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13. ABSTRACT (Maximum 200 words)

The MIT Research Laboratory of Electronics' Joint Services Program comprises seventeen work units (see below) that span a broad array of topics in high-speed optics, surface and phase transitions, submicron structures and quantum-effect devices, the electrical behavior of interconnect structures, and atomic and molecular physics. The work units include:

InGaAlAs Quantum Heterostructures for High-Performance Devices; Chemical Beam Epitaxy of II-VI/III-V Quantum Wells; Physics of InAlAs/InGaAs Heterostructure Field-Effect Transistors; Sub-100-Nanometer Structures: Technology, Electronics, and Optics; Single-Electron Electronics, Quantum Transport in Mesoscopic Systems; Statistical Mechanics of Quantum Dots; Single-Electron Microscopy; Femtosecond Quantum Optics; Ultrafast Optical and Electronic Processes; Excitations, Ground State Properties, and Phase Transitions of Surfaces; Synchrotron X-ray Studies of Semiconductor Surface Disorder; Step Structures and Epitaxy on Semiconductor Surfaces; Optical Frequency Metrology; Precision Physical Measurements; Ultracold Atoms; and Electromagnetic Waves in Complex Media.

Results of the research done under this contract are described in more detail in the attached "Overview."

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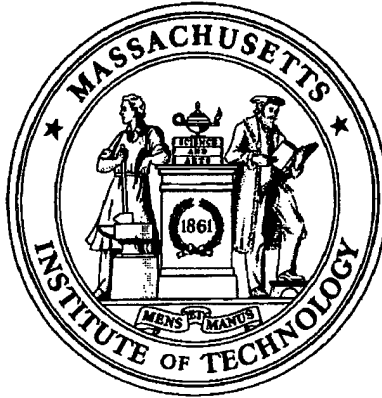
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“Basic and Applied Research in the Field of
Electronics and Communications”
November 1, 1994 - October 31, 1997**

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**Submitted by
Professor Jonathan Allen, Principal Investigator
February 1998**

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**Overview of the
MIT Research Laboratory of Electronics
Joint Services Electronics Program
Contract DAAH04-95-1-0038
November 1, 1994 - October 31, 1997**

The MIT Research Laboratory of Electronics Joint Services Program comprises seventeen work units that span a broad array of topics in high-speed optics, surface and phase transitions, submicron structures and quantum-effect devices, the electrical behavior of interconnect structures, and atomic and molecular physics.

The RLE program has developed and utilized state-of-the-art epitaxial growth techniques for high-performance devices that use indium gallium aluminum arsenide quantum heterostructures, as well as indium aluminum arsenide/indium gallium arsenide heterostructure field-effect transistors for high-speed, high-power telecommunication applications. The RLE program is unique in that it provides II-VI and III-V integrated growth facilities for a variety of projects, most notably the metalorganic molecular beam epitaxy of zinc selenide for blue light-emitter applications.

The RLE program continues to provide a strong array of capabilities in the sub-100-nanometer structure area, which is essential for our research in quantum-effect devices. Our x-ray nanolithography capability continues to expand. This will lead to the ability to grow extremely small MOSFETs with channels less than one-tenth of a micron in length. The acquisition of an electron beam lithographic capability has complemented our x-ray facilities. This has enhanced both our direct-write and mask masking capabilities.

Experiments with the single-electron transistor, which were previously reported, are aimed at developing new techniques to decrease the scale of these devices. This will enable these devices to operate at higher temperatures. Theoretical efforts have also been directed at single-electron transistors with a view towards understanding basic theory and revealing possibilities for new directions. The theoretical research is also focused on the statistical mechanics properties of quantum dots and how they can be utilized for new device applications.

Femtosecond optical capability is aimed at the provision of all-optical networks and all-optical switching by using compact, solid-state lasers that exhibit additive pulse modelocking. Soliton transmissions have been studied and implemented in these networks, thus permitting extremely long distances between repeaters in practical systems. The femtosecond optical capability is also utilized to probe electronic materials and to optimize transport properties in extremely fast electronic devices.

Surfaces are central to modern electronic and optical devices, and the RLE program continues its strong theoretical effort to characterize surface phase transitions, impurities, and stress. Realistic surface profiles are computed, and defect complexes on surfaces have been realistically characterized. Experimentally, synchrotron x-ray diffraction studies using high-power x-ray facilities have revealed new surface phenomena, including the ability to move plateaus on silicon surfaces through the introduction of surface currents. A detailed understanding of the atomic mechanisms of surface reconstruction has been obtained. The understanding of surface roughness, which is essential for many applications, has led to a better understanding of new fabrication techniques. By using accelerated neutral halogen atoms, surface reactions (similar to those

found in reactive ion etching) have been studied in detail. New techniques that avoid high pressure and associated surface defects have been devised for surface etching.

