

# Table of Contents

<b>The Research Laboratory of Electronics</b>	<b>1</b>
<b>PART I SOLID STATE PHYSICS, ELECTRONICS, AND OPTICS</b>	
<b>Section 1 Materials and Fabrication . . . . .</b>	<b>5</b>
<b>Chapter 1 Compound Semiconductor Materials and Devices . . . . .</b>	<b>7</b>
<i>Professor Clifton G. Fonstad, Jr.</i>	
1.1 Introduction . . . . .	7
• 1.2 Epitaxy-on-Electronics Integration Technology . . . . .	7
1.3 InGaAsP/GaAs Light Emitting Diodes Monolithically Integrated on GaAs VLSI Electronics . . . . .	9
1.4 The OPTOCHIP Project . . . . .	9
1.5 Low-Temperature Growth of Aluminum-Free InGaP/GaAs/InGaAs LED and Laser Diode Heterostructures by Solid Source MBE using a GaP Cell . . . . .	10
1.6 Dry-Etch Technology for Aluminum-free InGaP/GaAs/InGaAs Laser Diode Facets and Deflectors . . . . .	11
1.7 Monolithic Integration of Vertical-Cavity Surface-Emitting Laser Diodes on GaAs VLSI Electronics . . . . .	12
• 1.8 Hyperthermal Molecular Beam Dry Etching of III-V Compound Semiconductors . . . . .	13
1.9 Microwave Characterization of Optoelectronic Devices . . . . .	13
1.10 Monolithic Integration of 1550 nm Photodetectors on GaAs Transimpedance Amplifier Chips . . . . .	14
1.11 Design and Analysis of VCSEL-Based Resonant Cavity Enhanced Photodetectors . . . . .	15
1.12 Si-on-GaAs: Monolithic Heterogeneous Integration of Si CMOS with GaAs Optoelectronic Devices using EoE, SOI, and MEMS Techniques . . . . .	16
1.13 Aligned, Selective-Area Wafer-Scale Bonding of Optoelectronic Devices on GaAs Integrated Circuits . . . . .	17
1.14 Normal-Incidence Quantum Well Intersubband Photodetectors (QWIPs) for Monolithic Integration . . . . .	17
1.15 Publications . . . . .	18
<b>Chapter 2 Physics of InAlAs/InGaAs Heterostructure Field-Effect Transistors . . . . .</b>	<b>21</b>
<i>Professor Jesús A. del Alamo</i>	
• 2.1 Introduction . . . . .	21
• 2.2 A New Measurement Technique for On-State Breakdown Voltage . . . . .	22
• 2.3 On-State Breakdown Physics . . . . .	23
• 2.4 A New Model for On-state Breakdown Voltage . . . . .	25
• 2.5 Conclusions . . . . .	27
• 2.6 Publications . . . . .	27

<b>Chapter 3</b>	<b>Epitaxial Growth and Processing of Compound Semiconductors . . . . .</b>	<b>29</b>
<i>Professor Leslie A. Kolodziejski, Dr. Gale S. Petrich</i>		
3.1	Introduction . . . . .	29
3.2	Development of Semiconductor Optical Devices for All-Optical Communication Networks	29
3.3	Photonic Bandgap Structures . . . . .	33
3.4	Growth of Bandgap-Engineered Distributed Bragg Reflectors . . . . .	35
<b>Section 2</b>	<b>Quantum-Effect Devices . . . . .</b>	<b>37</b>
<b>Chapter 1</b>	<b>Single-Electron Electronics . . . . .</b>	<b>39</b>
<i>Professor Marc A. Kastner</i>		
• 1.1	Goals and Objectives . . . . .	39
• 1.2	Summary of Recent Work . . . . .	39
• 1.3	Publication . . . . .	41
<b>Chapter 2</b>	<b>Theory of Electron Transmission Through a Quantum Dot: Coulomb Blockade and the Kondo Effect . . . . .</b>	<b>43</b>
<i>Professor Patrick A. Lee</i>		
• 2.1	Project Description . . . . .	43
