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13. ABSTRACT (Maximum 200 words) The overall objective of this experimental program is to control the light emission properties and energy transfer mechanisms in nanoscale semiconductor structures in order to realize new or improved photonic devices. For nanostructures that are defined by buried heterojunction interfaces the focus is to define the regimes in which scattering and carrier collection dominate the performance of quantum well and superlattice devices. For nanostructures with exposed surfaces the focus is to understand the fundamental light emission mechanisms. The proposed research impacts device development and system architectures by demonstrating light emitters for wavelength division multiplexing, three dimensional IOEC structures, broadly tunable lasers, and low loss waveguides. Most recently the impact of these phenomena have been studied in the wide bandgap AlGaIn material system. We have demonstrated stimulated emission in GaN, InGaIn thin films and quantum well heterostructures. We have also done absorption measurements and observed multiple excitons.				
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Light Emission and Energy Transfer in Nanoscale Semiconductor Photonic Devices

FINAL PROGRESS REPORT

Dr. Robert M. Kolbas

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 1. "Monolithically Integrated SQW Laser and HBT Laser Driver Via Selective OMVPE Regrowth," D. B. Slater, Jr., P. M. Enquist, J. A. Hutchby, F. E. Reed, A. S. Morris, R. M. Kolbas, R. J. Trew, A. S. Lujan and J. W. Swart, Photonics Technology Letters 5, No. 7, pp. 791-794 (7 July 1993).
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22. "Absorption Coefficient, Energy Gap, Exciton Binding Energy and Recombination Lifetime of GaN Obtained from Transition Measurements," J. F. Muth, J. H. Lee, I. K. Shmagin, R. M. Kolbas, H. C. Casey, Jr., B. P. Keller, U. K. Mishra and S. P. DenBaars, to be published in Applied Physics Letters.
23. "Optical Data Storage in InGaN/GaN Heterostructures," I. K. Shmagin, J. F. Muth, R. M. Kolbas, R. D. Dupuis, P. A. Grudowski, C. J. Eiting, J. Park, B. S. Shelton and D. J. H. Lambert, to be published in Applied Physics Letters.
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Conference Presentations

1. "Investigation of High Quality P-Type GaN and InGaN from Multi-Wafer-Rotating-Disc MOCVD Reactor," C. Yuan, T. Salagaj, A. Gurary, A. G. Thompson, C. S. Chern, W. Kroll, R. A. Stall, C.-Y. Hwang, M. Schurman, Y. Li, W. E. Mayo, Y. Yu, S. Krishnankutty, R. M. Kolbas and S. J. Pearton, presented at the Spring Meeting of the 1995 Materials Research Society, San Francisco, California.
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4. "Investigation of the Photoluminescence Characteristics of Mg:GaN and Zn:InGaN", S. Krishnankutty, I. K. Shmagin, R. M. Kolbas, C. Yuan, T. Salagaj, A. Gurary, R. A. Stall, M. Schurman, Y. Li, W. E. Mayo, Y. Lu and J. M. Zavada, Topical Workshop on III-V Nitrides (TWN'95), Nagoya, Japan, Sept. 21-23, 1995.
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6. "Growth of Bulk InGaN Films and Quantum Wells by Atmospheric Pressure Metalorganic Chemical Vapor Deposition," S. Keller, B. Keller, U. K. Mishra, S. DenBaars, I. K. Shmagin, R. M. Kolbas and S. Krishnankutty, to be presented at the MOCVD Conference in Cardiff, Wales, UK, June 1996, and manuscript submitted to the MOCVD Conference Proceedings, 1996.

