Spotlight

On Alumnus Arnold Goldberg

Passive IR Imaging

By Dr. Arnold Goldberg

Arnold Goldberg, University of Maryland alumnus and Team Leader of the Passive IR Imaging Team of the EO/IR Technology Branch at Army Research Laboratory talks about IR Imaging and a career with the Federal government.

Introduction

I received my Ph. D. in Physics from the University of Maryland in 1996 but it was not by the "usual" method. I received my B.S. in Physics in 1981 from Maryland and I was fortunate enough to get a job as a research technician at Martin Marietta Laboratories (MML) in Baltimore. It was the corporate research and development (R&D) lab for Martin Marietta, a major defense contractor. I worked in the Advanced Infrared Technologies department where my initial job was to develop fabrication process for infrared (IR) photodiodes. Later on, I moved into device testing. During the period from 1983 to 1987 I went to school in the evenings to earn an M. S. in Applied Physics from Johns Hopkins University. From 1988 through 1996, I worked on my Ph. D. under Professor Robert Anderson at the University of Maryland. My thesis research was on electron transport in semiconductor superlattices.

In early 1995, just as I was finishing the experiments, Martin Marietta and Lockheed merged to form Lockheed Martin. A few months after that, management decided that they no longer needed a corporate research lab and Martin Marietta Laboratories was closed. By this time I had worked my way up from technician to scientist and I was supervising the laboratory and field testing of IR focal plane array (FPA) imagers. My group was transferred to a facility in Nashua, New Hampshire but there was no way I was going to move there. Again I was very fortunate in that a former colleague was able to get me - and a number of other laid off MML employees - jobs as contractors at the Army Research Laboratory (ARL) in Adelphi, MD (just 5 minutes from College

Spotlight

A Neutrino Telescope at the South Pole

By Dr. Gregory Sullivan

The UM Physics' Particle Astrophysics research group is striking out in a new research direction with the new "IceCube" experiment. Building on the success we have had with neutrinos over the past seven years, the experiment is designed to observe very high energy neutrino interactions 2km under the Antarctic ice at the South Pole.

The IceCube neutrino telescope will be approximately 1km3, and will search for astrophysical sources with high energy neutrinos, opening an entirely new window on the high energy universe. Neutrinos, neutral elementary particles, are unique because, in addition to the fact that they point back to the source like neutral gamma-rays, they are not absorbed or scattered by any intervening matter or light. This factor allows us to use a cernekov light technique, similar to the technique used in water for the Super-Kamiokande (Super-K) and Milagro projects, to detect neutrinos in the Antarctic ice. Our research group's experience detecting astrophysical sources with both the Milagro and the Super-K detectors, makes UM Physics and this new IceCube project a perfect match.

Construction of the IceCube detector at the South Pole is expected to begin in 2003-04. The $250 million project will occur in stages associated with each three month Antarctic summer period, when travel to and from the pole is possible. The detector will take approximately seven years to complete, but data will be available with the earliest deployment and build as the detector becomes closer and closer to completion.

Several university groups and government labs from around the world are taking part in this project. We are proud to be one of the groups taking a major role in the construction and science of this large and ambitious detector.

For photos, diagrams and more information about the IceCube experiment, please click here.

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University of Maryland. He is an active member of the particle astrophysics research group and has worked on both the Milagro and Super-K experiments.

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Park). I was actually an employee of the University of Maryland under a co-operative agreement with the Army. I was able to finish my thesis and to be given the responsibility of setting up a new IR test facility at ARL.

In January of 1999 I was hired as a Federal employee and now I am the Team Leader of the Passive IR Imaging Team of the EO/IR Technology Branch at ARL. I enjoy working for the Government because it allows me the freedom to be completely objective in my work. In my experience working 14 years in industry, there was always pressure to make the things we were working on look as good as possible and to continually advocate whatever technology we thought was best. There are several interesting projects that I am currently working on. I will try to give a short overview on what they are.

The United States Army relies heavily on infrared IR for night vision, target acquisition, and fire control. Advanced IR sensor systems allow operations to be conducted at night and under adverse weather conditions. At ARL, we are conducting research aimed at advancing the state-of-the-art in IR imaging sensor technology so that the vehicles of the Army's Future Combat System (FCS) will be able to identify hostile targets at ranges beyond those at which an enemy would detect our vehicle.

There has also been a rapid growth in the commercial use of IR sensors for such applications as medical diagnostics, industrial process monitoring and control, physical security, and firefighting. In addition, IR camera systems have begun to be installed in automobiles to enhance driver night vision (available on a Cadillac as a $2000 option). The military and commercial IR markets are expanding and there is a need for enhanced performance and lower cost of these sensors.

What is IR?

Before I get into the new technologies on which we at ARL are working in this area, I will give a short background on the IR. The IR portion of the electromagnetic spectrum is generally defined as those wavelengths just beyond those of visible light (about 700 nm) to wavelengths of 100 m. At longer wavelengths the IR blends into the "millimeter wave" spectrum.

