CENTER FOR ADVANCED STUDIES IN

PHOTONICS RESEARCH

(CASPR)

Second Annual Report

May 31, 2004

Covering Period June 1, 2003 to May 31, 2004

BY

UNIVERSITY OF MARYLAND, BALTIMORE COUNTY

UNDER

GRANT NUMBER NAG 5-12227

FROM THE

NASA GODDARD SPACE FLIGHT CENTER

CONTENTS PAGE

1. PREFACE

The University of Maryland, Baltimore County (UMBC) is pleased to submit this Second Annual Report of the Center for Advanced Studies in Photonics Research (CASPR) to the NASA Goddard Space Flight Center.

CASPR is operated at UMBC through a NASA grant which was initiated in June, 2002. Photonics research is being conducted in diverse disciplines covering subjects in Quantum Optics, Sensors, Lasers and Detectors, Very High Capacity Optical Fiber Communication, Nanotechnology, and Biophotonics in a collaborative effort to support the needs of Government, Industry, and Science. Projects are decentralized and are conducted within appropriate UMBC departments and laboratories. The staff is currently composed of 20 professors and post-doctoral scientists, plus a similar number of graduate students in the UMBC departments of Physics, Computer Science and Electrical Engineering, Mathematics and Statistics, and Chemical and Biochemical Engineering. The Director has a dual appointment, serving also as professor in both the Department of Physics and the Department of Computer Science and Electrical Engineering.
.
In state-of-the art fabrication laboratories, clean-rooms, and test facilities, new opto-electronic devices are being created, such as: high power, high-efficiency reliable semiconductor lasers for Earth Science lidar space missions; sensitive tunable narrow-band infrared radiation detectors using quantum-well structures; terahertz radiation generators and detectors suitable for molecular spectroscopy, environmental sensing, and homeland defense; and optical switches, modulators, splitters, and coupling devices for high rate long haul fiber communications. A new laboratory will study properties of ultrashort light pulses and their interactions with materials and nanostructures. In the fundamental physics of quantum-entangled photons and their exciting applications to ultra-precision remote clock synchronization, position tracking and remote spectroscopy, CASPR has been the leader in demonstrating its potential for valuable benefits to NASA, civilian, and military space and terrestrial programs. CASPR has unique capabilities in optical communication theory and outstanding laboratory facilities with connectivity to local and global optical fiber networks.

In the past year, CASPR was strengthened through the appointment, as Director, of Dr. Anthony M. Johnson (see CV in section 4) who brings a great wealth of expertise in photonics and professional reputation as scientist, teacher, and leader. His particular background in ultrafast photophysics and nonlinear optical properties of bulk, nanoclustered, and quantum well semiconductor structures, ultrashort pulse propagation in fibers and high-speed lightwave systems presents NASA with an opportunity to add valuable new elements to CASPR's program of research. These are dynamic areas of exciting new scientific discoveries and publications, which also interface closely with NASA's growing interests in such technologies as biophotonics and nanotechnologies. During this reporting period, the grant supported development of a new facility required by Dr. Johnson, his colleagues, and students, that will place CASPR in the forefront of academic research in ultrafast optics and optoelectronics. We will collaborate with Goddard in applying the results of that research to their programs.

CASPR will serve not only as a focal point for world class photonics research, but will also make use of the fact that photonics is a wonderful "visual" medium to attract young minds into science and engineering. One of the critical functions of the new Ultrafast Optics & Optoelectronics Lab will be in training the next generation of photonics experts, with a special emphasis on attracting underrepresented minorities and women. One of Dr. Johnson's goals is to extend the highly successful Graduate Meyerhoff Program in the Biomedical Sciences into the Physical Sciences & Engineering through the photonics efforts of CASPR and the cornerstone of this effort would be the Ultrafast Optics & Optoelectronics Lab.

For the initial research program, in June 2002, eight projects had been chosen, spanning subjects in Optical Communications, Optical Remote Sensing, and Quantum Optics. NASA/Goddard engineers and photonics scientists were invited to serve on CASPR program guidance and review committees, to insure maximum applicability of the research results to GSFC missions. During the second year of the NASA grant, funds were applied primarily to development of the new High Speed Optoelectronics Laboratory. However, research projects initiated under the first year of CASPR support also continued, for the most part, through the second year, with funding, as required, from other sources. In the third year we expect to resume funding for those and other projects through a collaborative selection process with scientists, engineers, and managers at NASA Goddard.

A meeting was held with Goddard technology managers on March 18, 2004 to discuss areas of future collaborative projects. As a result, small targeted working group meetings will be scheduled to develop plans for projects that apply CASPR's unique research expertise to NASA requirements for new technologies. Subjects which were identified for discussion at follow-on meetings, include

- Tunable, narrow-band infrared detectors using quantum-well structures. To develop a voltage-tunable, narrow-band, near-infrared detector to address needs of NASA programs that require 0.9 micron to 2.2 micron detectors, which would be tunable over 10 nm. They might have possible application, for instance, in wind velocity lidar.
- Application of CASPR's processing facility for optoelectronic devices, and nano-fabrication
- Electro-optic polymer THz devices, spectroscopy, and molecular modeling**.** Development of efficient, wideband THz devices based on electro-optic polymer composites would be important for NASA's programs to sense large biomolecules and chemical species, e.g. for analysis of vegetation, pollution, water quality and trace gases.
- Remote time-synchronization and precision tracking using quantum-entangled photons. This breakthrough new technology may permit femtosecond precision synchronization and precise location of distant telescopes for astronomical interferometry, gravity studies, or navigation satellites.
- Remote spectroscopy via entangled photons. This would permit spectroscopy in distant locations by means of a simple remote *in situ* detector and communication link.
- High-speed all-optical networks. CASPR has outstanding faculty expertise and laboratory capability to explore very high capacity long-distance data transmission in a variety of fiber optic environments. This may address NASA's use of all-optical networks for rapid and high volume communications to ship massive quantities of data efficiently over fiber.

The new CASPR laboratory has the capability to demonstrate and test communication over a 500 km fiber, 250 channel multi-wavelength system, > 10 Gb/s per channel, and connectivity to local and national fiber networks.

- o Nanotechnology. The new ultrahigh speed optics lab will give CASPR the ability to study nonlinear optical properties of nanodevices such as single-wall carbon nanotubes. The new nanoscale fabrication facility will permit study of semiconductor quantum wells, and quantum dots.
- o Biophotonics. We will be collaborating with the Center for Fluorescence Spectroscopy (Maryland Biotechnology Institute) in photonic sensing of biological molecules.

In these and other subjects, CASPR will continue to conduct research and to collaborate with Goddard researchers to develop joint projects.

In this document, we shall report on status of the new Ultrafast Optics & Optoelectronics Research and Teaching Facility, as well as on project activities and accomplishments related to the initial CASPR projects during the reporting period. Some special highlights of this period's report include:

- Access to the optical fiber line running down the I-95 corridor, for research related to very long distance High Speed All-Optical networks.
- Acquisition, as a gift from Corvis Corporation, of an extensive fiber-optic test bed with world-class research capabilities
- A new technique was demonstrated for obtaining remote "ghost images" using ordinary thermal radiation sources such as the sun or stars, which may do away with the requirement to generate entangled photons

During this second year, 9 papers were published in peer-reviewed journals, based upon results from CASPR-related research, and 5 others have been submitted but not yet published. In addition, 56 presentations were delivered at scientific and engineering society meetings and appear in their proceedings. Publication lists are included with the reports on each project.

2. PROJECT STATUS AND ACCOMPLISHMENTS

2.1 Ultrafast Optics & Optoelectronics Research & Teaching Facility

Personnel: Anthony Johnson, Ph.D., PI; Elaine Lalanne, Ph.D.

