolic, spherical, elliptical and aspheric – as fast as f/0.5.    |
| <b>Weight Savings</b>     | Typical lightweighting of up to 75% for terrestrial and airborne applications. Areal densities for space based applications ranging from 10 – 20 kg/m <sup>2</sup> . |
| <b>Delivery</b>           | Hextek is set up to meet quick delivery timing for custom substrates.                                                                                                |
| <b>Applications</b>       | Hextek Gas-Fusion™ Substrates have been selected for a wide range of applications by major institutions and government agencies worldwide. See below.                |

#### APPLICATIONS

- Astronomical Research
- Airborne Optical Systems
- Remote Sensing
- Laser Fusion Systems
- Spaceborne Satellite Systems
- LIDAR System
- Reference Optics
- Metrology Instrumentation
- Sounding Rocket Instrumentation

#### CUSTOMERS

National Labs

- Lawrence Livermore
- Los Alamos
- Oak Ridge
- Sandia

Universities

- U of Arizona
- U of Chicago
- U of Hawaii
- New Mexico State
- U of Wisconsin
- U of Washington
- Indiana University
- Ohio State University

Industrial Partners

- KLA-Tencor
- Kyohara Optics, Japan

Spaceborne / Airborne

- NASA, Goddard
- NASA, Marshall
- SAIC/BMDO (Star Wars)

Aerospace

- TRW Space & Technology Div
- Textron Systems
- Lockheed Martin
- Tires

Military

- United States Air Force
- United States Army
- United States Navy
- HELJTO

US & International Telescopes

- LBT (Large Binocular Telescope)
- Sloan Digital Sky Survey
- KECK - Lick Observatory
- MMT - Smithsonian Astronomical Observatory
- Subaru
- ARC - Astronomical Research Consortium
- NRC - Canada
- Korean Astronomical Observatory Telescope
- Lickteknicker Optics
- South African Automatic Photoelectric Telescope

INC 010903



**HEXTEK Corporation**  
520.623.7547  
www.hextek.com

## Mounting Solutions

### Mounting Bosses

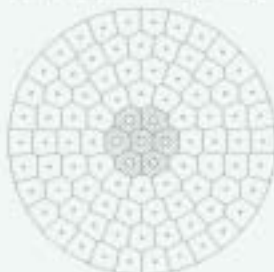
Mounting bosses are plates fused into the rib structure of the blank allowing the mirror to be held at the center of gravity plane.

Mirrors can now be mounted from the center of gravity (cg) plane rather than by the edge. This approach is accomplished by fusing mounting bosses (plates) into the rib structure of the mirror blank. Hextek mounting bosses are 100% fused into the rib structure providing secure attachment points. These bosses can be placed at as many points as necessary for the user application. Cg mounting within the mirror mechanical neutral plane helps minimize deflection of the optical surface.

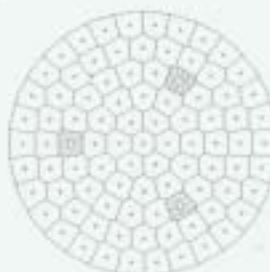


337 (02) lightweight mirror blank with center of gravity (cg) mounting bosses at the geometric center.

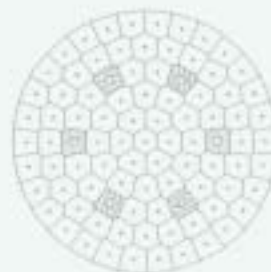
### Flexible Mounting Configuration



Center



3 Point



6 Point



247 x 177 blank with 3 mounting bosses – 2 up top, 1 bottom-center

### Size & Geometry Capabilities

Hextek offers this unique cg mounting feature on the following Gas-Fusion™ Blanks:

- Plano, concave and convex up to f/0.5
- Diameters from 12" to 50"
- Geometric flats up to 50"

## BOROFLOAT® Borosilicate Float Glass

Schott offers a highly chemically resistant borosilicate glass with a low thermal expansion that is being manufactured by the float method. BOROFLOAT® is a technologically significant development, achieving unsurpassed quality for flat borosilicate glass. It replaces TEMPAX®, a drawn flat borosilicate glass. The high quality resulting from the float glass process opens up new applications for borosilicate flat glass, which has proven itself over time in laboratories, chemical process plants and in the home appliance and lighting industries.

BOROFLOAT® flat glass is highly resistant to water, neutral, acidic and saline solutions, as well as to chlorine, bromine, iodine and organic substances. Even over long periods of time and at high temperatures that exceed 100°C, BOROFLOAT® exceeds the chemical resistance of most metals and other materials.

### Chemical Data

|                                       |   |
|---------------------------------------|---|
| • Hydrolytic Resistance (ISO-719-HGB) | 1 |
| • Hydrolytic Resistance (ISO 720-HGA) | 1 |
| • Acid Resistance (ISO 1776)          | 1 |
| • Alkali Resistance (ISO 695-A)       | 2 |

### Mechanical Properties

|                                                          |                        |
|----------------------------------------------------------|------------------------|
| • Density (@ 25°C/77°F)                                  | 2.23 g/cm <sup>3</sup> |
| • Modulus of Elasticity                                  | 63 kN/mm <sup>2</sup>  |
| • Knoop Hardness HK 0.1/20 (according to E DIN/ISO 9385) | 480                    |
| • Poisson's Ratio                                        | 0.2                    |

### Electrical Properties

|                                             |                     |
|---------------------------------------------|---------------------|
| • Dielectric Constant (@ 1 MHz & 25°C)      | 4.6                 |
| • Loss Tangent (@ 1 MHz & 25°C)             | $37 \times 10^{-4}$ |
| • Dielectric Strength (@ 50 Hz & 25°C)      | 16 kV/mm            |
| • Electric Volume Resistivity (log $\rho$ ) |                     |
| @ 250°C                                     | 8.0                 |
| @ 350°C                                     | 6.5                 |

### Physical Impact

The resistance of BOROFLOAT® to physical impact depends on the type of installation, the size and thickness of the glass panel, the type of physical impact, in addition to other parameters.

### Optical Properties

|                              |                       |
|------------------------------|-----------------------|
| • Refractive Index ( $n_D$ ) | 1.472                 |
| • Dispersion ( $n_D - n_F$ ) | $71.9 \times 10^{-4}$ |

### Thermal Properties

|                                                                         |                                      |
|-------------------------------------------------------------------------|--------------------------------------|
| • Linear Thermal Coefficient of Expansion $\alpha$ (20-300°C/ 68-572°F) | $3.25 \times 10^{-6}/^\circ\text{K}$ |
| • Transformation Temperature $T_g$                                      | 530°C/986°F                          |
| • Annealing Point ( $10^{13}$ dPa·s)                                    | 560°C/1040°F                         |
| • Softening Point ( $10^7$ dPa·s)                                       | 815°C/1508°F                         |
| • Thermal Conductivity $\lambda$                                        |                                      |
| @ 90°C                                                                  | 1.12 W/(m·°K)                        |
| @ 194°F                                                                 | 0.65 Btu·ft/h·ft <sup>2</sup> ·°F    |
| • Mean Specific Thermal Capacity $c_p$                                  |                                      |
| 20-100°C                                                                | 0.83 kJ/(kg·°K)                      |
| 68-212°F                                                                | 0.19 Btu/lb·°F                       |
| • Maximum Operating Temperature (Considering RTD <sup>1</sup> )         |                                      |
| Short term                                                              | 500°C/932°F                          |
| Long term                                                               | 450°C/842°F                          |
| • Resistance to Temperature Differences (RTD <sup>1</sup> )             |                                      |
| Short term exposure                                                     |                                      |
| (1 hour)                                                                | 110°K/198°R                          |
| (1-100 hours)                                                           | 90°K/162°R                           |
| Long term exposure                                                      |                                      |
| (>100 hours)                                                            | 80°K/144°R                           |
| • Resistance to Thermal Shock (RTS <sup>2</sup> )                       |                                      |
| Thickness <4 mm                                                         | 175°K/315°R                          |
| Thickness 4-6 mm                                                        | 160°K/288°R                          |
| Thickness 6-15 mm                                                       | 150°K/270°R                          |
| Thickness >15 mm                                                        | 140°K/252°R                          |

### Schott Corporation

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Yonkers, NY 10701-1405

Phone: (914) 968-8900  
Fax: (914) 968-4422  
Web Site: [www.schottglass.com](http://www.schottglass.com)

## Sheet Sizes and Tolerances

Stock sizes (standard)  $\pm 0.2$  mm  
 1150 x 850 mm (43.3 x 33.5 in.) [0.7 - 21 mm]  
 1700 x 1300 mm (66.9 x 51.2 in.) [16 - 21 mm]  
 2300 x 1700 mm (90.5 x 66.9 in.) [3.3 - 15 mm]

## Standard Thickness

| Nominal Thickness (mm) | Tolerance (mm) |
|------------------------|----------------|
| 0.7                    | $\pm 0.1$      |
| 1.1                    | $\pm 0.1$      |
| 1.75                   | $\pm 0.2$      |
| 2.0                    | $\pm 0.2$      |
| 2.25                   | $\pm 0.2$      |
| 2.75                   | $\pm 0.2$      |
| 3.3                    | $\pm 0.2$      |
| 3.8                    | $\pm 0.2$      |
| 5.0                    | $\pm 0.2$      |
| 5.5                    | $\pm 0.2$      |
| 6.5                    | $\pm 0.2$      |
| 7.5                    | $\pm 0.3$      |
| 9.0                    | $\pm 0.3$      |
| 11.0                   | $\pm 0.3$      |
| 13.0                   | $\pm 0.3$      |
| 15.0                   | $\pm 0.3$      |
| 16.0                   | $\pm 0.5$      |
| 19.0                   | $\pm 0.5$      |
| 21.0                   | $\pm 0.5$      |

## <sup>1</sup>RTD - Resistance to Temperature Differences

Panels measuring 25 x 25 cm<sup>2</sup> (10 x 10 inches) are heated in the center of the panel to a defined temperature, and the edges are maintained at room temperature. An RTD value is the difference in temperature between the hot center of the panel and the cool panel edge, at which breakage occurs to less than or equal to 5% of the samples.