<b>Chapter 3</b>	<b>Superconducting and Quantum-Effect Electronics . . . . .</b>	<b>45</b>
<i>Professor Terry P. Orlando</i>		
3.1	Engineering Josephson Oscillators . . . . .	45
3.2	Triangular Arrays of Josephson Junctions . . . . .	46
3.3	Nonlinear Dynamics Of Discrete Josephson Arrays . . . . .	47
3.4	Coupled Rings of Josephson Junctions: Interactions of Topological Kinks.	48
3.5	Meissner-like States in Josephson Arrays . . . . .	50
3.6	Self-Field Effects on Flux Flow in Josephson Arrays . . . . .	51
3.7	Quantum Device Simulations . . . . .	52
<b>Chapter 4</b>	<b>Nanostructures Technology, Research, and Applications . . . . .</b>	<b>55</b>
<i>Professor Henry I. Smith</i>		
4.1	NanoStructures Laboratory . . . . .	55
• 4.2	Scanning-Electron-Beam Lithography . . . . .	55
4.3	Spatial-Phase-Locked Electron-Beam Lithography . . . . .	56
• 4.4	X-Ray Nanolithography . . . . .	57
4.5	Zone-Plate Based X-Ray and Deep-UV Projection Lithography . . . . .	59
• 4.6	Improved Mask Technology for X-Ray Lithography . . . . .	60
4.7	Robust, High-Precision Mask Alignment and X-ray Exposure System . . . . .	61
4.8	Interferometric Lithography . . . . .	63
4.9	Sub-100 nm Metrology Using Interferometrically Produced Fiducial Grids . . . . .	64
4.10	Arrays of Nanomagnets for High-Density Information Storage . . . . .	65
4.11	Design and Fabrication of Single-Mask 50 nm MOSFETs . . . . .	67
4.12	CMOS Technology for 25 nm Channel Length . . . . .	68
4.13	Fabrication of T-gate Devices Using X-ray Lithography . . . . .	69
4.14	Single-Electron Transistor Research . . . . .	70
• 4.15	One-Dimensional Photonic-Band-Gap Devices in SOI Waveguides . . . . .	72

4.16 Three-dimensional Photonic Bandgap Structures . . . . .	74
4.17 Design and Fabrication of an Integrated Channel-Dropping Filter in InP . . . . .	75
4.18 Fabrication of an Integrated Optical Grating-Based Matched Filter for Fiber-Optic Communications . . . . .	77
4.19 High-Dispersion, High-Efficiency Transmission Gratings for Astrophysical X-ray Spectroscopy . . . . .	79
4.20 Super-smooth X-ray Reflection Gratings . . . . .	80
4.21 Transmission Gratings as UV-blocking Filters for Neutral Atom Imaging . . . . .	82
• 4.22 Submicrometer-Period Transmission Gratings for X-ray and Atom-Beam Spectroscopy and Interferometry . . . . .	83
4.23 Field-Emitter-Array Flat-Panel Displays for Head-Mounted Applications . . . . .	84
4.24 Development of High-Speed Distributed Feedback (DFB) and Distributed-Bragg Semiconductor Lasers . . . . .	85
4.25 Publications . . . . .	86
<b>Chapter 5 Subsurface Charge Accumulation Imaging . . . . .</b>	<b>89</b>
<i>Professor Raymond C. Ashoori</i>	
• 5.1 Introduction . . . . .	89
• 5.2 Publications . . . . .	93
<b>Section 3 Optics and Devices . . . . .</b>	<b>95</b>
<b>Chapter 1 Optics and Quantum Electronics . . . . .</b>	<b>97</b>
<i>Professor Hermann A. Haus, Professor Erich P. Ippen, Professor James G. Fujimoto, Professor Peter L. Hagelstein, Dr. Brett E. Bouma, Dr. Jay N. Damask</i>	
1.1 Modelocked Lasers using Erbium-doped Glass Waveguide Amplifiers . . . . .	97