Description and Status:

The Ultrafast Optics and Optoelectronic Laboratory is equipped with a variety of state of the art laser systems, opto-electronic equipment and other basic optical and electro-optical components to investigate the ultrafast photophysics and nonlinear optical properties. The various systems under study are bulk nanostructured and quantum well semiconductor structures, ultrashort pulses propagation in fibers and waveguides and high-speed lightwave systems. The laboratory currently has picosecond laser systems. The picosecond system consists of two Time-Bandwidth SESAMs (semiconductor saturable absorber mirrors) passively modelocked Nd:Vanadate lasers at 1064 nm (8W) and 1342 nm (4 W). The wavelength range can be extended by frequency doubling to 532 and 671 nm respectively. Both lasers operate at a high repetition rate of 76 MHz and short pulse duration of 10 ps. They can be frequency doubled to 532 and 671 nm respectively.

We are in the process of acquiring a state-of-the-art high peak power femtosecond laser system manufactured by Coherent. The ultrafast cw-modelocked Ti:S Oscillator/Regenerative Amplifier/Optical Parametric Amplifier system is cw-pumped with repetition rate capability from single-shot to 300 kHz from the regenerative and optical parametric amplifiers. This system can produce ~ 120 femtosecond pulses across a continuous spectrum with wavelengths from 350 nm to 2.5 μm. The Ti:sapphire oscillator's configuration can be conveniently changed from femtosecond to picosecond (τ_p ~ 2 ps) and vice-versa. We can obtain pulses of up to 3 μJ peak power, pulse width of 160 fs with a 250 KHz repetition rate with the regenerative amplifier.

We have diagnostic tools, such as optical spectrum analyzer, sampling and digital oscilloscopes. We are in the process of acquiring a multi-channel optical spectrometer that will be used to acquire entire transient absorption spectra in response to broadband radiation from ultrashort pulses. This system will be used as a standard probe of ultrafast electronic and vibrational processes in semiconductor materials. We also have a variety of photo-detectors, lock-in amplifiers, miscellaneous optics and high precision motorized translational stages for measurement purposes.

The scheduled completion for the lab is now the beginning of September 2004. The lasers and other equipment will be delivered also in September. The lab should be operational in late September/early October.

2.2 High Speed All-Optical Networks

Personnel: Gary M. Carter, Ph.D., Ray Chen, Ph.D.
Hai Xu, Graduate Research Assistant

Objectives: To demonstrate the feasibility of 10 Gb/s data transmission in a variety of fiber optic environments in order to avoid the high degree of "tuning" operations required for maximizing performance, through a "cross-platform" optical networking approach

Status:

During the last year we have concentrated on accurate polarization measurements to quantify the system degradation due to polarization-dependent loss and polarization mode dispersion. We have developed measurement techniques for our recirculating loop that allow the accurate determination of differential group delay (DGD) that is due to polarization mode dispersion. By proper polarization scrambling in the loop we have measured the distribution of DGD and demonstrated that our measured results emulate a straight-line system. We have recently shown with these new techniques that drift in the fiber polarization parameters significantly affects the distribution especially in the tails of the distribution corresponding to high DGD values. We have developed a model for this drift, and, for long time averages, have obtained excellent agreement with the experimental data.

UMBC has obtained access, from the Maryland Department of Transportation, to the optical fiber line running down the I-95 corridor, for research related to this project. This new link will enable us to connect directly to NASA and other government agencies to carry out sophisticated network experiments. We are in the process of planning these experiments. We have also obtained as a gift from Corvis Corporation an extensive fiber-optic test bed that will be part of these experiments.

Equipment acquisition:

During this reporting period the laboratory capability was enhanced through donation of an all-Raman amplified 500 km transmission test bed. It includes 250 channels for testing high channel count WDM transmission. This high performance system will be linked to our connection to other optical networks provided by the newly acquired link down the I-95 corridor.

Publications:

A. Publications that have appeared in refereed journals during the reporting period

"Measurement of Distributions of Differential Group Delay in a Recirculating Loop With and Without Loop-Synchronous Scrambling", Hai Xu, Hua Jiao, Li Yan, and Gary M. Carter, IEEE Photonics Technology Letters Vol. 16, pp. 1691-1693 (2004).

"Quantitative Experimental Study of Intrachannel Nonlinear Timing Jitter in a 10-Gb/s Terrestrial WDM Return-To-Zero System", Hai Xu, John Zweck, Li Yan, Curtis

R. Menyuk, and Gary M. Carter, IEEE Photonics Technology Letters Vol. 16, pp. 314-316 (2004).

B. Presented at professional conferences

"Timing Jitter Due to Intra-Channel Nonlinearities in an Installed Fiber Optic Network," A. S. Lenihan, G. E. Tudury, G. M. Carter, O. V. Sinkin, B. Marks, C. R. Menyuk, R. J. Runser, A. Goldman, and T. Lehman, CLEO 2004, San Francisco, CA, May 16-21, 2004, paper CThG3.

"Characterization of pattern dependent receivers", Gastón E. Tudury, Anthony S. Lenihan, Gary M. Carter, CLEO 2004, San Francisco, CA, May 16-21, 2004, paper CTuN3.

"Optimizing the input scrambling rate in a recirculating loop with EDFAs" Jonathan Hu, Yu Sun, Brian S. Marks, Li Yan, Gary M. Carter, and Curtis R. Menyuk, CLEO 2004, San Francisco, CA, May 16-21, 2004, paper CFN7.

"A comparison of measurement techniques for differential group delay in a long-haul optical system," H. Xu, B. S. Marks, L. Yan, C. R. Menyuk, and G. M. Carter, OFC 2004, Los Angeles, CA, February 22-27, 2004, paper FI4.

"Measurement of differential group delay in a recirculating loop," H. Xu, H. Jiao, L. Yan, and G. M. Carter, OFC 2004, Los Angeles, CA, February 22-27, 2004, paper FA6.

"Performance of a Mostly Raman-Amplified Dispersion-Managed Fiber Loop with Polarization Scrambling," A. S. Lenihan, Yu Sun, G. M. Carter, and C. R. Menyuk, OFC 2004, Los Angeles, CA, February 22-27, 2004, paper WE7.

"Effects of Polarization Dependent Loss and Polarization Mode Dispersion in Recirculating Loops", Gary M. Carter, Hai Xu, Hua Jiao, Yu Sun, Brian Marks, and Li Yan, IEEE LEOS 2003 Annual Meeting, Tucson, AZ, Oct. 26-30, 2003, paper TuQ4 (Invited).

2.3 Processing Facility for Micro Electro-Mechanical Systems (MEMS), Optoelectronic Devices, and Nano-Fabrications

Personnel: Fow-Sen Choa (PI), Ray Chen, Jim Plusquellic, Li Yan, CSEE Department
Govind Rao, Chemical Engineering Department
M. Anjanappa, Mechanical Engineering Department
Terry Worchesky and Bob Reno, Physics Department

Objectives: In this project we plan to expand and improve a research facility for MEMS, optoelectronic and nano-device fabrication, in order to grow the center's programs in the area of optoelectronics and bio-photonics.

Status:
A reactive-ion-etching tool has been purchased from auction. The MEMS laboratory, which was based on an old MOCVD laboratory, has been renovated. Two old MOCVD systems were removed and the middle wall was torn down. A new floor was built and the equipment has been shipped in. Two pump systems have been rebuilt and the whole system is ready for installation. However, completion of the installation and initiation of operations is awaiting a final funding increment.

