REPORT DOCUMENTATION PAGE	*Form Approved* *OMB NO. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comment regarding this burden estimates or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE 9/13/96	3. REPORT TYPE AND DATES COVERED Final 1 Jun 92 - 30 Jun 96

4. TITLE AND SUBTITLE "Laser and Optical Physics"	5. FUNDING NUMBERS DAAL03-92-G-0266

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9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211	10. SPONSORING / MONITORING AGENCY REPORT NUMBER ARO 29572.5 -PH

11. SUPPLEMENTARY NOTES

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.	12 b. DISTRIBUTION CODE 19961025 071

13. ABSTRACT *(Maximum 200 words)*

The following problems have been studied (1) the use of light-scattering techniques to make quasi-binary decisions about small systems in real time (2) tunneling through barrier between quantum wells (3) diffraction feedback lasers which involves the interaction of light with micro systems, including the use of spontaneous emission as a diagnostic tool.

DTIC QUALITY INSPECTED 1

14. SUBJECT TERMS Drop image using light scattering; Electronic tunneling; Diffraction Feedback semiconductor lasers			15. NUMBER IF PAGES 6
			16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL

"Laser and Optical Physics"

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The following problems were studied

(1) the use of light-scattering techniques to make quasi-binary decisions about small systems in real time

(2) tunneling through barrier between quantum wells

(3) Study of diffraction feedback lasers which involves the interaction of light with micro systems, including the use of spontaneous emission as a diagnostic tool.

Recent Progress on Sphere-Shell Discrimination

Significant recent progress is reported on the problem of using light scattering to discriminate between homogeneous spheres such as water droplets, and shells. such as a fluid that can be bacteriological encapsulated in a plastic shell.

This problem was considered well-nigh impossible two years ago because of the extremely rapid variation of the light scattering with index of refraction and radius, and because the light scattering measurements had only ten percent accuracy.

The first effort was a feasibility study. Would ten measurements supply enough information to discriminate, no matter how long it took. By combining Mie light scattering theory with a sophisticated decision theory analysis ten measurements were found to be adequate, but

close to 30 hours of Cray time was needed.

In the next stage, the scattering calculations were speeded up a factor of 10 by precomputing the Bessel functions used there. In the third stage, a sample data-base was set up for comparison purposes. Calculations were done in a reasonable time. But proper accuracy requires a full (not a sampled) data base. Because of the high variability of intensity with radius and index many points (indices and radii) were necessary. For the shell case, a trillion data words of 32 bits were needed. It would not matter how long it took to construct this data base, but it would take too long to search.

In the fourth stage, a compromise was made in which a complete calculation is made during the construction of the data base, but the information is stored in partial form. The information need not be stored to better than 10% accuracy. Moreover, the parameter region can be broken up into cells and one can record with a single bit if anywhere in the cell there are parameters compatible with a given intensity of scattering at a particular angle. This data base was only 200 million 8-bit bytes, and can be searched much faster than the original data base of one trillion 4 byte words. To compensate for this, after some "hits" are found in permissible cells, the numerical calculations must be repeated in the selected cells. Typically only one one-thousandth of the cells are eligible. Thus during the part of the calculation done on an experimental droplet, the calculation time was reduced by a factor one-thousand.

In the fifth and current stage, we have examined empirically, the extent to which a typical spherical droplet is compatible with a spherical data base, and the extent to which a shell is compatible withe the same sphere data base. We found that the shell usually had one or more errors with respect to a sphere data base, whereas sphere typically had none. Thus a preliminary judgement can be made using the much smaller spherical data base alone. Only if

one wishes, for a shell to determine its parameters is the shell database needed. The time for the preliminary judgement was 2 seconds on Sindoni's fast SGI machine at Edgewood arsenal.

Tunneling through quantum barriers

Tunneling through double barriers or heterostructures is important in high frequency electronics. Inelastic tunneling with phonon interactions requires non-perturbative techniques. We have developed a solvable model based on space independent interactions, and a Green's function method that permits space dependence. Arbitrary barrier structures are permitted.

Using the theory we developed, we have studied the following subject:

(a) the electron-phonon scattering in a resonant tunneling device;

(b) the electron transmission above a quantum well with dissipation;

(c) the effects of an applied infrared laser on electron tunneling;

(d) the spatial behavior of high-frequency tunneling current;

(e) the time response of the tunneling current to an applied pulse.

DFB (Diffraction Feedback) Semiconductor Lasers

We have solved the stationary nonuniform mode equations and obtained the main mode and corresponding gain profile for a DFB lasers. With the above gain we have calculated all "linear" (decaying) modes of DFB laser and have also obtained the gain differential between the main and the side modes of the DFB laser.

We have developed a general theory for noise fluctuations in open optical systems with gain or loss based on an expansion in terms of nonorthogonal quasimodes. Below

threshold, this method is formally equivalent to use of Green's matrices. The modes and the fluctuation spectra above threshold for a DFB laser have been calculated including gain saturation effects.

List of Publications

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[2]M. Lax and W. Cai, "Effect of Nonequilibrium Phonons on the Electron Relaxation and Transport", Intl. Journal of Mod. Phys. 6, 975-1006, (1992)

[3]B. E. Vugmeister and M. Lax "Electronic-excitation decay kinetics in disordered media: Independent-modes approximation", Phys. Rev. B 46, 6126-6130, (1992)

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[14]W. Cai, B. B. Das, F. Liu, M. Zevallos, M. Lax, R. R. Alfano, "Time Resolved Diffusion Tomographic Image Reconstruction in Highly Scattering Turbid Media" in *OSA TOPS on Advances in Optical Imaging and Photon Migration, 1996* Vol. 2 R. R. Alfano and James G. Fujimoto (eds) Optical Society of America

[15]V. A. Kremerman, M. Lax, S. G. Demos, Dana M. Calistru and R. R. Alfano "Nonradiative Energy Transfer From the Impurity ION Into The Host Lattice for Cr^{4+}-Doped Forsterite Laser Crystal" submitted to Phys. Rev. B

[16]A. Polishchuk, S. Gutman, M. Lax, and R. R. Alfano "Photon density modes beyond the diffusion approximation: scalar wave-diffusion equation" submitted to J. Opt. Soc. Amer. B

[17]W. Cai, B. B. Das, F. Liu, M. Zevallos, M. Lax, R. R. Alfano, "Time Resolved Optical Diffusion Tomographic Image Reconstruction in Highly Scattering Turbid Media" submitted to Proceedings of National Academy of Sciences

[18]W. Cai, B. Luo, M. Lax, B. B. Das, F. Liu, R. R. Alfano, "Impurity Detection in Turbid Media by

Diffusion Tomography'' submitted to Proceedings of the 1996 Scientific Conference on Obscuration and Aerosol Research, Aberdeen Proving Ground (1996)

[19]W. Cai, B. Luo, M. Lax, ''A Review of the Sphere-Shell Discrimination Problem'' submitted to Proceedings of the 1996 Scientific Conference on Obscuration and Aerosol Research, Aberdeen Proving Ground (1996)

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The following people have received at least partial support from this grant.

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