1.2 Publications . . . . .	98
• 1.3 Environmentally-Stable Stretched-Pulse Fiber Laser . . . . .	99
1.4 High-Repetition Rate Laser Sources . . . . .	100
1.5 Asynchronous Phase-Modulated Optical Fiber Buffer . . . . .	101
• 1.6 Optical Pulse Filtering with Dispersion-Imbalanced Loop Mirrors . . . . .	102
1.7 Stretched-Pulse Propagation . . . . .	106
1.8 Direct Measurement of Self-Phase Shift due to Fiber Nonlinearity . . . . .	107
1.9 Wavelength Stabilized Modelocked Laser Source Gyro Applications . . . . .	109
1.10 Optical Measurements of Photonic Bandgap Resonators in the Near Infrared . . . . .	109
1.11 Optical Resonant Structures . . . . .	110
• 1.12 Ultrafast Gain-Index Coupling in InGaAsP Diode Lasers . . . . .	112
• 1.13 Femtosecond Studies of THz Acoustic Phonons in PbTe Quantum Dots . . . . .	113
1.14 Ultrashort Pulse Generation and Ultrafast Phenomena . . . . .	113
1.15 Laser Medicine and Medical Imaging . . . . .	118
1.16 Analytical Confirmation of Stochastic Soliton Formulation . . . . .	129
1.17 Long-Time Evolution of Soliton Position and Phase in the Second-Quantized Model . . . . .	130
1.18 Local Consequences of Strong Phonon Excitation in a Lattice . . . . .	132
1.19 Steady State Hydrodynamic Ablation . . . . .	134

<b>Chapter 2</b>	<b>Optical Propagation and Communication . . . . .</b>	<b>137</b>
<i>Professor Jeffrey H. Shapiro, Dr. Ngai C. Wong</i>		
2.1	Introduction . . . . .	137
2.2	Nonlinear and Quantum Optics . . . . .	137
2.3	Object Detection and Recognition . . . . .	140
2.4	Optical Frequency Metrology . . . . .	142
<b>Chapter 3</b>	<b>Millimeter-wave, Terahertz, and Infrared Devices . . . . .</b>	<b>145</b>
<i>Professor Qing Hu</i>		
3.1	Introduction . . . . .	145
3.2	Micromachined SIS Millimeter-wave Focal-plane Arrays . . . . .	146
3.3	Intersubband-transitions Lasers . . . . .	148
3.4	Publications . . . . .	152
<b>Chapter 4</b>	<b>Semiconductor Lasers: Physics and Applications . . . . .</b>	<b>155</b>
<i>Professor Rajeev J. Ram</i>		
4.1	Introduction . . . . .	155
4.2	Band Structure and Optical Gain in Strained Layer Quantum Wells . . . . .	155
4.3	Band Gap Engineering of Distributed Bragg Reflectors . . . . .	157
4.4	Thermal Oxide for Ridge-Waveguide Semiconductor Lasers . . . . .	158
4.5	High-Speed Semiconductor Laser Development . . . . .	160
4.6	Nonlinear Response of DFB Lasers . . . . .	161
4.7	High-Fidelity, High-Dynamic Range Fiber Communications . . . . .	162
4.8	Device Level Modeling of Communication Systems . . . . .	164
4.9	Analog Signal Transmission Using Surface Emitting Lasers . . . . .	164
<b>Section 4</b>	<b>Surfaces and Interfaces . . . . .</b>	<b>167</b>
<b>Chapter 1</b>	<b>Mesoscopic Quantum Magnetic Conductors . . . . .</b>	<b>169</b>
<i>Professor Robert J. Birgeneau</i>		
• 1.1	Order Driven by Disorder . . . . .	169
<b>Chapter 2</b>	<b>Semiconductor Surface Studies . . . . .</b>	<b>171</b>
<i>Professor John D. Joannopoulos</i>		
• 2.1	Introduction . . . . .	171
• 2.2	Adatom Vacancies on the Si(111)-(7x7) Surface . . . . .	171
