PROJECT ADMINISTRATION DATA SHEET

Reissued 8/9/83 to correct project number

G-41-644

[x] ORIGINAL [ ] REVISION NO. ____

Project No. ~~G-41-677~~ GTRI/~~GIT~~ DATE 8 / 5 / 83

Project Director: Dr. R. F. Fox School/~~Lab~~ Physics

Sponsor: National Science Foundation

Type Agreement: Grant No. PHY-8303729

Award Period: From 7/15/83 To 12/31/85 (Performance) 3/31/85 (Reports)

Sponsor Amount:	This Change	Total to Date
Estimated:	$ 18,000	$ 18,000
Funded:	$ 18,000	$ 18,000

Cost Sharing Amount: $ ____ Cost Sharing No: G-41-319

Title: Stochastic Phenomena in Physics

ADMINISTRATIVE DATA OCA Contact William F. Brown Ext. 4820

1) Sponsor Technical Contact:

Richard A. Isaacson, Program Official
Division of Physics
MPS Directorate
National Science Foundation
Washington, D. C. 20550
(202) 357-9651

2) Sponsor Admin/Contractual Matters:

Dione Henry, Grants Official
Div. of Grants and Contracts
Administration Directorate
National Science Foundation
Washington, D.C. 20550
(202) 357-9651

Defense Priority Rating: NA Military Security Classification: NA

(or) Company/Industrial Proprietary: NA

RESTRICTIONS

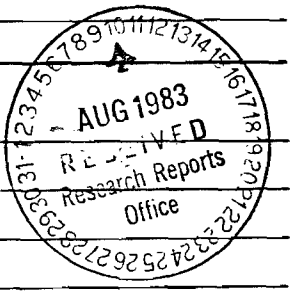
See Attached NSF Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with GIT; however, none proposed.

COMMENTS:

Continuing grant planned for three years.



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Research Communications (2)

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Other I. Newton

FORM OCA 4-383

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 3-20-87

Project No. G-41-644 School/~~Lab~~ Physics

Includes Subproject No.(s) N/A

Project Director(s) R.F. Fox GTRC / ~~GIT~~

Sponsor National Science Foundation

Title Stochastic Phenomena in Physics

Effective Completion Date: 12/31/86 (Performance) 3/31/87 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [ ] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [X] Final Report of Inventions - Questionnaire sent to P.I.
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No. Continued by Project No.

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Other Duane H.
Angela DuBose
Russ Embry

FORM OCA 69.285

GEORGIA TECH RESEARCH CORPORATION

ADMINISTRATION BUILDING
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332-0420

Telex: 542507 GTRIOCAATL
Fax. (404) 894-3120

Phone: (404) 894-4814

Refer to: LB/02.107.000.85.090

25 January 1985

National Science Foundation
Division of Physics
Theoretical Physics Program
1800 G Street, N.W.
Washington, DC 20550

Attention: Boris J. Kayser

Subject: Grant No. PHY-8303729; Request for Incremental-Funding for Continuing Grant entitled, "Stochastic Phenomena in Physics"

Gentlemen:

In accordance with NSF Grant Policies, the GEORGIA TECH RESEARCH CORPORATION is pleased to submit the Annual Progress Report and Request for Continued Support on the subject research project.

We believe that the enclosed material will provide you with all necessary information. However if additional information is required, please contact Dr. Fox at 404/894-5260 concerning the technical program. Contractual matters should be referred to the undersigned at 404/894-4814.

We appreciate the opportunity of submitting this request and look forward to the possibility of continuing our work with you on this project.

Sincerely,

Lynn Boyd
Contracting Officer

LB/cfd

Addressee: Five (5) copies/w enclosure
Enclosure: Progress Report - five (5) copies
Proposal Budget - five (5) copies
Statement of Funds Remaining - five (5) copies

PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION
Cover Page

FOR CONSIDERATION BY NSF ORGANIZATIONAL UNIT (Indicate the most specific unit known, i.e. program, division, etc.)	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? Yes____ No X : IF YES, LIST ACRONYM(S):
Theoretical Physics Program Division of Physics (PHY)	

PROGRAM ANNOUNCEMENT/SOLICITATION NO:	CLOSING DATE (IF ANY)

