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3  Infrared in the Service of the Navy II
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Introduction

The Forty-first conference on Infrared Technology and Applications was held April 20th-23th, 2015 at the Baltimore Convention Center in Baltimore, Maryland. The agenda was divided into 21 sessions:

1. NIR/SWIR FPAs and Applications
2. Infrared in the Service of the Navy I
3. Infrared in the Service of the Navy II
4. Infrared Imagers: Variations on a Theme
5. Infrared Imaging: Retaining Acquisition
6. Type II Superlattice FPAs I
7. Keynote Session
8. Type II Superlattice FPAs II
9. ROIC and NUC
10. HOT: High Operating Temperature FPAs
11. Uncooled FPAs and Applications I
12. Uncooled FPAs and Applications II
13. IR Optics I: Technologies and Design
14. Chalcogenide Glasses in IR Optical Design
15. Alternative Approaches and Tools in IR Optical Design I
16. Alternative Approaches and Tools in IR Optical Design II
17. Cryogenic Detector Coolers
18. HgCdTe
19. A Word from the Masters
20. Reducing the Pitch
21. Smart Processing
22. Alternative Photon Detectors and Applications

In addition, there were a number of poster papers presented for discussion on Tuesday evening—these have been added to the 21 sessions in the Proceedings.

Highlights of six topical areas are summarized below:

- Photon Detectors
- Uncooled Detectors
- Optics
- Coolers
- Applications
- Keynote Address

Photon Detectors

NIR/SWIR FPAs and Applications

Near-infrared and shortwave infrared imaging—0.7 to 3 μm—continues to rise in popularity because of its ability to make use of sky glow to enhance performance during exceptionally dark periods of the night.

Development of SWIR FPAs is continuing in order to meet the needs of both military and commercial applications. Most of these developments make use of InGaAs, although new SWIR developments were also presented in thin film colloidal quantum dot (CQD) detectors and T2SL (Type II Superlattice) detectors.

The standard pitch for InGaAs FPAs is now 15 μm, with 12.5 μm and smaller also available. One system manufacturer described how the reduction in InGaAs pitch from 20 μm to 15 μm improved their multispectral vis/SWIR zoom camera. The lower pitch FPA had lower dark current and readout noise, which, together with an improved optics design, resulted in a noise equivalent irradiance reduction by a factor of three.

A manufacturer of InGaAs cameras showed the value of its smart image enhancement algorithms for a SWIR day and night vision camera. Figure 1 shows the improvements achieved.

Development on thin-film PbS Quantum Colloidal Dot (CQD) FPAs processed from solution has reached the point where they have been processed on a 640 × 512 ROIC with 15 μm pixels. A dark current of 2.7 nA/cm² was achieved at room temperature with a 10 mV bias. Devices with response to 2.2 μm have been demonstrated.

The potential for extended wavelength SWIR devices using Type 2 superlattices was explored by one company which fabricated three different structures based on InGaAs/GaAsSb/InP and one on an InPSb alloy. Good uniformity was obtained with a cutoff to 2.5 μm.
Extended wavelength T2SL SWIR devices have been obtained by others and an FPA based on the technology was shown as a commercial product in the Exhibition.

Two papers describing enhanced CMOS imaging were presented. In the first, a low-noise 640 × 480/10 CMOS sensor was tested in the laboratory and shown to be comparable to a Gen III image intensifier under sub mLux starlight conditions.

In the second a “black silicon” layer prepared by ultra-fast laser processing is combined with low-noise CMOS image sensor design to provide enhanced sensitivity to 1.2 µm. Megapixel FPAs based on this design are capable of imaging at 60 fps in lighting conditions below 1 mLux with a latency of approximately 1 msec.

Type II Superlattice FPAs

There were a total of nine papers in the two sessions devoted to Type II Superlattice and Barrier detectors, and several more on this subject in the Poster session. This reflects the continued strong interest in the potential performance advantages that this technology has been predicted to have theoretically—long carrier lifetimes and a high optical absorption coefficient. Experimentally, lifetimes as long as those predicted have not yet been achieved, but improvements have been made recently for material structures that exclude gallium. Lifetimes continue to be shorter than for HgCdTe with comparable bandgaps. This year featured a larger focus on LWIR devices.

An overview of optimizing Type-II heterojunction infrared detectors was presented first.

