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Jianke Yang  University of Vermont, U.S.A.

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Chiang C. Mei  Massachusetts Institute of Technology, U.S.A.
Junkichi Satsuma  Aoyama Gakuin University, Japan
Tao Tang  Hong Kong Baptist University, China

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Chinese Mathematical Society
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## June 26

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### Coffee break / Poster session

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<td>Ragnisco/Zeng</td>
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<td>10:30~11:00</td>
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<td>11:00~11:30</td>
<td>Akylas</td>
<td>D. J. Zhang</td>
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<td>Akers</td>
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<td>13:30~14:00</td>
<td>Biondini</td>
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<td>Tredicce</td>
<td>Nachbin</td>
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<td>Skryabin</td>
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<td>Soljaci</td>
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<td>Z. Xu</td>
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<td>Y. Zhu</td>
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<td>H. P. Zeng</td>
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List of Talks
List of Talks
KEYNOTE TALKS

1. Demetrios Christodoulides  (University of Central Florida, U.S.A.)
   "Discrete Linear and Nonlinear Optics"

2. Thomas Yizhao Hou  (California Institute of Technology, U.S.A.)
   "Recent Progress on Dynamic Stability and Global Regularity of 3D Incompressible Euler and
   Navier-Stokes Equations"

3. Serguei Novikov  (University of Maryland, U.S.A.)
   "Singular Solitons and Fourier Transform on Riemann Surfaces"

4. Lev Pitaevskii  (University of Trento, Italy)
   "Non-linear dynamics of a thin soliton"

TUTORIAL

1. William L. Kath  (Northwestern University, U.S.A.)
   "Nonlinear signaling in neurons and networks of neurons"
MINISYMPOSIA

MS1. Advances in Nonlinear Waves

Organizer:
Paul Milewski (University of Wisconsin, Madison, U.S.A.)

This session will focus on recent advances in the study of nonlinear geophysical waves and of solitary waves.

List of Speakers:

1) Mark Ablowitz (University of Colorado, Boulder, U.S.A.)
   "Asymptotic reductions of water and internal waves and their solitary waves"

2) Triantaphyllos Akylas (MIT, U.S.A.)
   "Bound states in periodic lattices"

3) Benjamin Akers (University of Illinois, Chicago, U.S.A.)
   "Stability of resonant traveling water waves"

4) Gino Biondini (State University of New York, Buffalo, U.S.A.)
   "Soliton reflection in boundary value problems and a nonlinear method of images"

5) Roger Grimshaw (Loughborough University, U.K.)
   "The effect of rotation on internal solitary waves"

6) Yuji Kodama (Ohio State University, U.S.A.)
   "Normal forms and KP solitons"

7) Frederic Wan (University of California, Irvine, U.S.A.)
   "Localized Ectopic Expression of Dpp Receptors in a Drosophila Embryo"

8) Jianke Yang (University of Vermont, U.S.A.)
   "Fractal scattering in weak interactions of solitary waves"

9) David Amundsen (Carleton University)
   "Resonant Oscillations: Interaction between Nonlinearity, Geometry and Inhomogeneity"

10) Jean-Marc Vanden-Broeck (University College London, U.K.)
    "Mathematical models for nonlinear gravity-capillary waves"

11) Paul Milewski (University of Wisconsin, Madison, U.S.A.)
    "The Generalized Serre Equations for Shallow Water Waves"
MS2. Bose-Einstein Condensates: Past, Present and Future

Organizer:
Panos Kevrekidis  (University of Massachusetts at Amherst, U.S.A.)

The experimental realization of Bose-Einstein condensates 15 years ago was a major milestone that ushered a new era of tremendous potential at the forefront of atomic physics, and especially at its interfaces with wave physics, nonlinear dynamics and optical physics. An unprecedented level of control of this clean experimental system enabled the realization of a vast span of exciting features, potentials and structures, including but not limited to solitons, vortices, vortex lattices, structural phase transitions, multi-component dynamics, spinors, optical lattices, Feshbach resonances and space- as well as time-independent interactions, and dynamical instabilities. As this field is starting to mature, the nonlinear waves conference at Beijing is an excellent opportunity to reflect on successes of the past and to consider challenges of the future, directions of interest and possible applications. To that effect, gathering a diverse set of highly visible researchers in a dynamic environment such as that of this meeting, where there will be a considerable interest in interaction and cross-pollination with other areas of nonlinear physics, will provide an excellent environment for seeding future research, and potential collaborations.

List of Speakers:

1) Masahito Ueda  (University of Tokyo, Japan)
   "Topological excitations in Bose-Einstein condensates"

2) Natasha Berloff  (Cambridge University, U.K.)
   "Spatial pattern formation in nonequilibrium condensates"

3) Ashton Bradley  (University of Otago, New Zealand)
   "The Stochastic Projected Gross-Pitaevskii equation: theory and applications in high temperature Bose gases"

4) Chenyu Wang  (University of Massachusetts at Amherst, U.S.A.)
   "Double wells in Bose-Einstein Condensates"

5) T. P. Billam  (Durham University, U.K.)
   "Generation of bright solitary waves and experimental tests of mean-field theory in attractive Bose-Einstein condensates"

6) L. Hadzievski  (Vinca Institute of Nuclear Sciences, Serbia)
   "Discrete solitons and vortices in dipolar Bose-Einstein condensates"

7) Guoxiang Huang  (East China Normal University, China)
   "Dark and bright solitons in super uid Fermi gases in the BCS-BEC crossover"
8) Elena Ostrovskaya  (Australian National University, Australia)
   "Controlled dynamics of matter waves in two-dimensional optical lattices"

9) Volodya Konotop  (University of Lisbon, Portugal)
   "Matter Rogue Waves"

10) Wuming Liu   (Chinese Academy of Sciences, China)
    "Non-Abelian Josephson effect and half vortex of cold atoms in traps and microcavities"

11) Nick Proukakis  (University of Newcastle, U.K.)
    "Stochastic Soliton Dynamics in Finite Temperature Quantum Gases"

12) Brian Anderson   (University of Arizona, U.S.A.)
    "Persistent currents in an oblate, finite-temperature Bose-Einstein condensate"

13) Li You   (Georgia Tech, U.S.A.)
    "Mixtures of spinor atomic Bose-Einstein condensates"

14) Cheng Chin   (University of Chicago, U.S.A.)
    "Having your cake and seeing it too: Formation and dynamics of Incompressible Mott Insulating Domains in Ultracold Gases"

15) P. Kevrekidis  (University of Massachusetts at Amherst, U.S.A.)
    "Dark solitons and some generalizations thereof in Bose-Einstein condensates"
MS3. Large Amplitude Surface and Internal Waves

Organizer:
Roger Grimshaw (Loughborough University, U.K.)

The talks will describe some recent theoretical and modelling results for nonlinear surface water waves and internal waves. The topics covered will include deterministic and random wave fields, the generation and properties of solitary waves, and the effects of bottom topography.

List of Speakers:

1) Triantaphyllos Akylas (MIT, U.S.A.)
"Forced gravity-capillary lumps on deep water: theory and experiment"

2) Wooyoung Choi (New Jersey Institute of Technology, U.S.A.)
"Nonlinear evolution of broadband surface waves"

3) Gennady El (Loughborough University, U.K.)
"Transcritical shallow-water flow past topography: finite-amplitude theory"

4) Shijun Liao (Shanghai Jiao Tong University, China)
"On the nonlinear interactions of wave-wave and wave-currents"

5) Chiang C Mei (MIT, U.S.A.)
"Ships advancing near the critical speed in a shallow channel with a randomly uneven bed"

6) Paul Milewski (University of Wisconsin, Madison, U.S.A.)
"Diurnal forcing, trapped waves, and the meridional extent of the tropics"

7) Andre Nachbin (IMPA, Brazil)
"Discrete and continuous random water wave dynamics"

8) Katie Oliveras (University of Washington, U.S.A.)
"Stability of stationary periodic solutions to the Euler equations"

9) Natalia Stashchuk (University of Plymouth, U.K.)
"Three-dimensional modelling of nonlinear baroclinic tides in the South China Sea"

10) Vasily Vlasenko (University of Plymouth, U.K.)
"Long-term evolution of strongly nonlinear internal solitary waves in a rotating channel"

11) Mohammad-Reza Alam and Chiang C. Mei (MIT, U.S.A.)
"Tsunami runup by Lagrangian description"
MS4. New advances on integrable systems

Organizers:
Orlando Ragnisco (Università di Roma Tre, Italy)
Yunbo Zeng (Tsinghua University, China)

The modern theory of integrable systems, as it has been formulated starting from the early sixties and the modern theory of nonlinear waves are intimately related subjects: prototype examples of integrable infinite-dimensional systems (KdV, NLS, SG) are at the same time prototype examples of nonlinear wave equations.

The minisymposium on integrable systems will be focussed on some of the novel achievements in the research on integrable models which are in fact deeply connected with the investigation on the theory of nonlinear waves. Accordingly, it will be focussed on the following issues:
1. New developments in nonlinear field theory, classical and quantum;
2. Integrable NLEES in multidimensions: spectral theory and explicit solutions;
3. Dispersionless nonlinear waves: algebraic solutions
4. Integrability of classical systems in a discrete setting: search for reliable detectors;
5. Integrability of quantum systems in a discrete setting and new orthogonal polynomials;

List of Speakers:

1) S.Y. Lou (Ningbo University, China)
   "New integrable systems from known ones via anyon parameterization"

2) Alexei Morozov (ITEP, Moscow, Russia)
   "Recent developments in matrix models and conformal field theory"

3) Z.X. Zhou (Fudan University, China)
   "Darboux transformations for two dimensional elliptic affine Toda equations"

4) Barbara Prinari (Università di Lecce, Italy)
   "Inverse Scattering Transform (IST) for the Multicomponent Nonlinear Schrodinger (NLS) Equation Under Non-Vanishing Boundary Conditions"

5) W.X. Ma (University of South Florida, U.S.A.)
   "Exploring Hamiltonian structures by variational identities"

6) P. M. Santini (University of Rome, Italy)
   "On the dispersionless Kadomtsev-Petviashvili equation in n+1 dimensions: exact solutions, the Cauchy problem for small initial data and wave breaking"

7) Z.N. Zhu (Shanghai Jiaotong University, China)
"Multi-soliton, multi-positon, multi-negaton, and multi-periodic solutions of a coupled Volterra lattice system and their continuous limits"

8) Claude Viallet (LPTHE Paris VI, France)
"Integrable maps and lattice maps"

9) J.S. He (Ningbo University, China)
"Explicit Flow Equations and Recursion Operator of the ncKP hierarchy"

"Exactly Solvable (Discrete) Quantum Mechanics and Exceptional Orthogonal Polynomials"

11) D.J. Zhang (Shanghai University, China)
"Multisoliton solutions to the lattice Boussinesq equation"

12) Alberto Enciso (UCM Madrid, Madrid, Spain)
"Spin chains of Haldane-Shastri type and a generalized central limit theorem"

13) Youjin Zhang (Tsinghua University, China)
"On Symmetries of the WDVV Equations"

14) Y.B. Zeng (Tsinghua University, China)
"A new extended matrix KP hierarchy and its solutions"

15) Krzysztof Marciniak (Linkoping University, Sweden)
"Solutions of multicomponent Harry Dym hierarchy emerging from Stäckel separable systems"

16) Peter Clarkson (University of Kent, U.K.)
"Rogue waves and rational solutions of the Boussinesq and nonlinear Schröedinger equations"

17) David Trubatch (Montclair State University, U.S.A.)
"Solitary-Wave Interaction in the Short-Pulse Equation"

18) R. Conte (LRC MESO, France)
"A new closed form solution to the quintic complex Ginzburg-Landau equation"

19) Kai Tian (AMSS, Chinese Academy of Sciences, China)
"Supersymmetric Reciprocal Transformation and Its Applications"
**MS5. Nonlinear Dynamics in Magnetic Systems**

Organizer:
Mingzhong Wu   ( Colorado State University, U.S.A. )

This mini-symposium will bring together leading experimental and theoretical scientists in the field of nonlinear dynamics in magnetic systems. The symposium will consist of eight invited talks. The talks will cover the most recent and important developments in spin wave solitons, Bose-Einstein condensate of magnons, and nonlinear dynamics in spin-torque oscillators, among others.

List of Speakers:

1) Theo Rasing   ( Radboud University Nijmegen, Netherlands )
   "Controlling Spins with Light"

2) Mark Hoefer   ( North Carolina State University, U.S.A. )
   "Dissipative Droplet Solitons"

3) Alexander A. Serga   ( Kaiserslautern University of Technology, Germany )
   "Formation and collapse of guided spin-wave bullets in a medium with induced magnetic anisotropy"

4) Vladislav Demidov   ( Universität Münster, Germany )
   "Nonlinear Spin Waves in Micro-Nanostructures"

5) Vasil Tiberkevich   ( Oakland University, U.S.A. )
   "Non-Autonomous Dynamics of Nonlinear Spin-Torque Nano-Oscillators"

6) Wei Tong   ( High Magnetic Field Laboratory, Chinese Academy of Sciences, China )
   "Formation of Random Dark Envelope Solitons from Incoherent Waves"

7) M. Wu   ( Colorado State University, Fort Collins, U.S.A. )
   "Dimension control of chaotic surface spin waves in a magnetic film-based active feedback ring"
MS6. Nonlinear Optical Waves and Novel Phenomena

Organizer:
Zhigang Chen   ( San Francisco State University, U.S.A. & Nankai University, China )

This mini-symposium aims to bring together experts from the fields of nonlinear waves in optics and photonics, and related phenomena including nontrivial solitons, nonconventional optical beams, wave mixing, and novel nonlinear phenomena in micro- and nano- photonic structures. The scope of this symposium covers both theoretical and experimental study on wave phenomena in a variety of materials and structures, ranging from nematic liquid crystals, photorefractive crystals, to nonlocal nonlinear media, and from ring lasers, microresonators, to fiber laser arrays and photonic lattices.

List of Speakers:

1) M. Segev   ( Technion-Israel Institute of Tech, Israel )
   "Symbiotic Nonlinear Opto-Fluidity"

2) J.R. Tredicce   ( Institut Non Lineaire de Nice, France )
   "Cavity Solitons and Localized structures in bidirectional ring lasers"

3) Roberto Morandotti   ( INRS, Canada )
   "Extremely Efficient Frequency Generation in High-Index Doped Silica Glass Micro-Ring Resonators"

4) Marin Soljacic   ( MIT, U.S.A. )
   "Novel nonlinear nanophotonic phenomena"

5) S.G. Odoulov   ( Institute of Physics, Ukraine )
   "Optical multivibrator: untrivial dynamics of photorefractive coherent oscillators with two types of movable charge species"

6) Dmitry Skryabin   ( University of Bath, U.K. )
   "Solitons and vortex lattices in polaritonic microcavities"

7) Alejandro Aceves   ( Southern Methodist University, U.S.A. )
   "Modeling fiber laser arrays"

8) Nikos Efremidis   ( University of Crete, Greece )
   "Wave propagation in waveguide arrays with alternating positive and negative couplings"

9) Eugenio Del Re   ( Universita' dell'Aquila and Universita' di Roma, Italy )
   "Solitons and wave-mixing, an avenue to ultra-resolved microscopy in the volume"
10) Zhigang Chen (San Francisco State University, U.S.A. & Nankai University, China)
   "Generation and control of propelling and self-bending optical beams"

11) S. Wabnitz*, N.N. Rosanov and V.V. Kozlov (Università di Brescia, Italy)
    "Ultrawideband dissipative optical solitons"

12) Tim Marchant (University of Wollongong, Australia)
    "Boundary induced motion of optical solitary waves"

13) Heping Zeng (East China Normal University, China)
    "Interaction of intense femtosecond filaments for photonic crystal plasma waveguides"
MS7. Nonlinear optics and nanophotonics

Organizer:
Yuri Kivshar (Australian National University, Australia)

Nanophotonics deals with optical processes at the nanoscale, much smaller than the wavelength of optical radiation. Subwavelength confinement of electromagnetic radiation presents numerous opportunities for both fundamental research and technological applications. This symposium aims to bring together several key researchers working on innovative concepts of nonlinear nanoscale photonics for a design and operation of new compact nanoscaled devices for optical physics and applications. This will cover theoretical and experimental research on the photonic-crystal physics and engineering, subwavelength nonlinear optics, nonlinear switching optical devices at the nanoscale, tunable and active plasmonic structures, and nonlinear soft-matter systems including nanosuspensions.

Importantly, the research efforts during recent years which focused on both fundamental physics and applications of nonlinear optics demonstrate several major trends. First, the basic concepts of nonlinear optics penetrated into new areas of material science by exploring novel nonlinear materials and nonlinear propagation of light in engineered structures such as left-handed metamaterials. Secondly, we observe further development of novel concepts, such as tunable nonlinear response, and engineered and enhanced nonlinearities, which should be explored more extensively for developing novel optical tunable nonlinear devices. Moreover, in such novel structures many of the effects well studied in nonlinear optics can be enhanced by the cavity effects, heterostructures, or Fano-type resonances, which enable much stronger nonlinear response at lower powers, as well as demonstrate novel subwavelength localization phenomena and novel concepts of nonlinear wave physics.

List of Speakers:

1) Dragomir Neshev (Australian National University, Canberra, Australia)
   "Nonlinear beam manipulation in coupled optical waveguides"

2) Shanhui Fan (Stanford University, Stanford, U.S.A.)
   "Photonic transitions in nanophotonics: optical isolation and completely controllable single-pole optical resonance"

3) George Tsironis (University of Crete, Heraklion, Greece)
   "Nonlinear localized and propagating modes in metamaterials"

4) Costantino De Angelis (University of Brescia, Brescia, Italy)
   "Frequency addressing of nano-objects by electrical tuning of optical antennas"

5) Yuri Kivshar (Australian National University, Canberra, Australia)
   "Nonlinear Metamaterial and Plasmonic Structures"
6) Alexander Szameit (University of Jena, Germany & Technion, Israel)
   "Amorphous photonic lattices: disorder, band gaps, and effective mass"

7) Yaroslav Kartashov (ICFO, Barcelona, Spain)
   "Observation of two-dimensional superlattice solitons"

8) Meir Orenstein (Technion, Haifa, Israel)
   "Plasmonic nonlinearities at propagation and storage"

9) Dmitry Skryabin (University of Bath, England)
   "Spectral signatures of temporal solitons in subwavelength waveguide arrays: Theory and experiment"

10) Concita Sibilia *M.Centini & *A.Benedetti (Università di Roma "La Sapienza", Italy)
    "Nonlinear Optics at the Nanoscale"

* coauthor
MS8. Nonlinear Waves in 3D Euler Equations and Surface Geostrophic Flows

Organizer:
Xinwei Yu   ( University of Alberta, Canada )

The 3D Euler and 2D Surface Quasi-Geostrophic (SQG) Equations receive much interest in the past 20 years due to their importance in mathematical fluid mechanics and the development of the mathematical theory for nonlinear evolutionary partial differential equations. Recently, new progresses have been made in the study of both equations. On one hand, recent numerical, analytical, and geometrical results have revealed hidden structures in the nonlinear interactions of the 3D Euler and 2D SQG equations; On the other hand, understanding of existing 1D model equations of these equations is becoming more complete, and several new model equations highlighting possible singularity formation mechanisms have been proposed and studied. A thorough understanding of these new results will serve as a foundation for the future development of a complete theory of mathematical fluid mechanics. The objective of this minisymposium is to bring together experts worldwide and present state-of-the-art research results. It will also serve as a platform for the discussion of future directions of the study of the 3D Euler, 2D SQG, and related equations.

List of Speakers:

1) Ruo Li   ( Peking University, China )
 "Numerical Study of 3D Incompressible Euler Equations with highly Symmetric Initial Data"

2) Shu Wang   ( College of Applied Sciences, Beijing University of Technology, China )
 "On singularity formation of the 3D model for the incompressible Euler and Navier-Stokes equation"

3) Zuoqiang Shi   ( Caltech, U.S.A. )
 "On Singularity Formation of a 3D Model for Incompressible Navier-Stokes Equations"

4) Jian Deng   ( Central University of Finance and Economics, China )
 "A nonlinear depletion mechanism of vorticity in 2D Boussinesq equation"

5) Stephen Preston   ( University of Colorado, Boulder, U.S.A. )
 "Geometric aspects of hydrodynamic blowup"

6) Zhen Lei   ( Fudan University, China )
 "Well-posedness of Complex Fluids"

7) Baoquan Yuan   ( Henan Polytechnic University, China )
 "Some results of the magneto-hydrodynamic system in Besov spaces"
8) Francisco Gancedo  ( University of Chicago, U.S.A. )
   "Contour dynamics for 2D active scalars"

9) Yong Zhou  ( East China Normal University, China )
   "On the Camassa-Holm equation"

10) Ning Ju  ( Oklahoma State University, U.S.A. )
    "Longtime Dynamics for 2D Boussinesque System with Fractional Dissipation"
MS9. Nonlinear Waves in Quantum Systems

Organizers:
Joachim Brand   ( Massey University, New Zealand )
Lincoln Carr   ( Colorado School of Mines, U.S.A. )

Although many-body quantum mechanics is linear, observations are equivalent to averaging over quantum operators. This averaging process gives rise to effective nonlinearity, typically on a larger scale, while quantum degeneracy may still dominate many properties. The dynamical description of such averaged quantities, e.g. the order parameter or correlations, is given by one or more coupled nonlinear partial differential equations, solutions of which are nonlinear waves. Quantum systems in which nonlinear waves play a key role in experiments include Bose-Einstein or Fermi condensates in ultracold atomic gases, polariton-exciton condensates in solid state materials, and superfluid Helium. Manipulation of confining potentials and other external experimental controls lead to a tremendous variety of nonlinear PDEs, including equations relevant to cosmological and relativistic physics. This mini-symposium presents a broad view of nonlinear waves in quantum systems, from experiment to theory.

List of Speakers:

1) Jeff Steinhauer   ( Technion-Israel Institute of Technology, Israel )
   "A sonic black hole in a density-inverted Bose-Einstein condensate"

2) Luis Santos   ( University of Hannover, Germany )
   "Non-linear phenomena in polar gases and quasi-relativistic spinor condensates"

3) Lincoln Carr   ( Colorado School of Mines, U.S.A. )
   "Semions, skyrmions, and a zoo of nonlinear waves in the nonlinear Dirac equation"

4) Sean Nowling   ( University of Helsinki, Finland )
   "Holographic Solitons and the AdS/CFT Correspondence"

5) Klaus Sengstock   ( University of Hamburg, Germany )
   "Spinor-quantum gases in triangular and hexagonal optical lattices"

6) Sergej Flach   ( Max Planck Institute for the Physics of Complex Systems, Germany )
   "Universal spreading of wave packets in disordered nonlinear systems"

7) Daniele Sanvitto   ( Autonomous University of Madrid, Spain )
   "Observation of BEC-related phenomena in polariton condensates"

8) Lev Pitaevskii   ( University of Trento, Italy )
   "Sound propagation in cylindrically confined gas"
9) Natalia Berloff   ( Cambridge University, U.K. )
   "Turbulence and electron bubbles in liquid helium and Bose-Einstein condensates"

10) Makoto Tsubota   ( University of Kyoto, Japan )
   "Quantum turbulence and nonlinear instability in quantum fluids"

11) Kris Helmerson   ( Monash University, Australia )
   "A Bose-Einstein Condensate in an optical ring-shaped trap"

12) Yvan Castin   ( Ecole Normale Superieure, France )
   "Quantum solitons and their scattering on a barrier"

13) Joachim Brand   ( Massey University, New Zealand )
   "Spectroscopy of bound states with matter-wave solitons"

14) Biao Wu   ( Institute of Physics, Chinese Academy of Sciences, China )
   "Composition Relation between Gap Solitons and Bloch Waves in Nonlinear Periodic Systems"

15) Weidong Li   ( Shanxi University, China )
   "Nonlinear quantum physics in Bose-Einstein Condensates"

16) Matt Davis   ( University of Queensland, Australia )
   "Spontaneous formation of topological defects in ultra-cold"

17) Masahito Ueda   ( University of Tokyo, Japan )
   "Information thermodynamics"
**MS10. Numerical Computation of Nonlinear Waves**

Organizer:
S. V. Tsynkov  (North Carolina State University, U.S.A.)

The minisymposium aims at presenting a number of recent advances in the field of numerical simulation of waves, with the emphasis on nonlinear wave phenomena. It will bring together the researchers working in different subject areas, and will hopefully foster an efficient exchange of ideas and approaches. The speakers will cover a range of topics that include singular solutions of the standing-ring type for a variety of nonlinear evolution equations, such as the nonlinear Schrödinger equation, modeling of underground explosions and the interaction of the blast waves with buried structures, spectral element methods for the Wigner equation in quantum transport, nondeteriorating schemes for computing the solutions of Maxwell's equations over long time intervals, compact high order schemes for the variable coefficient Helmholtz equation, and others.

List of Speakers:

1) Wei Cai  (University of North Carolina, U.S.A.)
   "Adaptive conservative cell average spectral element methods for transient Wigner equation in quantum transport"

2) V.R. Feldgun  (Technion-Israel Institute of Technology, Israel)
   "Numerical Simulation of Underground Explosions near a Buried Structure"

3) Z. Huang  (Tsinghua University, China)
   "A tailored finite point method for high frequency waves in heterogeneous media"

4) S. V. Petropavlovskiy  (Finance Academy, Russia)
   "Quasi-Lacunae of Maxwell's Equations and their Use for Long-Time Computations"

5) S. Tsynkov  (North Carolina State University, U.S.A.)
   "Compact high order schemes for the Helmholtz equation with variable coefficients"

6) J. Yang  (University of Vermont, U.S.A.)
   "Newton-conjugate-gradient methods for computations of solitary waves and their linear-stability eigenvalues"

7) J. Yuan  (Providence University, Taiwan)
   "A dual-Petrov-Galerkin method for the fifth-order Korteweg-de Vries type equations"

8) Z. Feng  (University of Texas Pan American, U.S.A.)
   "Nonlinear wave phenomena to Korteweg-de Vries Burgers-type equation"
MS11. **Supersonic, Dispersive Fluid Flows**

Organizer:
Mark Hoefer  ( North Carolina State University, U.S.A. )
Boaz Ilan  ( University of California, Merced, U.S.A. )

There is growing experimental and theoretical interest in the dynamics of nonlinear dispersive (essentially non-dissipative) fluids. Examples of such "nonlinear superfluids" are Bose-Einstein atomic condensates and light propagating in nonlinear optical media. When the fluid velocity exceeds the local speed of sound, rich dynamical phenomena are excited such as solitons, dispersive shock waves, vortices, and various instabilities. Mathematically, many of these problems are related to the semi-classical or small dispersion limit of the NLS, KdV and other nonlinear dispersive equations. In light of recent progress, the time is ripe to have a broad discussion on this topic. This mini-symposium session will foster an exchange of ideas within and between the applied mathematics and experimental physics communities.

List of Speakers:

1) Gennady El  ( Loughborough University, U.K. )
   "Two-dimensional supersonic nonlinear Schrödinger flows past obstacles"

2) Mark Hoefer  ( North Carolina State University, U.S.A. )
   "Oblique Shock Waves in Dispersive Eulerian Fluids"

3) Boaz Ilan  ( University of California, Merced, U.S.A. )
   "Absolute and convective instabilities of oblique dispersive shock waves"

4) Jason Fleischer  ( Princeton University, U.S.A. )
   "Instabilities and turbulence in dispersive flow"

5) Peter Engels  ( Washington State University, U.S.A. )
   "Quantum hydrodynamics in ultracold atomic gases"

6) Brian Anderson  ( University of Arizona, U.S.A. )
   "Vortex dipoles in a Bose-Einstein condensate"

7) Virgil Pierce  ( University of Texas-Pan American, U.S.A. )
   "The Whitham equations for dispersionless higher order integrable systems"

8) Christian Klein  ( Institut de Mathematiques de Bourgogne, France )
   "Universality of critical behaviour in Hamiltonian PDEs"

9) Antonio Moro  ( SISSA, Italy )
   "Dispersive shock wave in the continuous limit of Fermi-Pasta-Ulam models"
List of Talks

MS12. The KP equation and shallow water waves

Organizers:
Yuji Kodama   ( Ohio State University, U.S.A. )
Sarbarish Chakravarty   ( University of Colorado, Colorado Springs, U.S.A. )

The purpose of this minisymposium session is to discuss a variety of topics related to the Kadomtsev-Petviashvili (KP) equation and recent results in the study of shallow water waves. These topics will include (but not limited to):
(i) the initial value problem of the KP equation including solution methods, existence-uniqueness results, stability of soliton solutions;
(ii) applicability (as well as non-applicability) of the KP equation to describe shallow water waves and their interactions;
(iii) comparison of the KP equation with other two-dimensional wave equations for shallow water;
(iv) experimental and numerical studies of shallow water waves. Talks discussing recent analytical, numerical and experimental investigations of the above and closely related topics will be presented.