Before the testing, the samples are abraded with sandpaper of grain size 40. This simulates extreme damage which is possible in usage.

## <sup>2</sup>RTS - Resistance to Thermal Shock

Panels measuring 20 x 20 cm<sup>2</sup> (8 x 8 inches) are heated in an oven with circulating air and afterwards are doused in the center with 50 ml of cold (room temperature) water.

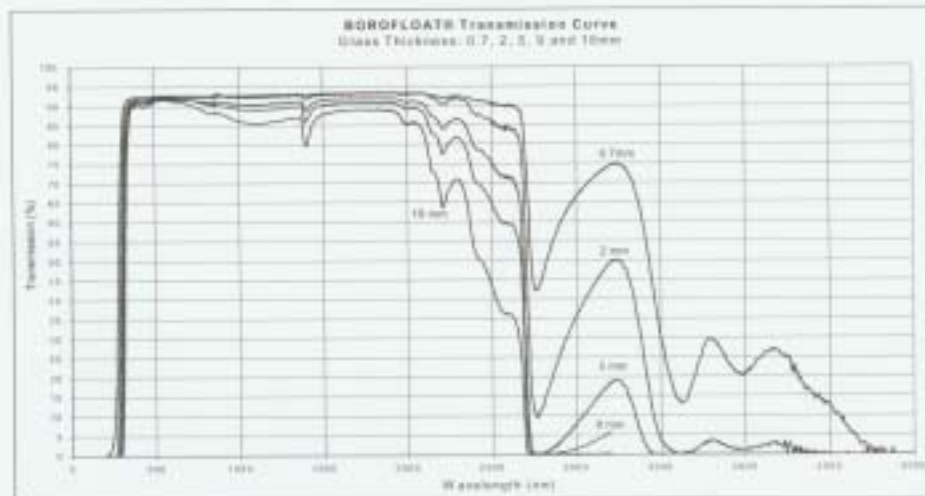
The RTS value is the difference in temperature between the hot panel and the cold (room temperature) water, at which breakage occurs to less than or equal to 5% of the samples.

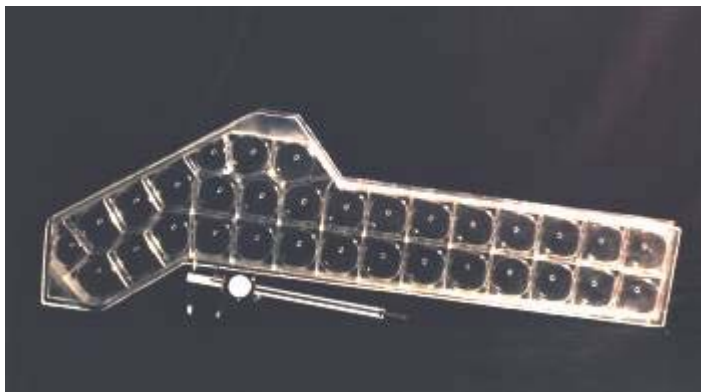
Before being heated, the samples are abraded with emery paper of grain size 220. This simulates a typical state of the surface in practical use.

All data are intended to be used as guidelines, unless otherwise stated. Please contact Schott should you have additional technical questions.

<sup>\*</sup>BOROFLOAT is a trademark of Jenaxer Glaswerk GmbH (Jena, Germany), a Schott Group company.

<sup>\*</sup>TEMPAX is a registered trademark of Schott Glaswerke, (Mainz, Germany).







## 5. IR\_Intensifier 資料



Infrared Equipment Sales  
Inspection Services  
IR Security & Surveillance Systems  
Software Support  
Training Programs

### Heat Find-IR

**LOW COST BUT HIGH RESOLUTION**

NEW



HFR with 25mm lens and handle attached. Weight only 4.5 pounds!

Most equipment manufacturers today are looking to low-resolution detectors in order to keep the costs of production down. Why limit your inspection availability and capabilities because you need to save money on the purchase of a Thermal Imaging system. Our new Heat Find-IR camera offers high-resolution IR imaging with features and capabilities not found in any camera system until now. You do the math and be amazed at what you will see with our HFR system.

Low-resolution cameras use a 160x120 FPA with 19,200 pixels. The HFR's high resolution 320x240 Microbolometer FPA has 76,800 pixels!

Which detector do you think will produce the clearest image?

Monroe Infrared Technology has helped thousands of customers benefit from implementing a Thermal Imaging program, and has developed the HFR in response to that need. In addition to the High resolution Microbolometer detector with B&W, Color or Isotherm display, the Heat Find-IR offers features such as a built in color visual camera, built in microphone, 2.5" color multi position LCD, interchangeable lenses (both thermal and visual), removable handle and easy to use image display controls! The HFR is the most affordable, feature packed, 320x240 IR camera available!

CEILING VISUAL



IR PICTURE



ELECTRICAL VISUAL



ELECTRICAL IR



**SPECIFICATIONS - MODEL HFR-25**

**DETECTOR:** Uncooled Focal Plane Array (Microbolometer)  
320 H x 240 V (76,800 Pixels)

**SPECTRAL RANGE:** 7.5 to 13.5 Microns

**SENSITIVITY:** Less than 0.1° C

**LENS:** 25mm F1.8 (Standard)

**FIELD OF VIEW:** 37.8° Horizontal x 28.25° Vertical  
Focus Approximately 24" to Infinity  
\*Zoom & other lenses available

**VIDEO MODES:** MONO/ISO/COLOR

**VIEWFINDER:** 2.5 inch LCD TFT Active Matrix Color

**COLOR VISUAL:** 14" NTSC color CCD

**WEIGHT:** Approximately 4.5 lbs. (w/o lens)

**SIZE:** 5.26"H x 4.84"W x 5.96"D

**VIDEO OUTPUT:** EIA RS-170 Monochrome, or NTSC Color

**BATTERY:** 4V, 3.5 Amp Hour (2.5 hrs run time)

**MICROPHONE:** Omni-directional integral to camera

**SUPPLIED ACCESSORIES**

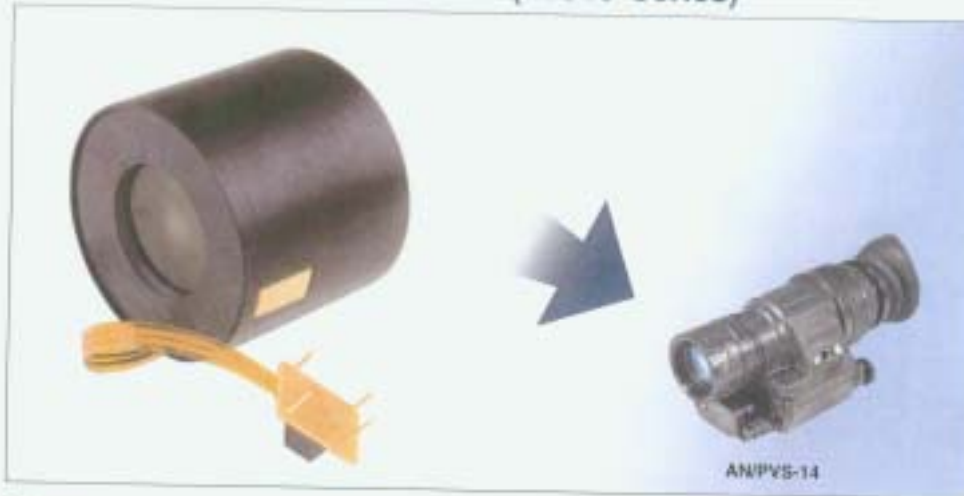
- Color LCD Viewfinder
- 25mm F1.8 lens
- Color visual camera with 7mm lens
- Removable Handle
- Battery (One Output DR-11 Type)
- AC Battery Charger
- Carrying Case

**OPERATIONAL CONTROLS AND INDICATORS**

- Power On/Off
- Contrast with Auto Switch
- Histogram/Invert (White Hot/Black Cool)
- Battery/Power Indicator: Icon in display
- Mono/Color/ISO Switch
- ISO Position Control
- Video/Audio Output (RCA Connections)
- Infrared/Visual Select Switch

\*SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE  
Headquarters: P.O. Box 1058 • Kennebunk, ME 04043  
1-800-221-0163 Email: [info@monroetech.com](mailto:info@monroetech.com) Web: [www.monroetech.com](http://www.monroetech.com)  
Other Locations: Ulma, MI • Orlando, FL

## Image Intensifier, Generation 3 18-mm MX-11769 (F9815 Series)



### Features

- Photoreponse Options (minimum) Ranging from 600 to 2000  $\mu\text{A/m}^2$
- Resolution Options Ranging from 45 to 64 lp/mm
- Signal-to-Noise Ratio Options Ranging from 14.5 to 25.0
- Sensitivity to Near Infrared
- Automatic Brightness Control
- Extended Operational Life (10,000 Hours)

ITT Industries Night Vision, the world's leading producer of image intensification devices, now offers the highest performance Generation (Gen) 3 image intensifier tubes available in the industry.

### Description

ITT continues to improve Gen 3 MX-11769 image intensifier tubes for use in variants of the AN/PVS-14 monocular night vision device (MNV). Combined improvements in resolution, signal-to-noise ratio and photocathode sensitivity have increased operational range and situational awareness for the user.

ITT's MX-11769 Gen 3 18-mm image intensifier is completely self-contained with an integral high-voltage power supply. Equipped with automatic brightness control (ABC), this power supply

provides constant output image brightness as light levels increase. It also provides bright-source protection to guard the tube against exposure to high levels of light.

The MX-11769 Gen 3 tube consists of a high-efficiency GaAs photocathode bonded to a glass input window corrected for veiling glare, a microchannel plate (MCP) current amplifier, and a phosphor screen. The photocathode is very sensitive to low-radiation levels of visible and infrared light in the wavelength region of 450 to 900 nm. The electronic image provided by the photocathode is proximity-focused on the MCP and amplified without distortion. The MCP's output electron image is then proximity-focused onto a green P-43 type phosphor screen that is deposited on an

inverting fiber-optic output window.

