

Table of Contents

1. Molecule Microscopy	1
1.1 Research Objectives	1
1.2 Design of Nanometer SDMM	2
1.3 Scanning Micropipette Molecule Microscopy (SMMM)	3
1.4 Electrical Neutrality of Molecules	4
2. Semiconductor Surface Studies	5
2.1 Excitations at Surfaces and Interfaces of Solids	5
3. Atomic Resonance and Scattering	7
3.1 Rydberg Atoms in a Magnetic Field	7
3.2 Multiphoton Ionization	9
3.3 Atoms in "Circular" States	10
3.4 Laser Induced Fluorescence Study of NaAr	14
3.5 Vibrationally Inelastic Collisions	15
3.6 Diffraction of Sodium Atoms by a Standing Wave Laser Field	15
3.7 A Search for Radiative Transitions in Atom-Molecule Systems	17
3.8 Rotationally Inelastic Collisions	18
4. Reaction Dynamics at Semiconductor Surfaces	19
5. X-Ray Diffuse Scattering	21
5.1 Intercalation Compound Structures and Transitions	21
5.2 Smectic Liquid Crystals	22
6. Phase Transitions in Chemisorbed Systems	25
6.1 Oxygen on Nickel and other Chemisorption Phase Diagrams	25
6.2 Commensurate-Incommensurate Phase Transitions, Domain Walls, and Helicity in Two-Dimensional Systems	26
6.3 Multicritical Phenomena in Cubic Symmetry Systems	26
6.4 Crossover to Equivalent-Neighbor Multicritical Behavior	27
6.5 Hydrogen-Bonding and Helix-Coil Transformations	27
6.6 Improved Renormalization-Group Transformations	28
7. Optics and Quantum Electronics	31
A. Nonlinear Phenomena	31
7.1 Picosecond Optical Signal-Sampling Device	31
7.2 Devices for High-Rate Optical Communications	32
7.3 Picosecond Optics	35
7.4 Ultrashort Pulse Formation	37
7.5 Femtosecond Laser System	37
7.6 Parametric Scattering with Femtosecond Pulses	38
7.7 Near-IR Diagnostics	38
7.8 Quaternary (InGaAsP) Diagnostics	39
B. Grating Structures	40
7.9 Surface Acoustic Wave Gratings	40
8. Photonics	43
8.1 Ultrahigh-Resolution Spectroscopy and Frequency Standards in the Microwave and MM Wave Regions Using Optical Lasers	43

8.2 Resonant Light Diffraction by an Atomic Beam	44
8.3 Precision Atomic Beam Studies of Atom-Field Interactions	45
8.4 Measurement of Natural Predissociation Effects in Iodine Molecules	46
8.5 Passive Ring Resonator Method for Sensitive Inertial Rotation Measurements in Geophysics and Relativity	46
8.6 Closed Loop, Low Noise Fiberoptic Rotation Sensor	47
8.7 Fiberoptic Ring Resonator Gyroscope	48
9. Optical Spectroscopy of Disordered Materials and X-Ray Scattering from Surfaces	49
10. Infrared Nonlinear Optics	53
10.1 Infrared Nonlinear Processes in Semiconductors	53
11. Quantum Optics and Electronics	55
11.1 Nonlinear Optical Interactions in Semiconductors	55
11.2 Picosecond Dye Laser Optics	56
11.3 Nonlinear Spectroscopy of Atoms and Molecules	56
12. Microwave and Millimeter Wave Techniques	59
12.1 Cooled FET Amplifiers at 8 and 15 GHz	59
13. Microwave and Quantum Magnetics	63
13.1 Millimeter Wave Magnetics	63
13.2 New Techniques to Guide and Control Magnetostatic Waves	64
13.3 Optical and Inductive Probing of Magnetostatic Resonances	64
13.4 Magnetostatic Wave Dispersion Theory	65
13.5 Magnetoelastic Waves and Devices	65
13.6 Microwave Hyperthermia Group	66
13.7 Design of Planar Arrays	66
14. Radio Astronomy	69
14.1 Microwave Spectroscopy of the Interstellar Medium	69
14.2 Galactic and Extragalactic Radio Astronomy	70
14.3 Interacting Galaxies	71
14.4 The 6 cm Radio Survey	71
14.5 Morphology and Optical Identifications	71
14.6 Interstellar Masers	72
14.7 VLBI Studies	72
14.8 Planned Program, 1983-84	73
14.9 Jovian Decametric Radiation	74
14.10 Long-Baseline Astrometric Interferometer	75
14.11 Tiroso-N Satellite Microwave Sounder	75
14.12 Improved Microwave Retrieval Techniques	76
14.13 Scanning Multi-Channel Microwave Radiometer (SMMR)	77
14.14 Video-Bandwidth Compression Techniques	77
14.15 Communications Satellites	78
14.16 Electrostatically-Figured Membrane Reflector	78
15. Electromagnetic Wave Theory and Remote Sensing	81
15.1 Electromagnetic Waves	81
15.2 Remote Sensing with Electromagnetic Waves	81

