EC

NewsFlash

The Electro-Optics Center
A Manufacturing Technology Center of Excellence

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Sapphire Dome Strengthening Manufacturing Technology project completed

The project was a $1.1M effort performed by the Raytheon Missile Systems Company and ELCAN, a Raytheon subsidiary.

The Navy MANTECH "Sapphire Dome Strengthening" project, a broad ranging effort investigating several methods for improving the high temperature strength of sapphire domes used to protect missile IR sensors, has been successfully completed. The project was a $1.1M effort performed by the Raytheon Missile Systems Company located in Tucson, AZ and ELCAN, a Raytheon subsidiary located in Midland, Ontario.

The original system application for the project was the IR seeker on the Standard Missile II, Block IVA (PMS-422). Due to restructuring of the SM-II, BLK IVA program implementation on the Standard Missile platform is being delayed. Subsequently, two additional potential stakeholders have been identified, AIM-9X Air-to-Air Missile (PMA-259) and the RIM-116 Rolling Airframe Missile (RAM) (PMS-472). Application of the sapphire dome strengthening technology is currently under evaluation for the AIM-9X LRIP and the next build of the RIM-116 RAM. In addition, the Manufacturing Technology developed in this program will be applicable to the SM-II, BLK-IVA follow-on missile system and technology components (e.g. improved fabrication) may be applicable to sapphire window programs for laser targeting pods.

Key achievements from the project include:

1) An improved sapphire dome fabrication (polishing) process has been developed and demonstrated to yield domes with approximately 20% greater strength at 600^0 C than domes produced with the conventional polishing process.

2) A new brazed sapphire dome-mounting joint has been developed for attaching the dome to the turret structure. The new design is expected to increase missile survival time 3 to 4 seconds compared to the current yet have improved manufacturability.

3). A sapphire dome quench test process was developed as an extension of an existing process used to proof test domes in a controlled manner. Quench testing equipment developed under the SM-II, BLK-IVA program has been transferred to the RIM-116 RAM program. The second test process involves the development of a particle impact facility at AT&T Government Solutions (GSI). This new capability will permit future investigations of improved coatings for protecting domes from particle impact from 100 μm diameter sand particles at velocities in excess of Mach 3. For additional information on this project, contact David Snyder at dsnyder@psu.edu.

The two pictures above show the polished and coated sapphire dome and a fully assembled dome turret using the designs developed under the MANTECH project.

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Message from the Director
By Dr. Karl A. Harris

Fiscal Year 2003 ended October 31st and proved to be one filled with significant success in the area of project transition. During the past year fourteen of the Electro-Optics Center's thirty MANTECH technical projects were completed and each project was successfully transitioned to the fleet or on to another stage of development.

Especially noteworthy was the fact that these completed projects covered each of the EOC's core technical areas.

Especially noteworthy was the fact that these completed projects covered each of the EOC's core technical areas. In the **Laser Group**, two separate efforts relating to laser micromachining were completed and a new, non-MANTECH, project was awarded in July. In the **IRFPA/Night Vision Group** seven projects were completed and each had follow on awards. The projects included advancements in development of night sights, the night vision windshield, uncooled focal plane arrays, and two-color long wave IT focal plane arrays. The **Materials Design and Process Technology Group** was responsible for the successful completion and transition of the Sapphire Dome Strengthening Program, which is featured in this issue of NewsFlash. The **Emerging Technology Group** was responsible for the completion and transition of the SiC APVT Crystal Growth. The deliverable wafers from this project are currently being evaluated under a separate project with the EOC's Material Design and Process Technology Group. Among the successes of the **Fiber Optics Technology Group** was the beginning of transition of the Remote Source Light Project to the DDX and the LPD-17. Finally the efforts of the **Workforce Development Group** (WFD) resulted in several successful projects and collaborations that included significant educational outreach. The WFD Group has supported the NSF-funded Science In Motion traveling classroom and assisted in curriculum development with some Pennsylvanina higher educational institutions. Several special topic workshops were held in Kittanning, PA, Washington, DC and Tampa, FL.

These programs and many others were reviewed as part of the annual EO Alliance Board meeting, open to all Alliance members and held in conjunction with the Armstrong County PA ARMTech Showcase. Alliance members were briefed on the EOC's efforts and provided valuable feedback to EOC personnel. The communication with and cooperation of the Alliance has been a key part of the successes mentioned. None of the success the EOC has experienced would be possible without two key players. The first being Congressman John P. Murtha who has been the principle driver and whose vision we work every day to fulfill. The second is the Office of Naval Research who has provided leadership, vision, support and resources. Together, we are working to advance the warfighter's capabilities.