### Models

This image intensifier is available in a wide range of performance levels to meet customer requirements. Variants and model numbers are detailed on back of this sheet.

### TRUST THE NIGHT TO ITT

ITT is the largest manufacturer of Gen 3 night vision equipment for U.S. and allied forces. As a full-service supplier, ITT offers capabilities that cover the spectrum: design/development of new tubes and systems; high-volume manufacturing and after-sale support, including manuals, training and depot maintenance. When your mission involves night operations, you can TRUST THE NIGHT TO ITT.



**ITT Industries**  
*Engineered for life*



# MX-11769 (F9615 Series)

## Performance Levels

| Model Number                                                                                                                          | F9615B <sup>1</sup><br>MX-11769<br>Oral II<br>Enhanced     | F9615C<br>MX-11769<br>Oral II<br>Enhanced                  | F9615J<br>MX-11769<br>Oral II<br>Plus                      | F9615M<br>MX-11769<br>Oral V/<br>Ultra                     | F9615P<br>MX-11769<br>Oral IV                              | F9615RQ<br>MX-11769<br>Oral II<br>Plus                     |
|---------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|
| Resolution, (lines, (Minimum)                                                                                                         | 45                                                         | 51                                                         | 54                                                         | 64                                                         | 64                                                         | 64                                                         |
| Photocathode Sensitivity (Minimum)<br>2000 K, $\mu\text{A/in}^2$<br>@ 830nm, mW                                                       | 800<br>NA                                                  | 1200<br>NA                                                 | 1250<br>135                                                | 1500<br>152                                                | 1600<br>190                                                | 2000<br>230                                                |
| Signal/Noise Ratio (Minimum)                                                                                                          | 14.5                                                       | 18.0                                                       | 19.0                                                       | 19.2                                                       | 21.9                                                       | 25.9                                                       |
| EBL X10" Inset <sup>2</sup> (Maximum)                                                                                                 | 2.5                                                        | 2.5                                                        | 2.5                                                        | 2.5                                                        | 2.5                                                        | 2.5                                                        |
| Rate                                                                                                                                  | 1.25                                                       | 1.47                                                       | 1.47                                                       | 1.25                                                       | 1.25                                                       | 0.90                                                       |
| Luminous Gain, f/c<br>@2010°<br>@2010°                                                                                                | 4000 - 7000 <sup>2</sup><br>1000 - 2000 <sup>2</sup>       | 4000 - 7000 <sup>2</sup><br>1000 - 2000 <sup>2</sup>       | 4000 - 7000 <sup>2</sup><br>1000 - 2000 <sup>2</sup>       | 4000 - 7000 <sup>2</sup><br>1000 - 2000 <sup>2</sup>       | 4000 - 7000 <sup>2</sup><br>1000 - 2000 <sup>2</sup>       | 4000 - 7000 <sup>2</sup><br>1000 - 2000 <sup>2</sup>       |
| Output Brightness, f/c<br>@ 1 and 20 f/c                                                                                              | 2.0 - 4.0 <sup>2</sup>                                     | 2.0 - 4.0 <sup>2</sup>                                     | 2.0 - 4.0 <sup>2</sup>                                     | 2.0 - 4.0 <sup>2</sup>                                     | 2.0 - 4.0 <sup>2</sup>                                     | 2.0 - 4.0 <sup>2</sup>                                     |
| Output Brightness Uniformity (Maximum)<br>@200 K<br>@830 nm                                                                           | 3:1<br>4:1                                                 | 3:1<br>4:1                                                 | 3:1<br>4:1                                                 | 3:1<br>3:1                                                 | 3:1<br>3:1                                                 | 3:1<br>3:1                                                 |
| MTF (Minimum)<br>@2.5 lp/mm<br>@7.5 lp/mm<br>@15.0 lp/mm<br>@25.0 lp/mm                                                               | 63%<br>60%<br>58%<br>18%                                   | 80%<br>70%<br>45%<br>20%                                   | 80%<br>80%<br>67%<br>38%                                   | 80%<br>80%<br>67%<br>38%                                   | 80%<br>80%<br>67%<br>38%                                   | 80%<br>80%<br>67%<br>38%                                   |
| Photocathode Diameter, mm (Minimum)                                                                                                   | 17.5                                                       | 17.5                                                       | 17.5                                                       | 17.5                                                       | 17.5                                                       | 17.5                                                       |
| Reliability, hrs. (Minimum)<br>Prothaler                                                                                              | 10000<br>P-43                                              | 10000<br>P-43                                              | 10000<br>P-43                                              | 10000<br>P-43                                              | 10000<br>P-43                                              | 10000<br>P-43                                              |
| Maximum Spots Allowed in Each Zone<br>Spot Size (in.)<br>>.015 - .020<br>>.022 - .035<br>>.036 - .050<br>>.051 - .070<br>>.071 - .100 | Zone<br>1 2 3<br>0 0 0<br>0 1 1<br>0 1 2<br>1 2 3<br>3 4 5 | Zone<br>1 2 3<br>0 0 0<br>0 1 1<br>0 1 2<br>1 2 3<br>3 4 5 | Zone<br>1 2 3<br>0 0 0<br>0 0 0<br>0 0 0<br>0 1 2<br>0 2 3 | Zone<br>1 2 3<br>0 0 0<br>0 0 0<br>0 0 0<br>0 1 2<br>0 2 3 | Zone<br>1 2 3<br>0 0 0<br>0 0 0<br>0 0 0<br>0 1 1<br>0 2 2 | Zone<br>1 2 3<br>0 0 0<br>0 0 0<br>0 0 0<br>0 1 1<br>0 2 2 |

<sup>1</sup> As available

<sup>2</sup> Or per customer request

## Dimensions (Inches)

Export of this product is regulated by the U.S. Dept. of State in accordance with guidelines of International Traffic in Arms Regulations (ITAR) and Title 22, Code of Federal Regulations, Parts 120-130.

Approved for Unrestricted Public Release per DS-S-1019

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Specifications subject to change without notice

Patents Pending

8-01

For further information, contact

## ITT Industries

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**ITT Industries**  
*Engineered for life*

## Image Intensifier, Generation 3 18-mm MX-10130 (F9810 Series)



### Features

- **Photoreponse Options** (minimum) Ranging from 800 to 2000  $\mu\text{A}/\text{lm}$
- **Resolution Options** Ranging from 45 to 64 lp/mm
- **Signal-to-Noise Ratio Options** Ranging from 14.5 to 25.8
- **Sensitivity to Near Infrared**
- **Automatic Brightness Control**
- **Extended Operational Life** (10,000 Hours)

ITT Industries Night Vision, the world's leading producer of image intensification devices, now offers the highest performance Generation (Gen) 3 image intensifier tubes available in the industry.

### Description

ITT continues to improve Gen 3 MX-10130 image intensifier tubes for use in variants of the AN/PVS-7 night vision goggles. Combined improvements in resolution, signal-to-noise ratio and photocathode sensitivity have increased operational range and situational awareness for the user.

ITT's MX-10130 Gen 3 18-mm image intensifier is completely self-contained with an integral high-voltage power supply. Equipped with automatic brightness control (ABC), this power supply provides

constant output image brightness as light levels increase. It also provides bright-source protection to guard the tube against exposure to high levels of light.

The MX-10130 Gen 3 tube consists of a high-efficiency GaAs photocathode bonded to a glass input window corrected for veiling glare, a microchannel plate (MCP) current amplifier, and a phosphor screen. The photocathode is very sensitive to low-radiation levels of visible and infrared light in the wavelength region of 450 to 900 nm. The electronic image provided by the photocathode is proximity-focused on the MCP and amplified without distortion. The MCP's output electron image is then proximity-focused onto a green P-43 type phosphor screen that is deposited on

a non-inverting fiber-optic output window.

### Models

This image intensifier is available in a wide range of performance levels to meet customer requirements. Tube variants and model numbers are detailed on back of this sheet.

### TRUST THE NIGHT TO ITT

ITT is the largest manufacturer of Gen 3 night vision equipment for U.S. and allied forces. As a full-service supplier, ITT offers capabilities that cover the spectrum: design/development of new tubes and systems; high-volume manufacturing and after-sale support, including manuals, training and depot maintenance. When your mission involves night operations, you can TRUST THE NIGHT TO ITT.