CASPR is now engaged in a Phase A NASA STTR project to develop a reliable high power and high efficiency diode laser array pump for spaceborne lidar applications. We expect that the Phase B effort will be approved and will lead to more effective and innovative future lidar and altimetry missions for Earth and Planetary Science missions.

Publications during the reporting period:

Refereed Journal papers:

1.Xiaobo Xie, Jacob B. Khurgin, and Fow-San Choa, "Suppression of Spurious Intensity Modulation in Frequency-Modulated Semiconductor Lasers", IEEE Journal of Selected Topics in Quantum Electronics, vol. 9, pp. 1294-1299, Sep./Oct. 2003.

2. Jie Lin, Junping Zhang, and Fow-Sen Choa, X. Zhao, J Khurgin, "A Low-Crosstalk Semiconductor Optical Amplifier", IEEE Photonic Technol. Lett. vol. 16, pp. 392-394, 2004.

3. G. Ru, X. Yu, Z. Chen, J Zhang, J Lin, F. S. Choa, "Material Quality Improvements of Ultra-Broadband Gain Materials Grown by Selective-Area-Growth Techniques," Submitted to Journal of Crystal Growth.

4. Xiaobo Xie, Jacob Khurgin, Fow-Sen Choa, Xiuqin Yu, Jason Cai, Jingzhou Yan, Xiaoming Ji, Yonglin Gu, Yun Fang, Yang Sun, and Zhibao Chen, "A model for optimization of the performance of frequency-modulated DFB semiconductor laser," Submitted to IEEE JQE

Conference Presentations:

1. X. Xie, J Khurgin, J. kang, F. S. Choa, Linearized electro-optical intensity modulator", Conference on Lasers and Electro-Optics and International Quantum Electronics Proceeding, paper CTuJ2, Baltimore, MD, 2003.

2. Y. Gu, J. Yan, R. Madhan, and F. S. Choa, G. V. Jagannathan, S. Trivedi, and J. Feng, "High-efficiency InP Based Multi-junction Solar Cells", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

3. Z. Chen, J. Cai, X. Ji, Y. Sun, J. Lin, X. Zhao, X. Yu, J. Zhang, F. -S. Choa, "On the Growth and Fabrication of an Integrated DFB Laser and EA Modulator", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

4. X. Zhao and F. -S. Choa, "The Effect of Contact Resistance in a Broad Band Semiconductor Optical Amplifier using SAG Techniques", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

5. Jingzhou Yan, Guoyun Ru, Fow-Sen Choa, "Study of N-Type Si Delta Doping on InP and $In_{0.53}Ga_{0.47}As$", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

6. Jingzhou Yan, G. Ru, Y. Gong, F. S. Choa, "Study of P-Type Carbon Doping on $In_{0.53}Ga_{0.47}As$, $In_{0.52}Al_{0.2}Ga_{0.28}As$ and $In_{0.52}Al_{0.48}As$", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

7. G. Ru, J. Yan, Z. Chen, F. -S. Choa, T. Worchesky, "$In_{1-x}Ga_xAs_yP_{1-y}$ nipi Structure and Its Application to Semiconductor Optical Amplifiers", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

8. G. Ru, Z. Chen, F. -S. Choa, "Γ-X band mixing in GaAs/AlAs superlattice", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

9. G. Ru, X. Yu, Z. Chen, F. -S. Choa, "Study of Wavelength Shift in Quantum Well Structure by MOCVD Selective Area Growth", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

10. G. Ru, X. Yu, Z. Chen, F. -S. Choa, "Study of Strain Effect in MOCVD Selective Area Growth", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

11. Y. Sun, Z. Chen, F. -S. Choa, "A New Open-Hole Buried Heterostructure Process for the Fabrication of Photonic Integrated Circuits", International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

12. Y. Gu and F.S. Choa “High Gain, High Speed, Low Noise Single-Avalanche-Stage APDs”, International Conference on Applications of Photonic Technology, SPIE Photonic North, Montreal, Quebec, Canada, June 2-5, 2003.

13. J. Cai, Z. Chen, X. Ji, Y. Sun, J. Lin, X. Zhao, X. Yu, J. Zhang, J. Yan, M. Raj, F. -S. Choa, “Fast Frequency Tuning Characteristics of a FM laser based on the Integrated MQW DFB Laser /EA Modulator Device”, IEEE LEOS Annual Meeting, Paper WT3, Tucson, AZ, Oct. 26-30, 2003.

14. G. Ru, X. Yu, Y. Sun, Z. Chen, F. -S. Choa, “Wavelength shift and strain in quantum well structure by MOCVD selective area growth”, IEEE LEOS Annual Meeting, Paper WAA5, Tucson, AZ, Oct. 26-30, 2003.

15. Y. Sun, X. M. Ji, Z. Chen, J. Z. Yan, J. X. Cai, M. Raj, F. -S. Choa, “A New Open-Hole Buried Heterostructure Process for the Fabrication of Photonic Integrated Circuits”, IEEE LEOS Annual Meeting, Paper THCC5, Tucson, AZ, Oct. 26-30, 2003.

16. Y. Gu and F.S. Choa, “Low bias, Low Noise Single-Avalanche-Stage APDs”, IEEE LEOS Annual Meeting, Paper THZ6, Tucson, AZ, Oct. 26-30, 2003.

17. Y. Gu, J. Yan, R. Madhan, and F. S. Choa, G. V. Jagannathan, S. Trivedi, and J. Feng, “High-efficiency InP Based Four-junction Solar Cells“, IEEE LEOS Annual Meeting, Paper THR5, Tucson, AZ, Oct. 26-30, 2003.

18. G. Ru, X Yu, J. Yan, M. Raj, F. –S. Choa, J.B. Khurgin, “Spatially-indirect photo- and electro-luminescence in the 1.3μm range at room temperature,” Conference on Lasers and Electro-Optics and International Quantum Electronics Proceeding, San Francisco, CA, Paper CTHF2, 2004.

19. Xiangjun Zhao, Fow-Sen Choa, and Junping Zhang, “The Effect of Series Resistance on the Linearity and Cross-talk of an SAG based Broad Band Semiconductor Optical Amplifier,” Conference on Lasers and Electro-Optics and International Quantum Electronics Proceeding, San Francisco, CA, Paper CTuP17, 2004.

20. J. Khurgin, J Kang, F. S. Choa, M. Boroditsky, “Comparative analysis of the optical buffers based on coupled resonators lines and on media with electromagnetically induced transparency,” Conference on Lasers and Electro-Optics and International Quantum Electronics Proceeding, San Francisco, CA, Paper CWA14, 2004

2.4 Multisensor Coding for Robust Wireless Optical Communications

Personnel: Joseph Thomas, Ph.D.

Objectives:
Wireless optical transmission offers an attractive solution to the "last mile" connectivity problem, namely the task of connecting existing public fiber communication networks to local networks. It is also used in less conventional areas such as airplane-to-airplane and other aerospace communication environments. In essence it requires the transmission of laser emissions over free space from the transmitting modem to the receiving modem. In contrast with optical fiber links, free space (or atmospheric) optical links lack the almost loss-free guided propagation path that is typically associated with optical communications. Atmospheric turbulence causes fluctuations in the amplitude and phase of the received signal. Wireless optical channels therefore experience the phenomenon of fading as in frequency-flat fading wireless RF channels. In addition, for high-bandwidth signals, i.e. narrow optical pulses, discrete multipath reception is observed, similar to the case of frequency-selective fading RF channels, resulting in the distortion of the transmitted pulse shapes during propagation. *This project sought to develop signaling schemes for channels with multiple-aperture transmitters and receivers to optimally exploit the potentially available diversity and multiplexing gains in such multichannel wireless optical communications.*

Accomplishments:
The primary objectives of this research have been achieved. Block-orthogonal schemes were proposed for slowly fading environments and an attractive iterative decoding receiver was proposed and studied. Suitable candidates for the inner code in the concatenation that is necessary in such multivariate signaling schemes were examined. Most importantly, an efficient layered multivariate code was proposed and an efficient iterative multivariate decoding scheme was developed under which the optimality of the proposed code in respect of the diversity-rate tradeoff was established. Further work in this area by the principal investigator focuses on the design of appropriate channel encoding of the parent stream (prior to spatial multiplexing) and in particular on lattice codes.

