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Coherence and chaos in partial differential equations was studied, with particular emphasis on ~~(1)~~ the damped-driven sine Gordon equation and ~~(2)~~ an optically bistable laser cavity. In addition, the propagation of rapidly oscillating nonlinear integrable waves was investigated.

The ~~principal~~ results about propagation in an optically bistable ring cavity ~~may be summarized as~~ are the identification of the interplay between coherent transverse spatial structures and temporal chaos in the characteristics of the laser beam. → next page

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Principal mathematical results on the damped-driven sine-Gordon equation include (1) a numerical study of low dimensional chaotic attractors with coherent spatial structures, including dynamical system diagnostics of their time series, and direct numerical measurements establishing that the attractor is well co-ordinatized by a few nonlinear normal modes; (2) complete analytical identification of all homoclinic structures for the integrable sine-Gordon equation; (3) direct numerical detection of homoclinic crossings along the chaotic attractor of the full system.

Principal mathematical results about the propagation of rapidly oscillating integrable waves include (1) the identification and derivation of a Hamiltonian structure for the modulation equations and (2) a study of the process by which singularities are smoothed by dispersion through the injection of additional degrees of freedom into the field.

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FINAL REPORT

HERMANN FLASCHKA

MAY 2, 1988

U. S. ARMY RESEARCH OFFICE

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UNIVERSITY OF ARIZONA

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Final Report -- H. Flaschka
Statement of the Problems studied

1) The structure of integrable and nonintegrable dynamical systems in the complex domain was investigated. The object is to relate singularities of solutions in the complex domain to the behavior of solutions for real time.

2) The Poisson geometry associated with various dynamical systems was studied. One wants to understand the connection between integrability and the existence of multiple Poisson structures.

3) Work continued on the analysis of the phase-space geometry of a particular dynamical system, the Neumann system. The goal is to understand the symmetries that underlie integrability.

These are all long-term projects. The research is continuing (with students and collaborators) and while the results have been presented in lectures, the final papers are not yet written.

Results

1) a) The Painlevé analysis for Nahm's equations was carried out. This is a rather intricate system arising in the theory of monopoles. The computation relies on representation theory of $sl(2, \mathbb{C})$. (To be published)

b) In collaboration with Y. Zeng, the Painlevé analysis for generalized integrable Toda lattices was carried out. The Painlevé data are given Lie-algebraic interpretation. (This work will be completed in China in May 1988.)

c) A student, M. Zou, has used complex domain techniques to prove nonexistence of analytic integrals of perturbed Toda lattices. He has also found various new examples relevant to Painlevé analysis: nonintegrable systems with the "weak Painlevé" property, integrable systems with polynomial Hamiltonian but nonalgebraic first integral, etc. (This work will form part of his Ph.D. thesis, expected by Spring 1989.)

2) a) A student, P. Damianou, has constructed an infinite set of Poisson structures on the Toda lattice phase space. This is a new example, which does not fit the hypotheses used in other work on bi-Hamiltonian structures. (A paper is being written.)

b) In collaboration with T. Ratiu, it was shown that the simultaneous resolution of simple singularities is a momentum map. It turned out that this result was known in representation theory; a detailed study of the Poisson-geometric implications (not known) is to be part of Damianou's thesis.

3) In collaboration with N. Ercolani, the Neumann system was related to the geometry of Kummer varieties. This was published. Further connections between this geometry and the formalism of Hirota equations are still under investigation.

Publications and papers in progress

N. Ercolani, H. Flaschka, "The geometry of the Hill equation and of the Neumann system," Phil. Trans. R. Soc. Lond. A 315, 405-422 (1985)

H. Flaschka, "Remarks on integrable Hamiltonian systems," submitted for publication.

H. Flaschka, Y. Zeng, "Lie-algebraic Kovalevskaya analysis for the Toda lattice," in preparation.

H. Flaschka, "Painlevé property of Nahm's equations," in preparation.

Also, Ph.D. theses of Pantelis Damianou and Maorong Zou, in progress.