E-O Workshop Held in Tampa

The Electro-Optics Center recently sponsored a one-day introductory E-O technology workshop. The sessions, conducted by DCS Corporation, was held on 5 November in Tampa, FL. Approximately 35 participants attended. Workshop participants were provided a strong introduction to electro-optics technology along with additional information on specific topics. Topical information included target signature and atmospheric effects, thermal imaging systems models and performance metrics, and description of state-of-the-art thermal imaging components, and image intensifiers.

The workshop audience consisted primarily of program managers and researchers. Feedback from the sessions was very positive. The EOC would like to thank Phil Richardson and Andy Struckoff of DCS Corporation for this collaborative initiative. Additional sessions on various other topics are being considered for future offerings. Requests for specific workshop topics should be directed to Wendy Gilpin at wlg5@psu.edu or by calling 724-545-9700.

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EOC Establishes New Technical Core Competency Area

The EOC has established a Reliability and Failure Analysis core competency area to address the increasing importance of reliability for national defense and space based applications. It is the charter of this new competency area to establish a systematic program to characterize the reliability of the materials, devices, modules, and systems used for these applications and to use the information gathered to impact designs on a continuous basis. Technological processes, miniaturization, and yield improvements, which translate to high performance, high packing density, and affordable cost are key drivers in the requirement for higher reliability devices, modules, and systems. In order to provide a decisive economic and strategic impact, reliability must continually be addressed in every step of the process. Along with rapid technology advances, the push toward miniaturization, and the high cost associated with state-of-the-art hardware and software comes a requirement to develop new and adapt existing tools and investigation techniques to analyze failures and assess reliability. Failure analysis will be conducted with the aim of determining the mechanism that brought it on, identifying the root cause, and eliminating it at the most convenient level. Planned failure analysis techniques include visual inspection, analysis and characterization of materials (to include optical and electrical measurements and structural and chemical analysis), evaluation of processes and packaging, and analysis of thermal stability. Methods planned to assess reliability include collection of field data (analyze the past to predict the future), screening, and accelerated testing. It takes considerable time and effort to verify life goals of these high reliability devices, modules, and systems. The EOC currently has reliability and failure analysis capability in the materials and laser technology areas (i.e. laser diode array evaluation). This capability will be expanded and apply across all core technology areas. Focal plane array and wide band gap reliability projects for the Joint Strike Fighter Program Office and Missile Defense Agency, respectively, have recently been initiated. For more information on this project, contact Ken Freyvogel at ksf10@psu.edu.

A heat chamber used in the new testing facility at EOC.

Roadmapping The Future Needs of Transportation

December 10-11, 2003

A workshop entitled "Optics and Photonics in Transportation and Infrastructure" will be held at the Department of Commerce in Washington, DC on December 10-11, 2003. The Departments of Transportation and Commerce are cosponsoring the event, along with OSA and SPIE optical societies.

The workshop will include land, sea, air, rail, and intermodal means of transportation, and issues covering home defense, safety, security, mobility, energy efficiency, and the environment. Key industry leaders will deliver talks followed by working breakout sessions with industry, academic, and government.

The International Society for Optical Engineering

OSA Optical Society of America

Scheduled speakers include:
Jeffrey N. Shane, Under Secretary of Transportation for Policy (invited)

Admiral James M. Loy, USCG (retired) and Administrator, Transportation Security Administration (invited)

Mortimer L. Downey, President, PB Consult, and former Deputy Secretary of Transportation

Major General William W. Hoover, USAF (retired), and Chairman, National Academies Aeronautics and Space Engineering Board (ASEB)

Rear Admiral Robert C. North, USCG (retired), North Star Maritime Land/intermodal

John Horsley, Executive Director, American Association of State Highway and Transportation Officials (AASHTO)

Robert M. Clarke, President, Truck Manufacturers Association

The event is limited to 100 attendees. For additional information, refer to www.jaop.org.

Hyperspectral Polarimetric Imaging Camera

Compact, multipurpose advanced imaging technology is a long-standing requirement for a large number of military and security applications. The desired features vary depending upon the application, but a generally desired characteristic is simultaneous imaging in multispectral pass bands, co-registered spatially in a real-time operating camera. AnaLux Inc, working with the Penn State ARL Electro-optics Center (EOC), has designed, fabricated, and demonstrated a new camera meeting these needs. This camera is an acousto-optic-based sensor with spectral band pass from 450 to 1100 nanometers. There are three implementations envisioned for this product, contingent upon the platform utilized:

This camera is an acousto-optic-based sensor with spectral band pass from 450 to 1100 nanometers.