Related Journal Publication:

- J. Thomas, "Iterative detection in block-orthogonal and spatially-multiplexed multisensor signaling schemes," to appear in *IEEE Transactions on Signal Processing* (in press, 2004).

2.5 Signal Processing for Photonics

Principal Investigator: Tulay Adali, Associate Professor, Dept. of CSEE, UMBC, Phone: (410) 455-3521, Email: adali@umbc.edu
Co-Investigator: Curtis R. Menyuk, Professor, Dept. of CSEE, UMBC, Phone: (410) 455-3501, Email: menyuk@umbc.edu
Research Assistants: Weir Wang and Wenze Xi

Research Objectives:
To approach the ultimate transmission capacity of fiber-optic networks with substantial reductions in transport costs, we adopt a fully-synergistic approach and develop electrical domain solutions based on equalization and coding for the next generation optical communication systems by fully taking the properties of the optical medium into account.

Status and Accomplishments:
Electronic domain (post-detection), techniques offer flexible and effective means for mitigating a wide array of optical domain impairments, and with the increasing availability of voltage-tunable integrated circuits for high speed operation, they promise practical cost-effective solutions since they can be seamlessly integrated within the receiver electronics. However, the current activity in the application of signal processing methods to optical communications is limited to ``off-the-shelf'' techniques that do not take into account characteristics of the optical domain, thus unable to truly take advantage of the possibilities that signal processing offer.

We demonstrated the effectiveness of our integrated approach by developing a new class of electronic mitigation techniques for optical communications. Because these solutions take into account the physics of the transmission medium, they are able not only to fully exploit the flexibility the electrical domain offers but also offer practical solutions that can be implemented within current technology. We showed the effectiveness of these solutions by simulations that take into account most major impairments in the optical communications systems and for realistic systems. Our current work focuses on the development of new equalizer structures that use error criteria based on higher order statistics, and optimum symbol-by-symbol and sequence detectors. The next stage will be the experimental verification of the operation of the solutions we develop.

We believe that solutions that fully integrate the strengths of the optical and electrical domains are the key to delivering on the promise of the optical revolution: the supply of ultra-high data rates to users at affordable prices. Such systems will ultimately make the transfer of large data sets commonplace and revolutionize how people communicate and interact.

Publications during reporting period:

Refereed Journal articles:

A. O. Lima, I. T. Lima, Jr., C. R. Menyuk, and T. Adali, ``Comparison of power penalties due to first- and all-order PMD distortions in optical fiber transmission systems,'' Optics Letts. vol. 28, no. 5, pp. 310--312, 2003.

Y. Cai, J.M. Morris, T. Adali, and C.R. Menyuk, ``On Turbo code decoder performance in optical fiber communication systems with dominating ASE noise", Journal of Lightwave Tech., vol. 21, no. 3, pp. 727--734, 2003.

Conference Proceedings:

W. Wang, O. V. Sinkin, T. Adali, J. Zweck and C. R. Menyuk,
``Prior-based Line-coding for WDM RZ Systems," in Proc. Conference on Lasers and Electro Optics (CLEO), San Francisco, CA, May 2004.

W. Xi, T. Adali, A. Lima, W. Wang, J. Zweck, and C. Menyuk,
``Electrical estimation of polarization mode dispersion parameters for compensation,"
in Tech. Digest Optical Fiber Communications (OFC) Conf., Anaheim, CA, March 2003, TuO5.

C.R. Menyuk, "Modeling Noise in Optical Fiber Communication Systems," The Third IMACS International Conference on Nonlinear Evolution Equations and Wave Phenomena: Computation and Theory, Athens, GA (April 7–10, 2003).

C.R. Menyuk, "PMD Modeling: Can It Help Us?" European Conference on Optical Communications, Rimini, Italy (Sept. 21–25, 2003)

C.R. Menyuk, "Accurate Calculation of the Bit Error Ratios in Optical Fiber Communications Systems," European Conference on Optical Communications, Rimini, Italy (Sept. 21-25, 2003), (tutorial).

C.R. Menyuk, "Accurate Calculation of the Bit Error Ratios in Optical Fiber Communications Systems," Conference on Lasers and Electro-Optics, Pacific Rim, Taipei, Taiwan (Dec. 15-19, 2003) (tutorial).

C.R. Menyuk, "Modeling Noise in Optical Fiber Communication Systems, Optical Fiber Communication Conference (Feb. 24-26, 2004) paper TuN5.

2.6 Terahertz and Holographic Technologies for Earth and Space Science Applications

Personnel: L. Michael Hayden, Ph.D., Principle Investigator

Objective: To develop and characterize efficient, wide-band emitter-detector pairs of electro-optic polymer composites useful for the generation and detection of THz radiation. New terahertz technologies, which are useful in NASA applications, will be explored.

Status: Research continued in this reporting period without funding from this NASA grant.

Publications in this reporting period:

Refereed Journal articles:

“New Materials for Optical Rectification and Electro-optic Sampling of Ultra-short Pulses in the THz Regime”. L. Michael Hayden, A. M. Sinyukov, M. R. Leahy, P. Lindahl, J. French, W. Herman, M. He, R. Twieg, J. Polymer Sci. B. Polymer Phys. 41, 2492-2500 (2003).

“Efficient electro-optic polymers for THz applications”, A. M. Sinyukov and L. Michael Hayden, J. Phys. Chem. B 108, 8515-8522 (2004).

“Resonance enhanced THz generation in electro-optic polymers near the absorption maximum,” A. Sinyukov, M. R. Leahy, L. Michael Hayden, J. Luo, A. K-Y. Jen, and L. R. Dalton, submitted to Appl. Phys. Lett. (2004).

Conference presentations:

“Progress in electro-optic polymers for broadband THz systems,” A. M. Sinyukov and L. Michael Hayden, Conf. on Lasers and Electro-Optics (Baltimore, MD, June 2003).

INVITED “Electro-optic polymers for THz science and applications”, L. Michael Hayden, Alvin Kwiram Symp. on Opt. Elect., Mag., Prop. of Organic and Hybrid Mater., (Seattle, WA, June 23-25, 2003).

“Electric field poling of nonlinear optical systems”, M. R. Leahy, J. A. French, and L. Michael Hayden, Accelrys World Symposium, (San Diego, CA March 2004).

“Electro-optic polymers for THz applications”, A. Sinyukov, M. R. Leahy, and L. Michael Hayden, Optics East, (Philadelphia, PA 2004).

“Atomistic molecular modeling of electric field poling of nonlinear optical polymers,” M. R. Leahy and L. Michael Hayden, ACS Annual Mtg. Organic Thin Films for Photonic Applications, (Philadelphia, PA, Aug. 22-26, 2004).

“Enhanced electro-optic coefficients using thin SiO2 charge barrier layers,” A. Hoffman and L. Michael Hayden, ACS Annual Mtg. Organic Thin Films for Photonic Applications, (Philadelphia, PA, Aug. 22-26, 2004).

