EOC

The Electro-Optics Center
A Manufacturing Technology Center of Excellence

NewsFlash

September 2003
V4:N3

Murtha Announces New EOC Facility

"This building is a major step forward into the next phase in the growth of the EOC."
U.S. Rep.
John Murtha

On August 8, 2003 Congressman John Murtha (PA 12) unveiled plans for a new facility to house the Electro-Optics Center (EOC) and an estimated 80 employees in Northpointe Industrial Park near Freeport, Pennsylvania.

In addition, Murtha and officials of the Pennsylvania State University and its Applied Research Laboratory announced the selection of a team led by the Jendoco Corporation of Pittsburgh as the developer/builder for the new Armstrong County building that will serve as the future home for the EOC.

Murtha unveiled the plans for the proposed 45,000 square foot structure at a breakfast held as part of the 2003 ARMTech Showcase of Industry and Technology. The Congressman has had a lead role in establishing the EOC in Armstrong County and has been a primary sponsor of its work. His continued support has enabled the Center to both develop the research and development capability for electro-optics and serve as a magnet to attract industry to the region for this critical defense activity.

"This building is a major step forward into the next phase in the growth of the EOC," Murtha said. "The EOC is established as a national resource for the fast-growing electro-optics industry, and this facility housing their technology quarters secures their future here in our area."

U.S. Rep. John P. Murtha and his grandson Jack pose with Armstrong County Commissioners Jim Scahill, Jack Dunmire and Homer Crytzer along with Karl Harris and Ed Liszka at the unveiling of the new EOC home.

Planned Penn State ARL Electro-Optics Center at Northpointe, Freeport, PA.

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Message from the Director
By Dr. Karl A. Harris

As the EOC's technical expertise and reputation has grown so has the number of projects, the funding levels, and number of personnel. As a result, growth has been an ongoing occurrence at the Electro-Optics Center. To accommodate our current growth needs we have been actively engaged in finding a permanent home.

The growth experienced by the EOC is a direct outcome of a nationally identified need for a Department of Defense "go to" center for electro-optics technology.

It is hard to believe that the original EOC facility, established in April 1999, consisted of an administrative office space shared within the Allegheny Power Offices in Kittanning. In spring of 2000 the EOC was relocated to our present Glade Drive location and now occupies approximately 22,500 square feet in the West Hills Industrial Park. With the ongoing growth of the Center, we have again exceeded capacity of the current facility.

The EOC expansion is occurring in two phases. The Materials, Design, and Process Technologies department recently relocated to a refurbished facility near Freeport. Penn State has leased approximately 10,000 square feet that now houses labs for crystal growth and thermal processing, fabrication, characterization, and laser diode array thermal testing and failure analysis. The materials department began occupying this new location in May of this year.

The second stage of expansion began in fall 2002 and involved seeking a permanent location for the remaining technology areas and administrative offices of the EOC. A development plan for relocation about 8 miles away at Northpointe (www.armstrongidc.org) was established and qualifications from firms interested in participating in a design, build, and leaseback arrangement with the University were sought. The response to the request for qualifications was outstanding, with twenty-nine (29) sets of qualifications being submitted. After review by a team led by Penn State's Office of Physical Plant, three companies were invited to provide the EOC with a design for the new facilities. These proposals were presented in July, and Congressman John P. Murtha unveiled the new building design during the 2003 ARMTech Showcase in August.

The growth experienced by the EOC is a direct outcome of a nationally identified need for a Department of Defense "go to" center for electro-optics technology. Congressman John P. Murtha (D-PA-12) first recognized this need in the early 1990's and we are now seeing the realization of his vision and support. The Office of Naval Research's Manufacturing Technology Program Office is our original sponsor and has encouraged the EOC to grow and leverage technology with the other services and agencies. Penn State University's Applied Research Laboratory has been instrumental in establishing and nurturing the EOC. Finally the EO Alliance has been key to the making the EOC model a success. We look forward to continued support and success as we strive to serve our warfighters.

