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Abstract

Some Tools from Homogenization and Applications in Electromagnetism

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I will introduce the notions of H-measures and variants, such as semiclassical measures, created by Luc Tartar, Patrick Gerard and other mathematicians. If I have enough time, I'll try to show some applications of these tools in the framework of homogenization in electromagnetic theory.

Abstract

2D Photonic Crystal Defect Cavities: Fabrication and Characterization

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The fabrication and characterization of optical nanocavities in 2D Photonic Crystals (PCs) is presented. Devices based on 2D PCs are promising candidates for integration in optical communication systems. The devices are made by drilling holes through a thin layer of semiconductor in a 2D triangular lattice fashion. The material is an InP/InGaAs/InP double heterostructure from which photoluminescence in the 1.55 micron region can be obtained. The optical cavity is formed by a plugged up hole at the center of the lattice. We experimentally observe the signature of the cavity in the emitted photoluminescence spectrum. Results on the tuning of the resonance wavelength and cavity Q are presented.

¶Presenter

Abstract

Random Lasing and Random Resonators in Disordered Dielectric Film [1]

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A real density of disorder-induced resonators with a high quality factor, $Q \gg 1$, in a film with fluctuating refraction index is calculated theoretically. We demonstrate that for a given $kl > 1$, where k is the light wave vector, and l is the transport mean free path, when on average the light propagation is diffusive, the likelihood for finding a random resonator increases dramatically with increasing the size of the scatterers, or, more precisely, the correlation radius of the disorder. Parameters of most probable resonators as functions of Q and kl are found.

[1]Work performed under the auspices of NSF under grant No. DMR-0202790 and Petroleum Research Fund under grant No. PRF 37890-AC6.

[¶]Presenter

Abstract

Directional Emission from a Microdisk Resonator with a Linear Defect[2]

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A microdisk resonator with a linear defect at some distance away from the circumference is studied theoretically. We demonstrate that the presence of the defect leads to (i) enhancement of the output efficiency, and (ii) directionality of the outgoing light. The dependence of the radiative losses and of the far-field distribution on the position and orientation of the defect are calculated. The angular dependence of the far field is given by a lorentzian with a width that has a sharp minimum for a certain optimal orientation of the defect line. For this orientation the whispering-gallery mode of a circular resonator is scattered by the extended defect in the direction normal to the disk boundary.

[2]Work performed under the auspices of NSF under grant no. DMR-0202790.
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Abstract

Nonlinear Interactions of Wavepackets in a Periodic Media

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We develop a consistent mathematical theory that describes nonlinear interaction of wavepackets in a nonlinear periodic dielectric media for the dimensions one, two and three. The theory is based on the Maxwell equations with quadratic and cubic constitutive relations. Solutions of the Maxwell equations on long time intervals are expanded in convergent series with respect to a small parameter alpha, which measures the contribution of the nonlinearity. After that we investigate in detail the principal term of the expansion in the case where the excitations (and, consecutively, solutions) have a form of wavepackets. The ratio of the amplitude frequency and the carrier frequency of a wavepacket is an important small parameter rho. The principal term describes the nonlinear interaction of a continuum of modes and is written in the form of an oscillatory integral. The phase function of the integral is written in terms of the Floquet-Bloch dispersion relations of the periodic media. We consider the situation when the stationary phase method is applicable, that means that initially the spatial extension of the wavepacket is larger then the period and much smaller then the domain where the medium is periodic. A detailed mathematical analysis shows that the interaction integral expands into sum of terms with different powers of rho and the leading terms correspond to only a few interacting modes. We give a classification of the nonlinear interactions between wavepackets in a media with generic dispersion relations based on the powers. The powers take on only a relatively small number of prescribed values collected in a table, their values depend on a type of degeneracy of phase functions formed by the dispersion relations of the media. The crucial role in selecting the strongest interactions, in particular the second harmonic generation in a quadratic medium, is played by internal symmetries of the phase function.

[¶]Presenter

Abstract

Propagation in Multiscale Media

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Many studies consider media with *microstructure*, which has variations on some *microscale* l, while the *macroproperties*, on some *macroscale* L, are under investigation. It is assumed that $l \ll L$. To study such situations, the *effective medium* approximation is developed. Sometimes the medium has several microscales, all of them being much smaller than the macroscale L. Sometimes the variations on the macroscale are also included, which are taken into account by some procedures, like WKB. What if the medium has variations on all scales from microscale l to macroscale L? This situation occurs in several practical problems. This talk is about such situations, in particular, passive tracer in a random velocity field, wave propagation in a random medium, Schrödinger equation with random potential. To treat such problems we develop the Statistical Near-Identity Transformation. We obtain first Green's function and derive an integral-differential equation for the function N_k (the square of the Fourier coefficient it is a certain trace of second Green's function). Using them, we obtain physical implications.

Abstract

Micromechanics-based Determination of Effective Elastic Properties of Polymer Bonded Explosives

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Polymer bonded explosives (PBXs) are primarily used as propellants for solid rockets. These materials are particulate composites containing high volume fractions ($>$ 90%) of explosive crystals coated by a rubbery binder. The ratio of the Young's modulus of the crystals to that of the binder can be as high as 20,000. Experimental determination of the effective properties of PBXs is hazardous and therefore expensive. On the other hand, accurate numerical simulations can be computationally prohibitive. In this research, an approximate method for determining the effective elastic properties of these composites, called the Recursive Cells Method (RCM), has been developed. The RCM technique is explored and applied to a specific polymer bonded explosive, PBX 9501. The calculated effective properties are compared with those obtained from detailed finite element calculations.

¶ Presenter

Abstract

Superfluid Inhomogeneity and Microwave Absorption in Model High-T$_c$ Superconductors

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We investigate the microwave absorption arising from inhomogeneity in the superfluid density of a model high-T$_c$ superconductor. Such inhomogeneities may arise from a wide variety of sources, including quenched random disorder and static charge density waves such as stripes. We show that both mechanisms will inevitably produce additional absorption at finite frequencies. We present simple model calculations for this extra absorption, and discuss applications to other transport properties in high-T_c materials. Finally, we discuss the connection of these predictions to recent measurements by Corson et al [1] of absorption by the high-temperature superconductor $Bi_2Sr_2CaCu_2O_(8+x)$ in the THz frequency regime.

[¶]Presenter

Abstract

Effective macroscopic response of an almost periodic composite: application to the linear and non-linear properties of a colloidal crystal

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Using the spectral approach, we analyze how the effective properties of a periodic composite are changed by slight deviations from perfect periodicity, with application to a simple cubic lattice of identical spheres. We find that, when the spheres are randomly displaced from their equilibrium positions, the sharp resonances seen in the periodic case are broadened. We use these results to analyze the effective linear and third-order nonlinear long-wavelength susceptibilities of a colloidal crystal under plausible physical conditions.

[¶] Presenter

Abstract

Is There an Effective Medium for the Coherent Reflectance from a System of Random Mie Spheres?

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We calculate the coherence reflection and transmission of electromagnetic waves from a slab with a dilute system of randomly-located polarizable spherical particles. We focus our attention on the case when the size of the spheres is comparable to the wavelength of the incident radiation. First, using scattering-wave and Mie theories, we derive expressions for the coherent fields that are transmitted and reflected by a very thin slab. Then we find the effective current distribution that would act as a source of these fields. We conclude that if the effective currents were induced in an effective medium, this medium must posses, besides an effective electric permittivity, also an effective magnetic permeability. We find that both of these optical coefficients become functions of the angle of incidence and the polarization of the incident wave. With these coefficients we calculate the effective index of refraction and, with Fresnel formulas, the half space reflectance we corroborate that these results are consistent with the wave scattering approach. Numerical results are presented for the optical coefficients as well as for the half-space reflectance as a function of several parameters. The reflectance is compared with that obtained without considering the magnetic response. Finally, we discuss the relevance and the physics behind our results, stressing the issue of the internal consistency of an effective-medium approach to this problem.

[¶] Presenter

Abstract

Exact relations between critical exponents for elastic stiffness and electrical conductivity of percolating networks

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It has long been known that the critical exponent T of the elastic stiffness $C_e \propto \Delta p^T$ of a d-dimensional percolating network ($\Delta p \equiv p - p_c > 0$ measures the closeness of the network to its percolation threshold p_c) satisfies the following inequalities $1 + d\nu \leq T \leq t + 2\nu$, where t is the critical exponent of the electrical conductivity $\sigma_e \propto \Delta p^t$ of the same network and ν is the critical exponent of the percolation correlation length $\xi \propto \Delta p^{-\nu}$. Similarly, the critical exponents which characterize the divergences $C_e \propto |\Delta p|^{-S}$, $\sigma_e \propto |\Delta p|^{-s}$ of a percolating rigid/normal network (i.e., a random mixture of normal elastic bonds and totally rigid bonds) and a percolating superconducting/normal network (i.e., a random mixture of normal conducting bonds and perfectly conducting bonds; $\Delta p \equiv p - p_c < 0$ now measures the closeness of the rigid or superconducting constituent to its percolation threshold p_c) have long been known to satisfy $S \leq s$. I now show that, when $d = 2$ or $d = 3$, T is in fact exactly equal to $t + 2\nu$ and S is exactly equal to s. This is achieved by a judicious use of some variational principles for electrical and elastic networks, and by a judicious treatment of constraints and short range correlations in those networks. An extension of these proofs to arbitrary (integer) values of the dimensionality d should be possible.

Abstract

Critical points in the macroscopic magnetotransport of normal conductor/perfect insulator/perfect conductor disordered composite

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The magnetotransport in a disordered composite medium, made of normal conductor, perfect insulator, and perfect conductor constituents, exhibits singular or critical point behavior at certain compositions, in the limit where the Hall conductivity of the normal constituent is much greater than its transverse Ohmic conductivity, but much less than its longitudinal Ohmic conductivity, e.g., if that constituent is a free electron conductor and a strong magnetic field is applied [1]. This critical behavior is sometimes related to the phenomenon of anisotropic percolation [2]. Self-consistent effective medium approximations are employed to discuss these critical points for two-dimensional as well as for three-dimensional microstructures [2,3]. Some simulations of random network models that represent such systems have been performed [4]; others are currently in progress. They will be described too.

[1] D. J. Bergman, Phys. Rev. B **64**, 024412-1–024412-12 (1 July 2001).
[2] D. J. Bergman, Phys. Rev. B **62**, 13820–13823 (2000).
[3] D. J. Bergman and D. G. Stroud, Phys. Rev. B **62**, 6603–6613 (2000).
[4] S. Barabash, D. J. Bergman, and D. G. Stroud, Phys. Rev. B **64**, 174419-1–174419-7 (2001).

Abstract

Electrokinetic Effects and Fluid Permeability

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Fluid permeability of porous media depends mainly on two parameters: porosity and a pertinent length-scale parameter. Electrical imaging methods typically measure electrical conductivity, which can then often be related to porosity by Archie's law. When electrical phase measurements are made in addition to the amplitude measurements, a measure of the pertinent length scale can then be obtained. Since fluid permeability controls the ability to flush unwanted fluid contaminants from the subsurface, inexpensive maps of permeability could improve planning strategies for remediation efforts. Detailed knowledge of fluid permeability is also important for oil field exploitation, where the distribution of this parameter in three-dimensions is a common requirement for petroleum reservoir simulation and analysis

Abstract

Modeling Intrinsically Complex Matter; Nonlinear, Nonadiabatic, Nonequilibrium

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A significant change of philosophy from traditional solid state and many-body approaches appears necessary to describe many classes of complex electronic and structural materials, both inorganic and organic. This is evident from more than a decade of rapidly improving experimental data resolution, and increasing failures of traditional interpretative frameworks. We conclude that multiscale complexity is fundamental to the science of synthesis-structure-property relationships in many "complex" materials. Measuring, modeling and using this complexity will be the basis for new generations of technology. A large class of such multiscale complexity appears to be driven by competitions of short- and long-range forces, resulting in "landscapes" of spatio-temporal patterns and metastable states, and associated glassy, hysteretic dynamics. We briefly summarize various materials and condensed matter systems exhibiting these competitions, including examples from: Josephson junction arrays and flux flow; surface morphology and evolution; organic self-assembly; polyelectrolytes and biomolecules; and complex organic and inorganic electronic materials. We emphasize challenges for theory and modeling; namely accurate incorporation of nonlinear, nonadiabatic, and nonequilibrium ingredients which are inescapable for the multiple, connected functional scales which constitute complex "systems".

note:poster

Abstract

Towards a Better Nonlinear Phase Shifting Element

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In this paper, we show that large nonlinear phase shifts can be achieved using cascaded microring resonators even if the constituent material has large linear and two-photon absorption. Constant intensity transmittance can also be maintained.