• 2.3	Unified Approach for Calculation of Force-Constants and Accelerated Convergence of Atomic Coordinates . . . . .	174
• 2.4	Publications . . . . .	177
<b>Chapter 3</b>	<b>Step Structures and Epitaxy on Semiconductor Surfaces . . . . .</b>	<b>179</b>
<i>Professor Simon G.J. Mochrie</i>		
• 3.1	Anisotropic Coarsening of Self-Assembling Periodic Grooves . . . . .	179
• 3.2	Publications . . . . .	183

**PART II APPLIED PHYSICS**

<b>Section 1</b>	<b>Atomic, Molecular, and Optical Physics . . . . .</b>	<b>187</b>
<b>Chapter 1</b>	<b>Quantum Optics and Photonics . . . . .</b>	<b>189</b>
<i>Professor Shaoul Ezekiel, Dr. Selim M. Shahriar, Dr. Stephen P. Smith</i>		
1.1	Polarization Selective Motional Holeburning for High-Efficiency, Degenerate Optical Phase Conjugation in Rubidium . . . . .	189
1.2	Demonstration of a Phase Conjugate Resonator using Degenerate Four-Wave Mixing via Coherent Population Trapping in Rubidium . . . . .	192
1.3	Intracavity High-speed Turbulence Abberation Correction in a Sodium Phase Conjugate Resonator . . . . .	193
1.4	Frequency-selective Time-domain Optical Data Storage by Electromagnetically Induced Transparency in a Rare-earth Doped Solid . . . . .	197
1.5	Spin Coherence Excitation and Rephasing with Optically Shelved Atoms . . . . .	201
1.6	Long-Term Optical Data Storage in Thick Holograms . . . . .	201
1.7	Atomic Interferometry for Nanolithography and Nonlinear Atom Optics . . . . .	203
1.8	Multi-atom Quantum Bits and Cavity Dark States for Quantum Computing in Spectral Holeburning Media . . . . .	204
1.9	Fiberoptic Damage Detection . . . . .	204
<b>Chapter 2</b>	<b>Basic Atomic Physics . . . . .</b>	<b>207</b>
<i>Professor Daniel Kleppner, Professor David E. Pritchard, Professor Wolfgang Ketterle</i>		
2.1	Determination of the Rydberg Frequency . . . . .	207
2.2	Recurrence Spectroscopy of Rydberg Atoms in an Oscillating Field . . . . .	211
• 2.3	Atom Interferometry . . . . .	215
• 2.4	Precision Mass Spectrometry of Ions . . . . .	217
2.5	Cooling and Trapping Neutral Atoms . . . . .	220
<b>Section 2</b>	<b>Plasma Physics . . . . .</b>	<b>227</b>
<b>Chapter 1</b>	<b>Plasma Dynamics . . . . .</b>	<b>229</b>
<i>Professor Abraham Bers, Professor Bruno Coppi, Dr. Didier Benisti, Dr. Stephano Migliuolo, Dr. Abhay K. Ram, Dr. Linda E. Sugiyama, Ronald J. Focia, Steven D. Schultz</i>		
1.1	Plasma Wave Interactions—RF Heating and Current Generation . . . . .	229
1.2	Physics of Thermonuclear Plasmas . . . . .	248
<b>Section 3</b>	<b>Electromagnetics . . . . .</b>	<b>265</b>
<b>Chapter 1</b>	<b>Electromagnetic Wave Theory and Applications . . . . .</b>	<b>267</b>
<i>Professor Jin Au Kong, Dr. Kung Hau Ding, Dr. Robert T. Shin, Dr. Y.-C. Eric Yang</i>		
1.1	Inversion of Sea Ice Parameters . . . . .	267
1.2	Study of the Effects of Radio Interference on ILS . . . . .	268
1.3	Development of Atmospheric Attenuation Model . . . . .	269
1.4	SIR-C Polarimetric Radar Image Simulation and Interpretation . . . . .	269