**ITT Industries**  
*Engineered for life*

# MX-10130 (F9810 Series)

## Performance Levels

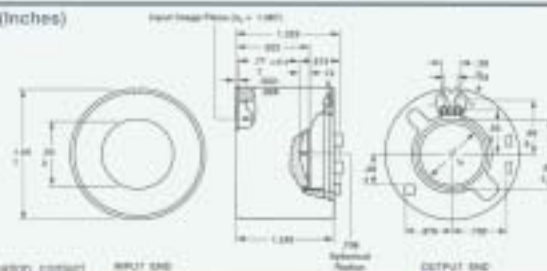
| Model Number                                                            | F9810B <sup>1</sup><br>MX-10130<br>Omni II<br>Enhanced                             | F9810C<br>MX-10130<br>Omni II<br>Enhanced                  | F9810J<br>MX-10130<br>Omni II<br>Plus                      | F9810N<br>MX-10130<br>Omni V /<br>Ultra                    | F9810P<br>MX-10130<br>Omni<br>IX                           | F9810RG<br>Omni II<br>Pinacle                              |
|-------------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------|
| Resolution, (lines, (Minimum)                                           | 45                                                                                 | 51                                                         | 64                                                         | 64                                                         | 84                                                         | 94                                                         |
| Photocathode Sensitivity (Minimum)<br>2000° K, 1 μA/W<br>@ 638nm, nA/W  | 800<br>5A                                                                          | 1300<br>NA                                                 | 1300<br>130                                                | 1300<br>100                                                | 1800<br>180                                                | 2300<br>230                                                |
| Signal/Noise Ratio (Minimum)                                            | 14.5                                                                               | 16.5                                                       | 19.0                                                       | 19.2                                                       | 21.2                                                       | 25.0                                                       |
| EBL X10 "exposed" (Maximum)                                             | 2.5                                                                                | 2.5                                                        | 2.5                                                        | 2.5                                                        | 2.5                                                        | 2.5                                                        |
| Halo                                                                    | 1.47                                                                               | 1.47                                                       | 1.25                                                       | 1.25                                                       | 1.25                                                       | 0.90                                                       |
| Luminous Gain, S/F <sup>2</sup><br>@210° K<br>@210° K                   | 4000 - 7000**<br>10000 - 20000**                                                   | 4000 - 7000**<br>10000 - 20000**                           | 4000 - 7000**<br>10000 - 20000**                           | 4000 - 7000**<br>10000 - 20000**                           | 4000 - 7000**<br>10000 - 20000**                           | 4000 - 7000**<br>10000 - 20000**                           |
| Output Brightness, f,<br>0.1 and 20 f                                   | 2.0 - 4.0**                                                                        | 2.0 - 4.0**                                                | 2.0 - 4.0**                                                | 2.0 - 4.0**                                                | 2.0 - 4.0**                                                | 2.0 - 4.0**                                                |
| Output Brightness Uniformity (Maximum)<br>@200° K<br>@680 nm            | 3:1<br>4:1                                                                         | 3:1<br>4:1                                                 | 3:1<br>4:1                                                 | 2:1<br>2:1                                                 | 2:1<br>2:1                                                 | 2:1<br>2:1                                                 |
| MTF (Minimum)<br>@2.5 lp/mm<br>@7.5 lp/mm<br>@15.0 lp/mm<br>@35.0 lp/mm | 63%<br>60%<br>58%<br>18%                                                           | 80%<br>70%<br>60%<br>20%                                   | 92%<br>80%<br>60%<br>38%                                   | 92%<br>80%<br>60%<br>38%                                   | 90%<br>80%<br>81%<br>38%                                   | 90%<br>80%<br>81%<br>38%                                   |
| Photocathode Diameter, mm (Minimum)                                     | 17.5                                                                               | 17.5                                                       | 17.5                                                       | 17.5                                                       | 17.5                                                       | 17.5                                                       |
| Reliability, hrs. (Minimum)                                             | 10000                                                                              | 10000                                                      | 10000                                                      | 10000                                                      | 10000                                                      | 10000                                                      |
| Phosphor                                                                | P-43                                                                               | P-43                                                       | P-43                                                       | P-43                                                       | P-43                                                       | P-43                                                       |
| Maximum Spots Allowed in Each Zone<br>Spot Size (in.)                   | Zone<br>1 2 3<br>>215 - 225<br>>212 - 215<br>>209 - 212<br>>206 - 209<br>200 - 206 | Zone<br>1 2 3<br>0 0 0<br>0 1 1<br>0 1 2<br>1 2 3<br>3 4 5 | Zone<br>1 2 3<br>0 0 0<br>0 1 1<br>0 0 0<br>0 1 2<br>0 2 3 | Zone<br>1 2 3<br>0 0 0<br>0 0 0<br>0 0 0<br>0 1 2<br>0 2 3 | Zone<br>1 2 3<br>0 0 0<br>0 0 0<br>0 0 0<br>0 1 1<br>0 2 2 | Zone<br>1 2 3<br>0 0 0<br>0 0 0<br>0 0 0<br>0 1 1<br>0 2 2 |

\* As available

\*\* Or per customer request

NOTE: Model F9810K (MX-101300) is the full U.S. Mil Spec Omni IV tube.  
Model F9810L (MX-101300) is the full U.S. Mil Spec Omni V tube.

## Dimensions (Inches)



Export of this product is regulated by the U.S. Dept. of State in accordance with guidelines of International Traffic in Arms Regulations (ITAR) per 22 CFR 176.20, Code of Federal Regulations, Part 120.130.

Approved for Unlimited Public Release per DD-AUTH13 and UNCLASSIFIED

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0101

For further information, contact

INPUT END

Output  
End

OUTPUT END

ITT Industries

High Vision  
7615 Plantation Road, Roseland, NJ 07068  
Attention: Marketing Department  
Telephone: (201) 523-5500 or (540) 583-0771  
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## Night Vision Goggles/Image Intensifier Set AN/AVS-9 (F4949 Series)

ITT Industries Night Vision, the world's leading producer of Generation (Gen) 3 night vision devices, offers the AN/AVS-9 (ITT F4949 Series) Night Vision Goggle/Image Intensifier Set with various objective lens filter options and various flight helmet-mount configurations – all designed to meet individual customer requirements.

### Features and Benefits

- Gen 3 tube performance offering high resolution, high gain, photoresponse to near infrared, and exceptional reliability
- Class A, B, C, and UK 645 minus-blue filters for objective lens available to suit all types of cockpit lighting, including color displays and fighter HUDs.
- Helmet mount configurations designed for fixed-wing and rotary-wing applications, adapting to most aviator helmets (U.S. HGU-55/P, HGU-56/P, HGU-84/P, SPH-4A/T, SPH-4B, SPH-5; British Alpha 202 and Mk4; French OS and CGF). Other mounts available upon request.
- 25-mm eye-relief eyepieces easily accommodate eyeglasses
- Low-profile battery pack improves aviator head mobility and increases battery life
- Other features include flip-up/flip-down capability, simple binocular attachment, individual interpupillary adjustment, tilt, vertical and fore-aft adjustments to fit all aviators.



### Standard Accessories

- Carrying case tailored to system
- Lens caps
- Lens paper
- Operator's Manual
- Helmet attachment instructions
- Neck cord (rotary-wing versions)
- Low-profile battery pack (rotary wing versions)

### Optional Accessories

- Battery pack adapter (fixed-wing versions)
- Low-profile battery pack (fixed-wing versions)
- Clip-on power source



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## Night Vision Goggles/Image Intensifier Set, AN/AVS-9 (F4949 Series)

### Description

First developed by ITT in 1992, the F4949 night vision system continually has improved and is now designated the AN/AVS-9(V) by the U.S. Government. The (V) indicates there are many versions in service. The F4949 series is the standard night flying system for the air crews of the U.S. Air Force and Navy. Over 13,000 F4949 systems are in service in 34 nations, worldwide.

**Rotary-wing** versions of the F4949 feature a rear-mounted, low-profile battery pack, which uses four AA alkaline batteries, allowing operation for more than 50 hours. Power is provided by a cable extending from the battery pack, over the helmet, and into a connector in the mount.

**Fixed-wing** versions feature a front-mounted battery pack, which uses two 1/2 AA lithium batteries that allow operation for more than 16 hours. An optional battery pack adapter enables connection of the fixed-wing F4949 to the rear-mounted battery pack, providing the same operational time as the rotary-wing versions when ejection is not a consideration. An optional clip-on power source enables hand-held operation of the binocular without use of a flight helmet.

ITT's F4949 series of aviators' night vision systems is available in over 40 different configurations. The type of aircraft and type of helmet being used will determine which configuration – existing or customized – will best meet our customers' requirements.

### Specifications

|                                |                                                                                |
|--------------------------------|--------------------------------------------------------------------------------|
| Spectral Response              | Visible to 0.90 $\mu$ m (IR)                                                   |
| Field of View                  | 40° nominal                                                                    |
| Magnification                  | Unitary                                                                        |
| Resolution                     | 1.3 cycles/mm (1.38 typical)                                                   |
| Brightness Gain                | 5500 f/1, minimum                                                              |
| Coloration                     | <1° convergence                                                                |
| Interocular Adjustment         | Independent, 51 to 72 mm total                                                 |
| Vertical Adjustment            | 25 mm, range                                                                   |
| Fore-and-Aft Adjustment        | 27 mm, range                                                                   |
| TR Adjustment                  | 10°, range                                                                     |
| Objective Lens                 | EP, 25 mm F/1.28, 1/1.35                                                       |
| Objective Lens Filters         | Class A, B, C, UK 645 available                                                |
| Objective Lens Focal           | Range 47 mm to infinity                                                        |
| Eyepiece Lens                  | EP, 27 mm                                                                      |
| Eyepiece Exit Pupillary Relief | On axis: 14 mm @ 25-mm distance<br>Full-field: 6 mm @ 25-mm distance           |
| Eyepiece Adjustment            | +1.0 to -6.0 Diopters                                                          |
| Flip-up/Flip-down              | Button release                                                                 |
| Automatic Breakaway            | 11 to 15 g                                                                     |
| Battery Type                   | Fixed-wing: 2 no. 1/2 AA size, lithium<br>Rotary-wing: 4 no. AA size, alkaline |
| Weight of Binocular            | 550 grams                                                                      |
| Weight of Mount                |                                                                                |
| Fixed-Wing                     | 250 grams                                                                      |
| Rotary-Wing                    | 330 grams                                                                      |
| Operating Temperature Range    | -12°C to +52°C                                                                 |

For further information, contact:

ITT Industries Night Vision

7635 Plantation Road, Round Lake, NY 24019

Attention: Marketing Department

Telephone: 800-533-5562 or 540-563-0377

Fax: 540-344-9015

E-mail: [nvsales@itt.com](mailto:nvsales@itt.com)

[www.nightvision.com](http://www.nightvision.com)

Port of this product is regulated by the U.S. Dept. of State in accordance with guidelines of "Unrestricted Traffic in Arms Regulations (ITAR)" per Title 22, Code of Federal Regulations, Parts 120-130.

Approved for unclassified release per DTIC 01223

Specifications subject to change without notice.

Rev. 2-02

### Intelligence for Critical Missions . . .

### Innovative Solutions on Demand

ITT Industries is the leading developer and supplier of Generation 3 image intensifier devices for U.S. and international military forces, federal agencies and law enforcement officers. We continue to advance the state of the art in low-light imaging technology. Our engineering expertise, customer responsiveness and commitment to quality ensure our customers' intelligence for critical missions with innovative solutions on demand.