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8. "Selective Deposition of Strongly Luminescent Eu-doped Yt_2O_3 Nanoparticles," P. D. Milewski, S. K. Strieffer, A. I. Kingon, I. K. Shmagin, R. M. Kolbas and S. Krishnankutty, 2nd International Conference on the Science and Technology of Display Phosphors, San Diego, Ca, Nov. 18-20, 1996; also submitted to Proceedings of the Science and Technology of Display Phosphors.
9. "Investigation of the Optical Properties of InGaN/AlGaIn QW Structures Emitting in the Blue and Green Spectrum," V. A. Joshkin, M. A. Aumer, J. C. Roberts, F. G. McIntosh, S. M. Bedair, S. Krishnankutty, I. K. Shmagin, R. M. Kolbas, S. Lin and L. Wang, Materials Research Society Fall Meeting, Boston, MA, December 2-7 (1996).
10. "Determination of Refractive Index and Absorption Coefficient of Gallium Nitride from Optical Transmission, Reflectance and Photoluminescence", J. F. Muth, I. K. Shmagin, R. M. Kolbas, S. Krishnankutty, S. Keller, U. K. Mishra, and S. P. DenBaars, Materials Research Society Fall Meeting, Boston, MA, December 2-7 (1996).
11. "Growth of Bulk AlN and GaN Single Crystals by Sublimation", C. M. Balkas, Z. Sitar, T. Zheleva, L. Bergman, I. K. Shmagin, J. F. Muth, R. M. Kolbas, R. Nemanich, and R. F. Davis, Materials Research Society Meeting, Boston, MA, Dec. 2-7, 1996.
12. "Absorption Coefficient, Exciton Binding Energy and Bandgap of GaN," J. F. Muth, I. K. Shmagin, R. M. Kolbas, H. C. Casey, Jr., and S. P. DenBaars, Workshop on Wide Band Gap Semiconductors: Defects and Fundamental Parameters, January 15-16, 1997, Raleigh, NC.
13. "Stimulated Emission and Gain Measurements from InGaIn/GaN Heterostructures", I. K. Shmagin, J. F. Muth, R. M. Kolbas, S.

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15. "MOCVD Growth of Group-III Nitrides for High Quality Photonic and Electronic Devices", S. P. DenBaars, P. Kozodoy, S. Keller, Y. F. Wu, A. Ambare, M. Mack, M. Minsky, E. Hu, J. S. Speck, L. A. Coldren, U. K. Mishra, I. K. Shmagin, J. F. Muth, and R. M. Kolbas, Invited Paper presented at the Army Research Office Workshop on Wide Band Gap Semiconductors: Defects and Fundamental Parameters, Research Triangle Park, NC, January 15-16 1997.
16. "Optical Properties of High Quality Bulk GaN Single Crystals," I. K. Shmagin, J. F. Muth, R. M. Kolbas, C. M. Balkas, Z. Sitar, and R. F. Davis, accepted at the 39th Electronic Materials Conference, June 1997.
17. "Absorption Coefficient, Excitonic Structure and Band Gap of Gallium Nitride at Room Temperature Using Optical Transmission Measurements," J. F. Muth, I. K. Shmagin, R. M. Kolbas, H. C. Casey, Jr., P. Fini, S. Keller, S. P. DenBaars, accepted at the 39th Electronic Materials Conference, June 1997.
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8. SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD:

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Irina Shmagin (Ph.D. expected Fall '97)

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9. REPORT OF INVENTIONS (BY TITLE ONLY):

"Bias Induced Color-tuned Semiconductor Light Emitter", R. M. Kolbas, D. Zhang, U. S. patent (disclosure, July 9, 1992, NCSU file # 92-77).

BRIEF OUTLINE OF RESEARCH FINDINGS

The overall objective of this experimental program is to control the light emission properties and energy transfer mechanisms in nanoscale semiconductor structures in order to realize new or improved photonic devices. For nanostructures that are defined by buried heterojunction interfaces the focus is to define the regimes in which scattering and carrier collection dominate the performance of quantum well and superlattice devices. For nanostructures with exposed surfaces the focus is to understand the fundamental light emission mechanisms. The proposed research impacts device development and system architectures by demonstrating light emitters for wavelength division multiplexing, three dimensional IOEC structures, broadly tunable lasers, and low loss waveguides. Most recently the impact of these phenomena have been studied in the wide bandgap AlGaIn material system. We have demonstrated stimulated emission in GaN, InGaIn thin films and quantum well heterostructures. We have also done absorption measurements and observed multiple excitons.

Major advances resulting from this program include:

- The first demonstration of a three terminal semiconductor light emitter where the optical output intensity is controlled by the voltage applied to one of the terminals and the color is controlled by the voltage applied to the other terminal. (Bias Induced Color-Tuned Emitter, BICE)
- Demonstration of optical memory effects in InGaIn that has potential applications for optical memory storage and optical signal processing.