Scientific personnel

N. M. Ercolani,	Assoc. Prof., Dept. of Mathematics, University of Arizona;
Y. B. Zeng,	Assoc. Prof., Dept. of Mathematics, University of Science and Technology of China (visiting scholar at Univ. of Arizona, 1985-1987);
P. Damianou	Ph.D. thesis student, Dept. of Mathematics, University of Arizona (partial support on this contract);
M. R. Zou	Ph.D. thesis student, Dept. of Mathematics University of Arizona (partial support on this contract);
H. Nadelhoffer	First-year graduate student, Dept. of Mathematics University of Arizona (partial support on this contract).

Final Army Report - David W. McLaughlin

Statement of the Problem Studied.

Coherence and chaos in partial differential equations was studied, with particular emphasis on (1) the damped-driven sine Gordon equation and (2) an optically bistable laser cavity. In addition, the propagation of rapidly oscillating nonlinear integrable waves was investigated.

The principal results about propagation in an optically bistable ring cavity may be summarized as the identification of the interplay between coherent transverse spatial structures and temporal chaos in the characteristics of the laser beam. We were the first to study transverse effects in an optically bistable laser cavity with the natural nonlinear evolution equation of the system. Solitary wave profiles were shown to be the fixed points of an infinite dimensional map which describes the system; these solitary waves form the basis of a projection method which reduced the infinite dimensional map to a two dimensional one, from which the physical characteristics of the fixed points were deduced with extreme accuracy; two competing instabilities (propagational through the nonlinear cavity versus feedback) were identified and analyzed; a chaotic response was identified and its features connected to these instabilities. The above study was carried out in one transverse dimension. At the end of the grant period, a two dimensional study was initiated which is still in progress. References [1, 3, 5, 13, 17; Ph.D. thesis, H. Adachihara].

Principal mathematical results on the damped-driven sine-Gordon equation include (1) a numerical study of low dimensional chaotic attractors with coherent spatial structures, including dynamical system diagnostics of their time series, and direct numerical measurements establishing that the attractor is well co-ordinatized by a few nonlinear normal modes; (2) complete analytical identification of all homoclinic structures for the integrable sine-Gordon equation; (3) direct numerical detection of homoclinic crossings along the chaotic attractor of the full system. This study is a first in two respects: the first complete mathematical classification of all homoclinic structures for an integrable pde and the first direct numerical correlation of these objects with the chaotic attractors of the perturbed pde. At present we are using the mathematical expressions for these homoclinic structures in analytical (as opposed to numerical) studies. References [2, 4, 5, 6, 8, 9, 10, 11, 12, 16, 18, 19, 22].

Principal mathematical results about the propagation of rapidly oscillating integrable waves which were obtained during the duration of this grant include (1) the identification and derivation of a Hamiltonian structure for the modulation equations and (2) a study of the process by which singularities are smoothed by dispersion through the injection of additional degrees of freedom into the field. Current work is in progress with N. Ercolani and D. Levermore. [References 7, 14, 15, 18, 20, 21, Ph.D. thesis, Jin Shan].

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2. "Chaos and Nonlinear Modes in a Perturbed Toda Chain", (with A. Bishop, K. Fesser, and B. Holian), Phys. Rev. A 31, 2728 (1985).

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6. "Coherence and Chaos in the Driven Damped Sine-Gordon Equation: Measurement of the Soliton Spectrum", (with A.R. Bishop and E.A. Overman II), Physica 19D, 1 (1986).

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8. "Modulational Instabilities of Periodic Sine-Gordon Waves: A Geometric Analysis", (with N. Ercolani and M.G. Forest), Lect. Appl. Math. 23, 47 (1986).

9. "A Quasi-Periodic Route to Chaos in a Near-Integrable PDE", (with A.R. Bishop, M.G. Forest, and E.A. Overman II), Physica 23D, 293-328 (1986).

10. "Phase-Pulling and Space-Time Complexity in an AC Driven Damped One-Dimensional Sine-Gordon System", (with A. Mazor and A. Bishop), Phys. Lett. A (1987).