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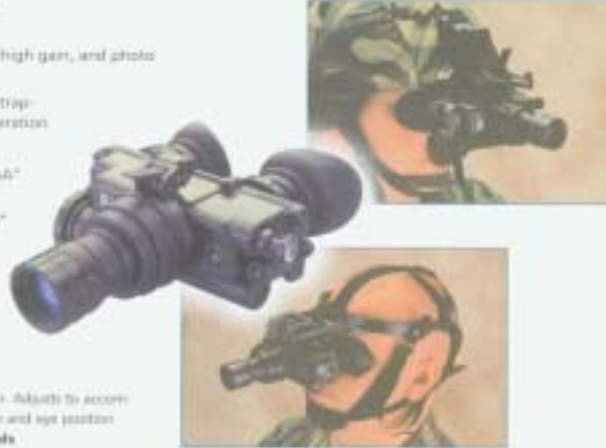
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## Night Vision Goggles, Gen 3 AN/PVS-7D (F5001 Series)

ITT Industries Night Vision, the world's leading producer of Generation (Gen) 3 night vision devices, offers the popular AN/PVS-7D night vision goggles with various accessory options - all designed to meet individual customer performance requirements.

### Features and Benefits

- Offers optimum resolution, high gain, and photo response to near infrared
- May be mounted on head strap-mounted for hands-free operation
- Lightweight - 680 grams
- Uses universally available "AA" batteries
- Equipped with "momentary" IR switch



### Standard Accessories

- **Head Mount Assembly**  
Allows hands-free operation. Adjusts to accommodate the user's head size and eye position.
- **Medium and Thick Brow Pads**  
Changeable pads to accommodate head sizes.
- **Eye Cups**  
Prevent the ingress of stray light or facial reflections.
- **Desmist Shields**  
Snap onto the eyepiece to prevent condensation on the optics.
- **Sacrificial Window**  
Shields the objective lens from airborne sand, dust or anything that may scratch the lens.
- **Carrying Case**  
Provides convenient storage.
- **Shoulder Strap**  
Attaches to the F5001 carrying case for easy portability.
- **Lens Paper**  
Used to lightly clean the objective and eyepiece glass surfaces.

### Optional Accessories

- Helmet Mount Assembly
- IR Spot/Flood Lens
- Magnetic Compass
- 3X or 5X Magnifier Lens
- Tethering Cord
- Shipping/Storage Case



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## AN/PVS-7D Night Vision Goggles (F5001 Series)

### Description

ITT's AN/PVS-7D (F5001) night vision goggles enable military ground forces to conduct critical missions during the darkest nights of the year. Extremely lightweight, the AN/PVS-7D has been human engineered for long-wearing comfort. It can be hand held, helmet mounted, or head-strap mounted for hands-free operation. Key features include: a quick-release lever to permit one-handed attachment/detachment from helmet or head harness; an automatic highlight cutoff to protect the image intensifier; an "IR on" indicator; and a low-voltage indicator.

### Specifications

|                             |                                                              |
|-----------------------------|--------------------------------------------------------------|
| Spectral Response           | Visible to 800 nm (IR)                                       |
| Field of View               | 40°                                                          |
| Magnification               | Unity                                                        |
| Resolution                  | 1.15 cycles minimum                                          |
| Brightness Gain             | 3000 fL/s, minimum                                           |
| Collimation                 | 1" ± 1" convergence<br>± 1/2" divergence                     |
| Dioptric Adjustment         | +2 to -6 diopters                                            |
| Interpupillary Adjustment   | 55 to 71 mm                                                  |
| Eye-Relief                  | 15 mm                                                        |
| Objective Lens              | EF 26 mm, Ø1.2, Ø1.3                                         |
| Eyepiece Lens               | EF 26 mm                                                     |
| Focal Range                 | 20 cm to infinity                                            |
| Voltage Required            | 2.7 Vdc ± 0.0 Vdc, battery<br>(50 mA, maximum)               |
| Battery Type                | Two AA-size 1.5-V alkaline or<br>one 3.0-V lithium (BA-5567) |
| Weight                      | 480 grams maximum                                            |
| Operating Temperature Range | -51°C to +52°C                                               |
| Storage Temperature Range   | -51°C to +85°C                                               |

### INTELLIGENCE FOR CRITICAL MISSIONS...INNOVATIVE SOLUTIONS ON DEMAND

ITT Industries is the leading developer and supplier of Generation 3 image intensifier devices for U.S. and international military forces, federal agents and law-enforcement officers. We continue to advance the state-of-the-art in low-light sensing technology. Our engineering expertise, customer responsiveness and commitment to quality assure our customers intelligence for critical missions with innovative solutions on demand.

For further information, contact:  
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[www.ittnightvision.com](http://www.ittnightvision.com)

Export of this product is regulated by the U.S. Department of State in accordance with guidelines of "International Traffic in Arms Regulations (ITAR)" per Title 22, Code of Federal Regulations, Parts 120-130.

This data sheet is approved for unlimited release per DTIC 0-072401.

Specifications subject to change without notice.

Rev. 10/02

Supersedes 001-001 & 002 (former publications of ITT) (0-072401-0, 0-02)



**ITT Industries**  
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## Gen 3 Intensified CCD Camera with Auto-Gating ISA-780/1180

ITT Industries Night Vision, the world's leading producer of Generation (Gen) 3 night vision devices, offers the ISA-780/1180, a Gen 3 intensified CCD camera with auto-gating. It represents the latest in intensified low-light-level technology. The ISA-780/1180 is ideally suited for use in military operations, surveillance and security applications in which the sensor is required to operate during both low light and nighttime conditions.

### Features and Benefits

- Exceptional Low-Light-Level Imaging Performance
- Compact and Rugged for Demanding Operational Environments
- Gated for Wide Dynamic Range
- Exceptional Resolution of >525 TVL
- Advanced High-Voltage Power Supply
- Bonded CCD/Intensifier Design
- Choice of Intensifier
- "C"-mount Lens Interface

ISA-780/1180



### Description

With a faceplate sensitivity of  $1 \times 10^{-6}$  fc, the ISA-780/1180 camera delivers usable imagery under adverse lighting conditions. Dynamic range is improved through the use of an advanced gain and gating Automatic Brightness Control (ABC) to deliver high-quality images over eight decades of light levels. More than 12 decades of light control can be achieved using the appropriate auto-iris lens.

The spectral response of the ISA-780/1180 is optimized for the near-infrared area of night sky illumination. Scientific applications in the 500 – 900 nanometer range will benefit from the high sensitivity of the ISA-780/1180 when performance and resolution are critical.

Measuring only 2.625 inches high, 2.3 inches wide and 6 inches in length, the ISA-780/1180 facilitates installation in locations that would otherwise preclude a high-performance intensified CCD video camera. In addition, the case structure and internal mountings of the camera components are ruggedized and designed to withstand the rigors of demanding operational environments. The RS-170 video output and input power signals are accessed via a rear-panel-mounted I/O connector and BNC connector.

### Accessories:

- ISA-LPS  
110-220V Universal AC Adapter  
Power Supply



**ITT Industries**  
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## 6. Kodak 公司 CCD 資料

| <b>Kodak</b><br>I M A G E   S E N S O R   S O L U T I O N S                                               |                   |                                      |                                                                                                                |
|-----------------------------------------------------------------------------------------------------------|-------------------|--------------------------------------|----------------------------------------------------------------------------------------------------------------|
| Device                                                                                                    | Pixels<br>(H x V) | Pixel Size<br>(H x V $\mu\text{m}$ ) | Features                                                                                                       |
| <b>FULL-FRAME</b>                                                                                         |                   |                                      |                                                                                                                |
| KAF-4202                                                                                                  | 2048 x 2048       | 9 x 9                                | <10pA/cm <sup>2</sup> dark current (25°C); MPP                                                                 |
| <b>BLUE PLUS FULL-FRAME</b>                                                                               |                   |                                      |                                                                                                                |
| KAF-0261E                                                                                                 | 512 x 512         | 20 x 20                              | <30pA/cm <sup>2</sup> dark current (25°C); MPP; Selectable amplifier                                           |
| KAF-0402E(ME)                                                                                             | 768 x 512         | 9 x 9                                | <10pA/cm <sup>2</sup> dark current (25°C); MPP; "LE" option available with antiblooming; Microlens Option (ME) |
| KAF-0401LE                                                                                                |                   |                                      |                                                                                                                |
| KAF-1001E                                                                                                 | 1024 x 1024       | 24 x 24                              | <30pA/cm <sup>2</sup> dark current (25°C); MPP; Selectable amplifier                                           |
| KAF-1301E Series                                                                                          | 1280 x 1024       | 16 x 16                              | <30pA/cm <sup>2</sup> dark current (25°C); MPP; "LE" option available with antiblooming                        |
| KAF-1402E(ME)                                                                                             | 1320 x 1035       | 6.8 x 6.8                            | <10pA/cm <sup>2</sup> dark current (25°C); MPP; Microlens Option (ME)                                          |
| KAF-1602E Series                                                                                          | 1536 x 1024       | 9 x 9                                | <10pA/cm <sup>2</sup> dark current (25°C); MPP; "LE" option available with antiblooming                        |
| KAF-3200E(ME)                                                                                             | 2184 x 1510       | 6.8 x 6.8                            | <10pA/cm <sup>2</sup> dark current (25°C); MPP; Microlens Option (ME)                                          |
| KAF-4301E                                                                                                 | 2084 x 2084       | 24 x 24                              | <30pA/cm <sup>2</sup> dark current (25°C); MPP; Selectable amplifier                                           |
| KAF-6303E                                                                                                 | 3088 x 2056       | 9 x 9                                | <10pA/cm <sup>2</sup> dark current (25°C); MPP; "LE" option available with antiblooming                        |
| KAF-6302LE                                                                                                |                   |                                      |                                                                                                                |
| KAF-16801E Series                                                                                         | 4096 x 4096       | 9 x 9                                | <10pA/cm <sup>2</sup> dark current (25°C); MPP; "LE" option available with antiblooming                        |
| <b>BLUE PLUS COLOR FULL-FRAME</b>                                                                         |                   |                                      |                                                                                                                |
| KAF-5101CE                                                                                                | 2614 x 1966       | 6.8 x 6.8                            | Color; antiblooming; <10pA/cm <sup>2</sup> dark current (25°C); MPP-                                           |
| KAF-16802CE                                                                                               | 4080 x 4080       | 9 x 9                                | Color; antiblooming; <10pA/cm <sup>2</sup> dark current (25°C); MPP                                            |
| <b>New</b> KAF-22000CE                                                                                    | 4080 x 5440       | 9 x 9                                | Color; antiblooming; <10pA/cm <sup>2</sup> dark current (25°C); MPP                                            |
| <b>SUPPORT CHIPS</b>                                                                                      |                   |                                      |                                                                                                                |
| <b>New</b> KSC-3000                                                                                       |                   |                                      | Color processing firmware; megapixel resolution at 30 fps                                                      |
| <b>New</b> KSC-1000                                                                                       |                   |                                      | Programmable timing generator                                                                                  |
| <b>New</b> = Samples available; Consult Eastman Kodak Company for production schedule and product updates |                   |                                      |                                                                                                                |
| 07/06/03                                                                                                  |                   |                                      |                                                                                                                |