This was followed by an excellent presentation on LWIR Type II superlattice detectors using an XBp structure. Fig. 2 illustrates the XBp detector structure. A 640 × 512 array with 15 µm pixels has been developed having a 9.5 µm cutoff at 77 K. Fig. 3 illustrates the 13 mK NE∆T of at 78 K for a 65% well fill achieved by averaging 8 frames taken at 240 Hz for a net 30 Hz frame rate.

Theoretical and experimental investigation of SW/MWIR dual-band Type II detectors was presented. A barrier detector design showed advantages over of a pin structure.
The interpretation that Type II InAs/GaSb homojunction detectors are limited by Schockly-Read-Hall centers was challenged in a paper that analyzed the current-voltage data from two LWIR Type II wafers over a wide temperature range. They attributed their analysis to show that shunt leakage was the limiting mechanism. Fig. 4 shows the shunt resistance for surface and area for one of the wafers.

Carrier transport in unipolar barrier detectors based on Type II materials was discussed in the context of minority-carrier blocking and the potentially very low hole mobility in \( nBn \) structures. Fig. 5 illustrates the effect this can have on the bias voltage needed to saturate the quantum efficiency. Taking into account hole-mixing effects, the effective mass of holes may be lower than expected.

Photoluminescence as a function of laser power was used to study the lifetime of carriers in InAs/InAsSb Type II superlattice materials. Results were shown for both MWIR and LWIR samples. Data were relatively consistent with previous results. Quantum efficiency was also measured as shown in Fig. 6.

Confocal Raman spectroscopy and atomic-force microscopy were used to study the sidewalls of InAs/GaSb Type II superlattice mesa detectors. One of the conclusions is that the sidewalls show considerable damage compared to the center of the 24 \( \mu \text{m} \) pixels. Fig. 7 shows the Raman spectra at different locations on a small portion of the array. Peak intensities are reduced on the sidewalls compared with the array center.

Development of 4-to-7-inch GaSb substrates was reported—Fig. 8 shows an example of the new, large boule size compared to 2-to-3-inch boules. In a subsequent paper, the successful growth of InAsSb/AlAsSb bulk \( nBn \) epitaxial detectors was demonstrated.
A final paper in this session reported on the IR transmission of large GaSb substrates as a function of doping. Transmission can be low in the V LWIR range when there is too much p-type doping due to absorption from transitions between the light- and heavy-hole bands. Te doping was used to partially compensate residual p-type dopants. Figure 9 illustrates how the IR transmission can vary with Te counter-doping.

**ROICs and NUC**

Three papers were presented describing readout designs. Three additional papers on this subject area were presented as posters. Readout designs included the following formats:

- A digital ROIC design was described for LWIR detectors suitable for either staring or scanning formats using a pulse frequency modulation that can accommodate $> 2 \times 10^9$ charge storage per pixel—equivalent to 20 bits in a 30 µm unit cell.

- A SWIR ROIC featuring a CTIA input in a 1280 × 1024 format with 15 µm pitch was reported. On-chip provision for bias and timing is included. Noise is $< 5$ e- in the very high gain mode. Fig. 10 shows modular USB-based camera electronics based on this design.

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**Fig. 7** Micro-Raman spectra of a T2SL-FPA structure measured at different points. Lorentzian fitting was performed to distinguish different phonon features in the spectra (red lines { fitting results; green lines { contributions from individual phonon modes). The inset images show the location of the laser spot corresponding to the measured spectra. Dashed lines are guides to the eye.

**Fig. 8** Standard 2”/3” (left) and larger format 4”-7” (right) GaSb boules.

**Fig. 9** Transmission measurement taken at the center point of slices A, B, C and D cut from boule LM2019Te.

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**Fig. 10** Modular USB based camera electronics.
• Cryogenic measurements of the digital pixel design described in the first bullet above were made to evaluate the design.

• Low-voltage differential signalling was proposed for linking an FPA to a microprocessor input.

• An uncooled microbolometer readout was described in a 640 × 480 format with 17 µm pixels.

• An ASIC—Near Infrared Readout and Controller (NIRCA)—was unveiled to provide a generic interface between FPAs and a master system controller. Fig. 11 shows an image of the ASIC chip.

High Operating Temperature (HOT) FPAs

The goal of increasing the operating temperature of FPAs without sacrificing performance is motivated by the reduction in cooler power, improved cooler efficiency, longer cooler lifetime, smaller imager size, and lighter weight sensor systems that this makes possible. This goal is being pursued using HgCdTe, Type II superlattices, and nBn materials and has relevance especially in the MWIR and LWIR spectral bands.