11. "Homoclinic Orbits for the Periodic Sine Gordon Equation", (with N. Ercolani and M.G. Forest), to appear in Physica D.

12. "A Quasi-Periodic Route to Chaos in a Near-Integrable PDE: Homoclinic Crossings", (with A. Bishop and E.A. Overman II), Phys. Lett. A 127, 335 (1988).

13. "Solitary Waves as Fixed Points of Infinite-Dimensional Maps for an Optical Bistable Ring Cavity: Analysis", (with H. Adachihara, J. Moloney, and A.C. Newell), J. Math. Phys. 29, 63-85 (1988).

14. "Hamiltonian Structure for the Modulation Equations of a Sine-Gordon Wavetrain", (with N. Ercolani, M.G. Forest, and R. Montgomery), Duke Math. Journal 55, 949-983 (1988).

15. "On the Weak Limit of Rapidly Oscillating Waves", (with L. Chierchia and N. Ercolani), Duke Math. Journal 55, 759-764 (1988).

16. "Geometry of the Modulational Instability. Part 1: Local Results; Part 2. Global Results", (with N. Ercolani and M.G. Forest), submitted to Memoirs AMS (1988).

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17. "An Infinite Dimensional Map from Optical Bistability Whose Regular and Chaotic Attractors Contain Solitary Waves", (with J.V. Moloney and A.C. Newell), in Chaos in Nonlinear Dynamical Systems, ed. J. Chandra (SIAM, Philadelphia, 1984).

18. "Oscillations and Instabilities in Near-Integrable PDE's", (with N. Ercolani and M.G. Forest), Lect. Appl. Math 23, 3 (1986).

19. "Modulational Instabilities of Periodic Sine Gordon Waves: A Geometric Analysis", (with N. Ercolani and M.G. Forest), Lect. Appl. Math. 23, 47 (1986).

20. "On the Construction of Modulating, Multiphase Wave Trains", Proceedings of Conference on Nonlinear Oscillations, University of Minnesota, 1985, eds. D. Kinderlehrer and M. Slemrod (1986).

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22. "A Quasiperiodic Route to Chaos in a Near Integrable PDE" (with A. Bishop, M.G. Forest, and E.A. Overman II), Proceedings of Los Alamos Conference on Spatial Coherence and Temporal Chaos, 1987, Physics 23D, 293-328 (1986).

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PAPERS FROM THE PERIOD 1984-1987 FOR ARMY GRANT

The main contributions during this period were:

i. A series of papers developing a method for obtaining macroscopic equations for describing the dynamics of patterns. # 1, 7, 12, 13, 19, 20, 21

ii. A series of papers on nonlinear optics. # 2, 4, 5, 8, 9, 18, 22, 23, 24

iii. Some new ideas on Turbulent transport. # 6

1. Convection patterns in large aspect ratio systems, *Physica* 10D, 299-328 (1984) (with M. Cross).
2. Non-predictable behavior in partial differential equations, *Proc. of "Workshop on Instabilities in Continuous Media"*, Interassociation Committee on Mathematical Geophysics, International Union Geodesy and Geophysics, sponsored by IUGG, National Science Foundation, Dec. 3-7, 1984, Venice (with D. McLaughlin and J. Moloney).
3. Reflections from solitary waves in channels of decreasing depth. *J. Fluid Mech.*, **153**, 1-16 (1985) (with C. Knickerbocker).
4. An infinite dimensional map from optical bistability whose regular and chaotic attractors contain solitary waves, in *Chaos in Nonlinear Dynamical Systems*, pp. 94-119. Ed. J. Chandra, SIAM (1984)(with J. Moloney and D. McLaughlin).
5. A new class of instabilities in passive optical cavities, *Physics Review Letters,* **54**, 681 (1985) (with D. McLaughlin and J. Moloney).
6. Chaos and turbulence; is there a connection?, Special Proc. of Conf. on Mathematics Applied to Fluid Mechanics and Stability Dedicated in Memory of Richard C. DiPerna, *published by SIAM*, 157-189 (1986).
7. The shape of stationary dislocations, *Phys. Letters.,* **113A,5**, 289 (1985) (with D. Meiron).
8. Chaos and coherent structures in partial differential equations, *Physica* **18D**, 85-112 (1986) (with A. Aceves, H. Adachihara, C. Jones, J. C. Lerman, D. McLaughlin, J. Moloney).
9. Two-dimensional spatial patterns in ring cavities (with D. McLaughlin and J. Moloney), to be submitted.
10. The Hirota Conditions, *Journal of Mathematical Physics* 27, 2016-2021 (1986) (with Yunbo Zeng).
11. Soliton Mathematics, *SMS NATO Advanced Study Institute, Vol. 103* Published by the Univ. of Montreal, survey article pages 9-116 (1986) (with T. Ratiu, M. Tabor and Z. Yunbo).
12. Benjamin-Feir turbulence in binary mixture convection, *Physica* 23D, 345-361 (1986) (with H. Brand, P. Lomdahl).
13. Evolution of the Order Parameter in Situations with Broken Rotational Symmetry, *Phys. Letters* **A118**, 67-73 (1986) (with H. Brand and P. Lomdahl).