Materials with strong nonlinearity are desirable for optical switching devices. Recent research shows that ring resonators can be used in a nonlinear Mach-Zehnder interferometer to significantly reduce the switching power by increasing the nonlinear phase sensitivity. In a serially cascaded, or sequence, of resonators, the nonlinear sensitivity can be further improved. When taking material absorption into account, a ring resonator can facilitate a larger nonlinear phase shift and greater figure of merit than the constituent bulk material. However, this arrangement produces an intensity transmittance that is non-ideal for a general-purpose phase shifting element. We show that a simple modification to the serial-cascaded microring (CMRR) configuration - adding an extra output port on the top of the last ring 8211; facilitates an enhanced nonlinear sensitivity, a large saturating phase shift, and nearly ideal intensity transmittance characteristics even if the material itself has large linear and two-photon absorption.

¶Presenter

Abstract

Large Nonlinear Optical Response of Photonic Microcavity Arrays

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An array of microcavities in a photonic bandgap lattice allows a large increase in the third-order nonlinear phase shift over bulk. In one dimension, these structures are similar to interference bandpass filters and can be fabricated using multiple thin film layers. We have performed extensive numerical simulation which shows that nonlinear enhancements by two orders of magnitude should be possible. Initial experimental results using z-scan measurements on a multi-layer structure consisting of silicon dioxide and silicon nitride support these conclusions.

[¶]Presenter

Abstract

Dipole-Dipole Interaction Effect on the Optical Response of Quantum Dot Ensembles

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We studied the effect of concentration on the optical spectra in the visible and FIR regions of ensembles of semiconductor quantum dots (QDs).

Semiconductor QDs possess discrete exciton and phonon spectra, which determine their dielectric response in the visible and FIR regions, respectively.

We found experimentally that, when the QDs concentration increases, both exciton and phonon related peaks in the absorption shift to the lower energy side and broaden.

This is explained by the increasing dipole-dipole interaction between the QDs, polarized by the electromagnetic wave. We performed calculations based on the couple dipoles equations, which confirm the observed effects experimentally.

[¶]Presenter

Abstract

Wave scattering by inhomogeneous media: efficient algorithms and applications

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An overview will be presented of a variety of efficient computational techniques for evaluation of scattering of electromagnetic and acoustic waves by inhomogeneous media. In particular I will mention perturbative methods for scattering and eigenvalue problems, accurate integral scattering solvers and new high-frequency integral approaches. The applications to be presented include volumetric microscopy via optical coherence, oceanic scattering, and evaluation of radar cross-sections for remote sensing, communications, etc.

Abstract

Understanding and Control of Random Lasing

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Random lasing attracts much attention because its fundamental significance for understanding coherent phenomena in disordered media and potential applications in optoelectronics because of easy preparation (no need in mirrors) and small size down to several microns. Since the first experimental demonstration by Cao and coworkers in 1998 of the lasing emission from the ZnO nanopowder the remarkable progress in studying the material, geometry and external pumping dependences of laser properties and efficiency has been reached. I will demonstrate that lasing occurs from the special random cavities of high quality formed within the active medium. They can be described as the decaying eigen optical modes within the medium and the optical mode having the minimum decay rate is responsible for lasing. Numerical and analytical studies of the properties of these modes permit to interpret existing experiments and suggest the ways to optimize the performance of lasers.

[¶]Presenter

Abstract

Lasing with resonant feedback in random media

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We observed lasing in highly disordered gain media. The coherent feedback for lasing is supplied by recurrent light scattering. We studied in detail the dependence of random laser on the transport mean free path, the gain volume, and the sample size. A model based on the concept of quasistates is developed to explain the behaviors of random lasers.

We also demonstrated the difference between random lasers with resonant feedback and random lasers with nonresonant feedback. With an increase in the amount of scattering, we showed the transition from lasing with nonresonant feedback to lasing with resonant feedback.

Abstract

To what extent is the structure of a random composite compatible with a percolation model?

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Recent developments of local field microscopy allow a considerable improvement over more traditional techniques (like transmission electron microscopy) of the knowledge of the actual structure of composites made of conducting particles dispersed in an insulating polymer matrix. The Resiscope is an attachment to an AFM microscope that provides at the same time a classical image of the sample surface and a new image representative of the local electrical conduction through the sample, between the tip and the back. Using the thickness of the sample as an independent variable, we have obtained original data on the 3D structure of the finite clusters as well as of the infinite cluster and their relative variations with the particle concentration in a series of carbon black filled elastomers. These data are concerned with the geometry and the electrical resistance of the conducting paths inside the material and provide new conducting path size and local resistance histograms. The comparison of their respective behaviors with sample thickness and particle concentration with classical scaling results of percolation theory turned out to be difficult due to the particular "tip-to-bottom" plane experimental geometry, that has never been considered in the literature. We have performed computer simulations on percolation cubic networks aimed at providing similar data when both the filling factor p and the sample "thickness" (number of planes) are allow to vary. We have found that in spite of a general agreement between experimental and calculated data, there exist significant differences that seem to prove that the actual structure is more complex than the one predicted by a classical percolation model of random composite.

[¶]Presenter

Abstract

Dynamics of Structures Bi-Modal Elements

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Bi-modal link is a nonlinear spring with multiple equilibria. The link may be reversible or damageable (irreversible). Structures of bi-modal links and masses model phase transition in solids, plasticity, tension they possess abnormally high resistance to dynamic impact. When impacted, the structure initiates waves that carry away the energy of the impact, transform low-frequency motion of an impact into high-frequency vibration, fairly distribute "partial damage" over the structure.

The paper outlines the study of dynamics and effective behavior of these structures, conducted in collaboration with Alexander Balk, Elena Cherkaev, Leonid Slepyan, Toshio Yoshikawa, and Liya Zhornitskaya.

Abstract

Analysis of Stress Fields in Optimal Structures: Two-dimensional and Three-dimensional cases

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The paper analyses optimality conditions for fields in an optimal composite. Optimality is understood as the maximal stiffness of a structure under a given loading. The optimality of a design for a two-phase material can be formulated as follows: The stress field in each material should be distributed evenly throughout the designed domain. We show that a special rotationally-invariant norm of the stress tensor must be constant within each present phase of the design. One can judge how close the design is to an optimal one by observing the variation of norm of the stress. Using this principle, we propose a numerical procedure that checks the optimality of the claimed optimal structures. The procedure can quantitatively evaluate suboptimal structures, made either of composites or of finite skeleton-type reinforcement ligaments. The tool, Analyzer, computes norms of stress fields over the structure.

[¶]Presenter

Abstract

Reconstruction of the Microstructure of a Random Mixture

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In many heterogeneous materials such as porous media, biological materials, and artificial composites, the scale of microstructure is much smaller than the wavelength of the electromagnetic signal. In this situation, the wave cannot resolve all the details of the microstructure, and the response of the medium is homogenized. The talk discusses a problem of deriving information about the fine scale structure of a two component mixture from homogenized or effective measurements. The structural information is contained in the spectral measure in the Stieltjes representation of the effective complex permittivity. The spectral measure can be reconstructed from effective measurements. It is shown that the identification problem for the spectral function has unique solution, however the problem is extremely ill-posed. Several stabilization techniques are discussed such as quadratically constrained minimization, regularization using nonnegativity constraint, and reconstruction in the class of functions of bounded variation. The reconstructed spectral function can be used to estimate geometric parameters of the structure as well as to evaluate other effective properties of the same medium, such as effective thermal or hydraulic conductivity.

Abstract

Effect of Boundary Layers on Transmittance of Defect Mode in One-Dimensional Photonic Band Structures

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We study the effect of the outermost boundary layers on the transmittance of a defect mode in a one-dimensional (1D) photonic band structure (PBS). The structure consists of a single defect layer sandwiched by the two identical 1D PBS's. The calculation shows that the transmittance of the defect mode is 1.0 when the two outermost layers of film have the same value of refractive indices. This fact is unaffected by the change in the frequency of the defect mode, i.e., the variation of the thickness and/or the refractive index of the defect layer. With two outermost layers of different refractive indices, the transmittance of the defect mode becomes less than one, being minimum at the center of the band gap and maximum near the band edges.

¶Presenter

Abstract

From Opals to Optics: Building Photonic Band Gaps in Nanostructured Materials

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The gemstone opal exhibits a brilliant visible iridescence due to the regular spacing of submicron colloids which comprise its structure. This natural motif can be replicated in the laboratory, and artificial opals can be cast as thin films of controlled thickness using colloidal assembly techniques. Numerous solids, ranging from polymers to metals, can be cast around the colloidal network and the colloids subsequently removed. The macroporous materials that result have arrays of spherical cavities interconnected by smaller windows. The diffractive properties of these inside-out structures are even stronger than the host opal, and can in some cases can possess nearly complete photonic band gaps at visible wavelengths. In addition, these sponge-like materials can serve as hosts for further growth of nanostructured solids with complex architectures. We demonstrate this using porous PMMA to construct solid, hollow and core-shell nanospheres in a variety of shapes.

Abstract

Multiple Light Scattering in Multistratified Media: Model, Experiment

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The model presented here is based on the resolution of the radiative transfer equation (R.T.E.), by the Discrete Ordinate Method (D.O.M.), in the steady-state domain. A matricial formulation leads to the resolution of the problem of light scattering through multislabs, with index mismatch at each interface. In that way, the spatial distribution of out-going fluxes, the Bidirectional Scattering Distribution Function (B.S.D.F.), is obtained. A complete dissociation between volume scattering and interfaces behavior allows the introduction of elaborated theories to describe them properly. For instance, to account for interactions between scatterers, when high volume fractions are considered, we introduce the so-called Multiple Dependent and Coherent (M.D.C.) light scattering theory. Theoretical calculations are compared to experiments obtained with a spectro-scatterometer designed in our laboratory, dedicated to the measurements of the B.S.D.F. Experiments have been performed on colloidal latex beads suspensions (diameter 0.1 and 3μm) with high volume fraction (1,5% and 4%), placed into silica plates and different thickness (5mm and 100μm) are considered. For the cases considered, strong interaction between scatterers is taken into account.

[¶]Presenter

Abstract

A Spectral Representation for the Dielectric Properties of Layered Materials[3]

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We present a spectral representation for the effective dielectric function of a sample that consists of two homogeneous layers joined with a rough interface. This spectral representation is closely related to the Bergman-Milton spectral representation for bulk composites, and is easily extended to multilayered materials. By comparing the layered system to a reference layered system that has a flat interface we form a surface spectral function that captures all the effects of surface structure on the effective dielectric function of the layered sample, and is independent of the dielectric functions of the two layers. Because of the anisotropy of the layered system there are two surface spectral functions, one for the case where the applied field is parallel to the interface, and one for the case where the applied field is perpendicular to the interface. We discuss a reciprocity relationship between these two spectral representations and present sum rules that are directly related to the degree of surface roughness. We present numerical calculations of the surface spectral function for some model geometries, including the Gaussian random surface that has been extensively used to study light scattering from rough surfaces, and show that the simulations verify the sum rules and reciprocity relationships. We show how the surface profile and interactions between layers of the multilayered materials are related to the features of the surface spectral function and we discuss the possibility of determining the spectral function directly from reflectivity measurements.

[3]Work done in collaboration with M. F. Thorpe (Michigan State University), A. R. McGurn (Western Michigan University) and D. J. Bergman (Tel Aviv University).

Abstract

The Peculiarities of Hydrogen-Type Systems in Thin Semiconductor Films (QWS) in Presence of Transverse Magnetic Field

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At present time the uniqueness of the properties of hydrogen-type systems (excitons, small impurity centers) in thin semiconductor films is widely recognized [1]. Firstly this uniqueness is due to the fact, that in definite conditions the nature of the center's internal interaction between the particles becomes two-dimensional Columbic [2]. Under these conditions the conventional approximate approach in the theory of diamagnetic excitons (see e.g., [3]) becomes inapplicable while studying hydrogen-type systems in QWS structures in the case when a strong external magnetic field is perpendicular to the film's plane. The peculiarity of the current problem is in the fact that as the Columbic internal interaction as well as the interaction with the external magnetic field takes place in the film's plane and at the direction of the size quantization only the film's potential acts.

In the present work the hydrogen-type system is studied by means of variation technique without any limiting restrictions on the value of the magnetic field.

By means of two variation parameters the wave function and the energy of the ground state are obtained. The evolution of wave-function is studied in a wide range of magnetic field's changeover. It is shown, that in the case of extreme strong fields the system is described by means of Landau states, while in the case of extreme weak fields — by means of the states of a hydrogen-type center. In the case of moderate fields the state of system is considered to be a peculiar symbiosis of the two extreme cases.