An extensive and detailed paper on the trade-offs of Size, Weight, and Power (SwaP) considerations for cooled FPAs was presented with extensive analysis. Fig. 12 shows how the detection range varies with operating temperature for an MWIR HgCdTe array using narrow field-of-view f/4 optics as a function of operating temperature. The cooled FPA has greater range for temperatures below about 195 K.

High operating temperature HgCdTe detectors featuring enhanced functionality were described in another paper. Fig. 13 shows the weight advantages of HOT MWIR detectors compared to microbolometers. Fig. 14 illustrates imagery that can be bring out subtle details in the imagery using local-area contrast enhancement.
Another HOT paper reported on MWIR unipolar barrier detectors based on Type II superlattice material in a pBiBn configuration illustrated in Fig. 15. Spectral response for this device at 200 K is shown in Fig. 16.

The effects of AlSb barriers on the properties of InAs/InAsSb superlattice material were explored in a paper on photoluminescence and Hall effect properties. Samples with two (VL17), one (VL19), and no AlSb barriers (VL18) were studied. Mobility at 10 K was considerably reduced for the sample with barrier—see Fig. 17.

Interband cascade photodetectors were reviewed as HOT detector candidates for both MWIR and LWIR bands. Significant progress over the past year was reported. Fig. 18 illustrates the MWIR spectral $D^*$ for a wide range of temperatures and Fig. 19 shows the LWIR spectral $D^*$.
CdS/PbSe heterojunction detectors were the subject of the final paper in the HOT session. This topic was explored using a one-dimensional model to determine the key variable that can improve the device structure illustrated in Fig. 20. These materials have very low Auger recombination rates compared to other IR detector materials and thus have great potential for HOT applications.

**HgCdTe**

The HgCdTe alloy detector—characterized by a high absorption coefficient and a long lifetime—continues to dominate the choice for a broad range of infrared applications. Aside from applications that are ideal for either InSb in the MWIR spectral band, or InGaAs in the 1.7 μm SWIR band, or those that can utilize uncooled FPAs, HgCdTe continues to be the most popular choice. Papers in this section update how HgCdTe is continuing to develop and evolve. Papers on this topic were presented one session on HgCdTe detectors as well as in the HOT session, the Applications sessions, and in the Poster session.

RMS noise modeling of MWIR and LWIR HgCdTe FPAs has been studied in order to be able to model the main distribution of background limited diodes and those with elevated noise due to 1/f defects. Noise histograms were reviewed using linear, log, and cumulative density plots as illustrated in Fig. 21. This was correlated with material quality as shown in Fig. 22.

MBE-grown HgCdTe on GaAs substrates was the subject of another paper. Results from single-color MWIR and LWIR were reviewed, and also MWIR/MWIR two color devices. Fig. 23 shows an SEM image of dual color pixels that has an npn structure.

Improvements in HgCdTe FPA performance were described, including pixel pitch reduction from 20 to 10 μm. LPE material was used. Fig. 24 illustrates how the NEΔT improves with integration time/charge storage capacity.

LPE HgCdTe was evaluated for space applications in the LWIR/VLWIR range (10 - 17 μm) using a p-on-n device structure. Results were improved over n-on-p structures that rely on vacancy doping. Quantum efficiency decreased below ~ 50 - 60 K.
A paper described HgCdTe HOT detectors for MWIR operation with an nBnn structure as shown in Fig. 25. Data from the first samples was presented and compared with Rule 07.

The thermal stability of Al₂O₃ films on HgCdTe were reported in the final paper of this session.

**Word from the Masters**

We enjoyed two presentations by distinguished members of the IR detector community who have recently retired. The first was Michael Kinch from DRS—formerly Texas Instruments. Mike described his career in detector technology (paper included in the proceedings).

The second talk was by Gérard Destefanis who talked about his career in HgCdTe in France—inside a HgCdTe castle with a growing number of threats—see Fig. 26. Gérard talked about the development of HgCdTe in France, the current state-of-the-art, and the challenges from competing technologies.