NAME OF SUBMITTING ORGANIZATION TO WHICH AWARD SHOULD BE MADE (INCLUDE BRANCH/CAMPUS/OTHER COMPONENTS)

GEORGIA TECH RESEARCH CORPORATION

ADDRESS OF ORGANIZATION (INCLUDE ZIP CODE)

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GA 30332-0420

TITLE OF PROPOSED PROJECT

Stochastic Phenomena in Physics

REQUESTED AMOUNT	PROPOSED DURATION	DESIRED STARTING DATE
$20,177	7/1/85 - 6/30/86	7/1/85

PI/PD DEPARTMENT	PI/PD ORGANIZATION	PI/PD PHONE NO.
School of Physics	**GEORGIA INSTITUTE OF TECHNOLOGY**	

PI/PD NAME	SOCIAL SECURITY NO.*	SIGNATURE	MALE*	FEMALE*
Ronald F. Fox	544-48-7262		X	
ADDITIONAL PI/PD				
ADDITIONAL PI/PD				
ADDITIONAL PI/PD				
ADDITIONAL PI/PD				

FOR RENEWAL OR CONTINUING AWARD REQUEST, LIST PREVIOUS AWARD NO.:	SUBMITTING ORGANIZATION IS: ☐ For-Profit Organization: ☐ Small Business; ☐ Minority Business; ☐ Women-Owned Business; (See cover page instructions, Page 3)
Continuing award #PHY-8303729	

*Submission of social security numbers is voluntary and will not affect the organization's eligibility for an award. However, they are an integral part of the NSF information system and assist in processing the proposal. SSN solicited under NSF Act of 1950, as amended.

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW:

☐ Animal Welfare	☐ Human Subjects	☐ National Environmental Policy Act
☐ Endangered Species	☐ Marine Mammal Protection	☐ Research Involving Recombinant DNA Molecules
☐ Historical Sites	☐ Pollution Control	☐ Proprietary and Privileged Information

PRINCIPAL INVESTIGATOR/ PROJECT DIRECTOR	AUTHORIZED ORGANIZATIONAL REP.	OTHER ENDORSEMENT (optional)
NAME: Ronald F. Fox	NAME: Lynn Boyd	NAME: Edward W. Thomas
SIGNATURE	SIGNATURE	SIGNATURE
TITLE: Professor of Physics	TITLE: **Contracting Officer**	TITLE: Director, School of Physics
DATE: 1/14/85	DATE: 1/16/85	DATE: 1/14/85
TELEPHONE NO. Area Code: (404) 894-5260	TELEPHONE NO. Area Code: (404) 894-4814	TELEPHONE NO. Area Code: (404) 894-5200

(REV. 8/5/83)

OMB No. 3145-005B
Exp. Date 12/31/85

SUMMARY PROPOSAL BUDGET

FOR NSF USE ONLY

ORGANIZATION: GEORGIA TECH RESEARCH INSTITUTE

PROPOSAL NO.

DURATION (MONTHS): Proposed | Granted

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR: Ronald F. Fox

AWARD NO.

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. PI - Ronald F. Fox			2	$ 9,245	$
2.					
3.					
4.					
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
6. (1) TOTAL SENIOR PERSONNEL (1-5)			2	9,245	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL-CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				9,245	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 24.3% of A.6				2,247	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				11,492	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000:)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				500	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $					
2. TRAVEL					
3. SUBSISTENCE					
4. OTHER					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/PAGE CHARGES				1,000	
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS				1,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				12,992	
I. INDIRECT COSTS (SPECIFY) Overhead: 55.3% of Direct Costs (rate effective through 7/1/84 - 6/30/85 and is subject to change thereafter)					
TOTAL INDIRECT COSTS				7,185	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				20,177	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 20,177	$

PI/PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY
Ronald F. Fox	1/14/85	INDIRECT COST RATE VERIFICATION
INST. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked | Date of Rate Sheet | Initials - DGC / Program
Lynn Boyd	1/16/85	

NSF Form 1030 (4-83) *Supersedes All Previous Editions*

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

Continuation request for NSF Grant PHY-8303729 by Ronald F. Fox

Summary of Scientific Progress

Several related research problems have received the most attention in the last year. Each has something to do with stochastic processes in physical systems.