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¶Presenter

Abstract

Binding Energy of Hydrogen-Type Impurities in Quantum Well Wires of InSb/GaAs

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The III-V-type semiconductors are widely used for construction of nanostructures. The dispersion law of charge carriers in these semiconductors is essentially nonparabolic and is the same one as the relativistic dispersion law in the two-band approximation. So the binding energy of hydrogen-type impurities in a quantum well wire (QWW) of finite depth is investigated by means of a variational approach as a function of the wire's radius and of the impurity's location [1].

The total energy of the impurity state is determined in the two-band approximation from Kane's analog of the Klein-Gordon equation. The binding energy of hydrogen-type impurity in QWW of InSb semiconductors was investigated in [2] by variational method in the case of the circular cross section and of infinite depth.

The nonparabolicity of dispersion law leads to a considerable increase of the binding energy of the hydrogen-type impurity in InSb/GaAs QWW in comparison with the analogous value in the wire with a standard dispersion law (e.g., GaAs/AlAs [1]).

In present work it is shown that the binding energy is maximal when the impurity center is localized on the wire's axis and it decreases at its deflection from the axis, similar to the parabolic case. The binding energy in nonparabolic semiconductors, in comparison to the standard case, is greater for all values of a shift parameter characterizing the deflection of the impurity center from the axis.

One can consider the vertical interband transitions from the valence band, with nonparabolic dispersion law, to the basic donor level using the analytical expressions for the wave functions and energy spectrum for the finite electron's states as it has been done for InSb QWW in [3].

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¶Presenter

Abstract

Dichotomic Random Processes and Scaling Properties of One-Dimensional Anderson Model with Diagonal Disorder

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In this paper we study scaling and statistical properties of finite size Lyapunov exponent (LE) in a model of one-dimensional Anderson localization described by a tight-binding Hamiltonian with a correlated diagonal disorder. We consider a model, in which a dichotomic process describes the distribution of site energies. In a simplest case a dichotomic process corresponds to a random variable, which can only take two different values, while the length of segments with same energy are distributed according to a Poisson law. Such a system is characterized by two parameters, the rms fluctuation and the radius of correlation. Numerical Monte-Carlo simulations shows that the spectrum of the system can be divided in three regions with qualitatively different behavior LE. For the values of energy corresponding to extended states, which would exist in homogeneous systems with both values of site energies, the behavior is universal, and demonstrates single parameter scaling (SPS). In the spectral regions where extended states would have existed for the homogeneous system with one of the site energies, SPS fails, and behavior is non-universal. In the third region, where extended states would not have arisen in none of the possible homogeneous systems, behavior becomes universal again. We showed that for large enough correlation radius there exist a simple analytical description, which gives good agreement with numerical calculations for both regions with non-SPS behavior.

[¶]Presenter

Abstract

Optimal Mode Localization in Heterogeneous Media

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One of the fundamental features of photonic bandgap structures is that localized defects in the periodic structure lead to localized states, associated with certain frequencies within the bandgap. These localized states allow the construction of waveguides, laser cavities, and other useful devices. In certain applications such as laser cavities, it is advantageous to obtain highly localized states, since these lead to large energy densities in the gain medium. It is well-known that the spatial energy decay rate of a localized mode depends on the distance of its frequency to the band edge, so that periodic structures with large band gaps tend to yield highly localized modes. Still, such results say nothing about the structure of the defect itself. The basic question addressed in this paper is: “what material distribution within a defect produces ‘optimal’ energy localization”. The problem is formulated as a minimization. Results on well-posedness of the problem, an algorithm for approximating solutions, and preliminary numerical results will be presented.

Abstract

Diffraction in Left-Handed Materials and Theory of Veselago Lens

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A theory of diffraction in the system consisting of the left-handed and the right-handed materials is proposed. The theory is based upon the Huygens's principle and the Kirchhoff's integral and it is valid if the wavelength is smaller than any relevant length of the system. The theory is applied to the calculation of the smearing of the foci of the Veselago lens due to the finite wavelength. We show that the Veselago lens is a unique optical instrument for the 3D imaging, but it is not a "superlens" as it has been claimed recently.

¶Presenter

Abstract

Microstructural controls on transport phenomena in sea ice

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The polar sea ice covers greatly affect the energy transfer between ocean and atmosphere and play a key role in the global radiation budget. The physical properties of the ice are controlled largely by the volume fractions and microstructure of the component phases: ice, brine, gases as well as particulate inclusions. Apart from its importance in the climate system, sea ice is of considerable interest as a porous medium that exhibits pronounced temporal and spatial variability in the relevant transport properties as a function of temperature and composition. For Arctic sea ice, liquid phase fractions typically vary between < 0.001 and > 0.1, while variables such as intrinsic permeability range over 6 orders of magnitude for temperatures between 0 and -25 C. The presentation will focus on linkages between pore microstructure (studied through thin sectioning and magnetic resonance imaging) and transport through sea ice. Specifically, I will discuss (1) how physico-chemistry and microstructure of sea ice control the transition between a low- and a high-permeability regime and (2) how temporal and spatial constraints greatly aggravate the experimental identification of percolation thresholds in natural sea ice.

Abstract

Correlation structure effects on edge-accessible porosity and chemical distance near the percolation threshold

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Most studies in percolation theory assume a random infinite medium, while natural porous media are neither random nor infinite. A few studies have examined the impact of short-range correlation structure on the percolation threshold, but not its broader influence on fluid transport. Furthermore, there have been no investigations of longer-range correlation structures such as fBm. We investigate the impact of exponential and fBm random field connectivity structures on pore accessibility and tortuosity. In particular, we examine the porosity fraction which is accessible from the edge of the porous medium (e.g., a fracture face) but is not part of the infinite cluster. Near the percolation threshold, this portion of the porosity may have important contributions to long-term diffusion behavior in the presence of oscillating boundary conditions, such as intermittent wet/dry cycles inside Yucca Mountain.

¶Presenter

Abstract

Localization and Diffusion of Transient Waves in Random Media

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Frequency coherence of classical waves in random media is studied by means of the path integral technique. The technique allows the investigation of the two-frequency mutual coherence function to be made in a most general way without regard to the dimensionality of the medium or to the explicit form of the power spectrum of fluctuations. Based on this results the propagation of narrow-band signals is studied on the "microscopic" level, i.e., starting from the wave equation for fields, not from the "macroscopic" diffusion or transport equations for intensities. This enables us to account for the coherent interference of scattered fields, which is disregarded in the diffusion approximation. It is shown that a pulse radiated by a point source in both one- and two-dimensional random media is strongly localized. Explicit expressions for the corresponding localization lengths are obtained. In three dimensions the results interpolate between the ballistic propagation of pulsed waves in forward scattering media and a diffusive regime in strongly disordered systems. For the lowest-order temporal moments of pulse a universal scaling is shown to be held in both regimes: the excess delay time increases with the distance, L, as L^2, while the pulse width grows proportionally to $L^{3/2}$.

¶Presenter

Abstract

On the Crystal Optics of Ferroelectric-Semiconductors

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On the crystal optics of ferroelectric-semiconductors in soliton regime incommensurate phase

The characteristics of linear and nonlinear crystal optics in soliton regime incommensurate phase of crystals are investigated. The space dependence of the dielectric permeability and nonlinear susceptibility tensors are derived. The character of temperature evolution of soliton lattice is determined. The characteristic matrixes for soliton regime incommensurate phase are determined by solving the linear and nonlinear Maxwell equations. The temperature dependence transmission coefficient in wives as oscillation function is determined. For the nonlinear properties it is shown that there is a generation of the second harmonic due to low local symmetry. The temperature dependence the intensity of second harmonic is established. The comparison of the received results with experimental data is discussed.

Abstract

New Advances in Numerical Micromagnetics Simulations

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After a brief introduction to micromagnetics, the speaker will present the Gauss-Seidel Projection Method, an unconditionally stable method for the Landau-Lifshitz equations. With this method we were able to correctly simulate the magnetization reversal process in a ferromagnetic sample in the presence of vortices.

¶Presenter

Abstract

Metal-dielectric composites: Local-field distribution function and high-order field moments

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During the last two decades, the physics of nonlinear optics saw a vast improvement in our understanding of the optical properties for various inhomogeneous media. One such medium is a metal-dielectric composite, where metal inclusions have the filling factor p, with the rest, (1-p), being a dielectric host. Computations carried out by using different theoretical models and experimental data both show the existence of giant local electric and magnetic field fluctuations in such composites. In this presentation, we introduce a new 2D model that allows one to determine exactly the local-field distribution function (LFDF) and all other relevant parameters of the system. For small filling factors, the LFDF is shown to transform from the lognormal to the "single-dipole" distribution function. We also confirm the scaling theory predictions for high-order field moments and compare our results with recent experimental observations.

¶Presenter

Abstract

Percolation in Sea Ice

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Sea ice is a composite of pure ice with brine and air inclusions. It is distinguished from many other porous media, such as sandstones or bone, in that its microstructure and bulk material properties depend strongly on temperature. Above a critical value of around -5 degrees C, sea ice is permeable, allowing transport of brine, nutrients, biomass, and heat through the ice. These processes play an important role in air-sea-ice interactions, in the life cycles of sea ice algae, and in remote sensing of the pack. Recently we have used percolation theory to model the transition in the transport properties of sea ice. We give an overview of these results, and how they explain data taken in Antarctica. We also describe recent work on electromagnetic remote sensing of sea ice, and how percolation processes come into play.

Abstract

Photophysics of Pristine and C60 Doped Disubstituted Polyacetylene

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We present continuous wave optical spectroscopies of films of disubstituted polyacetylene poly-disubstituted-acetylene (PDPA-nBu). We found that although PDPA-nBu is a degenerate ground state polymer, nevertheless it shows strong photoluminescence (PL) with quantum efficiency larger than 60%. Polarized PL measurements show that the PL emission originates from intrachain excitons rather than from the polymer side groups. The absorption spectrum was measured and compared with the proposed model of Shukla et al. The photoinduced absorption (PA) spectrum of PDPA-nBu in toluene solution indicates that only polarons are photoegenerated, whereas PDPA-nBu films show both polaron and soliton photoexcitations. We also investigated the charge transfer (CT) process in the PDPA-nBu/C_{60} composites. While the absorption spectrum in the visible and infrared ranges of PDPA-nBu/C_{60} blend do not show any evidence for CT in the ground state, the PA spectrum shows the signature of CT in the form of a PA band that peaks at about 1.15 eV, which is associated with C_{60}^{-}. PADMR spectroscopy also shows the signature of the photoinduced CT reaction. We also observed two spins 1/2 resonances one associated with positive polarons of the polymer chains and the other related to C_{60}^{-}.

¶Presenter

Abstract

Magnetic Nanocomposites Close to the Percolation Threshold: Magnetotransport and Magnetooptics

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Granular ferromagnet-insulator solids consist of nanometer size ferromagnetic granules embedded in an insulating medium. They display a wide variety of magnetic, transport, optical and magneto-optical properties related to their unique nanostructure. For example, close to the percolation threshold they exhibit tunneling magnetoresistance, giant extraordinary Hall effect, nonlinear transport and optical phenomena and so on. The specific mechanisms of these effects are far from being well understood, the simple models based on the percolation theory, mean-field approaches or developed by analogy with spin-dependent transport in multilayers are not appropriate. On the other hand a significant interest to magnetic nanocomposites has been triggered by possible applications of the above effects to the development of magnetic sensors, magnetic heads, discontinuous metal-insulator spin-valve elements, high frequency magneto-impedance and magneto-optical devices etc. In addition, due to the extremely high precision of magnetic measurements magnetic nanocomposites are very suitable for study of percolation models, relevant for many problems in physics, mathematics, and life science. In the discussion, I will present some recent theoretical and experimental results on magnetotransport and magneto-optical properties of magnetic nanocomposites, focusing on compositions close to the percolation threshold. In particular, I will discuss the possible mechanisms of giant extraordinary Hall effect, field-dependent tunneling thermoelectric power, magneto-optical spectra in a wide spectrum range, enhanced magneto-optical response, non-linearity of magneto-optical phenomena with respect to magnetization and intensity of light, and magnetorefractive effect.

Abstract

Properties of Conically Propagating Electromagnetic and Elastodynamic Waves in Periodic Media

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This talk presents analysis of electromagnetic and elastodynamic waves conically propagating through a doubly periodic array of cylindrical fibres. A new method, based on a multiple scattering approach, has been proposed to reduce these spectral problems for partial differential equations to certain algebraic problems of the Rayleigh type: its matrix elements decay exponentially away from the main diagonal, giving rise to higher-order multipole coefficients that decay similarly quickly.