| Device                       | Pixels<br>(H x V) | Pixel Size<br>(H x V $\mu\text{m}$ ) | Features                                                                                                                         |
|------------------------------|-------------------|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| <b>INTERLINE</b>             |                   |                                      |                                                                                                                                  |
| KAI-0330D Series             | 648 x 484         | 9 x 9                                | Color or monochrome; electronic shutter; progressive scan; microlenses; 60 fps (KAI-0330S) & 120 fps (KAI-0330D); fast line dump |
| KAI-0330S Series             |                   |                                      |                                                                                                                                  |
| KAI-0373M Series             | 768 x 484         | 11.6 x 13.6                          | Color or monochrome; electronic shutter; progressive scan; microlenses                                                           |
| KAI-1003M                    | 1024 x 1024       | 12.8 x 12.8                          | Monochrome; electronic shutter; progressive scan; microlenses; high dynamic range                                                |
| KAI-1010M Series             | 1008 x 1018       | 9 x 9                                | Color or monochrome; electronic shutter; progressive scan; microlenses; 30 frames/sec; fast line dump                            |
| KAI-1020M Series             | 1000 x 1000       | 7.4 x 7.4                            | Color or Monochrome; On-chip CDS, vertical clock drivers, electronic shutter driver; 50 fps; fast line dump                      |
| KAI-2001M Series             | 1600 x 1200       | 7.4 x 7.4                            | Color or monochrome; electronic shutter; progressive scan; microlenses; 30 frames/sec; fast line dump                            |
| KAI-2093M Series             | 1920 x 1080       | 7.4 x 7.4                            | Color or monochrome; electronic shutter; interlaced or progressive scan; microlenses; 30 frames/sec; fast line dump              |
| <b>New</b> KAI-4010M Series  | 2048 x 2048       | 7.4 x 7.4                            | Color or Monochrome; electronic shutter; progressive scan; microlens; fast line dump                                             |
| KAI-4020M Series             |                   |                                      |                                                                                                                                  |
| <b>New</b> KAI-11000M Series | 4008 x 2672       | 9 x 9                                | Color or Monochrome; electronic shutter; progressive scan; microlens; fast line dump                                             |

#### LINEAR

|            |           |           |         |                                                             |
|------------|-----------|-----------|---------|-------------------------------------------------------------|
| <b>New</b> | KLI-2113  | 2098 x 3  | 14 x 14 | RGB color channels; independent electronic exposure control |
|            | KLI-4104  | 8160 x 1  | 5 x 5   | 4 Channels (RGB, Monochrome);                               |
|            |           | 4080 x 3  | 10 x 10 | High Data-Rate (30MHz/output)                               |
|            | KLI-5001  | 5000 x 1  | 7 x 7   | Monochrome; dual synchronous outputs; on-chip CDS           |
|            | KLI-6013  | 6002 x 3  | 12 x 12 | RGB color channels; independent electronic exposure control |
|            | KLI-8023  | 8002 x 3  | 9 x 9   | RGB color channels; independent electronic exposure control |
|            | KLI-8811  | 8800 x 1  | 7 x 7   | Monochrome; 4 outputs (30MHz each)                          |
|            | KLI-10203 | 10200 x 3 | 7 x 7   | RGB color channels; independent electronic exposure control |
|            | KLI-14403 | 14404 x 3 | 5 x 5   | RGB color channels; independent electronic exposure control |

## 7. Ohara 公司 CCZ 材料資料

*Ultra Low Expansion Glass-Ceramic for Wide Temperatures CLEARCERAM-Z (CCZ)*

### CCZ

Ohara's CLEARCERAM-Z (CCZ) is an Ultra Low Expansion glass-ceramic that is suitable for use over a wide temperature range. The Coefficient of Thermal Expansion (CTE) of CCZ is near zero from -60 to +160 °C and the material provides excellent mechanical strength and chemical resistance. CCZ is suitable for machining and can be polished to achieve ultra low surface roughness and flatness values. CCZ also has better internal transmittance values than conventional low expansion materials.

### ADVANTAGES

- Alkali (Na, K) Free
- High internal transmittance
- Excellent optical homogeneity
- Near Zero Coefficient of Thermal Expansion (CTE)
- Suitable for use over a wide temperature range
- Excellent mechanical strength & chemical resistance
- Suitable for machining and optical bonding
- Enables ultra low surface roughness and flatness values

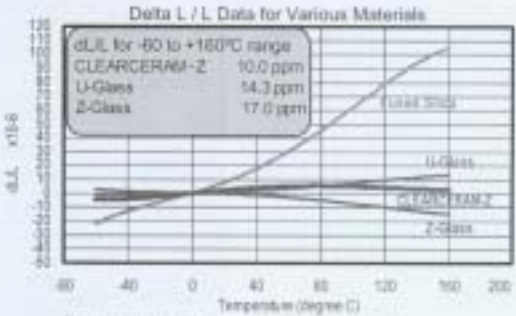
### APPLICATIONS

- Optical Components - mirrors, windows, optical flats, cavities, etalons & spacers
- Microlithography - stepper stages, liquid crystal steppers, precision scales & lengths
- Available as cut blanks, polished substrates & machined parts



### Delta L / L Data for Various Materials

| Material     | CTE (ppm) |
|--------------|-----------|
| CLEARCERAM-Z | 10.0      |
| U-Glass      | 14.3      |
| Z-Glass      | 17.0      |



Data shown based upon Ohara's measurements of individual samples. Other suppliers may provide different results.



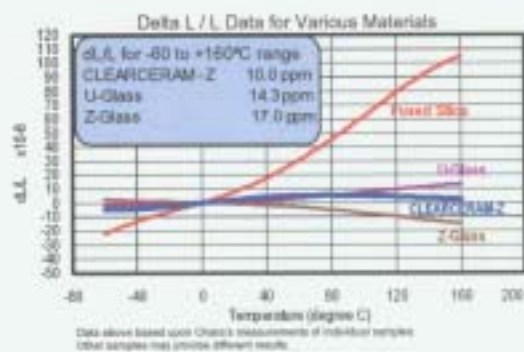
OHARA CORPORATION  
www.oharacorp.com



## Ultra Low Expansion Glass-Ceramic for Wide Temperatures CLEARCERAM-Z (CCZ)

### CCZ

Ohara's CLEARCERAM-Z (CCZ) is an Ultra Low Expansion glass-ceramic that is suitable for use over a wide temperature range. The Coefficient of Thermal Expansion (CTE) of CCZ is near zero from -60 to +160 °C and the material provides excellent mechanical strength and chemical resistance. CCZ is suitable for machining and can be polished to achieve ultra low surface roughness and flatness values. CCZ also has better internal transmittance values than conventional low expansion materials.



### ADVANTAGES

- Alkali (Na, K) Free
- High internal transmittance
- Excellent optical homogeneity
- Near Zero Coefficient of Thermal Expansion (CTE)
- Suitable for use over a wide temperature range
- Excellent mechanical strength & chemical resistance
- Suitable for machining and optical bonding
- Enables ultra low surface roughness and flatness values

### APPLICATIONS

- Optical Components - mirrors, windows, optical flats, cavities, etalons & spacers
- Microlithography - stepper stages, liquid crystal steppers, precision scales & lengths
- Available as cut blanks, polished substrates & machined parts

**OHARA**  
OHARA CORPORATION  
[www.oharacorp.com](http://www.oharacorp.com)



## Ultra Low Expansion Glass-Ceramic for Wide Temperatures CLEARCERAM-Z (CCZ)

### CLEARCERAM-Z Properties

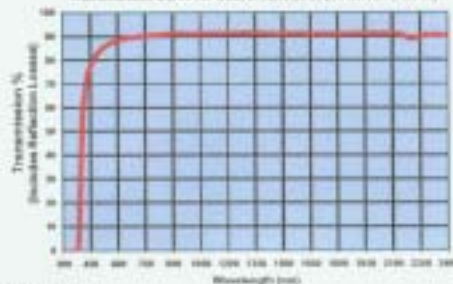
| Properties                              |                                          |                        |                      |
|-----------------------------------------|------------------------------------------|------------------------|----------------------|
| Thermal Properties                      | CTE -80 to +180°C                        | (10 <sup>-7</sup> /°C) | 0.4                  |
|                                         | Thermal Conductivity                     | (W/m • K)              | 1.75                 |
|                                         | Thermal Diffusivity                      | cm <sup>2</sup> /s     | 0.00781              |
|                                         | Specific Heat                            | (J/kg • K)             | 0.679                |
| Mechanical Properties                   | Young's Modulus                          | (GPa)                  | 90                   |
|                                         | Rigidity Modulus                         | (GPa)                  | 36                   |
|                                         | Poisson's Ratio                          | -                      | 0.25                 |
|                                         | Knoop Hardness                           | Hk                     | 600                  |
|                                         | Vickers Hardness                         | Hv                     | 680                  |
|                                         | Abrasion                                 | As                     | 62                   |
|                                         | Bending Strength                         | (N/mm <sup>2</sup> )   | 143                  |
|                                         | Specific Gravity                         | -                      | 2.55                 |
| Optical Properties                      | Refractive Index                         | n <sub>d</sub>         | 1.55                 |
|                                         | Abbe Number                              | V <sub>d</sub>         | 55.5                 |
|                                         | Internal Transmittance (%)<br>10mm thick | 500 nm                 | >95                  |
|                                         |                                          | 980 nm                 | >98                  |
| Chemical Properties<br>*JG18<br>**OHARA | Water Resistance                         | RW(P)*                 | 2                    |
|                                         | Acid Resistance                          | RW(A)*                 | 1                    |
|                                         | Weathering Resistance                    | WS(J)**                | 1                    |
|                                         | Acid Resistance                          | SR ISO                 | 1.0                  |
| Electrical Properties                   | Dielectric Constant<br>1MHz              | 25°C                   | 8                    |
|                                         | Volume Resistivity<br>Ohm•m              | 25°C                   | 5.1×10 <sup>10</sup> |

Properties subject to change without notice

Surface Roughness (AFM Image)



Transmission Curve for CLEARCERAM-Z (10 mm thickness)



Please contact us to discuss your specific requirements.