In November, 1984, a paper appeared in Physical Review A on work done in collaboration with R. Roy on dye laser noise measurements and theory. We were able to establish a first principles approach to this problem which explains otherwise anomalous measurements of intensity correlations. This theory has several levels of description, starting at the density matrix level and ending at the semi-classical, phenomenological level used in the published paper. The density matrix level of description leads to equations which are tractable by numerical computation only. They have relevance for near threshold and sub-threshold behavior which has recently been explored experimentally by Mandel. A graduate student is currently engaged in attempting to apply these equations to Mandel's recent measurements and to measurements by R. Roy.

Also in the November issue of Physical Review A, a paper on long time tail measurements by light scattering appeared. I am continuing to study this phenomenon, although the problem now calls for new measurements rather than more theory.

Another graduate student is working on the application of my earlier work, on stochastic density matrices, to the analysis of light absorption spectra. We are looking at the consequences of accounting for non-Markovian effects of "colored" noise in this problem.

The study of the transition from order to chaos in non-linear systems has also become the object of intense study during the last year. We are

especially interested in the effects of external noise on such transitions. Some such studies have already been made by others since 1980, but no one else has distinguished between the effects of "additive" versus "multiplicative" noise in these systems. All previous work has used additive noise, whereas we have begun investigating multiplicative noise effect which have a strong physical basis. Preliminary results here are very encouraging.

Most exciting of all, however, is our study of the transition to chaos in a two level quantum system in a one mode resonant cavity. The cavity enhances the feedback action of the two level system's electromagnetic field, at least for one particular mode. The expectation values of all quantities describing the two level system and the electromagnetic field satisfy a closed system of non-linear equations, in the limit of a sufficiently populated electromagnetic field state. Using our Sun computer, we have been able to simulate the behavior of this system of five coupled equations and have found bifurcations, incommensurate frequency mixing, and full blown chaos. This last state is being investigated for its liapunov exponents, as an independent check of our spectral characterization. There is no doubt in our mind that we have discovered conditions for bona fide "quantum chaos", and we have identified the features necessary for its existence.

I have also been studying a biologically interesting population dynamics model in which "mode locking" occurs, and have been able to explain some of this behavior. This work is related to a Guggenheim fellowship I have been awarded to study the physical basis for biological evolution.

Statement of Budget and Residual Funds

Approximately $600 in travel and materials and supplies remains in my present grant. This will be spent before June, 1985.

My Guggenheim fellowship runs from January, 1985 to June, 1985 and overlaps only a little with my NSF work.

A separate proposal to work on dye laser noise with R. Roy was submitted to the DOE. It was essentially approved, at all levels, last November, but no money was awarded. Next month (February) a final disposition regarding actual funding will be made. Nevertheless, I proposed to the DOE that they pay me for the 12th month of my salary (9 month academic + 2 months NSF). My NSF research would then cover all my other projects only, with special emphasis on external noise in non-linear systems and its effect on the transition to chaos, and on the intrinsic transition to chaos in quantum systems.

Continuation request for NSF Grant PHY-8303729 by Ronald F. Fox

Summary of Scientific Progress

A major advance has been made during the past year in the facet of my research program dealing with dye laser fluctuations. In collaboration with Rajarshi Roy, an experimentalist in quantum optics who joined our staff a little over a year ago, I reviewed the theory of noise in lasers as it was formulated up to about 1982. For conventional lasers, this theory works well. For dye lasers, or any other secondary sources of coherent radiation, the statistical properties were found to be inconsistent with the predictions of the conventional theory. Roy, as a student with L. Mandel, had made the first and most extensive measurements of dye laser statistics. Several theoretical attempts by others did not really explain the new observations. I decided to return to the basic quantum mechanical description of a four level molecule in a pumping field and coupled to a lasing field. Using my density matrix theory for stochastic quantum mechanical systems, I was able to derive new contracted descriptions for the laser intensity of a dye laser, with a very precise accounting of how the fluctuations arise and affect the measured results. The theory differs, in several important respects, from the phenomenological guesses of other researchers. With Roy, computer simulations of the new equations were run and compared with all currently available measured data. The agreement is very heartening. A physical review letter preprint is enclosed as well as a preprint from a recent meeting in India (3rd International Symposium on Lasers and Applications, India Institute of Technology, Kanpur, India). A full length paper, to be submitted to Physical Review A, is in the last stages of preparation.