A combination of circumstances defines the regions of the spectrum where most IR sensors are designed to operate. It turns out that the Earth's atmosphere is relatively transparent in only certain spectral "windows" as shown in Figure 1. These three spectral bands in which the atmosphere is relatively transparent are called short-wave IR (SWIR 0.7 - 2 m), mid-wave IR (MWIR 3 - 5 m), and long-wave IR (LWIR 8 - 14 m). It also turns out that the wavelength of maximum blackbody emission for objects near room temperature (300 K) is 10 m, right in the middle of the LWIR band. The wavelength of maximum thermal contrast, the wavelength at which the derivative of the Planck radiation function is maximal, for a blackbody at room temperature is in the MWIR band. Therefore, most IR sensor systems have been designed to work in either of these bands. There are a number of different semiconductor materials that may be used for IR detection. Entire books have been devoted to that subject so I won't go into that here.

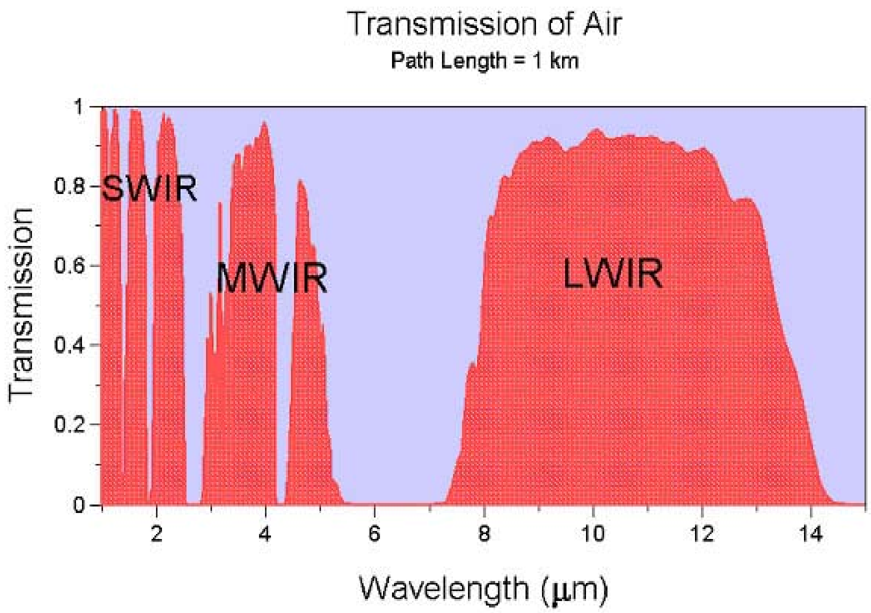

Figure 1. Atmospheric transmission in the infrared showing the principal transmission windows.

Army Research in IR

Under ARL's Federated Laboratory program which lasted from 1996 - 2001 and its successor the Collaborative Technology alliance (2001 - 2006) ARL has teamed with a consortium of academic and industrial partners to research areas of interest to the Army. IR imaging is one of these areas and the particular focus of that program was to develop IR detector arrays that can see in both the MWIR and LWIR atmospheric transmission windows independently yet simultaneously, a dual-band IR FPA. Such an FPA would allow operation in a wider range of ambient conditions (fog, smoke, etc.) than a single-band FPA and holds the promise of being able to detect targets in cluttered scenes better than a single-band FPA. To produce a dual-band FPA the detectors sensitive to LWIR and MWIR light had to be stacked on top of each other and contacted independently. This concept presented serious challenges to the material growth and processing capabilities for the IR FPA foundries as well as for the read-out integrated circuit (ROIC, also called a multiplexer) design.

We at ARL worked closely with Lockheed Martin Sanders (now part of BAE Systems North America) to produce dual-band FPAs using the GaAs/AlGaAs quantum well infrared photodetector (QWIP) technology and with DRS Infrared Technology to produce dual-band FPAs using HgCdTe material. The FPAs were delivered to ARL and I characterized their performance in the laboratory; the results were published in the literature.

To demonstrate the usefulness of dual-band IR imaging, Figure 2 shows an image taken with the QWIP dual-band IR FPA of a coffee mug (filled with hot coffee) that I got from a trade show from nFocus, a laser company. The mug has printed lettering with the company's logo as well as lettering with words like "optics" bead-blasted into the surface. The bead-blasted lettering shows up well in the LWIR image because the rough surface enhances the local emissivity. LWIR emission is very sensitive to the surface roughness. On the other hand, the printed lettering suppresses the MWIR emission because it is highly reflective in that band. Thus materials at equal temperatures can have very different IR signatures. We hope to exploit this effect to defeat camouflage of other deception techniques. The right image in Figure 2 is a color fusion of the individual LWIR and MWIR images. The LWIR image has been mapped to shades of red and the MWIR image to shades of cyan (opponent colors). In the resulting fused image, pixels where LWIR emission dominates are shaded red and those where MWIR is dominant are shades of cyan. Those in which the MWIR and LWIR emission are approximately equal are shades of gray. The fused image not only shows the details of the mug that were apparent in the individual images, but also the background objects on the table that were too dim to see in the individual images. Thus, by fusing the LWIR and MWIR images into a single image, more information from the seen can be visualized than with a single-band image.