• A low-end product, which is a spectrometer with a 90-degree field-of-view (FOV), and a non-image quality Acoustic Optical Tuned Filter (AOTF) suitable for low-resolution spectral analysis/ motion detection only. This version is a spectrometer with a field-of-view for motion tracking.

• A mid-range product that is a multispectral camera with a 90-degree FOV with limited image processing capability. This implementation would have mid-range performance FPAs for Visible/NIR, with image quality AOTF. This would have limited, up-gradable software for nuisance alarms and threat signatures.

• A high-end product that is a full capability hyperspectral-imaging camera that can be pointed at targets of interest. It incorporates high sensitivity FPAs (Visible and Near IR), with highest optical quality AOTF employing advanced materials, such as PMN-PT, TAS, $HgCl2$. In addition, the best available imaging software would be incorporated for accurate threat signature ID, and with good capability to identify and ignore nuisance targets to avoid unacceptable false alarms

These AnaLux sensor products are based on optical technology (Spectro-Polarimetric Imaging (SPI)), developed by and licensed from Carnegie Mellon University (CMU), along with ultra-wide bandwidth (UWB) radar technology developed by and licensed from ANRO, Inc. of Sarasota, Florida. It is a platform product strategy, in the sense that the cost and performance of an optical sensor is determined by the selection of the components, which is dominated by the focal plane array (depicted as a CCD camera) and the AOTF. AnaLux will seek to become a qualified vendor for the Air Force Tactical Automated Security System (TASS) program and the Army Integrated Commercial Intrusion Detection System (ICIDS) program. The camera development on the EOC program will dramatically improve the infrared optical capability of the TASS and ICIDS products

The low and mid range products can be used as stand alone optical sensors for TASS and ICIDS but are intended to be deployed with an ANRO Quick Perimeter Intrusion Detection (QUPID) radar sensor. QUPID is currently being purchased by the Air Force for perimeter security.

The camera will ultimately be capable of high resolution spectro-polarimetric imaging at 5 nanometer increments, where each spectral band is spatially co-registered. The camera technology has multiple applications in surveillance and target identification, and has growth potential to a wider spectral band including the infrared. The EOC program with Analux will enhance camera operation, provide examples of hyper-spectral imaging; explore applications, and present the potential for an advanced imaging capability using this unique imaging tool.

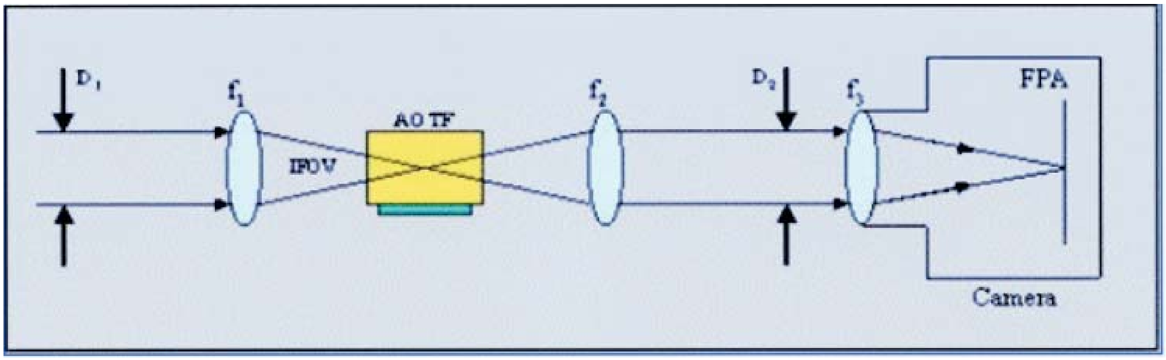

Figure 1: A typical optical design.

ANALUX's Hyperspectral Polarimetric Imaging Camera has numerous military applications.