We obtain a formulation in terms of an eigenvalue problem that enables us to construct the high-order dispersion curves and to study both photonic and phononic bang gap structures in oblique Incidence [1].

We also address the question of a singular perturbation induced by the conical incidence parameter for both electromagnetic and elastic modes. We finally discuss some effective properties for ferro-magnetic photonic crystal fibres in the long wavelength limit [2].

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[¶] Presenter

Abstract

The Manipulation of Light: one nanoparticle at a time

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Metal Nanoshells are precisely layered metal-dielectric nanoparticles whose optical resonances are controlled by the relative thicknesses of their constituent layers. This layered topology gives precise control over optical fields at subwavelength dimensions, and can be considered a fundamental component of nano-optics, where electromagnetic properties are controlled by nanoscale design. This topology also provides a new way to study the electronic and dynamical properties of mesoscopic metals that is complementary to the low-temperature, transport based methods commonly used.

Unlike photonic crystals, which require long-range periodicity to manipulate light, individual Metal Nanoshells can be integrated with existing materials and device structures, allowing one to modify and manipulate the optical properties of materials in unique and unusual ways. The example of a nanoshell-polymer composite material with a dramatic opto-mechanical response will be discussed. Gold nanoshells also provide a biocompatible substrate for the conjugation of proteins: this has led to the development of real time medical testing based on Surface Enhanced Raman Scattering, and also provides a promising strategy for cell-specific photothermal cancer therapy.

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Abstract

Phonons and thermal transport in nanoscale devices and nanomaterials

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Although mesoscopic electron physics has been under intense study for over 15 years now, the regime of mesoscopic phonon physics, where the phonon wavelength becomes comparable to the size of the structure under study, has been much more difficult to access experimentally. To reach this regime, we have fabricated freely-suspended integrated semiconductor devices and performed the first direct thermal transport measurements on nanostructures. We have used these devices to provide the first experimental measurement of the quantum of thermal conductance in one-dimensional phonon waveguides. We have performed theoretical modelling that allows us to correlate the details of our thermal conductance measurements with the physical structure of our devices. We have also used similar devices to measure thermal transport at higher temperatures, in order to directly observe surface effects on phonon scattering in nanostructures. Finally, we have examined the thermal properties of carbon nanotubes, whose small size and high phonon velocity allows them to show quantum effects at relatively large temperatures. These measurements also allow us to probe the mechanical properties of the nanotubes, such as their stiffness (Young's modulus) and the coupling between neighboring tubes in bundles.

[¶]Presenter

Abstract

Fast, High-Order Methods in Computational Scattering

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Scattering theory remains an active and challenging scientific and mathematical field. Although most scattering problems take on a similar mathematical form, they find application in a wide range of fields: communications, materials science, plasma physics, biology and medicine, radar and remote sensing, etc. At the same time, obtaining solutions to the scattering equations requires novel mathematical approaches and powerful computational tools.

We present fast, high-order integral equation methods for acoustic scattering by two- and three-dimensional inhomogeneous media. In the two-dimensional case, we approximate the Green's function and the solution by truncated Fourier series in polar coordinates. In the three-dimensional case, on the other hand, a partition of unity decomposes the Green's function into smooth and singular parts. In each case, the required convolutions are accomplished via efficient and high-order accurate Fourier-based integration methods. We thereby obtain methods that require only O(N log N) operations per iteration and achieve high-order convergence even for discontinuous scatterers. Finally, we demonstrate the performance of these methods through several computational examples.

¶Presenter

Abstract

Electroluminescence from Eu-doped GaN MIS Structure

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Visible electroluminescence (EL) at room temperature has been achieved from a metal-insulator-semiconductor device (MIS) made on GaN thin film doped with Eu ions. The GaN film used for this investigation was grown by metal-organic chemical vapor deposition (MOCVD) on sapphire and implanted with Eu ions. MIS devices were fabricated on GaN films using silicon dioxide layer (9.5 nm) and indium-tin-oxide (100 nm) as transparent electrode deposited by electron beam evaporation. The EL spectra show dominant red emission line at 622 nm and weaker lines at 554 nm, 594 nm and 665 nm, corresponding to the transition between $^5D_{0,1}$ and $^7F_{1,2,3}$ states in Eu^{3+}. A systematic study of EL signal was conducted in 10–300 K temperature range with an applied bias voltage changing from 10–110 V, respectively. The strongest EL signal due to $^5D_0 \rightarrow {}^7F_2$ transition was recorded at 300 K under forward bias.

¶Presenter

Abstract

Morphology-dependent Optical Properties of Substituted Poly(p-phenylene-ethynylene)

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Two different batches of substituted poly(p-phenylene-ethynylene) [PPEs] were synthesized where the substituents dibutyl(a), di-2-ethylhexyl(d) were placed on the 2,5 positions of the phenyl rings. The PA spectrum of PPE(a) shows a polaron band at about $850cm^{-}1$. Whereas PPE(d) doesn't show any polaron absorption band. Visible photomodulation spectrum of PPE(a) has two main bands at $T = 10K$ around 1.25eV and 1.9eV plus a broad shoulder at 2.1eV. From PADMR spectrum we found that in PPE(a), the 1.9eV PA has spin $1/2$, thus it is long-lived polaron generated in the polymer through photoexcitation, whereas the 1.25eV PA doesn't have any spin $1/2$ resonance.

¶Presenter

Abstract

Photonic band gap materials: Semiconductors of light

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I will discuss the ability of photonic band gap (PBG) materials to localize light and to controllably alter the light emission properties of atoms and molecules. These effects have important applications to novel active devices such as micro-transistors as well as to integrated optics on a microscopic scale.

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Abstract

Inverse Bioelectric Field Problems: Modeling, Simulation, and Visualization

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Inverse problems are broadly characterized by their use of mathematical models for determining unknown system inputs, sources, parameters and/or states from observed system outputs and responses. One important class of inverse problems are those found in bioelectric field imaging of cardiology and neuroscience. Generalized electrocardiographic (ECG) and electroencephalographic (EEG) imaging, use an inverse solution applied to electric voltages recorded on the body/head surface to estimate 1) the complete distribution of electric voltages throughout the torso/head, and/or 2) the cardiac/neural current source characteristics that produce those distributions. To produce such images requires the construction of large-scale geometric patient models, the solution of field equations for the voltage and current distributions, and regularization to deal with the extremely ill-posed nature of the problem. I will present modeling, simulation, visualization, and software results of large-scale bioelectric field problems in cardiology and neuroscience.

Abstract

High-Q Cavities Without a Complete Photonic Band Gap

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Although the most ideal system for optical cavities is a 3d crystal with an omnidirectional band gap, the challenge of their fabrication has led many to consider simpler 1d and 2d periodic systems lacking a complete gap. Such a hybrid system is the photonic-crystal slab, employing a combination of vertical index guiding and a two-dimensional band gap in the horizontal plane. For high-contrast systems, operating below the light line, the in-plane periodic structure itself does not cause out-of-plane scattering, even for strong periodicity. However, any time the periodicity is broken, e.g. by a resonant cavity or waveguide bend, vertical scattering is possible. In this talk, we discuss mechanisms for minimizing such scattering losses, focusing in particular on the case of high-Q resonant cavities, which are most sensitive to any losses. We show how one can trade off field localization for Q (cavity lifetime), and alternatively demonstrate how one can cancel low-order multipole moments of the radiated field in order to maximize Q for a fixed degree of localization. Moreover, we also present a simple new structure, a 1d-periodic stack of cylindrical waveguides, in which arbitrary Q can be achieved for finite modal volume, if only a single analytical condition on the dielectric contrasts is satisfied. Such high-Q cavities with strong confinement are an integral component of many potential devices, from lasers to channel-drop filters to coupled-cavity slow-light waveguides.

Abstract

The impedance boundary conditions and effective surface impedance of inhomogeneous metals

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Received:

We present the nonperturbative results for the effective impedance of strongly inhomogeneous metals valid in the frequency region of the impedance (the Leontovich) boundary conditions applicability [1,2]. The inhomogeneity is due to the properties of the metal or/and the surface roughness.

If the surface of an inhomogeneous metal is flat, the effective surface impedance associated with the reflection of an averaged electromagnetic wave is equal the value of the local impedance tensor averaged over the surface inhomogeneities (Ref.[1]). This result is exact within the accuracy of the impedance boundary conditions. It is suitable both under the conditions of normal and anomalous skin effect.

As an example, we examine strongly anisotropic polycrystalline metals (the inhomogeneity is due to the misorientation of discrete single crystal grains). Under the conditions of normal skin effect the effective impedance is expressed in terms of the principle values of the static conductivity tensor of single crystal grains (Ref.[1]).

Under the conditions of extremely anomalous skin effect the relation between the current and the electric field strength is non-local. With regard to the spatial dispersion the elements of the impedance tensor of a single crystal metal are expressed in terms of integrals over the Fermi surface. The Fermi surfaces of the majority of real metals are extremely complex. On the other hand, it is usual to think of a polycrystal as of an effective isotropic metal with a spherical Fermi surface.

Abstract

Low Frequency Corrections to the Static Effective Dielectric Constant of a Composite Material with a Cubic Lattice of Identical Spheres

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Using the expressions for dynamic lattice sums and equations for determining the coefficients of Debye potentials:

$$S^{y}_{im}(k, K_1) = \sum y_i(kR_p)T(\varphi_p, \phi_p)e^{ik_i R_p},$$

$$\sum_{l_1, m_1}(\delta_{ll}, \delta_{mm_1} + T^{\gamma^{-1}}\sigma_{lm;l_1m_1})A^{\gamma}_{l_1m_1} = 0.$$

for a 3-dimensional cubic lattice of identical spheres we discuss the low frequency corrections to the static effective dielectric constant of composite materials with this triply periodic lattice. In comparison with the results of homogenization problem in Maxwell-Garnett approximation we drive the first dynamic correction to the effective refractive index for a cubic lattice spheres and a constraints on the wavenumber region for which the Maxwell-Garnett approximation is accurate.

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Abstract

Tuning of Anisotropic Optical Properties of Two-Dimensional Dielectric Photonic Crystals

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We investigate theoretically the practical methods of tuning the anisotropic long-wavelength optical properties of two-dimensional (2D) dielectric photonic crystals (PCs), based on the formulas derived by Halevi et al. An efficient tuning can be achieved by slightly distorting the symmetry of 2D PCs by applying an external shear stress to the two edges of the PCs. Another method is to tune the dielectric constant of one of two constituents, for instance, that of the liquid crystal infiltrated in 2D PCs by changing temperature. The variation of birefringence observed in the structures studied in this work is shown to be larger than the birefringence of quartz. This makes the tunable anisotropic optical properties to be very attractive for applications in polarization optical devices. We also discuss the effects of tuning on the superprism phenomenon in PCs.

¶Presenter

Abstract

The Importance of Microstructure in Defibrillation

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Defibrillation of cardiac muscle by the application of a large brief current is used routinely in hospitals to save hundreds of lives daily. Although this technique was discovered in the late 1940's and has been steadily improved since then, until recently there has been no theory describing how or why defibrillation works. In fact, previous theory predicted that it cannot work, even though it obviously does.

Within the last few years a theory describing the mechanism of defibrillation has been proposed. This theory exploits the spatial inhomogeneity of the normal heart. However, a substantial controversy remains about the nature of the most important inhomogeneities, with one view favoring large scale inhomogeneities, such as anisotropy and changes in fiber direction, and another favoring small scale inhomogeneities.

In this talk, I will describe this proposed mechanism for cardiac defibrillation and use homogenization theory to develop a mathematical model that shows when it works and why it fails. I will also demonstrate why there is a crucial dependence on the spatial scale of inhomogeneity.

Abstract

Predicting Oil Recovery using Percolation Theory

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Hydrocarbon reservoirs are large, geologically complex entities with heterogeneities on all length scales from millimetres to kilometres. Modern mathematical models of reservoir geology can be very detailed with up to 20 million gridblocks. This is a much higher level of detail than can be resolved by numerical flow simulation required to predict oil recovery rates. In order to span this difference in scales a variety of methods of upscaling have been used. In this paper we describe how percolation theory can be used to estimate the large scale flow rates in hydrocarbon reservoirs. We use a scaling theory to predict the probability distribution of time to breakthrough of an injected fluid (typically water). This breakthrough time is extremely important as it influences the economic recovery rates from oil fields. The scaling law predicts the entire probability distribution semi-analytically something that would be extremely computationally time consuming by conventional Monte Carlo and flow simulation approaches. We also demonstrate the validity of this approach on a real field example.