**Reducing the pitch**

Smaller pitch HgCdTe FPAs was the topic of one session. The challenges associated with obtaining small pitch—~5 μm—were outlined, including:

- pixel delineation
- pixel hybridization
- unit cell well-capacity
- dark current

MOVPE-grown HgCdTe array development with reduced pitch was discussed. Fig. 27 shows the evolution of MOVPE HgCdTe pixel shrinkage. New arrays with 8 μm pitch for MWIR applications were presented along with an NEΔT histogram.

10 μm pitch FPAs were also reported in a second paper in this session. Fig. 28 illustrates the improvement in range for the 10 μm pixel referenced to an earlier design with 15 μm pitch.
Very small—5 \( \mu \text{m} \)—pixels were unveiled in a paper featuring a 2040 \( \times \) 1156 format InAsSb HOT MWIR array. Fig. 29 shows an image from a laboratory camera with this FPA. Details of the advantages of oversampling were described in some examples.

**Smart processing**

One paper was presented in the smart processing session. The subject was on improving image clarity when looking through turbulence. Certain regions of a frame may be relatively clear, with the relatively-clear region varying from frame to frame. The paper described assembling an enhanced image from a collection of frames with relatively clear or “lucky” regions (LRF). Hardware—a graphics processing unit (GPU)—was used to accelerate this collection. Fig. 30 illustrates the improvement in image clarity.

**Alternative photon detectors and applications**

There were two QWIP papers in this session. The first was an update on resonator QWIP development. Electric field effects were modeled as illustrated in Fig. 31, and their impact on quantum efficiency was used to calculate FPA performance.

The second QWIP paper reported on theoretical considerations of FPA uniformity. The impact of nonlinearity in the electronics is illustrated in Fig. 32.
Uncooled Detectors

The availability of uncooled IR microbolometer technology continues to expand. The number of manufacturers seems to be ever increasing, and the distribution of those producers is spreading across the globe. Size, weight, power and cost, raisons d’être for uncooled IR, continue to shrink.

The first two papers of the uncooled sessions presented to the Western world for the first time the progress of uncooled IR detector and system technology development in China, from the industrial point of view. Vanadium Oxide (VOx) and amorphous silicon (a-Si) are both in production. VOx arrays are available in arrays ranging from 160 × 120 to 640 × 512 with pixel sizes ranging from 45 µm down to 20 µm. A-Si arrays range from 160×120 to 640 × 480 with pixels sizes from 35 µm to 17 µm. Typical specified NEΔTs are in the 50 – 60 mK range for the smaller pixel sizes.

Two U.S. companies have made remarkable strides in reduction of size and cost of uncooled IR cores and systems. VOx arrays are being packaged at the wafer level to reduce size and cost, and pixel pitch is down to 12 µm. Custom ICs further reduce size, weight and power. In one case, a IR sensors are available that plug directly into the micro-USB port of Android and iOS phones, as shown in Fig. 33. In another instance, the entire sensor, including optics, is a stacked-chip assembly directly integrable into a smart phone, as shown in Fig. 34.

Japan placed a compact uncooled infrared camera in orbit as a technology demonstration payload and evaluated its performance using targets of opportunity on the earth’s surface. Methods were established to evaluate both MTF and radiometric quality. The camera was shutterless.

Papers from Israel, Belgium and Germany addressed shutterless operation of uncooled IR cameras. Innovations discussed include improved nonuniformity analysis and calibration, scene-based NUC, noise-reduction algorithms and improved dynamic range compression. Performance remains somewhat degraded relative to sensors having a well-designed shutter mechanism, but the gap is closing, and performance is adequate for many applications.

Meanwhile, a U.S. company has developed shutters with embedded microprocessors. Shutters are used to provide a uniform scene of relatively constant temperature for real-time uniformity correction. It is desirable to minimize the transmission time in order to maximize the time available for calibration while minimizing interruption of imaging. Embedding a microprocessor in the shutter permits efficient control blade motion for rapid transitions with minimal power. Three papers addressed enhancement to IR absorption in bolometric detectors. Two of these were from Japan and one from the U.S., and all were cooperative efforts between industry and academia. The U.S. paper investigated enhanced absorption by use of a pattern gold black absorber, stabilized with a protective coating.
evaporated oxide. The two Japanese papers described plasmonic absorbers, one of which provided photolithographic tuning of spectral response, and the other of which, a poster paper, provided selective polarization, also photolithographically.