The problem of long time tails for the velocity autocorrelation function has also occupied my attention. A long paper appeared in Physical Review A

last June. In March, I will present an invited talk on this subject at the Conference on Statistical Mechanics at Davis, California.

I have employed computer approaches to this problem during the last year. These include a quantum mechanical analysis of a one-dimensional Kronig-Penney model with delta function potentials, and a "lattice gas" model in 2 dimensions. Both of these problems rapidly lead to programs which saturated the capacity of the available computers, because they involve rather large array processing schemes. I am currently engaged in trying to modify my programs for greater efficiency, or in order to run them on really big machines.

I have become very interested in the utilization of analogue computing techniques in the analysis of stochastic equations. The simulation of noise on a digital computer using a random number generating routine leads to several difficulties including slow speed and correlation artifacts of the generator. Analogue noise generation coupled to a digital computer by an analogue-digital converter looks very promising. Roy and I are already getting ready to try this technique on our laser noise simulations.

I have been also working on an old problem - the problem of multiphoton processes in molecules. I have found an elegant way of generalizing the well-known dipole coupling results to higher multipoles, which may prove to be of great importance for modern multiphoton work. A paper is in preparation.

Statement of Residual Funds

$1,643 remain in the budget for fiscal year 1983. However, between $6-700 will be required for the meeting in March, 1984, and the remainder will be needed for page charges. Both of these requirements will be encumbered soon.

Statement of Budget Increase

The request for $19,704 exceeds the nominal figure of $18,000 previously estimated for the fiscal year 1984. The 9.5% increase is a result of several factors: 1) increased salary level; 2) increased overhead rate; and 3) increased fringe benefits. Even so, I have still had to eliminate funds requests for computing, foreign travel, and for student or postdoctoral support. Hopefully, this modest increase can be accomodated.

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I—PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
School of Physics Georgia Institute of Technology Atlanta, Georgia 30332	Theoretical Physics	PHY-8303729
	4. Award Period From 7/15/83 To 12/31/86	5. Cumulative Award Amount $ 56,677

6. Project Title

STOCHASTIC PHENOMENA IN PHYSICS

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

Stochastic processes involve random fluctuations and their influence on physical phenomena. This research report covers five separate but related projects: 1) Laser light fluctuations; 2) Long-time-tails; 3) Stochastic differential equations; 4) Quantum chaos; and 5) Stochastic theory of spectral line shapes. Altogether, this work resulted in 8 publications and one thesis (see attachments) during the applicability of this grant. 1) Laser light fluctuations require careful analysis in order for the many applications of lasers to research and technology to be as precise as possible. The work reported here (papers 1, 2, 3) was done in collaboration with an experimentalist, R. Roy. It includes a novel method of fluctuation characterization (first passage times) with special emphasis on pump fluctuations which have not previously received adequate scrutiny. 2) The long-time-tails occur in kinetic theory of gases and liquids. The work reported here (paper 4) finishes earlier work supported by prior NSF funds. The emphasis this time is on experimental measurements and their interpretation. 3) The work on stochastic differential equations (paper 5) is of basic mathematical character and utilizes the functional calculus to examine the consequences of "colored" noise. This is very important for the extended applicability of stochastic processes to real physical phenomena in which colored noise naturally occurs. 4) Quantum chaos involves the possibility that a deterministic quantum system can exhibit stochastic behavior just as has been seen in classical systems. The work reported here (papers 6, 7) presents the first fully analyzed example of such behavior in a quantum system. 5) Finally, the work on spectral line shapes is the thesis work of K. Faid and it provides a novel explanation of earlier efforts on this important, traditional application of stochastic thinking.

