STC Annual Report

I. GENERAL INFORMATION

Date Submitted: 4/30/03
Reporting Period: 8/02-8/03
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Executive Summary:

The National Science Foundation (NSF) Science & Technology Center (STC) on Materials & Devices for Information Technology Research (MDITR) hit the ground running upon receipt of funding in late October 2002 (with an August 1, 2002 start date). The immediate objective of the Center Management was (1) to implement the Cooperative Agreement securing an effective and dynamic management structure and (2) to implement the Strategic Plan by moving forward toward the vision of the Center which is "to become a national research and education resource for the photonic and information technology communities by providing innovative solutions to the ever-changing challenges that the information technology industry and the broader society will experience in the next decades." The immediate objective has been accomplished through the implementation of an effective intra-center communication system that initially involved weekly meetings with telephone conference calls with the management team and more recently weekly videoconferencing meetings. The viability of the management structure is evident from the fact that it has responded effectively to challenges associated with participants changing professional affiliations and to the changing economic climate that influences industrial interactions, has promoted collaborative research that has achieved significant scientific and technological advances toward realization of five year goals, has launched key educational activities (including web module development and educational workshops), and has succeeded in satisfying the key components of the Cooperative Agreement.

With respect to the Cooperative Agreement, a full time Manager of Center Administration (Karen Monteiro) has been hired as well as a full time Director of Education, Human Resource Development and Outreach (EHRDO) (Dr. Jasmine Bryant). All hires are extremely qualified individuals who also are from under-represented groups. A full-time webmaster has been hired at the University of Washington (UW) and a comparable appointment has been made at University of Arizona (UA). To support these key administrators, a part time fiscal specialist and administrative assistant have been added. The Administrative Core, consisting of the above individuals, together with the Executive Committee, has implemented the key communication, statistical information gathering and analysis, and reporting functions. This administrative structure has also demonstrated that it can respond effectively to unanticipated challenges including the anticipated move of four Center participants from UA to Georgia Institute of Technology (GaTech) and challenges of formalizing industrial affiliations associated with intellectual property issues in the current economic climate. Each potential problem has been

turned into an opportunity and the capability of the Center to meet its vision has been enhanced as a consequence.

We will shortly review each of the Center goals stated in the strategic plan and indicate progress toward achieving those goals; however, we would first illustrate that this Center is indeed already successful in achieving highly integrated, interdisciplinary, multi-institutional research and education that is having national impact. As an example we note that the **Theory Thrust (TT)** has implemented quantum and statistical mechanical methods that have led to new paradigms for the design of electro-optic chromophores and their incorporation into nanoscopic material lattices of acentric (ferroelectric) order. Researchers in the **Electro-Optic and All-Optical Materials Thrust (EOAOT)** have used this theoretical guidance to prepare new materials exhibiting electro-optic coefficients of greater than 100 pm/V at all telecommunication wavelengths (a critical step toward meeting five year Center goals in this thrust). New microwave synthesis techniques have been developed that not only enhance reaction yields but also permit isolation of key intermediates associated with the implementation of theoretically suggested paradigms. Other researchers in the EOAOT have implemented new device concepts including all organic ring microresonator devices (motivating support by Intel Corporation of $75K/year), organic/silicon microresonator structures, organic/inorganic photonic bandgap device structures, superprism structures, and voltage controlled coupling structures. These major advances in theory, materials synthesis and processing, and device development involved researchers and students (including extended stay travel exchanges between universities) at UW, Caltech, USC, UA, and Norfolk State University from the disciplines of chemistry, physics, electrical engineering, and material science & engineering. This work has motivated several industrial and Federal laboratory research efforts, e.g., the optical gyro program at China Lake/Redstone Arsenal; and has motivated several new Federal initiatives, e.g., a multi-million dollar Boeing-DARPA effort on chipscale wavelength division multiplexing (CS-WDM) for mobile platforms and a new DARPA molecular photonics (MORPH) Focal Point initiative to be funded under the Chip-to-Chip Optical Interconnect BAA (this funding would involve interaction of STC participants with Lockheed Martin, Photonics Systems, Lumera, and Arizona Microsystems). STC members presented invited lectures in public forums including the Distinguished Lecture Series of the NSF, the Seattle Technology Alliance, and various Federal and industrially-sponsored workshops. The dramatic successes achieved through the unique interactions of this Center argue that the ten-year goals related to electro-optic materials and device development will almost certainly be achieved with significant economic consequence. The successes achieved to-date also illustrate the integrative nature of various research, education, knowledge transfer, and technology transfer activities. Indeed, the research on electro-optic materials correlate with other materials initiatives in the Center; for example, the new DARPA MORPH program focuses on both electro-optic and all-optical materials reflecting the advances that have occurred in both categories.