¶Presenter

Abstract

Photoexcitations in Trans-Polyacetylenes: Long-Living Story about Short-Living Species

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We studied the primary photoexcitations in doubly phenyl-substituted polyacetylenes (PDPAs) using femtosecond pump-probe spectroscopy in the spectral range from 0.5 to 2.5 eV. We show that excitons and neutral solitons with distinctly different absorption bands and dynamics are photogenerated in pristine films and fullerene-doped films within 100 fs. The obtained polarization memory decay reveals that during relaxation excitons migrate among different polymer chains, whereas solitons are highly localized on the chains in which they were originally photogenerated. We also found that in C_{60} doped PDPA the branching between neutral solitons and intrachain emissive excitons occurs prior to the exciton dissociation, so that the soliton band dynamics remains unaffected. Finally, we compare the fundamental photoexcitations in degenerate-ground state polymers to those in nondegenerate ground state polymers.

[¶]Presenter

Abstract

Physical Properties of Gallium Infiltrated into Opal Photonic Crystals

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Measurements of the electrical and optical properties of gallium infiltrated into 3D photonic crystals will be presented. These metallic photonic crystals have been fabricated by filling artificial silica opals having a lattice period 300 nm by pure (99.999%) gallium under high pressure (1 kbar) at high temperature (1000 C). Temperature dependence of dc-electrical conductivity was measured from 100 to 300 K. Data on optical reflectivity have been obtained in the wavelength range between 0.3 to 50 microns. Comparison of the experimental data with theoretical predictions will be discussed.

¶Presenter

Abstract

Surface plasmon polariton band structures for two-dimensional periodic surfaces

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By the use of the homogeneous form of the reduced Rayleigh equation for the electric field above and on the rough surface of a metal in contact with vacuum, we have obtained the dispersion relation for surface plasmon polaritons propagating across such an interface. This dispersion relation is exact within the domain of validity of the Rayleigh hypothesis upon which it is based. It is applied to a two-dimensional vacuum-metal interface formed from a periodic array of hemiellipsoids on the planar surface of the same metal. Nonperturbative numerical solutions of the resulting dispersion relation are obtained for wave vectors along the boundary of the irreducible element of the first Brillouin zone for a square and a triangular array of the hemiellipsoids. Absolute band gaps in the frequency spectrum, where the density of states vanishes, are found, and the dependence of the position and width of these gaps on various geometrical parameters of each array is investigated. We also study the influence of radiative damping and ohmic losses on the dispersion curves. Our theoretical results are compared with existing experimental data.

¶Presenter

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Abstract

Influence of Concentration Fluctuation on mv Properties of Composites

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Recently, there has been reborn the interest to metal-dielectric mixtures. First of all this is a demand of modern industry that requires mv materials with high values of the real part of permittivity and low dissipation. The materials prepossess by the simplicity of their manufacturing and machine processing.

The theoretical background is the percolation theory that predicts high values of dielectric constant without dissipation just below the percolation threshold. It is really true at zero frequency but at high frequencies there appear the Maxwell currents which connect separate conducting clusters and cause dissipation. Unfortunately, the dissipation observed in practice significantly exceeds the percolation theory prediction. Usually, the effect is withdrawn on the contacts since there is no reliable information of them. Is shown that the skin effect is responsible for observed dissipation. It is well known that the skin effect on a separate metal inclusion (skin effect of the first kind) shifts the dissipation line into low comparing with conductivity of the metal frequency band. If we deal with the system the concentration of which is near but below percolation threshold then even small concentration deviation in some volume can bring the volume just above percolation threshold. The skinning of the fields at the volume (the skin effect of the second kind) shift the dissipation line resulting in its broadening and significant increase of the dissipation at frequencies just below undisturbed line. It is worth emphasizing that in opposite to skin effect of the first kind which results in renormalization of metal conductivity only the skin effect of the second kind is an example of the system where the Bergman-Milton spectral theory should fail due to solenoidal nature of fields which do not governed by the Laplace equation.

[¶] Presenter

Abstract

Light scattering and fluctuations under extreme conditions

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We will review results on obtaining the strongest scattering materials. In addition to measuring transport properties we measure fluctuations in phase and amplitude of scattered light.

Our samples have been obtained with different preparation methods. A very promising method is the use of electrochemical etching. Recently, we have shown that macroporous gallium phosphide (GaP) can be obtained in that way. Gallium phosphide has a very high refractive index (n=3.3) at sub-band gap wavelengths and a band gap of 2.24 eV, corresponding to a wavelength of 0.55 microns. This makes GaP transparent for light in the red part of the visible spectrum.

We present a detailed investigation of pore formation and the scattering strength as a function of the doping concentration and the etching potential. It is easy to tune the scattering strength of porous GaP in a wide range. Enhanced backscattering and transmission measurements are used to quantify the scattering strength of porous GaP.

We will discuss the possibility of anistropic etching in which the goal is to make samples with mean free paths that depend on direction.

Abstract

Dynamic Effective Medium Theory of Nanosphere Materials

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A dynamical effective medium theory is developed for modeling the optical properties of square and cubic arrays of non-magnetic nanospheres in a dielectric medium. The theory yields dielectric functions, $e_{eff}(k, ø)$, for nanoparticle materials in terms of the polarizabilities of the individual nanospheres, the nanosphere volume fraction, and the dielectric constant of the medium (Lazarides and Schatz, Theochem 529, 2000). The dielectric functions satisfy the dispersion relation that characterizes plane wave propagation through the nanosphere lattice of spheres. The effective dielectric functions are calculated by inverting the lattice dispersion relation for lattice dipole polarizabilities derived by Draine and Goodman (Astrophysical J. 405, 1993) for use in discrete-dipole representations of bulk media. The dynamical effective medium theory is tested by comparing extinction spectra for finite samples calculated using the effective medium model with spectra calculated using an explicit model of the interacting nanosphere components and found to be accurate for 13 nm gold particles at metal volume fractions up to 0.4. The theory is compared with several other effective medium theories including Maxwell-Garnett theory, Torquato-Lado theory, and theories that apply partial dynamical corrections to quasi-static theory. Of the dipole theories, Maxwell-Garnett theory (with a particle-size dependent inclusion dielectric function) is found to provide the closest agreement with the dynamical effective medium theory and explicit coupled particle calculations. An explanation is provided for the well-documented observation that quasi-static theories provide surprisingly accurate continuum descriptions of materials that are heterogeneous on length scales that are substantial fractions of the wavelength of light. Higher-order static theory, tested against explicit coupled multipole electrodynamic calculations, is found to overestimate the interparticle interaction.

[¶]Presenter

Abstract

Dielectric and Electro-Optical Properties of Dilute Suspensions

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The dielectric properties of dilute liquid suspensions of microellipsoids may be controlled by reorientation of the particles in an applied electric field. The particle orientation distribution is determined by a thermal average of the electrostatic energy that seeks to orient the particles in the direction of the applied field. The magnitude of the resulting electro-optical effects is determined by the intrinsic dielectric anisotropy of the particles and by their shape. By calculating the field-dependent dielectric tensor of such a suspension, we find an explicit link between the particle properties, their orientation distribution and the field induced birefringence and electro-optical phase shift for fields of arbitrary strength. The electro-optical effects turn out to be quite sensitive to changes in particle parameters and may therefore be useful for studying reorientation phenomena in these materials.

Abstract

Structural, Optical, and Structural-Optical Properties in First-Year Arctic Sea Ice

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The optical properties of sea ice have a large impact on the surface heat and mass balance of the Arctic ocean. Observations show large temporal changes in the state of the ice and in its optical properties, particularly during the summer melt season. Absorption and scattering in sea ice are governed by the microstructure of the ice, specifically inclusions of brine, gas, and precipitated salts. In order to predict changes in the absorption and scattering, a better understanding of this microstructure is needed. This paper describes a process study designed to simultaneously collect detailed information on the microstructure of natural sea ice and its optical properties over the temperature range of -30 C to -2 C. An imaging system was used to examine the size distributions for brine and gas inclusions. Number densities for both types of inclusions were observed to be an order of magnitude larger than previously reported. Large changes in the microstructure were observed as samples were cooled to -30 C, and subsequently warmed to -2 C. Interactions between brine inclusions, the disappearance of gas bubbles as the ice cooled, and the precipitation of salt crystals within brine pockets were documented. These observations were used in conjunction with observations of the apparent optical properties of the samples to develop and test a structural-optical model necessary for detailed radiative transfer modeling in sea ice. The optical properties of sea ice were found to: (1) change dramatically at temperatures below -23 C, where they are determined primarily by bulk ice salinity, (2) remain fairly constant between -23 and -8 C, although the magnitude of the optical properties still depend on bulk salinity, and (3) vary only weakly above -8 C due to the temperature dependence of the brine refractive index. We expect this general pattern will be found in most types of natural sea ice, regardless of the exact distribution of inclusions.

Abstract

Design of Functionally Graded Dielectrics Using Prescribed Microstructures

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Composite dielectric insulators for use in power transmission need to possess suitable overall dielectric properties while at the same time minimize electric field concentrations. It is often the case that microstructures available to the designer are limited by manufacturing constraints. In this context we illustrate a rigorous strategy for the design of composite dielectrics with graded properties for control of field concentrations.

Abstract

Fluorescence excitation in a periodic array of sub-wavelength metal apertures

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We report the observation of the fluctuated fluorescence excitation from Cy-5 labeled analyte molecules coated on periodic arrays of sub-wavelength gold apertures with the diameter from 100nm to 200nm. We attribute the fluctuation to the coupling of light with the plasmons — electronic excitations — on the surface of the periodically patterned gold films. The two-dimensional arrays of cylindrical cavities in gold films were fabricated by e-beam lithography. The fluorescence signal was collected through a band-pass filter by CCD camera. The initial experimental results show that the fluorescence intensity changes with the incident angle and reaches the maxima at certain angles, where we think that the surface plasmons generate.

¶Presenter

Abstract

Generalized Conductivity Scaling and Transport in Random Networks

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Received:

We present a 3D network model of fractures that allows a systematic study of the interplay and relative importance of the two key factors determining the character of flow and transport in the system. These factors are geometry of the network and the aperture variability of its elements. Empirical functional relationship is obtained that quantifies the dependence of the effective hydraulic conductivity on aperture variability and on the network structure. This leads to an explanation for the field-length dependence of permeability observed in fractured and heterogeneous porous formations. Transport through the network is investigated and relation between aperture variability and the Peclet number is established.

[¶]Presenter

Abstract

Photonic Crystal Slab

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A theoretical study is presented of the electromagnetic modes of a photonic crystal slab. The system is composed of an infinite slab of a finite uniform thickness. The slab is made up of a periodic array of dielectric cylinders and exhibits periodic behavior in the planes of the slab surfaces. The slab is free standing and embedded in a uniform isotropic background medium. Results are presented for the dispersion relations, modal wavefunctions, and the density of states for parameters based on experimentally realizable systems. The dependence of these properties on slab thickness is determined.

Abstract

The Correct Modeling of the Second Order Terms of the Complex ac Conductivity Results for Continuum Percolation Media, Using a Single Phenomenological Equation

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In the last 30–40 years the most widely used and probably successful approach in the modeling of experimental results for the dc and first order ac conductivity (dielectric constant) results of good conductor-bad conductor (Metal-Insulator) media, near the second order Metal-Insulator Transition at the critical volume fraction, has been percolation theory. Recent experiments will be presented that will show that the standard percolation equations (which are actually power laws with an unspecified constant) are unable to, in some cases not even qualitatively, model the second order terms of the complex ac conductivity of continuum percolation composites. It will then is shown that a phenomenological equation, which has the same parameters as the percolation equations and reduces to them in some ideal cases, can usually accurately but always qualitatively, fit all the experimental results (first and second order) as a function of volume fraction and frequency. The second order terms are the dielectric loss (conductivity) below the critical volume fraction and a hump, as seen in water-oil emulsions, in the real dielectric constant, which often peaks beyond the critical volume fraction. New results show that $1/f$ noise, just above the critical volume fraction, is characterized by two exponents, and not one as has previously been observed. A qualitative model for this behaviour in granular conductor–insulator media is presented. This model helps explain the difficulty in the exact modeling of the conductivity results, just above the critical volume fraction, near the percolation threshold in granular systems.

[¶]Presenter

Abstract

Fitting the dc conductivity and first order ac conductivity results of continuum percolation media, using percolation theory and a single phenomenological equation.