List of Speakers:

1) Mark Ablowitz   ( University of Colorado, Boulder, U.S.A. )
   "Reformulation and asymptotic reductions of water and interfacial waves"

2) Wooyoung Choi   ( New Jersey Institute of Technology, U.S.A. )
   "Modeling weakly two-dimensional water wave motions"

3) Youichi Murakami   ( Osaka Prefecture University, Japan )
   "Numerical and analytical study on instabilities of the line soliton of the KP I equation and related recurrent phenomena"

4) Alexey Slunyaev   ( Inst. of Appl. Phys., Novgorod )
   "Exact solutions for the Gardner equation"

5) C. Klein   ( Université de Bourgogne, France )
   "Numerical study of oscillatory regimes in the Kadomtsev-Petviashvili equation"

6) Philippe Guyenne   ( University of Delaware, U.S.A. )
   "Long waves over random topography"

7) Ken-ichi Maruno   ( University of Texas Pan-American, U.S.A. )
   "Soliton interactions of the two-dimensional Boussinesq-type equation"

8) Hidekazu Tsuji   ( Kyushu University, Japan )
   "Two-dimensional interaction of Benjamin-Ono solitons --- Comparison with solution of KP"
9) Harry Yeh (Oregon State University, U.S.A.)
   "KP solitons: Part 1. Experiments"

10) Yuji Kodama (Ohio State University, U.S.A.)
    "KP solitons: Part 2. Theory"

11) Chiu-Yen Kao (Ohio State University, U.S.A.)
    "KP solitons: Part 3. Simulations"

12) Sarbarish Chakravarty (University of Colorado, Colorado Springs, U.S.A.)
    "Some combinatorial problems related to the KP line-solitons"
CONTRIBUTED TALKS

C1. Integrable Systems:

1) X. J. Chen (Jinan University, China)
   "Double-pole soliton solution for the derivative nonlinear Schrödinger equation with nonvanishing boundary conditions"

2) A. Hariton (Université de Montréal, Canada)
   "Invariant solutions of supersymmetric nonlinear wave equations"

3) A. Rybkin (University of Alaska Fairbanks, U.S.A.)
   "The inverse scattering transform and meromorphic solutions to the KdV equation with non-decaying initial data"

4) D. Wu (Academia Sinica, Taiwan, China)
   "The Cauchy problem of the Ward equation"
C2. Matter waves and water waves:

1) R. Liao (Massey University, New Zealand)
"Families of dark solitons in the superfluid Fermi gas across the BCS-BEC crossover"

2) E.A. Ostrovskaya (The Australian National University, Australia)
"Two-component azimuthons in Bose-Einstein condensates"

3) T. Soomere (Institute of Cybernetics, Estonia)
"Water transport in groups of nonlinear wake waves from high-speed vessels"

4) H. Xia (The Australian National University, Australia)
"Applicability of weak turbulence theory to capillary wave"
C3. Nonlinear optics:

1) C. De Angelis (Università di Brescia, Italy)  
   "Nonlinear envelope equation for broadband optical pulses in quadratic media"

2) O. Bahat-Treidel (Technion, Israel)  
   "Nonlinear Waves in Honeycomb (graphene-like) Photonic Lattices"

3) S. Barbay (Laboratoire de Photonique et de Nanostructures, France)  
   "Cavity solitons and dynamical states in a laser with saturable absorber"

4) S. Barbay (Laboratoire de Photonique et de Nanostructures, France)  
   "Homoclinic snaking in a semiconductor based optical system"

5) T. Hansson (Chalmers University of Technology, Sweden)  
   "Quasi-Linear Evolution and Saturation of the Modulational Instability of Partially Coherent Optical Waves"

6) Yi Hu (Nankai University, China)  
   "Wing flipping, restoration and degeneration of deformed Airy beams"

7) K. Kim (Ajou University, Korea)  
   "Electromagnetic wave propagation in nonlinear metamaterials"

8) S. Kim (Ajou University, Korea)  
   "Nonreciprocal frequency doubling of electromagnetic waves through double resonance and Bragg reflection in photonic crystals"

9) A. Komarov (Russian Academy of Sciences, Russia)  
   "Dissipative solitons in passive mode-locked fiber lasers with nonlinear polarization rotation technique"

10) Z. Xu (The Australian National University, Australia)  
    "Interface vortex solitons in quadratic photonic lattices"

11) Yi Zhu (University of Colorado at Boulder, U.S.A.)  
    "Conical diffraction in honeycomb lattices"

12) A. Miroshnichenko (The Australian National University, Australia)  
    "Reversible optical nonreciprocity in periodic structures with liquid crystals"

13) F. Setzpfandt (Friedrich Schiller University, Germany)  
    "Properties of discrete quadratic multiband solitons"
14) J. M. Dudley (CNRS-Université de Franche-Comté, France)
   "Extreme events and nonlinear rogue waves in optics"

15) A.V. Kim (Russian Academy of Science, Russia)
   "Elliptically polarized few-optical-cycle solitons: structures and its dynamics"
C4. Other aspects of nonlinear waves:

1) J. Villarroel (Univ. de Salamanca, Spain) 
   "Random discontinuous perturbations of NLS"

2) J. Caputo (Avenue de l'Universite, France) 
   "Localized oscillator in a cavity: an adapted spectral approach"

3) N. Karjanto (The University of Nottingham Malaysia Campus, Malaysia) 
   "Modulational instability of the nonlinear Schrödinger equation with viscosity effect"

4) L.Z. Khadeeva (Russian Academy of Science, Russia) 
   "Gap discrete breathers in two- and three-dimensional diatomic crystals with Morse interactions"

5) B. Nguyen (Ajou University, Korea) 
   "Interplay between disorder and nonlinearity in the propagation of waves in one-dimensional nonlinear random media: Fixed input case"

6) T. Yang (National Cheng Kung University, Taiwan, China) 
   "Effects of actuator impact on the nonlinear dynamics of a valveless pumping system"

7) Z. Zhang (Tsinghua University, China) 
   "Adaptive artificial boundary conditions for two-dimensional nonlinear Klein Gordon equation on unbounded domain"

8) W. Duan (Northwest Normal University, China) 
   "Phase transition and critical depinning point in two dimensional Frenkel-Kontorova(FK) model"
POSTER

1) Azucena Alvarez  ( University of Sevilla, Spain )
   "Collisions of different discrete breathers"

2) Anh Minh Bui Boi  ( State University of New York, U.S.A. )
   "Soliton reflection in defocusing NLS with linearizable boundary conditions"

3) Anakewit Boonkasame  ( University of Wisconsin, U.S.A. )
   "Simple waves and nonlinear stability of two-layer flows"

4) Jing Gong  ( Uppsala University, Sweden )
   "Shock wave diffraction calculations using very high order difference schemes"

5) Michael Hay  ( Kyushu University, Japan )
   "Casorati determinant solutions to the non-autonomous cross-ratio equation"

6) Juan Hu  ( AMSS, Chinese Academy of Sciences, China )
   "A three-dimensional three-wave resonant interaction equation with self-consistent sources"

7) Yuhan Jia  ( The Ohio State University, U.S.A. )
   "Higher order corrections to the Miles theory of shallow water waves"

8) Ji Lin  ( Zhejiang Normal University, China )
   "Symmetry group and exact solutions for the 2+1 dimensional AKNS equation"

9) Yi-Ping Ma  ( University of California, Berkeley, U.S.A. )
   "Defect-mediated snaking: A new growth mechanism for localized Structures"

10) Chang-Guang Shi  ( Shanghai University of Electric Power, China )
    "Knots in a conformal nonlinear sigma model"

11) Dengshan Wang  ( Institute of Physics, Chinese Academy of Sciences, China)
    "Integrable properties of the general coupled nonlinear Schrodinger equations"

12) Lei Wu  ( Zhejiang Forestry University, China)
    "Exact stable vortex modes in two-dimensional Bose-Einstein condensates and in nonlinear optics"

13) Guofu Yu  ( Shanghai JiaoTong University, China )
    "Eigen-solutions of Biconfluent Heun with respect to a complex weight"

14) Jiefang Zhang  ( Zhejiang Normal University, China )
"Matter-wave solitons and finite-amplitude Bloch waves in optical lattices with a spatially modulated nonlinearity"
Abstracts
Singular Solitons and Fourier Transform on Riemann Surfaces

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A lot of singular solutions to the soliton equations like KdV are known. They do not have any direct physical meaning in the Theory of Nonlinear Waves. Corresponding Schrodinger operators do not have any direct meaning in the Quantum Mechanics as well as in the spectral theory of operators in the standard Hilbert Spaces. Indeed, a lot of mathematical works were dedicated to them in the literature. It was found in the late 1980s that singular soliton-type constructions can be used for the right definition of Fourier series on the Riemann Surfaces needed for the operator quantization of strings. In the recent works joint with P.Grinevich, we constructed and investigated the analog of Fourier Transform on Riemann Surfaces. We found that indefinite analogs of Hilbert Spaces are needed. In particular, famous singular Schrodinger operators (like Lame’ operator on the whole line) with singular soliton-type potential are in fact self-adjoint in the indefinite Hilbert Space.
Recent Progress on Dynamic Stability and Global Regularity of 3D Incompressible Euler and Navier-Stokes Equations

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Whether the 3D incompressible Navier-Stokes equations can develop a finite time singularity from smooth initial data is one of the seven Millennium Open Problems posted by the Clay Mathematical Institute. We review some recent theoretical and computational studies of the 3D Euler equations which show that there is a subtle dynamic depletion of nonlinear vortex stretching due to local geometric regularity of vortex filaments. The local geometric regularity of vortex filaments can lead to tremendous cancellation of nonlinear vortex stretching, thus preventing a finite time singularity. Our studies also reveal a surprising stabilizing effect of convection for the 3D incompressible Euler and Navier-Stokes equations. Finally, we present a new class of solutions for the 3D Euler and Navier-Stokes equations, which exhibit very interesting dynamic growth property. By exploiting the special structure of the solution and the cancellation between the convection term and the vortex stretching term, we prove nonlinear stability and the global regularity of this class of solutions.
Non-linear dynamics of a thin soliton

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The aim of this talk is to investigate the dynamics of a soliton in a general form, without direct reference to an equation to the order parameter, in terms of the energy $E_s(V,\mu)$ of a soliton in an uniform medium where $V$ is the velocity of the soliton and $\mu$ is the chemical potential. The number of atoms in the soliton can be calculated as $N_s = \int \infty (-\bar{n}) dx = -\partial E_s/\partial \mu$. If the medium is placed in an external potential $U(x)$, the motion of a "thin" soliton, whose thickness is small in comparison to characteristic length scale of the potential, is defined by the equation of conservation of energy $E_s(dX/dt,\mu - U(X)) = E_0$ or

$$m_I d^2X/dt^2 = -N_s \partial U/\partial X,$$

(1)

where the "inertial mass" $m_I = 2\partial E_s/\partial V^2$. In typical examples both $N_s$ and $m_I$ are negative. For example, a soliton in BEC, described by the GP-equation, moves as a particle of mass $2m$.

Important and nontrivial problems arise in connection with the phase imprinting experiment, where an optical perturbation creates a soliton with given jump $\Delta \varphi$ of the phase of the order parameter. Assuming that the system possesses Galilean invariance and the equation for order parameter can be obtained by an energy minimization, one can calculate the relation $V(\Delta \varphi)$ from the equation

$$\int_0^V \frac{\partial E_s}{\partial V} dV = mN_s V + \frac{m}{m_B} \hbar \bar{n} [\Delta \varphi - \pi],$$

(2)

where $m_B = m$ for the bosonic superfluid and $m_B = 2m$ for the fermionic one.

This equation gives a relation between the "canonical" momentum of the soliton $p_c = \int_0^V \frac{\partial E_s}{\partial V} dV$ and the "physical" one $mN_s V$. The physical meaning of this relation is discussed. It follows that the maximum value of $p_c$ is $\pi (m/m_B) \hbar \bar{n}$. For a soliton in a harmonic trap with frequency $\omega_x$, equation (2) gives the equation for the frequency of small oscillations of a soliton

$$\left(1 - \frac{\omega^2}{\omega^2}\right) m_I = \frac{\hbar \bar{n}}{m_B} \left[ \frac{d}{dV} \Delta \varphi \right]_{V \rightarrow 0}.$$

(3)

Confirmation of this equation in real or numerical experiments would be an important check of the theory. Introducing $E_s$ is quite useful for 2D and 3D problems, where it plays role of the surface tension of the soliton. For example, an element of the soliton surface with principal radii of curvature $R_1$ and $R_2$ moves along its normal with the acceleration

$$d^2X/dt^2 = \frac{E_s}{m_I} \left(\frac{1}{R_1} + \frac{1}{R_2}\right).$$

(4)

This relation can be used to investigate solitons stability and solve problems of dynamic of soliton "bubbles", which can be interesting from experimental point of view.
Discrete Linear and Nonlinear Optics

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Discrete optics opens up new opportunities in manipulating light flow. We provide an overview of recent experimental and theoretical developments in this area. The effects of discreteness on linear and nonlinear optical interactions are discussed.

Discretizing light behavior requires optical elements that can confine optical energy at distinct sites. One possible scenario in implementing such arrangements is to store energy within low loss high Q microcavities and then allow photon exchange between such components in time. This scheme requires high-contrast dielectric elements that became available with the advent of photonic crystal technologies. Another possible avenue where such light discretization can be directly observed and studied is that based on evanescently coupled waveguide arrays. As indicated in several studies, discrete systems open up whole new directions in terms of modifying light transport properties. One such example is that of discrete solitons. By nature, discrete solitons represent self-trapped wavepackets in nonlinear periodic structures and result from the interplay between lattice diffraction (or dispersion) and material nonlinearity. In optics, this class of self-localized states has been successfully observed in both one- and two-dimensional nonlinear waveguide arrays. In recent years such photonic lattices have been implemented or induced in a variety of material systems, including those with cubic (Kerr), quadratic, photorefractive, and liquid-crystal nonlinearities. In all cases the underlying periodicity or discreteness can lead to new families of optical solitons that have no counterpart whatsoever in continuous systems. Interestingly, these results paved the way for observations in other physical systems obeying similar evolution equations like Bose-Einstein condensates.

New developments in laser writing ultrashort femtosecond laser pulses, may now allow the realization of all-optical switching networks in fully 3D environments using nonlinear discrete optics. Using this approach all-optical routing can be achieved using blocking operations. The spatio-temporal evolution of optical pulses in both normally and anomalously dispersive arrays can lead to novel schemes for mode-locking and pulse compression. A strong signature of discrete X-wave formation was also demonstrated in such structures. In the last two years, Anderson localization was unequivocally observed in array systems where the transition from ballistic transport to diffusive, and the cross-over to Anderson localization was studied as a function of disorder and nonlinearity. In recent studies synthetic lattices exhibiting parity-time (PT) symmetry were also considered. The interplay of gain and loss in this latter family of structures leads to counterintuitive characteristics and behavior such as non-reciprocal propagation and power oscillations. The realization of discrete array systems at subwavelength scales is another important direction that is nowadays intensively pursued.

References:
Nonlinear signaling in neurons and networks of neurons

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Abstract:

With its estimated 100 billion neurons and 200 trillion interconnections, the human central nervous system is one of the most complex systems known. How does this collection of neurons transmit and process information? This tutorial will explain the basic biophysics of neurons and mathematical models that describe how they actively signal one another. It will begin with a characterization of the membrane properties of neurons in terms of ordinary differential equations and how these properties combine to produce the principal neuronal signal known as the action potential. This will be followed by a discussion of the partial differential equation that describes the spread of voltage through the different parts of a neuron (e.g., the dendrites and axon) and its solution. It will finish with a mathematical description of chemical and electrical signaling between neurons, and how this signaling leads to the larger networks of neurons capable of performing more sophisticated operations.
Asymptotic reductions of water and internal waves and their solitary waves

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Abstract:

Nonlocal spectral formulations of water and internal waves are a convenient means to obtain asymptotic reductions. We use these systems to obtain high order asymptotic expansions describing one dimensional solitary waves with surface tension and two-dimensional systems including the Benney-Luke (BL) and the intermediate BL equation and their two-dimensional lump-type solitary waves. If time permits, a brief discussion of novel discrete nonlinear wave equations in two dimensional photonic lattices will be included.
BOUND STATES IN PERIODIC LATTICES

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Abstract:

The bifurcation of gap solitary waves near edges of Bloch bands in 1-D periodic media is studied in terms of the nonlinear Schrodinger (NLS) equation with a periodic potential. Based on standard multiple-scale perturbation theory, in the small-amplitude limit, solitary waves bifurcating from band edges are in the form of wavepackets, modulated by a “sech” envelope whose position relative to the underlying periodic Bloch mode remains undetermined. It is shown by means of exponential asymptotics that, out of this one-parameter solution family, only two branches of truly locally confined solutions bifurcate from band edges; these fundamental branches correspond to “on-site” and “off-site” gap solitons, the former being stable and the other unstable. In addition, there exist an infinite number of solution branches that comprise more than one fundamental gap solitons; such bound states, however, bifurcate in the interior of the band gap at small but finite amplitude. The predictions of the asymptotic theory are compared against numerical results.
Stability of resonant traveling water waves

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Abstract:

A boundary perturbation algorithm will be presented for computing the spectral data of traveling wave solutions to the potential flow equations. This algorithm extends the transformed field expansion technique of Nicholls (2002) to compute the spectral stability of resonant waves, for example Wilton Ripples.

References:

Solitons reflection in boundary value problems and a nonlinear method of images

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Abstract:

One of the hallmarks of integrability is the existence of exact \( N \)-soliton solutions. It is well known that each soliton is associated to a discrete eigenvalue for the scattering problem via the inverse scattering transform (IST). Recent studies have shown that this characterization holds not only for initial value problems (IVPs), but also for initial-boundary value problems (IBVPs). The purpose of this talk is to characterize the solutions of IBVPs for discrete and continuous nonlinear Schrödinger (NLS) systems on a semi-infinite domain with linearizable boundary conditions (BCs).

The IBVP for the NLS equation
\[
\dot{q} + q_{xx} + 2|q|^2 q = 0 \quad \text{on } 0 < x < \infty
\]
with homogeneous Dirichlet or Neumann BCs at the origin was studied in [1] using the IST on the whole line and an odd or even extension of the potential, respectively. The case of homogeneous Robin BCs,
\[
q_x(0,t) - \alpha q(0,t) = 0 \quad \text{with } \alpha \text{ a real constant},
\]
was also linearized in [2–4]. Importantly, in all of these methods the relation between solitons and discrete eigenvalues existing in the IVP is preserved in the IBVP. This leads to a paradox, however, since the soliton solutions of the NLS equation do not satisfy the linearizable BCs. A further paradox is that numerical solutions of the IBVP for the NLS equation show unequivocally that solitons are reflected at the boundary. But the soliton velocity is the real part of the discrete eigenvalue, which does not change in time. In this talk we show that the resolution of these apparent paradoxes is that discrete eigenvalues in the IBVP appear in quartets, as opposed to pairs in the IVP. This means that, for each soliton in the physical domain a symmetric counterpart exists, with equal amplitude and opposite velocity, whose presence ensures that the whole solution satisfies the BCs. The ostensible reflection of the soliton at the boundary of the physical domain then corresponds simply to the interchanging of roles between the “physical” and “mirror” solitons.

These results are similar in spirit to — and represents a nonlinear analogue of — the method of images that is used to solve boundary value problems in electrostatics. Here, however, the soliton reflection comes accompanied by a corresponding position shift, which is a reminder of the nonlinear nature of the problem. Similar phenomena arise for the focusing [5] and defocusing [6] NLS equations and also for the integrable discrete analogue of the NLS equation, the Ablowitz-Ladik (AL) lattice [7].
References:
3 R F Bikbaev and V O Tarasov, J. Phys. A 24, 2507 (1991);
7 G Biondini and G Hwang, Applic. Anal. 82, to appear (2010)
The effect of rotation on internal solitary waves

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Abstract:

Internal solitary waves are commonly observed in the coastal oceans and in the lower atmospheric boundary layer. They are often modeled by nonlinear wave equations of the Korteweg-de Vries type, which are well-known to support exact solitary wave solutions. However, they are observed to survive for long periods, and hence it is necessary to examine the effect of the earth’s rotation on their long-time evolution. In this case, the relevant nonlinear wave equations can no longer support exact solitary wave solutions, and instead an initial solitary-like disturbance decays into radiating inertia-gravity waves. In this talk, we will demonstrate through a combination of theoretical analyses, numerical simulations and laboratory experiments that the long-time outcome of this radiation is a wave packet, whose carrier wavenumber is determined by an extremum in the group velocity.
Normal forms and KP solitons

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Abstract:

The KP equation describes two-dimensional nonlinear dispersive waves at the leading order approximation under the assumptions of small amplitude, weakly dispersive and quasi-two dimensionality. We develop a normal form theory to study the higher order corrections to the KP equation including the effects of larger amplitude and higher dispersion and diffraction in both $x$- and $y$-directions. For the case of one-dimensional problem where the KdV equation gives the leading order approximation, we have developed the normal form theory in [1,2] and found that the first order correction to the KdV equation can be transformed to the 5th order KdV equation, that is, the perturbed equation is asymptotically integrable up-to this order. However, in the case of the KP equation, there are several obstacles to obtain the similar results for asymptotic integrability. The normal form theory for the KP equation in [3] states that in the next order correction, there are five conditions among ten higher order terms for the asymptotic integrability. In this talk, I will explain the detailed structure of the normal form theory, and present an application of the theory to real experiments of shallow water waves.

References:
Localized Ectopic Expression of Dpp Receptors in a Drosophila Embryo

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Abstract:
Receptor-mediated bone morphogen protein (BMP) degradation has been seen to play an important role in allowing for the formation of relatively stable (PMad) patterns of biological tissues. To the extent that receptors act as a "sink" for BMPs, one would predict that the localized over-expression of signaling receptors would cause a net flux of freely diffused BMPs toward the ectopic, i.e., abnormally high concentration, receptor site. One possible consequence would be a depression of BMP signaling in adjacent areas since less BMPs are now available for binding with the same normal concentration of receptors at the adjacent areas. However, recent experiments designed to examine this possible effect were inconclusive. In this talk, we investigate the possibility of depression of Dpp signaling outside the area of elevated tkv receptor concentration in a Drosophila embryo by modeling mathematically the basic biological processes at work in terms of a system of nonlinear reaction diffusion equations with spatially varying (and possibly discontinuous) system properties. The steady state signaling morphogen gradient is investigated by the method of matched asymptotic expansions and by numerical simulations.

References:
Fractal scattering in weak interactions of solitary waves

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Abstract:

Weak interactions of solitary waves refer to the interactions where two solitary waves initially are well separated and having almost the same velocities. These interactions occur due to the tail overlap between the two waves. Previous work has shown that in a large class of generalized NLS equations, weak interactions of solitary waves exhibit a universal fractal scattering phenomenon, i.e., the interaction outcome depends on the initial conditions in a universal fractal manner [1]. Through two successive asymptotic reductions, this fractal scattering was found to be governed by a universal second-order map which does not contain any free parameters [2,3]. In this talk, we analyze the properties of this second-order map. We show that this map exhibits a fractal structure of its own. More importantly, this fractal of the map gives a complete characterization of universal fractal structures arising in the original generalized NLS equations. The physical mechanism for fractal scatterings is also investigated. This scattering is linked to second-order solitons in the integrable NLS equation whose zero in the spectral plane is double-fold. Due to the degeneracy of this double zero, when these second-order NLS solitons are perturbed, whether they will stay together or break apart depends sensitively on the perturbations. This sensitivity is ultimately responsible for fractal scatterings in the generalized NLS equations. This physical mechanism is very different from the previous mechanism of resonant energy exchange between translational motion and internal oscillations, which was responsible for fractal scatterings in solitary wave collisions [4]. This talk is based in part on the materials in Ref. [5].

References:
Resonant Oscillations: Interaction between Nonlinearity, Geometry and Inhomogeneity

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Abstract:

The propagation of acoustic waves in closed containers provides a natural context in which to study the mechanisms of shock formation in cylindrical\textsuperscript{1,2} and more general settings\textsuperscript{3}. Key to this is the fundamental interplay between nonlinearity, geometry and inhomogeneity of the underlying density profile. In order to illustrate and examine this, the case of an isentropic gas in an axisymmetric geometry provides a simple yet robust setting possessing these key features. Beginning with the associated system of model equations and applying a forcing along the axis of symmetry at or near resonance, the resulting linear and (weakly) nonlinear theory is developed through a perturbative framework. Comparisons with numerical approximations will then be drawn, providing a basis for further understanding and extension of the analytic results.

This work is in collaboration with M.P. Mortell (UC Cork) and B.R. Seymour (UBC).

References:

1. W. Chester, J. Fluid Mech., 18, 44-64 (1964)
Mathematical models for nonlinear gravity-capillary waves.

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Abstract:

Nonlinear waves propagating at the surface of an incompressible and inviscid fluid are considered. The flow is assumed to be irrotational. The effects of gravity and surface tension are included in the dynamic boundary conditions. The fully nonlinear problem is solved by boundary integral equation methods. In addition various weakly nonlinear models are discussed. In two-dimensions there are multiple periodic solutions, generalized solitary waves and solitary waves with decaying oscillatory tails. The connections between these various types of waves are discussed. In three dimensions it is found that there are solitary waves with decaying oscillations in the direction of the propagation and monotonic decay in the direction perpendicular to the direction of propagation. Very recent results on the dynamics of two-dimensional solitary waves are also discussed.
The Generalized Serre Equations for Shallow Water Waves

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Abstract:

The Serre equations were first written in 1953 and govern fully nonlinear weakly dispersive shallow water waves. They have been studied much less than their weakly nonlinear counterparts the Boussinesq equations, despite having better properties: Gallilean invariance, simple energy and momentum expressions and explicit solitary waves. (In fact the Serre equations have been independently rederived several times and are sometimes called the Su-Gardner system or the Green-Naghdi equations.) We shall discuss several aspects of these equations: (i) the inclusion of surface tension effects, (ii) the one-parameter family of equations resulting from expanding the solutions about an arbitrary depth in the fluid, (iii) a consistent fully “time-explicit” version of the equations and (iv) a symmetric splitting based on the non-dispersive Riemann invariants of the system.

References:
Topological excitations in Bose-Einstein condensates

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Abstract:

Spinor and/or dipolar Bose-Einstein condensates can host a rich variety of topological excitations due to their internal degrees of freedom and anisotropic nature of the interaction. In this talk, I will present some of the recent developments on this topic such as the Kibble-Zurek mechanism, knot excitations, non-Abelian vortices, and vortex tiling.
Spatial pattern formation in nonequilibrium condensates

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Abstract:

Quasiparticles in semiconductors — such as microcavity polaritons — can form condensates in which the steady-state density profile is set by the balance of pumping and decay. We model trapped, pumped, decaying condensates by a complex Gross-Pitaevskii equation and analyse the density and currents in the steady state. If the pumping spot is larger than the Thomas-Fermi cloud radius, then rotationally symmetric solutions are replaced by solutions with spontaneous arrays of vortices. These vortex arrays arise without any rotation of the trap, spontaneously breaking rotational symmetry. By taking account of the polarization degree of freedom for such condensates, and considering the effects of an applied magnetic field, I will discuss the interplay between polarization dynamics, and the spatial structure of the pumped decaying condensate. Interactions between the spin components can influence the dynamics of vortices; produce stable complexes of vortices and rarefaction pulses with both co- and counter-rotating polarizations; and increase the range of possible limit cycles for the polarization dynamics, with different attractors displaying different spatial structures.
The Stochastic Projected Gross-Pitaevskii equation: theory and applications in high temperature Bose gases

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Abstract:

An overview of the stochastic Gross-Pitaevskii theory of the high temperature Bose gas will be presented, emphasizing recent developments, both formal and numerical. Since it incorporates thermal fluctuations and nonlinear interactions, the theory is well suited to describing the dynamics of defect formation during the BEC phase transition, and the decay of coherent metastable excitations such as vortices and solitons. The role of thermal and quantum fluctuations will be emphasized and a survey of recent applications will be given.
Double wells in Bose-Einstein Condensates

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Abstract:

I will introduce some models motivated by studies of Bose-Einstein condensates (BECs) trapped in double-well potentials (DWPs), within the context of the well-established mean-field model, namely the Gross-Pitaevskii equation (GPE).

In previous work, the prototypical model in a quasi-1D setting was examined by using a Galerkin-type two-mode approach, a powerful handle on studying the steady states and predicting the bifurcation diagram. We aim at extending the analysis of the DWP setting to various modified models.

We first consider a collisionally inhomogeneous environment, in which case a potential spatial variation of the nonlinearity is to be introduced. It turns out that the inhomogeneity induces a significant modification of the bifurcation diagram.

We then move on to some multi-component systems. We begin with a two-component system, i.e. a mixture of two hyperfine states of the same species, followed by a three-component system, where the spin degree of freedom is considered. Numerous branches of steady solutions that involve one, two or three counterparts are observed.