Below we list the Center goals as stated in our original strategic plan. Following the goals in **boldface** we briefly note the progress that has been made toward the realization of those goals.

- Developing, by rational design that exploits recent advances in quantum and statistical mechanics, transformative new electro-optic materials and devices with enhanced properties including bandwidth, drive voltage, optical loss, power consumption, and stability—**Center goals for material performance have been met or exceeded in every category, new device structures have been demonstrated, a seed project (at University of Maryland Baltimore County) on terahertz generation and detection has been very successful, materials and device concepts are being successfully transitioned to (and indeed are stimulating) Federal and industrial initiatives. Public awareness of this success is**

growing and we are attracting the interest of young people, including those from under-represented groups, in this area of research. The research is being featured in an upcoming special issue of the Journal of Polymer Science on photorefractive and EO materials.

- Enabling all-optical information processing by development of new third-order nonlinear optical materials that offer ultra-fast, large nonlinearities and low loss at telecommunication wavelengths—**Important improvements have been made in the magnitude of third order optical nonlinearities and progress toward five year goals is on track. Already materials have been identified and used to demonstrate a variety of applications ranging from pulse diagnostics for telecommunication to image reconstruction. Our advances have been recognized as critical by DARPA and new DARPA funding is being awarded for our researchers at UW and GaTech. The collaboration between researchers at UW/CalTech/GaTech on incorporating luminescent and third-order materials into optical fibers (Ann Mescher) and photonic bandgap devices (Alex Scherer) may represent a breakthrough relevant not only to information processing but to sensing. These achievements are of interest to Boeing and other companies. A start-up company has been launched by seed project collaborator Professor Charles Spangler of Montana State University.**
- Implementing new infrared light sources, amplifiers, and detectors based on organic and hybrid electroluminescent materials that can be readily integrated into opto-chips—**Progress is on schedule but this was viewed as an objective with anticipated impact occurring in the longer term. A strong interaction has been established between Professor Heeger (UCSB) and researchers at UW and UA with material advances being transitioned to DuPont Displays. Dendritic quinacrione derivatives for organic light emitting diodes and lasers have been synthesized and incorporated into displays. Materials are being incorporated into plastic optical fibers for optically pumped lasers by Ann Mescher and into powdered thin-film AC electroluminescent devices by Durel Corporation.**
- Integrating, seamlessly, materials and devices from the nanoscale to the microscale using self assembly, two-photon photolithography, and reactive ion etching for the low cost production of dense 3D optical and electro-optical circuitry—**Exceptional progress (work by William Steier, Joseph Perry, Axel Scherer, and Amnon Yariv) has been made in a variety of projects in this area. Three dimensional micro-ring resonator WDM transmitter/receiver systems have been fabricated. Both single and double ring resonators have been fabricated and exceptional performance parameters (free spectral range, voltage sensitivity product, finesse) have been demonstrated. A start-up company, Focal Point Microsystems, has been launched to exploit two-photon photolithography.**
- Exploiting photonic bandgap lattices and control of coupling to microresonators to enhance both second (electro-optic) and third-order nonlinear optical device performance—**Exceptional progress (work by Axel Scherer, Younan Xia, William Steier, and Amnon Yariv) has been achieved in theoretically and experimentally exploring microresonator, superprism, and photon bandgap structures. Both all polymer and organic/inorganic (silicon) hybrid device structures have been investigated incorporating both second (electro-optic) and third-order all-optical nonlinear optical materials. A DARPA/Boeing funded exploitation of these advances has been launched and collaborations with Northwestern and Cornell Universities have been initiated. Incorporation of third-order and luminescent materials from UW and UA into Caltech fabricated devices suggest the potential for a new generation of sensors. A start-up company, Luxtera, has been launched to exploit this technology.**