1.5	Polarimetric Passive Remote Sensing . . . . .	270
1.6	Analytic and Monte Carlo Studies on Electromagnetic Interactions with Nonspherical Dense Media . . . . .	271
1.7	Analysis of Electromagnetic Interaction with Ships on the Ocean . . . . .	271
• 1.8	Electromagnetic Waves in Complex Media . . . . .	272

1.9	Research on SAR Simulation Model . . . . .	272
1.10	Research on SAR Interferometry . . . . .	273
1.11	Publications . . . . .	273
<b>Section 4</b>	<b>Radio Astronomy . . . . .</b>	<b>277</b>
<b>Chapter 1</b>	<b>Remote Sensing and Estimation . . . . .</b>	<b>279</b>
	<i>Professor David H. Staelin, Dr. Philip W. Rosenkranz</i>	
1.1	Geostationary Microwave Sounder Study . . . . .	279
1.2	Algorithms for Operational Meteorological Satellite Instruments . . . . .	279
1.3	Development and Operation of an NPOESS Aircraft Sounder Testbed Passive Microwave Sensor . . . . .	279
1.4	Earth Observing System: Advanced Microwave Sounding Unit . . . . .	280
1.5	High-Resolution Passive Microwave Imaging of Atmospheric Structure . . . . .	280
1.6	Reduction of Variation . . . . .	281
<b>PART III</b>	<b>SYSTEMS AND SIGNALS</b>	
<b>Section 1</b>	<b>Computer-Aided Design . . . . .</b>	<b>285</b>
<b>Chapter 1</b>	<b>Custom-Integrated Circuits . . . . .</b>	<b>287</b>
	<i>Professor Jonathan Allen, Professor Srinivas Devadas, Professor John L. Wyatt, Jr., Professor Berthold K.P. Horn, Professor Hae-Seung Lee, Professor Charles G. Sodini, Dr. Ichiro Masaki, Dr. Joseph F. Rizzo III</i>	
1.1	Interactive Learning Environment for Integrated Circuit Design . . . . .	287
1.2	Vision Project . . . . .	288
1.3	Cost-Effective Hybrid Vision Systems for Intelligent Highway Applications . . . . .	292
1.4	Computer-Aided Design Techniques for Embedded System Design . . . . .	295
1.5	Functional Verification of VLSI Systems . . . . .	297
<b>Chapter 2</b>	<b>Computational Prototyping Tools and Techniques . . . . .</b>	<b>301</b>
	<i>Professor Jacob K. White</i>	
2.1	Free-Surface Hydrodynamics for Offshore Structure Analysis . . . . .	301
2.2	Simulation Tools for Micromachined Device Design . . . . .	301
2.3	Simulation Algorithms for RF Circuits . . . . .	302
2.4	Numerical Techniques for Integral Equations . . . . .	303
2.5	Efficient Three-Dimensional Interconnect Analysis . . . . .	304
<b>Chapter 3</b>	<b>Computer-Assisted Prototyping of Advanced Microsystems . . . . .</b>	<b>307</b>
	<i>Professor Donald E. Troxel, Michael B. McIlrath</i>	
3.1	Advanced Modeling and Computational Prototyping . . . . .	307
3.2	Distributed Collaborative Design and Prototyping Infrastructure . . . . .	312
3.3	Scheduling Language for Manufacturing Systems . . . . .	316

<b>Section 2</b>	<b>Digital Signal Processing . . . . .</b>	<b>317</b>
<b>Chapter 1</b>	<b>Digital Signal Processing Research Program . . . . .</b>	<b>319</b>
<i>Professor Alan V. Oppenheim, Professor Arthur B. Baggeroer, Professor Anantha P. Chandrakasan, Professor Gregory W. Wornell</i>		
1.1	Introduction . . . . .	319
1.2	Dual-Channel Signal Processing. . . . .	320