A poster paper from Turkey described metal-insulator-metal (MIM) diodes for rectification of antenna-coupled IR detectors. In these devices an antenna responds to IR radiation by producing currents in the THz range. MIM diodes provide more efficient rectification than junction diodes, which increases the effective quantum efficiency of the detector. The design of the MIM device included an aluminum layer beneath an Al2O3 insulator layer. The top metal was chromium overlaid with gold. The design achieved quantum efficiencies as high as 29%.

Uncooled IR technology is very mature – even commoditized – in many ways; yet, innovation continues. Pixel sizes are approaching the practical limit, but continued performance enhancements could extend that limit. It seems certain that new applications and more demanding requirements will continue to drive new developments.

Optics

The subjects of the three IR Optics sessions, 13 – 15, are essentially divided into two. The first part reports on chalcogenide optical materials and their use in optical system design while the second part discusses alternative approaches and tools in IR optical design.

Multispectral and hyperspectral systems are required to increase target acquisition performance as well as to answer SWaP-C requirements for military and paramilitary systems. While today’s FPAs can potentially enable compact, lightweight multiband spectral systems, there are few optical materials covering the SWIR – LWIR transmission range. The result of this is that several optical components are needed to correct for chromatic aberrations over a broad wavelength spectrum – adding size and excessive weight to the systems.

Several laboratories have lately presented results of their efforts to fill up the infrared glass map – closing the many gaps in the refractive index values – in order to enable compact multiband optical systems. Foremost among these is the U.S. Naval Research Laboratory. A full session was devoted to recently developed chalcogenide materials and their use in optical designs. Fig. 35 shows a typical transmission plot of an NRL chalcogenide glass. The glasses are amenable to single point diamond turning for complex surfaces and molding for low cost volume production. One presentation pointed out that an added advantage in using these materials is that the glasses may be bonded. This results in a reduction of the number of air/glass interfaces. Examples were given of layered and bonded optics.

Another presentation from the same laboratory described use of chalcogenide glasses for making IR GRIN (Gradient Refractive Index) optical elements. These elements have tailored index variations that manipulate and control the radiation path within the bulk of the material. As the elements are designed with simultaneous optical power and chromatic correction a reduction in the number of elements in a wideband optical system is possible. Fig. 36 shows the IR GRIN process with diffusion and, alternatively, with bonded layers.
One company discussed their efforts to reduce the cost of chalcogenide glass optics for high-volume thermal imaging lenses. Following their thorough study where they compared the properties of germanium-free As$_{40}$Se$_{60}$ with the more expensive Ge$_{28}$Sb$_{12}$Se$_{60}$, they concluded that the former offers promising potential for improved thermal performance and lower cost for high volume consumer applications.

Another company explored the production process for affordable chalcogenide lenses from design to manufacture. Fig. 37 illustrates the expected growth of consumer demand.

One company provided an exciting example of how GRIN materials can provide an answer to a common problem like narcissus in imaging systems. Narcissus is caused by reflection of the cold stop off a lens surface back to the image plane of a cooled infrared system. The system’s narcissus can be greatly reduced by changing the shape of one or more of the lenses. These changes will, however, in many cases also change the first order parameters and MTF of the original optical system. The presenter demonstrated that by employing GRIN materials in one or more of the component lenses, the original first order parameters and MTF may be retained for the near narcissus-free optical system.

Two presentations addressed testing of chalcogenide and GRIN optical elements. Both destructive and non-destructive means of measuring the GRIN index profile were investigated. Destructive testing involved slicing the optic. Non-destructive methods aim to correlate physical properties with the index of refraction. Both Raman mapping and CT scanning were used. Another non-destructive method for calculation of the refractive index is based on prism refractometry.

Among the alternative approaches in part 2, diffractive optics has not been accorded a separate presentation in our earlier sessions. The reason for this is that the use of diffractive optical elements, DOEs, in imaging has been limited. It is now realized that diffractive optics provides system developers and optical designers with additional flexibility in systems’ architectures, resulting in solutions with reduced overall size and weight, as well as enhanced performance characteristics. One company discussed single and dual band optical systems based on non-chalcogenide materials. In one example the use of DOEs reduced the axial length and the weight of the system by factors of 2 and 3, respectively — see Fig. 38.

One company offered advice to fearful optical designers wishing to design a dual broadband VIS-SWIR diffraction-limited zoom lens system. It was pointed out that a set of diffraction-limited modules does not ensure diffraction-limited performance of the zoom lens. The inherent aberrations from one module can interact with aberrations from another module and cause induced aberrations which vary as the positions of the modules change through zoom. (Your editor was not altogether freed of varo-achro-phobia. See note at end of these optics reviews).