“Efficient, wideband THz emission from thin electro-optic polymer films,” L. Michael Hayden, A. M. Sinyukov, M. R. Leahy, J. Luo, A. K-Y. Jen, L. R. Dalton, K. Liu, and X.C. Zhang, OSA Topical Mtg., Nonlinear Optics: Materials, Fundamentals, and Applications (Waikaloa, HA Aug 2-6, 2004).

2.7 Tunable, Near-Infrared Detector Based on Quantum-Well Excitons

Personnel: Terrance L. Worchesky, Ph.D., Principle Investigator
Chen Lu, Graduate Research Assistant

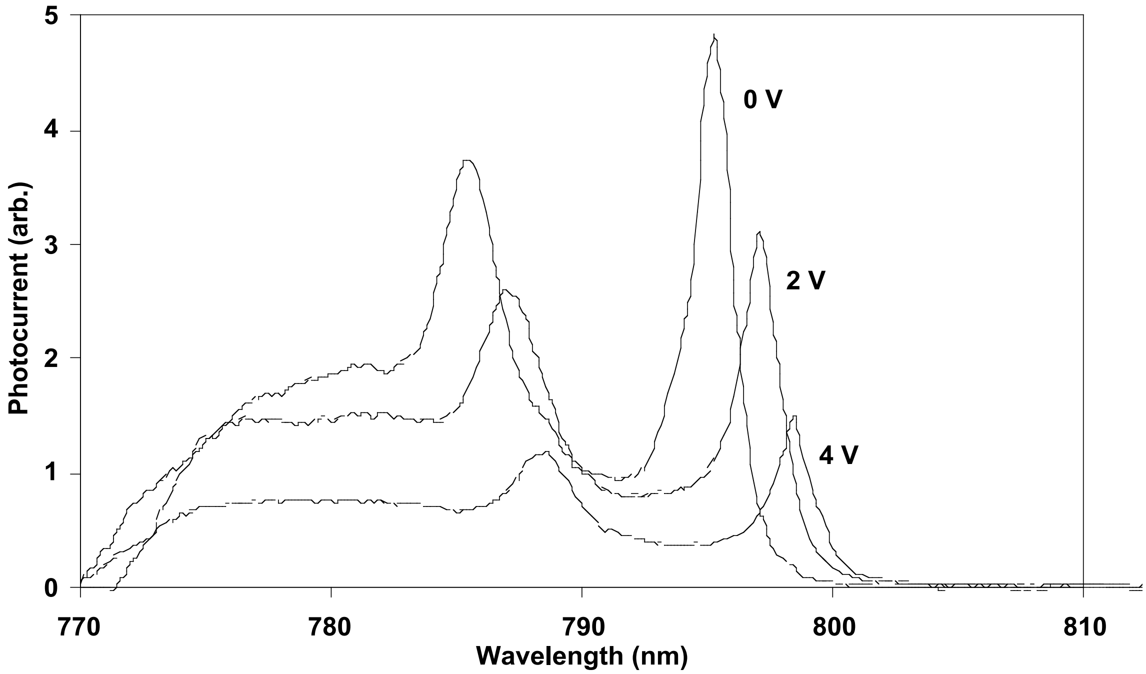
Objective: To demonstrate the feasibility of a voltage-tunable, narrow-band, near-infrared detector to address the needs of NASA LIDAR efforts. The long-term goals are a 0.1-nm bandwidth detection system with a voltage-tunable range of 10 nm, and the capability to develop other similar semiconductor detectors to meet NASA, DoD, and commercial requirements.

Summary of Recent Progress:

During this effort several quantum-well designs were examined for use in tunable detector structures. Measurements of these designs were used to further refine the quantum-well band structure models to shifts in the barrier heights caused by temperature effects.

Several prototype detectors were fabricated and the linewidth of their photoluminescence and photocurrent were measured at various temperatures. The GaAs/AlGaAs structures were designed to have an absorption peak at 795 nm. At a temperature of 50 K, the exciton-enhanced, quantum-well absorption has a linewidth of approximately 2 nm. Using the quantum-confined Stark effect, this absorption was wavelength shifted with a reverse-bias voltage. The peak of the absorption shifted at a rate of approximately 1 nm per volt to longer wavelengths. The absorption shifted linearly with applied bias throughout the range of 0 to 5 volts.

No publications have been submitted on this work during the reporting period. Results from this work are being used in a proposal on detectors for space applications to NASA under their Human and Robotic Technology BAA (Broad Area Announcement). Also, these results are being used in a proposal on intermixing of quantum-confined electrons for two-photon detection to ARO under their Multidisciplinary University Research Initiative in Quantum Coherence.



Photocurrent measured at 50 K on a 50-period quantum-well detector structure for three reverse-bias voltages. Exciton absorption features for both the heavy-hole and light-hole bands are present at this temperature.

2.8 Numerical Simulation and Analysis of Fiber Optic Compensators

Personnel: Dr. Susan Minkoff, PI, Dr. John Zweck, Dept. of Mathematics and Statistics

Objectives and Summary:

Data sent along fiber optic communication lines over long distances is degraded due to the combined effects of amplifier noise, chromatic dispersion, fiber nonlinearity, and polarization mode dispersion (PMD). In this project we focus on one of these effects, namely PMD. PMD is caused by the randomly varying birefringence (irregularities) in the fiber and results in a fast and a slow polarization state for light traveling through the fiber. Light launched down the fiber in these two states will travel with different speeds. This traveltime difference is called the differential group delay (DGD). DGD varies for different pieces of fiber, for signals launched at different frequencies, and for signals traveling through the fiber at different times of the day (due to temperature variations). Generally, light pulses will be launched in a combination of these two principal states (unknown *a priori*) and the pulses will therefore spread due to PMD. Data, which starts out on its travels as a pristine string of ones and zeros will eventually reach its destination with losses and distortions in signal power (amplitude) causing zeros to grow and ones to decrease. Recovering the correct bit string of ones and zeros from these distorted pulses can be tricky and may ultimately result in a corrupted message.

In order to overcome the distortion and pulse spreading caused by PMD, devices known as compensators can be used. Because the DGD of the transmission fiber varies randomly with time, we must continuously control the compensator using a feedback mechanism, which involves optimizing a cost functional. Two of the most interesting types of feedback mechanisms for compensation are the subharmonic method and the degree of polarization (DOP) ellipsoid method. In the subharmonic method, we attempt to increase the power of the electric signal at certain chosen frequencies. For the DOP ellipsoid method we feedback on the DGD, which is extracted from measurements of the output DOP of a signal which has been polarization scrambled at input. This work focuses on mathematical and computational modeling and analysis of fiber optic compensation.

Summary of Recent Progress:

To facilitate numerical modeling studies of PMD compensation, we have coupled the optical communications simulator (OCS) (developed by Zweck and his collaborators in Professor Curtis Menyuk's group) with two numerical optimization software packages --- the Hilbert Class Library (HCL) developed at Rice University, and the Design Analysis Kit for Optimization and Terascale Applications (DAKOTA) developed at Sandia National Laboratories. HCL provides local optimization routines, which generally use gradient information to approach the minimum of a cost functional. Our initial studies (see Zweck et al.) were performed using HCL. Local optimization methods are often a good place to start investigation, as they are very fast (when they work -- i.e., when a good starting guess is available, the objective function is smooth or one only needs to find a local optimum). This past summer (2003) we hooked DAKOTA into our fiber optics simulator. DAKOTA provides a complimentary set of non-gradient based, global optimization routines such as genetic algorithms and pattern search methods. Hybrid methods that exploit the best features of both global and local methods are also available in DAKOTA.