14. Nonlinear Tunneling Through Random Media (with J. G. Caputo, W. Faris, C. N. Newman and M. Shelley), to be submitted.
15. A Unified Approach to Painlevé Expansions, to appear *Physica* D (December 1987). (with M. Tabor and Y. Zeng).
16. Lax Pairs, Bäcklund Transformations and Special Solutions for Ordinary Differential Equations, to appear *Nonlinearity* (with J. D. Gibbon, M. Tabor and Y. Zeng).
17. Chaos and Turbulence. Proc. Wood's Hole Summer Seminar in Geographical Fluid Dynamics on "Shear Flow Turbulence", *WHOI-86-45*, 90-103 (1986).
18. Solitary Waves as Fixed Points of Infinite-Dimensional Maps for an Optical Bistable Ring Cavity: Analysis, to appear in *Journal of Mathematical Physics* (with H. Adachihara, D. W. McLaughlin and J. V. Moloney).
19. The dynamics of patterns: A survey. *Springer Proc. in Physics*. Proc. Conf. on "Propagation in Nonequilibrium Systems" at Les Houches 1987, Springer-Verlag Publisher (1987).
20. Wavenumber selection of convection rolls in a box, accepted *Physics of Fluids Letters*, (with W. Arter and A. Bernoff).
21. Numerical simulation of Rayleigh-Benard convection in shallow tanks, accepted for *Physics of Fluids*, (with W. Arter).
22. Trajectories of Surface Waves at the Interface between Nonlinear Dielectrics (with A. Aceves and J. Moloney), submitted to *Physics Review Letters*.
23. Reflection, Transmission and Stability Characteristics of Optical Beams Incident at Nonlinear Dielectric Interfaces, accepted *Journal Optical Society of America* B. Special issue on Nonlinear Waveguides. Eds. G. I. Stegeman and R. H. Stolen. November 1987. (With A. Aceves, and J. Moloney).
24. Fixed Points and Chaotic Dynamics of an Infinite Dimensional Map. *Chaos, Noise and Fractals*, pp. 137-186, Eds. E.R. Pike and L.A. Lugiato, Adam Hilger (1987) (with J.V. Moloney, H. Adachihara, D.W. McLaughlin).
25. Binary mixture convection near onset. In preparation (with H. Brand, J. Powell and B. Zieeinska).
26. A Calculus curriculum for the nineties. Proceedings NRC-MAA "Calculus Curriculum" October 1987, (with D. Lovelock).

