Bernard Kippelen of Georgia Tech, front, holds solar cell (inset). *Photos: Nicole Cappello, Georgia Tech.*

CENTER ON MATERIALS AND DEVICES FOR INFORMATION TECHNOLOGY RESEARCH CMDITR

CENTER HAS ITS "HIGH BEAMS" ON

Existing electronic and photonic devices based on inorganic materials such as silicon, gallium arsenide, and lithium niobate are about to "hit the wall"—that is, they are approaching their practical limits in terms of speed, flexibility, and cost.

Researchers at the Center on Materials and Devices for Information Technology Research (CMDITR) are working on organic-materials-based technologies that may provide attractive alternatives to those based on inorganic materials. Outcomes of center research are expected to provide the technological foundation for a thousandfold increase in throughput of telecommunications and information systems.

The center's research program has helped to attract interest from federal agencies, says center director Larry Dalton, professor of chemistry at the University of Washington (UW). "NSF-funded technology has produced complementary interest among mission-oriented agencies to focus on translation of basic research into defense applications."

Ultimately, center researchers hope to lay the groundwork for radically new approaches to the design of computers and sensors, with a move to ultrafast "all-optical" technologies and ubiquitous, embedded systems. CMDITR research will be key to the development of next-generation radar and navigation systems that will enhance U.S. defense capabilities, transform transportation, and facilitate space exploration.

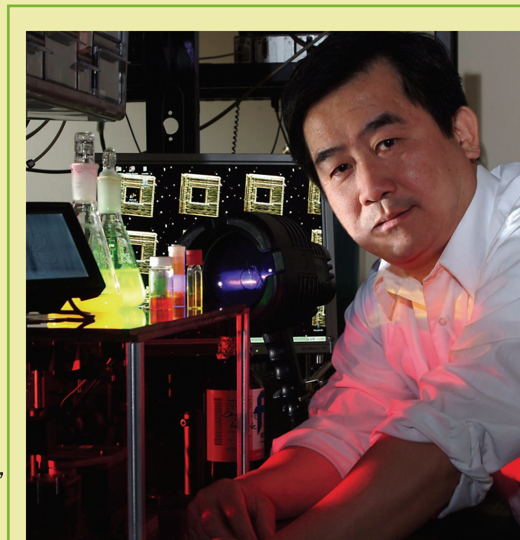
Benefits in the energy sector are also targeted, including the commercial deployment of practical, inexpensive, and lightweight solar cells.

The manufacturing operations needed to produce organic-based technologies not only will provide exquisite control of material structure on very small scales, but are also expected to employ manufacturing processes and materials that are safer, cheaper, and more environmentally benign than those employed in the silicon-based semiconductor industry.

One research area, led by Alex Jen, UW professor and Boeing/Johnson Chair of Materials Science and Engineering, concerns electro-optic (E-O) materials, used to convert information between the electronic and photonic (light) domains at ultrahigh speeds. These materials can be used in devices called electro-optic modulators that transform electrical signals into optical signals and back again as signals enter and leave the ends of a fiber-optic cable. If you've made a long-distance telephone call lately, you've likely used electro-optic modulators.

The process involves the fast and efficient manipulation of the refractive index (ability to modulate light) of a material with an applied electric field. Efforts at the center are therefore aimed at developing suitable materials with high E-O activity, a measure of a material's ability to undergo change in its refractive index with an applied field.

CMDITR researchers have developed and tested a class of novel organic materials that achieve an order of magnitude improvement in E-O activity compared to the best inorganic rivals. The new materials also are specially designed to self-assemble into a structure that facilitates fabrication for computing and communication applications, explains Jen, who is director of the new Washington Institute of Advanced Materials Science and Technology based at the UW.



Above: Alex Jen

At right: Susan Ermer

The new high E-O materials offer several advantages: They can be produced in thin films with much smaller size than their inorganic counterparts, offering the possibility of higher density of integration and higher speed and bandwidth for information technology applications. Devices made of these new materials also have the advantage of a lower drive voltage and therefore, lower power consumption.

This research thrust is of keen interest to Susan Ermer of Lockheed Martin, an industrial affiliate of the center since its inception. Ermer works on the research side of the organization—as she puts it, the side required to "have the high beams on."