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In the last 30–40 years the most widely used and probably successful approach in the modeling of experimental results for the dc and first order ac conductivity (dielectric constant) results of good conductor-bad conductor (Metal-Insulator) media, near the second order Metal-Insulator Transition at the critical volume fraction, has been percolation theory. Recent experiments will be presented that will show that the standard percolation equations (which are actually power laws with an unspecified constant) and a phenomenological equation, which has the same parameters as the percolation equations, are both able to quantitatively fit dc and first order experimental results, as a function of volume fraction and frequency, for continuum percolation media. However, only the analytical phenomenological equation, which has the same parameters as the percolation equations and reduces to them in the ideal cases, is able to fit the results for all frequencies and volume fractions, as well as the second order ac results. It can also be used to generate scaling functions for the dc results, as a function of the ratio of the conductivity of the two components and the volume fraction, as well as the first order terms of the ac conductivity as a function of frequency and volume fraction.

The major problem, with even the very accurately fitted results, is that the exponents s, t, $u(x)$ and $v(y)$ can sometimes, but not always, be described using existing theories. Also, in many instances, there is no theory which relates s, t, u and v. This applies to results fitted both to the original percolation equations or the new phenomenological equation. Reasons why previous theories for the exponents in granular systems, those most often measured, and the relations between them are inadequate will be advanced.

These experiments, for the first time, show that the exponent s is not the same for the dc conductivity and the ac dielectric constant below the critical volume fraction. These measurements also show that the dielectric exponent s is a function of frequency.

[¶]Presenter

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Abstract

3-D DC Conductivity of Polymer–Carbon Fibre Composites

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Although some investigators have reported the practical advantages of using carbon nanofibres in conducting composites, little has been done to understand the nature of the processing and the electrical behaviour of the polymer-nanofibre mixtures. In this study vapour-grown carbon fibres (VGCF) were mixed into a polypropylene (PP) matrix to make nanofibre composites by injection moulding in the form of a thin disk. Rectangular samples with one side along the flow direction were cut from disk at the same distance from the disk centre. As expected the DC conductivity versus filler volume fraction plots of both the systems show typical percolative behaviour in all three directions. However, the percolation threshold in the direction normal to the sample plane is higher than for the two other directions both for the PP/CCF and PP/VGCF composites. The conductivity data has been analysed using the single percolation type equation that has been successfully used to fit a wide number of continuum systems. This analytical method has revealed that the conductivity critical exponents for studied systems are similar in any direction. It has been found that the carbon fibres in both systems are highly oriented in the polymer flow direction and have an extremely low degree of disorientation with respect to the direction normal to the sample plane. Despite percolation theories predicting that there should be no anisotropy in percolation thresholds for infinitely large systems like the PP/VGCF composites such unexpected behaviour has been experimentally observed in this study. The anisotropy of percolation thresholds are discussed as a combined effect of the specific 3-D fibre orientation distribution and anisotropy of electrical conductivity in carbon fibres.

[¶]Presenter

Abstract

Structural Colours through Photonic Crystals

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It is becoming increasingly evident that Nature has developed a panoply of sophisticated optical systems which enable living creatures to control the way they reflect light. In most circumstances, chemical means (pigments) are used, but sometimes organisms need to use light efficiently, or particular pigments are difficult to make, or expensive in terms of energy. They then resort to structural means, creating composite materials in which interference and diffraction are used to create striking or camouflaging colour effects.

We discuss here the structures present in a marine creature, the sea mouse (Aphrodita sp., Polychaeta:Aphroditidae), and a butterfly (Teinopalpus imperialis). We show both exploit partial photonic band gaps to achieve colour effects. In the former case, the sea mouse achieves a striking iridescence of its spines and felt, with a strong peak reflectance which tunes with angle. We show the microstructure responsible for this and the iridescent effects in the figure below.

¶Presenter

Abstract

Spin Glass Behavior in Metalloporphyrin-based Magnets[4]

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Magnets are technologically very important materials that are essential in today's high-tech society. One new class magnets being studied is based on manganoporphyrins. Bulk magnetic ordering is observed with ordering temperatures, T_c, occurring below 30 K depending on the substituent, solvent, etc. Typically, this class of magnets exhibit frequency dependent ac magnetic susceptibility characteristic of spin glass behavior. Although spin glass behavior is well studied it is for spin dilute systems, it is not for spin concentrated, systems. Experimental data characteristic of the spin glass behavior will be presented, and the data will be discussed in terms of a novel viscous glassy behavior in a quasi-one-dimensional cluster glass.

[4]Supported in part by Department of Energy Grant Nos. DE FG 03-93ER45504 and DE-FG02-86ER45271 and NSF CHE-110685.

¶Presenter

Abstract

Exact Solutions for the Dispersion Relation in a Wide Class of Periodic Media with Complex Moduli

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In the physics of heterogeneous periodic media it is rare to find exact solutions for the overall effective behavior. Here we will obtain exact solutions for the dispersion relation for a large class of materials with complex moduli. In media where the dependence of the dielectric (or viscoelastic) tensor is analytic in the spatial variable z and bounded in the upper half plane $\Im(z) > 0$ (so that apart from constants the real and imaginary parts are Hilbert transforms with respect to z of each other) we find that the three-dimensional Bloch equations are macroscopically equivalent to those in a medium where the moduli are averaged over z. This effectively reduces the problem to a two-dimensional one. Moreover if the average over z is independent of x and y, one has replaced the heterogeneous material by an equivalent homogeneous one. Alternatively, if the dielectric (or viscoelastic) tensor of this new medium has a similar analytic dependence on the spatial variable y, one is left with a one-dimensional to solve.

Abstract

Using Terahertz Pulses to Study Light Scattering

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We describe a new experimental technique for studying the propagation of waves in scattering media, and apply it to the investigation of thin samples of a synthetic random medium. The measurements are based on terahertz time-domain spectroscopy, in which broadband single-cycle pulses of free-space terahertz (THz) radiation are generated and coherently detected using ultrafast photoconductive sampling. This technique offers several unique advantages over other methods used to study multiple scattering phenomena. First, the results are easier to interpret because the samples are extremely well controlled, and the refractive index and residual absorption coefficient are both known accurately. Second, the broad bandwidth of the THz radiation enables the observation of mean free paths ranging over nearly two orders of magnitude within the pulse spectrum. In principle, this permits the characterization of a full range of behavior in a single measurement. Finally, because the technique permits the direct measurement of the spectral phase of the transmitted radiation, a great deal of additional information is available. As a first demonstration of the utility of the THz system, we study the ballistic transport of THz pulses through dense distributions of spherical scatterers. We construct a model scattering medium using commercially available PTFE (teflon) spheres, of 0.794 mm diameter, contained in teflon sample cells. In order to study the ballistic transport as a function of path length, we have fabricated a series of cells, with a range of optical path lengths. These are inserted into the focus of the terahertz beam. The transmitted terahertz pulses can be used to determine the complex propagation constant for the ballistic radiation inside the medium, over a broad bandwidth. We compare these results to the predictions of the quasi-crystalline approximation (QCA). With this theoretical formulation, we compute the propagation constant using the Percus-Yevick pair distribution function to account for positional correlations of the spheres. These experiments probe a regime of very high volume fraction, which has not been thoroughly explored previously, but which could be of relevance in the understanding of electromagnetic propagation in biomedical systems. The correspondence between theory and experiment is reasonable, particularly with regard to the effective group velocity. This is somewhat surprising, since the fractional volume of particles in our experiment exceeds the accepted limits of the validity of the QCA.

¶Presenter

Abstract

Comparison of FFT-based methods for computing the response of composites with highly contrasted mechanical properties

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Numerical simulations of the behavior of composite materials have to take into account the complexity of their microstructural geometry. Realistic simulations involve a large number of degrees of freedom, and are consequently extremely consuming in terms of memory and CPU time.

FFT-based methods have proved their efficiency for mechanical problems (composites with linear elastic or elastic-plastic phases), and can often be much more efficient than classical finite elements methods. However the iterative method initially proposed by Moulinec and Suquet (1994) requires a number of iterations roughly proportional to the contrast between the moduli of the individual phases. The improved method proposed by Eyre and Milton (1999) has a rate of convergence proportional to the square root of the contrast, but still cannot be applied to composites with infinite contrast (like porous materials). An alternate scheme based on augmented Lagrangians and Fourier Transforms has been proposed by Michel, Moulinec, Suquet (2000) for highly contrasted or even infinitely contrasted materials.

The efficiency of these three methods are compared as the contrast between the phases is varied, and some applications are shown.

[¶]Presenter

Abstract

Critical Behaviour of Thermal Relaxation in Composites

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At a composition far above the percolation threshold, the resistance of a composite sample increases with time as a constant current is passed through the sample due to Joule heating. For a current less than the breakdown current, the resistance eventually reaches a steady value. The increase is found to be well described by a simple first-order exponential term with a characteristic relaxation time τ_h. Similarly, when the sample is allowed to cool down from the steady state by reducing the constant current to a small value the resistance relaxation is again described by a first-order exponential with a relaxation time τ_c which is however different from τ_h. Thus, relaxations during heating and cooling appear to possess different characteristic times. Both τ_h and τ_c exhibit critical behaviour as a function of the current I. Interestingly, it is found that the product $\tau_h \tau_c$ is a constant independent of I. τ_h diverges with I as $\tau_h \sim (1 - I^2/{I_b}^2)^{-\alpha}$ where I_b is the breakdown current and α is an exponent equal to 0.14. Consequently, τ_c goes to zero as I approaches I_b. Attempts to understand this unusual phenomena will be discussed.

¶Presenter

Abstract

Design of transportation network by an amoeba-like organism

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We report here evidence that an effective transportation network is designed by an amoeba-like organism of true slime mold Physarum polycephalum, which has network of tubes to transport chemical materials all through the organism. When many food-sources were distributed on an agar plate where the organism crawled, the organism found them and changed the network shape to connect the food-sources through only a few tube. Geometrical shape of the network is drastically variable depending on a set of locations of food-source. Statistical observation shows that the network geometry meets multiple requirements for effective network; short total length of tubes, close connection (small number of transit food-sites between any two food-sites) and fault-tolerance against an accidental disconnection of tubes. Local self-sustained cellular rhythms interact each other in the organism and pattern formation of the cellular rhythm underlie in mechanism of development of tube-network. Along this line, a mathematical model for self-organization of transport network is proposed and discussed.

Abstract

Time Domain Reflectometry Measurement of Bulk Permittivity of Porous Mixtures Containing Bound Water

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Time domain reflectometry has become an important measurement technique for determination of porous media water content and electrical conductivity in the earth sciences due to its simplicity and accuracy. Water content is inferred from the bulk dielectric permittivity of the medium usually based on travel time analysis along simple waveguides, whereas bulk electrical conductivity is inferred from TDR signal attenuation along a waveguide. The objectives are to (1) review TDR applications and primary factors affecting dielectric permittivity measurements and inference of water content of porous mixtures; (2) discuss approaches for estimation of critical parameters required for permittivity modeling such as water binding surface area, and constituent composition, shape and distribution; and (3) model porous mixture permittivity using dielectric mixing theories. Primary factors influencing permittivity measurements are free and bound water contents, chemical composition, temperature, constituent shape and phase configuration, and measurement frequency. The bound water content of porous materials often exhibits a reduced dielectric signature (within TDR frequency range) compared to that of free water due to strong association with hydrophilic surfaces, especially in the presence of appreciable amounts of clay minerals and similar materials. Bound water associated with solid surfaces exhibits a 'thermodielectric' effect that has been modeled using the temperature-dependent volume exchange between the bound and free water phases. Particle shape, layering and phase configuration, and bound water effects on permittivity predictions are accounted for in a three-phase dielectric mixing model.

Abstract

Scaling Conditions for Multiple Scattering in Fractal Aggregates[5]

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It is well know that under the first Born approximation, the cross section $d\sigma/d\Omega$ for light scattering from a fractal of dimension d_f scales with wavevector Q as Q^{-d_f}. The use of this formula to interpret scattering experiments performed at frequencies close to the resonances of the system is questionable, as multiple scattering cannot be neglected. In a previous work we studied the scaling properties of the light scattered by colloidal aggregates,[6] employing a novel multi-resolution hierarchical algorithm which allowed us the study of large systems taking fully into account the long-range of the interactions in multiple scattering calculations. Employing a scalar approximation, we obtained the conditions under which scaling may be present. Here we extend that work accounting fully for the vectorial nature of the polarization. We find that even under resonant conditions, the scattering cross section may scale with the fractal dimension d_f, but only if the aggregate is larger than a dissipation and frequency dependent length-scale L_h. For smaller aggregates, $d\sigma/d\Omega$ might scale with a different exponent or it might not scale at all, depending on the frequency of light employed. This could explain the discrepancies between experiments performed on similar systems within the strong scattering regime.

