AIR FORCE OFFICE of SCIENTIFIC RESEARCH [AFOSR]
Manager of the Basic Research Investment for the Air Force

Research HIGHLIGHTS

JUL AUG SEP 04

Breakthrough in the Nanotechnology of Long Wavelength Infrared Detection

The efforts to follow enemy aircraft at night may take a quantum leap thanks to a collaborative research effort and a breakthrough in quantum dot-based infrared photo detectors (QDIPs).

Armed with a grant from the Air Force Office of Scientific Research (AFOSR) through the Multidisciplinary Research Inititative (MURI), scientists from the University of Southern California (USC) and University of Texas at Austin (UT-A) have established a major milestone for normal incidence infrared (IR) detectors in the 8-12 micron wavelength atmospheric window. By using QDIPs, researchers led by Drs. Anupam Madhukar and Joe Campbell have demonstrated a performance comparable to the established quantum well IR photo-detectors or QWIPs. The finding, which appeared in the April 26 issue of the *Applied Physics Letters,* establishes the use of QDIPs in everything from night vision, environmental monitoring and medical diagnostics.

Semiconductor quantum dots are nano-scale volumes of one type of semiconductor material surrounded by another appropriate semiconductor. Together they provide new quantum mechanical behavior for the electrons of the three-dimensionally-confined material not found in materials with less than three-dimensional confinement. Through appropriate combination of the two types of materials, semiconductor quantum dots have emerged as the most viable semiconductor nanotechnology for communication and infrared detection. Its tailored properties could impact nano-technology-based devices such as lasers, detectors, transistors and tunneling diodes, to name a few.

To achieve their QDIPs breakthrough, Madhukar and Campbell's teams of scientists synthesized quantum dots, exploiting the formation of defect-free nanoscale three-dimensional islands in the deposition of indium arsenide (InAs) upon gallium arsenide (GaAs). It prompted a phenomenon that occurs spontaneously due to the stress between the two materials arising from their significantly different inter-atomic spacings.

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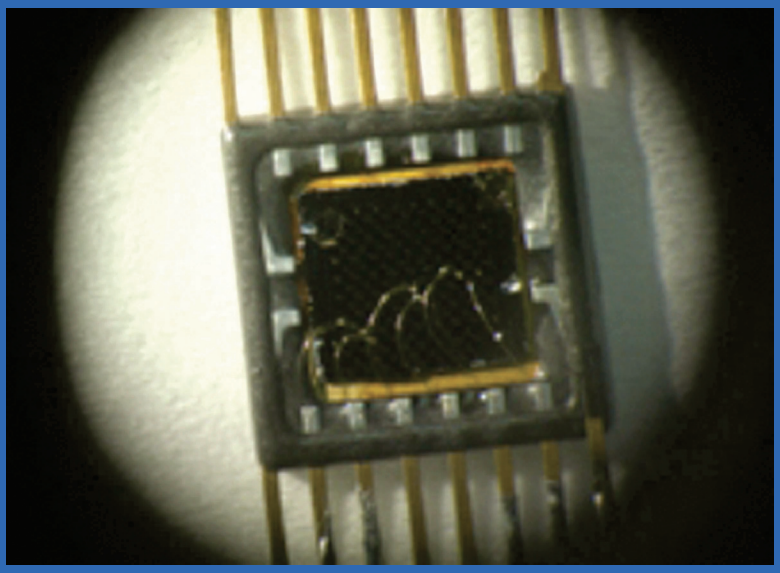
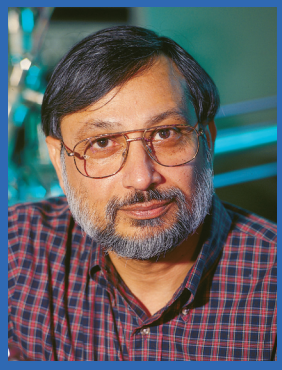


Dr. Joe Campbell



Dr. Anupam Madhukar

LEFT: Quantum Dot IR Receptor Unit

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When buried with an appropriate material overgrowth the islands behave as quantum dots.

The particular significance of the QDs for infrared detectors arises from their three-dimensional quantum confinement effect that allows normal incidence IR radiation to be strongly absorbed in the QDs. This produces the creation of imaging arrays with relative ease and potentially reduced costs. Additionally, in QDs, the electrons excited to higher energy states by the absorption of the infrared radiation have significantly long life times before de-excitation. This property enables easier extraction of the electrons through application of an electric field, thus making QDs ideally suited for realizing photocurrent-based, high performance quantum dot infrared detectors.

The researchers expect that placing the QDIPs in a special configuration, called a resonant cavity, can help enhance their "detectivity" significantly. A resonant cavity is essentially two "mirrors" bounding the space that the quantum dots reside. The mirrors allow the passing infrared radiation to bounce back and forth, thus passing many times through the region of the QDs. This, in turn, enhances the probability of the passing radiation to be absorbed by the quantum dots, enhancing their detection.

