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Final Report

Workshop on Optical Properties of Mesoscopic Semiconductor Structures

ONR Contract No. N00014-91-J-1302

Principal Investigator:

P. Craig Taylor
Department of Physics
University of Utah
Salt Lake City, UT 84112

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Abstract

A Workshop on Optical Properties of Mesoscopic Semiconductor Structures was held at Snowbird, UT on 23-26 April 1991. The workshop attracted approximately 85 attendees with 22 invited speakers and approximately 20 contributed speakers. The objective of the workshop was to focus on fundamental electronic and optical processes and device applications of novel semiconducting microstructures, with particular emphasis upon understanding, optimizing and exploiting large optical nonlinearities.

Conference Summary

The Workshop on Optical Properties of Mesoscopic Semiconductor Structures held at Snowbird, UT between April 23 and April 26, 1991 provided a broad-based forum for discussion of new results—both experimental and theoretical—aimed towards understanding the physical basis for fast electronic and optical responses in semiconductors, especially in semiconductor heterostructures, superlattices, quantum wires and dots. The invited and contributed papers discussed the following topics:

- Bulk and interfacial atomic structure of semiconducting structures
- Optical absorption, reflectivity, and dielectric response of semiconducting materials and structures
- Microscopic features affecting electronic structure, recombination, and linear and nonlinear optical response
- Spatial localization and atomic scattering potentials and their influence on interlevel, electronic k-space mixing, including band dispersion under superlattice formation
- Electronic and optical properties of excitons and exciton-polaritons in bulk and quantum structures
- Fast carrier (and excitonic) cooling and carrier-carrier scattering
- Fast carrier (and excitonic) radiative and nonradiative recombination processes
- Excitonic screening on fast time scales
- Carrier and excitonic decay and nonlinear response in symmetric versus asymmetric quantum wells, and in type II heterostructures and superlattices
- Experiment and/or theory relating to 2D to 3D microstructure behavior
- Optical measurement in any highly polarizable excitonic system
- Impurity-related optical nonlinearities
- Transient grating, 4-wave mixing, and echo experiments and theory relating to electronic dephasing processes in bulk and microstructures
- Incoherent and coherent energy transfer processes, both intrinsic and extrinsic

- Quantum beats and coherent polarization decay in semiconductors
- Gain, stimulated emission, and superradiance and their dependences on semiconductor microstructure
- Nonlinear mixing under high electric fields in small structures
- Phenomena leading to high-speed generation, response, and switching
- Coulombic and piezoelectric influences on linear and nonlinear optical response
- Conceptual and physical limitations for devices and device structures

The goal of the conference, which was by-and-large achieved, was to provide a platform for a unified, cross-disciplinary approach to optical processes in semiconductor nanostructures that emphasized atomic-scale dimensions and interactions. Researchers were brought together from diverse fields—those who have traditionally not met in the past—for the express purpose of discussing optical nonlinearities. A copy of the program for the Workshop is enclosed in the Appendix. There were no proceedings published as a result of this Workshop.

APPENDIX

Workshop on

OPTICAL PROPERTIES OF MESOSCOPIC SEMICONDUCTOR STRUCTURES

April 23-26, 1991
Snowbird, Utah

MONDAY, APRIL 22

- 6:00 Registration
8:00 Reception in Eagles Nest

TUESDAY, APRIL 23

- 8:00 *Discussion Leader: G. Döhler*
Invited Speaker: H. Gibbs, University of Arizona, *Nonlinear Physics and Photonics with MBE Heterostructures*
- 8:30 Discussion
- 9:00 *Discussion Leader: L.J. Sham*
Invited Speaker: G.F. Bassani, Scuola Normale Superiore, *Polaritons in Quantum Wells*
- 9:30 Discussion
- 10:00 BREAK
- 10:30 *Discussion Leader: M. Jaros*
Invited Speaker: E. Hanamura, University of Tokyo, *Mesoscopic Enhancement of Excitonic Optical Nonlinearities and Superradiant Decays*
- 11:00 Discussion
Contributors: R. Tsu, *Physics of 3-D Quantum Confinement*
- 11:30 *Discussion Leader: T. Reinecke*
Invited Speaker: D. Smith, Los Alamos National Laboratory, *Influence of Piezoelectric Fields on the Optical Properties of Mesoscopic Semiconductor Structures*
- 12:00 Discussion
Contributor: B.V. Shanabrook, *Intersubband Transitions in Piezoelectric Superlattices*