Overall, the work reported here covers basic mathematics, physical applications, and comparison with experiment. Both analytical and numerical methods have been used. Several more papers, already accepted for publication, extend this work, but will be covered under a future report for the renewal of this grant, which is currently active.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx Date
a. Abstracts of Theses		X			
b. Publication Citations		X			
c. Data on Scientific Collaborators		X			
d. Information on Inventions	X				
e. Technical Description of Project and Results		X			
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Ronald F. Fox		3/5/87

NSF Form 98A (1-87) Supersedes All Previous Editions

Form Approved OMB No. 3145-0058

PART IV - SUMMARY DATA ON PROJECT PERSONNEL

NSF Division PHYSICS

The data requested below will be used to develop a statistical profile on the personnel supported through NSF grants. The information on this part is solicited under the authority of the National Science Foundation Act of 1950, as amended. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. NSF requires that a single copy of this part be submitted with each Final Project Report (NSF Form 98A); however, submission of the requested information is not mandatory and is not a precondition of future awards. If you do not wish to submit this information, please check this box ☐

Please enter the numbers of individuals supported under this NSF grant.
Do not enter information for individuals working less than 40 hours in any calendar year. 1

*U.S. Citizens/ Permanent Visa	PI's/PD's		Post-doctorals		Graduate Students		Under-graduates		Precollege Teachers		Others	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
American Indian or Alaskan Native												
Asian or Pacific Islander												
Black, Not of Hispanic Origin												
Hispanic												
White, Not of Hispanic Origin	1											
Total U.S. Citizens	1											
Non U.S. Citizens												
Total U.S. & Non-U.S. ..	1											
Number of individuals who have a handicap that limits a major life activity.												

*Use the category that best describes person's ethnic/racial status. (If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)

AMERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America, and who maintains cultural identification through tribal affiliation or community recognition.

ASIAN OR PACIFIC ISLANDER: A person having origins in any of the original peoples of the Far East, Southeast Asia, the Indian subcontinent, or the Pacific Islands. This area includes, for example, China, India, Japan, Korea, the Philippine Islands and Samoa.

BLACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

HISPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

WHITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa or the Middle East.

THIS PART WILL BE PHYSICALLY SEPARATED FROM THE FINAL PROJECT REPORT AND USED AS A COMPUTER SOURCE DOCUMENT. DO NOT DUPLICATE IT ON THE REVERSE OF ANY OTHER PART OF THE FINAL REPORT.

Attachment

Part IIIa. Thesis: "Stochastic Theory of Relaxation and Collisional Broadening of Spectral Line Shapes", by K. Faid.

Two papers from this thesis are already accepted for publication in Physical Review A., but were supported by the currently active renewal grant PHY 86-03729, and do not come under this report for PHY 83-03729. However, they illustrate that this thesis contains publishable work. Thesis summary and table of contents are attached.

STOCHASTIC THEORY OF RELAXATION AND COLLISIONAL BROADENING OF SPECTRAL LINE SHAPES

A THESIS
Presented to
The Faculty of the Division of Graduate Studies

By

Karim FAID

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in Physics

Georgia Institute of Technology
December, 1986

SUMMARY

A complete stochastic theory of relaxation is developed in terms of a homogeneous equation for the averaged density matrix of a system immersed in a thermal bath.

This theory is then used as the basis of a new stochastic approach to the phenomenon of collisional broadening of spectral line shapes. Single photon and multiphoton processes are studied.

The features of a line shape are linked by simple expressions to the statistical properties of a stochastic hermitian Hamiltonian. The ordinary line shape predicted by Kubo's approach is generalized. The present approach predicts broadening as well as asymmetry and shift. A representation of line shapes in multiphoton processes by diagrams is also developed.

TABLE OF CONTENTS

Attachment

Part IIIb. Publications.

1) "Laser With a Fluctuating Pump: Intensity Correlations of a Dye Laser", with G. E. James and R. Roy, Physical Review Letters 52, 1778-1781 (1984).

2) "Stochastic Pump Effects in Lasers", with G. E. James and R. Roy, Physical Review A30, 2482-2494 (1984).

3) "Laser-Noise Analysis by First-Passage-Time Techniques", Physical Review A34, 3405-3408 (1986).

4) Theoretical Analysis of Long-Time-Tail Observations by Light Scattering off of Polystyrene Spheres", Physical Review A30, 2590-2596 (1984).