We also extend to a 2D model in the setting of a four-well potential, combined by a strong harmonic trap and a periodic potential. Due to the 2D nature, a four-mode reduction is developed.

Lastly, a model with nonlocal interactions will be considered to examine how, in turn, nonlocality may affect the bifurcation picture.
Generation of bright solitary waves and experimental tests of mean-field theory in attractive Bose-Einstein condensates

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Abstract:

Bright matter-solitary waves in attractive atomic Bose-Einstein condensates are an intriguing example of nonlinear wave phenomena with potential applications in metrology and the study of atom-surface interactions. Several experiments to date have produced bright solitary waves and shown them to be relatively robust, but multiple bright solitary waves have only been produced by processes involving collapse of the condensate [1,2]. Such processes are difficult to precisely control and unlikely to reliably generate the specific and reproducible states needed for matter-wave interferometry experiments using multiple solitary waves.

We consider phase imprinting and interference-based methods to reliably split the ground state of an attractive BEC into multiple solitary waves without inducing collapse. The relative phases and outgoing velocities of the generated solitary waves can be precisely controlled, and a harmonic confining potential leads to subsequent periodic re-collisions of the waves at the trap center [3]. Observation of these re-collisions provides a way to experimentally address the much-discussed issue of the importance of beyond-mean-field effects in solitary wave-solitary wave collisions [4,5], and could be accomplished using configurations such as the Durham $^{85}$Rb experiment.

References:
Discrete solitons and vortices in dipolar Bose-Einstein condensates

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Abstract:

The problems of existence, stability and dynamics of discrete localized modes in dipolar Bose-Einstein condensates (BEC) confined in the cigar-shaped and disk-shaped traps in the presence of the one-dimensional (1D) and two-dimensional (2D) optical lattices, respectively, are presented. Assuming the very deep optical lattices, the dipolar BECs are modelled by two difference-differential equations of the corresponding dimensionality, both derived from the underlying 3D Gross-Pitaevskii equations developing the corresponding dimension reduction and discretization procedures [1-4]. These are the discrete Schrödinger equations with local cubic and nonpolynomial nonlinearities, and with an additional nonlocal term accounting for the dipole-dipole (DD) interactions. The existence and stability of fundamental unstaggered solitons in 1D and 2D BECs and vortices of the topological charge 1 and 2 in dipolar BECs are studied for attractive and repulsive signs of both the local and nonlocal interactions. In 1D BEC with both cubic and nonpolynomial nonlinearity, the DD forces strongly affect the shape and stability of on-site and inter-site discrete solitons. In the second case the collapse threshold is effected by the nonlocal DD interactions. The corresponding existence and stability regions in the parametric space are summarized in the form of diagrams, which feature a multiple stability exchange between the on-site and intersite soliton families. The study is extended to the 2D BEC [3]. The analysis is focused on the influence of the DD interactions on fundamental localized modes (2D discrete solitons). The repulsive isotropic DD interaction extends the existence and stability regions of the fundamental solitons. New families of on-site, inter-site and hybrid solitons built on top of a finite background are found as a result of the interplay of the isotropic repulsive DD interaction and attractive contact nonlinearity. These solutions are unstable, evolving into robust breathers which exist on an oscillating background. In the presence of the repulsive contact interaction, fundamental localized modes exist if the DD interaction (attractive isotropic or anisotropic) is strong enough. They are stable in the narrow regions close to the anticontinuum limit, while unstable solitons evolve into breathers. Finally, within the framework of the 2D BEC model with cubic nonlinearity, the analysis of the existence, stability and dynamics of discrete vortices with topological charge $S = 1$ and $S = 2$ is presented [4]. Various species of discrete vortices, which are known in the model of the condensate with local interactions only, are found to exist in the presence of the DD interaction too. In locally self-attractive condensates, the isotropic DD repulsion, which corresponds to the orientation of atomic dipoles perpendicular to the confinement plane, extends the region of the vortex stability, while in the case of anisotropic DD interactions, corresponding to the in-plane orientation of the dipoles, vortices are unstable. In the former case, those vortices which are unstable may evolve into robust ring-shaped breathers. The attractive isotropic DD interaction can create localized vortices in the condensate with the local self-repulsion, but they all are unstable, evolving into single-peak asymmetric structures.
References:
Dark and bright solitons in superfluid Fermi gases in the BCS-BEC crossover

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Abstract:

We study, both analytically and numerically, the formation and propagation of dark and bright solitons in a superfluid Fermi gas in the crossover from Bardeen-Cooper-Schrieffer (BCS) superfluid to a Bose-Einstein condensate (BEC). Starting from a superfluid order-parameter equation we derive Korteweg-de Vries equations for weak nonlinear excitations in the cases of small and large particle numbers. We present dark and bright soliton solutions valid for both BCS and BEC limits and also for the crossover, and show that the solitons in different superfluid regimes possess different features. We study also the head-on collision between two solitons and demonstrate that the phase shift due to the collision changes non-monotonically along the BCS-BEC crossover. All analytical results are checked by numerical simulations and good agreements between them are found [1,2].

References:
Controlled dynamics of matter waves in two-dimensional optical lattices

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Abstract:

Controlled manipulation of spatially localized collective excitations of ultracold atomic gases is an attractive idea from the point of view of the developing atomic interferometry and precise measurement techniques based on the use of the Bose-Einstein condensates (BECs). In the recent years optical lattices were suggested as a means of achieving controlled transport of matter waves. In particular, theoretical studies of nonlinearly localized matter-wave solitons, loaded into a rapidly driven one-dimensional asymmetric optical lattice potential, have demonstrated that such an “optical ratchet” supports dynamically stable solitons and enables their mass-dependent transport [1,2].

Transport of matter-wave solitons in two- and three-dimensional trapping geometries is a more complex and challenging task, especially considering the intrinsic instability of the condensate with the negative scattering length and the fact that an optical lattice potential may greatly inhibit the mobility of the localized states. The main challenge is to suggest an efficient method for non-destructive, dynamically controlled transport of the stabilized wavepackets.

In this talk we will review the main features of the nonlinear matter-wave dynamics in a driven potential and present the theory of controlled transport of two-dimensional matter-wave solitons created in a BEC with a negative scattering length. The transport is realized by means of a driven “rocking” two-dimensional optical lattice [3]. Our numerical analysis, based on the mean-field model, and the theory based on the time-averaging approach, demonstrates that a fast time-periodic rocking of the 2D optical lattice enables efficient stabilization, manipulation, and “routing” of nonlinear localized matter wavepackets.

References:
Matter Rogue Waves

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Abstract:

We describe excitation and evolution of deterministic rogue waves in Bose-Einstein condensates either loaded into a parabolic trap or embedded in an optical lattice. In the latter case, rogue waves can be observed in condensates with a positive scattering length. The rogue waves are immensely enhanced by the lattice: local atomic density may increase up to tens times. We extend the theory to binary mixtures of the condensates where inter-atomic dramatically affect the existence of rogue waves (compared to the situation when only one of the respective components is present). Different dynamical regimes in the presence of linear interspecies coupling are described. Ways of experimental excitation of rogue waves are discussed.
Non-Abelian Josephson effect and half vortex of cold atoms in traps and microcavities

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Abstract:

We investigate the non-Abelian Josephson effect in F=2 spinor Bose-Einstein condensates with double optical traps. We propose a real physical system which contains non-Abelian Josephson effect and has very different density and spin tunneling characters compared with the Abelian case. We calculate the frequencies of the pseudo Goldstone modes in different phases between two traps respectively, which are the crucial feature of the non-Abelian Josephson effect. We also give an experimental protocol to observe this novel effect in future experiments [1]. We also study Josephson effect for photons in two weakly linked microcavities [2], and quantum magnetic dynamics of polarized light in arrays of microcavities. We also investigate localization and the Kosterlitz-Thouless transition of fermion with disorder in hexagon lattices [3]. We investigate dynamic creation of fractionalized half-quantum vortices in Bose-Einstein condensates of sodium atoms. Our simulations show that both individual half-quantum vortices and vortex lattices can be created in rotating optical traps when additional pulsed magnetic trapping potentials are applied. We also find that a distinct periodically modulated spin-density-wave spatial structure is always embedded in square half-quantum vortex lattices. This structure can be conveniently probed by taking absorption images of ballistically expanding cold atoms in a Stern-Gerlach field [4].

References:
Stochastic Soliton Dynamics in Finite Temperature Quantum Gases

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Abstract:

A number of recent experiments with ultracold quantum gases has led to the observation and study of dark solitons. At low temperatures, solitons were observed to oscillate in the harmonic confining potential [1], while the presence of a thermal cloud has been predicted to lead to a gradual increase in the oscillation amplitude due to damping. Previous work has focused on the average behaviour of solitons in such systems, often leading to very accurate predictions [2]. However, an accurate modelling of the motion of such a macroscopic structure through a medium requires consideration of any residual fluctuations in the medium, an effect which is typically present in realistic experiments.

We present [3] an ab-initio discussion of soliton dynamics which takes account of the anticipated shot-to-shot variation in the soliton trajectories between different experimental realisations at all nonzero temperatures. We also undertake a statistical analysis of soliton trajectories, and identify an optimal regime for the experimental characterisation of this effect.

Our analysis is based on the Stochastic Gross-Pitaevskii equation [4] which accounts for shot-to-shot fluctuations in both the density and the phase of the underlying medium, the latter becoming increasingly important in highly-elongated geometries. This model not only provides an ab initio determination of the average dissipation experienced by the soliton, but most importantly it also describes time-dependent random stochastic kicks to the propagating soliton, thereby modelling the experimentally-relevant shot-to-shot variations.

We acknowledge funding from the EPSRC.

References:
Persistent currents in an oblate, finite-temperature Bose-Einstein condensate

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Abstract:

We report new experimental observations of multiply charged persistent currents in a Bose-Einstein condensate (BEC). Our BECs are formed in an axi-symmetric highly oblate trapping potential. The trap is pierced with a blue-detuned laser beam propagating along the trap axis to create a toroidal potential well. At finite temperatures, with many unpinned vortices initially in the BEC, thermal damping establishes and stabilizes a persistent current about the trap axis. We have observed multiply charged persistent superfluid currents lasting for up to 50 seconds in this configuration. Our experimental methods will be compared with finite-temperature and zero-temperature numerical simulations probing the formation and stability of BEC persistent currents.
Mixtures of spinor atomic Bose-Einstein condensates

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Abstract:

We study the ground state and classify its phase diagram for a mixture of two spin-1 condensates in the absence of external magnetic (B-) field according to atomic parameters for intra- and inter-species spin exchange coupling and singlet pairing interaction.
Dark solitons and some generalizations thereof in Bose-Einstein condensates

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Abstract:
Motivated by recent experiments in Bose-Einstein condensates, in this talk we will examine the dynamics and interactions of dark solitons in such settings. We will attempt to characterize both the oscillations and the interactions between the solitons, connecting the relevant results with numerical simulations, as well as with experimental findings. Additionally, we will attempt to generalize some of the relevant properties of the dark solitons to both higher dimensional settings (using them to understand the dynamics of vortices), as well as to multi-component settings (using them to understand the dynamics of dark-bright and of vortex-bright solitary waves).
Having your cake and seeing it too: Formation and dynamics of incompressible Mott insulating domains in ultracold gases

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Abstract:

Bose-Hubbard model describes one of the simplest realizations of a quantum phase transition, a phase transition that occurs even at zero temperature [1]. Near the phase boundary (critical point), quantum criticality, resembling that of Ising-type magnetics in higher dimensions, is expected to emerge with a full universal behavior. In particular, fluctuations and correlations are expected at all length scales.

Our observation of atomic density profiles in optical lattices provides a powerful tool to determine all relevant thermo-dynamical quantities, as well as density fluctuations and density-density correlations [2]. I will describe our efforts to identify the superfluid-Mott insulator phase boundary, to extract quantum fluctuations and correlations, and also discuss the prospects to identify and characterize quantum criticality and critical dynamics based on trapped quantum gases in an optical lattice.

References:

Forced gravity-capillary lumps on deep water: theory and experiment

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Abstract:

The nonlinear wave pattern generated by a localized pressure source moving over the surface of deep water at speeds below the minimum phase speed is investigated theoretically and experimentally. This is joint work with Yeunwoo Cho (MIT) and J. H. Duncan & J. D. Diorio (University of Maryland).
Nonlinear evolution of broadband surface waves

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Abstract:

A fully nonlinear surface wave model based on a pseudo-spectral method is adopted to study the nonlinear evolution of broadband surface waves and its numerical solutions are validated with laboratory experiments. The modified nonlinear Schrodinger (MNLS) equation is also studied to examine its capability to predict the evolution of broadband wave spectrum. For oceanic applications, energy dissipation due to wave breaking and wind forcing are parameterized and incorporated into the fully nonlinear model, and their effects on the evolution of wave spectrum are investigated numerically. Joint work with Arnaud Goulet (NJIT), Matt Malej (NJIT), Marc Perlin (UMichigan), Zhigang Tian (KAIST).
Transcritical shallow-water flow past topography: finite-amplitude

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Abstract:

In this talk I will present recent results obtained jointly with Roger Grimshaw (Loughborough) and Noel Smyth (Edinburgh) on the generation of undular bores in one-dimensional fully nonlinear shallow-water flows past localised topographies [1]. The description is made in the framework of the forced Su-Gardner (a.k.a. 1D Green-Naghdi) system of equations, with a primary focus on the transcritical regime when the Froude number of the oncoming flow is close to unity. A combination of the local transcritical hydraulic solution over the localized topography, which produces upstream and downstream hydraulic jumps, and unsteady undular bore solutions describing the resolution of these hydraulic jumps, is used to describe various flow regimes depending on the combination of the topography height and the Froude number. We take advantage of the recently developed modulation theory of Su-Gardner undular bores [2] to derive the main parameters of transcritical fully nonlinear shallow-water flow, such as the leading solitary wave amplitudes for the upstream and downstream undular bores, the speeds of the undular bores edges and the drag force. Our results confirm that most of the features of the previously developed description in the framework of the uni-directional forced KdV model [3] hold up qualitatively for finite amplitude waves, while the quantitative description can be obtained in the framework of the bi-directional forced Su-Gardner system.

References:
On the nonlinear interactions of wave-wave and wave-currents

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Abstract:

In this talk, the nonlinear interactions between wave and wave or current are investigated. By means of the homotopy analysis method which is valid for highly nonlinear problems, the convergent series solutions are obtained, and the influence of physical parameters of wave and/or currents on the interactions are discussed.

References:
Ships advancing near the critical speed in a shallow channel with a randomly uneven bed

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Abstract:

Unlike a transonic flow in compressible aerodynamics, a ship cruising steadily in a channel at nearly the linearized long wave speed generates unsteady wave motion. In a channel of limited width, solitons are radiated periodically up-stream. Such waves may have been the cause of a fatal accident at the Port of Harwich, England, and were described by a witness “like the white cliffs of Dover”. Although noted long ago in tank experiments, scientific interest was renewed by laboratory observations of ship-induced solitons by Ertekin et al (1986) for a channel of horizontal and smooth bottom. Past theories (both two and three-dimensional) have shown that the free surface elevation is governed by the forced Korteweg-deVries equation.

In this presentation we shall first recall the earlier findings by Mei and Choi (1987) of a ship in a channel of smooth bed, but focus attention on the more recent work on a randomly rough bed (Alam and Mei (2008), when the ship speed is near-critical. Invoking Boussinesq approximation in shallow waters, we apply the approach of Mei and Li (2004) for long waves propagating in still water over a randomly rough bed, to show that the wave evolution in the moving frame of reference is also governed by an integro-differential equation which combines features of Korteweg-deVries and and Burgers equations. Forces on a slender ship is handled by matched asymptotics. For an isolated ship the bottom roughness weakens the transient waves radiated both fore and aft. When many ships advance in tandem, a steady mount of high water can be formed in front and a depression behind. Wave forces on both an isolated ship and a ship in a caravan are obtained as functions of the mean-square roughness, ship speed and the blockage coefficient. Future extensions to ship moving near a river bank are worthwhile.
Stability of stationary periodic solutions to the Euler equations

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Abstract:

Euler’s equations describe the dynamics of gravity waves on the surface of an ideal fluid with arbitrary depth. In this talk, I discuss the stability of one-dimensional traveling wave solutions for the full set of Euler’s equations via a generalization of a non-local formulation of the water wave problem due to Ablowitz, Fokas and Muslmani. Transforming the non-local formulation into a traveling coordinate frame, we obtain a new scalar equation for the stationary solutions using the original physical variables. Using this new equation, we develop a numerical scheme to determine traveling wave solutions by exploiting the bifurcation structure of the non-trivial periodic solutions. Next, we determine numerically the spectral stability for the periodic traveling wave solution by extending Fourier-Floquet analysis to apply to the non-local problem. We can generate the full spectra for all traveling wave solutions. In addition to recovering well-known results such as the Benjamin-Feir instability for deep water waves, we confirm the presence of high-frequency instabilities for shallow water waves. Finally, I discuss preliminary stability results of a two-dimensional surface with respect to two-dimensional perturbations.
Discrete and continuous random water wave dynamics

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Abstract:

Research on water waves propagating over large amplitude, random bottom topography in general requires good reduced models, good asymptotic theory plus accurate/reliable numerical simulations. Usually the truncation procedure regarding the continuous dynamics (namely in obtaining the reduced models) is quite different from that performed in order to get the discrete models. Hence, when possible, it is very important to compare the statistics produced by the continuous dynamics with those produced by the discrete one. This is the main issue addressed in this talk.

First I will briefly review some results on the effective dynamics of water waves in the presence of highly disordered (random) forcing by the topography. Then I will address a recent study where the long wave (random) reflection process, generated through potential theory, comes out to be the same as the one generated by a hydrostatic model. The regime under study accounts for large amplitude, rapidly varying topographies. To validate/illustrate this limiting reflection process issue the (dimensionless) theoretical results were compared against Monte Carlo simulations with a hydrostatic (dimensional) Navier-Stokes numerical model. The challenge in this part of our work was to first set the numerical data accordingly with the dimensionless regime of interest, and then compare the numerical statistics with that given by the stochastic theory. Namely, the discrete signals were (Monte Carlo) averaged and compared to a Central Limit Theorem characterization for the continuous reflection process. Very good agreement was observed. The simulations were then pushed beyond the regime of validity of the theory, leading to interesting questions.
Diurnal forcing, trapped waves, and the meridional extent of the tropics.

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Abstract:

This talk proposes a dynamical theory explaining the sharp transition between tropics and extra-tropics in terms of the diurnal cycle of thermal forcing by the sun. This transition, at a latitude of 30 degrees, coincides with the outer edge of the Hadley cells, and is marked by a steep jump in the height of the troposphere, from fifteen kilometers in the tropics to nine in the mid and high latitudes. The tropics, equatorwards of 30 degrees, are characterized by easterly surface winds -the Trades- and a strong diurnal signal in the wind, pressure and temperature, often marked by regular daily storms in the rainy season. Polewards of 30 degrees, the winds are westerly, and the weather systems have longer spatio-temporal scales.

All of this behavior can be explained in terms of diurnal waves, created by thermal forcing and trapped equatorwards of 30 degrees by the Coriolis effect. These create - in a dynamical model of starting from a globally uniform atmosphere - regions of enhanced mixing of stratospheric air into the troposphere in the tropics and to the Hadley circulation in a layered shallow-water model. We shall present first simple mathematical model of a forced linear shallow water problem and expand to nonlinear conservation laws with entraining discontinuities at the tropopause (troposphere-stratosphere boundary) and also accounting for the entrainment into the troposphere from the surface boundary layer.

References:
Three-dimensional modelling of baroclinic tides in the South China Sea.

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Abstract:

The modelling of baroclinic tides generated in the Luzon Strait is carried out using the fully-nonlinear nonhydrostatic Massachusetts Institute of Technology general circulation model. The model is forced by typical for the area semidiurnal and diurnal tidal harmonics. The tidal components and typical for summer and winter density distributions were taken from tidal models and observations.

The barotropic tide interacting with supercritical bottom topography produces a complex multimodal baroclinic tidal signal radiating from the source of generation. The generated waves gradually transform into a series of large-amplitude solitary internal waves with amplitudes up to 100m and more alternating with small amplitude wave trains. The most intriguing outcome from the performed series of numerical experiments concerns a possibility of generation of second-mode solitary internal waves propagating along with solitary waves of depression towards the Chinese continental shelf. Their amplitudes and spatial characteristics were comparable with that of the first-mode solitary waves. The focus of the modelling efforts was on the investigation of the conditions of their generation (sensitivity to the topography profile, fluid stratification, tidal forcing) and their dynamics, i.e. three-dimensional characteristics, spatial and temporal variability.
Long-Term Evolution of Strongly Nonlinear Internal Solitary Waves in a Rotating Channel.

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Abstract:

The evolution of internal solitary waves (ISWs) propagating in a rotating channel is studied numerically in the framework of a fully-nonlinear, nonhydrostatic numerical model. The aim of modelling efforts was the investigation of strongly-nonlinear effects, which are beyond the applicability of weakly nonlinear theories. Results reveal that small-amplitude waves and sufficiently strong ISWs evolve differently under the action of the rotation. At the first stage of evolution an initially two-dimensional ISW transforms according to the scenario described by the rotation modified Kadomtsev-Petviashvili equation, namely, it starts to evolve into a Kelvin wave (with exponential decay of the wave amplitude across the channel) with front curved backwards. This transition is accompanied by a permanent radiation of secondary Poincaré waves attached to the leading wave. However, in a strongly-nonlinear limit not all the energy is transmitted to secondary radiated waves. Part of it returns to the leading wave as a result of nonlinear interactions with secondary Kelvin waves generated in the course of time. This leads to the formation of a slowly attenuating quasi-stationary system of leading Kelvin waves, capable of propagating for several hundreds hours as a localized wave packet.
Tsunami runup by Lagrangian description

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Abstract:

Tsunamis can be generated by underwater earthquakes or by landslides. Mathematical models are useful for advanced warning and for estimating possible damages in order to design coastal protection. Rational predictions must include both transocean propagation and coastal runup. For the former task the linearized theory of dispersive waves is an adequate basis for computations. For coastal runup, nonlinearity must be accounted for. Based on Eulerian description coastal runup on an infinitely long beach has been solved by Carrier and Greenspan (1957) whose theory has been the cornerstone of tsunami prediction for half a century. Numerical computation for more complex coastal bathymetry is challenging because the moving shoreline is an unknown boundary and must be found as a part of the solution. For certain free boundary problems the use of Lagrangian description can be more advantageous. In the Eulerian description, all physical quantities are functions of fixed field points and time. In the Lagrangian description they are defined at the instantaneous position of each fluid particle. As a result the position of the free surface is known at all time, as required by the kinematic condition. The use of Lagrangian coordinates in nonlinear long waves was started by Airy (see Lamb, 1932, pp 259-260). Applications to tsunami has been made by Shuto (1967, 1968, 1978) who showed that runup predicted by linearized Lagrangian equations give good runup predictions. Further application to tsunami along an open coast have been reported by Goto (1979, 1980) and Fujima 2007).
New integrable systems from known ones via anyon parameterization

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Abstract:

It is known that stating from a known integrable system, one may use many kinds of methods to get new integrable systems, for instance, via different types of transformations including the Miura transformation, hodograph transformation and so on. In this report we propose a new method to get new integrable systems via the anyon parameterization procedure. Especially, taking the KdV equation as a seed example, various new integrable systems are obtained.
A new closed form solution to the quintic complex
Ginzburg-Landau equation.

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09 March 2010

Abstract:

The quintic complex Ginzburg-Landau equation

\[ iA_t + pA_{xx} + q \; \text{mod} \; A^2 A + r \; \text{mod} \; A^4 A - i\gamma A = 0, \; \Im(p/r) \neq 0, \; (p, q, r) \in \mathbb{C}, \; \gamma \in \mathbb{R}, \]

is not integrable, and very few closed form solutions are known [1–4] for its traveling wave reduction

\[ A = \sqrt{M(\xi)}e^{i(-\omega t + \varphi(\xi))}, \; \xi = x - ct. \]

In this work, exploiting the general method developed in [5,6], we obtain a new closed form solution, which contains one more arbitrary parameter than the elliptic solution presented in [4].

References:

Darboux transformations for two dimensional elliptic affine Toda equations

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Abstract:

The Darboux transformations for the two dimensional elliptic affine Toda equations corresponding to all seven infinite series of affine Kac-Moody algebras, including $A^{(1)}_l$, $A^{(2)}_{2l}$, $A^{(2)}_{2l-1}$, $B^{(1)}_l$, $C^{(1)}_l$, $D^{(1)}_l$ and $D^{(2)}_{l+1}$, are presented. The Darboux transformation is constructed uniformly for the latter six series of equations with suitable choice of spectral parameters and the solutions of the Lax pairs so that all the reality symmetry, cyclic symmetry and complex orthogonal symmetry of the corresponding Lax pairs are kept invariant. The exact solutions of all these two dimensional elliptic affine Toda equations are obtained by using Darboux transformations.
Inverse Scattering Transform (IST) for the Multicomponent Nonlinear Schrodinger (NLS) Equation Under Non-Vanishing Boundary Conditions

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Abstract:

This talk reports on the development of the IST for vector NLS under nonvanishing boundary conditions (NBCs) for an arbitrary number $N$ of components. For the scalar NLS equation, which is termed here the $N = 1$ case, the scattering problem with NBCs is already complicated by the fact that the scattering parameter $k$ “live” on a two-sheeted Riemann surface; however one still has two complete sets of analytic scattering functions. When $N > 1$, an additional complication arises: $2(N - 1)$ out of the $2(N + 1)$ scattering eigenfunctions are not analytic on either sheet of the Riemann surface, and one has to suitably complete the basis. The $N = 2$, or the 2-component case (so-called Manakov system) is somehow special. The IST for the Manakov system under NBCs was developed in 2006 [1] and the basic idea was to use the adjoint scattering problem to construct two additional analytic eigenfunctions. This technique, however, does not admit an obvious generalization to an arbitrary number of components. Moreover, when $N > 3$ yet another complication is added: the eigenvalue associated to the nonanalytic scattering eigenfunctions becomes a multiple eigenvalue, with multiplicity $N - 2 > 1$. In order to obtain complete the basis of analytic eigenfunctions for the general multicomponent scattering problem, we generalize the approach suggested in [2] for general scattering and inverse scattering on the line but developed under the assumption of vanishing BCs. The key step is the introduction of a fundamental tensor family as solutions of a suitable scattering problem associated to the given one, in such a way that each tensor is analytic on either one or the other sheet of the Riemann surface. Then we show that it is possible to algorithmically reconstruct the fundamental matrices of solutions of the scattering problem from the fundamental tensors, and to establish their analyticity properties.

References:
Exploring Hamiltonian structures by variational identities

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Abstract:

Component-trace identities associated with matrix spectral problems will be presented and shown to be fundamental tools in establishing Hamiltonian structures of integrable couplings associated with non-semisimple Lie algebras. Applications of bi-trace identities will furnish Hamiltonian structures of dark equations and nonlinear integrable couplings.

References:
On the dispersionless Kadomtsev-Petviashvili equation in n+1 dimensions: exact solutions, the Cauchy problem for small initial data and wave breaking

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Abstract:

We study the \( n+1 \)-dimensional generalization of the dispersionless Kadomtsev-Petviashvili (dKP) equation, a universal equation describing the propagation of weakly nonlinear, quasi one dimensional waves in \( n+1 \) dimensions, and arising in several physical contexts, like acoustics, plasma physics and hydrodynamics. For \( n = 2 \), this equation is integrable, and it has been recently shown to be a prototype model equation in the description of the two dimensional wave breaking of localized initial data. We construct an exact solution of the \( n+1 \) dimensional model containing an arbitrary function of one variable, corresponding to its parabolic invariance, describing waves, constant on their paraboloidal wave front, breaking simultaneously in all points of it. Then we use such solution to build a uniform approximation of the solution of the Cauchy problem, for small and localized initial data, showing that such a small and localized initial data evolving according to the \( n+1 \)-dimensional dKP equation break, in the long time regime, if and only if \( 1 \leq n \leq 3 \); i.e., in physical space. Such a wave breaking takes place, generically, in a point of the paraboloidal wave front, and the analytic aspects of it are given explicitly in terms of the small initial data.

References:
Multi-soliton, multi-positon, multi-negaton, and multi-periodic solutions of a coupled Volterra lattice system and their continuous limits

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Abstract:

In this talk, we aim to find new explicit solutions including multi-soliton, multi-positon, multi-negaton, and multi-periodic for a coupled Volterra lattice system. This coupled lattice system is an integrable discrete version of the coupled KdV equation which has many physical applications. The dynamical properties of these new solutions are discussed in detail. We also show that the theory of the coupled Volterra lattice system including the Lax pair, the Darboux transformation, and explicit solutions yield the corresponding theory of the coupled KdV equation in the continuous limit.

References:
2. V. A. Brazhnyi and V. V. Konotop, Phys. Rev. E, 72, 026616 (2005).
Integrable maps and lattice maps

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Abstract:

Going to the discrete world turns differential equations into maps, and similarly turns partial differential equations into “lattice maps”. We will describe such maps, and comment on their integrability. We will in particular explain the link of integrability with complexity, as measured by the so called algebraic entropy.