12:30 BREAK

2:00 *Discussion Leader: S. Bishop*

Invited Speaker: D.J. Wolford, IBM Yorktown, *Optical Spectra of Interface Free GaAs Structures-- From Bulk to the Quantum Limit*

2:30 Discussion

Contributors: M. Dutta, *GaAs-AlAs Quantum Wells Coupled via the X-valley in the Barriers*

R.G. Ulbrich, *Optical Interband Transitions in Gallium Arsenide: The Effect of Magnetic Confinement on Absorption and Emission Spectra*

3:00 *Discussion Leader: R.G. Ulbrich*

Invited Speaker: W.H. Knox, AT&T Bell Laboratories, *Ultrafast Dynamical Response of Quantum Well Excitons in Applied Fields*

3:30 Discussion

Contributors: P.M. Faucher, *Femtosecond Refractive Nonlinearities Due to Hot-Carrier and Many-Body Effects in Thin GaAs Films*

T. Reinecke, *Effects of Phonon Confinement on the Optical Properties of Semiconductor Nanostructures*

P.Y. Yu, *Study of Nonequilibrium Phonons and Electron-Phonon Interaction in Quantum Wells*

M. Strosio, *Transition from LO-Phonon Scattering to SO-Phonon Scattering in Superlattices and Scaling of Phonon Scattering Rates in Mesoscale Structures*

J.J. Song, *Study of Well-to-Well Phonon Coupling in GaAs/Al_xGa_{1-x}As Superlattices*

4:00 BREAK

4:30 *Discussion Leader: D. Ferry*

Invited Speaker H. Haug, University of Frankfurt, *Coulomb Effects in Semiconductor Microstructures*

5:00 Discussion

Contributor: D. Ferry, *Monte Carlo Simulation of Fast Processes in Semiconductors*

5:30 *Discussion Leader: M. Reed*

Invited Speaker J. Shah, AT&T Bell Laboratories, *Coherent Oscillations of an Electronic Wavepacket in Quantum Wells*

6:00 Discussion

WEDNESDAY, APRIL 24

- 8:00 *Discussion Leader: D. Wolford*
- Invited Speaker: T. Kennedy, Naval Research Laboratory, *Recombination in Superlattices Studied through Optically-Detected Magnetic Resonance*
- 8:30 Discussion
- Contributors: B. McCombe, *Barrier Penetration Effects on Hydrogenic Donor Levels and Cyclotron Resonance in Doped GaAs/Al_{0.5}Ga_{0.7}As Superlattices*
- J.L. Merz, *The Effect of Quantum Confinement on Impurities in Semiconductors*
- K.L. Wang, *Intersubband Transitions in Step Quantum Wells*
- E.E. Haller, *Far IR Spectroscopy at Large Hydrostatic Pressures*
- 9:00 *Discussion Leader: D.L. Smith*
- Invited Speaker: A. Smirl, University of Iowa, *Nonlinear Optical Properties of Binary Short-Period, Strained-Layer Superlattices*
- 9:30 Discussion
- Contributor: G. Döhler, *How to Optimize Optical Nonlinearities Due to Bandfilling Effects by Using Hetero n-i-p-i Structures*
- 10:00 BREAK
- 4:00 *Discussion Leader: P.M. Petroff*
- Invited Speaker: G.B. Stringfellow, University of Utah, *Naturally Occurring Superlattices in III/V Alloys*
- 4:30 Discussion
- Contributors: O.J. Glembocki, *Scanning Tunneling Microscopy in Optical Interactions of Mesoscopic Systems*
- F.H. Pollak, *Optical Properties of Mesoscopic Structures for Surface/Interface Studies*
- M. Maserjian, *Optically Induced Absorption in Periodically δ -Doped InGaAs Multiple Quantum Well Structures*
- 5:00 *Discussion Leader: R. Bhargava*
- Invited Speaker: J. Khurgin, Johns Hopkins University *Coulomb Enhancement of Nonlinearities in Semiconductor Heterostructures*
- 5:30 Discussion
- Contributor: J.S. Harris, *Optical Non-linearities in Asymmetric Quantum Wells*