Much of our research effort in Fall 2002 and Spring 2003 involved comparison of compensator performance given different feedback control signals (eye opening penalty, DOP ellipsoid, subharmonic method, etc). We numerically determined the optimal setting of the polarization controller in the compensator using a single gradient-based optimization algorithm for all control signals (HCL). The aim of our current research is to examine the influence the particular optimization algorithm has on compensator performance. Although several authors have studied the effect that the control signal has on performance, there have been no studies that we are aware of on the effect that the numerical optimization algorithm has on the performance of the compensator.

Work in Summer and Fall of 2003 primarily focused on connecting the DAKOTA toolkit to OCS. A large suite of experiments were run using both quasi-Newton (local methods) and hybrid techniques. The engineering community is interested in assessing both what the global optimum is and whether local techniques might be ``good enough'' to get close to the global minimizer of the feedback cost functional. Hybrid methods are especially useful for such studies. The hybrid method we used consisted of a global (non-gradient based) pattern search technique used to locate a small neighborhood of the global minimum followed by a fast gradient-based technique (conjugate gradients) which zeroed in on the function optimum. In Summer of 2003 we primarily investigated the subharmonic and eye-opening feedback controllers using DAKOTA.

Implementation of the DOP ellipsoid controller in combined OCS/DAKOTA was completed in the Spring of 2004. Our current aim is to finalize the numerical results relating optimization algorithms to feedback controllers for fiber optic compensation. A journal article will be forth coming on this work. Our working hypothesis is that the optimization algorithm needs to be tailored to suit the particular control signal. For example, our experience suggests that the degree of polarization ellipsoid and subharmonic control signals generate very smooth objective functions, which can be optimized quickly using gradient-based methods. The eye opening feedback (a rougher function) may require a non-gradient based method.

Related Work:

Several collaborative research projects of the co-PI, Zweck, with the theoretical and experimental group of Menyuk and Carter are closely related to our research on the analysis of PMD compensators. First, in a series of papers with Ivan Lima we quantified how the performance of the receiver in a fiber optic communications system (with or without a PMD compensator) depends not only on the shape of the noise-free signal, the optical signal-to-noise ratio and the shapes of the receiver filters, but also on the degree of polarization of the noise and the relative polarization states of the signal and the noise. Second, with Yu Sun and Hai Xu, we studied how the performance of a recirculating fiber-optic loop system is affected by polarization effects. These studies gave additional validation for the receiver models developed with Lima. Finally, with A. and I. Lima, we have developed new importance sampling algorithms to more efficiently simulate rare events due to polarization effects in optical fiber communications systems.

Large Equipment Acquisition:

In Spring of 2004 CASPR money provided an improvement in our numerical simulation capabilities. Faster desktop and home machines were purchased for Minkoff as upgrades to her (four year old) computing environment. In addition, two new dual-node machines were added to Minkoff's existing parallel cluster. These four machines have allowed our simulation work to progress faster and will continue to be of use as we work to complete the optimization and engineering papers on feedback controllers. This work requires us to simulate ``low probability events" repeatedly. Even with the advances of importance sampling, Monte Carlo simulation of one-half a million different fiber realizations is to be expected. These simulations are independent and will be most efficiently run in parallel on the cluster. For smaller-sized simulations, serial runs (on the desktop machines) suffice. Once again, the speed and memory improvements of the new desktop machines will mean we can run far more simulations faster for our research even in serial mode.

Publications:

(Minkoff) ``Numerical Simulation and Analysis of Fiber Optic Compensators" at the Society for Industrial and Applied Math's Annual Meeting, June 16--20, 2003, Montreal, QC, Canada.

(Zweck) ``A Comparative Study of Feedback Controller Sensitivity to All Orders of PMD for a Fixed DGD Compensator" at the 2003 Optical Society of America, Optical Fiber Communications Meeting, March, 2003, Atlanta, GA.

RECEIVERS PAPERS:

J. Zweck, I.T. Lima, Jr., Y. Sun, A.O. Lima, C.R. Menyuk, and G.M. Carter, ``Modeling recievers in optical communication systems with polarization effects", *Optics and Photonics News*, November 2003, pp. 30--35

I.T. Lima, Jr., A.O. Lima, J. Zweck, and C.R. Menyuk, ``Performance characterization of chirped return-to-zero modulation format using an accurate receiver model", *Photonics Technology Letters*, **15**, (4), pp. 608--610, 2003

A. Karla, J. Zweck, and C.R. Menyuk, ``Comparison of bit-error ratios for receiver models with integrate-and-dump and realistic electrical filters using the Gaussian approximation", *Conference on Lasers and Electro-Optics*, San Fransisco, CA, 2004, *[accepted for publication]*

I.T. Lima Jr., A.O. Lima, J. Zweck, and C.R. Menyuk, ``An accurate formula for the *Q*-factor of a fiber transmission system with partially polarized noise", *Conference on Lasers and Electro-Optics 2003*, Baltimore, MD, paper CThJ2

H. Jiao, I.T. Lima Jr., A.O. Lima, Y. Sun, J. Zweck, L. Yan,
C.R. Menyuk, and G.M. Carter, ``Experimental validation of a realistic receiver model for systems with unpolarized noise", *Conference on Lasers and Electro-Optics 2003*, Baltimore, MD, paper CThJ1

I.T. Lima Jr., A.O. Lima, J. Zweck, and C.R. Menyuk, ``Computation of the *Q*-factor in optical fiber systems using an accurate receiver model", *Optical Fiber Communications 2003*, Atlanta, GA, paper MF81

LOOP PAPERS:

Y. Sun, A.O. Lima, I.T. Lima Jr., J. Zweck}, L. Yan, C.R. Menyuk, and G.M. Carter, ``Statistics of the system performance in a scrambled recirculating loop with PDL and PDG", *Photonics Technology Letters*, **15** (8), pp. 1067--1069, 2003

H. Xu, J. Wen, J. Zweck, L. Yan, C.R. Menyuk, and G.M. Carter, ``The effects of distributed PMD, PDL, and loop scrambling on BER distributions in a recirculating loop used to emulate a

long-haul terrestrial transmission'', *Optical Fiber Communications 2003*, Atlanta, GA, paper TuO2

Y. Sun, I.T. Lima Jr., A.O. Lima, H. Jiao, J. Zweck, L. Yan, C.R. Menyuk, and G.M. Carter ``Effects of partially polarized noise in a receiver'', *Optical Fiber Communications 2003*, Atlanta, GA, paper MF82

Y. Sun, A.O. Lima, I.T. Lima Jr., L. Yan, J. Zweck, C.R. Menyuk, and G.M. Carter, ``Accurate *Q*-factor distributions in optical transmission systems with polarization effects'', *Optical Fiber Communications 2003,* Atlanta, GA, paper ThJ4

IS PAPERS:

J. Zweck, I.T. Lima, Jr., R. Holzl-ohner, and C.R. Menyuk, ``New advances in modeling optical fiber communication systems'', *Integrated Photonics Research (Technical Digest)*, Vancouver, Canada, July 17--19, 2002

I.T. Lima, Jr., A.O. Lima, {\bf J. Zweck}, and C.R. Menyuk, ``Efficient computation of outage probabilities due to polarization effects in a WDM system using importance sampling'', *Photonics Technology Letters*, **15**, (1), pp. 45--47, 2003

A.O. Lima, I.T. Lima Jr., {\bf J. Zweck}, and C.R. Menyuk, ``Efficient computation of PMD-induced penalties using multicanonical Monte Carlo simulations'', *ECOC-IOOC 2003*, Rimini, Italy, paper 507

Zweck, J., Minkoff, S. Lima, A., Lima, I. and Menyuk, C., "A Comparative Study of Feedback Controller Sensitivity to All Orders of PMD for a Fixed DGD Compensator", *Optical Society of America, Optical Fiber Communications Meeting*, (Atlanta, GA), pp.590—591, 2003.