The MURI program supports basic science and engineering research of critical importance to national defense. The program is focused on multidisciplinary research efforts that intersect more than one traditional science and engineering discipline. By supporting multidisciplinary teams, it is complementary to other DoD programs supporting university research through single-investigator awards.

Lt. Col. Todd Steiner, AFOSR/NE

Space Scholars

An Air Force Office of Scientific Research Mathematics and Space Science directorate-funded program may provide the link to future innovations in space.

The Space Scholars Program invites undergraduate, masters, and doctorate science and engineering students to participate in a unique summer program that could lead to graduate fellowships and full-time employment. These opportunities exist in the Air Force Research Laboratory's (AFRL) Space Vehicles Directorate. They have facilities at Kirtland AFB, N.M.; Hanscom AFB, Mass.; Solar Research, Sunspot, N.M., and the Air Force Maui Optical and Supercomputing (AMOS) in Maui, Hawaii.

The program allows promising students an opportunity to closely interact with one of the laboratory's highly-regarded researchers. These researchers function as a mentor and offer close support and guidance to the student carrying out the research.

Eugene Brevdo, a student from Rensselaer Polytechnic Institute in Troy, N.Y., is spending his summer at the Air Force Maui High Performance Computing Center. He said he is pleased to be able to put his strong computational background to work.

"This is an excellent opportunity to work with experts in their field, and to apply all that I've learned in school," Brevdo said.

Potential areas of focus include computational algorithms, computational image enhancement and object identification, scientific application development, scientific application benchmarking, and performance analysis.

Another area of research is with the AMOS metrics program, where students assist in advancing space surveillance technologies through innovative astrodynamics research, analysis, and metric tracking sensor development, and optical satellite tracking. The space scholar would pursue these and/or other space surveillance topics consistent with the AMOS mission.

Eugene Brevdo (left), a student from Rensselaer Polytechnic Institute, is spending his summer assisting Dr. Chris Sabol at the Air Force Maui High Performance Supercomputing Center in Maui, Hawaii.

Carlson receives Presidential Rank Award

Dr. Herbert C. Carlson Jr. is already revered in international circles for his work in space science, however, his recent nomination for a U.S. Air Force Presidential Rank Award (PRA) has launched his stellar career into another stratosphere.

Dr. Carlson, the Chief Scientist for the Air Force Office of Scientific Research (AFOSR), won the prestigious PRA honor in the Meritorious Senior Professional category. He was recognized for his leadership role in defining the science and technology programs critical to the Air Force of 2020 in a report to Congress. The resulting visionary document, approved by the Secretary of Defense and Congress, provided six fundamental definitions of Air Force long-term challenges. Congress praised the report for its articulate and creative content. Furthermore, as an added endorsement, they wrote into law that this process be repeated every four to five years.

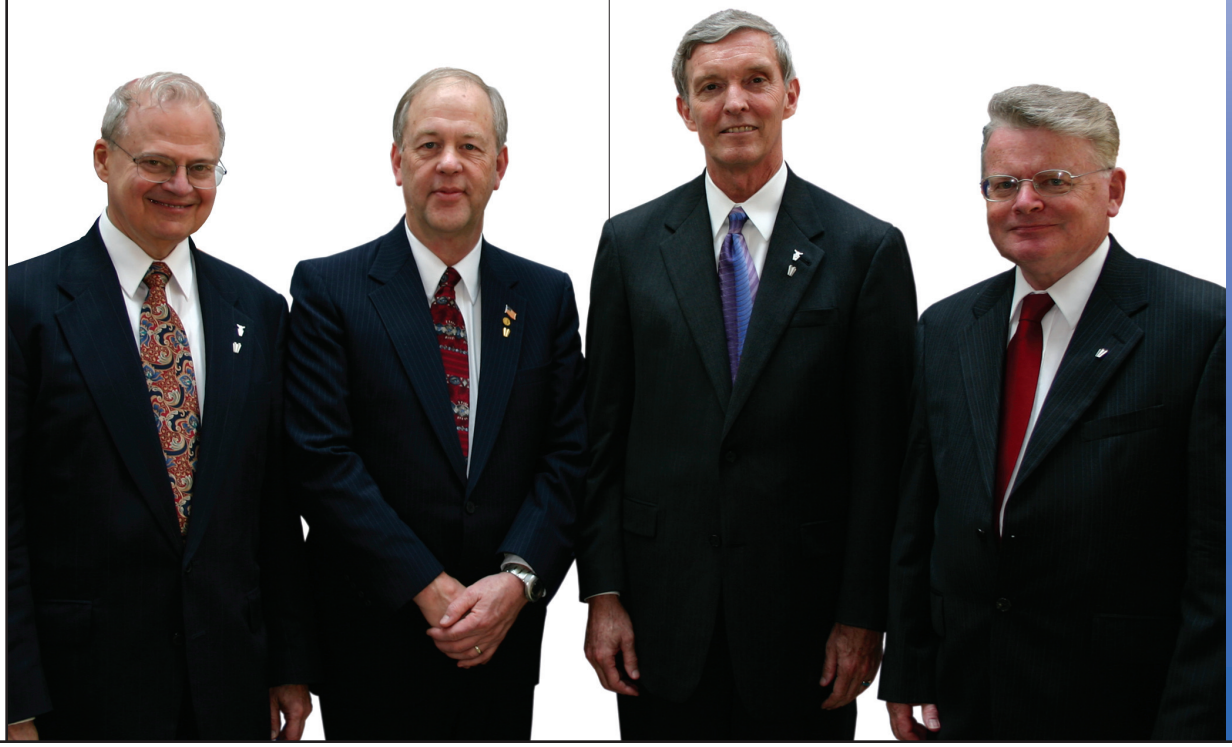
"Dr. Carlson has made direct, significant, and lasting contributions to the Air Force and to our national security," stated a Secretary of the Air Force letter.