- Producing organic electronic materials and devices that will be processed into low cost circuits—**This is a longer-term objective and important progress has been made in the area of charge transport (one of the benchmarks of STC progress in this and related transport dependent material and device development efforts). For example, a room temperature electron mobility of 10^{-3} cm^2/V has been measured by time of flight experiments in self-assembled columnar discotic liquid crystals based on oxadiazoles (*Langmuir*, in press).**
- Creating cross-disciplinary curricula and educational resource materials that are directly tied to the research function and expertise of this Center and evaluating their impact—**Such educational material development is on track. A web based educational module on refraction is nearing completion in terms of the projected preliminary development phase and will be piloted early this summer. Educational materials have been developed and implemented into a variety of courses at the participating universities, e.g., Chem 560 at UW, and Chem 535 at UA. In addition an ethics handbook for the Center is being created to supplement ethics training courses.**
- Recruiting and tracking, proactively, under-represented minorities and women, into the Center, through seminar programs, internships, fellowships, strategic interactions with the Alliance for Nonlinear Optics, Northern Arizona U., Norfolk State University, and Cal State U. Los Angeles—**This effort is on track. Funding from the American Chemical Society for a Workshop on the Chemistry of Information Technology has been secured. The planning of this workshop (scheduled for June 18-25, 2003) has been completed. In addition, a symposium will be held in June as well. The proceedings from this workshop/conference will be published as a special issue of the *Journal of Physical Chemistry*. Seminars have been presented at designated minority institutions such as Norfolk State University and Florida International University and student participation has been secured in Center workshops and other research/education experiences. Extensive outreach to the K-graduate under-represented minority communities has been initiated coordinating with existing community, state, and Federal programs and institutions.**
- Enabling commercialization of new technology developed within the center by licensing to industry, by tracking developed technology, and by fostering the creation of new spin-off companies—**Three new start-up companies (Luxtera, Focal Point Microsystems, and TPA Technologies) have been launched and interaction with a number of established companies have been initiated. Considerable attention has been given to define improved paradigms for enhanced knowledge and technology transfer. Significant progress has been made despite current economic difficulties and the research of this Center is clearly inspiring new initiatives in Federal and State governments and in American industry.**

No significant changes in plans have been made although adjustments have been made due to external events affecting the Center. These include the anticipated movement of four core faculty (Marder, Perry, Brédas, Kippelen) from UA to GaTech. A subaward will be made to GaTech following completion of negotiations. While negotiations are not yet complete, it is clear that the performance of the Center will be enhanced by this modification and that all matching and intellectual property agreements will be maintained. GaTech's historical national leadership role in the training of minority students will ensure that diversity in the Center will be enhanced. The diversity of participating faculty has also been enhanced by the addition of Michal Lipson (Assistant Professor of Electrical Engineering at Cornell). Michal brings important new material and device concepts to the STC, promotes interaction with the Cornell Nanofabrication Facility, and promotes coordination with DARPA funded technology development.

Delayed funding, evolving NSF management requirements, and new opportunities for the Center have necessitated adjustments. The Center has lost one senior participant (Professor Kalonji who has withdrawn from the STC to focus on other activities) and added Galen Stucky (UCSB) to its team. These changes demonstrate that the Center is able to adapt to ever changing situations to optimize implementation of Center goals. Implementation of an industrial affiliates program is a work in progress. Implications for intellectual property had to be carefully considered at some length and in consultation with the Strategic Advisory Board of the Center. The current economic climate is dramatically impacting corporate decision making processes. Nevertheless, important knowledge and technology transfer is being implemented as is ethics training.

A formal meeting of the Strategic (external) Advisory Board, as well as several informal meetings of working groups of that Board, has been held. The Strategic Advisory Board is fulfilling its role in providing input related to all aspects of the Center and is facilitating contact with important components of the broader community (industry, educational organizations, state government, charitable foundations, and community groups). A second meeting of the SAB is planned to coincide with the June workshop.

From the administrative side, all key administrative positions have been filled after national searches where attention was paid to equal opportunity employment. The Center website has been launched for information dissemination and database management. Formal policies and responsibilities have been defined. Critical training activities have been initiated.