1.3	Multipass Receivers for Spread-Signature CDMA Systems . . . . .	320
1.4	Channel Equalization. . . . .	321
1.5	Steganographic Communication . . . . .	321
1.6	Data Transmission and Storage under Dynamic Bandwidth Constraints . . . . .	321
1.7	Underwater Acoustic Communication over Doppler Spread Channels. . . . .	322
1.8	Algebraic and Probabilistic Structure in Fault-Tolerant Computation . . . . .	322
1.9	Estimation and Equalization of Wireless Fading Channels. . . . .	323
1.10	Distributed Signal Processing . . . . .	323
1.11	Transmit Antenna Arrays for Multiple-User Wireless Communication. . . . .	324
1.12	Approximate Signal Processing. . . . .	324
1.13	A Framework for Low-Complexity Communication Over Channels with Feedback . . . . .	325
1.14	Analysis and Applications of Systems Exhibiting Stochastic Resonance . . . . .	325
1.15	Linear Models for Randomized Sampling of Discrete-Time Signals . . . . .	326
1.16	Modeling and Design of Approximate Digital Signal Processors and Approximate DSP Networks . . . . .	326
1.17	Sinusoidal Analysis Synthesis. . . . .	327
1.18	Speech Enhancement with Side Information. . . . .	327
1.19	Communications Using Chaotic Systems . . . . .	327
1.20	Parameter Estimation for Autoregressive Gaussian-Mixture Processes. . . . .	328
1.21	Array Processing Techniques for Broadband Mode Estimation . . . . .	328
1.22	Multiscale State-Space Algorithms for Processing 1/f Signals . . . . .	329
1.23	Publications . . . . .	329
1.24	Self-Powered Signal Processing . . . . .	331
<b>Chapter 2</b>	<b>Advanced Telecommunications and Signal Processing Program. . . . .</b>	<b>333</b>
<i>Professor Jae S. Lim</i>		
2.1	Introduction . . . . .	333
2.2	Signal Processing for Signals with Arbitrarily Shaped Regions of Support. . . . .	334
2.3	Source Multiplexing for Variable Bit Rate Video with Partial or Complete Information . . . . .	334
2.4	Speech Enhancement. . . . .	335
2.5	Real-Time Video on the Internet . . . . .	335
2.6	Digital Processing of Underwater Images . . . . .	335
2.7	HDTV Transmission Format Conversion and the HDTV Migration Path. . . . .	336
2.8	Study on Migration to a Higher Resolution Digital Television System. . . . .	336

<b>Section 3</b>	<b>Microelectromechanical Systems . . . . .</b>	<b>339</b>
<b>Chapter 1</b>	<b>Computer Microvision for Microelectromechanical Systems. . . . .</b>	<b>341</b>
<i>Professor Dennis M. Freeman, Professor Donald E. Troxel, Michael B. McIlrath</i>		
1.1	Computer Microvision for Microelectromechanical Systems . . . . .	341
1.2	Calibration of Fatigue Test Structures. . . . .	341
1.3	Modal Analysis of the Draper Gyroscope . . . . .	343
1.4	Speckle Heterodyne Microscopy. . . . .	345
1.5	Test Studies for Microelectromechanical Systems . . . . .	346
<b>PART IV</b>	<b>LANGUAGE, SPEECH, AND HEARING</b>	
<b>Section 1</b>	<b>Speech Communication . . . . .</b>	<b>351</b>
<b>Chapter 1</b>	<b>Speech Communication . . . . .</b>	<b>353</b>
<i>Professor Kenneth N. Stevens, Dr. Joseph S. Perkell, Dr. Stefanie Shattuck-Hufnagel</i>		