Gen. Gregory S. Martin, Air Force Materiel Command commander, was equally impressed by Dr. Carlson's accomplishments.

"This is the first time in the history of these awards that an executive with a scientific background has been honored," Martin said. "Dr. Carlson's vision, talent, leadership and courage have done a great service to our country."

In order to create the content of the 2001 congressionally-mandated Air Force Science and Technology (S&T) report for Congress, Dr. Carlson had to lead a diverse team of more than 300 military and civilian people from a wide array of organizations, each with differing priorities. The team was tasked to define the Air Force capabilities most critical to national defense that could be achieved within the next 20-50 years. In just six months of innovative thinking, the Carlson-led effort produced a plan the Air Force Under Secretary and the Air Force Deputy Director of Strategic Planning said "exceeded their greatest hopes." The Government Accounting Office also praised the process and its implementation.

Dr. Carlson has earned praise on many other fronts during his career. His many years of unparalleled technical achievements opened a new frontier in polar ionospheric physics; he did not pursue a research program, he invented one. He also is known throughout the national and international research community as the "Father of High Frequency Ionospheric Heating," an area crucial to communications through our near-space environment. Dr. Carlson's achievements were made through personal creativity and discovery, unusual scientific leadership and great dedication. He has been called upon for his analysis, research and findings in situations critical to the security of our nation. Dr. Carlson has been a force for integration of technology across AFRL, and has positioned AFRL for the future by aligning its S&T workforce with the future vision of the U.S. Air Force.



Dr. Herbert Carlson Jr., (far left) with fellow Presidential Rank Award recipients Dr. Robert Fugate, Dr. William Baker, and Dr. Alan Garscadden.

AWARDS:

Dr. Richard A. Soref

Fics, Dr. Richard A. Soref, an Air Force Research Laboratory Sensor's directorate scientist, has been named a Fellow of the Institute of Physics (IOP). The IOP is Britain's most prestigious professional organization for physicists, similar in acclaim to its American counterpart, the American Physical Society. The IOP is comprised of more than 37,000 members and is regarded as a leading international professional body. Its aim is to promote the advancement of physics, pure and applied.

For more than a decade Dr. Soref has led the research in silicon-based photonics and optoelectronics under the Air Force of Scientific Research's (AFOSR) support. He is credited with inventing many types of waveguides on silicon and waveguide-integrated optical switches. He also has been a leader in investigations of Si-Ge optoelectronic devices. Additionally, he has had breakthrough discoveries in laser structures based on III-V and Group IV semiconductor materials, including long wavelength infrared (LWIR) and terahertz emitters. The phonon-pumped semiconductor laser he proposed requires no electrical current or optical pumping.

Dr. Soref has overseen several Air Force contracts, including two recent Defense Advanced Research Projects Agency-funded projects valued at $1 million each. Through an AFOSR Physics and Electronics directorate-sponsored program, he collaborated with the EM Photonics Corporation to help them transition silicon-on-insulator photonic bandgap structures into commercial devices.

Dr. Soref is also a recipient of the Air Force Basic Research award, as well as being a Fellow of the Institute of Electrical and Electronics Engineer, the Optical Society of America and the Air Force Research Laboratory.

Dr. Gernot Pomrenke, AFOSR/NE

Dr. Howard Schlossberg

Dr. Howard Schlossberg, Air Force Office of Scientific Research's Physics and Electronics directorate program manager, was selected as a *"Life Fellow of the Institute of Electrical and Electronics Engineers (IEEE)."* He was recognized for his many years of loyal membership and support of Institute activities.

Schlosssberg was named as a Fellow of the IEEE for "contributions to electro-optics and quantum electronics." IEEE helps promote the engineering process of creating, developing, integrating, sharing and applying knowledge about electrical and informational technologies. In his current position at AFOSR, Schlossberg is responsible for managing the $18.7 million Medical Free Electron Laser program for the Department of Defense.

Research Highlights

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Research Highlights is published by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission. *Research Highlights* is available on-line at:

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