Many electronic and optical systems require extremely high-precision measurements and standards. The RLE JSEP program has pioneered the development of optical frequency standards. These developments can then be exploited in many electronic systems that involve the synchronization and coordination of worldwide systems. Highly accurate techniques to measure mass are now available for ultrahigh-resolution studies of electronic and optical materials. These techniques also provide a uniform and portable ultraprecision standard for mass.

RLE participates with other JSEP universities in electromagnetic studies. The focus at RLE is on propagation through multilayer media, such as that found in computer interconnect structures. Direct solutions in the time domain have provided a new understanding and the capability to decrease the delays imposed by these networks.

A continuing direction of the RLE program is the study and exploitation of individual atoms and molecules, as well as their contribution to the behavior of practical electronic and optical devices. The direct control of individual charge carriers is now feasible, and there is an increased understanding of possibilities for new quantum-effect devices based on cavity quantum electrodynamics in solid-state Coulomb blocking effects. The RLE program continues its efforts to realize new, practical devices with outstanding performance to exploit these effects.

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Degrees Awarded under JSEP Support
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InGaAlAs Quantum Heterostructures for High-Performance Devices

Aggarwal, R.J. Ph.D., 1996
Hoshino, I. Ph.D., 1997
Peng, L.-H. Ph.D. (Harvard Univ.), 1994
Smet, J.H. Ph.D., 1994

Chemical Beam Epitaxy of II-VI/III-V Quantum Wells

Ho, E. Ph.D., 1996
Warlick, E.L. M.Eng., 1996

Physics of InAlAs/InGaAs Heterostructure Field-Effect Transistors

Adams, T. S.B., 1994
Ernst, A. M.Eng., 1997
Greenberg, D.R. Ph.D., 1995
Putnam, C. M.Eng., 1997
Reiner, J.W. S.B., 1994

Sub-100-Nanometer Structures: Technology, Electronics, and Optics

Burkhardt, M. Ph.D., 1995
Damask, J.N. Ph.D., 1996
Ferrera, J. S.B./S.M., 1994
Hector, S.D. Ph.D., 1994
Hu, H. Ph.D., 1994
Jackson, K.M. S.M., 1996
Kumar, A. Ph.D., 1994
Li, H. S.B./S.M., 1994
Meinhold, M. S.M., 1996
Owen, G.M. S.M., 1994
Shah, S. S.M., 1995
Yang, I. Ph.D., 1996
Yasaka, A. S.M., 1995
Yee, K.W. S.M., 1996

Single-Electron Electronics

Abusch-Magder, D. Ph.D., 1997

Quantum Transport in Mesoscopic Systems

Chklovskii, D.B. Ph.D., 1994

Statistical Mechanics of Quantum Dots

Andreev, A. Ph.D., 1996
Mucciolo, E.R. Ph.D., 1994

Single-Electron Spectroscopy

Silevitch, D.M. S.B., 1996
Sokolinski, I. S.B., 1995

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Femtosecond Quantum Optics

Boivin, L. Ph.D., 1996
Lenz, G. Ph.D., 1995
Singer, A.C. Ph.D., 1996
Wong, V.V. Ph.D., 1995

Ultrafast Optical and Electronic Processes

Ramaswamy, M. Ph.D., 1994
Sun, C.-K. Ph.D. (Harvard Univ.), 1994
Ulman, M. Ph.D., 1994

Excitations, Ground State Properties, and Phase Transitions of Surfaces

Capaz, R. Ph.D., 1996
Cho, K. Ph.D., 1994

Synchrotron X-ray Studies of Semiconductor Surface Disorder

Ramstad, M.J. Ph.D., 1996
Young, M.J. Ph.D., 1996

Step Structures and Epitaxy on Semiconductor Surfaces

Song, S. Ph.D., 1996

Optical Frequency Metrology

Lutwak, R. Ph.D., 1996

Precision Physical Measurements

Chapman, M.S. Ph.D., 1995
DiFilippo, F. Ph.D., 1994
Hammond, T.D. Ph.D., 1997
Martin, P.S. Ph.D., 1996
Pelly, J.D. S.B., 1994
Rusinkiewicz, S.M. S.B., 1995
Tannian, B.E. S.B., 1994

Ultracold Atoms

Davis, K.B. Ph.D., 1995
Entin, I.A. S.B., 1995
Huang, E.W. S.B., 1996
Mewes, M.-O. Ph.D., 1997
Thompson, Jr., S.H. S.B., 1995
Wan Morshidi, W.Y. S.B., 1994
Yesley, P.S. S.B., 1995

Electromagnetic Waves in Complex Media

Johnson, J.T. Ph.D., 1996
Li, K. Ph.D., 1995
Tomisio, N. S.M., 1997
Yan, J.K. S.M., 1996
Yeang, C.-P. S.M., 1996

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