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EDUCATION:

1966	B.S. (Physics and Mathematics), Creighton University
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1971	Ph.D. (Theoretical Physics), Indiana University

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1970-72	Assistant Professor, Mathematics, New York University
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1979-present	Professor, Mathematics, University of Arizona
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1966-70	NDEA Title IV Fellow
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1978	"The Soliton - A New Concept in Applied Science" (with A. C. Scott and F. Y. F. Chu). Acknowledged by Citation Index as a "Citation Classic"
1978	Member, US-Japan Scientific Exchange
1979	Member, US-USSR Academy Exchange on Solitons

GRANTS:

1972-present	National Science Foundation, Mathematics
1975-	National Science Foundation, Conf. Solitons
1977-78	National Science Foundation (Japan Prog.)
1978-79	Army Research Office
1983-84	National Science Foundation, Conf. Inverse Methods
1983-present	Air Force Office of Scientific Research
1985-present	Office of Naval Research, Engineering
1985-present	Army Research Office.

SERVICE:

1975	Organized Soliton Conference, Tucson.
1977-present	Member, Applied Mathematics Program, University of Arizona.
1978-80	Member, Organizational Committee, Center for Nonlinear Studies, Los Alamos.
1983-84	Organized AMS Conferrence on Inverse Methods, New York.
1984	Member, Organization Committee, Nonlinear Equations Conference, Santa Fe.

THESIS AND DISSERTATION COMMITTEES:

1975-78	E. A. Overman, Ph.D. (Co-direction with F. A. Hopf)
1975-79	M. G. Forest, Ph.D.
1984-	H. Adachihara (Co-direction with A. C. Newell)

PUBLICATIONS

1. "Quantum Theory of a Swept Gain Amplifier II" (with F. A. Hopf and P. Meystre), Phys. Rev. A 13, 777-783 (1976).

2. "Canonically Conjugate Variables for the Korteweg-de Vries Equation and TODA Lattice with Periodic Boundary Conditions" (with H. Flaschka), Prog. Theor. Phys. 55, 438-456 (1976).

3. "Solitons under Perturbations" (with J. P. Keener), Phys. Rev. A 16, 777-790 (1977); Erratum in 17, 1555 (1977).

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9. "Multiphase Averaging and the Inverse Spectral Solution of KdV" (with H. Flaschka and M. G. Forest), Comm. Pure Appl. Math. 33, 739-784 (1980).

10. "On Davydov's Alpha Helix Solitons" (with J. Myman and A. C. Scott), Physica 3D, 23-44 (1981).

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12. "Shocks in the Toda Lattice: Analysis" (with B. J. Holian and H. Flaschka), Phys. Rev. A 24, 2595-2623 (1981).

13. "Nonlinear Normal Modes for the Toda Chain" (with W. E. Ferguson, Jr. and H. Flaschka), J. Comp. Phys. 45, 157-209 (1981).

14. "Spectral Theory of the Periodic Sine Gordon Equation: A Concrete Viewpoint" (with M. G. Forest), J. MAth. Phys. 23, 1248-1277 (1982).

15. "Breather Annihilaton by Simple Dissipation: (with E. A. Overman II), Phys. Rev. A 26, 3497-3507 (1982).

16. "Modulations of Sinh-Gordon and Sine-Gordon Wavetrains" (with M. G. Forest), Studies in Appl. Math. 68, 11-59 (1983).

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18. "Modulations of Perturbed KdV Wavetrains" (with M. G. Forest), SIAM J. Appl. Math. 44, 287-300 (1983).

19. "Modulational Stability of Two Phase Sine Gordon Wavetrains (with N. Ercolani and M. G. Forest), Studies in Appl. Math. 71, 91-101 (1984).

20. "Interactions between Mean Flow and Finite-Amplitude Mesoscale Eddies in a Barotropic Ocean" (with B. Cushman-Rosin and G. Papanicolaou), Geophys. Astrophys. Fluid Dynamics, 29, 333-353 (1984).

21. "Chaos and Nonlinear Modes in a Perturbed Toda Chain" (with A. Bishop, K. Fesser, and B. Holian), Phys. Rev. A 31, 2728 (1985).

22. "A New Class of Instabilities in Passive Optical Cavities" (with J. V. Moloney and A. C. Newell), Phys. Rev. Lett. 54, 7 (1985).

23. "Convection of Microstructure and Related Problems" (with G. Papanicoloau and O. Pironneau), SIAM J. Appl. Math 45, 5 (1985).