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[¶]Presenter
[6]G. P. Ortiz and W. L. Mochán SPIE **4419** 752 (2001).

Abstract

Bulk Response of Composites from Finite Samples

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Due to the long range of the dipolar interaction, boundary effects on the polarization induced on composite media made up of a disordered array of spherical particles remain finite even in the thermodynamic limit. Thus, the numerical calculation of the response of composites has frequently been preformed on infinite systems constructed by repeating periodically replicas of a unit cell with a finite number of particles and using Ewald summation techniques to compute the interactions between particles and their replicas [1]. As this procedure is computationally demanding, the number of particles in the unit cell has necessarily been modest. In this work we propose an alternative procedure. We calculate directly in real space the response of a finite spherical disordered composite sample taking account explicitly of its depolarization. To obtain an accurate result we have to include a relatively large number of particles, but with no replicas and therefore with simpler interactions. Furthermore, we accomplish our calculation in a very efficient way by employing a newly developed multi-resolution hierarchical scheme [2]. We compare our results with the numerical results of Ref. [1] and with those of an analytical theory [3] based on a renormalized polarizability which differs from the response of individual particles due to the fluctuations of the dipolar interactions. We have also extended the renormalized polarizability theory by calculating these fluctuations within our scheme without employing approximate expressions in terms of the two-particle correlation functions [3].

This work was supported by DGAPA-UNAM, CONACYT and CIP-COMEX.

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¶Presenter

Abstract

Resistance Switching and Memory in a Metal-Dielectric Nanocomposite System

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We observe electrically driven switching between stationary resistance states in a metal-dielectric composite system with hopping conduction, confined to a small volume. Sample preparation includes two main stages. First, a metal column consisting of Co and Cu layers is deposited in a via (channel) of dimensions 50×50, 100×100, 250×250, or $500 \times 500 nm^2$, etched by focused ion beams in a SiO_2 film. Then the microstructure is transformed irreversibly by application of a controlled high density current to the metal column. The transformation is manifested in both a considerable increase of resistance and a transition from metallic type of conduction to thermally activated tunneling. The resulting system is characterized by non-linear I–V curves with hysteresis. The resistance state can be switched by positive or negative voltage greater than 1.3 V. The minimum switching time is less than 1 ns. For interpretation of the switching and memory effects we apply the Simmons-Verderber model of charge trapping and release to a narrow dielectric gap containing metal granules.

¶Presenter

Abstract

Time reversal, imaging and communications in random media

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I will present an exposition of the mathematical problems that arise in using arrays of transducers for imaging and communications in random media. The key to understanding their performance capabilities is the phenomenon of statistically stable super-resolution in time reversal, which I will explain carefully. Signals that are recorded, time reversed and re-emitted by the array into the medium tend to focus on their source location with much tighter resolution when there is multipathing because of random inhomogeneities. I will explain how this super-resolution enters into array imaging and communications when there is multipathing.

Abstract

Improved Transmittance in One-Dimensional Metallic Photonic Crystals

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We show, from theoretical calculations including the absorption losses in metal layers, that the transmittance of a one-dimensional metallic photonic crystal can be increased up to 67%. The structure consists of five layers of Ag and four layers of GaN. The layer thickness of Ag is 30 nm, and that of GaN 64 nm. We further add one GaN layer of 32 nm at the top and the bottom, respectively. The total thickness of Ag layers in this photonic crystal is 150 nm, which is several times longer than the skin depth of Ag. However, we could achieve the peak value of 67% transmittance at 500 nm wavelength owing to the two half thick GaN layers added at the top and bottom of the film. Without these additional two layers, strong oscillations appear in the transmittance spectrum with the peak value of only 30%. When only one half-thick GaN layer is added to the structure, the oscillation becomes smoothed out so that the overall transmittance increases, but the peak value is still 30%. The two additional layers make the spectrum smoother and further increase the transmittance.

¶Presenter

Abstract

Theory of the Optical Properties of DNA-Modified Gold Nanoparticle Composites

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DNA-modified gold nanoparticle composites are materials consisting of many small gold particles (with diameters typically of order 20–40 nm) linked together by DNA strands. The optical properties of such composites depend dramatically on temperature [1,2]. At high temperatures, there is a strong extinction peak around 500 nm which is attributed to the surface plasmon resonances of individual gold nanoparticles, but as the temperature is lowered, this peak shifts towards longer wavelengths and broadens substantially. In this talk, we will describe a theory for this temperature-dependent change. The theory consists of two parts: (i) a model for the temperature-dependence of the composite structure, which is responsible for the change in the optical properties and (ii) a model calculation for the extinction coefficient of the composite, based on an application of the discrete dipole approximation [3] to the temperature-dependent structure.

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¶Presenter

Abstract

Refining the Perfect Lens

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Some time ago it was shown that a slab of material with, $\epsilon = -1$, $\mu = -1$ and suspended in vacuo, has the ability to focus a perfect image: both the near field and far field components are delivered to the image plane with the correct amplitude and phase reproducing every detail in the original source [1]. Real materials fall short of this ideal particularly in respect of losses which manifest themselves as imaginary components to ϵ and μ. In this talk we shall examine how to minimise the restrictions imposed on the lens. For example, we have been able to show that a slab of negative refractive index imbedded between two media of different (positive) refractive index also behaves as a near-perfect lens whose performance is limited by only the effects of absorption and retardation. that a slab of negative refractive index imbedded between two media of different (positive) refractive index also behaves as a near-perfect lens whose performance is limited by only the effects of absorption and retardation. It is only necessary that the perfect-lens conditions, which are also the conditions for the existence of a surface mode, are met at one of the interfaces.

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Abstract

Complex yet translucent: The optical properties of sea ice

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Keywords: Sea ice is a naturally occurring material with an intricate and highly variable structure consisting of ice platelets, brine pockets, air bubbles, and precipitated salt crystals. The optical properties of sea ice are directly dependent on this ice structure. Since sea ice is a material that exists at its salinity determined freezing point, its structure, and optical properties, are significantly impacted by small changes in temperature. Understanding the interaction of sunlight with sea ice is important to a diverse array of scientific problems, including those in polar climatology. A key optical parameter for climatological studies is the albedo, the fraction of the incident sunlight that is reflected. The albedo of sea ice is quite sensitive to surface conditions. A presence of a snow covered enhances the albedo, while surface meltwater reduces the albedo. Radiative transfer in sea ice is a combination of absorption and scattering. Differences in the magnitude of sea ice optical properties are due primarily to differences in scattering, while spectral variations are mainly a result of absorption. Physical changes that enhance scattering, such as the formation of air bubbles due to brine drainage, result in more light reflected and less transmitted.

Abstract

Estimating Conductance in Small Samples of Heterogeneous Materials by Random Walks

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The conductance of a small specimen of heterogeneous conductor relative to the conductance of a specimen of pure conductor of the same size and shape can be estimated through means of path-based properties of simple random walks. The procedure can be applied to any specimen whose internal structure is known, and does not require any assumptions regarding symmetry of structure or the size of heterogeneous inclusions. It generalizes methods for determining the effective resistance of a circuit from lattices to continuous specimens, and, when employed upon regular arrays of spheres, produces results statistically indistinguishable from those obtained by asymptotic methods. It is of potential use in the study of small samples of highly heterogeneous materials in which effective medium theories and similar asymptotic methods would be invalid.

¶Presenter

Abstract

Simulating Photons and Plasmons in a Three Dimensional Metallic Lattice

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We report on the development of a new finite element code, *Curly*, for solving the vector Helmholtz equation in a three-dimensional, periodic lattice. *Curly* differs from other codes in several respects: (1) it uses a novel scheme for the discretization of the identity operator to accelerate the convergence of the numerical error, (2) the stiffness matrix is assembled using a hash table object to provide unstructured mesh features, and (3) the code is written in the object oriented scripting language Python for ease of use, portability and graphics. Numerically intensive calculations, such as sparse matrix inversion, are relegated to fast C routines. Thanks to *Curly*'s accelerated convergence algorithm, the code operates at lower resolution than would otherwise be required for prescribed accuracy. Plasmons and photonic band structure calculations are presented in the Brillouin zone for a lattice consisting of intersecting conductors.

¶Presenter

Abstract

Electrodynamics of Metallic Photonic Crystals and Problem of Left-Handed Materials

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An exact analytical theory of the electromagnetic waves in metallic photonic crystals with a small volume fraction of a metal is presented. It is shown that there are waves with a very low cutoff frequency ω_0 and that the permittivity ϵ is negative below ω_0. We show that if the crystal is embedded into a medium with negative μ, it has no propagating modes at any frequency. Thus, such a compound system is not a left handed material (LHM). The recent experimental results on the LHM are discussed.

¶Presenter

Abstract

Random Lasing in Pi-conjugated Polymer Films

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When an active medium is placed in a resonance cavity, laser emission can occur. Surprisingly, laser emission can occur in systems where there is no obvious external cavity, the term "random lasing" is often applied to these various systems. We studied films of a Pi-conjugated polymer which showed narrow, < 0.5nm, emission lines. Photon counting established the lines were coherent, and therefore laser emission. Coherent backscattering showed the mean scattering length was approximately 10 emission wavelengths. The average Fourier transform of many individual locations revealed a universal resonator length in the films.

¶Presenter

Abstract

Quantum Hopping in Doped Conducting Polymers[7]

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Metallic doped polymers (polyaniline and polypyrrole) have an electromagnetic response [1,2] that, when analyzed within the standard theory of metals, is provided by an extremely small fraction of the total number of available electrons ˜0.1% (in contrast to ˜100% for common metals such as Cu, Ag, Al, or Ni) but with anomalous long scattering time $>$ 10–13 s (˜100 times longer than for common metals). We show that a network of metallic grains (the polymer's crystalline domains) connected by resonance quantum tunneling through strongly localized states in surrounding disordered medium produces this behavior. The small fraction of electrons is assigned to the low density of resonance states and the long scattering time is related to the narrow width of energy levels in resonance.

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Abstract

Transport of Fluid Mixtures in Nanoporous Materials

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Nanoporous materials are currently of great interest. Examples include membranes, catalyst, adsorbents, low-dielectric materials, skin and biological tissues. These materials, depending on their pore space morphology, contain a range of pore sizes. However, the main resistance to the transport process is offered by interconnected nano- and mesopores. Because of the exceedingly small sizes of the pores, the behavior of fluids and their mixtures inside such pores is very different from that in the bulk. Hence, one must resort to molecular dynamics simulations in order to gain a better understanding of transport of fluid mixtures in such materials. Since transport in such materials takes place under an external driving force, such as a chemical potential or pressure gradient, one must use non-equilibrium molecular dynamics simulations, which are far more complex than equilibrium MD methods, especially when one wishes to simulate transport of fluids in a three-dimensional pore structure. We describe recent advances in understanding transport of fluid mixtures in nanoporous materials using NEMD methods. We also describe a statistical mechanical theory that provides adequate description of some of the phenomena that occur in nanopores during transport of fluid mixtures.

Abstract

Plasmons in Nano-wires and Left-handed Plasmonic Materials

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Recently, the problem of EM field distribution for long and thin nanometer-sized needles (nano-wires) has attracted growing interest (see, e.g., [1]). We consider metal needles, whose diameter is much smaller than the wavelength of incident light, and whose length is of the order of the wavelength. The electromagnetic field distribution for nanowires is found, by using the discrete dipole approximation beyond the quasi-static approximation as well as analytical solution for a plasmon localized in a nanowire [2]. By using these approaches we simulate the field distribution for individual nm-sized metal needles and for a percolation composite formed by such needles. For individual needles, it is found that the surface plasmon polaritons can be excited, resulting in large local fields. For percolation composites formed by the needles, our simulations suggest localization of the plasmons and strong local field enhancement associated with these localized plasmons. The theory is in agreement with the near-field optical experiments performed by Moskovits' research team in UCSB [3].

We also show that in plasmonic composite nanomaterials both dielectric permittivity and magnetic permeability can be negative, opening up new means for fabricating left-handed materials [2], with the negative refractive index in the visible and near-infrared parts of the spectrum. Specifically, such optical left-handed materials can be fabricated, using metal nano-wires or metal-dielectric percolation composites [2,4].