References:
Explicit Flow Equations and Recursion Operator of the ncKP hierarchy

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Abstract:

In this talk, the noncommutative Kadomtsev-Petviashvili(ncKP) hierarchy will be discussed. The explicit expression of flow equations of the ncKP hierarchy is derived. By comparing with the flow equations of the KP hierarchy, this result shows that the additional terms in flow equations of the ncKP hierarchy indeed consist commutators of dynamical coordinates \{u_i\}. The recursion operator for the flow equations under the n-reduction is presented. As an example we calculate the recursion operator of the noncommutative Korteweg-de Vries(ncKdV) hierarchy, which generates a hierarchy of local, higher order flows. Thus we solve the open problem suggested by P.J.Olver and V.V.Sokolov(Commun.Math.Phys. 193 (1998), 245-268).

References:
Exactly Solvable (Discrete) Quantum Mechanics and Exceptional Orthogonal Polynomials

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Abstract:

Theory of exactly solvable discrete quantum mechanics was developed by Osake-Sasaki [1], by generalising the Darboux-Crum transformation methods to difference Schrödinger equations. They are also solvable in the Heisenberg picture [2], providing the exact creation/annihilation operators and the dynamical symmetry algebras. The eigenfunctions consist of the hypergeometric orthogonal polynomials, for example, the Wilson, Askey-Wilson or the (q)-Racah polynomials. Further deformations of the exactly solvable (discrete) quantum mechanics led to the discovery of infinitely many exceptional orthogonal polynomials [3], which satisfy second order differential (difference) equations. The simplest examples of the exceptional orthogonal polynomials were introduced in [4].

References:
Multisoliton solutions to the lattice Boussinesq equation

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Abstract:

In this talk we will first introduce the concept of multi-dimensional consistency for discrete systems. Then we will consider the lattice Boussinesq equation (BSQ) which is a three-component difference equation defined on an elementary square of the 2D lattice, with 3D consistency. We construct its background solution and 1-soliton solution through Bäcklund transformation. The lattice BSQ can then be bilinearized into 4 equations. Since there is a parameter $\delta$ in the solutions we can derive out a generalized lattice BSQ with $\delta$. Relation between the lattice BSQ and $\delta$-lattice BSQ is also discussed. Finally solutions in Casoratian form are given.

References:
Spin chains of Haldane-Shastri type and a generalized central limit theorem

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Abstract:

We shall discuss how the density of energy levels of a wide class of finite-dimensional quantum systems tends to a Gaussian distribution as the number of degrees of freedom increases. Our result will be based on a variant of the central limit theorem which is especially suited to models whose partition function is explicitly known. In particular, we shall prove that the level density of several spin chains of Haldane–Shastry type is asymptotically Gaussian when the number of sites tends to infinity, as suggested by previous numerical experiments.

References:
Rogue waves and rational solutions of the Boussinesq and nonlinear Schrödinger equations

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Abstract:

In this talk, I shall discuss special polynomials associated with rational solutions of the Painlevé equations and of the soliton equations solvable by the inverse scattering method, specifically for the Boussinesq and nonlinear Schrödinger equations.

The Painlevé equations are six nonlinear ordinary differential equations that have been the subject of much interest in the past thirty years, and have arisen in a variety of physical applications. Further the Painlevé equations may be thought of as nonlinear special functions. Rational solutions of the Painlevé equations are expressible in terms of the logarithmic derivative of certain special polynomials. For the fourth Painlevé equation these polynomials are known as the generalized Hermite polynomials and generalized Okamoto polynomials, derived by Noumi and Yamada [1]. The locations of the roots of these polynomials have a highly symmetric (and intriguing) structure in the complex plane [2].

It is well known that soliton equations have symmetry reductions which reduce them to the Painlevé equations. For example, scaling reductions of the Boussinesq and nonlinear Schrödinger equations are expressible in terms of the fourth Painlevé equation. Hence rational solutions of these equations can be expressed in terms of the generalized Hermite and generalized Okamoto polynomials. Further there are generalizations of these rational solutions of the Boussinesq and de-focusing nonlinear Schrödinger equations, which involve arbitrary parameters [3,4].

I shall also describe some additional rational solutions of the Boussinesq and focusing nonlinear Schrödinger equations which have applications to rogue waves [5].

References:

A new extended matrix KP hierarchy and its solutions

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Abstract:

With the square eigenfunctions symmetry constraint, we introduce a new extended matrix KP hierarchy and its Lax representation from the matrix KP hierarchy by adding a new $\tau_B$ flow. The extended KP hierarchy contains two time series $t_A$ and $\tau_B$ and eigenfunctions and adjoint eigenfunctions as components. The extended matrix KP hierarchy and its $t_A$-reduction and $\tau_B$ reduction include two types of matrix KP hierarchy with self-consistent sources and two types of (1+1)-dimensional reduced matrix KP hierarchy with self-consistent sources. The generalized dressing approach for solving the extended matrix KP hierarchy is proposed and some solutions are presented.
Solutions of multicomponent Harry Dym hierarchy emerging from
Stäckel separable systems

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Abstract:

Various relations between finite- and infinite-dimensional nonlinear integrable systems have been investigated since the middle of 70’s in a long sequence of papers starting from the paper [1]. The main idea of these efforts was to pass from infinite- to finite-dimensional integrable systems. In this talk I will demonstrate that also an opposite way is possible: that of passing from ordinary differential equations integrable in the sense of Arnold-Liouville to infinite-dimensional integrable systems (soliton hierarchies). More precisely, I will demonstrate a way of constructing both local and nonlocal parts of the multicomponent Harry Dym hierarchy (for the definition and properties, see [2]-[5]) from corresponding families of classical Stäckel separable Hamiltonian systems using a certain variable elimination in a class of weakly nonlinear semi-Hamiltonian hydrodynamic-type systems closely related with Stäckel separable systems. This method leads to various interesting rational and implicit solutions of this hierarchy. The method is rather general and it can be applied to other soliton hierarchies as well, for example to multicomponent KdV hierarchy [6]-[7]. The presented results were obtained in a joint work with M. Blaszak, Poland.

References:
Recent developments in matrix models and conformal field theory

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Abstract:

Integrability plays a prominent role in modern quantum field theory. It is a universal property of effective actions, obtained as result of functional integration, and reflects the freedom to change integration variables. Many examples are already known, though each time revealing the hidden integrable structure takes certain effort and becomes a piece of art. Each time effort is justified: once established, integrability provides a powerful tool for performing the technically involved calculations and promotes the subject into a quantitative, not just qualitative science. The talk will mostly focus on recent developments around the AGT conjecture, which unifies a number of seemingly different topics, from 2d conformal theory to hypergeometric series, from matrix models to Hurwitz numbers, from instanton calculus to knot invariants, from Seiberg-Witten theory to AdS/CFT-correspondence. It is in this context that quantum, not just classical, integrability manifests itself in the properties of effective actions. This is a new development with broad perspectives and many potential applications.

References:
On Symmetries of the WDVV Equations

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Abstract:

This talk is based on a joint work with Dingdian Xu[1]. For two solutions of the WDVV equations that are related by two types of symmetries of the equations given by Dubrovin, we show that the associated principal hierarchies of integrable systems are related by certain reciprocal transformation, and the tau functions of the hierarchies are either identical or related by a Legendre transformation. We also consider relationships between the Virasoro constraints and topological deformations of the principal hierarchies.

Reference:
1. Dingdian Xu, Youjin Zhang, On Symmetries of the WDVV Equations, eprint arXiv: 1002.0034
Solitary-Wave Interaction in the Short-Pulse Equation

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Abstract:

The short-pulse equation (SPE) describes the propagation of light pulses of ultra-short duration in nonlinear optical media. Breather soliton solutions of SPE have been constructed previously by a transformation from the Sine-Gordon equation [1]. We describe the results of simulations of the collision of pairs of these solitons. The soliton interaction is observed to vary qualitatively as a function of a parameter which measures the “shortness” of the pulse envelope relative to the internal oscillations. These changes are intermittent as the parameter varies. Moreover, for some parameter values, soliton interaction generates persistent, highly oscillatory coherent states.

References:
Supersymmetric Reciprocal Transformation and Its Applications

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Abstract:

The supersymmetric analog of the reciprocal transformation is introduced. This is used to establish a transformation between one of the supersymmetric Harry Dym equations and the supersymmetric modified Korteweg-de Vries equation. The reciprocal transformation, as a Bäcklund-type transformation between these two equations, is adopted to construct a recursion operator of the supersymmetric Harry Dym equation. By proper factorization of the recursion operator, a bi-Hamiltonian structure is found for the supersymmetric Harry Dym equation. Furthermore, a supersymmetric Kawamoto equation is proposed and is associated to the supersymmetric Sawada-Kotera equation. The recursion operator and odd bi-Hamiltonian structure of the supersymmetric Kawamoto equation are also constructed.
“Controlling Spins with Light”

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Abstract:

The interaction of light with magnetic matter is well known: magneto optical Faraday or Kerr effects are frequently used to probe the magnetic state of materials, or manipulate the polarisation of light.

The inverse effects are less known but certainly as fascinating: with light one can manipulate magnetic matter, for example orient their spins. Using femtosecond laser pulses we have recently demonstrated that one can generate ultrashort and very strong (∼Teslas) magnetic field pulses via the so called Inverse Faraday Effect. Such optically induced magnetic field pulses provide unprecedented means for the generation, manipulation and coherent control of magnetic order on very short time scales, including the complete reversal of a magnet with a single 40 fs laser pulse and inertia-driven spin switching in antiferromagnets. Recent results demonstrate that both linearly and circularly polarized light can be used to manipulate magnetic order at fs timescales, increasing the possibilities of all-optical control of magnetism even more.

References:
Dissipative Droplet Solitons

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Abstract:

Large amplitude, vectorial, localized, "droplet solitons" in anisotropic magnetic media were first studied theoretically some time ago [1] but have not been observed experimentally. These states satisfy a conservative Landau-Lifshitz equation with uniaxial anisotropy. This talk presents an extension of the notion of a droplet soliton to a physically realizable system: thin ferromagnetic films driven by a spin polarized current. This two-dimensional dissipative droplet soliton arises as the balance between a spatially localized spin torque and a uniform damping torque in addition to nonlinearity and dispersion. Using perturbative techniques and numerical calculations, properties of this fully nonlinear, coherently precessing state will be discussed including existence conditions, stability, and hysteresis. These properties will be used to argue that dissipative droplet solitons have been observed in recent experiments.

References:
Formation and collapse of guided spin-wave bullets in a medium with induced magnetic anisotropy

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Abstract:

The formation of quasi-2D nonlinear spin-wave eigenmodes in longitudinally magnetized stripes of a ferrimagnetic film, the so-called guided spin-wave bullets [1], was experimentally observed by using time and space-resolved Brillouin light scattering spectroscopy and confirmed by numerical simulation. These bullets represent stable spin-wave packets propagating along a waveguide structure, for which both transversal instability and interaction with the side edges of the waveguide are important. Our experimental and theoretical investigations show that formation of these stable nonlinear wave packets is strongly affected by the transverse confinement of the medium. The discovery of these modes demonstrates the existence of quasi-stable nonlinear solutions in the transition regime between one-dimensional and two-dimensional wave packet propagation. It has been later found that further increasing of the spin-wave amplitude leads to the destabilization of the bullet which becomes apparent through a strong 2D compression of the spin-wave packet followed by a wave collapse. The spin-wave energy involved in the collapse process is emitted by the moving collapsing area in the form of four spin-wave caustic beams. The beams are pairwise symmetrically arranged relative to the bias magnetic field. The peculiarities of the observed directional radiation from a moving area are well described by the theoretical model. Support by the DFG within the SFB/TRR 49, the Australian Research Council, and the University of Western Australia is gratefully acknowledged.

References:
Nonlinear Spin Waves in Micro-Nanostructures

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Abstract:

In this talk we discuss our recent experiments on nonlinear spin waves in microscopic magnetic structures based on thin Permalloy films. The experiments were performed with the help of space- and time-resolved micro-focus Brillouin light scattering spectroscopy enabling visualization of spin-wave propagation with sub-micrometer spatial and nanosecond temporal resolutions. We show that the nonlinearity of the spin-system of metallic magnetic films together with microscopic-scale confinement effects lead to anomalous nonlinear magnetic phenomena, which do not appear on the macroscopic scale. In particular, we present experimental results on nonlinear spatial self-modulation of spin-wave beams observed for propagation geometry characterized by the repulsive nonlinearity, nonlinear hybridization of the eigenmodes of microscopic Permalloy ellipses, and spin-wave confluence processes resulting in an efficient nonlinear excitation of higher-order propagating spin-wave modes of microscopic waveguides. These experimental findings contribute to the recently established scientific field of spin-wave nano-optics, as well as to the general physics of strongly dissipative nonlinear systems. We believe that the presented results will stimulate further theoretical studies in the nonlinear physics and bring new ideas for technical applications of high-frequency magnetization dynamics in magnetic nanostructures.

References:
Non-Autonomous Dynamics of a Nonlinear Spin-Torque Oscillator

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Abstract:

A perturbative analytic approach to the description of non-autonomous dynamics of a spin-torque nano-oscillator (STNO) is developed. The proposed approach is based on using the autonomous (unperturbed) STNO dynamics obtained either analytically or numerically as a zero approximation. The role of a small parameter is played by the ratio of the energy of the STNO interaction with an external perturbation to the energy of the autonomous (unperturbed) STNO motion. The proposed approach is valid for any STNO geometry and any amplitude of the autonomous STNO motion. This approach is also valid for an arbitrary (but sufficiently small) external perturbation and, in particular, for the perturbation in the form of periodic signals coming from other STNOs forming a large STO array. To illustrate our approach we solved a problem of phase-locking of an STNO having a non-trivial geometry with two coupled (by both spin-torque and dipole-dipole interaction) ferromagnetic layers to an external periodic signal h(t).
Formation of Random Dark Envelope Solitons from Incoherent Waves

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Abstract:

This letter reports experimental results on random temporal dark solitons. One excites an incoherent large-amplitude propagating spin-wave packet in a ferromagnetic film strip with a repulsive, instantaneous nonlinearity. One then observes the random formation of dark solitons from this wave packet. The solitons appear randomly in time and in position relative to the entire wave packet. They can be gray or black. For wide and/or very strong spin-wave packets, one also observes multiple dark solitons. In spite of the randomness of the initial wave packets and the random formation processes, the solitons show signatures that are found for conventional coherent dark solitons.

References:

Dimension control of chaotic surface spin waves in a magnetic film-based active feedback ring

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Abstract:

Magnetic thin films support the propagation of spin waves. Like other waves, the spin waves damp out during the propagation due to loss mechanisms such as magnon-phonon scattering and impurity relaxation. With an active feedback, however, one can effectively drive damped spin waves. Such a magnetic film-active feedback system constitutes a driven damped system. This presentation reports on the excitation of chaotic surface spin waves in a magnetic film active feedback ring and the control of the dimension of such chaotic waves. The experiments utilized a magnetic yttrium iron garnet (YIG) thin film strip in a surface spin wave configuration. Two microstrip line transducers were placed over the YIG strip to excite and detect spin waves. The output signal from the detection transducer was fed back to the excitation transducer through an adjustable microwave attenuator and a linear microwave amplifier. The ring signal was sampled through a directional coupler, with feeds to a spectrum analyzer for frequency analysis and a fast oscilloscope for temporal signal measurements. The measurements were done in a regime where the dominant nonlinear processes were the three-wave interactions between surface and backward volume spin waves. With an increase in the ring gain coefficient, one observed the excitation of one ring eigenmode, the development of sideband modes, period doubling, onset of chaos, and an increase in the fractal dimension of chaotic signals. A further increase in the ring gain led to the excitation of another ring eigenmode and a corresponding jump of about one in the dimension. Additional increases in the ring gain resulted in the development of a broad spectrum around the second eigenmode and a corresponding increase in the dimension. As one increased the ring gain from 0.92 dB to 2.32 dB, the correlation dimension increased from 2.0 to 7.8. In spite of this substantial change in dimension, however, the maximum Lyapunov exponent remained relatively constant.
Abstract:

We demonstrate symbiotic dynamics of light and nano-particles suspended in liquid. Light-force varies the local particle density, modifies the fluid properties (surface-tension, viscosity), inducing motion/rotation in the fluid, causing synergetic nonlinear-dynamics of light and fluid.
Cavity Solitons and Localized Structures in Bidirectional Ring Lasers

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Univ. de Nice-Sophia Antipolis, Institut Non Lineaire de Nice, UMR 6618 CNRS 1361 Route des Lucioles, 06560 Valbonne, France

Abstract:

We show that Class A bi-directional ring lasers do not support the existence of cavity solitons even under the presence of diffusion for the electromagnetic field. However there is a parameter range where an infinite number of patterns coexist. Such coexistence yields optical localized structures whose dynamical properties are in many ways similar to those of cavity solitons. In particular they allow writing and erasing under the action of very specific perturbations thus making them useful for information storage.
Solitons and vortex lattices in polaritonic microcavities

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\textsuperscript{2}. Institute of Condensed Matter Theory and Solid State Optics, Friedrich-Schiller-University, Jena, Germany

Abstract:

I am going to report our recent results on two aspects of nonlinear physics of microcavity polaritons. First, is the two-dimensional localization of exciton polaritons in a coherently pumped semiconductor microcavity operating in the strong-coupling regime. 2D polariton-solitons can exist despite the fact that the effective mass of linear polaritons has the opposite signs along the orthogonal directions in the momentum space. Nonlinearities compensating the opposing mass signs have different physical origin, but act simultaneously. They are due to repulsion of polaritons, which compensate the negative mass effects, and due to parametric four-wave mixing, which compensate the positive mass effects. Both of these nonlinearities support their respective families of one-dimensional solitons, which coexist one with another and with 2D solitons. Second part of my talk is about vortex lattices of exciton polaritons in microcavities operating in the four-wave mixing regime. These lattices can be practically seeded by a weak signal pulse formed by a superposition of three interfering beams and can be either very robust or can melt through annihilation of vortex-antivortex pairs.
Novel nonlinear nanophotonic phenomena

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2. Department of Mathematics, MIT, USA
3. Sandia National Laboratories, USA

Abstract:

We present two photonic crystal enabled platforms, exhibiting novel active optical phenomena. First, using a detailed theoretical and numerical analysis, we show how a Purcell-effect inspired nonlinear nanophotonic scheme could enable optimal and compact THz sources via optical difference frequency generation. Second, we show how electromagnetic one-way edge modes analogous to quantum Hall edge states, originally predicted by Raghu and Haldane in gyroelectric photonic crystals, can appear in more general settings. In gyromagnetic YIG photonic crystals operating at microwave frequencies, time-reversal breaking is strong enough that the effect is readily observable. We present our experimental results on this novel phenomena.
Optical multivibrator: untrivial dynamics of photorefractive coherent oscillators with two types of movable charge species

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Abstract:

Unconventional operation mode of coherent photorefractive oscillators based on ferroelectric Sn2P2S6 is described [1-3]. As distinct from previously known types of oscillation dynamics (smooth continuous wave, with the cosine temporal modulation of output intensity, and with irregular chaotic temporal behavior) the reported regime consists in periodic sequence of nearly triangular pulses with the phase alternating between two fixed values, 0 and π. The output of such an optical circuit is analogous to that of the known electronic circuit called multivibrator (relaxation oscillator) which consist of two cross-coupled transistors and switches permanently between the two discrete states.

The origin of discovered unusual dynamics nests in competition of two complimentary space-charge gratings (shifted in space exactly to half grating spacing) that are initiated by moving charge carriers of opposite sign, electrons and holes. Depending on experimental parameters (coupling strength, pump intensity ratio) it is possible to observe the pure mode of optical multivibrator or its superposition to the cosine temporal variation caused by Feinberg frequency splitting of the phase conjugate reflectivity in backward wave four wave mixing.

The considered operation mode is specific for the material and not for particular type of the oscillator. It was first observed in semilinear photorefractive oscillator with two counterpropagating pump waves [1] and later revealed also in oscillator geometry of double phase conjugate mirror [3].

References:
Extremely Efficient Frequency Generation in High-Index Doped Silica Glass Micro-Ring Resonators

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2. Dept of Physics, University of Toronto, Canada
3. Infinera Ltd, California, USA
4. CUDOS, School of Physics, University of Sydney, Australia

Abstract:

All-optical signal processing is critical for ultra-high bit rate communications systems since current electronic processing speeds are approaching fundamental limits near 40 Gb/s. Wavelength conversion, in particular, is of significant interest for its potential applications in wavelength agile optical networks. However, challenges still remain to reduce device footprint size, meet required optical power levels and improve overall device performance for practical applications. An alternative approach, based on phase-matched parametric four-wave mixing (FWM), has been used to demonstrate wavelength conversion in integrated silicon nano-wire waveguides, although initial demonstrations were either fundamentally narrow band or required large devices or large pump powers [1-3].

Recently, ultra-low pump power FWM based wavelength conversion was reported in silicon micro-ring resonators [4]. In these devices the high Q cavity enhancement of the micro-rings was exploited to achieve conversions with CW pump powers as low as 5mW. It is of interest, however, to investigate other material systems, since silicon is well known to suffer from two-photon absorption (TPA) that induces free carrier losses and affects performances at high pump powers [5]. Even though this can be eliminated via p-i-n junctions to sweep carriers out [6], the intrinsic nonlinear figure of merit for silicon still remains less than 0.5 [7].

Here, we report [8] CW low power wavelength conversion via FWM in high index (1.7) doped silica glass buried waveguides [9,10], as well as other exciting recent findings. By employing high Q ring resonators we achieve FWM with 5mW of CW pump power in the C-band. Further, in experiments with high peak power optical pulses, using a 45cm long spiral waveguide, we show that these waveguides exhibit negligible saturation or nonlinear absorption up to extremely high peak powers 领略25GW/cm², leading to an host of useful and novel applications.

References:

2. H. Fukuta et al., Optics Express 13 4629 (2005).
Modelling fiber laser arrays

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Abstract:

Building an array of fiber amplifiers is a potentially useful approach to build high power fiber-based lasers. A technological challenge is to find efficient coupling schemes that scale the coherent output as the number of fiber elements increase. In this talk I will present current models and future directions in this field. Specific to our model, we will discuss stability properties.
Generation and control of propelling and self-bending optical beams

Zhigang Chen
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Abstract:

We generate optical propelling beams with rotating intensity blades and self-accelerating truncated Airy beams. For the propelling beams, we demonstrate the control of rotating speed and blade configuration without any mechanical movement or phase-sensitive interference. This could find applications in optical trapping and manipulation. For the Airy beams, we show how it can be set into motion in a general ballistic trajectory, while the range and height of the trajectory can be controlled at ease. This brings about a possibility to send the peak intensity of a laser beam into any desired location, passing through disordered media and getting over obstacles.
Solitons and wave-mixing, an avenue to ultra-resolved microscopy in the volume

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Abstract:
Structured microscopy allows the extension of the limits of optical resolution beyond those imposed by diffraction. We will discuss the recent ideas we are developing to augment these techniques with optical solitons, electro-holography and electro-activation, and with more pioneering solutions based on evanescent wave reconstruction upon detection (structured detection).
Wave propagation in waveguide arrays with alternating positive and negative couplings

Nikos Efremidis
University of Crete, Greece

Abstract:

We introduce physically realizable waveguide array models with alternating positive and negative couplings between adjacent waveguides. The beam dynamics exhibit several interesting properties such as the beam self-splitting and self-induced Talbot oscillations.
Ultrawideband dissipative optical solitons

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Abstract:

In this talk we present the study on generation of few-cycle dissipative solitons in the semiconductor host material dopped with amplifying and absorbing two-level quantum dots. Solitons down to one cycle in duration are demonstrated. The response of free electrons of the host semiconductor is described by the Drude equation, while the interaction of the electric field with bound electrons of both types of quantum dots is governed by two sets of Bloch equations. We present linear stability analysis of the Maxwell-Drude-Bloch problem as well as full-scale numerical nonlinear study of formation of the few-cycle dissipative solitons from incident femtosecond pulse, based on application of the finite-difference time-domain method.
Boundary induced motion of optical solitary waves

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Abstract:

Spatial solitary waves in bulk media result from a balance between the diffractive spreading of a light beam and nonlinear and/or nonlocal focusing. One particular nonlinear, nonlocal optical medium which has received much attention is a nematic liquid crystal, due in part to its large nonlinear response which allows nonlinear effects to be observed over small distances. A series of elegant experiments have shown that stable spatial solitary waves, so-called nematicons, can propagate in nematic liquid crystals.

A modulation theory is developed to describe the boundary induced motion of a nematicon in a one-dimensional cell and it is found that good agreement between the semi-analytical and numerical solutions is obtained. The role of nematicon shape and location (in relation to the cell boundaries), for the evolution of the nematicon, is discussed.
Interaction of intense femtosecond filaments for photonic crystal plasma waveguides

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Abstract:

Self-propagation of intense ultrashort pulses undergoes filamentation with self-stabilized intensity clamping in neutral media. Multiple filaments occur above the critical self-focusing power. Interaction of multiple filaments exhibits abundant self-action nonlinearities, such as filament fusion, fission, and spiraling, which may stimulate vast applications with non-linearly-coupled multiple filaments instead of a single filament. Nevertheless, filament coalescence cannot increase the tightly-guided peak intensity beyond the clamping limit.

Here we report on our recent experimental observations of filament interaction by grating-assisted coalescence of intersected filaments and interaction between far-delayed filaments through molecular alignments, which are anticipated to open an avenue to control filament interactions and high-intensity nonlinear optics.

Spatial interference of non-collinear intense femtosecond pulses establishes a plasma density modulation due to filamentation around the interference peaks, resulting in a photonic-crystal plasma waveguide with a wavelength-scale periodic lattice of plasma microstructures. Strong spatiotemporal couplings therein induce observable filament elongation. In addition, third harmonic generation beyond the end of the elongated filaments is enhanced at least two orders in energy conversion as compared with that from a single filament.

On the other hand, nonlinear filament interactions are also observed for non-synchronized filaments by properly matching the molecular alignment revivals of the pre-excited diatomic molecules in the pump-probe configuration. Repulsion and attraction of parallel filaments are distinctly observed even they are delayed far away without temporal synchronization and spatial overlapping.

As one of the most important fundamental aspects of filamentation nonlinear optics, the observed filament interaction, grating-assisted filament coalescence, and photonic crystal plasma waveguides are promising for high-intensity nonlinear optics and ultrashort ultraviolet pulse generation.
Nonlinear beam manipulation in coupled optical waveguides
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Abstract:

The arrays of coupled optical waveguides have become the preferred platform for studies on nonlinear localisation in periodic photonic structures and lattices. Due to their versatility one can engineer both the diffraction and nonlinear response of beams, opening new opportunities for direct observation of fundamental nonlinear phenomena of light localisation. This talk will review some of the recent advances in nonlinear beam manipulation in arrays of optical waveguides. In particular we will focus on (i) light localisation in diffraction managed arrays [1], (ii) nonlinearity management in arrays with quadratic nonlinear response [2]; (iii) interplay between gain and nonlinearity in photonic lattices with a feedback [3].

Fig 1: Measured spectrally-resolved output beam profiles. (a) Illumination time of 5 s, input power of 1 µW. (b-d) Illumination time of 35, 60, and 420 s, respectively; input power of 18.0 mW.

For example in Fig. 1 we show the formation of diffraction managed polychromatic solitons in periodically curved defocusing LiNbO3 waveguide arrays. While in the linear regime the beam exhibits dynamic localisation for the yellow spectral components [Fig. 1(a)], in the nonlinear regime, it experiences asymmetric reshaping [Figs. 1(b,c)]. At even longer illumination times (high nonlinearity) we observe self-localization of all spectral components to a single waveguide. This is, to the best of our knowledge, the first experimental observation of diffraction-managed polychromatic soliton. These results suggest novel opportunities for engineered all-optical tuning of beams and in particular for spectral filtering of supercontinua. These results suggest novel opportunities for engineered all-optical tuning of beams and in particular for spectral filtering of supercontinua.

References:
Photonic transitions in nanophotonics: optical isolation and completely controllable single-pole optical resonance

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Abstract:
When subject to temporally harmonic refractive index modulation, photonic states in nanophotonic structures can go through photonic transition [1], in a manner similar to electronic transitions in semiconductors. In this talk, we show that such transition can be used to create new optical functionalities. In particular, in a periodic system described by a photonic band structure, the use of a modulation can impart both a frequency and a wavevector shift in the photon transition process, creating an indirect inter-band photonic transition. We show that such an inter-band transition can be used to break time-reversal symmetry and create complete and linear optical isolation [2][3], without the use of magneto-optical effect. As such the fundamental difficulty for achieving on-chip optical isolation in standard optoelectronics can be overcome. In addition, we show that photonic transition can be created between a state that is completely localized, and a propagating continuum of states. This process achieves a single-pole optical resonance in which both the resonant frequency and the quality factor is entirely specified by dynamics [4], leading to greater flexibilities and accuracies in controlling optical resonance.