Figure 2. Image of a coffee mug with bead-blasted and printed lettering. At right is a color image fusion of the LWIR and MWIR images.

We have also inserted the dual-band FPAs into camera systems and taken them to field tests against military targets. An example of an image in the field is shown in Figure 3. At first glance the LWIR and MWIR images appear very similar but the fused image points out the significant differences between them. The concrete slab at the right of each image is highly emissive in the MWIR band and therefore shows up as bright cyan in the fused image. Conversely, the dirt road emits mores strongly in the LWIR band and appears red in the fused image. The exhaust plume in back of the tank emits strongly in the MWIR (especially farther out from the vehicle) and is therefore acquires a blue shading in the fused image. More results of field imaging using these dual-band FPAs can be found in the literature.

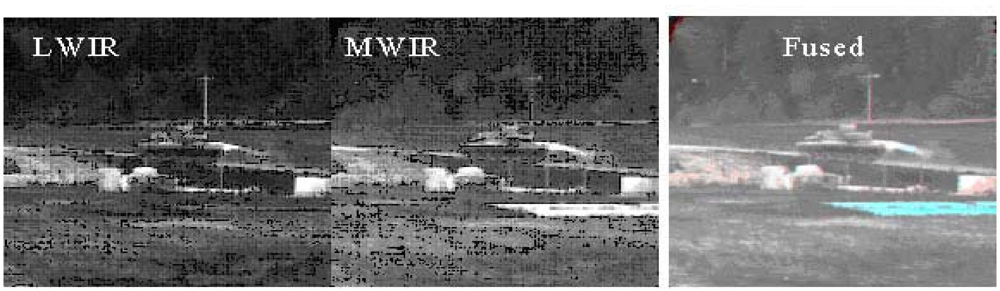

Figure 3. Dual-band image of an M60 tank taken with a dual-band IR FPA. At right is a color fusion of the individual images .

Another application of dual-band IR imaging is detection of buried mines. It has been shown that the disturbed soil associated with buried mines has high emissivity in a narrow portion of the LWIR spectrum relative to undisturbed soil. Other parts of the LWIR spectrum show little or no effect of the disturbance. We have developed a dual-band LWIR FPA to search for this effect. The FPA was installed in a camera system and taken to a simulated mine field at Ft. A. P. Hill, VA. Figure 4 shows some of the results of this test. The IR band 1 was designed to see the disturbed soil feature described above. Band 2 was designed to see the part of the LWIR spectrum that sees little effect of soil disturbance. The resulting image fusion at the bottom of Figure 4 is a subtraction of band 2 data from band 1. Negative values were assigned to shades of blue while positive values were assigned to shades of red. The blue areas indicated disturbed soil and were exactly in the places that the simulated mines were buried. Details of this experiment have been published.

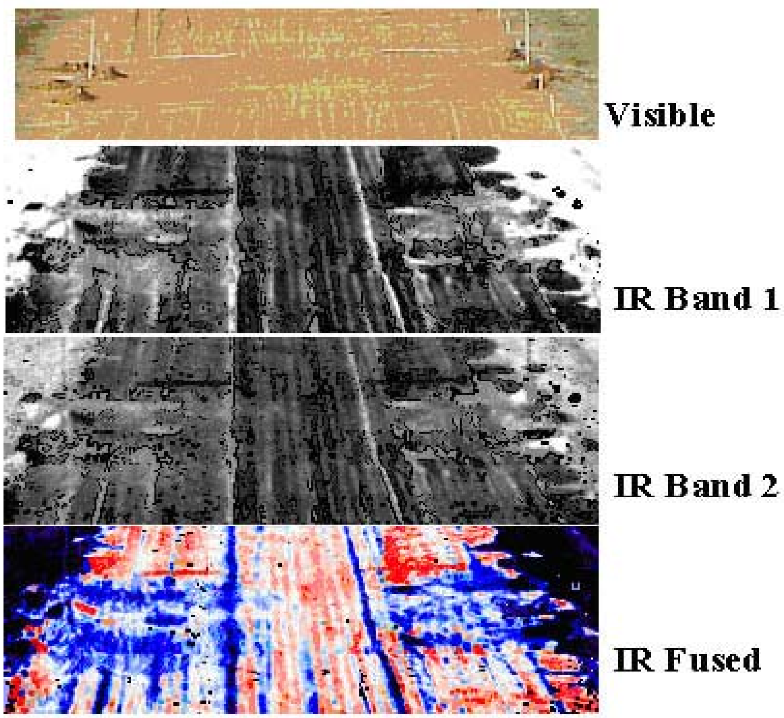

Figure 4. Dual-band LWIR imagery of a simulated mine field. At top is a visible image. At the bottom is a fused subtraction of the two IR bands. The blue shows the areas of disturbed soil that are indicative of buried mines.

These efforts at producing and evaluating dual-band IR FPAs are important steps in the ongoing effort to improve the IR imaging capability of Army systems. Eventually, it is envisioned that dual-band IR FPAs will be an important component of future Army sensor systems.

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