A Growing Experience

The Electro-Optics Center internship program is underway and growing. Students from various institutions and education levels are being afforded opportunities to work with EOC scientists and engineers to gain valuable work experience and to grow themselves.

The Materials, Design and Process Technology Department provided internship opportunities for students from Penn State, University of Pittsburgh, and Carnegie-Mellon University. Eric Frantz, an Electro-Mechanical Engineering Technology student from Penn State's New Kensington campus, supported the MANTECH Automated Testing of Laser Diode Arrays program and the Missile Defense Agency's Enhancement of High Power Laser Diode Arrays programs. Eric has been involved with the assembly of a thermal characterization laboratory test station, the performance of tests to characterize the thermal

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A Growing Experience *continued*

performance of laser diode arrays, and the development of a fixture to evaluate the performance of an uncooled laser diode array tile. Joe Burg, a Penn State Materials Science major, worked at the Freeport facility to construct a high temperature hydrogen etching reactor. Joe's work supported the DARPA Silicon Carbide Surface Processing program and the Air Force Semi-Insulating Silicon Carbide substrate program. Jordan Negley, an Electrical Engineering student from the University of Pittsburgh has been with the EOC for two years and has been developing a laser diode array thermal test lab.

In addition to the undergraduate students employed at the Freeport facility this summer, the Materials, Design and Process Technology Department also supports a number of graduate students. Jeremy Acord and Dan Perez are Ph.D. candidates in Penn State's Material Science and Engineering Department. Both are being funded under an Air Force Research Laboratory contract for the development of semi-insulating silicon carbide technology. Jeremy's research focuses on the deposition and characterization of epitaxial III-nitride layers on sapphire and silicon carbide substrates. Dan's research interests include electrical characterization of II-N epitaxial films and HEMT structures grown of 6H-SiC substrates.

MIT student Edana Gallagher works on software and instrumentation development as part of her EOC internship.

The Materials area supports Ph.D. students from Carnegie-Mellon University as well. Hun Jae Chung's research involves silicon carbide halide CVD. Jae Won Lee's research involves aluminum nitride crystal growth. Tom Kuhr is working with silicon carbide crystal growth and defect characterization.

Ben Campbell, a Penn State Electrical Engineering student, received his master's degree in August. Ben has been employed at the EO Center for over a year and has been writing software for micromachining of Mercury Cadmium Telluride for IR arrays using the femtosecond laser.

Nevin King, a PSU computer science undergraduate student, recently joined the laser group and will be working with Dr. Vlad Semak on computational simulation of laser effects on materials. Also working in the laser area are Sophia and Eftihia Vlahos, both PSU EE master's degree students. Sophia is working on experimental measurements and theoretical study of laser beam scattering in composite materials. Eftihia is studying the effect of near surface plasma on laser beam intensity distribution at the sample surface. These students will support the EOC throughout the academic year.

For a second year the EOC hosted a high school student through the Manufacturing Pathways Initiative Program. Jamie Hanzel participated in the 6-week program, comprised of both classroom instruction and on-the-job activities. During his time with the EOC, Jamie worked in the laser area on an experiment to characterize RF power between radar horns. To this end, Jamie set up equipment, recorded data, interpreted results and produced a final report and presentation.

Edana Gallagher joined the EOC's Night Vision and Infrared Focal Plane Group for a summer internship. Edana, an MIT EE/Computer Science undergraduate, worked on software and instrumentation development efforts. Edana used the National Instruments LABVIEW programming language to automate temperature dependant current-voltage measurements on Vanadium Oxide microbolometers, used in uncooled infrared cameras planned for several military, fire fighting and homeland security applications. Ms. Gallagher made substantial contributions to the establishment of an EOC test facility designed to understand conduction mechanisms in these devices, especially under temperature and electrical stress.

As the EOC internship program continues to grow, incoming interns will be required to culminate their work experience by developing a poster display and presentation to be presented at the 2004 EOA Board meeting and ARMTech showcase.

For more information regarding EOC internship experiences contact Dr. Wendy Gilpin at wlg5@psu.edu or call the EOC at 724-545-9700.