A typical optical design (figure 1) consists of the following components:

- A variable iris D_1 at the camera entrance
- An input focusing lens $f_{1,}$
- A variable retarder R,
- An acousto optic tunable filter AOTF
- A second transfer lens f_2,
- A second variable iris D_2 ,
- A lens f_3 selected to fill the area of the focal plane array FPA of the CCD camera

Broadband light enters (figure 2) the TeO_2 crystal illustrated. The light then interacts with the RF-generated traveling acoustic wave traversing the crystal. Three angularly separated ray groups emerge. The left and right beams are spectrally filtered and orthogonally polarized. The middle (yellow) ray group is all of the remaining broadband input light. The AOTF is optimized for the right spectrally filtered ray group (as view from above). For present purposes, the other two beams must not enter the field-of-view acceptance aperture of the CCD FPA. Separation and elimination of the unwanted ray bundles while maintaining high throughput of the intended ray group require precise alignment procedures.

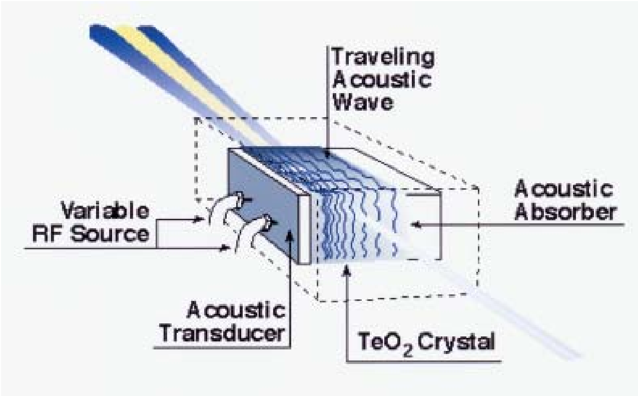

Figure 2: A pictorial description of how an AOTF functions.

Camera performance was evaluated by the EOC in collaboration with Analux to verify the design and assess viability for a wide range of applications. The spectral band-pass was documented using narrow band sources, and images collected under a variety of background conditions. The sensitivity of the camera to background variations was assessed using both controlled indoor sources and under a range of outdoor ambient conditions. Target characteristics in various backgrounds were recorded, and an assessment made of target discrimination capability with varying background and environmental conditions. Spectral characteristics of visually camouflaged targets were collected, and compared to background.

The camera evaluation established the feasibility for real-time spectrally tuned, hyperspectral two dimensional focal plane camera operating in the visible and very near IR spectral bands. The camera technology is directly extendable to the near- to mid-band infrared, yielding near a simultaneous hyperspectral-imaging cube from 450 to 5000 micrometers. This provides a novel imaging tool with implications in large number of military and homeland security systems. For more information on this project, contact John Perkins at jfp11@psu.edu.

Panoramic Infrared Imaging System - Field Trials

Background

The transition of advanced technology from the laboratory to a system field demonstration marks a major event on the path toward getting equipment to the user. The EOC infrared sensor development program is supporting technology contributing to these advanced systems' demonstrations. One of the more comprehensive user evaluations is currently ongoing with the Raytheon developed panoramic, mid-wave infrared imager (Night Vision Windshield) for rotary wing aircraft. Users are evaluating the sensor suite in flight trails at Fort Eustis, Virginia; Fort Campbell, KY; and at Fort Bragg, NC. The integration of the sensor suite with the aircraft and the image data collection are major undertakings, bringing together a multi-disciplinary team of contractors and government personnel team. The issues being addressed range from sensor noise reduction and signal processing to aircraft flight worthiness.

The sensor demonstration system for the Night Vision Windshield consists of three (3) 1000 x 1000 indium antimonide arrays integrated into an UH-60 Blackhawk helicopter, and integrated at strategic locations to provide the panoramic view. The image data from these arrays is transmitted to multiple helmet mounted displays, worn by the pilot, crew chief and other crew members. Each user has the freedom to look in any direction to access information from the infrared sensors. In preparation for the flight test, laboratory evaluations and ground tests have been ongoing for past eighteen months.

Sensor Integration

Successful completion of these preliminary evaluations provided sufficient confidence to begin the aircraft integration activities. The Raytheon integration team arrived at Fort Eustis, Virginia at the Aviation Applied Technology Division on September 15. Immediately, the impact of the transition from laboratory to field trails confronted the aircraft integration team. Electronic racks required additional re-enforcement to meet the requirements of safety review; cables and cooling air ducts were run along the installation paths; and air-conditioners and power supplies were lifted onto the aircraft. Each key component of the system and test equipment was weighed on hangar scales to verify final weight on the helicopter.

Successful completion of these preliminary evaluations provided sufficient confidence to begin the aircraft integration activities.