**OHARA**  
GLASS CORPORATION  
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## 8. SBSI 公司小型干涉儀資料

### **SBSI™ - Small Beam Shear Interferometer**

#### Collimation and Wavefront Analysis in Real-time

The Small Beam Shear Interferometer (SBSI™) allows quick adjustment and analysis of focus, coma, astigmatism and spherical aberrations in laser optical systems and collimated laser diodes. Models are available for laser beam diameters from 0.25 to 8 mm and wavelengths from the mid-UV to near IR. In addition, SBSI interfaces with IntelliWave Software and a camera allowing complete quantitative analysis of the aberrations in your beam.



The SBSI is a small beam lateral shear interferometer that uses an air gap between glass plates to shear the beam and then projects a magnified interference fringe pattern on a camera or fluorescent viewing screen. Optical aberrations can be identified and corrected while viewing the SBSI fringe pattern. For example, coma can be corrected by changing the tilt of a collimating lens in an optical system so the fringes on the SBSI change from curved to straight. A reference line on the SBSI screen indicates the best focus (collimation) angle for the fringes. When the fringes are parallel to the SBSI reference line, all optical aberrations are minimized. Beams can be checked directly or in reflection using a rotating beam-splitter cube mounted on the front of the SBSI.

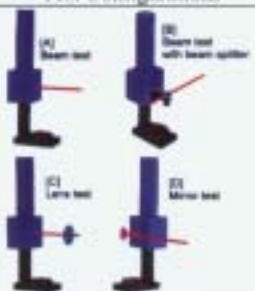
Focus alignment sensitivity is approximately 130 micro radians of beam divergence, corresponding to 3° rotation of the fringes for 3½ fringes. Each SBSI is optimized for 3½ fringes for a specific wavelength and beam diameter, but every SBSI can be used to check beams over a certain range of wavelengths and diameters. Please inquire about special SBSI designs that are optimized for your application.

#### Current Applications

- Wavefront and collimation testing.
- Test laser diodes at wavelengths from below 200 nm to 1700 nm.
- Test small beams from 0.25 mm to 8 mm diameter. Or smaller with beam expander.
- Alignment and collimation of fiber optic systems.
- Optical alignment of holographic storage & disk mastering systems.
- Alignment of laser mask pattern generation systems.
- Characterization of optics.
- Reduce alignment time to minutes.

#### Coming Soon

- Phase shifting for wavefront analysis using the popular IntelliWave software. IntelliWave is a powerful interferometric data acquisition and analysis software package that can interface with virtually any interferometer for static or interferometric analysis. Using the SBSI and IntelliWave's Shearing Analysis capabilities, complete aberration and statistical analyses can be performed on the wavefront of a beam. An optical phase map difference (OPD) can be generated and displayed in 3D.

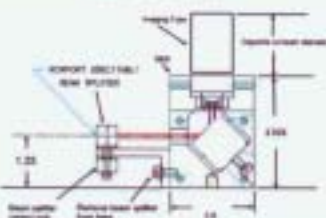
| SBSI-1B with Camera                                                                 | SBSI-1A: Fluorescent Screen                                                         | Test Configurations                                                                  |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |  |

## SBSI™ Images

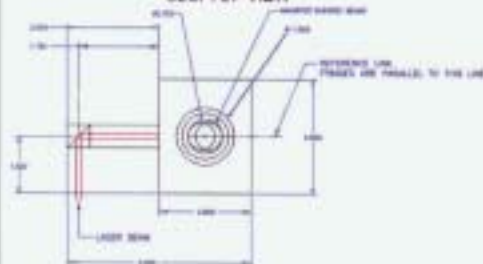
Computer-generated images shown below simulate the SBSI display and illustrate the sensitivity of the SBSI to various aberrations in a beam.

|  |                                                                                                                                         |
|--|-----------------------------------------------------------------------------------------------------------------------------------------|
|  | From left to right: no aberrations (perfect focus), .25 waves of defocus (diverging beam), and -.25 waves of defocus (converging beam). |
|  | .25 waves of spherical and -.25 waves of spherical.                                                                                     |
|  | .25 waves of coma at 0° and -.25 waves of coma at 0°.                                                                                   |
|  | .25 waves of coma at 90°, .25 waves of coma at -90°, .25 waves of coma at 45°, and .25 waves of coma at -45°.                           |
|  | .25 waves of astigmatism at -45°, .25 waves of astigmatism at 0°, .25 waves of astigmatism at 45°.                                      |
|  | .25 waves coma and .25 waves spherical at 0°, .5 waves coma and .5 waves spherical at 0°, and 1 wave of spherical.                      |
|  | 3 waves of spherical and 5 waves of spherical.                                                                                          |

### SBSI SIDE VIEW



### SBSI TOP VIEW



### Specifications

#### \*Wavelength Coverage

|              |                        |
|--------------|------------------------|
| SBSI-1A      | 225 to 670 nm          |
| SBSI-1B      | 325 to 1064 nm         |
| SBSI-1B-NIR5 | 1550 nm                |
| SBSI-1B-NIR7 | 1700 nm                |
| SBSI-1B-UV   | Below 200 nm to 340 nm |

#### Beam Diameter Coverage

0.25 mm to 8 mm diameter  
Or smaller with a beam expander

#### \*\* Sensitivity

50 to 170  $\mu$ m (wavelength & beam size dependent)

#### Size (main module)

2.625"H x 2.5"W x 2"D

(fluorescent screen tube) \*\*\* add from 1" to 5"H

(camera tube module) \*\*\* add from 1.5" to 5"H

#### Weight

2.25 lbs

#### SBSI-1A

This model uses a fluorescent diffuse screen for 225 nm in the UV through the visible region. This unit is very portable, as it requires no power.

#### SBSI-1B

This model projects the sheared interferograms onto an integrated camera for wavelengths 340nm to 1064 nm (viewable with the 5.6" LCD display). A battery pack is provided making the system completely portable.

Camera: 752x582 resolution Monitor: CCR/EIA 5.6" TFT display

#### SBSI-1B-NIR5/7 & SBSI-1B-UV

These models are the same as the SBSI-1B except the camera has a phosphor coating to enhance the working wavelength to the specified NIR or UV wavelength. Light sensitivity allows use down to one (1) mw beams.

\* SBSI 1A and 1B are used from 325 nm through the visible. Below 325 nm requires SBSI-1A or SBSI-1B-UV. NIR wavelengths require SBSI-1B-NIR.  
\*\* When ordering, an optimum wavelength and beam diameter must be specified. Sensitivity and magnification will be maximized at these values.  
\*\*\* Depends on magnification required. NIR and UV versions also have sensitivity in the visible.

## 9. TINSLEY 公司資料

*t h e a s p e r e a d v a n t a g e*

**ORIGINAL EQUIPMENT MANUFACTURERS**

*Tinsley's* optical components are frequently the key elements in the products of Original Equipment Manufacturers (OEMs). By meeting our customers' exacting specifications and tight tolerances, *Tinsley's* precision lenses and mirrors enhance the performance of OEM optical assemblies. With *Tinsley* precision lenses and



mirrors, optical systems outperform the sum of their parts.

**THE ASPHERE ADVANTAGE**

The relentless pressure for new optical functions by both government and private industry have greatly increased the importance of aspheres, the *Tinsley* specialty.

**Why ASPHERES?**

Spherical optics can produce aberrations and distortions, undesirable flaws that can be offset by still other spheres, at the expense of added weight and size. The asphere, a non-spherical opti-



cal surface, permits new dimensions in optical performance by eliminating aberrations and distortions without added weight and size. Until now, aspheres have had two principal disadvantages: cost and difficulty in replication.

**MEETING THE ASPHERE CHALLENGE**

*Tinsley* has overcome the historical disadvantages of aspheres by developing unique and sophisticated automated manufacturing capabilities. With Computer Controlled Optical Surfacing

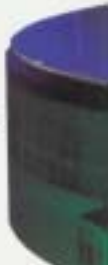
(CCOS), *Tinsley* manages costs and produces aspheres in production quantities. CCOS



dramatically improves polishing efficiency over traditional optical production methods.

**THE GROWING RANGE OF ASPHERIC APPLICATIONS**

*Tinsley's* CCOS technology also permits the utilization of increasingly complex aspheric surfaces for the cost effective solution of optical problems. Applications for *Tinsley* aspheres range from the tiny lenses used in microlithography to the large 10-meter Keck Telescopes in Hawaii, and the strong lenses that handle the powerful laser pulses in laser fusion.