THURSDAY, APRIL 25

- 8:00 *Discussion Leader: K. Bajaj*
- Invited Speaker: D. Heitmann, Max-Planck Institute, *Excitons and Polaritons in GaAs Quantum Wires*
- 8:30 Discussion
- Contributors: J. Christen, *Optical Properties of Semiconductor Quantum Wire Heterostructures Grown by Organometallic Chemical Vapor Deposition on Nonplanar Substrates*
- L.I. Sham, *Hole Relaxation and Its Effect on Luminescence Spectra*
- 9:00 *Discussion Leader: J.D. Dow*
- Invited Speaker: K. Kash, Bellcore *Spectroscopy of Excitons Confined to Quantum Wires and Dots by Strain Gradients*
- 9:30 Discussion
- Contributor: M.A. Reed, *Semiconductor Quantum Dot Resonant Tunneling Spectroscopy*
- 10:00 BREAK
- 10:30 *Discussion Leader: G.B. Stringfellow*
- Invited Speaker: P.M. Petroff, University of California, Santa Barbara, *Electronic Structure and Optical Properties of (Ga,Al)As Quantum Wire Arrays Formed by Serpentine-Superlattices*
- 11:00 Discussion
- Contributors: Y.-C. Chang, *Optical Properties and Phonon Modes of Semiconductor Quantum Wires*
- 11:30 *Discussion Leader: J.L. Merz*
- Invited Speaker: M. Pilkuhn, University of Stuttgart, *Optical Properties of 1D/2D Structures: Recent Results on the Influence of Barriers*
- 12:00 Discussion
- Contributor: C.S. Lent, *Optical Properties of Quantum Waveguide Structures*
- 12:30 BREAK
- 2:00 *Discussion Leader: P.M. Fauchet*
- Invited Speaker: J.G. Fujimoto, Massachusetts Institute of Technology, *Femtosecond Studies of Nonresonant Optical Nonlinearities in Waveguide Devices for all Optical Switching*
- 2:30 Discussion
- 3:00 *Discussion Leader: K.K. Bajaj*
- Invited Speaker: J. Singh, University of Michigan, *Intrinsic Power and Speed Issues in Stark Effect*

Optical Devices and Strained Quantum Well Lasers

- 3:30 Discussion
Contributor: K.K. Bajaj, *Quantum Well Based Spatial Light Modulators: Effects of Potential Profiles on Their Performance*
- 4:00 BREAK
- 4:30 *Discussion Leader: K.J. Vahala*
- Invited Speaker: A. Yariv, California Institute of Technology, *Optical Properties of Quantum Confined Lasers and Their Applications*
- 5:00 Discussion
- 5:30 *Discussion Leader: S. Das Sarma*
- Invited Speaker: E. Yablonovitch, Bellcore, *Electronic and Photonic Band Structure Engineering of Semiconductor Lasers*
- 6:00 Discussion
- 7:30 BANQUET in Golden Cliff Room

FRIDAY, APRIL 26

- 8:00 *Discussion Leader: J.S. Harris*
- Invited Speaker: G.R. Olbright, Sandia National Laboratories, *Cascadable Surface-emitting Laser Logic*
- 8:30 Discussion
- 9:00 *Discussion Leader: R. Tsu*
- Invited Speaker: T.C. McGill, California Institute of Technology, *Optical Properties of II-VI Mesoscopic Structures*
- 9:30 Discussion
Contributors: G. Livescu, *Quantum Well Opto-Electronic Devices--Materials and Design Issues*
A.V. Nurmikko, *Optical Physics and Device Prospects in Lower Dimensional II-VI Quantum Confined Systems*