Materials, Design and Process Technology Department Expands Into New Facility

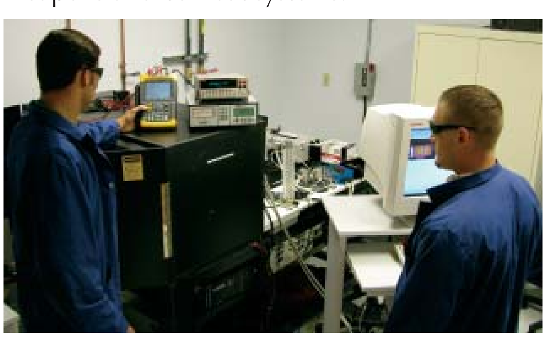
Due to the recent increase in the number of technical programs requiring in-house laboratory facilities, the EOC Materials, Design and Process Technology Department recently moved to a 10,000 sq.ft. facility located near Freeport PA, approximately 10 miles south of the current EOC Main Facility. The Freeport facility will allow for expansion of the Crystal Growth Laboratories, Processing Laboratory, and Materials Characterization Laboratory while freeing up space in the existing EOC facility for new laboratories for the Infrared and Night Vision Department.

The Materials Department serves as a bridge between basic science at universities and government laboratories and industry.

The Materials Department is responsible for a wide range of technical activities centered around five main thrusts:

- Crystal growth, materials processing and process development
- Fabrication of electro-optic and electronic materials for device applications
- Optical, electrical and surface characterization
- Laser diode array and microlaser thermal and physical characterization
- Simulation and analysis of processes and EO components

Using the synergy between these five thrusts the Materials Department mission is to advance the production, processing, and characterization of EO materials and design of EO components by improving their performance and reliability while reducing the cost of materials and devices. In this way the Materials Department serves as a bridge between basic science at universities and government laboratories and industry. Current focus is on wide bandgap semiconductor materials for radar, power electronics, communication and biological agent detection, optical materials for imaging and guidance, piezoelectric materials, and laser gain and nonlinear optical materials for laser weapons and combat systems.



Laser Diode Array Thermal Test and Characterization Laboratory.

New home of the EOC Materials Department in Freeport, PA.

Five high temperature vacuum furnace systems are used for crystal growth, annealing and thermal processing of semiconductor materials.

Automated COREMA non-contact electrical characterization system used to measure and map resistivity of semi-insulating silicon carbide substrates produced commercially and in the research crystal growth systems at the EOC.

The Crystal Growth Laboratory has been expanded to include four Class 10,000 cleanrooms to maintain the appropriate purity required for each process:

1. Silicon carbide crystal growth by physical vapor transport (PVT) and chemical vapor deposition (CVD) techniques
2. Thermal processing (thermal oxidation, thermal annealing, and hydrogen etching)
3. Thin film epitaxy (nitride and oxide molecular beam epitaxy (MBE))
4. High temperature processing (aluminum nitride growth, sintering, and solid state recrystallization)

The laboratory offers a range of unique furnace capabilities for high temperature processing up to 2500ºC under a variety of ambient gas environments including high vacuum (10^{-7} torr), inert, oxidizing and hydrogen. These furnace systems provide the ability to study sublimation crystal growth, chemical vapor deposition, etching, annealing, sintering, and solid state material synthesis for a wide range of material systems.

Computers used in the Process Design and Simulation group to model crystal growth processes, thermal processing, and laser diode array thermal management system.

ZYGO white light interferometry system used for measuring and mapping surface roughness and curvature on wide bandgap semiconductor substrates, optical surfaces, and various electro-optical components.

Fabrication laboratory with ID, OD, and wire slicing and dicing capabilities. Polishing laboratory used to develop advanced chemi-mechanical polishing chemical slurries and processes.