"We have ongoing projects in the area of electro-optic materials and devices and we know that this center has creative expertise and depth of knowledge and extensive networks. We've got a long-standing interest in this very specific area, but beyond that, we also see that this interdisciplinary group of people who have been brought together in the center are the ones that have the headlights on into the future," she says.

Ermer is senior manager of materials and structures technologies at Lockheed Martin's Advanced Technology Center in Palo Alto, Calif. Her group comprises about 85 chemists, metallurgists, structural designers, materials scientists, physicists, and engineers.

"In industry, you often have many people who have no choice but to be putting out brushfires, and that's what keeps the enterprise going," says Ermer. "As a research site, though, we should be looking to the future, but very frequently we're tied up in day-to-day things. The relationship with the center allows us to have these pioneers scouting out there and we get the benefit of that."

Georgia Tech researchers Elisa Riedo and Robert Szoszkiewicz

MORPHING THE TECHNOLOGY

One government entity that has funded a major effort in the area of electro-optic materials is the Defense Advanced Research Projects Agency (DARPA), which is providing multimillion-dollar contracts for the development of materials and devices for applications in radar, phased array antennas, and remote control of antennas, among others.

It's part of a program called Supermolecular Photonics Engineering, or MORPH for short, led by DARPA program manager Devanand Shenoy. Having passed initial Phase I milestones, the MORPH program recently was awarded Phase II funding by DARPA.

"This is an area that is going to have a lot of impact for not only the military, but also the commercial sector," says Shenoy. "Center researchers have demonstrated a factor of ten improvement in electro-optic activity over lithium niobate. That's just one parameter—there are other parameters to keep in mind, such as the optical loss, stability, reliability of the materials, all of which will be tested in Phase II of this program. This is going to enable a large number of applications not only for the military for the next generation RF photonic components, for example, but also in enhancing bandwidth for voice, video, and data communication using devices that operate at a low drive voltage."

The participants in this effort, which is separate but related to the center, include researchers at the UW and Georgia Institute of Technology (GT) and a Seattle-area company called Lumera.

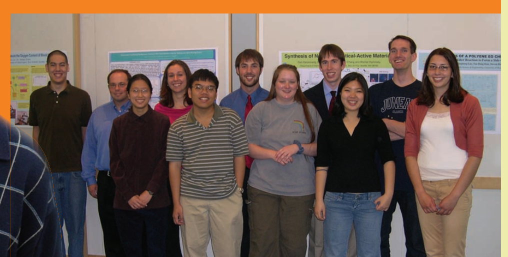
"The university researchers are doing a remarkable job in terms of pushing the state of the art," says Shenoy. "It's a good approach in that the paradigm of using theoretical guidance to develop new molecules and materials appears to be working."

Lumera's role is to demonstrate that the materials that have met the Phase I metrics can indeed be scaled up to large quantities with the same performance characteristics and to implement these materials into state-of-the-art electro-optic polymer modulators with low driving voltage, low insertion loss, and large bandwidths. "It is critical for success in the program that the Lumera team and the UW team work closely with each other to really push the performance," Shenoy says.

The key issue now is addressing the robustness, photostability, and chemical, thermal, and temporal stability of the new materials and electro-optic modulators. "Once we address all of those issues, we will enable the transformation of the next generation of photonics materials and devices," says Shenoy. "There's no doubt in my mind that this is going to be a huge step forward for our military capabilities." □

HOOKED ON PHOTONICS

The center is trying to promote the interest of undergraduates in research with its program of summer research experiences, called "Hooked on Photonics." The program has a particular focus on lower-division undergraduates from community colleges and small four-year colleges—the so-called "gateway" undergraduates, or students with no exposure to research at their home institutions. Some 34 undergraduates took part in the 2005 summer program, 18 of which were female and 14 of which were from underrepresented minorities.



Left: Chemistry professor Phil Reid leads Hooked on Phonics.