References:
Nonlinear Metamaterial and Plasmonic Structures

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Abstract:

Theory of nonlinear metamaterials [1] predicted that the hysteresis-type dependence of magnetic permeability on the field intensity may allow dramatic changes of the material properties. As the first step towards creating tunable nonlinear metamaterials we studied dynamic tunability of the magnetic resonance of a single nonlinear split-ring resonator [2] and revealed different tuning regimes of metamaterial. At higher powers the nonlinear response of the split-ring resonator becomes multi-valued, indicating that the memory effect can be potentially observed in nonlinear metamaterials. Recently, we fabricated the first tunable nonlinear magnetic [3] and nonlinear electric [4] metamaterials by placing varactors in each of the split-ring resonators or each of the electric resonators of the structure. We measured a very pronounced shift of the resonance, and observed a change of the transmission through the nonlinear metamaterial with split-ring resonators for different power levels [3]. We observe experimentally the intensity-suppressed and intensity-induced transparency, when the frequency of the incoming wave is at the left edge of the resonance. The achieved nonlinear suppression of the beam transmission is 20 dB for magnetic metamaterial [3], and almost 50dB for electric metamaterial [4].

Left-handed materials at optical frequencies are closely related to plasmonics. We aim to study the fundamental nonlinear effects in plasmonics [5] and, as the first step, we found the families of guided modes of a nonlinear slot waveguide and revealed that the symmetric mode undergoes the symmetry breaking and becomes primarily localized near one of the interfaces. We discuss self-focusing of a plasmon beam at large powers and soliton formation even in the presence of losses. In addition, we analyze phase matching in planar metal-dielectric nonlinear waveguides supporting highly localized plasmon polariton modes and reveal that quadratic phase matching between the plasmon modes of different spatial symmetries becomes possible in the planar waveguide geometry.

References:
Nonlinear localized and propagating modes in metamaterials

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Abstract:

Discrete magnetic metamaterials (MMs) comprised, e.g. of periodically arranged nonlinear split-ring resonators (SRRs), may support highly localized excitations in the form of discrete breathers (DBs) \([1]\). In practice, the SRRs can become nonlinear by the insertion of nonlinear electronic components into their slits \([2]\). Recently, a novel MM comprised of two types of SRRs was investigated theoretically and it was demonstrated that in the nonlinear regime such binary MMs are suited for the observation of phase-matched parametric interaction and enhanced second harmonic generation \([3]\). The binary structure of the SRR lattice allows for generation of DBs through direct external induction by a frequency-chirped incident field \([4-6]\). That method has been applied successfully for DB generation in experiments on dielement cantilever arrays \([7]\). MMs are driven by alternating fields and thus it is expected that dissipative DBs are relevant to these type of experiments when nonlinearity is present. We have generated numerically dissipative DBs in a model nonlinear binary MM with frequency-chirped driver for several parameter sets \([4-6]\). Since it is in principle possible to construct a binary MM with strong on-site nonlinearity, we propose that an experiment with frequency-chirped applied field can lead to dissipative DB generation.

Moreover, we have investigated the transmission of power in SRR arrays driven at one end. We have found that the incoming power can be transmitted effectively for frequencies not only within the linear band, but also within other narrow frequency intervals, where nonlinear resonances appear. Importantly, the power is transferred by breather-like, resonant excitations, that are continually formed in the array.

References:

Frequency addressing of nanoCobjects by electrical tuning of optical antennas

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Abstract:

Recent years have witnessed an impressive amount of research on optical devices conceived to efficiently couple free-space propagating light with localised light emitters or receivers, for a wide variety of potential applications, including nonlinear optics, efficient solar cells, near-field optical microscopy, and spectroscopy [1]. Beyond confining light of a given frequency at fixed locations, there is a need for dynamical control of such hot-spots [2, 3]. The possibility of dynamically tuning the resonance frequency of optical antennas might thus open new frontiers in probing of matter by optical means. To reach this goal, in our work we analyse a linear wire aerial immersed in a uniaxial anisotropic medium. The behaviour of surface plasmon resonances in uniaxial anisotropic media has been already discussed both theoretically and experimentally in the literature; in this framework both individual and coupled spherical nanoC particles have been considered. From the application viewpoint, in terms of antennas and equivalent circuits, what is needed is to determine the self impedance and effective length of a cylindrical wire and the load impedance describing the role played by a small gap in it. With these results at hand, we will then be able to discuss the tuning mechanism controlled by the director orientation for a linear wire optical antenna immersed in a nematic liquid crystal.

References:

Amorphous photonic lattices: disorder, band gaps, and effective mass

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Abstract:

Conventional intuition in solid state physics holds that, in order for a solid to have an electronic band gap, it must be periodic, allowing the use of Blochs theorem. Indeed, the free-electron approximation implies that Bragg scattering in periodic potentials is a necessary condition for the formation of a band gap [1]. But this is obviously untrue: looking through a window reveals that glassy silica (\(\text{SiO}_2\)), although possessing no order at all, still displays a band gap spanning the entire photon energy range of visible light, without absorption. In our presentation, we present the first experimental study of amorphous photonic lattices: a 2D array of randomly-organized evanescently-coupled waveguides (Fig. 1a). We will demonstrate that the bands in this medium, comprising of inherently localized Anderson states [2], are separated by gaps, despite the total lack of Bragg scattering (Fig. 1b). Further, amorphous photonic lattices support the existence of strongly localized defect states, whose widths is much narrower than the Anderson localization length (ensemble average over transport via the Anderson states comprising the bands), as shown in Fig. 1c. Finally, we prove the existence of a region of negative effective mass (anomalous diffraction). Superimposing a weak spatial modulation on the random potential (refractive index) causes a wavepacket with a negative effective mass to move opposite to the direction it would have moved had it had positive effective mass.

Figure 1: (a) Microscope image of the front facet of an amorphous waveguide lattice. (b) Eigen spectrum of this lattice, showing a clear band gap. (c) A highly localized defect state, residing in this gap.

References:
Observation of two-dimensional superlattice solitons

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Abstract: Lattice solitons have been investigated in a number of settings and in different nonlinear materials (see [1,2] for recent reviews). Particular attention has been paid to the precise tuning of the properties of such states. In this respect periodic systems with complicated transverse shapes, such as photonic superlattices, open new opportunities for soliton control. A variety of linear and nonlinear phenomena have been demonstrated in superlattices, but experimental investigation of superlattice solitons were limited to one-dimensional settings [3]. Thus, the properties of two-dimensional entities remained unobserved.

In this talk we report on the experimental observation of two-dimensional solitons in superlattices comprising alternating deep and shallow waveguides [4]. Our experiments were conducted in superlattices that were fabricated using the femtosecond-laser direct writing technique in a fused silica samples with a length of 105 mm. The relevant lattice sites were excited with a Ti: Sapphire laser, delivering 200 fs pulses at a wavelength of 800 nm with a repetition rate of 1 kHz, while output patterns were recorder with a CCD camera. The symmetry of the linear diffraction patterns, soliton shapes, and threshold powers for soliton excitation in superlattices largely differ for excitations centered on deep and shallow waveguides. This is illustrated in Figs. 1,2 showing the output intensity distributions at specific powers for excitation of deep (Fig. 1) and shallow (Fig. 2) guides located either in the center (first column), at the edge (second column), or in the corner (third column) of the superlattice. The first row in each figure corresponds to the almost linear regime of propagation for 200 kW excitation peak power. The second and third rows show different stages of localization for input peak powers of 1 MW and 2 MW, respectively. Figures 1 and 2 illustrate that the dynamical excitation of solitons centered on deep guides is achieved at substantially smaller input peak powers than excitation of solitons on shallow guides (compare the patterns in the same rows in Figs. 1 and 2). Moreover, while an increasing input power results in the monotonic contraction of the output pattern for excitation of deep guides, an abrupt intermediate spreading can be observed upon excitation of shallow guides because of the matching of the effective index of excited shallow guide due to nonlinear contribution with refractive index in deep neighboring guides. We found that in all cases corner solitons exhibit the smallest threshold for their excitation, while center solitons require the highest threshold.
References:
Plasmonic nonlinearities at propagation and storage

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Abstract:

Although surface plasmons are not long propagating waves, the ultrahigh field confinement and the unique dispersion characteristics are a potential source for substantial nonlinear properties.

In this talk we will discuss propagation of nonlinear waves in plasmonic nanostructures. Plasmon-soliton propagation is shown to be enabled exhibiting ultra small confinement of the electromagnetic field. This soliton is unique by having two important polarization components including a substantial longitudinal field. Generating such solitons around a circular metallic rim is considered.

At high confinement the field is mainly restricted to the metal and majorly longitudinal. At this point metal nonlinearity becomes important. We will describe in details the effect of high fields in plasmonic nanostructures. The ponderomotive force electron depletion from high field regions is shown to be the native nonlocal nonlinearity in metal and we analyze propagation of plasmon polaritons due to this effect. It is shown that the ponderomotive force results in a large Kerr like nonlinearity which slows the plasmon propagation and generates intensity induced cutoff. We will show also that this nonlinearity may limit the field enhancement of localized plasmons in metal nanoparticles.

In addition and if time allows - we will describe metal nonlinearities due to symmetry breakdown and slow plasmon propagation.
Spectral signatures of temporal solitons in subwavelength waveguide arrays: Theory and experiment

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Abstract:

We report theory and experimental observations of resonant radiation by solitonic supermodes in an array of three silicon-on-insulator photonic wires. When several supermodes in the array of three coupled subwavelength silicon-on-insulator waveguides are excited simultaneously by a spatially localized pump, emission of Cherenkov radiation is observed. With changing the pump position across the array, a gap in the radiation spectrum opens up. We provide evidences that the missing radiation is associated with the anti-symmetric supermode, which is not excited when the pump is centered in the middle of the array. This experimental observation confirms excitation of solitonic supermodes inside the array, since the Cherenkov radiation is known to be associated only with solitonic or non-dispersive quasi-solitonic pulses. Our results pave the way for future research into frequency conversion and switching applications using spatio-temporal solitonic effects in periodic nanostructures.
Nonlinear optics at the nanoscale

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Abstract:

Development of nanotechnologies and interest for metamaterials has put a renewed interest on the subject of nonlinear optical properties of patterned metallic structures. Structures made of metal sub-wavelength objects like nanorods, or nano horseshoe shaped resonators and nanowires periodically arranged in dielectric matrices have been realized and linearly characterized. The same way, the linear behaviour of transmitted fields trough nano-apertures and slits on metal screens have been deeply investigated. It is well known that sub-wavelength features can be responsible for transparency regions in the visible range. Indeed, enhanced transmission from thick metal screens with sub-wavelength apertures has been extensively studied and observed in the linear regime [1]. The phenomenon in based on surface plasmon polariton excitation and fulfilment of resonant conditions inside the aperture as a function of the screen depth [2] leading to fields enhancement effects. Nevertheless, the study and the understanding of non linear phenomena in these systems is still at a seminal stage concerning theoretical models and numerical tools. Several models have been proposed in the regime of quasi static approximation or by taking advantage of effective medium approximation. .. In this work we present an overview of a numerical method developed [3] in order to study the nonlinear quadratic response of nanopatterned metals, of different metallic geometries and dielectric structures. A comparison with experimental results [4] is also presented.

References:
3. A.Benedetti, M.Centini, C,Sibilia, M.Bertolotti C In press on JosaB
Numerical Study of 3D Incompressible Euler Equations with Highly Symmetric Initial Data

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Abstract:

The Kida-Pelz type high symmetric initial value for 3D incompressible flow is a very attractive candidate as the invisible flow with possible finite time blowup behavior. The numerical results for the Navier-Stokes equations indicate strongly that there will be a finite time blowup. In 1997, Pelz presented a filament model to mimic this blowup behavior observed in the Navier-Stokes computation and a finite time blowup with certain scaling properties was produced. To check if the blowup of the filament model is due to the modelling error of the filament model equation, or due to the nature of the Euler equations, we revised this filament model to a periodic configuration, which can be numerical solved by both the filament model equation and the full 3D Euler solver. The periodic filament model equation was numerical solved with an Ewald summation technique. The blowup behavior with the same scaling properties reported by Pelz was observed again in our computation, which appeared quite robust to the perturbation on the profile of the initial filament. The full Euler equations were solved with a standard pseudo-spectral code with a recently developed high order Fourier filter to remove the aliasing error. To our surprise, the numerical results of the full Euler equations deviated from the numerical results of the filament model simulation and behaved as a comparative stable structure. Therefore, the most possibility based on current numerical results is that the high symmetric filament model missed certain intrinsic properties in the Euler equation to produce the strange numerical behavior observed in the Navier-Stokes computation.
On the Singularity formation of the 3D model for the incompressible Euler and Navier-Stokes equations

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Abstract:
In this talk, the singularity formation of a 3D model for the incompressible Euler and Navier-Stokes equations is studied. This 3D model is derived from the axisymmetric Navier-Stokes equations with swirl using a set of new variables. This model preserves almost all properties of the full 3D Euler or Navier-Stokes equations except for the convection term which is neglected. We will prove rigorously that the 3D model develops finite time singularities for a class of initial data with finite energy and appropriate boundary conditions, and it has the global regularity in time for another class of smooth initial data. Some results of generalized 1D and 3D models are also discussed.

References:
On Singularity Formation of a 3D Model for Incompressible Navier-Stokes Equations

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Abstract:

We investigate the singularity formation of a 3D model that was recently proposed by Hou and Lei in [1] for axisymmetric 3D incompressible Navier-Stokes equations with swirl. The main difference between the 3D model of Hou and Lei and the reformulated 3D Navier-Stokes equations is that the convection term is neglected in the 3D model. This model shares many properties of the 3D incompressible Navier-Stokes equations. One of the main results of this paper is that we prove rigorously the finite time singularity formation of the 3D model for a class of initial boundary value problems with smooth initial data of finite energy. We also prove the global regularity for a class of smooth initial data.

References:

A nonlinear depletion mechanism of vorticity in 2D Boussinesq equation

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Abstract:
Here we present one nonlinear depletion mechanism of vorticity in the 2D Boussinesq equation by defining an elliptic region in the flow where the magnitude of vorticity $\omega^2$ is larger than $tr(\nabla v \cdot \nabla v^t)$, and showing that as long as one particle lies in the elliptic region, and the magnitude of vorticity on the particle is monotonically increasing, then the vorticity on the particle will not blowup in finite time.
Well-posedness of Complex Fluids

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Abstract:

Complex fluids are prevalent in many important physical, biological and engineering applications. This talk will address some of the fundamental analytical issues of viscoelastic materials of complex fluids. More precisely, we will present the global well-posedness of classical solutions for (1) and (2) with small initial data, and (3) and (4) with general data.

(1) Infinite Weissenberg number, macroscopic system reads (Lin-Liu-Zhang 05 CPAM, Lei-Zhou 05 SIMA, Lei-Liu-Zhou 08 ARMA, Chen-Zhang 06 CPDE)

\[
\begin{cases}
    u_t + u \cdot \nabla u + \nabla p = \nabla \cdot \left( \frac{\partial W(F)}{\partial F} F^T \right) + \mu \Delta u, \\
    F_t + u \cdot \nabla F = \nabla u F, \quad \nabla \cdot u = 0.
\end{cases}
\]

Here \( u \) is the velocity field, \( p \) is the pressure, \( F \) is the deformation tensor and \( \tau = \frac{\partial W(F)}{\partial F} F^T \) is the elastic Cauchy stress tensor.

(2) Small strain case, Strain-Rotation model 2D Strain-Rotation Model (Lei 10 ARMA):

\[
\begin{cases}
    V_t + u \cdot \nabla V = D(u) + \frac{1}{2} (\nabla u V + V \nabla u^T) + \frac{1}{2} (\omega_{12}(u) - \gamma) (VA - AV), \\
    \nabla^\perp \theta_t + u \cdot \nabla \nabla^\perp \theta = \frac{1}{2} \Delta u - (\nabla^2 u \cdot \nabla \theta, \nabla u \cdot \nabla \theta)^T + \nabla^\perp \gamma.
\end{cases}
\]

Here \( A \) is an anti-symmetric constant matrix and \( \gamma \) is a nonlinear term.

(3) Micro-Macro FENE model in \( \mathbb{R}^2 \):

\[
\partial_t \psi + (u \cdot \nabla) \psi = \text{div}_R \left[ -W(u) \cdot R \psi + \beta \nabla R \psi + \nabla R \psi \right].
\]

(4) Micro-Macro Smoluchowski equation coupled with NS:

\[
\partial_t \psi + (u \cdot \nabla) \psi + \text{div}_2 (G(u, \psi) \psi) - \Delta_2 \psi = 0, \quad (x, m) \in \mathbb{R}^2 \times M.
\]
On the Camassa-Holm equation

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Abstract:

This talk is focused on recent progress of studies for the Camassa-Holm equation. First, we will give a brief review on the derivations, well-posedness for the strong solution, blow-up phenomenon and existence of the weak solutions. Then, infinite propagation speed for the Camassa-Holm equation will be proved in the following sense: the corresponding solution $u(x,t)$ with compactly supported initial datum $u_0(x)$ does not have compact $x-$support any longer in its lifespan. Moreover, we show that for any fixed time $t > 0$ in its lifespan, the corresponding solution $u(x,t)$ behaves as: $u(x,t) = L(t)e^{-x}$ for $x \gg 1$, and $u(x,t) = l(t)e^x$ for $x \ll -1$, with a strictly increasing function $L(t) > 0$ and a strictly decreasing function $l(t) < 0$ respectively. Finally, some interesting open problems will be listed.

References:

Some results of the magneto-hydrodynamic system in Besov spaces

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Abstract:

In this talk, we present the global well-posedness of solutions to the Cauchy problem of incompressible magneto-hydrodynamics system for large initial data in homogeneous Besov space $\dot{B}^{2-1}_{p,r}(\mathbb{R}^2)$ for $2 < p < \infty$ and $1 \leq r \leq \infty$. In the case spatial dimension $n \geq 3$ we establish the global well-posedness of solution for small data and the local one for large data in Besov space $\dot{B}^{n-1}_{p,r}(\mathbb{R}^n)$, $1 \leq p < \infty$ and $1 \leq r \leq \infty$ or $1 \leq r < \infty$ (in the local case). Moreover, we also prove the weak-strong uniqueness of solutions with data in $\dot{B}^{n-1}_{p,r}(\mathbb{R}^n) \cap L^2(\mathbb{R}^n)$ for $\frac{n}{2} + \frac{2}{r} > 1$.

References:

1. J. Bergh and J. Löfstrom, Interpolation spaces, an introduction,
2. J.M. Bony, Calcul symbolique et propagation des
3. M. Cannone, Harmonic analysis tools for solving
Contour dynamics for 2D active scalars

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Abstract:

In this talk we discuss two free boundary problems given by fluid domains which are weak solutions of incompressible equations. We consider the contour dynamics Muskat problem and the evolution of a sharp front by the 2D surface Quasi-geostrophic equation. Both systems are described by means of a transport equation for the active scalar $\rho(x,t)$ which takes constant values on complementary domains. The velocity field is determined by $\rho(x,t)$ by singular integral operators. However the solutions of these two physical scenarios have completely different outcomes regarding well-posedness and regularity issues.

References:


Geometric aspects of hydrodynamic blowup

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Abstract:

The Arnold approach to hydrodynamics views ideal fluid flows as geodesics on the Riemannian manifold of volume-preserving diffeomorphisms. The curvature of this manifold is related to stability of the fluid in Lagrangian coordinates; it is known to be mostly negative but sometimes positive.

In this talk, I will describe how a strengthened version of the Beale-Kato-Majda criterion for blowup of the Euler equation on $T^3$ can be interpreted geometrically, in terms of the appearance of conjugate point locations near the blowup time. The result is that blowup implies either the appearance of an infinite sequence of conjugate points (which can be detected geometrically), or a specialized form for the deformation tensor near the blowup location.

References:
Longtime Dynamics for 2D Boussinesque System with Fractional Dissipation

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Abstract:

2D Boussinesque equations make up an important system modeling geophysical fluid motions. Mathematically, this system for incompressible fluid flows is an interesting one possessing some of the essential properties of the well know Navier-Stokes equations, while at the same time reflecting its own special properties. In the talk, the long time dynamical behavior of the solutions of this system especially under low fractional dissipation will be discussed in details.
Observation of BEC-related phenomena in polariton condensates

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Abstract:

Exciton-polaritons are quasi-particles formed in semiconductors microcavities under strong light-matter coupling obtained by making use of an intense optical cavity field in resonance with the exciton transition of a Quantum Well. Polaronic has shown very interesting properties such as $\chi^3$ non-linearities [1], peculiar spin dynamics [2], and recently Bose Einstein condensation [3], all given by the extremely peculiar dispersion relation, which happens to be fully accessible experimentally by angular and energy resolved spectroscopy.

In this talk we will review the experimental achievements and the characteristics of a condensate of exciton-polaritons under non-resonant and resonant excitation and show the recent observation of superfluid behaviour manifested as frictionless motion [4,5], splitting with no scattering and permanent circulation in presence of vortex states [6].

References:

Sound propagation in cylindrically confined gas

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INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento,
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and
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Abstract:

The propagation of density and temperature waves in a cylindrically trapped gas with radial harmonic confinement is investigated. Starting from two-fluid hydrodynamic theory, an effective 1D equations for the chemical potential and the temperature which explicitly account for the effects of viscosity and thermal conductivity are derived. Differently from quantum fluids confined by rigid walls, the harmonic confinement allows for the propagation of both first and second sound in the long wave length limit. Quantitative predictions for the two sound velocities of a superfluid Fermi gas at unitarity are given. For shorter wave lengths the response function exhibits a peculiar damping of non dissipative nature which is explicitly calculated in the limiting case of a classical ideal gas.
Turbulence and electron bubbles in liquid helium and Bose-Einstein condensates

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Abstract:

Electrons and positive ions – complex entities whose structure is determined by the interactions with helium atoms– have proved to be successful probes of superfluidity of liquid helium. Recently developed technique of ion injection [1] makes it possible to generate tangles of quantized vortex lines with negligible large-scale flow. Explosion of electronic bubbles at negative pressures assists in visualization of vortex lines and leads to formation of novel objects in helium [2]. A single electron in trapped ultra-cold gases can be used to study interaction processes and explore entanglements in hybrid quantum systems [3]. I will use a mean-field theory to elucidate the dynamics, transport properties and explosion of electron bubbles in superfluids.

References:
Quantum turbulence and nonlinear instability in quantum fluids

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Abstract:
We will discuss quantum turbulence and related nonlinear instability. In quantum condensed systems appear quantized vortices through the order parameters (macroscopic wave functions), and turbulence consisting of quantized vortices is called quantum turbulence (QT). Quantized vortices and QT were discovered in superfluid helium in the 1950's, while they have become one of the most important themes in low temperature physics [1]. The recent striking output would be the confirmation of the Kolmogorov law (K41) of the energy spectra through the Gross-Pitaevskii model [2]. Nowadays QT is studied actively in superfluid $^4$He and $^3$He, even in cold atoms [3].

In this talk, we will first introduce the recent main motivations and the results in QT. Then we will discuss some current topics on nonlinear instability in quantum fluids. One is quantum Kelvin-Helmholtz instability (KHI) in two-component Bose-Einstein condensates [4]. KHI is well known in classical fluids, while we discuss characteristic phenomena of quantum KHI in quantum fluids. The other is realization of steady state in thermal counterflow QT in superfluid $^4$He [5]. This system reminds us of the pioneering work by Schwarz [6], which had some difficulties. By considering the full interaction between vortices, we overcame the difficulties to obtain the steady state.

References:
A sonic black hole in a density-inverted Bose-Einstein condensate

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Abstract:

We have created the analogue of a black hole in a Bose-Einstein condensate. In this sonic black hole, sound waves, rather than light waves, cannot escape the horizon. The black hole is realized via a counterintuitive density inversion, in which an attractive potential creates a region of low density. This allows for measured flow speeds which cross and exceed the speed of sound by an order of magnitude. The Landau critical velocity is therefore surpassed. The point where the flow speed equals the speed of sound is the sonic horizon. The effective gravity is determined from the profiles of the velocity and speed of sound.
Non-linear phenomena in polar gases and quasi-relativistic spinor condensates

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Abstract:

In this talk I will overview some of our recent results on non-linear phenomena in two different physical scenarios: polar gases and quantum gases in the presence of artificial electromagnetism. In the first part I will discuss novel phenomena in polar gases, including the peculiar nature of Faraday patterns in dipolar condensates, the formation of Schrödinger cats in three-well systems, and novel physics in polar gases in optical lattices, including filamentation and enhanced instability. In the second part of this talk, I will briefly comment on the non-linear physics of spinor condensates in the presence of artificial electromagnetic fields, and most specifically spin-orbit coupling. I will show how the system may be described by a nonlinear Dirac equation, which may present self-localized solutions similar to those encountered in high-energy physics in the context of the massive Thirring model. These self-localized condensates which may exist as well in 2D and 3D present a rather peculiar dependence on interactions which largely depends on dimensionality.
Spontaneous formation of topological defects in ultra-cold gases

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Abstract:

The formation of topological defects in symmetry breaking phase transitions is commonplace in a wide range of physical systems. The well-known Kibble-Zurek mechanism is a universal theory that estimates the scaling law for the density of topological defects in both quantum and classical phase transitions [1,2]. It has been applied to a wide range of systems covering classical and quantum physics, from liquid crystals through to cosmological scenarios. However while the Kibble-Zurek prediction for the scaling of defect density has been shown theoretically a number of times, it has yet to be conclusively observed in an experiment. Recent experiments in quantum gases have reported the observation of spontaneous formation of topological defects in spin-one [3] and single component [4] Bose-Einstein condensates. The cleanness and flexibility of ultra-cold gas systems raises the possibility of experimentally measuring the scaling of defect density predicted by the Kibble-Zurek mechanism for the first time.

In this paper we describe our work outlining two experimental systems for observing a Kibble-Zurek scenario in ultra-cold gases. The first is in the thermal Bose-Einstein condensation transition in a weak, oblate harmonic trap. The second is a novel Kibble-Zurek mechanism in a coupled, two component Bose-Einstein condensate in an elongated trap undergoing a controlled quantum phase transition between miscibility and immiscibility.

References:
Universal spreading of wave packets in disordered nonlinear systems

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Abstract:

I will analyze mechanisms and regimes of wave packet spreading in nonlinear disordered media. Wave packets can spread subdiffusively in two regimes of strong and weak chaos [1,2,3]. I will discuss resonance probabilities, nonlinear diffusion equations, and a dynamical crossover from strong to weak chaos. The crossover is controlled by the ratio of nonlinear frequency shifts and the average eigenvalue spacing of eigenstates of the linear equations within one localization volume. I consider generalized models in higher lattice dimensions [4] and obtain critical values for the nonlinearity power, the dimension, and norm density, which influence possible dynamical outcomes in a qualitative way.

References:
Abstract:

The second law of thermodynamics presupposes a clear-cut distinction between the controllable and uncontrollable degrees of freedom by means of macroscopic operations. The cutting-edge technologies in quantum information and nano-science seem to force us to abandon such a notion in favor of the distinction between the accessible and inaccessible degrees of freedom. In this talk, I will discuss the implications of this paradigm shift by focusing on how the second law of thermodynamics can be generalized in the presence of a feedback control.

References:

A Bose-Einstein Condensate in an optical ring-shaped trap

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Abstract:

We report on the creation of a Bose-Einstein condensate of sodium atoms in an optical, ring-shaped trap. The all optical potential enables trapping of all spin states of the atoms and circumvents the thermal drift problem that limited the lifetime of persistent currents in our previous ring-shaped trap formed by the combination of magnetic and optical fields [1]. The ring geometry trap opens up new possibilities for studies of nonlinear phenomena, such as soliton dynamics the atomic analog of a SQUID. The latter can be realized by introducing a thin, repulsive sheet-of-light across the ring to act as a Josephson like tunnel barrier [2]. Progress towards this goal will also be discussed.

References:

Quantum solitons and their scattering on a barrier

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Abstract:

A quantum soliton of matter waves in a 1D wave guide is a fascinating bound state of matter, already realized with cold atoms using a Feshbach control of the interaction strength [1,2]. In these experiments, a soliton contains a thousand of lithium atoms, it is ten times more massive than a $C_{70}$ fullerene. Interferometric experiments have already been realized with fullerenes [3]. Performing them with quantum solitons would be even more intriguing: much larger de Broglie and coherence lengths would be obtained, and a new regime where the center of mass kinetic energy becomes as large as the binding energy of the interferometric object would be at hand.

Along this line, we shall present in our talk a proposal to produce and observe a Schrödinger cat state in real space by scattering a quantum soliton on a barrier [4]. The intuitive idea is to send the soliton with a center of mass kinetic energy (i) smaller than the soliton single particle binding energy (so as to avoid fragmentation of the soliton), and (ii) very close to the barrier height, so that the soliton is transmitted and reflected with roughly equal probability amplitudes $\approx \frac{1}{\sqrt{2}}$.