15.3 Acoustic Wave Propagation Studies	82
15.4 Remote Sensing of Vegetation and Soil Moisture	82
15.5 Passive Microwave Snowpack Experiment	82
15.6 Remote Sensing of Earth Terrain	83
16. Electronic Properties of Amorphous Silicon Dioxide	87
17. Photon Correlation Spectroscopy and Applications	89
17.1 Research Program	89
18. Submicron Structures Fabrication and Research	91
18.1 Submicron Structures Lab	91
18.2 Microstructure Fabrication at Linewidths of 0.1 μm and Below	92
18.3 Reactive Sputter Etching Studies	92
18.4 Electronic Conduction in Ultra-Narrow Silicon Inversion Layers	93
18.5 Corrugated-Gate MOS Structures	94
18.6 Graphoepitaxy of Si and Model Materials	94
18.7 Zone Melting Recrystallization of Si for Solar Cells	95
18.8 Zone Melting Recrystallization of InSb and InP	95
18.9 Submicrometer-Period Gold Transmission Gratings and Zone Plates for X-Ray Spectroscopy and Microscopy	95
18.10 High Dispersion, High Efficiency Transmission Gratings for Astrophysical X-Ray Spectroscopy	96
18.11 Switchable Zero-Order Diffraction Gratings as Light Valves	96
18.12 Filters Based on Conversion of Surface Acoustic Waves to Bulk Plate Modes in Gratings	97
18.13 Collaborative Projects	97
19. Plasma Dynamics	101
19.1 Relativistic Electron Beams and Generation of Coherent Electromagnetic Radiation	101
19.2 Nonlinear Wave Interactions—RF Heating and Current Generation in Plasmas	107
19.3 Tokamak Research: RF Heating and Current Drive	112
19.3.1 Top Launching Experiments	113
19.3.2 Particle Confinement	117
19.3.3 Versator Upgrade	119
19.3.4 S-Band Current Drive Experiment	119
19.3.5 Tail Mode Instability	120
19.3.6 Ion Heating	121
19.3.7 Diagnostic Experiments	122
19.3.8 UV and Visible Diagnostics	122
19.3.9 Thomson Scattering	122
19.3.10 X-Ray Measurements	123
19.4 Physics of Thermonuclear Plasmas	124
20. Optical Propagation and Communication	127
20.1 Atmospheric Optical Communication Systems for Network Environments	127
20.2 Atmospheric Propagation Effects on Infrared Radars	128
20.3 Improved Millimeter-Wave Communication Through Rain	129
20.4 Two-Photon Coherent State Light	129
20.5 Fiber-Coupled External-Cavity Semiconductor High-Power Laser	130
21. Digital Signal Processing Group	133

21.1 Introduction	133
21.2 Parabolic Wave Equation Modeling for Underwater Acoustics	136
21.3 Adaptive Image Restoration	137
21.4 Signal Reconstruction from Partial Fourier Domain Information	137
21.5 Knowledge-Based Pitch Detection	138
21.6 Multi-Dimensional High-Resolution Spectral Analysis and Improved Maximum Likelihood Method	139
21.7 Processing and Inversion of Arctic Refraction Data	140
21.8 Signal Estimation from Modified Short-Time Fourier Transform	141
21.9 Speech Enhancement Using Adaptive Noise Cancelling Algorithms	142
21.10 Overspecified Normal Equations for Autoregressive Spectral Estimation	142
21.11 Spectral Analysis Methods for Non-Stationary Time Series	143
21.12 Speech Coding Using the Phase of the Long-Time LPC Residual Signal	144
21.13 The Numerical Synthesis and Inversion of Acoustic Fields Using the Hankel Transform with Application to the Estimation of the Plane Wave Reflection Coefficient of the Ocean Bottom	144
21.14 Optimal Signal Reconstruction and ARMA Model Identification Given Noisy and Incomplete Observation Data	145
21.15 The Use of Speech Knowledge in Speech Enhancement	146
21.16 Estimation of the Degree of Coronary Stenosis Using Digital Image Processing Techniques	147
21.17 Automatic Target Detection in Aerial Reconnaissance Photographs	148
21.18 Enhancement of Helium-Degraded Speech	149
21.19 Facial Parameterization for Low Bit Rate Video Conferencing	149
21.20 Bottom Profile Determination in a Shallow Ocean	150
22. Speech Communication	151
22.1 Speech Recognition	152
22.1.1 Phonological Properties of Large Lexicons	152
22.1.2 Lexical Access	153
22.1.3 Acoustic Cues for Word Boundaries	154
22.1.4 Speaker-Independent, Continuous Digit Recognition	155
22.1.5 LAFS Recognition Model	155
22.1.6 Interactive Speech Research Facilities	155
22.2 Auditory Models and Analysis Techniques	156
22.3 Speech Synthesis	156
22.4 Physiology of Speech Production	157
22.5 Acoustics of Speech Production	158
22.6 Speech Production Planning	159
22.7 Studies of Acoustics and Perception of Speech Sounds	160
22.8 Speech Processing in Children and Older Subjects	161
23. Linguistics	163
24. Cognitive Information Processing	165
24.1 Picture Coding	165
24.2 Digital Wirephoto ²⁶ System	
24.3 Graphic Arts Applications	167

²⁶Trademark of the A.P.