A company, well known for its mirror design and manufacturing, discussed its efforts to reduce SWAP-C of reflective optical systems for aerospace and defense applications. Minimizing the number of elements in the optical system was recognized as the obvious starting point for size and weight reduction. Diamond ma-
chining was considered for incorporation of aspheric/freeform surfaces which would enable elimination of elements. Other important factors considered were structural optimization, substrate stiffness and density, as well as surface finish quality. The same company reported on a new ultra-low surface finishing process for their aluminum mirrors. This finishing was applied to a 13 inch diameter parabolic mirror.

As modern IR/EO systems become more complex and the lines between optical and mechanical software become more blurred, there is a need for both optical and mechanical software to develop software-agnostic links to enable users to fully benefit from the advantages of each software suite. One company presented their software-agnostic process that does not depend on optical or mechanical software or plugins.

Note on next year’s Infrared Optics sessions:
These sessions will be expanded and absorbed in a new DSS conference – Advanced Optics for Defense Applications – UV through LWIR.

Coolers

Infrared systems mounted on a soldier’s weapon or in a small UAV need to be small, light and require low power. Cooled detectors operating at high temperatures up to 150 K and above (HOT) require less power hungry coolers than detectors cooled to 77 K temperature. See example in Fig. 39. A cooler drawing less power is usually smaller and lighter as well.

Two companies addressed HOT mechanical cryocoolers of both linear and rotary types. One company conducted trade-off analysis, mainly at system level, between start-up time, power consumption and reliability needs. Their linear cooler used a moving-magnet dual opposed-piston compressor which, combined with a free displacer cold finger, was effective in the application of active vibration reduction measures. Fig. 40 shows an example of regulated power vs. displacer length at 150 K for a HOT rotary cooler.

The other company defined as their goal for the rotary cooler a regulated power consumption down to 2 W DC for a cooling temperature of 150 K. The results shown in Fig. 41 were obtained by using a new high-efficiency motor and a thinned and shortened cold finger that reduce the self-heat loads. Stirling cycle simulation software was used in the performance optimization process.

A complete refrigeration system fundamentally consists of a thermodynamic device, like a mechanical, optical or thermo-electrical cooler, and the electronics to drive the device. Even the simplest of applications require a power source and a precision temperature control servo. Both of the two HOT cryocooler presentations discussed their miniaturized drive electronics. One pointed out the advantage of having dual
Two companies focused on cryocoolers for specific applications. One discussed the development of a Microsat Cryocooler System with cooling capability of at least 0.5 W at a temperature of 140 K or below. Most of the report discussed the design of the radiation hardened miniature low-cost cryocooler electronics. This is recognized as the key technology requiring maturation to enable the objective missions. Fig. 42 shows a linear mechanical cooler and its electronics which together fit within the specified boundary of 10 cm x 20 cm x 6 cm.

One company reported on their development of cryocoolers required for operation under very harsh conditions. The specific application is for cooling the IR focal plane of a missile warning system mounted in a fighter aircraft, helicopter or a commercial airliner. One example of harsh environmental requirements was operation at temperatures between -46 C and +102 C and at random endurance vibration rates of 21.2 g rms. Test results showed that several of the company’s cryocoolers have passed the qualification programs at system levels.

An elevated heat load of an Integrated Dewar-Detector Assembly (IDDA) may indicate a loss of vacuum due to natural outgassing, release of trapped contaminations or insufficient mechanical integrity. The evaluation of incoming heat flow has therefore become an important part of standard test procedures. The traditional method of heat flow measurement involves boil-off calorimetry. This is convenient for cryocoolers operating at 77 K, but for HOT coolers this method is not recommended due to inaccuracies, logistical difficulties and health and safety hazards. The proposed method of warm-up multi-slope calorimetry compares heating rates during warm up of an initially precooled cold finger in the IDDA, under different trial heat loads. Fig. 43 shows the experimental set-up.

Note on next year’s Cryogenic Detector Coolers sessions:

These sessions will be expanded and absorbed in a new DSS conference – Tri-Technology Device Refrigeration (TTDR). This conference will in addition to mechanical cryocoolers also include optical and thermo-electrical cryocoolers.

Applications

Presentations focusing on applications of the various infrared technologies in systems and subsystems were presented in Oral Sessions 2 - 5 and in the Poster Session. As applications are the main drivers for technology R&D, references to system applications can be found throughout the Proceedings.