24. "The Origin and Saturation of Modulational Instabilities" (with N. Ercolani and M. G. Forest), Physica 18D, 472 (1986).

25. "Focusing Singularity of the Cubic Schroedinger Equation," Phys. Rev. A 34, 2, 1200 (1986).

26. "Chaos and Coherent Structures in PDE's" (with A. Aceves et al.), Physica 18D, 85 (1986).

27. "Coherence and Chaos in the Driven Damped Sine-Gordon Equation: Measurement of the Soliton Spectrum" (with A. R. Bishop and E. A. Overman II), Physica. 19D, 1 (1986).

28. "Oscillations and Instabilities in Near Integrable PDE's" (with N. Ercolani and M. G. Forest), Lect. Appl. Math. 23 3 (1986).

29. "Modulational Instabilities of Periodic Sine-Gordon Waves: A Geometric Analysis" (with N. Ercolani and M. G. Forest). Lect. Appl. Math. 23, 47 (1986).

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31. "Phase-Pulling and Space-Time Complexity in an AC Driven Damped One-Dimensional Sine-Gordon System" (with A. Mazor and A. Bishop), Phys. Lett. A (1987).

32. "Homoclinic Orbits for the Periodic Sine Gordon Equation" (with N. Ercolani and M. G. Forest), to appear in Physica D.

33. "A Quasi-Periodic Route to Chaos in a Near-Integrable PDE: Homoclinic Crossings" (with A. Bishop and E. Overman), to appear in Phys. Lett. A.

34. "Solitary Waves as Fixed Points of Infinite-Dimensional Maps for an Optical Bistable Ring Cavity: Analysis" (with H. Adachihara, J. Moloney, and A. C. Newell), to appear in J. Math. Phys.

35. "Hamiltonian Structure for the Modulation Equations of a Sine-Gordon Wavetrain" (with N. Ercolani, M. G. Forest, and R. Montgomery), to appear in Duke Math. J. (1988).

36. "On the Weak Limit of Rapidly Oscillating Waves" (with L. Chierchia and N. Ercolani), to appear in Duke Math. J. (1988).

37. "Geometry of the Modulational Instability. Part 1: Local Results; Part 2. Global Results" (with N. Ercolani and M. G. Forest), submitted to Comm. Pure Appl. Math.

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2. "A Multisoliton Perturbation Theory" (with A. C. Scott), in Solitons in Action, eds. K. Konngren and A. C. Scott (Academic Press, NY, 1978).

3. "Concrete Periodic Inverse Spectral Transform" (with W. E. Ferguson adn H. Flaschka), in Proc. Kyoto Conf. on Theory of Nonlinear Waves, Inst. Math. Sciences, Kyoto University, January 1978.

4. "A Physical Description of the Spectral Transform," in Nonlinear Electromagnetics, ed. G. Uslenghi (Academic Press, 1980).

5. "Overview of Soliton Mathematics," in Proc. Conf. on One-Dimensional Physics, Fribourg, eds. J. Bernasconi and T. Schneider (1981).

6. "Nonlinear Evolution Equations with Rapidly Oscillating Initial Data" (with G. Papanicoloau and O. Pironneau), in Macroscopic Properties of Disordered Media, eds. R. Burridge, S. Childress, and G. Papanicoloau, Lecture Notes in Physics 154 (Springer-Verlag, 1981).

7. "Convection of Microstructure" (with G. Papanicoloau and O. Pironneau), in Computing Methods in Applied Sciences and Engineering, V, eds. R. Glowinski and J. L. Lions (North-Holland, 1982).

8. "Solitary Waves with Dispersion and Dissipation," in Proc. Conf. on Structure and Dynamics of Proteins, ed. E. Clementi (1982).

9. "An Infinite Dimensional Map from Optical Bistability Whose Regular and Chaotic Attractors Contain Solitary Waves" (with J. V. Moloney and A. C. Newell), in Chaos in Nonlinear Dynamical Systems, ed. J. Chandra (SIAM, Philadelphia, 1984).