In addition to the weight and balance of the aircraft, resonant vibration frequencies of the sensors and additional equipment must not interfere with vibration modes of the aircraft. A frequency too close to aircraft resonant modes could cause aircraft instabilities or degrade the integrity of the sensor mounts. Engineers mounted accelerometers on the external imaging sensors to monitor stress during flight, and maintain sensor mounting integrity.

Helmet Mounted Display and Tracker

Internal to the aircraft, a key component of helicopter integration involved the head tracker and associated electronics. The team carefully reviewed head tracker camera placement and orientation, and made selections to provide a stable, continuous image stream from the external infrared cameras to the user helmet-mounted display. Helmet alignment, magnification and general tracking performance were monitored in extensive ground tests. Alignment of the helmet image and correlation with the image data from the external sensors proved challenging, but once completed, provided a smooth, jitter-free image as the pilot or crew chief turned to view the external world from positions within the helicopter.

A variety of image correction and enhancement methods were evaluated in real-time, and an assessment made based upon the wide variety of scene backgrounds that could be encountered in flight. Adjustments were made to helmet boresight

Figure 1: UH-60 copilot seat with head tracker mounting bracket.

and magnification, and software optimizations of the head tracker interface were tested with good results.

As a final check, the helmet displays were run in a closed loop mode at a 50 Hz image rate, with a critical eye to detect imaging artifacts and anomalies. A pilot viewing the helmet mounted display is shown in Figure 1.

First Flight

After thorough evaluation of safety and performance issues, the team received Airworthiness Release and conducted the first flight on October 24, 2003. Although image data collection is the primary objective, this type of comprehensive field evaluation involves multiple factors, including aircraft performance under stress, structural integrity and helicopter control margin. After a thorough ground check, including running the rotors throughout their full RPM range, the first flight was accomplished with no problems or issues.

The vibration measurements were within acceptable limits throughout the flight envelope. High rate of decent was demonstrated with the standard power settings and sixty (60) degree bank turns executed without problems with sensor mounts. Figure 2 shows the initial takeoff of the MH-60 with sensors mounted in place.

Image Data Collection

The image data collection will continue for the next four to six weeks. Plans are for flights at each of the military bases and feedback from users to stimulate improvements in sensor performance, image processing and display.

Figure 2: UH-60 with three-to-five micron infrared sensor package mounted at nose of the aircraft. This is one of three sensors integrated around the aircraft for the flight demonstration.

Summary

The step from the laboratory evaluation to user field trials involves a multitude of issues related to the sensors system and the platforms. The integration of sensors into an airborne platform for operation in a battlefield scenario demands precision assembly, analysis of sensor placement, and mode of display to the user. These steps, which have just begun with the Night Vision Windshield program, provide the basis for user acceptance of new technology. The early and continual involvement of the war-fighter in this process is paramount to success. For more information on this project, contact Ray Balcerak at rbalcerak@psu.edu.

EO Materials Divisions Expands Crystal Growth Capability

The EO Materials Division is expanding its capabilities for high temperature bulk and epitaxial growth with the acquisition of two new crystal growth systems to be located in the EOC Freeport facility.

An EMCORE chemical vapor deposition with custom-designed bulk and epitaxial reactors will be installed for process development and scale-up efforts for the Halide CVD growth of silicon carbide under a joint project with Carnegie Mellon University. The equipment was acquired under a project sponsored by the Air Force Research Laboratory's Materials Directorate and will also be used for a DARPA sponsored project on bulk semi-insulating silicon carbide.

In addition, a dual-chamber SVTA molecular beam epitaxy (MBE) system capable of depositing III-Nitride and Oxide films will be installed under an ONR sponsored program. The system will be used to develop single-crystal oxide films on wide bandgap semiconductors for integration of tunable capacitors for next generation radar systems.

For additional information on these activities, contact David Snyder at dsnyder@psu.edu or Mark Fanton at mfanton@psu.edu.

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UPCOMING EVENTS

Defense Manufacturers' Conference, 1-4 December 2003, Washington DC

Electronic Imaging, 20-21 January 2004, San Jose, CA

Photonics West, 27-29 January 2004, San Jose, CA

Defense & Security Symposium, 13-15 April 2004, Kissimmee, FL

Great Lakes Photonics Symposium, 7-11 June 2004, Cleveland, OH

SPIE Annual Meeting, 2-6 August 2004, Denver, CO

Tech Trends, 3-6 August 2004, Pittsburgh, PA

ARMTECH, 18 August 2004, Kittanning, PA

OSEie - Optical Science Engineering for Industry and Environment, 26-27 October 2004, Philadelphia, PA