This idea raises non-trivial questions. How to prove experimentally that a cat is formed? What are the constraints on the state preparation and on decoherence? Is the transmission process through the barrier a macroscopic quantum tunneling, hopelessly sensitive to barrier fluctuations? How to calculate the soliton transmission and reflection amplitudes $t$ and $r$, knowing that the barrier breaks the integrability of the many-body problem? These questions will be answered, in particular thanks to a rigorous result “bracketing” $t$ and $r$ in the complex plane.

References:
Spectroscopy of bound states with matter-wave solitons

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Abstract:

We theoretically investigate the scattering of bright solitons in a Bose-Einstein condensate on narrow attractive potential wells. Reflection[1], transmission and trapping[2] of an incident soliton are predicted to occur with remarkably abrupt transitions upon varying the potential depth. Numerical simulations of the nonlinear Schrödinger equation are complemented by a variational collective coordinate approach. We also present pilot calculations of full quantum simulations based on the multi-particle Schrödinger equation. The mechanism for nonlinear trapping is found to rely both on resonant interaction between the soliton and bound states in the potential well as well as radiation of small amplitude waves. These results suggest that solitons can be used to probe bound states that are not accessible through scattering with single atoms.

References:
Semions, Skyrmions, and a Zoo of Nonlinear Waves in the Nonlinear Dirac equation

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Abstract: A Bose-Einstein condensate in a honeycomb optical lattice gives rise to long-wavelength excitations described by a nonlinear Dirac equation (NLDE). Having previously established this equation and its symmetries [1], we proceed to solve the NLDE. The four components of the Dirac spinor allow for a large class of localized nonlinear excitations. In order to evaluate the experimental viability of these solutions, we have developed a complete linear perturbation theory, a relativistic generalization of the Boguliubov-de-Gennes equation; we call this new equation the Relativistic Linear Stability Equation (RLSE). We present various soliton, vortex, semion (vortices with fractional statistics), and skyrmion solutions of the NLDE, and their associated stability properties according to the RLSE.

References:
Composition Relation between Gap Solitons and Bloch Waves in Nonlinear Periodic Systems

Yongping Zhang and Biao Wu
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Abstract: We show with numerical computation and analysis that Bloch waves, at either the center or edge of the Brillouin zone, of a one dimensional nonlinear periodic system can be regarded as infinite chains composed of fundamental gap solitons (FGSs). This composition relation between Bloch waves and FGSs leads us to predict that there are $n$ families of FGSs in the $n$th band gap of the corresponding linear periodic system, which is confirmed numerically. Based on this composition relation, it becomes clear that all high-order gap soliton, and other stationary solutions of a one-dimensional nonlinear periodic system can be regarded as composed of these FGSs. In other words, FGSs are building blocks for the stationary solutions of one-dimensional nonlinear periodic system.

References:
Nonlinear quantum physics in Bose-Einstein Condensates

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Abstract:
In this talk, nonlinear quantum physics in Bose-Einstein Condensates (BECs) are introduced, based on one exact solution of Gross-Pitaevskii Equation (or Nonlinear Schrödinger equation). For nonuniform BECs, we introduce one novel orthogonal basis, and the stability of the ground and first excited state are analyzed. For two weak linked BECs, symmetry-preserving and symmetry-breaking stationary solutions are introduced and the behind reasons are given. Based on these stationary solutions, we find that the nonlinear tunneling (induced by the nonlinear interaction) induces an important correction to its dynamical and stationary properties in the case of strong nonlinear interaction. For BECs in a periodic array of quantum wells, we find nonlinear Bolch solutions and corresponding Wannier functions. We study the sound velocity, effective mass and so on as a function of the nonlinear parameters. Starting from these, the parameters for Bose Hubbard Model are presented.

References:
Holographic Solitons and the AdS/CFT Correspondence

Sean Nowling, Ville Keränen, Esko Keski-Vakkuri, and Patta Yogendran
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Abstract:

One of the most exciting recent theoretical developments has been the evolution of the holographic gauge/gravity duality. This duality relates the behavior of a strongly coupled field theory to string theory in a higher dimensional space [1]. In the last few years there have attempts to construct holographic models of superfluidity using these tools [2]. Because the duality generally involves both bosonic and fermionic fields, the precise character of the superfluid’s low lying excitations is quite complicated and still largely unknown.

After reviewing the basic structure of the gauge/gravity duality and holographic superfluidity, we will discuss dark soliton and vortex solutions in the gravitational theory. By tuning parameters in the gravitational theory, it is possible to model features of solitons in both fermionic and bosonic superfluids.

References:
Spinor-quantum gases in triangular and hexagonal optical lattices

Klaus Sengstock

Abstract:
Adaptive conservative cell average spectral element methods for transient Wigner equation in quantum transport

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Abstract:

A new adaptive cell average spectral element method (SEM) is proposed to solve the time-dependent Wigner equation for transport in quantum devices. The proposed cell average SEM allows adaptive non-uniform meshes in phase spaces to reduce the high-dimensional computational cost of Wigner functions while preserving exactly the mass conservation for the numerical solutions. The key feature of the proposed method is an analytical relation between the cell averages of the Wigner function in the $k$-space (local electron density for finite range velocity) and the point values of the distribution, resulting in fast transforms between the local electron density and local fluxes of the discretized Wigner equation via the fast sine and cosine transforms. Numerical results with the proposed method are provided to demonstrate its high accuracy, conservation, convergence, and a reduction of the cost using adaptive meshes.
Numerical simulation of underground explosions near a buried structure

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Abstract:

The problem of a buried explosion, subsequent propagation of the shock waves, and their attenuation with distance is of substantial interest and great complexity. The interaction of these waves with a buried obstacle is of an even greater interest for many applications, yet it presents a further increase in complexity.

There exists a rather well developed theory for explosions in air and liquids, and a number of methods are available to assess the blast loads acting on a structure above the ground as a function of the explosive characteristics and the geometrical data. A similar problem of explosions in soils and rocks is not nearly as well understood due to its considerably higher complexity. The propagation of shock waves in such media is a rather intricate phenomenon, it is strongly affected by a much more sophisticated constitutive model, including irreversible bulk compaction (with or without full locking) and deviatoric elastic plastic behavior (that depends on the current pressure). An additional difficulty is associated with the soil porosity and water content.

In the talk, we will address a number of issues related to the blast response of a lined buried structure due to an underground explosion. The constitutive modeling of the soil medium is based on a bulk irreversible compressible elastic plastic medium, including full bulk locking and dependence of the current deviatoric yield stress on the pressure. We are currently working on extending this model to account for its solid, air and water fractions. The structure is represented either as a rigid inclusion of a given shape or as an elastic plastic structural element, often with the circular shape of a tunnel lining. We will present a coupled 2D Godunov – variational difference approach for the soil-structure interaction due to a nearby explosion, including the process of soil-structure real contact conditions, e.g., transient separation of the soil from the structure’s boundary. The approach is based on coupling the shock and rarefaction waves with finite difference equations of the shell motion by means of a simple iteration method. It allows the reduction of the contact problem to a self-similar symmetric Riemann problem.

The contact stress distribution and the soil free surface motion are studied as they depend on the soil and lining properties, and on the scaled distance between the charge and the structure. Some of the observations with regard to the interaction stresses, deformation patterns, and explosion’s crater shape will also be presented.
A tailored finite point method for high frequency waves in heterogeneous media

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Abstract:

In this talk, we propose a tailored finite point method for the numerical solution of the Helmholtz equation with high wave numbers in heterogeneous media. Our finite point method demonstrates a uniform rate of convergence with respect to the wave number $k$ in the $L_2$ norm.
Quasi-lacunae of Maxwell’s equations and their use for long-time computations

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Abstract:

We compute the propagation of electromagnetic waves over a region that extends from the sources of the field, e.g., antennas or scatterers, to infinity. To enable practical solution, the problem shall be truncated to a bounded domain, which necessitates setting the artificial boundary conditions (ABCs) at the outer computational boundary.

We propose a novel approach to addressing this issue. It further develops and extends our previous ideas of constructing the ABCs using lacunae \cite{1}. The proposed algorithm possesses several useful properties. It applies to any well-posed problem governed by the homogeneous Maxwell equations outside the computational domain (inside this domain, the setup can be far more sophisticated). It completely eliminates the reflections of the outgoing waves from the artificial boundary back to the computational domain (as opposed to an approximate or partial cancellation of those reflections). It does not deteriorate when integrating over arbitrarily long time intervals (provably and experimentally). Finally, the associated computational cost per unit time is fixed (and moderate), i.e., it does not increase as the time elapses.

The algorithm employs a new concept of quasi-lacunae of Maxwell's equations. Unlike the classical lacunae that are the regions of zero solution behind aft fronts of the waves \cite{2}, quasi-lacunae have an electrostatic solution at their bottom. The use of quasi-lacunae allows us to overcome a key limitation of the previous methodology \cite{1} — the artificial currents needed for building the ABCs no longer have to be solenoidal.

If combined with a PML (such as in \cite{3}), the new approach demonstrates practically the same computational efficiency as the PML alone, and at the same time, it completely eliminates the intrinsic instability that plagues many popular PMLs and that often prevents their successful application to the integration over long times.

The performance of the new algorithm is corroborated in full 3D using the Yee scheme. Our results show that there is indeed no error associated with the domain truncation, i.e., no spurious reflections, for as long as the computation is run. In contrast, a conventional PML triggers an instability at an early stage of the computation.

References:

2. I. Petrowsky, Matematicheski Sbornik (Recueil Mathematique) 17, 289 (1945).
Compact high order schemes for the Helmholtz equation with variable coefficients

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Abstract:

In many problems, one wishes to simulate the propagation of waves in inhomogeneous media, and use a high order accurate method (e.g., fourth order accurate) to alleviate the points-per-wavelength constraint via reducing the dispersion errors. At the same time, one often prefers to have a scheme built on a compact stencil, as it considerably simplifies setting the boundary conditions and also helps reduce the bandwidth of the resulting matrix. The time-harmonic waves in an inhomogeneous medium are governed by the Helmholtz equation with variable coefficients within the Laplacian-like term; besides, the variation of coefficients in the equation may also be due to the geometry. This renders existing fourth order finite difference methods inapplicable. We develop a new compact scheme that is provably fourth order accurate even for these formulations. For exterior problems, one also needs an absorbing boundary condition at the outer surface to mimic the Sommerfeld radiation condition. We construct methods that accomplish this with higher order accuracy as well. Finally, we present numerical results that corroborate the fourth order convergence rate for several model problems.

Joint work with S. Britt (NC State University) and E. Turkel (Tel Aviv University).
Nonlinear wave phenomena to Korteweg-de Vries – Burgers-type equation

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Abstract:

In this talk, our goal is to study a modified Korteweg-de Vries –Burgers equation with two higher-order nonlinearities. By means of the Lie symmetry reduction method and the Preller-Singer procedure, we show that there exist nontrivial bounded solitary wave solutions under certain parametric conditions. Numerical simulations of waves are illustrated, which provide us rich dynamic information and are in agreement with our theoretical analysis.
A dual-Petrov-Galerkin method for the fifth-order Korteweg-de Vries type equations

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Abstract:

In this talk, we shall show our recent work [2-5] on the 5th-order KdV-type equation that models many physical phenomena such as gravity-capillary waves and magneto-sound propagation in plasmas. Dual-Petrov-Galerkin approximations [1] to those equations are considered. The key idea of this method is to use the trial functions satisfying the underlying boundary considerations of the differential equation and the test functions satisfying the dual boundary conditions. Our theoretical analysis and numerical results indicate that the proposed dual-Petrov-Galerkin method is extremely accurate and efficient.

References:
Newton-conjugate-gradient methods for computations of solitary waves and their linear-stability eigenvalues

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Abstract:

Computations of solitary waves and their linear-stability eigenvalues are important issues in nonlinear waves. So far, a number of iteration methods have been developed for these computations. Examples include the Petviashvili method [1], the squared-operator iteration method [2], and the accelerated imaginary-time evolution method [3] for solitary-wave computations, as well as their counterparts for eigenvalue computations [4]. However, convergence of these methods can still be slow in many situations. In this talk, we propose Newton-conjugate-gradient methods for these computations. These methods are based on Newton iterations, coupled with conjugate-gradient iterations to solve the resulting linear Newton-correction equation. For solitary waves, the preconditioned conjugate-gradient method is proposed to directly solve the underlying Newton-correction equation. For linear-stability eigenvalues, the underlying Newton-correction equation is first turned into a positive-definite normal equation, which is then solved by the preconditioned conjugate-gradient method. These methods will be applied to compute both the ground states and excited states of solitary waves, as well as their stable and unstable discrete linear-stability eigenvalues, for a large number of physical problems such as the two-dimensional NLS equations with and without periodic potentials in optics, and the fifth-order KP equation in water waves. Numerical results show that these proposed methods are much faster than the other existing numerical methods, often by orders of magnitude. In addition, these methods are very robust and always converge in all the examples being tested. Furthermore, they are very easy to implement. This talk is based in part on the materials in [5, 6].

References:
The Whitham equations for dispersionless higher order integrable systems

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Abstract:

We have calculated the weak limit of the self-similar solutions of the higher order KdV equations, and of other higher order integrable systems such as the defocusing complex mKdV equations and Camassa-Holm equation. Our computations show a subtle difference in the form of solutions to the Whitham equations for these higher order problems from the lower order cases such as the KdV and NLS equations. This is joint work with T. Grava, Y. Kodama, and F.-R. Tian.

References:
Oblique Shock Waves in Dispersive Eulerian Fluids

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Abstract: Two-dimensional, non-stationary oblique shock waves in a class of dispersive Eulerian fluids will be constructed using Whitham averaging. This construction takes advantage of irrotationality and recently developed methods for Whitham averaging of one-dimensional, non-integrable equations [1]. Example applications to Nonlinear Schrödinger (NLS) flows, water waves, ion-acoustic plasma, and optical media with saturable nonlinearity will be presented. Connections to supersonic dispersive, NLS flow over corners will also be discussed [2]. This is joint work with Boaz Ilan.

References:
Absolute and convective instabilities of oblique dispersive shock waves

Boaz Ilan

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Abstract:

Absolute and convective instabilities of oblique dispersive shock waves are studied in the context of the (2+1)-dimensional Gross-Pitaevskii (GP) equation. The transition between absolute and convective instabilities is analyzed and compared with analytic results based on the suitable jump conditions and with direct numerical simulations of the GP equation. This is joint work with Mark Hoefer.
Rayleigh-Taylor Instability in Nonlinear Schrödinger Flow

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Abstract:

The Rayleigh-Taylor instability (RTI) is a fundamental fluid instability which occurs when a heavy fluid is accelerated into a lighter one. While the RTI in classical fluids is a textbook problem, the instability in quantum fluids has received little attention. Here, we observe the instability directly in the equivalent optical system and show that the wave dynamics is strongly nonlinear and compressible from the start. The interpenetration is effectively supersonic, with density fingering always accompanied by vortex generation. The growth rate for perturbations, obtained analytically, shows that inhibition due to wave diffraction has the same spectral form as viscosity and diffusion, despite the fact that the system is dispersive rather than dissipative. This gives formal support for the observation that turbulence in quantum fluids has the same scaling as that in normal fluids. The results hold for any Schrödinger flow, e.g. superfluids and quantum plasma, and introduce a new class of fluid-inspired instabilities in nonlinear optics. Joint work with Shu Jia.
Quantum hydrodynamics in ultracold atomic gases

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Abstract:

When atomic gases are cooled to temperatures close to absolute zero, they can enter a quantum degenerate regime in which the wavemechanical behavior of matter becomes apparent. Bosons can form a Bose-Einstein condensate, characterized by a large number of atoms being described by a single wavefunction. Fermionic atoms, in contrast, form a Degenerate Fermi sea in which only one atom is allowed to occupy a given quantum state due to the Pauli exclusion principle. Interatomic interactions as well as the Pauli principle can lead to intriguing nonlinear dynamics in these systems.

In this talk I will describe our recent and ongoing experiments with Bose-Einstein condensates and Degenerate Fermi seas. In the condensates nonlinear dynamics are directly observed. Particular emphasis is put on the generation of dispersive shock waves as well as the formation of solitons in these systems. The behavior of the fermions is very different and shock waves, while predicted to exist, are more difficult to detect. This showcases the striking influence of quantum statistics that becomes apparent when matter changes from classical behavior at room temperature to quantum behavior near absolute zero.
Vortex dipoles in a Bose-Einstein condensate

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Abstract:

While quantized vortices and vortex lattices in Bose-Einstein condensates (BECs) have received much recent attention, the formation and dynamics of vortex dipoles have been nearly unexplored in experimental BECs. Vortex dipoles consist of a pair of vortices of opposite circulation moving under the influence of each other, and may be considered as metastable topological structures that carry linear momentum in a fluid. In this talk, a collaborative experimental and numerical study of the formation, dynamics, and lifetimes of vortex dipoles in BECs will be presented. In our work [1], single vortex dipoles were deterministically nucleated by causing highly oblate, harmonically trapped BECs to move past a repulsive obstacle above a supercritical flow velocity. Our measured critical velocity for vortex dipole shedding, and the subsequent dipole dynamics, are in good agreement with new numerical simulations. We find that vortex dipoles can survive for many seconds in the BEC without self-annihilation, and that multiply charged vortex dipoles can be formed with high enough flow velocities.

References:
Universality of critical behaviour in Hamiltonian PDEs

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Abstract: We consider Hamiltonian dispersive PDEs and study the behaviour of solutions when the dispersion goes to zero. We show that at critical points such behaviour is universal in the sense that it does not depend on the initial data neither on the equation. We describe such behaviour in terms of Painlevé transcendent.
Two-dimensional supersonic nonlinear Schrödinger flows past obstacles

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Abstract:

I will present recent results on the analytic description of the waves generated by a two-dimensional supersonic flow of a superfluid past a large slender obstacle [1]. If the speed of the oncoming flow is sufficiently high, the generated wave pattern in each half-plane generally represents a combination of two steady oblique dispersive shock waves (DSWs) having contrasting asymptotic properties. The front DSW transforms into a linear Kelvin-Bogoliubov “ship-wave” [2] at sufficiently large distances from the obstacle, while the rear one assumes the form of a “fan” of convectively stable oblique dark solitons [3], [4]. Detailed modulation description of the generated waves is obtained in the hypersonic approximation when the original 2+0 boundary problem for the nonlinear Schrödinger equation (defocusing) can be asymptotically reduced to a 1+1 dispersive piston problem [5], [6]. The analytic results are supported by full 2D unsteady numerical simulations.

References:
Dispersive shock wave in the continuous limit of Fermi-Pasta-Ulam models

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Abstract: We consider the continuous limit of a chain of nonlinear oscillators interacting by cubic and quartic potentials (Fermi-Pasta-Ulam models). We provide an analytic description of the local behaviour near the catastrophe point and perform numerical analysis of the dispersive shock wave onset in the framework of the universality conjecture.
Reformulation and asymptotic reductions of water and interfacial waves

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Abstract:

Nonlocal spectral reformulations of classical water waves and multi-fluid interfacial waves are developed in terms of data only on the free surfaces. The reformulation has a fixed boundary. From the nonlocal spectral system Dirichlet-Neumann series, asymptotic reductions and integral relations can be obtained. In certain limits the Kadomtsev-Petviashvili (KP) and the intermediate KP equation are found and their lump type solutions are obtained numerically.
Modeling weakly two-dimensional water wave motions

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Abstract:

Strongly nonlinear models for two-dimensional surface and internal waves in shallow water will be described and their numerical solutions will be presented for the propagation and interaction between large amplitude solitary waves. In addition, under the assumption that the wave motions are weakly two-dimensional, their reduction to simpler models will be discussed and its validity will be examined in comparison between the fully and weakly two-dimensional model solutions. Joint work with Arnuad Goulet and Qi Yi Zhou (NJIT).
Numerical and analytical study on instabilities of the line soliton of the KP I equation and related recurrent phenomena

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Abstract:

We report some numerical results on time-evolutions of the KP I equation under periodic boundary conditions, which are compared with exact solutions. It has been shown analytically that conventional line solitons are linearly unstable to long-wave transverse disturbances[1]. An analytical solution of the line soliton with a small unstable mode has been also obtained, which shows that it becomes another smaller line soliton and a periodic soliton (i.e. the array of the localized structures) [2,3]. On the other hand, time-evolutions of the line soliton with general disturbances are not available to us. A series of numerical simulations are conducted in order to clarify how the line soliton develops with the following more general disturbances: (a) a finite-amplitude unstable mode, (b) a small sine wave with one periodicity similar to the case treated in [4] and (c) two small unstable modes. The Fourier-Galerkin method is applied for spatial discretization and the fourth-order Runge-Kutta method based on the integrating factor method is devised. In case (a) when the disturbance is small enough, the result agrees with the analytical solution. As the magnitude of the disturbance is larger, ripples grow and the remaining line soliton is deformed. In case (b) the time-evolution is very similar to case (a), but both solitons are a little different from those in case (a) with a very small unstable mode. In case (c) two periodic solitons and another line soliton appear after the line soliton is destroyed by the disturbances. The shape of the resulting solitons is independent of the ratio of the magnitude of two given modes though the processes of the time-evolution are different. The solitons interact with each other owing to the periodic boundary conditions. If the parameters of two solitons are satisfied with the resonant condition[5,6], they fuse into a soliton. Furthermore if the parameters of the fused soliton and the other soliton are satisfied with the resonant condition, they fuse into the initial linearly unstable line soliton, which is regarded as a recurrent phenomenon. A numerical simulation shows that the recurrent soliton appears after some interactions. The solitons appeared in passing numerically are in good agreement with the exact soliton solutions that are expected based on the resonant condition. The linearly unstable soliton may correspond to the fixed point of homoclinic orbits.

References:

4. E. Infeld, A. Senatorski and A. A. Skorupski, 72, 1345-1347 (1994).
Exact solutions for the Gardner equation

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Abstract:
This talk is devoted to the solution of the extended quadratic-cubic Korteweg - de Vries (KdV) equation, also known as the Gardner equation. This equation is integrable by means of the Inverse Scattering Technique, and thus admits exact analytical solutions. Depending on the coefficients, solitons and breathers represent the nonlinear localized waves related to the discrete part of the spectrum of the associated scattering problem. The discrete spectrum, in contrast to the KdV case, may be complex, what results in existence of the breather solution, which is the generalization of the breather solution of the modified KdV equation. Due to two nonlinear terms in the evolution equations, specific limiting solitons exist, which are the algebraic soliton, algebraic breather and the wide (or ”top-table”) soliton. The composite nonlinear law supports the complicated manner of nonlinear wave interactions, which are studied in detail [1, 2]. These effects have been already confirmed partly within the frameworks of generalized equations. Generation of solitons and breathers from initial disturbances of simple shapes is studied by means of the solution of the associated scattering problem, as well as by the direct numerical integration of the evolution equation [3, 4]. Again, some of these results have been already reproduced in numerical simulations of extended and strongly nonlinear models, in particular, the generation of couples of solitary waves [5], and the formation of a breather in realistic conditions [6]. The higher-order generalization for the Gardner equation was presented in [7], and that model was shown to be close to the asymptotically integrable one. It is an intriguing fact that the Gardner equation describes exactly the velocity of nonlinear long interfacial waves [7, 8], what may explain the particular place of the Gardner equation in the description of interfacial and internal waves in a stratified fluid. The talk reviews the last author’s research on the topic in collaboration with other researchers (see the reference list) and reports the recent results.

References:
5. A.V. Porubov, G.A. Maugin, V.V. Gursky, V.V. Krzhizhanovskaya, C. R. Mecanique 333, 528-533 (2005).
Numerical study of oscillatory regimes in the Kadomtsev-Petviashvili equation

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Abstract:

The aim of this talk is the accurate numerical study of the KP equation. In particular we are concerned with the small dispersion limit of this model, where no comprehensive analytical description exists so far. To this end we first study a similar highly oscillatory regime for asymptotically small solutions, which can be described via the Davey-Stewartson system. In a second step we investigate numerically the small dispersion limit of the KP model in the case of large amplitudes. Similarities and differences to the much better studied Korteweg-de Vries situation are discussed as well as the dependence of the limit on the additional transverse coordinate. This work is extended to generalized KP equations. In particular we are concerned with the small dispersion limit of this model. Comparisons with the KP case and with the analytically far better understood KdV situation are drawn.

References:
Long waves over random topography

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Abstract:

In this talk, we present a Hamiltonian formulation for water waves over a variable bottom based on potential flow theory. The problem is reduced to a lower-dimensional system involving boundary variables alone. This is accomplished by introducing the Dirichlet–Neumann operator which expresses the normal fluid velocity at the free surface in terms of the velocity potential there, and in terms of the surface and bottom variations. A Taylor series expansion of the Dirichlet–Neumann operator in homogeneous powers of the surface and bottom variations is proposed [2]. This formulation has implications for the convenience of asymptotic calculations and direct numerical simulations of the Euler equations for water waves. We derive asymptotic models for long waves over a random bottom topography [1,3], and develop an efficient and accurate numerical method based on the fast Fourier transform to solve the Euler equations [4]. Numerical applications will be presented.

This is joint work with A. de Bouard, W. Craig, O. Diaz-Espinosa, D. P. Nicholls and C. Sulem.

References:
**KP solitons: Part 1. Experiments**

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**Abstract:**

As the first part of this series, I present laboratory experiments of the KP solitons. The experiments are performed in a wave tank that was designed and constructed specifically for precision experiments for long waves. The tank is equipped with a directional-wave maker, capable of generating arbitrary-shaped multi-dimensional waves; hence the apparatus is adequate for realization of the KP solitons in the real-fluid environment. Temporal and spatial variations of water-surface profiles are captured using the Laser Induces Fluorescent method - a nonintrusive optical measurement technique. Our experiments yield accurate anatomy of the KP solitons and their evolution behaviors, which stimulate the theoretical analysis and the numerical experiments presented in Parts 2 and 3 by Kodama and Kao.

**References:**

KP solitons: Part 2. Theory

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Abstract:

After observing real experiments of shallow water waves in Part 1 by Yeh, I now present a classification theorem for exact soliton solutions of the KP equation. The classification theorem is closely related to the theory of the totally non-negative Grassmann manifold, $\text{Gr}^+(N,M)$. Each of the exact solutions is then identified as a point of $\text{Gr}^+(N,M)$, and is parametrized by a unique chord diagram representing the derangement of the permutation group $S_M$. The corresponding chord diagram also describes the asymptotic structure of the solution which consists of arbitrary numbers of line-solitons in both $y \to \pm \infty$. We also propose a method based on the classification theorem to identify the exact solution from certain initial waves including the examples given in Part 1. With this method, we first express the initial wave in an incomplete chord diagram, and then we make a minimal completion of this incomplete diagram. The minimality implies that among all possible completions, we choose the completed diagram which has the minimum total length of the chords and represents the minimum dimensional cell in $\text{Gr}^+(N,M)$. In Part 3, Kao will demonstrate the minimal completion by means of the direct numerical simulation of the KP equation.

References:

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Abstract:

As the final part of this series, I now present a numerical method to study the initial value problem of the KP equation with certain initial waves. The numerical approach is based on the pseudo-spectral method with a window technique to take care of the non-periodic condition at the computational boundary. We show that for those initial waves, the solutions asymptotically converge to some of the exact solutions discussed in Part 2 by Kodama. The convergence is in a locally defined $L^2$-sense that the main part of the interaction pattern of the solution agrees with that of the exact solution. The corresponding exact solution is then identified via a minimization process. Finally, based on the present numerical study, we will discuss the stability of the exact soliton solutions of the KP equation.

References:

Soliton interactions of the two-dimensional Boussinesq-type equation

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Abstract:

It is well known that the Kadomtsev-Petviashvili (KP) equation can be derived from a weak two-dimensional approximation of the Boussinesq-type equations in shallow water waves and ion-acoustic waves. The recent development in the study of line soliton interactions of the KP equation \([1,2]\) brings us to the detailed study of line soliton interactions of the two-dimensional Boussinesq-type equations in shallow water waves and ion-acoustic waves \([3,4,5,6,7]\). Since the two-dimensional Boussinesq-type equations are no longer integrable, we need to clarify which properties of line soliton interactions of the KP equation remain in the two-dimensional Boussinesq-type equations and what happens in line soliton interactions when the KP approximation is invalid.

Employing a pseudo-spectral method and a finite difference method, we study line soliton interactions of the two-dimensional Boussinesq-type equation. Based on numerical results, common properties and differences between soliton interactions of the two-dimensional Boussinesq-type equation and of the KP equation are discussed. Some of numerical results are explained by using an analytical approximation method. The interpretation in shallow water waves is also discussed.