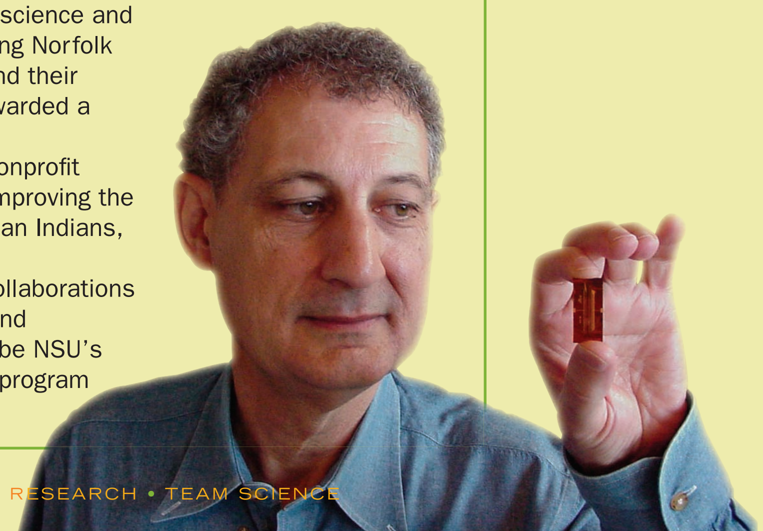
DIVERSITY ENHANCEMENT

Larry Dalton

For his long-term commitment to promoting diversity in science and engineering, and in particular for his recent work advising Norfolk State University (NSU) and Alabama A&M as they expand their graduate programs, center director Larry Dalton was awarded a "Giants in Science" award from the QEM Network.

The Quality Education for Minorities Network is a nonprofit organization based in Washington, D.C., dedicated to improving the education of African Americans, Alaska Natives, American Indians, Mexican Americans, and Puerto Ricans.

Dalton has spearheaded one of CMDITR's major collaborations to help develop a Ph.D. program in Materials Science and Engineering (MSE) at Norfolk State University. This will be NSU's second Ph.D. program and only the second MSE Ph.D. program in a Historically Black College or University (HBCU).



BUILDING A LEGACY: $3M SOLVAY GRANT TO GEORGIA TECH FOR RESEARCH ON ORGANIC LIGHT-EMITTING DIODES

The Center for Organic Photonics and Electronics (COPE) was established at Georgia Tech as a vehicle to help provide a legacy for the STC so that the center research at GT could continue once the STC funding was over, explains COPE director and CMDITR deputy director Seth Marder.

With a recent grant of over $4 million from an industrial sponsor for research on organic light-emitting diodes (OLEDs) and photovoltaic materials, that goal seems well on its way to being realized.

OLEDs are thin films of organic molecules that give off light when electricity is applied. The devices could be used in everything from television and computer monitors to household lighting and handheld computing devices.

Solvay, an international chemical and pharmaceutical group headquartered in Brussels, Belgium, with units in more than 50 countries and a strong presence in Georgia, has signed a three-year commitment with GT for the research.

Marder says the STC provided a "launching pad for us to get a lot of the research going that enabled us to attract Solvay as a sponsor. It is consistent with the STC's philosophy to get work going and to inspire industrial support that both enhances the work going on within the STC and potentially, a vehicle to transition that work into industry."

COPE has already developed a unique material platform for OLEDs that may be deposited over large areas using ink-jet printing and patterned using photolithography. GT researchers have found that exposing the material to ultraviolet light leads to hardened materials that are insoluble and maintain stability under high temperatures. This allows researchers to build a multilayered, solid-state device from liquid materials.

In addition to Marder, a professor of chemistry and biochemistry, other principal investigators at COPE include Jean-Luc Bredas, professor of chemistry and biochemistry and a Georgia Research Alliance Eminent Scholar; Bernard Kippelen, associate director of COPE and professor in GT's School of Electrical and Computer Engineering; and Marcus Weck, associate professor of chemistry and biochemistry.

Léopold Demiddeleer, director of Solvay Corporate R&D and New Business Development, noted that "the New Business Development division of the Solvay Group was looking worldwide to build a strong knowledge and innovation base in advanced materials for organic electronics. COPE was right on target, at the right time and at the right location for us. This winning partnership will take advantage of the world-class expertise of COPE and the industrial potential of Solvay in this highly challenging field. I consider this as the first critical step of a major long-term program for the company."

RESEARCH ETHICS

SHARPEN YOUR SKILLS

Alvin Kwiram CMDITR Executive Director

CMDITR has established a comprehensive program of ethics training and certification within the cross-disciplinary and multi-institutional context of the center for all faculty, postdocs, students, and staff who are classified as participants. This certification consists of three easy-to-use Web-based modules: (1) Rights and Obligations; (2) Collaboration, Communication, and Grants Management; and (3) Intellectual Property. The online tutorials are now available to the public for educational purposes. To register, visit www.responsibleresearch.org.