The Fabrication Laboratory was established to study and develop manufacturing technologies for processing of electronic, optical, and electro-optical materials and metallographic analysis of components. The laboratory has complete capabilities for x-ray orientation, slicing (OD, ID, wire), grinding, dicing and polishing (mechanical and chemi-mechanical). A major effort currently underway is the development of high removal rate, damage free chemi-mechanical polishing for semi-insulating silicon carbide electronic substrates.

The Materials Characterization Laboratory was established to provide rapid feedback on critical properties of materials and surfaces to guide and accelerate process development. The laboratory has a variety of systems including a ZYGO white-light interferometer which is used to rapidly assess surface finish of polished surfaces and a COREMA non-contact resistivity measurement system used to map the electrical resistivity of high purity semi-insulating silicon carbide wafers produced commercially and grown in-house. Non-routine characterization is typically conducted using the facilities at the Penn State Materials Research Institute.

A New Methodology for System Insertion: The Next Generation Infrared Imaging

Background

Infrared imaging technology has reached a high level of maturity, demonstrated by the large number of Defense Systems with infrared imaging critical to system performance. Target acquisition, missile seekers, missile warning, surveillance and man-portable applications are just a few of the generic system categories that take advantage of infrared imaging. The current imaging systems, refined over years of development and field trails, exhibit excellent performance. However, many of these systems utilize imaging arrays that were designed over twenty years ago. Since many of these systems are produced in low volume, array production lines are difficult to maintain, and cost continues to increase. A new generation of infrared imaging components is now ready for system integration. The question is: How to make the latest in infrared imaging available to the warfighter, without throwing out the excellent system technology, which has matured over the years.

A new generation of infrared imaging components is now ready for system integration.

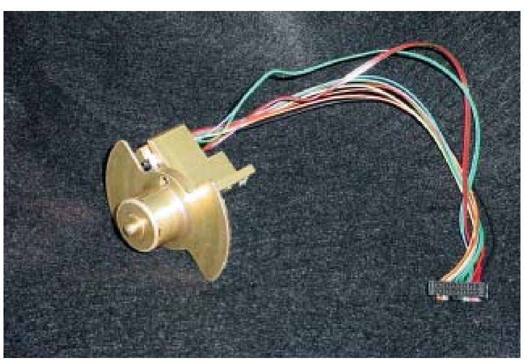
New Electro-Optic Imaging Components

DRS Infrared Technologies, working with the Electro-Optics Center, devised an innovative approach to upgrade infrared imaging systems with state of the art focal plane arrays. Two specific imaging systems, the Avenger Air Defense System and the Night Sight for the TOW missile, are the first upgrade candidates. After completing a comprehensive system and component analysis, DRS devised a "plug-and-play" upgrade kit for these systems. For the TOW system, the big payoff to both the warfighter and taxpayer is that the performance (1.5X range extension) and reliability (7X increase) of these systems is significantly improved; while over the system life-cycle, the cost of the "works-in-a-drawer" upgrade is less than replacing the old arrays and electronics.

This was made possible through an optical and electronic design that retains the existing infrared telescope and housing, and maintains all the weapon system interfaces. Two of the key optical components, the chopper and dither mechanism, are shown in Figure 1. The chopper provides accurate infrared calibration for the detector array, and the dither mechanism enhances optical resolution and improves system performance. These new components maintain the optical interface that warfighters have been trained with over the years.

The big payoff in system performance is in the detector array. The existing TOW imager uses a sixty-element line array of detectors that are scanned with a mirror to create the infrared image. Each detector in this array is individually wire bonded to electronics that amplify and process the signal. The sixty element linear arrays have become a specialty item; difficult to maintain in production. The DRS upgrade takes advantages of an integrated 320 x 240 focal plane array, where each detector in the array is directly integrated to a signal processor. This integrated detector/signal processor chip is shown in Figure 2. The chip is fabricated using processes similar to integrated circuit manufacturing, providing not only a large, multi-element array, but also the cost advantages associated with integrated circuit manufacturing. The processes are similar to those used to fabricate the chips in your computer.