References:

Two-dimensional interaction of Benjamin-Ono solitons
— Comparison with solution of KP equation —

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Abstract:

Benjamin-Ono(BO) equation is a model equation for weakly nonlinear long waves in a two-layer fluid in which one layer has infinite depth and the other layer is shallow compared to the wavelength. The authors studied two-dimensional interaction of the BO solitons by the two-dimensional BO(2dBO) equation which describes strong interaction for the small angle of propagation directions[1]. As a result the generation of large soliton and its dependency of interaction angle were found. This previous analysis is limited to symmetric initial conditions in which the waves with same amplitude are located symmetrically to a coordinate axis. In this study the interaction for the asymmetrical initial conditions is investigated using the windows method[2].

This study is closely related to the Kadomtsev-Petviashvili(KP) equation which also describes two-dimensional behavior of the nonlinear shallow water wave, long wave in stratified fluid and so on. Kodama et al.[3] clarified the relation between the numerically obtained asymptotic solution of V-shape initial value problem and new class of soliton solutions. We investigate the similar initial value problem of 2dBO equation and compare the result with the one of KP equation.

References:
Some combinatorial problems related to the KP line-solitons

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Abstract:
A permutation \( \pi \in S_M \) of the index set \([M] = \{1, 2, \ldots, M\}\) with no fixed points is called a derangement, and an index \( i \in [M] \) such that \( i < \pi(i) \) is called an excedance of the permutation \( \pi \). Given positive integers \( N, M \), the line-soliton solutions of the KP equation are enumerated by the set of all derangements \( D(N, M) \) of \([M] \) with \( N \) excedances. This leads to a classification of the KP line-solitons discussed in Refs.[1, 2], and is related to the enumeration of totally non-negative cells of the Grassmannian \( \text{Gr}(N, M) \). Each derangement \( \pi \in D(N, M) \subset S_M \) can be represented by a chord diagram with a certain number of pair-wise crossings of chords. The crossings describe the resonant interactions among the line solitons. The number of crossings and the excedance number \( N \) determine the number of free parameters in each line-soliton solution. Moreover, the derangement set \( D(N, M) \) is invariant under the action of the cyclic shift \( c : i \to i + 1 \pmod{M} \), which preserves the number of crossings. This action induces a “Bäcklund” transformation taking a given line-soliton solution of KP to another solution with the same number of free parameters but with a different resonant interaction pattern.

References:
Double-pole soliton solution for the derivative nonlinear Schrödinger equation with nonvanishing boundary conditions

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Abstract:

The derivative nonlinear Schrödinger equation is an integrable extension for the ubiquitous nonlinear Schrödinger equation with inclusion of the nonlinear dispersion, also describing nonlinear waves in many fields of classical and quantum physics. We find the equation possesses multiple poles under nonvanishing boundary conditions and find a double-pole soliton solution for it. The solution is a weakly bound state of a bright soliton and a dark soliton and, unlike those found in scalar equations with vanishing boundary conditions[1-5], is not limits of its simple-pole solitons[6-7] when merging distinct simple poles.

References:
Invariant solutions of supersymmetric nonlinear wave equations

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Research performed in collaboration with A. M. Grundland (Université de Montréal and Université du Québec à Trois-Rivières, email: grundlan@crm.umontreal.ca) and L. Snobl (Czech Technical University in Prague, email: Libor.Snobl@fjfi.cvut.cz).

Abstract:

In this talk, we present a group-theoretical symmetry analysis for the supersymmetric versions of specific nonlinear equations. Specifically, we consider supersymmetric extensions of the (1+1)-dimensional sine-Gordon equation, the (1+1)-dimensional sinh-Gordon equation and the following generalized polynomial form of the Klein-Gordon equation

\[ u_{xt} + au + bu^3 + cu^5 = 0. \] (9)

In each case, the supersymmetric version of the equation is constructed on the 4-dimensional Grassmannian superspace \( \{(x, t, \theta_1, \theta_2)\} \). Here, the variables \( x \) and \( t \) represent the bosonic coordinates of 2-dimensional Minkowski space, while the quantities \( \theta_1 \) and \( \theta_2 \) are anticommuting fermionic variables. The bosonic function \( u(x, t) \) is replaced by the scalar bosonic superfield

\[ \Phi (x, t, \theta_1, \theta_2) = \frac{1}{2} u(x, t) + \theta_1 \phi(x, t) + \theta_2 \psi(x, t) + \theta_1 \theta_2 F(x, t), \] (10)

where \( \phi \) and \( \psi \) are fermionic-valued fields and \( F \) is a bosonic field. The supersymmetric extension is constructed in such a way that it is invariant under a set of supersymmetry transformations (generated by vector fields \( Q_x \) and \( Q_t \)) which link the bosonic independent variables \( x \) and \( t \) to the fermionic independent variables \( \theta_1 \) and \( \theta_2 \) respectively. This is ensured by writing the supersymmetric equation in terms of covariant derivative operators \( D_x \) and \( D_t \) which anticommute with the supersymmetry generators \( Q_x \) and \( Q_t \) respectively. For each of the supersymmetric equations under consideration, we use a generalization of the method of prolongation in order to determine the Lie superalgebra of symmetries of the equation, and we present a systematic classification of all one-dimensional subalgebras of this resulting Lie superalgebra. The method of symmetry reduction then allows us to derive invariant solutions of the supersymmetric model. Some interpretation of the obtained results is given.

References:

The inverse scattering transform and meromorphic solutions to the KdV equation with non-decaying initial data

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Abstract:

We are concerned with the Cauchy problem for KdV equation on the whole line with initial profiles which are decaying sufficiently fast on the right half line and arbitrary (with on decay assumption) on the left half line. We show that a reflection coefficient can be suitably defined in terms of the Titchmarsh-Weyl m-functions associated with the two half-line Schrodinger operators. In the short-range case our reflection coefficient agrees with the standard one. It is however well defined for much larger class of potentials as it is composed of Titchmarsh-Weyl m-functions which exist under almost no restriction on the potential. Moreover, since the m-function has a Herglotz property in the upper half plane, the reflection coefficient also has a certain analytic structure. Although the transmission coefficient need not exist but nevertheless the analyticity allows one to push the inverse scattering transform (IST) method far beyond the standard decay assumptions. The Marchenko integral equation of the inverse scattering theory can then be suitably regularized and the machinery of the IST smoothly works (including existence, uniqueness, well posedness, etc.). Our analysis of the Marchenko equation is based on certain subtle properties of the Titchmarsh-Weyl m-function. We show that the solution obtained this way represents a meromorphic function of the spatial variable. Among others, our approach yields some relevant results due to Cohen, Kappeler, Khruslov, Venakides, and others.
The Cauchy problem of the Ward equation

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Abstract:

Taking a dimension reduction and a gauge fixing of the self-dual Yang-Mills equation in the space-time with signature (2, 2), one derives an integrable system, the Ward equation:

\[-(J^{-1}J_t)_t + (J^{-1}J_x)_x + (J^{-1}J_y)_y + \left\{(J^{-1}J_t)_y - (J^{-1}J_y)_t\right\} = 0, \quad J(x, y, t) \in SU(N).\]

Our main contribution is solving the inverse scattering problem and the Cauchy problem of the Ward equation without small data constraints. More precisely, we generalize the results in [Dai-Terng, 07], [Villarroel, 90], [Fokas-Ioannidou, 01], [Dai-Terng-Uhlenbeck, 06] by showing:

1. Suppose the potential \(Q\) is in \(P\). Then there is a bounded set \(Z \subset \mathbb{C}\), where \(Z \cap (\mathbb{C} \setminus \mathbb{R})\) is discrete in \(\mathbb{C} \setminus \mathbb{R}\), such that the associated eigenfunction \(\psi(x, y, t, \lambda)\) exists uniquely for \(\lambda \in \mathbb{C} \setminus (\mathbb{R} \cup Z)\) and is \(\lambda\)-meromorphic with poles at \(Z \cap (\mathbb{C} \setminus \mathbb{R})\).

2. A notion of scattering data \(v\) is formulated for \(Q \in P\) if \(Z\) is empty. The algebraic and analytic characterization of such scattering data \(v\) is derived. Conversely, for each data \(v\) satisfying these constraints, there is a corresponding potential \(Q\) satisfying certain decay at \(\infty\) and smoothness.

3. Suppose the initial potential \(Q_0\) is in \(P\), \(Z_0\), the set of poles of \(\psi(x, y, 0, \lambda)\), is of finite number and \(Z \subset (\mathbb{C} \setminus \mathbb{R})\). Then the Cauchy problem of the Ward equation admits a global solution \(Q(x, y, t)\) satisfying certain decay at \(\infty\) and smoothness.

A one-to-one correspondence between \(Q\) and \(J\), a precise definition of the potential space \(P\), and a description of the smoothness and decay at \(\infty\) are provided in [Wu, 08], [Wu, 09]. Moreover, important algebraic properties of the Lax pair, (i) derivation property; (ii) translating invariant property; (iii) the principal part being equivalent to a \(\bar{\partial}\)-operator, are used in resolving the large data difficulty. Hence the Result 1, and the existence of \(Q\) in 2 are reduced to solving two types of Riemann-Hilbert problem with large data.

If the set of poles of \(\psi(x, y, 0, \lambda)\) is of finite number and contained in \(\mathbb{C} \setminus \mathbb{R}\), then we use Result 2 to decompose \(\psi(x, y, 0, \lambda)\) as two factorization: one factorization has a rational factor \(g_0\) as its tail, and the other has a holomorphic (in \(\mathbb{C} \setminus \mathbb{R}\)) tail \(f_0\). Using \(f_0\) and \(g_0\) as initial eigenfunctions, we then solve the Cauchy problems of the Ward equation by Result 2 and the theory of Backlund transformation established in [Dai-Terng, 07]. From these two solutions, we can construct the solution of Result 3 by using Backlund transformation again.
Families of dark solitons in the superfluid Fermi gas across the BCS-BEC crossover

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Abstract:

Fermionic superfluids of ultra-cold atomic gases provide a unique opportunity to study nonlinear waves throughout the transition from a weakly-interacting quantum gas to a strongly-correlated quantum liquid. Here, we numerically find families of solutions of the time-dependent Bogoliubov-de Gennes (TDBdG) equation corresponding to moving dark solitons. The TDBdG equation presents the mean-field theory for the superfluid Fermi gas through the BEC-BCS crossover. We calculate the soliton energy as a function of velocity and determine the critical velocity below which solitons can propagate. Consequences for soliton oscillation in harmonically trapped gases are discussed.
Two-component azimuthons in Bose-Einstein condensates

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Abstract:

The study of nonlinear localization effects, in particular high-dimensional spatial solitons and solitons with nontrivial phase, had made significant progress in the two fast developing areas of physics: nonlinear optics and nonlinear atom optics. Due to the similarities between the physics of coherent light waves propagating in a nonlinear medium and coherent matter waves derived from weakly interacting Bose-Einstein condensates (BECs) of neutral atoms, many theoretical concepts developed in the field of nonlinear photonics have found their analogues and received verification in experiments with matter waves. In this talk we introduce with one of such cross-disciplinary concepts, which has important physical implications for the behavior of trapped ultracold atomic gases in quasi-two-dimensional (2D) confining geometry.

Specifically, we describe matter-wave vector azimuthons, i.e. spatially localized vortex states with azimuthal modulations of density, in multi-component Bose-Einstein condensates. These localized states generalize spatially modulated vortex solitons introduced earlier in nonlinear optics [1] and Bose-Einstein condensates [2]. Azimuthons appear via continuous azimuthal deformations of a vortex soliton and are characterized by angular velocity or, equivalently, by the depth of azimuthal modulation of the condensate density. Such nonlinear localized states are found in BECs as stationary solutions to the mean-field Gross-Pitaevskii model in a rotating coordinate frame and constitute a link between vortex solitons and other types of nonlinear localized excitations without a topological charge. We show that in the vector azimuthons, interacting components of the spatially localized structure coexist with nontrivial phases and different modulation patterns [3]. In particular, we consider in detail both non-rotating and rotating azimuthons in the physical system of two-species BECs with a negative scattering length in a quasi-2D parabolic trap.

References:
Water transport in groups of nonlinear wake waves from high-speed vessels

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Abstract:

Tallinn Bay is one of the few places in the world where high-speed ferries operate at or close to service speeds close to the shoreline, with up to 50 departures or arrivals per day. The faster vessels enter the transcritical regime (depth Froude number $\sim 0.9$) in some places.

We report results of recent studies (2008–2009) into the properties of such wakes based on high-resolution (5 Hz, $\pm 1$ mm) water surface profiling using an echosounder in 2.5-3 m water depth, $\sim 100$ m offshore, $\sim 2700$ m from the sailing line. Their role in the wave energy budget and the impact on the coastal environment in terms of wave energy and power, properties of the largest waves, and potential ship-wave-induced coastal erosion are discussed.

During calm conditions, vessel generated non-broken waves of up to 1.5 m, with periods of 10–13 seconds were measured. The typical daily highest ship wave is approximately 1.2-1.3 m. Such waves add significantly to the total wave energy experienced on certain sections of the shoreline. Most of the largest waves demonstrated significant asymmetry. Vessel generated waves also have a significant effect on the morphology and sediment budget of the shoreline not only because of their large periods, but also because of their different direction of propagation compared with predominant wind waves.

We also report a new mechanism producing onshore transport of substantial amounts of water remote from the fairway in wake waves generated by high-speed vessels.

Water is transported by precursor solitons and by the largest vessel waves that normally produce water level set-up. The major mechanism of water transport, however, is connected with an elevation event that arrives in remote areas well after the precursors. It is able to carry several times as much water as the solitons and the other wave disturbances put together. Its characteristic position just before the highest wave group suggests that it may be a specific forced disturbance created by the ship motion. The backflow of this water potentially contributes to fast removal of sediment from non-equilibrium beaches by forming strong offshore-directed flow during the latter phase of the wake-wave event.
Applicability of weak turbulence theory to capillary wave

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Abstract:
In this talk, new experimental results in parametrically driven capillary waves will be reported. We present experimental tests of the weak turbulence theory (WTT) of capillary waves [1] which include tests of the main assumptions of the WTT, scaling of the frequency spectrum of the surface elevation, the dependence of the spectral power density on the energy flux (forcing), and calculation of the energy transfer due to three-wave interactions.

The experimental setup is similar to that described in Ref.[2]. Waves are excited parametrically in a vertically shaken container. A circular container of the inner diameter of 14 cm filled with distilled water to a height of 17.5 mm is mounted on the top plate of the 4kN electrodynamic shaker (Brüel & Kjær Model TV 5550/LS 4KN). The container is shaken at the frequency of $f_0 = 60$ Hz which parametrically excites waves at the frequency of the first subharmonic $f_1 = 30$ Hz and many of its harmonics of smaller amplitudes. The forcing is varied in the acceleration range of $a = (0.5 - 3)g$. The surface elevation of the fluid is measured using the light diffusion technique and fast imaging of the fluid surface [3].

The frequency spectrum of the surface elevation agrees with the power law given by the WTT with the accuracy better than 5%. However, the integrated spectral power changes linearly with forcing, which contradicts the predicted $P_f \sim P^{1/2}$ scaling of the WTT. The spectral energy transfer analysis shows no nonlinear energy transfer in the generation of continuous spectrum, which contradicts to predictions of the WTT. The reason WTT is not applicable here may be the high dissipation in the capillary wave range. Energy input into the system due to the parametric excitation is distributed in the spectrum through the generation of higher harmonics. With the increasing energy input into the harmonics, their spectral width broaden, dissipating more energy locally. At higher accelerations, droplets are formed which may be the alternative energy dissipation mechanism. The continuous spectrum is generated as a result of the nonlinear broadening of the harmonics, possibly due to the interactions between quasisolitons.

References:
Nonlinear envelope equation for broadband optical pulses in quadratic media

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Abstract:

We outline the derivation of a nonlinear envelope equation (NEE) to describe the propagation of broadband optical pulses in second order nonlinear materials. Our approach goes beyond the usual coupled wave description of $\chi^{(2)}$ phenomena and provides an accurate modelling of the evolution of broadband pulses also when the separation into different coupled frequency bands is not possible or not profitable.

The analysis of optical pulse propagation typically involves the definition of a complex envelope “slowly” varying with respect to the oscillation of a carrier frequency [1]. Different authors showed how to extend the validity of the envelope equation to pulse duration down to the single optical oscillation cycle [1] and to the generation of high order harmonics [2]. When second order nonlinearities are considered, the usual approach is to write coupled equations for the separated frequency bands relevant for the process. However if ultra-broadband $\chi^{(2)}$ phenomena take place, the different frequency bands might merge, generating a single broad spectrum, as observed in recent experiments [3, 4] and in these cases the coupled NEE description fails due to the overlapping between different frequency bands.

We derive here a single wave envelope equation to describe ultra-broadband $\chi^{(2)}$ interactions. To date, such a model is not available and the only way to numerically describe phenomena as those reported in [3, 4] is to solve directly Maxwell equations in time domain, with an immense computational burden. Our equation can be solved with a modest computational effort and can be easily generalized to include other kind of nonlinearities such as Kerr or Raman.

References:
Elliptically polarized few-optical-cycle solitons: structures and its dynamics

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Abstract:

The progress in the last decade in laser science has established a new field of extreme nonlinear optics, which involves very short laser pulses comprising only a few optical cycles (see, e.g., [1]). This actually raises the question of whether the concept of optical solitons can be extended to this new regime. Indeed, some important results have recently been obtained by employing a unidirectional approach, which is based on the slowly evolving wave field approximation (SEWA). Within this approach a few-optical-cycle solitons with linear [2] and circular [3] polarization are found and it is shown that they play an important role in the pulse propagation dynamics. Moreover, a circularly polarized soliton solution within the framework of an exact full wave equation is also found indicating that the soliton concept can be extended to higher intensities and shorter durations where the SEWA is not applicable [4]. In this report, we generalize the few-cycle soliton concept to arbitrary polarization states, in particular we show that these wave solitons cover the range from the fundamental Schrodinger solitons, which occur for long pulses involving many field oscillations, to extremely short pulses, which contain only one optical period. We prove numerically that they are stable and play a fundamental role in the pulse propagation dynamics. We also show that the concept of the high-order solitons can be effectively applied to the few-cycle regime and used for efficient pulse compression down to the single cycle duration. Dynamical properties of elliptically polarized few-cycle solitons will also be discussed, where particular attention to the properties of pair collisions of circularly polarized solitons rotating in opposite directions will be given.

References:
Homoclinic snaking in a semiconductor based optical system

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Abstract:

We present experimental results on the formation and control of single and cluster states of Cavity Solitons (CSs) in a vertical cavity semiconductor optical amplifier. CSs are self-localized states appearing in extended nonlinear dissipative systems. In optics, they have been found in several systems and in particular in semiconductor microcavities [1,2] where their potential use as pixels for all-optical processing of information has raised a great interest. They generally appear as bright spots sitting on a dark background and are spatially controllable. When cavity solitons are far away from each other, they are independent objects while at short distances they can form bound-states. Understanding and control of these cluster states are of crucial importance for applications, while it sheds some light on the relation between localized states and patterns on a more fundamental viewpoint. Our experimental system is composed of a Vertical Cavity Semiconductor Optical Amplifier [3]. Experiments are carried out in quasi-1D and 2D configurations. As a parameter is varied (the pump intensity), a bifurcation sequence (homoclinic snaking curve) is recorded. It is in very good qualitative agreement with what is expected from theoretical calculations [4]. In 2D, the situation is slightly more complex given the additional degrees of freedom in the system. We nevertheless evidence multistability between multi-peaked structures. However, in our system, there is not coexistence of all the different localized states due to a tilt in the bifurcation sequence. We show in particular the possibility to excite only single-peaked CSs in certain parameter ranges and this proves very important for applications: it means that independently of the local excitation power needed to switch-on one CS, only single peaked CSs (corresponding to a unique bit of information) can form.

References:
Nonlinear Waves in Honeycomb (graphene-like) Photonic Lattices

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Abstract:

We study the dynamics of waves in honeycomb lattices. Wave dynamics in honeycomb lattices exhibits unique phenomena that cannot be observed in any other periodic system, such as conical diffraction [1] and Klein tunneling. The origin of these intriguing phenomena is the conical intersection between the two bands and the presence of two atoms in each unit cell. These two properties make it possible to describe the dynamics of the Bloch modes by the massless Dirac equation - the same equation describing neutrinos that are massless spin-half particles. It is very well known that when particles (or a wave-packet) incident upon an infinite potential step of height $V_0$ with energy lower than the step are always reflected. However, Dirac particles (relativistic fermions) have non-zero transmission probability [2]. This remarkable phenomenon is named Klein tunneling, first proposed in 1929. Even more surprising is the scattering of quasi-particles in graphene/carbon nanotubes that behave as massless fermions. The later do not exhibit ordinary Klein tunneling but instead they exhibit unit transmission probability [3, 4].

Here, we study scattering of wave packets from potential steps in deformed honeycomb photonic lattices, and find that below a critical deformation - in which a gap in the spectrum is formed - the wave packet is completely transmitted, i.e., an optical beam exhibits unit transmission [5]. On the other hand, beyond the critical deformation we find total reflection for a wave packet incident upon a step in the deformation direction [5]. Hence, we witness a very sharp transition from unit transmission to total reflection, giving an indication for a possible quantum phase transition.

This remarkable phenomenon occurring only in honeycomb lattices is completely linear. However, it is most interesting to also study the nonlinear dynamics of waves in honeycomb lattices. We study the nonlinear propagation of a circular wave-packet from the Dirac cone, that under linear conditions evolves into two rings with zero intensity in the middle, i.e., conical diffraction [1]. Surprisingly, we find that the same circular wave-packet evolves into “triangular rings” (triangles with slightly curves lines). By projecting the output beam onto the Bloch modes of the system, we find that the nonlinearity is responsible for energy transfer between different Bloch modes, and eventually the wave packet is comprised of Bloch mode that do not reside inside the Dirac cone anymore. Hence, the nonlinearity breaks the Dirac dynamics in honeycomb lattices, giving rise to completely new phenomena.

References:
5. O. Bahat-Treidel et al., accepted to PRL (2010).
Quasi-Linear Evolution and Saturation of the Modulational Instability of Partially Coherent Optical Waves

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Abstract:

Modulational instability (MI) is a generic feature in nonlinear wave propagation governed by the Nonlinear Schrödinger equation. MI has recently in theoretical as well as experimental works been found to take place also for partially coherent optical waves. The partial coherence has been shown to provide a stabilizing effect that tends to suppress the MI [1]. However as the developing MI grows it will ultimately begin affecting the background wave, a problem which has already been investigated for the coherent case [2].

In this work we extend the previous coherent analysis by considering the development of the MI of a partially coherent wave in a dispersive nonlinear Kerr medium beyond its initial linear stage. The analysis is based on the Wigner formalism of partial coherence. It is found that the self-consistent interaction between the unstable perturbation and the background wave may be described by a quasi-linear diffusion equation for the Wigner distribution, which characterizes the coherence properties of the background. In fact, in this formalism the problem is mathematically similar to the phenomena of Landau damping/growth of electron plasma waves and the concomitant quasi-linear diffusion of the electron velocity distribution [3].

It is found that the quasi-linear evolution of the Wigner distribution tends to counteract the MI by further degrading the coherence of the background wave until the growth rate of the MI is made to vanish. In the case when the MI is originally stabilized by the damping due to the partial coherence, the redistribution may increase the coherence of the background until either the perturbation is completely quenched or the growth rate of the MI is made to vanish.

References:

Wing flipping, restoration and degeneration of deformed Airy beams

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Abstract:

We study linear propagation of deformed Airy beams in free space. Varying the angle between two wings leads to wing flipping and change in acceleration. Restoration and degeneration of deformed Airy beams are also observed.

References:

Electromagnetic wave propagation in nonlinear metamaterials

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Abstract:

We develop a generalized version of the invariant imbedding theory of electromagnetic wave propagation in various kinds of stratified nonlinear optical media. The main idea of the method is to transform the boundary value problem of the original wave equation into an equivalent initial value problem of coupled ordinary differential equations. This allows an exact and very efficient numerical calculation of all wave propagation characteristics. We demonstrate the advantages of our method by applying it to several interesting problems in optics. In the first case, we apply the method to the propagation of electromagnetic waves in nonlinear metamaterials. We solve the electromagnetic wave equations in arbitrarily inhomogeneous stratified media where both the dielectric permittivity and magnetic permeability depend on the strengths of the electric and magnetic fields. We apply our method to a uniform nonlinear slab and find that in the presence of strong external radiation, an initially uniform medium of positive refractive index can spontaneously change into a highly inhomogeneous medium where regions of positive or negative refractive index as well as metallic regions appear. We also study the influence of nonlinearity on the lateral shift associated with surface plasmon excitations in metal-dielectric multilayer systems and on the mode conversion phenomena in inhomogeneous plasmas.

References:
Nonreciprocal frequency doubling of electromagnetic waves through double resonance and Bragg reflection in photonic crystals

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Abstract:

A computational study of the uni-directional second-harmonic generation in a one-dimensional dual photonic crystal structure made of GaAs, AlAs and SiO\textsubscript{2} with quadratic optical nonlinearity and material dispersion is presented. The computational approach uses a shooting method to solve nonlinear wave equations for coupled fundamental and second-harmonic fields and the invariant imbedding method to obtain the linear transmittance and group index spectra. The dual structure consists of two substructures, the left structure creating a strongly enhanced second-harmonic signal and the right structure blocking the fundamental frequency field by Bragg reflection while permitting the passage of the second-harmonic field. The left structure is built with an elementary cell consisting of four sublayers whose thicknesses are systematically varied. Doubly-resonant second harmonic generation with very high conversion efficiency is achieved for light propagating from left to right by choosing the geometrical parameters of the elementary cell optimally and controlling the band structure. A new mechanism to enhance second-harmonic generation by controlling the energy flow between the fundamental frequency and second-harmonic fields has also been found.

References:
Cavity solitons and dynamical states in a laser with saturable absorber

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Abstract:

Lasers with saturable absorber are often considered as model systems for the study of many different nonlinear phenomena. Bistable and self-pulsing (Q-switching) operation can be encountered depending on the system parameter values. Self-localized states have also been predicted [1] in this kind of system and later on observed both in semiconductor laser systems in an extended-cavity configuration [2] and in a monolithic microcavity [3]. We present recent experimental results on the control and dynamics of cavity solitons in a monolithic, vertical cavity surface emitting laser with a saturable absorber section (cf. Fig.2). Laser cavity solitons appear as self-localized microlasers [4] on top of the laser-off state. They form a zero-parameter family of solutions whose size is fixed by the system parameters and appear in single peaked or cluster states. They can be controlled (created or destroyed) by an external beam. On one hand, we show the fast and independent manipulation of two laser cavity solitons and demonstrate a flip-flop operation with a single control-beam. On the other hand, we evidence the existence of a pulsing localized structure and demonstrate the control of a pulsing multispot structure that can be switched-on and off. These results are promising in view of the obtainment of a pulsed and monolithic cavity soliton laser.

Figure 2: Three dimensional surface plot of the surface image of the cavity soliton laser showing two self-localized microlasers.

References:
Dissipative solitons in passive mode-locked fiber lasers with nonlinear polarization rotation technique

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Abstract:

The passive mode-locked fiber lasers are of great interest for a study of diversified features of a soliton dynamics. Dispersion parameters and a form of intensity-dependent nonlinear losses in the fiber lasers with nonlinear polarization rotation technique can be changed in a very large range that provides a distinct manifestation of varied soliton properties including a quantization of an intracavity radiation into individual identical solitons, multi-stability and multi-hysteresis related with set of pulses in a laser cavity, multi-stable steady-states of single soliton due to its different pedestal, a coexistence of steady-state solitons and cw-component of radiation, a quantization of binding-energy for a pair of interacting structural solitons (the binding-energy can be large and comparable with an energy of an individual soliton) and so on \cite{1-3}. Due to strong interaction and great binding energy, intracavity solitons can form structures analogous to different states of the matter \cite{1}. In particular, in real experiment we have identified a gas, a supersonic gas flow, a liquid, a polycrystal and a crystal of solitons. In certain cases a train of equidistant pulses fills completely a laser resonator and harmonic passive mode-locking is realized. In numerical experiment we have demonstrated the realization of highly-stable information soliton sequences with any required distribution along the soliton train of various types of bonds between neighboring pulses \cite{3}.

Existing theories describing above mentioned peculiarities of a soliton dynamics are based on model with isotropic laser fiber. In this paper we develop a theory which takes into account the birefringence of the fiber. In the frame of this model, for some laser parameters, a critical dependence of nonlinear losses on intensity of radiation can be realized that results in a change of the nature of soliton interaction and of properties of lasing regimes. Soliton interaction and lasing regimes realizing under such conditions are analyzed.

References:

Interface vortex solitons in quadratic photonic lattices

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Abstract:

In this talk, we will address the properties of vortex solitons supported by an interface between two distinct optical lattices imprinted in nonlinear quadratic media. We analyze the impact of guiding parameters of lattices and phase mismatching conditions on the existence and stability of two-color interface vortex solitons.