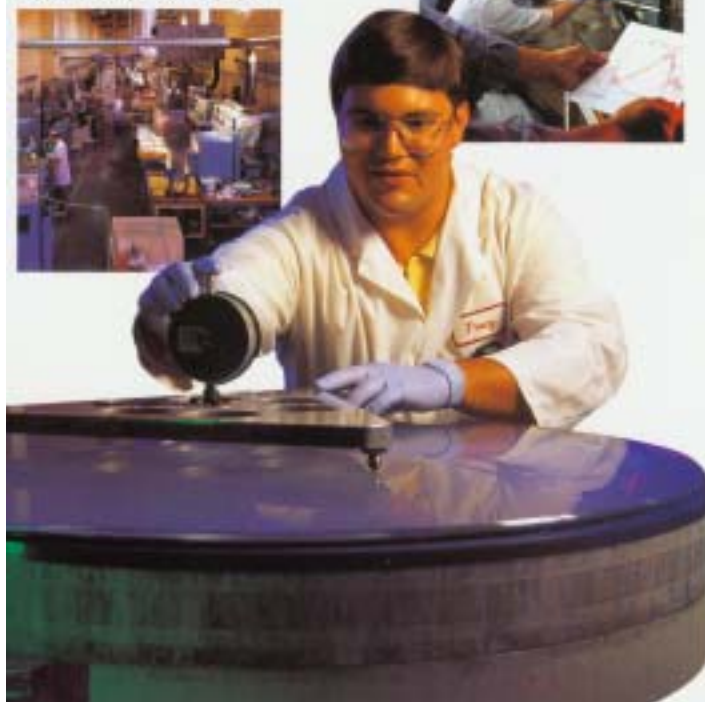


Many military and commercial aircraft are now equipped with Head Up Displays (HUDs) that project essential flight information on cockpit windscreens without impeding the pilot's view of the landscape. The critical component of the HUD is an aspheric lens that must fit into an extremely restricted space. **Tinsley** also supplies the aspheres that project



the high resolution images used in flight simulators.

Increasingly, **Tinsley** aspheres are being used to solve optical problems in a cost effective and timely way for a myriad of industries and end uses.



**Tinsley** has worked closely with government agencies, research organizations, and private



industry on new applications of precision optics. We are collaborating with Lawrence Livermore National Laboratory to provide aspheric focus lenses for their experiments in Inertial Confinement Fusion. We are also collaborating with Lawrence Livermore in the development of new technology for the precision optics required for the next generation of "steppers," the machines that manufacture computer chips.

**tinsley**

TINSLEY LABORATORIES, INC.  
The Asphere Company

o c o m p e t i t i o n

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n

#### THE CONTINUING GROWTH OF COMMERCIAL USE

Our in-house technology has enabled us to achieve higher rates of production and continued cost control. These efforts have made our products more and more accessible to commercial markets, and we are continually upgrading the performance of our products for private industry. With the



acquisition of Century Precision and Schwem Technology, we are supplying advanced optical products for cinematography and the professional video market, and gyro-stabilized video cameras for TV news and sports coverage. As the future unfolds, we will continue to emphasize the commercial applications of our ever-improving proprietary technology.

#### APPLICATIONS OF **TINLEY** PRECISION OPTICS

*Flight Control:* Head Up Displays (HUDs), including holographic combiners, for military and commercial aircraft and the Space Shuttle.



*Pilot Training:* High resolution, wide angle aspheric lenses for simulators and simulated combat exercises.

*Reconnaissance and Defense:* Camera windows, wide angle camera lenses, FLIRs (Forward Looking Infrared Lenses), and missile guidance optics.

*Science and Space Research:* High resolution camera lenses for unmanned space flights; aspheric mirrors for Hubble Space Telescope correction mission; aspheric mirror segments for Keck

10-meter Telescopes; aspheric lenses for laser fusion experiments.

*Micro lithography:* Aspheric



lenses for micro lithographic production of printed integrated circuits.

*Cinematography and Videography:* Camera and accessories for film and TV industries (Century Industries) image stabilizing lenses for film and TV (Schwem Technology).

*TV Manufacturing:* Aspheric phosphor exposure lenses for the production of color television tubes.

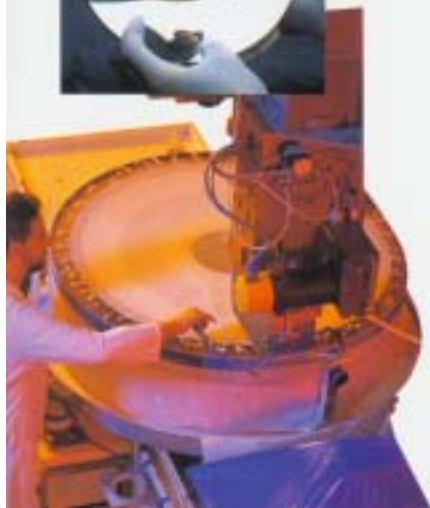
**Tinley** has remained a small company. We compete with much larger, integrated corporations with correspondingly vaster resources than our own. We are able to use our size to



*e c i s i o n*

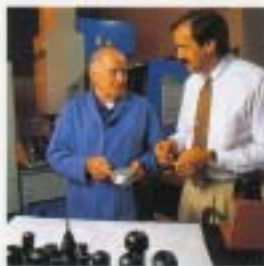
*o p t i c s*

our advantage, however. We are highly flexible, and we move rapidly to solve optical problems. Our size simplifies our communication with customers. We keep our customers informed, and we listen to what they have to say. Customer feedback, frequently relayed to us as official recognition of the work of our employees, is a major resource for **Tinsley**.



#### HELPING OUR CUSTOMERS' PRODUCTS WORK BETTER

Our continuing, long term mission is to design and produce products that advance steadily in optical precision for the express purpose of improving



the performance of our customers' products. At the same time, we work to stay on the frontier of the precision optics industry by continually refining and strengthening our proprietary processes — in manufacturing, in testing, and in precision metrology. We know, however, that it is not enough to improve our products and our processes. We will also continue to carefully cultivate the relationships that have allowed us to thrive, and we will keep building on the legacy of service that has been the foundation of our growth.

#### CUSTOMER RECOGNITION — OUR HIGHEST REWARD

Nothing demonstrates the



success of our approach more than the recognition we receive from our customers. We have been given performance awards from such customers as General Electric, Hughes Aircraft, GTE, Lawrence Livermore National Laboratory, Jet Propulsion Laboratory, Ball Aerospace Systems Group, and the California Association of Research in Astronomy.

We are particularly proud of having received the prestigious NASA Goddard Space Flight Center Contractor Excellence Award for 1994, Goddard's highest award.

## 10. 行動觀測系統資料



INSTRUMENTATION MARKETING CORP.

A PHOTO-SONICS COMPANY



LEADER IN HIGH SPEED PHOTOGRAPHIC METER ANALYSIS SYSTEMS

---

### PHOTO-SONICS MOBILE COMPACT OPTICAL TRACKING SYSTEM



- Computer Based Precision Tracking System
- Highly Mobile
- Full Computer Integration of all Sensors and Controls
- Manned or Unmanned Operation
- Multiple Sensors
  - Film Cameras
  - Digital Cameras
  - Video Cameras
  - Video Acquisition and Tracking
  - Radar
  - IR
  - Laser Range Finder
  - GPS
- Complete Control Software
  - Standby Mode
  - Tracking Mode
  - System Preparation Mode
  - Star Calibration
  - Simulation Mode
  - Fault Status Mode
  - Maintenance Mode



- 4 Primary Payloads + 2 Auxiliary
- Remote Control Console with Fiber-optic Communication
  - Touch Screen Monitor
  - Local Sensor Control
  - Video Switcher
  - Video Recorder (2)
  - UPS
- Protective Shelter



---

WE HAVE A WAY OF LOOKING AT THINGS!

## GENERAL SPECIFICATIONS:

|                            |                                                                                                                                                                      |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Size:</b>               | 82"L x 82"W x 85.62"H plus 18" trailer tongue                                                                                                                        |
| <b>Weight:</b>             | MCOTS - 6240 lbs. (no payload)<br>Tongue weight - 1260 lbs.                                                                                                          |
| <b>Payload:</b>            | 600 lbs. total                                                                                                                                                       |
| <b>Power Requirements:</b> | 208 VAC, 60 Hz, 3 phase<br>380VAC, 50 Hz, 3-phase (optional)<br>Total peak power 7.5 KVA providing 1500 ft. lbs.<br>Azimuth torque and 750 ft. lbs. elevation torque |
| <b>Road Clearance:</b>     | 12 inches                                                                                                                                                            |
| <b>Roadability:</b>        | Highway 55 mph<br>Unimproved roads 35 mph                                                                                                                            |



## Dynamic Performance

The following apply to a payload of 600 lbs:

|                           |           |                                                            |
|---------------------------|-----------|------------------------------------------------------------|
| <b>Travel:</b>            | Azimuth   | 600 degrees total                                          |
|                           | Elevation | 100 degrees (-10 to +95)                                   |
| <b>Torque:</b>            | Azimuth   | 1 x 1500 ft. lbs. permanent magnet motor                   |
|                           | Elevation | 2 x 375 ft. lbs. permanent magnet motors                   |
| <b>Acceleration:</b>      | Azimuth   | Greater than 2.5 radians per second per second             |
|                           | Elevation | Greater than 3.5 radians per second per second             |
| <b>Velocity:</b>          | Azimuth   | Configurations available from sidereal to 1.75 radians/sec |
|                           | Elevation | Configurations available from sidereal to 1.75 radians/sec |
| <b>Dynamic Range:</b>     |           | 1000:1                                                     |
| <b>Bandwidth:</b>         | Azimuth   | 12 Hz                                                      |
|                           | Elevation | 15 Hz                                                      |
| <b>Non-Orthogonality:</b> |           | Less than 15 arc seconds                                   |
| <b>Bearing Wobble:</b>    |           | Less than 5 arc seconds                                    |
| <b>Drive System:</b>      |           | Direct drive DC motors and servo amplifier                 |



## Control Electronics

- Dual Gate Video Tracker
- Global Positioning System (or BUC-DB) for timing
- Global Positioning System for position
- Photo-Sonics Film Data Recording System
- Video Data Recording System
- Optical Encoders, 20 bit
- On-board Computer systems (3): 15 slot VME in trailer, 5 slot VME in trailer and 19-inch rack mounted PC in the Remote Control Console
- Dual Bay Remote Control Console

## Software Components

- Extensive pre-flight preparation, calibration and built-in tests
- Real time TSP input and output
- Nominal Trajectories
- Target Simulation
- Colonial Calibration designed specifically for an off-axis tracking system with sensors mounted on either side of the rotational axis for better than 5 arc-second accuracy
- Remote control capabilities from the Remote Control Console
- Extensive Fault Detection
- Comprehensive Man-Machine Interface



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TEL: +44(1904) 280800  
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本授權書所授權之出國報告書名稱：

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