5) "Functional-Calculus Approach to Stochastic Differential Equations", Physical Review A33, 467-476 (1986).

6) "Quantum Chaos and a Periodically Perturbed Eberly-Chirikov Pendulum", with John Eidson, Physical Review A34, 482-492 (1986).

7) "Quantum Chaos in a Two-Level System in a Semiclassical Radiation Field", with J. C. Eidson, Physical Review A34, 3288-3292 (1986).

8) "Elementary Explanation of Boundary Shading in Chaotic-Attractor Plots for the Feigenbaum Map and the Circle Map", with J. Eidson, S. Flynn, C. Holm, and D. Weeks, Physical Review 33A, 2809-2812 (1986).

Co-author R. Roy on papers 1 and 2 is an experimental colleague in the School of Physics. G. E. James on the same papers is a student. Neither was supported by the grant. Co-author J. Eidson on papers 6, 7, and 8 is a graduate student of mine, and is not supported by the grant. The other co-authors on paper 8 are graduate students.

Attachment

Part IIIe. Technical Description of Results.

1) Laser light fluctuations.

Papers 1 and 2 provide a first principles derivation of pump fluctuations in dye lasers starting from a quantum mechanical density matrix formalism. This formalism was developed by me over the last 15 years while supported by NSF grants. The application to lasers provides a rigorous test of the approach. This work was done in collaboration with experimental colleague R. Roy. Paper 3 provides an analysis of first-passage-time results for laser start-up. This technique was developed by Roy in order to measure dye laser noise parameters more easily. My analysis shows that the observed phenomena are explained by our earlier theory and that the agreement between theory and measurement is very good. All of this work has been extended under NSF grant PHY8603729, and a collaborative paper with Roy just appeared in Physical Review A.

2) Long-time-tails.

Paper 4 concludes an earlier study I engaged in with earlier NSF support. In this paper I analyze experimental results involving light scattering off of polystyrene spheres. These measurements lead to an anomaly which my paper attempts to explain. The explanation invokes molecular scale non-locality.

3) Stochastic differential equations.

Paper 5 introduces a functional calculus approach to the analysis of stochastic differntial equations with a special emphasis on colored noise. This paper provides a nearly transparent derivation of a variety of results, thereby unifying this rapidly growing and diverse field of study. Several other researchers have now taken up my results and put them to the test with favorable outcomes. Under my currently active NSF grant PHY 8603729, I have already had accepted 3 more related papers: a) one which refines the mathematical formalism; b) one which applies the colored noise results to laser measurements; and c) one which applies the colored noise results to numerical simulation algorithms for noise problems. Each of these applications shows that the paper cited above (#5) has been a seminal paper with many spin-offs.

4) Quantum Chaos.

Paper 6 and 7 present the results of the efforts of my graduate student J. Eidson. We have fully analyzed a quantum system for chaotic behavior. In spite of published papers suggesting that quantum chaos cannot exist, we clearly see chaos and we are able to identify its mechanism. Moreover, we see why we are not subject to the inhibitions of the doubters. This work has led to a recent, third paper which rigorous supports our published findings by giving an analytical basis for our numerical studies. We believe that this is the only quantum system so far studied in which chaos has been clearly established and explained with a detailed mechanism. Eidson will receive his Ph.D. next quarter for a thesis based on this work. He did not, however, receive any support from the grant.

5) Spectral line shapes.

K. Faid received his Ph.D. in December, 1986 for his thesis on spectral line shapes. Using my density matrix formalism, which works so well for laser noise, he developed a detailed account of collisional broadening and spectral line shape. He was able to include temperature dependence and colored noise dependence. Two Physical Review papers have appeared, but they are covered by NSF grant PHY 8603729. Two more are in progress and several other applications of the method are being pursued. Faid did not receive support from the grant.

6) Graduate Student Support.

To date, I have not received NSF support for graduate students. Eidson, Faid, and a recent student, Steiger, have been very productive. I would hope that this success would aid future requests for Ph.D. student support which is increasingly needed if I am to continue to attract quality students. Note also that paper 8 was published with 4 graduate students (only one of whom is mine). This paper resulted from a project in an advanced level graduate course. It shows the general interest of graduate students in this aspect of my research interests.