Surface modes appear as a special type of waves localized near an interface separating two different media. In optics, linear electromagnetic surface waves are known to exist at an interface separating homogeneous and periodic media [1]. Recently, the interest in the study of electromagnetic surface waves has been renewed, and it was shown that periodic waveguide arrays can support discrete surface solitons. It is interesting to note that a novel type of surface modes with screw phase dislocation [2] can be formed at the interface between dissimilar periodic media [3]. Surface solitons have been normally considered in cubic or saturable nonlinear media, however, recently it is shown that surface solitons can be formed in nonlinear quadratic media [4, 5].

In this work, for the first time to our knowledge, we consider vortex solitons supported by an interface between two distinct optical lattices imprinted in nonlinear quadratic media. It is shown that quadratic lattices support rich families of surface states with a phase dislocation, including both on-site and off-site vortex solitons. The salient point is that profiles of interface vortex solitons are highly asymmetric and non-canonical, which are normally the feature of solitons supported at the interface of hetero-photonic waveguides [5]. We analyze the impact of guiding parameters of lattices on the existence and stability of interface vortex solitons in different phase mismatching conditions, and show that there exist lower and upper cutoff values of the propagation constant for the formation of vortex solitons. There also exists a narrow instability region near the lower cutoff value of the propagation constant, while interface vortex solitons are completely stable in the existence domain close to the upper cutoff of the propagation constant.

References:
Conical diffraction in honeycomb lattices

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Abstract:

Conical diffraction in honeycomb lattices is analyzed in this talk. Conical diffraction is an optical phenomenon that a narrow beam entering an inhomogeneous crystal spreads into a hollow cone within the crystal. Our analysis focuses on the phenomenon arose in nonlinear Schrödinger equations with honeycomb lattice potentials which has been recently observed experimentally [1]. A key property associated with this phenomenon is the existence of the Dirac points in the linear dispersion relation of the honeycomb potential. In the tight-binding approximation, the dispersion relation is obtained analytically and we also demonstrate that the input wave envelope propagates within the crystal in a manner governed by a nonlinear Dirac system. Numerical simulations show that the Dirac system and the lattice NLS equation have the same conical diffraction properties. Similar conical diffraction occurs in both the linear and nonlinear regimes. The nonlinear Dirac system reveals the underlying mechanism for the existence of conical diffraction in honeycomb lattices [2].

References:
Extreme events and nonlinear rogue waves in optics

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Abstract:

Extreme value phenomena have dramatic impact in many fields in the physical and social sciences, and are thus the subject of wide scientific importance. The systematic study of extreme value phenomena, however, has been significantly hampered in two ways: (i) the intrinsic scarcity of the events under study and (ii) the fact that such events are often of most interest when they appear in environments (e.g. the ocean) where measurements are difficult. These problems have led to an absence of extensive data sets generated under controlled conditions, resulting in difficulties in studying their generation mechanisms in a clear and quantitative manner.

In this context, however, recent research from the domain of optical physics published in Nature in late 2007 has attracted significant interest [1]. In particular, this research has shown that a convenient laboratory-based system based on nonlinear wave propagation in optical fiber can generate extreme value events with similar statistical properties to the large amplitude hydrodynamic rogue waves observed on the surface of the ocean. These results have motivated a tremendous international research effort in studying how an optical system can be used to directly and conveniently study extreme-value processes. The aim of this paper is to present an overview of our own current research in this area, including recent progress in describing the physics of optical rogue wave formation in terms of nonlinear modulation instability and breather propagation [2-4]. Some aspects of this work have been confirmed by experiments in nonlinear fiber propagation that we will describe in detail. We also consider the particular links between the emergence of a single large amplitude pulse and the propagation of a localised soliton pulse amidst a turbulent low amplitude background [5].

References:
Reversible optical nonreciprocity in periodic structures with liquid crystals

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Abstract:

We demonstrate how to achieve reversible nonreciprocal optical response in a periodic photonic structure with a pair of defects, one of them being a nonlinear liquid crystal defect layer. We show that nonreciprocal effects can be reversed by changing the wavelength as a consequence of the light localization at the defect mode dependent inside the structure.

Optical nonreciprocity is usually associated with breaking of time-reversal symmetry [1]. A typical optical system with a nonreciprocal response employs the magneto-optical effect of gyrotropic materials. Nonreciprocity in nonlinear structures is employed in all-optical diodes and directional couplers. In all such systems the nonreciprocal response is characterized by the light propagating predominantly in one fixed direction, which cannot be changed afterwards.

In this study we suggest a novel approach for creating nonreciprocal tunable optical structures based on nematic liquid crystals (NLC) placed inside a periodic photonic structure. By analysing properties of one of such structures we show that changing the wavelength of the input light can reverse its nonreciprocal response. In general, the scattering setup implies that the field distribution inside the photonic structure is asymmetric. Above a certain threshold of the field intensity the NLC molecules start to reorient, this leads to a change of the effective refractive index [2]. This phenomenon is known as the optical Fréederickz transition (OFT). By placing a NLC defect layer asymmetrically inside the periodic structure, we may change the threshold for the light propagating from two different directions due to an asymmetric field distribution. By adding the second defect into the structure, we can reverse the nonreciprocal response by a proper choice of the wavelength. This makes the whole structure colour-sensitive with an unique possibility to invert the nonreciprocity of the response.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure.png}
\caption{(a) Schematic of the proposed nonreciprocal tunable device. (b) Calculated transmission vs. wavelength for different wavelengths. (c) Transmission vs. wavelength for different wavelengths. (d) Graph showing the change in transmission with different wavelengths.}
\end{figure}
Fig.1 (a) Schematic view of the 1D photonic crystal with two defect layers, where one of them is nematic liquid crystal; (b) optical Fréedericksz threshold in opposite directions; (c) and (d) demonstrates reversible optical diode operation for different wavelengths.

References:
Properties of discrete quadratic multiband solitons

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Abstract: The properties of discrete quadratic solitons with coupled fundamental and second harmonic waves are studied and transitions of soliton topology were found theoretically and experimentally.

Discrete quadratic solitons were shown to have complex field profiles for distinct sets of parameters [1], where the fields in the individual waveguides can either be in phase (unstaggered) or out of phase (staggered). In all experiments up to now, only quadratic solitons with unstaggered SH could be observed [2] since the coupling of the second harmonic (SH) part of the waves was always negligible.

![Diagram](image_url)

Figure 3: Topology of the SH wave of the soliton with equal coupling of FW and SH.

We will present results about the topology of discrete quadratic solitons with coupling in both the fundamental wave (FW) and the SH component. We studied the structure of these multiband solitons in a wide range of parameters and found that for staggered FW fields the SH field can either be staggered or unstaggered. Which topology is realized depends on the phase mismatch between FW and SH wave and the propagation constant of the soliton. At certain propagation constants a phase transition of the SH from the unstaggered to the staggered structure takes place.

Furthermore we will show experimental results of the excitation of these multiband solitons in lithium niobate waveguide arrays and the observation of SH phase transitions.

References:
Random discontinuous perturbations of NLS

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Abstract:

We consider the nonlinear Schrödinger equation \[1\] driven by a certain generalized "Dirac random comb" of the form

\[iu_t + u_{xx} + 2|u|^2u = i(-\Gamma u + \sum_n (e^{-\gamma_n} - 1)\delta(t - t_n)u(t_n^-,x))\] \hspace{1cm} (11)

where \(\Gamma \in \mathbb{R}^+\) is the normalized damping coefficient and \(t_n > t_{n-1}\) and \(\gamma_n > 0\) (jump positions and magnitudes) are certain sequences of random numbers. Such a perturbation incorporates the possibility of sudden changes in the field stemming from inhomogeneities in the media as might occur for an optical pulse propagating in a nonlinear optical fiber [2,3] which has impurities at certain random locations \(t_n\) at which the amplitude decreases from the "input" value \(u(t_n^-,x)\) to an "output" value \(e^{-\gamma_n}u(t_n^-,x)\).

If \(\Gamma = 0\) we show that the resulting equation can be piecewise related to the unperturbed NLS equation and show how to solve the initial value problem in a global way. The construction involves the classical Poisson jump-process [4]. Even though the solution itself has jump discontinuities in time we show that a complete set of global conserved quantities exists for all time.

In the general case \(\Gamma \neq 0\) the resulting equation is no longer integrable by IST ([5,1]). Nevertheless we determine the random evolution of several physically relevant quantities under the natural assumptions (i) \(\delta_n \equiv t_n - t_{n-1} > 0\) is a sequence of independent, identically distributed random variables (iidrv), (ii) \(\gamma_n\) is a sequence of iidrv, (iii) \(\delta_n\) is independent of \(\gamma_m\) and (iv) given that there are a fixed number \(n\) of jumps \(t_1 < \ldots t_n\) on \([0,t]\) then they are uniformly distributed on the interval. We show that their average value decreases exponentially in time due to the "impurities". We next formulate a linear integral equation that the mean half-life of the field Energy satisfies and, by means of a Laplace transform, find the solution.

References:
Localized oscillator in a cavity: an adapted spectral approach

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Abstract:

We consider a very general model in a cavity where a wave equation is coupled to a localized oscillator. This can arise in many contexts like an array of Josephson junctions in superconductivity or an electromagnetic wave coupled to a ferroelectric film. The model consists in the wave equation coupled to a Duffing oscillator for the film which we assume infinitely thin. We derive the normal modes of the system and show that they are orthogonal with a special inner product which we introduce. These modes are well suited to describe the system even for a film of finite thickness. By acting on the film we demonstrate switching from one cavity mode to another. Since the system is linear, little energy is needed for this conversion. Moreover the amplitude equations describe very well this complex system under different perturbations (damping, forcing and nonlinearity) with very few modes. These results are very general and can be applied to different situations like for an atom in a cavity or a Josephson junction in a capacitor and this could be very useful for many nano-physics applications.

References:
1. J.-G. Caputo, E. V. Kazantseva, L. Loukitch and A.I. Maimistov
Modulational instability of the nonlinear Schrödinger equation with viscosity effect

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Abstract:

The modified Korteweg-de Vries equation with viscosity effect has been derived by Miles (1976). See also a similar earlier work by Ott and Sudan (1970). In this paper, the corresponding wave packet evolution equation is derived using the multiple scale method (Kevorkian, 1961; Nayfeh, 1973). This corresponding evolution equation is the nonlinear Schrödinger equation with viscosity effect, which has not really been explored extensively. The modulational instability of this equation is investigated in this paper and an interesting comparison with several evolution equations will also be presented (Benjamin and Feir, 1967).

References:
Gap discrete breathers in two- and three-dimensional diatomic crystals with Morse interactions

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In this talk, gap discrete breathers (DBs)[1-4] in two- and three-dimensional diatomic crystals with Morse interatomic interactions are analyzed. Three-dimensional lattices has the $L1_2$ structure with $A_3B$ stoichiometry while in the two-dimensional case a (111) plane of this structure is considered preserving the $A_3B$ stoichiometry. Parameters of the potential reproduce main properties of Ni$_3$Al intermetallide. In both cases we study the effect of the atomic weight ratio ($M_A/M_B$) on the phonon spectra and on the conditions of existence and properties of the gap DBs. It was found that the gap DBs can be easily excited in the presence of wide gap in the phonon spectrum, which appears for sufficiently large mass ratio ($M_A/M_B > 3.5$ in our study). We have also found that the DB frequency decreases with increase in its amplitude so that the Morse potentials result in soft anharmonicity, which suggests that it is unlikely to find DBs with the frequencies above the phonon spectrum. Thus, the DBs in Morse crystals can be expected only in the lattices with a gap in the phonon spectrum and this may happen for the crystals with a complex structure.

Then we study numerically the dynamics of a modulationally unstable Brillouin-zone-boundary phonon mode and demonstrate that the so-called anti-Fermi-Pasta-Ulam mechanism of energy localization [5] gives rise to formation of the gap DBs with the lifetime much greater than the period of their oscillations. The smaller the amplitude of the phonon mode, the longer is the lifetime of DBs. Slow radiation of energy by the DBs results in the subsequent thermal equilibrium of the system.

References:
Interplay between disorder and nonlinearity in the propagation of waves in one-dimensional nonlinear random media: Fixed input case

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Abstract:

The tight-binding Anderson model including the nonlinear effect is used to study the interplay between diagonal disorder and nonlinearity in the propagation of waves in one-dimensional random media for a fixed input problem. The system is described by the time-independent discrete nonlinear Schrödinger equation. We solve this equation in a numerically exact manner for a given random potential and obtain physical quantities by averaging over a large number of disorder configurations. We find substantial differences between our results and previous results obtained for the fixed output case. The Anderson localization is found to be enhanced by both focusing and defocusing nonlinearities and contrary to the fixed output case, the power law decay of the average transmittance is not observed. We also show that the dependence of the localization length on disorder changes as the energy is changed from the band edge value toward the band center value.
Effects of actuator impact on the nonlinear dynamics of a valveless pumping system

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Abstract:

Valveless pumping assists in fluid transport in various biomedical and engineering systems. In this talk, we shall focus on one factor that has often been overlooked in previous studies of valveless pumping, namely the impact that a compression actuator exerts upon the pliant part of the system when they collide. In particular, a fluid-filled closed-loop system is considered, which consists of two distensible reservoirs connected by two rigid tubes, with one of the reservoirs compressed by an actuator at a prescribed frequency. A lumped-parameter model with constant coefficients accounting for mass and momentum balance in the system is constructed. Based upon such a model, a mean flow in the fluid loop can only be produced by system asymmetry and the nonlinear effects associated with actuator impact. Through asymptotic and numerical solutions of the model, a systematic parameter study is carried out, thereby revealing the rich and complex system dynamics that strongly depends upon the driving frequency of the actuator and other geometrical and material properties of the system. The driving-frequency dependence of the mean flowrate in the fluid loop and that of the mean reservoir pressures also are examined for a number of representative cases.

References:
Adaptive artificial boundary conditions for two-dimensional nonlinear Klein Gordon equation on unbounded domain

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Abstract: The nonlinear Klein-Gordon equation arises in various problems in science and engineering. In this paper, the numerical solution of the two-dimensional nonlinear Klein-Gordon equation, especially, the sine-Gordon equation on an unbounded domain is studied. Adaptive artificial boundary conditions are obtained by the operator splitting method and the windowed Fourier transform, then the original problem is reduced to an initial boundary value problem on a bounded computational domain, which can be solved by the finite difference method. Several numerical examples are provided to show the advantages and effectiveness of the given method, and some interesting collision behaviors are also observed.

References:
Phase transition and critical depinning point in two dimensional Frenkel-Kontorova(FK) model

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Abstract:

Based on a 2D Frenkel-Kontorova(FK) model with special square symmetry, the locked-to-sliding phase transition is studied. Two critical depinning points are defined which depend on the direction and the magnitude of external driving force, the adhesive force from the substrate, the interaction strength between atoms in the upper layer and especially the misfit angle $\theta$ between two layers. For some certain misfit angle, the friction force is very slow which can quantitatively explain the results recently found in experiments(M. Dienwiehel, et al. Phys. Rev. Lett. 92, 126101 (2004)). Generally, the phase diagram for this system can be divided into three regions according to the magnitude of the external driving force. The dynamical behaviors of the system and atoms of system are completely different in these three different regions. For the case of misfit angle $\theta = 0^\circ$, the analytical expressions of two depinning points are obtained and they are in agreement with numerical ones. For the case of $\theta \neq 0^\circ$, it is numerically found that two depinning points are in fractal structure.

References:
5. O. M. Braun, A. R. Bishop, and J. Röder, Phys. Rev. Lett. 79, 3692 (1997);
Collisions of different discrete breathers

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Abstract:

Discrete breathers are localized vibrations in nonlinear discrete lattices. By perturbing
them slightly in such a way that it breaks the phase symmetry the breathers become
mobile. They radiate energy through phonons and eventually disappear. Nevertheless,
they have long lives and conserve their shape and most of their energy during a long time.
In Refs. [1,2] we have studied for systems with a Morse on-site potential two identical
moving breather which collide either with the same or opposite phase, identical or different
velocity. In Ref. [3] we have extended the study to systems with other on-site potentials
as the sine-Gordon and $\phi^4$.

In the present work the research is also focused on systems with Morse on-site potential
but the collisions considered are between a moving breather and a stationary one and
between two moving breathers travelling in the same direction but with different velocities,
so that the faster reaches the slower. This scenarios are more appropriate for a real
system as for example a DNA chain, where breathers can be a means for transporting
energy and information, have been suggested as initiators of the transcription bubble and
where breathing bubbles have been observed. When a moving breather interacts with a
stationary one, the outcome may be reflection, generation of two breathers moving either
in the same or in opposite directions. When a fast moving breather reaches a slower
one the fast one overtakes the other with relatively minor changes, while the slower one
becomes pinned to the lattice, or jumps back and then continues its path or, finally, starts
moving in the opposite directions.

References:
   (2008).
   (2009).
Simple waves and nonlinear stability of two-layer flows

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Abstract:

Nonlinear stability of two-layer flows under the shallow-water assumption and with the Boussinesq approximation has been studied in [2] and [4]. These two papers also provide necessary and sufficient conditions, respectively, for nonlinear stability of quasilinear systems of mixed type in general. In the current work, we examine nonlinear stability of two-layer flows under the shallow-water assumption but without the Boussinesq approximation. Furthermore, we use the concept of simple waves to understand nonlinear stability and to obtain results for hyperbolic systems analogous to the maximum principles for elliptic and parabolic systems. All the results are illustrated with numerical computations.

References:

Soliton reflection in defocusing NLS with linearizable boundary conditions

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Abstract:

Boundary value problems (BVPs) for integrable nonlinear evolution equations have received renewed interest over the past decade. In particular, a general methodology was proposed in [5], based on an extension of the inverse scattering transform. In all of the approaches to the BVP, however, the problem only truly becomes linear for certain choices of boundary conditions (BCs), which are therefore called linearizable. For the nonlinear Schrödinger (NLS) equation \( iq_t + q_{xx} - 2\nu|q|^2q = 0 \) the linearizable BCs for the BVP on the half line \( x > 0 \) are \( q_x(0,t) - \alpha q(0,t) = 0 \), with \( \alpha \) an arbitrary real constant.

For the focusing NLS (\( \nu = -1 \)) with linearizable BCs, it was shown in [3] that discrete eigenvalues appear in quartets (as opposed to pairs in the initial value problem), and explicit relations exist for the corresponding norming constants. Here we discuss BVPs for the defocusing NLS (\( \nu = 1 \)) with non-zero BCs at infinity and linearizable BCs at \( x = 0 \). We show that, in the BVP, discrete eigenvalues appear in symmetric pairs in the interval \(( -q_0, q_0 \) ), and a corresponding symmetry exists for the norming constant. As in the focusing case, the apparent reflection of each soliton at the boundary of the spatial domain (see figures) is then due to the presence of a “mirror” soliton, with equal amplitude and opposite velocity, located beyond the boundary.

Figure 4: Soliton reflection with Dirichlet BC (left) and Neumann BC (right).

References:

Shock wave diffraction calculations using very high order difference schemes

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Abstract:

Shock wave diffraction over convex walls have previously been investigated both experimentally and numerically [1, 2]. In this paper, we use numerical simulations to investigate the flow over a 90 degree sharp corner and multi-facet geometries.

The main focus is a two-facet geometry and flow with Reynolds number up to $10^6$. We analyze how very weak features such as shear layers and vorticies can coexist together with strong features such as shocks.

To capture all these features we use a very high order difference schemes (4th, 6th, 8th order) [3, 4] together with a locally added amount of artificial dissipation [5] in the vicinity of shocks. The accuracy of the results is verified by comparison with experimental results.

Our technique with weak no-slip boundary conditions [3] provides us with a way to decide when the computation is resolved. For a coarse mesh we have a slip velocity at the wall, as the size of the mesh decreases, the slip velocity goes to zero. For a sufficiently fine mesh, the computation is well resolved.

With the maximum amount of computational resources available, we construct the finest mesh that we can manage in a reasonable time. Next we run on the highest Reynolds number that can be resolved (such that we have a vanishing no-slip velocity). This procedure optimize our computational resources for a given flow case.

References:

Casorati determinant solutions to the non-autonomous cross-ratio equation

Michael Hay
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Abstract:
We explain how to use known solutions to bilinear equations to solve integrable non-linear partial difference equations. We begin with non-autonomous Casorati determinant, N-soliton solutions to the discrete two-dimensional Toda lattice equation, which is a well-known, bilinear, integrable equation. These solutions are adapted to construct explicit solutions to the discrete Scharzian KP equation and the non-autonomous cross-ratio equation.
A three-dimensional three-wave resonant interaction equation with self-consistent sources

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Abstract:

In this paper, a three-dimensional three-wave resonant interaction equation with self-consistent sources (3D3WRI ESCS) are constructed via the source generation procedure. The corresponding Gram-type determinant solutions are then derived. As a simple case, the (1, 1, 1) lump solution is subsequently examined. A new feature of this 3D3WRI ESCS is that we allow \((a_1X_1 + a_2X_2 + a_3X_3)\)-dependence of the arbitrary constants in the determinant solution for the 3D3WRI equation while applying the source generation procedure. Finally, we show how this 3D3WRI ESCS is transformed into other cases of 3D3WRI ESCS.
Higher order corrections to the Miles theory of shallow water waves

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Abstract:

We reconsider the Miles theory of solitary wave interactions in shallow water, and confirm that the leading order of the theory is indeed equivalent to the KP theory. We then consider the higher order corrections to the Miles theory. There were several numerical simulations, in which all the authors concluded that the results indicated disagreements with the Miles theory. Contrary to those previous numerical studies, we found that their results are in good agreements with the theory when the higher order corrections are included.
Symmetry group and exact solutions for the 2+1 dimensional AKNS equation

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Abstract:
A (2+1) dimensional Ablowitz-Kaup-Newell-Segur (AKNS) system is obtained from the potential Boiti-Leon-Manna-Pempinelli equation by means of an asymptotically exact reduction method based on Fourier expansion and spatiotemporal rescaling. Furthermore, applying the modified direct method to the (2+1) dimensional AKNS system, we get its symmetry and the relationship between the new solution and the old one. Based on the relationship, a new solution can be obtained by using a given solution of the equation.
Defect-mediated snaking: A new growth mechanism for localized structures

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Abstract:

Stationary spatially localized patterns in parametrically driven systems are studied, focusing on the 2 : 1 and 1 : 1 resonance tongues as described by the forced complex Ginzburg-Landau equation. Homoclinic snaking is identified in both cases and the nature of the growth of the localized structures along the snaking branches is described. The structures grow from a central defect that inserts new rolls on either side, while pushing existing rolls outwards. This growth mechanism differs fundamentally from that found in other systems exhibiting homoclinic snaking in which new rolls are added at the fronts that connect the structure to the background homogeneous state.

References:
Knots in a conformal nonlinear sigma model
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Abstract:
Recently, electromagnetic knots have attracted much attention. They are the solutions of Maxwell equations possessing knot structures. They might be important in plasma physics and fluid dynamics. On the other hand, Ferreira succeeded in obtaining the 3 + 1 dimensional exact solutions of a model, which we refer to as the conformal nonlinear σ model (CNLSM), for a complex scalar field. It is expected that the CNLSM has connections to the low energy limit of the Yang-Mills theory and the Skyrme-Faddeev model.

The Lagrangian density of CNLSM is given by
\[ LF = \frac{1}{4} H_{\mu\nu}H^{\mu\nu}, \]
\[ H_{\mu\nu} = \frac{1}{2} n \cdot (\partial \mu n \times \partial \nu n) \]
Here \( n \) denotes a point on \( S^2 \), \( n = (n^1, n^2, n^3) \), \[ \sum a = 1 \] \( n^a n^a = 1 \), which is related to the complex field \( u \) by the stereographic projection \( u = \frac{n^1 + in^2}{1-n^3} \). The field equations are given by
\[ \partial \mu (H^{\mu\nu} \partial \nu u) = 0, \]
\[ \partial \mu (H^{\mu\nu} \partial \nu u^*) = 0. \]

Because of the conformal symmetry of electromagnetism and CNLSM, solutions of both theories cannot be energetically-stable. The solutions of both theories, however, can be topologically-stable in the sense that conserved topological numbers called Hopf indices can be defined for them.

The present authors have recently pointed out that Ferreira’s solution of CNLSM supplies us with a class of exact magnetic knot configurations in some electric charge and current distributions. We have also shown that electromagnetic knot solutions of Maxwell equations can yield solutions of CNLSM other than Ferreira’s solutions.

In this talk, we discuss the properties of the magnetic knots induced by Ferreira’s Hopf soliton solutions of CNLSM. The electric charge and current densities associated with these magnetic knots should satisfy some constraints. Their behavior for some cases of Hopf indices are investigated analytically and numerically.

Acknowledgements This research was partially supported by the National Natural Science Foundation of China (Grant No.10601031) and the Innovation Program of Shanghai Municipal Education Commission (Grant No. 09ZZ183).

References:
Integrable properties of the general coupled nonlinear Schrödinger equations

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Abstract:

In this paper, a general integrable coupled nonlinear Schrödinger system is investigated. In this system, the coefficients of the self-phase modulation, cross-phase modulation, and four-wave mixing terms are more general while still maintaining integrability. The N-soliton solutions in this system are obtained by the Riemann–CHilbert method. The collision dynamics between two solitons is also analyzed. It is shown that this collision exhibits some new phenomena (such as soliton reflection) which have not been seen before in integrable systems. In addition, the recursion operator and conservation laws for this system are also derived.
Exact stable vortex modes in two-dimensional Bose-Einstein condensates and in nonlinear optics

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Tel: 13516859649, email: physicswulei@163.com

Abstract:

We construct exact solutions for solitary vortices in 2D models of Bose-Einstein condensates and spatial-domain propagation in optics, with a spatially modulated nonlinearity of either sign and a harmonic trapping potential. In the context of Bose-Einstein condensates, the BEC dynamics at ultra-low temperatures is accurately described by the Gross-Pitaevskii equation (GPE), the cubic nonlinearity being determined by the $s$-wave scattering length of interatomic collisions, which can be controlled by means of the magnetic [1] or low-loss optical [2] Feshbach-resonance technique, making spatiotemporal management of the local nonlinearity possible through the use of time-dependent and/or non-uniform fields. A counterpart of the GPE, which is a basic model in nonlinear optics, is the nonlinear Schrödinger equation. In the latter case, the modulation of the local nonlinearity can be implemented too—in particular, by means of indiffusion of a dopant resonantly interacting with the light. We found that the number of vortex-soliton modes is determined by the discrete energy spectrum of a related linear Schrödinger equation. The vortex-soliton families in the system with the attractive and repulsive nonlinearity are mutually complementary. Stable vortex-solitons with vorticity $S \geq 2$ and those corresponding to higher-order radial states are reported for the first time, in the case of the attraction and repulsion, respectively.

References:

Eigen-solutions of Biconfluent Heun with respect to a complex weight

Guofu Yu
Department of Mathematics, Shanghai Jiao Tong University, P. R. China

Abstract:

The Heun equation belongs is a canonical second order linear differential equation with four regular singular points on the Riemann sphere. It has one more regular singularity point than the Gauss hypergeometric equation. We will look at one of its confluence cases and to show that there exists eigensolutions with respect to a complex weight. We shall make an effort to explain why these equations are important before going into the more technical issues.
Matter-wave solitons and finite-amplitude Bloch waves in optical lattices with a spatially modulated nonlinearity

Jie-Fang Zhang\textsuperscript{a}, Yi-Shen Li\textsuperscript{b}, Jianping Meng\textsuperscript{a}, Lei Wu\textsuperscript{a} and Boris A. Malomed\textsuperscript{c}

\textsuperscript{a}Institute of Nonlinear Physics, Zhejiang Normal University, Jinhua, Zhejiang 321004, P. R. China
\textsuperscript{b}Department of Mathematics, University of Science and Technology of China, Hefei, Anhui 230026, P. R. China
\textsuperscript{c}Department of Physical Electronics, Faculty of Engineering, Tel Aviv University, Tel Aviv 69978, Israel

Abstract:

We investigate solitons and nonlinear Bloch waves in Bose-Einstein condensates trapped in optical lattices. By introducing specially designed localized profiles of the spatial modulation of the attractive nonlinearity, we construct an infinite number of exact soliton solutions in terms of the Mathieu and elliptic functions, with the chemical potential belonging to the semi-infinite bandgap of the optical-lattice-induced spectrum. Starting from the exact solutions, we employ the relaxation method to construct generic families of soliton solutions in a numerical form. The stability of the solitons is investigated through the computation of the eigenvalues for small perturbations, and also by direct simulations. Finally, we demonstrate a virtually exact (in the numerical sense) composition relation between nonlinear Bloch waves and solitons.

PACS numbers: 03.75.Lm, 05.45.Yv, 42.65.Tg

2. J. Belmonte-Beitia, V. M. Pérez-García, V. Vekslerchik, and V. V. Konotop, PRL100, 164102 (2008).
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B: Science Building
科学馆
(parallel sessions)
C: Students Activity Center
学生活动中心（蒙民伟楼）
(opening ceremony and keynote talks)
D: Jinchunyuan Hotel
近春园