The two Navy sessions, with updates from the first Navy session held in 2010, discussed potential impact of emerging imaging-related technologies on shipboard situational awareness and targeting systems. The challenges associated with the maritime environment and constraints associated with shipboard operation were considered.
Naval surveillance and reconnaissance systems, like IRST, require high spatial resolution in order to acquire small targets at long ranges. Development of focal plane arrays with high pixel count and small pixel pitch, together with near-diffraction-limited multiband optical subsystems, enable excellent resolution for systems mounted on stable, non-vibrating platforms.

Lack of good stabilization of platforms can easily reduce this resolution. A company with long experience in stabilization of their own and other reconnaissance systems discussed the relative merits of two means of stabilization – opto-mechanical and electronic – for imaging and non-imaging payloads against various scenes. Fig. 44 shows the company’s long range, high resolution, observation payload with sub-pixel mechanical LOS stabilization.

One government institution discussed (presentation only) their maritime situational awareness and obstacle detection sensor system operating in the SWIR spectral band. A novel design achieves 360 degrees horizontal coverage with a single system having static FPA and objective optics. While employing an inverted multi-faceted pyramidal prism several azimuthal sectors are investigated with no image smearing or dead-time between observation of individual sectors. The design enables dual spectral sequential target search.

One company reported on their naval IRST which is based on the distributed aperture systems (DAS) concept for 360 degrees azimuth coverage. The purpose of the system is to detect and track maritime pirates at relatively short ranges.

The imager for a soldier’s weapon sight is required to acquire targets at day and night. Low SWaP-C is another strong requirement. The first requirement calls for two sensors – one sight optimized for day and one for night. Having the two sensors mounted side-by-side will result in a heavy and clumsy sight which will slow the soldier carrying out his task. Changing and re-boresighting the sensor when light conditions change is another solution rejected by soldiers.

A company – a co-leader in the field – discussed the need for Clip-On In-Line Weapon Sights which answer all the above-mentioned requirements. After reviewing the evolution—see Fig. 45—of this type of weapon sights, the company outlined their plans for future development of their clip-on sights – developments that will further decrease SWaP-C and assure longer target acquisition ranges.

Military vehicles with small payload capacity, such as Unmanned Aerial Vehicles (UAV), require sensor systems with small volume, low mass and low power consumption (SWaP) while exhibiting target acquisition at long ranges. One company demonstrated a unique answer to these challenging requirements. Their approach consists of integrating the IR optical system inside the cold shield of the Detector Dewar Cooler Assembly (DDCA). A demonstrator system, having a low NETD due to cooling of the optics, was presented—see Fig. 46. The total optical track length of the miniaturized camera is only 3.8 mm. Application...
tions like wide FOV reconnaissance, multi- or hyperspectral imaging and others are envisaged.

A government laboratory reported on a spin-scan tomographical imager. The principle of its operation is shown in Fig. 47 where the imaged scene is rotated over a linear array of parallel elongated detector elements. A unique optical solution, based in part on the construction of a lobster’s eye, is proposed for flipping the image. The design of the imager enables measurement of transient processes at speeds above that set by the imager’s frame rate.

IR imagers are liable to be blinded by radiation from lasers, explosions, and the sun. One company presented their passive threshold-triggered protection filters, WPF, operating in individual wide spectral bands between the Visible and LWIR. Dual band IR imagers are used for target detection and recognition. The company discussed their choices for protection filters and substrates being optimal for simultaneous operation in MWIR and LWIR bands—see Fig. 48.

The absence of spectral information in a monochrome image obtained with an IR target acquisition system may result in the observer’s slow reaction and impaired situational awareness. One company outlined their solution to this critical issue. The company proposed addition of daylight color appearance to the raw monochrome image in order to increase contrast and enable faster and longer range target acquisition. The easy implementation of single band colorization was demonstrated. See example in Fig. 49.
**Keynote address**

The Keynote address was presented by Dr. Donald Reago, Director of the Night Vision and Electronic Sensors Directorate (NVESD). He reviewed the mission of his organization and key technology thrusts, including:

- Digital low-light sensors
- Micro-displays
- Uncooled technologies
- Digital ROICs
- III-V and II-VI FPA technologies

Efforts also include manufacturing technology programs to move developments into production. Trends in the technology were briefly described.