.

2.9 Synchronization of Distant Clocks Using Two-Photon Interferometry

Personnel: Morton H. Rubin, Ph.D., Co-Principle Investigator
Yanhua Shih, Ph.D., Co-Principle Investigator
Xuehua He, Faculty Research Assistant
Heyi Zhang, Faculty Research Assistant
Milena D'Angelo, Graduate Research Assistant

Objective: To apply well established two-photon interferometric techniques developed at UMBC to achieve distant clock synchronization with unprecedented pico-second accuracy for future NASA space applications. The project includes both theoretical and experimental studies:

Accomplishments: One-way clock synchronization and position location operations utilizing techniques employing entangled photons were demonstrated: the precision achieved was shown to agree with theoretical predictions. Measurements included sending one photon of an entangled pair to a detector kilometers from the other photon detector, via optical fiber. Plans were developed to build a compact apparatus with which engineering design parameters could be obtained for practical space implementation of this concept. Entangled photon technology has also been applied to cost-effective spectroscopic analysis of remote media, and to remote "ghost imaging". A new technique was demonstrated, for obtaining remote "ghost images" using ordinary thermal radiation sources such as the sun or stars, which may do away with the requirement to generate entangled photons.

Publications:

Published book Chapters:

"Entangled Photons", in IEEE Journal of Selected Topics in Quantum Electronics on Quantum Internet Technology (2003).

"Entangled Two-photon Source", in Reports on Progress in Physics, Institute of Physics Publishing, (2003).

"Quantum Imaging, Quantum Lithography and the Uncertainty Principle", in Special Issue of European Physics Journal D (2003).

Publications in Refereed Journals:

"Two-photon 'Ghost' Imaging with Thermal Light", (submitted to PRL); quant-ph/0408001, (A. Valencia, G. Scarcelli, M. D'Angelo and Y.H. Shih).

"Two-photon Interference of Thermal light", Valencia, M. D'Angelo, G. Scarcelli and Y.H. Shih, to be published in Phys. Rev. A (2004).

"Ulra-high Accuracy Nonlocal Timing and Positioning using Entangled Photon-pairs", Appl. Phys. Lett, Sept. Issue (2004); quant-ph/0407204, (G. Scarcelli, A.

Valencia and Y.H. Shih).
"Remote Spectral Measurement Using Entangled Photons", Appl. Phys. Lett, Vol. 83, 5560 (2003) (G. Scarcelli, A. Valencia, S.Gompers and Y.H. Shih).

"Experimental Entanglement Concentration and Universal Bell-State Synthesizer", Phys. Rev. A, Vol. 67, Rapid Comm., 010301(R) (2003) (Y.-H. Kim, M.V. Chekhova, S.P. Kulik, and Y.H. Shih).

3. *EDUCATIONAL PROGRAMS*

The new CASPR Ultrafast Optics & Optoelectronics Research & Teaching Facility will serve as an education focus for the entire CASPR effort at UMBC. Throughout his career at Bell Labs and NJIT, Dr. Johnson has demonstrated a strong commitment to leading edge photonics research and training undergraduate and graduate students – with a special emphasis on attracting underrepresented minorities and women into the scientific enterprise. CASPR and the new state-of-the-art laboratory is the ideal vehicle to continue this legacy in a nurturing and supportive environment at UMBC. UMBC already possess' a national reputation and legacy in the Biomedical Sciences through its Graduate Meyerhoff Program. Translating this highly successful program into the Physical Sciences & Engineering will be one of the primary goals of the new CASPR Ultrafast Optics & Optoelectronics Research & Teaching Facility. In Physics, for example, the US the annual production of PhDs is on the order of 1000, while the production of African-American and Latino-American PhDs hovers around 10-15 for each group. The next three examples are indicative of an already successful program to attract a highly talented and diverse cadre of individuals to CASPR as a direct result of the promise of a state-of-the-art Ultrafast Optics & Optoelectronics Research & Teaching Facility:

(1) Dr. Elaine Lalanne received her PhD in Applied Physics with Dr. Johnson at NJIT in May 2003. Dr. Lalanne has the distinction of likely being the only African-American female in the US to receive a PhD in Physics in 2003. Dr. Lalanne has joined the CASPR personnel as an Assistant Research Scientist with the main responsibility of helping run and develop the Ultrafast Optics & Optoelectronics Research & Teaching Facility.
(2) Mr. Robinson Kuis (Latino-American) joined my research group at NJIT as an undergraduate McNair Scholar and decided to stay on as a graduate student, despite the fact that he also received the highly prestigious Bell Labs/Lucent Technologies Graduate Research Fellowship in 2002 to attend any graduate school in the US. Mr. Kuis is currently pursuing a PhD in Applied Physics in Dr. Johnson's research group.
(3) Ms. Frances Carter (African-American) was recruited by Dr. Johnson at the recent joint Meeting of the National Society of Black Physicists and National Society of Hispanic Physicists to join his research group. Ms. Carter was greatly attracted to the possibility of completing an Applied Physics PhD in Dr. Johnson's state-of-the-art research laboratory. Ms. Carter has the honor and distinction of recently being awarded a highly prestigious 2004 National Science Foundation Graduate Research Fellowship. Ms. Carter included UMBC/CASPR in the NSF application/proposal and will join UMBC in September 2004.

These are but a few examples of the highly talented and diverse graduate students that are attracted to the promise of a new CASPR Ultrafast Optics & Optoelectronics Research &

Teaching Facility and represents a small beginning to the concept of starting a Meyerhoff-like graduate program in the Physical Sciences & Engineering.

CASPR has submitted a proposal to the NSF IGERT (Integrative Graduate Education and Research Traineeship) Program. This program is intended to support the PhD education of US scientists and engineers by providing interdisciplinary graduate education in an environment for collaborative research. It involves internships and mentoring in industrial, national lab or other settings, integrated with an innovative course curriculum and collaborative doctoral dissertation. At the heart of this proposal is the new CASPR Ultrafast Optics & Optoelectronics Research & Teaching Facility which will serve as a focal point for the overall CASPR recruiting effort. The theme of the NSF IGERT proposal will be "Novel Properties of Photons and Nanostructures." NIST has agreed to join CASPR as a partner in this proposal. Therefore, UMBC graduate students will have the opportunity to work with world class CASPR faculty in addition to the possibility of having a world class NIST scientist as a mentor and NIST internship. The partnership of NIST and UMBC/CASPR on this NSF IGERT proposal is an exciting prospect for the educational goals of CASPR.

4. PERSONNEL

4.1 Administration Office

Anthony M. Johnson, Ph.D., *Director*, CASPR

Dr. Johnson was a Distinguished Member of Technical Staff in the Photonic Circuits Research Department at AT&T Bell Laboratories, in Holmdel, New Jersey. After 14 extremely rewarding years at Bell Labs, he joined the New Jersey Institute of Technology (NJIT) in Newark, NJ, on January 1, 1995 where he was the Chairperson (1/95-1/03) and Distinguished Professor of Physics (8/97-9/03). In addition to position of Director of CASPR, he is a Professor of Physics and a Professor of Computer Science and Electrical Engineering, and holds the 2004 Wilson H. Elkins Professorship of the University System of Maryland. His general area of research is in ultrafast optical and optoelectronic phenomena. He has over 60 refereed publications, 2 book chapters, and 4 US patents. His current research interests include the ultrafast photophysics and nonlinear optical properties of bulk, nanostructured, and quantum well semiconductor structures, ultrashort pulse propagation in fibers and high-speed lightwave systems. He served as Editor-in-Chief of the number one ranked letters journal in the field of optics, Optics Letters (11/1/95-12/31/01). He served as the 1990 Program Co-Chair, 1992 Conference Co-Chair and 1996 Steering Committee Chair of the Conference on Lasers and Electro-Optics (CLEO '90, '92, '96). He was a General Councillor (94-97), Member of the Executive Board (96-97) and Chair of the Committee on Minorities in Physics (92-93) of the American Physical Society (APS); Member of the Board of Governors (93-95) of the IEEE Lasers and Electro-Optics Society (LEOS). He is currently a member of the DOE Basic Energy Sciences Advisory Committee (BESAC, 99-05) and a member of the Governing Board of the American Institute of Physics (AIP, 02-05). He was the 2002 President of the nearly 16,000 member Optical Society of America (OSA) and is currently the 2004 Chair of the Nominating Committee. Among his awards and honors, he received the 1988 AT&T Bell Labs