1.1	Studies of the Acoustics, Perception, Synthesis, and Modeling of Speech Sounds . . . . .	354
1.2	Studies of Normal Speech Production. . . . .	357
1.3	Speech Research Relating to Special Populations . . . . .	360
1.4	Speech Production Planning and Prosody . . . . .	363
1.5	Models of Lexical Representation and Lexical Access . . . . .	364
1.6	Laboratory Facilities for Speech Analysis and Experimentation . . . . .	366
1.7	Publications . . . . .	366
<b>Section 2</b>	<b>Sensory Communication. . . . .</b>	<b>369</b>
<b>Chapter 1</b>	<b>Sensory Communication . . . . .</b>	<b>371</b>
<i>Professor Louis D. Braida, Nathaniel I. Durlach, Dr. Cagatay Basdogan, Dr. Julie E. Greenberg, Dr. William M. Rabinowitz, Dr. Charlotte M. Reed, Dr. Mandayam A. Srinivasan, Dr. Thomas E.v. Wiegand, Dr. Patrick M. Zurek</i>		
1.1	Introduction . . . . .	371
1.2	Hearing Aid Research . . . . .	371
1.3	Enhanced Communication for Speechreaders . . . . .	375
1.4	Tactile Communication of Speech. . . . .	379
1.5	Multimicrophone Hearing Aids. . . . .	381
1.6	Hearing-Aid Device Development . . . . .	382
1.7	Binaural Hearing . . . . .	382
1.8	Virtual Environment Technology for Training . . . . .	383
1.9	Training for Remote Sensing and Manipulation . . . . .	393
1.10	Training Spatial Knowledge Acquisition Using Virtual Environments . . . . .	398
1.11	Further Research on Superauditory Localization for Improved Human-Machine Interfaces. . . . .	399
1.12	Role of Skin Biomechanics in Mechanoreceptor Response . . . . .	399
1.13	Force-Reflecting Soft-Tissue Models for Simulating Laparoscopic Surgical Procedures in Virtual Reality Systems . . . . .	407

<b>Section 3</b>	<b>Auditory Physiology . . . . .</b>	<b>409</b>
<b>Chapter 1</b>	<b>Signal Transmission in the Auditory System . . . . .</b>	<b>411</b>
<i>Professor Dennis M. Freeman, Professor William T. Peake, Professor Thomas F. Weiss, Dr. Bertrand Delgutte, Dr. John J. Rosowski</i>		
1.1	Middle and External Ear . . . . .	411
1.2	Cochlear Mechanisms . . . . .	413
1.3	Auditory Neural Coding of Speech . . . . .	418
1.4	Neural Mechanisms of Spatial Hearing . . . . .	420
<b>Section 4</b>	<b>Linguistics . . . . .</b>	<b>423</b>
<b>Chapter 1</b>	<b>Linguistics . . . . .</b>	<b>425</b>
<i>Professor Morris Halle, Professor Noam A. Chomsky</i>		
1.1	Introduction . . . . .	425
1.2	Abstracts of Doctoral Dissertations . . . . .	425
<b>APPENDICES</b>		
<b>Appendix A</b>	<b>RLE Publications and Papers Presented . . . . .</b>	<b>431</b>
A.1	Meeting Papers . . . . .	431
A.2	Journal Articles . . . . .	443
A.3	Books/Chapters in Books . . . . .	457
A.4	RLE Publications . . . . .	458
A.5	RLE Theses . . . . .	459
<b>Appendix B</b>	<b>Current RLE Personnel . . . . .</b>	<b>463</b>
<b>Appendix C</b>	<b>Milestones . . . . .</b>	<b>467</b>
C.1	New Faculty and Research Staff . . . . .	467
C.2	Honors and Awards . . . . .	467
C.3	Promotions . . . . .	469
C.4	Retirement . . . . .	470
<b>Appendix D</b>	<b>RLE Research Support Index . . . . .</b>	<b>471</b>
<b>Project Staff and Subject Index . . . . .</b>		<b>475</b>