24.4 Automated Engraving of Gravure Printing	168
25. Custom Integrated Circuits	171
25.1 Conversion of Algorithms to Custom Integrated Circuits	171
25.2 A Circuit Theory for Digital VLSI Systems	175
25.3 Very Large Scale Integrated Circuit Research	176
26. Communications Biophysics	179
A. Signal Transmission in The Auditory System	179
26.1 Basic and Clinical Studies of the Auditory System	179
B. Auditory Psychophysics and Aids for the Deaf	181
26.2 Intensity Perception and Loudness	181
26.3 Hearing Aid Research	182
26.4 Tactile Perception of Speech	186
26.5 Discrimination of Spectral Shape by Impaired Listeners	187
C. Transduction Mechanisms in Hair Cell Organs	190
26.6 Evidence of Length-Dependent Mechanical Tuning of Hair Cell Stereociliary Bundles in the Alligator Lizard Cochlea: Relation to Frequency Analysis	190
27. Physiology	193
28. Publications and Reports	195
28.1 Meeting Papers Presented	195
28.2 Journal Papers Published	209
28.3 Journal Papers Accepted for Publication	212
28.4 Letters to the Editor Published	213
28.5 Letters to the Editor Accepted for Publication	215
28.6 Special Publications	215
28.7 Technical Reports Published	215
29. Personnel	217
30. Research Support Index	225

List of Figures

Figure 3-1:	Two-Photon Resonance in Lithium	8
Figure 3-2:	The cross section for 4 photon ionization of atomic hydrogen as calculated by Reinhardt for a single frequency laser. To facilitate comparison, the cross section has been divided by I^3 . As the intensity increases, the peaks shift to the blue and become broader.	10
Figure 3-3:	Ionization profiles produced by laser intensity I^0 and at five times that intensity $5I^0$. As the laser intensity is increased, the ionization profile becomes broad and asymmetric and is shifted to the blue of threshold.	11
Figure 3-4:	Schematic diagram of the excitation process, illustrated with hydrogen, $n = 4$. a) (above) Energy levels in an electric field, neglecting the second order Stark effect. The bold arrows show the excitation path used to populate the circular state, $ m = 3$; the light arrows show an alternative excitation route; the dashed arrows show "leakage" transitions which must be avoided. b) (below) The progression of $n_1 = 0$ levels in a decreasing field, with the second order Stark effect exaggerated for clarity. An adiabatic rapid transition can occur whenever the energy level separation passes through resonance with the microwave frequency ν . Because of the second order Stark effect these transitions occur successively, "stepping" the population along the route shown in a), above.	12
Figure 3-5:	Distribution of population in lithium for various values of $ m $ as revealed by selective field ionization. States are $n = 19, n_1 = 0$. The ionization field increases with time. The ionization thresholds occur in increasing fields as $ m $ increases. a) $ m = 2$ states initially populated by laser excitation in a field of 830 Vcm^{-1} . The signal is clipped due to saturation of the detector. The small peak to the left is due to $ m = 0$ atoms. The small peak to the right is due to $ m = 2$ atoms which ionize hydrogenically. The $ m = 2$ peak occurs at approximately 4.5 kVcm^{-1} . b) Same as a), but with the adiabatic rapid passage field ramp on for a time $\tau_{rp} = 4 \mu\text{s}$. The $ m = 2$ population has been transferred predominantly to $ m = 17$. c) τ_{rp} increased: ionization signals for $ m = 17$ and 18 are both visible. d) $\tau_{rp} > 4.5 \mu\text{s}$. The $ m = 18$ circular states is populated. No further change in the ionization signal occurs with increasing τ_{rp} . The ionizing field is approximately 5.9 kVcm^{-1} .	13
Figure 3-6:	Figure 3	16
Figure 3-7:	Figure 4	16
Figure 7-1:	Figure 5	36
Figure 19-1:	Soft x-ray spectra of (a) ohmic discharge before RF pulse (b) during injection of 45 kW of lower-hybrid power	116
Figure 19-2:	Temporal evolution of signals during the LHCD density increase: (a) plasma current, (b) loop voltage, (c) density, (d) central chord brightness of H_{β} 4661A, (e) central chord brightness of CV 2271A $P_{RF} = 10 \text{ kW}, \Delta\phi = +60^\circ$	117
Figure 19-3:	Temporal evolution of signals during LHCD density increase (a) plasma current, (b) loop voltage, (c) density, (d) density fluctuation level from 2 mm microwave scattering, $f_0 = 325 \text{ kHz}$, (e) hard x-ray signal, (f) edge density from Langmuir probe, (g) central chord brightness of H_{β}	118
Figure 19-4:	Frequency spectrum of RF bursts with/without LHCD from RF probe in limiter shadow	121

Figure 19-5: Hard x-ray profiles from scanning hard x-ray spectrometer
Figure 20-1: Photograph of External Cavity

123
131