Distinguished Technical Staff Award; the 1989 AT&T Bell Labs Research Area Affirmative Action Award; 1993 Distinguished Alumnus Award (Polytechnic Univ.); 1994 Black Engineer of the Year Special Recognition Award; 1996 Edward A. Bouchet Award of the APS. He is a Fellow of the following societies: OSA (1991), National Society of Black Physicists (NSBP) [1992], APS (1995), American Association for the Advancement of Science (AAAS) [1996], and IEEE (2000). He is a member of the American Association of Physics Teachers (AAPT). Dr. Johnson was a Member and Co-Founder of the OSA Ad Hoc Committee on Women and Minorities in Optics (88-93); Co-Chair, OSA Committee on Women and Minorities in Optics (94-98). Dr. Johnson holds a B.S. (Physics, Magna Cum Laude, 1975), from the Polytechnic Institute of New York and a Ph.D. in Physics (1981) from the City College of the City University of New York – the PhD thesis research was conducted at Bell Labs, Murray Hill, NJ with support from the Bell Labs Cooperative Research Fellowship Program (CRFP) for Minorities. Dr. Johnson is one of 6 six scientists highlighted in an educational interactive video designed for elementary school children called Minorities in Science, which was partially funded by NSF (http://www.csy.com/DrAnthonyJohnson.htm).

Most recent publications include:

H. Han, S. Vijayalakshmi, A. Lan, Z. Iqbal, H. Grebel, E. Lalanne and A. M. Johnson, "Linear and Nonlinear Optical Properties of Single-Wall Carbon Nanotubes within an Ordered Array of Nanosize Silica Spheres," Applied Physics Letters 82, 1458 (2003).
H. Garcia, A. M. Johnson, F. A. Oguama, and S. Trivedi, "New approach to the measurement of nonlinear refractive index of short (<25 m) lengths of silica and erbium-doped fibers," Optics Letters 28, 1796 (2003).

Henry H. Plotkin, Ph.D., Associate Research Scientist

Before the establishment of CASPR, Dr. Plotkin served as Associate Director and Chief Scientist of the Goddard Earth Sciences and Technology (GEST) Center at UMBC, and as Senior Research Scientist in JCET (Joint Center for Earth Systems Technology). He received a B.S. in physics from CCNY in 1946; M.S. in physics from NYU in 1948; and a Ph.D. in physics from MIT in 1957. Dr. Plotkin conducted research in magnetic materials at the Westinghouse Research Laboratories, and research in atomic frequency standards at the U.S. Army Signal Research and Development Laboratories. He served in a number of positions at GSFC from 1960 to 1994. Most recently he was Assistant Director of Engineering for Technology Development, responsible for planning and directing development and flight of new technology in spacecraft subsystems, sensors, lasers, robotics, and information systems. From 1974 to 1981 Dr. Plotkin served as Chief of the Earth Observation Systems Division, in the Applications Directorate, developing advanced sensors, instruments, and techniques to study the land, oceans, and atmosphere in the microwave, infrared, visible, and ultraviolet regions of the spectrum. He implemented aircraft, balloon, and space missions to evaluate new techniques and to validate science data and algorithms. His publications deal with laser ranging, optical instrumentation, spectroscopy, and atomic frequency control. Dr. Plotkin pioneered the use of laser systems for precise space tracking and optical communication, proposed and developed the first series of reflecting geodetic satellites, and was a member of the original team for the Lunar Laser Reflectors, which were placed on the moon during Apollo 11, 15, and 16. He joined JCET at

UMBC in October 1995, as a senior research scientist and the UMBC Physics Department as a faculty member. He was a member of the team that wrote the successful proposal for GEST and was appointed Associate Director of GEST at its inception. In October, 2002, Dr. Plotkin received the "SLR (Satellite Laser Ranging) Pioneer Award" from the International Laser Ranging Service.

Gayle Chapman, CPA, Assistant Director

Ms. Chapman has been a licensed accounting and administrative professional for 20 years. Prior to joining the university as CASPR's first fully dedicated staff member, she operated a small business and individual financial consulting service, which included such services as arranging small business loans and commercial mortgages, residential mortgages, accounting, and business development consulting (96-02). Ms. Chapman co-founded and operated two licensed, private schools, Columbia Academy Preschool and Columbia Academy Elementary School in Columbia, Maryland, which had a combined student enrollment of 350 children and employed 40 licensed teachers and staff (91-96). Before the establishment of the schools, she was co-owner and office administrator of Candid Realty, Inc., Ann Arbor, Michigan, a real estate development corporation (86-91), and was a senior auditor for a large regional CPA firm also in Ann Arbor, Icerman, Johnson & Hoffman (82-85). As senior auditor she performed audit and management consulting services for numerous non-profit organizations and large and small municipalities. Ms. Chapman received a B.B.A. degree with an emphasis in Accounting from Eastern Michigan University, Ypsilanti, Michigan, 1982.

Elaine N. Lalanne, Ph.D., Assistant Research Scientist

Before joining CASPR as an Assistant Research Scientist, Dr. Lalanne received a PhD from the joint department of Applied Physics from New Jersey Institute of Technology/ Rutgers University-Newark in May 2003. She conducted research investigating the ultrafast photophysics and nonlinear optical properties of Silicon nanostructured materials and single-walled carbon nanotubes. Her dissertation work focused on the nonlinear refractive index and time resolved measurements. She received an IEEE/LEOS Graduate Student Dissertation Fellowship in 2001. She received a BA in physics from Wellesley College in 1994. She has extensive experience in the use of ultra-fast laser systems such as Ti:Sapphire oscillator, Ti:Sapphire regenerative amplifier, Ti:Sapphire pumped optical parametric oscillator and Nd:YAG. At CASPR, she is responsible for helping Dr. Johnson to develop and run the Ultrafast Optics and Optoelectronics Laboratory. She has extended her research to investigate ultrashort pulse propagation in fibers and optical limiting. She is a member of Optical Society of America (OSA), American Physical Society (APS) and National Society of Black Physicists (NSBP).

4.2 CASPR faculty (not funded through the NASA grant in this reporting period).

Adali, Tulay	Associate Professor	CSEE
Carter, Gary M.	Professor	CSEE
Chen, Yung Jui (Ray)	Professor	CSEE
Choa, Fow-Sen	Professor	CSEE
Curtis R. Menyuk	Professor	CSEE
Hayden, L. Michael	Associate Professor	Physics
Joel Morris	Professor	CSEE
Lomonaco, Samuel	Professor	CSEE
Minkoff, Susan E.	Assistant Professor	Math& Stat
Rubin, Morton H.	Professor	Physics
Shih, Yanhua	Professor	Physics
Thomas, Joseph	Assistant Professor	CSEE
Worchesky, Terrance L.	Associate Professor	Physics
Yan, Li	Professor	CSEE
Zweck, John	Assistant Professor	Math & Stat