DRS has integrated the 320 x 240 focal plane array into a prototype system and shown excellent infrared imaging. These infrared imaging experiments verify performance predictions and establish the foundation for the next phase of system integration and testing. In addition, the focal plane array technology provides target identification



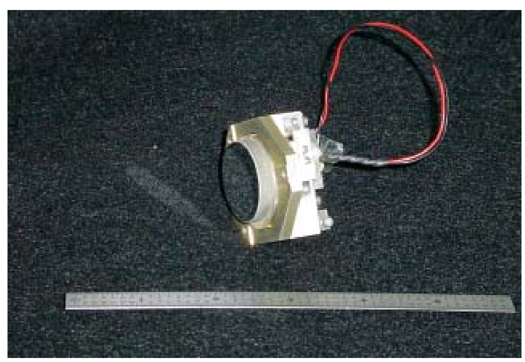


Figure 1: Infrared chopper and dither mechanism are optical components, critical for the upgrade of existing systems to the high performance infrared focal plane arrays.

at substantially longer range. This is extremely important to the TOW gunner, since identification allows them to determine friend from foe on the battlefield. The increase in identification range will help save lives.

Defense Systems

The first TOW infrared imaging system is currently being integrated, with delivery planned in June 2003. These systems will undergo rigorous user field trails, and system qualification. MRT (Minimum Resolvable Temperature) measurements will be performed at the EOC. The MRT, which is critical to infrared system performance, assesses system capability to resolve bar targets of various line spacing, or spatial frequency. These laboratory measurements will then be correlated with field performance, and system specifications verified.

The initial system benefits of this upgrade philosophy are shown in the Figure 3. The TOW system is designed to attack and defeat tanks and other armored vehicles. The system is extremely versatile, and used on a variety of platforms. Examples include the HMMWV, the M151 jeep, the armored personnel carrier, the Bradley Fighting Vehicle, COBRA helicopter, and the Marine Corp light armored vehicle.

The Avenger Air Defense System forms an element of the US Army's Forward Air Defense System, and can operate in a stand alone version or mounted on a variety of military vehicles. Targets are acquired with the infrared system; the autotracker locks on to the target and provides a tracking signal for control of the turret. The Avenger System includes eight Stinger Missiles in two launch pods, shown in figure 4.

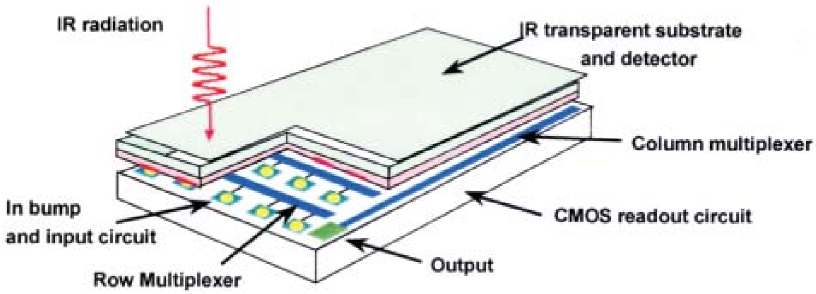


Figure 2: Infrared focal plane arrays include large two dimensional detector arrays with an integral signal-processing chip. This is a dramatic improvement over the existing technology, where each detector is wire bonded and signal processing is perfromed on circuit cards.
(Courtesy DRS Infrared Technologies, LP)

Summary

The integration of advanced components into weapon systems is never easy, and in fact, transition of new technology is a major concern. The large investment in component development must be accompanied by a methodology for insertion, without the design and fabrication of entire new systems. The DRS upgrade to infrared focal plane arrays is revolutionary, demonstrating substantial performance improvement, but at the same cost as replacing the existing detectors. Extension of this philosophy to other systems will provide a new way of doing business in defense systems.

Figure 3: AN/TAS (4X) Targeting Sight for TOW Missile Launcher.

Figure 4: Avenger Acquisition Sight for Stinger Missile Launcher.

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UPCOMING EVENTS

DMC 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

Optical Science & Technology Expo, 3-5 August 2004, Denver, CO

OptoSense , 26-27 October 2004, Philadelphia, PA

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