10. "Oscillations and Instabilities in Near-Integrable PDE's" (with N. Ercolani and M. G. Forest) Lect. Appl. Math. 23, 3 (1986).

11. "Modulational Instabilities of Periodic Sine Gordon Waves: A Geometric Analysis" (with N. Ercolani and M. G. Forest), Lect. Appl. Math. 23, 47 (1986).

12. "On the Construction of Modulating, Multiphase Wave Trains," Proceedings of Conference on Nonlinear Oscillations, University of Minnesota, 1985, eds. D. Kinderlehrer and M. Slemrod (1986).

13. "Weak Limits of Nonlinear Conservation Laws with Oscillating Data," in Proceedings of Conference on Nonlinear Oscillations (with G. Papanicoloau and L. Tartar), University of Minnesota, 1985, eds. D. Kinderlehrer and M. Slemrod (1986).

14. "A Quasiperiodic Route to Chaos in a Near Integrable PDE" (with A. Bishop, M. G. Forest, and E. A. Overman), Proceedings of Los Alamos Conference on Spatial Coherence and Temporal Chaos, 1987, Physica 23D, 293-328 (1986).

15. "On the Construction of a Modulating Multiphase Wavetrain for a Perturbed KdV Equation," Proceedings of Conference on Nonlinear Oscillations and Compensated Compactness, University of Minnesota (1987).

16. "Weak Limits of Semi-Linear Hyperbolic Systems with Oscillating Data," Proceedings of Conference on Nonlinear Oscillations and Compensated Compactness, University of Minnesota (1987).

OTHER PUBLICATIONS

1. "Theory and Applications of Solitons" (ed. by H. Flaschka), Proc. of NSF Conf. on Solitons, Special Volume of the Rocky Mountain Math. Journal (1978).

2. "Inverse Problems" (ed. D. McLaughlin), Proc. of AMS-SIAM Conf., 1983.

INVITED LECTURES

1981 Fifth International Symposium on Computing Methods in Applied Sciences and Engineering, Paris.
1982 International Conference on Soliton Perturbation Theory, Nice.
1982 International Conference on Structure and Dynamics of Proteins, La Jolla.
1983 Workshop on Coherence and Chaos, Los Alamos.
1983 International Conference on Nonlinear Biophysics, Loma Linda.
1983 Analysis Colloquium, Duke University.
1984 Western States Mathematical Physics Meeting, Cal. Tech.
1984 Lectured at Bucharest Institute for Physics, Romania.
1984 Conference on Raman Scattering, Los Alamos.
1984 Conference on Applied Solitons, Los Alamos.
1984 Applied Mathematics Colloquium, Stanford University.
1984 Conference on Nonlinear Transport, Los Alamos.
1984 AMS-SIAM Conference on Nonlinear Evolution Eq^s, Santa Fe.
1984 Mathematics Colloquium, Penn State University.
1984 Conference on Turbulent Flows, Nice.
1984 Inaugural Conference of Nonlinear Research, Berkeley.
1985 Conference on Oscillation Theory, Mathematics Institute, Minnesota.
1986 Seminar, College of France.
1986 Lecture on Dynamical Systems at INRIA Workshop, Paris.
1986 PDE Seminar, Ecole Normale Superieure, Paris.
1986 Mathematics Seminar, Universite de Paris, XIII.
1986 Seminar, Observatoire de Nice.
1986 Physics Seminar, University of Montpellier.
1986 Mathematics Seminar, Heriot-Watt University, Edinburgh.
1986 Aerospace and Mechanical Engineering Seminar, University of Southern California.
1986 Lecture at Inaugural MIDIT Workshop, Lyngby, Denmark.
1987 Cornell University
1987 Mathematical Sciences Research Institute, Berkeley, California.
1987 Montpellier, France
1987 Oberwolfach, West Germany
1987 Cetraro, Italy
1987 Joint Summer Research Conferences in the Mathematical Sciences, University of Colorado
1987 Second Howard University Symposium on Nonlinear Semigroups, Partial Differential Equations, and Attractors.