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Abstract

Resistance of Size-Quantized Inhomogeneous Films

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Investigations of transport phenomena in low-dimensional systems such as size-quantized films or quantum wells have attracted much attention recently. As a rule short-range models of impurity potential are used to treat the carrier scattering. Meanwhile, there are 2D-systems (films) where nanoscale inclusions may be embedded. In the present work we have investigated the resistance of the inhomogeneous 2D-systems with long-range scatterers. As a model of the 2D-system is considered the size-quantized film in which two-dimensional electron gas with a two-dimensional subband structure is formed. It is assumed that in 2D-systems there are nanocenters (for instance, hetero phase inclusions or quantum dots). In this case extended states of the 2D-system may be interfered with localized states of nanocenters. The resonances caused by the coupling of the extended states of the two-dimensional subband with the localized states of the nanocenters are predicted. It is demonstrated that the finite size nanocenters give rise to a series of quasi-localized states, which manifest themselves as resonance-antiresonance pair in the cross sections and in the residual resistance. It is shown that the characteristic of resonances determine the magnitude of the configuration coupling of different states in quantum films (A. M. Satanin and V. B. Shtenberg, JETP Letters, Vol. 75, No 3, 146 (2002)). The resonance contribution to the resistance can be revealed, e.g., by the dependence of the resistance on the position the Fermi level.

¶Presenter

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Abstract

Dispersion and Localization of Excitations in Disordered Polar Matter

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It is well known that the coupling between photons and phonons in polar matters, for instance, ionic crystals or polar semiconductors, is strong near optical-phonon-photon resonance and gives rise to new quasiparticles — polaritons (M. Born and K. Huang, Dynamical theory of crystal lattices, 1954 J. J. Hopfield, Phys. Rev. 112, 1555 (1958)). In the present work we have investigated polariton excitations in inhomogeneous (disordered) polar matters. A simple model of isotropic disordered polar matter is formulated. To describe transverse optical excitations the displacement and the vector-potential are entered. Intermixing ions and electromagnetic excitations may be depicted by coupled mechanical and electromagnetic equations. In a homogeneous system as a consequence of the matters coupling the dispersion may be found from a forth order algebraic equation while in an inhomogeneous polar matter with random parameters eigen frequencies have to be found from the nonlinear eigenvalue problem. We have shown that in the space of doubled dimension the problem of polariton propagating may be reformulated as the Anderson localization problem with a nonsymmetric random matrix. By using an effective numerical approach we investigate the density of states and the level distribution. The eigenvalues near the polaritonic gap are tested for localization by a calculation of the participation rate.

Abstract

Statistical Modeling of Light Propagating Through a Semi-Transparent Cone

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How does the light propagate through a transparent medium? The answer is straightforward — along the straight line. In the optic fiber, in contrary, the light can propagate in any direction even in the orthogonal if the fiber is bent accordingly. The important factor, however, is the curvature of the bending. If the radius of curvature is small enough the light can escape. Modes of light propagating through the fiber are well studied in framework of classical and wave optics both. Here, we study the propagation of light in different geometries such as a cone, a truncated cone, a pyramid, a parabolic cone, or a hyperbolic cone. A code has been written to analyze different geometries, different refraction indices and absorption coefficients, and the input parameters of the beam (such as aperture, different angular distributions, and diameters of the beam). The objective was to analyze the output parameters (and modes) of optical details concentrating mainly on angular and spatial distributions of light on the screen located on a given distance from the cone and finding the geometry which provides the most even distribution (in one case) and the most sharp distribution of intensity (in the second case). Mathematically the problem is formulated as the transport equation in semi-transparent medium (no dispersion) with semi-reflective semi-transparent boundary conditions. Rays of light passing through the medium had unit intensity at the entry point. While propagating the rays split and multiply on the boundary losing the intensity and, as a result, form a unique distribution of light on the screen. Optimization of spatial distribution had been carried out. This research can be used in undergraduate teaching and as the illustration of method of statistical modeling and basic optical principles.

Abstract

Plasmonic Nanophotonics: Manipulating Light and Sensing Molecules

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Metal-dielectric nanostructured materials, which can support various plasmon modes, open new avenues for manipulating light with light itself and sensing molecules with unsurpassed sensitivity. Fundamentals of optical properties of meso- and nano-structured metal-dielectric composites, both ordered and disordered, are reviewed in this presentation. Specifically, the following unique properties and applications of plasmonic nanomaterials are emphasized. (i) We argue that metal nanostructures can be employed for fabricating low-loss plasmonic band-gap structures with large and scaleable photonic band gaps and as left-handed materials (ii) We show that optically thick metal films with modulated refractive index can support both propagating and localized plasmon modes, allowing the extraordinary light transmittance, which can be controlled by the light itself via optical nonlinearities. (iii) We also show a feasibility of photon circuiting in plasmonic materials, similarly to conventional electron circuits, which might result in novel applications in the emerging area of nanophotonics. (iv) Finally, we demonstrate that the scale-invariant fractal symmetry of disordered nanocomposites results in localization of plasmons by random, nanometer-sized plasmonic resonators, where the local field exceeds the applied field by many orders of magnitude and optical nonlinearities are dramatically enhanced in a broad spectral range from the near-UV to the far-IR. The electromagnetic modes focused within the nm-sized "hot spots" act like nano-antennas and make possible a number of novel applications in photonics, laser physics, and spectroscopy.

¶Presenter

Abstract

Coarse-grained models of the visual cortex

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The visual cortex performs some of the first, fundamental tasks in the dynamical processing of visual information by the brain. It also has a fascinating neuronal architecture that is characterized by a laminar structure, activity and coupling across multiple scales, and an input signal that is apparently a mix of ordered and disordered information. The functional consequences of this architecture are just beginning to be understood. I will discuss coarse-graining (CG), or homogenization, methods used for constructing reduced models of the neuronal network dynamics. The resulting CG models capture both the effects of ordered and disordered input, and of cortical network coupling, and are being used to understand the mechanisms by which more complicated "point-neuron" models produce physiologically consistent responses

Abstract

Locally Resonant Sonic Materials[8]

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We have fabricated a new type of composites with a microstructure size in the millimeters to 2 cm range, which display localized sonic resonances at 350 Hz to 2000 Hz. Around the resonance frequencies the composite behaves as a material with effective negative elastic constants and as a total wave reflector—a 2 cm slab of this composite material is shown to break the conventional mass density law of sound transmission by order(s) of magnitude. When the microstructure is periodic, our composites exhibit large elastic wave bandgaps at the sonic frequency range, but with a lattice constant order(s) of magnitude smaller than the corresponding sonic wavelength in air. Good agreement is obtained between theory and experiment.

[8]Work done in collaboration with Zhengyou Liu, Yiwei Mao, Xixiang Zhang, Zhiyu Yang, and C. T. Chan.

Abstract

Novel Left-Handed Material Based on a Network of Plasma Channels

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Left-handed materials (LHM) have the unusual property of having negative magnetic permittivity $\mu < 0$ and dielectric constant $\epsilon < 0$. Due to their counter-intuitive refractive properties, LHMs have been recently proposed for making novel lenses. While LHMs do not occur in nature, they can be designed from naturally occurring building blocks. We present the results of numerical and analytic modeling of such a medium. The new composite medium is periodic in two dimensions, and consists of two materials with different dielectric constants, $\epsilon_1 > 0$ and $\epsilon_2 < 0$. Conceptually, this medium can be thought of as the periodic network of plasma channels. This periodic structure is conceptually simple and does not involve the complicated split ring resonators which were employed for constructing the LHM in the microwave range. Therefore, the proposed composite material shows the path to extending LHMs to terahertz or optical frequency bands. Depending on the desired frequency, the plasma-like medium can be composed of a phonon-polariton material (e.g., LiTaO3) or thin wires. We present the mean-field description of the thin-wire meshes in two and three dimensions.

¶Presenter

Abstract

Probing the Spontaneous Generation of Nanoscale Energy Localization[9]

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It has been realized for decades that spatially localized vibrational modes can occur in purely harmonic lattices only when disorder is introduced so that the translational invariance of the underlying lattice is removed. In recent years it has been recognized that some excitations in perfect periodic lattices which contain both nonlinearity and discreteness can localize resulting in inhomogeneous dynamical patterns, thus the study of this intrinsic localization in nonlinear periodic lattices is now under intense investigation for a variety of different physical systems. For macroscopic nonlinear systems such as Josephson junction arrays intrinsic localized modes (ILMs) have been readily observed. For condensed matter the spins in an antiferromagnetic crystal provide an experimentally accessible atomic system and here I describe our continuing investigation of the production of nanoscale localization for spin excitations. Our experimental and simulation studies show that in certain cases when the uniform mode is excited into a highly nonlinear regime it becomes modulationally unstable and breaks up into ILMs. This talk will outline the physically exciting context that is currently emerging: how macroscopic parameters such as crystal shape, DC magnetic field, and details of the E&M coupling can influence the nanoscale ILM generation process.

[9]Work supported by NSF-DMR and carried out in collaboration with L. English, B. Hubbard, R. Lai, and M. Sato.

Abstract

An effective field perspective on the nonlinear optical properties of artificially structured materials

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In recent years there have been a number of breakthroughs in the fabrication of artificially structured materials with optical properties are of interest. These include not only photonic crystals, but coupled cavity and coupled microresonator structures as well. Because these structures are periodic or nearly so in at least one dimension, their linear optical properties are characterized by dispersion relations that can exhibit regions of high and low group velocity, and high and low dispersion. Their nonlinear properties will therefore be characterized by soliton and solitary-wave like effects, should be of interest from the fundamental perspective of nonlinear dynamics, and may be of use in switching operations for telecommunication applications.

Despite the fact that the index contrast of the constituent materials in these structures can be quite large, and varies on the order of the wavelength of light, realistic effective field theories for these materials can be developed for the propagation of pulses of light whose length is many times the lattice period. We describe one approach to constructing such theories, based on a canonical description of the electromagnetic field, that allows for an easy construction of conserved quantities and their relation to the symmetries of the system.

Illustrations are given using structures of both fundamental and practical interest.

Abstract

Fluid permeability and DC conductivity of networks with a broad distribution of bond resistances: Comparison of the critical path approximation with 3-D Monte Carlo simulations

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Viscous fluid flow and electrical conduction in porous media has been studied in the past using a random resistor network model with a wide distribution of bond conductances. Calculations of fluid permeability and DC conductivity for these systems can be made using the critical path method. The basic idea of the critical path method is that in strongly inhomogeneous media flow occurs primarily on a few pathways that have significantly lower resistance than all other possible pathways, and that the biggest resistors on those low resistance pathways control the overall resistance of the system. Percolation theory is used in critical path analysis to quantify the expected number of low resistance pathways and to calculate the system conductivity. Monte Carlo computations of the conductivity for two-dimensional systems are in agreement with the critical path calculation, but three-dimensional computations have consistently deviated from the critical path prediction. It has been speculated that the discrepancy in 3D is due finite-size effects on the percolation correlation length. The present work evaluates the 3D critical path approximation using Monte Carlo data that are more extensive than previously available, and includes an analysis of finite-size effects.

Abstract

Vector Percolation Model for Flow of Fluid and Diffusion of Air Through a Porous Medium

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We discuss the application of percolation theory and fractal modeling to porous media. Percolation is a vector process, which can be characterized by new specifically vector characteristic like the curl of the vector velocity of fluid. Only the universal percolation model that covers scalar and vector cases simultaneously can give a real topological picture of a porous media. One of the most useful aspects of percolation is that many very complicated systems have the same behavior with the same critical exponent. This central property of theory is known as universality. The experimental hydraulic permeability of fluid and gas flow through unconsolidated sand shows good agreement with relative permeability curve of a percolation model, consisting of random network with variable-sized channels (straight tubes). The low-Reynolds-number flow problem is solved by Stokes equation. We calculate permeability and diffusion in micro scale (for single pore with radii r corresponds different local permeability laws such as r, r2, r3 or r4) and in the larger scale to describe the effects of randomness and topology in porous media.

¶Presenter

Abstract

Negative Refractive Composite Media

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We have demonstrated, using simulations and microwave experiments, that a composite medium possessing a frequency band over which the electric permittivity and magnetic permeability are simultaneously negative can be constructed. This composite medium, termed a "left-handed" medium by V. G. Veselago, has an index of refraction that is also negative, a property not found in naturally occurring materials. The fabricated material is a periodic array comprised of two interleaved composite arrays: a conducting rod medium and a conducting Split Ring Resonator (SRR) medium. Both of these constituent materials have been recently analyzed by J. B. Pendry et al., who showed that the rod medium has a negative permittivity below a cutoff (or "plasma") frequency, and that the SRR medium has a region of negative permeability. While not immediately obvious, combinations of these medium result in a composite in which the properties of each sub-array are retained that is, interaction effects between the rod and SRR arrays are minimal.

We have utilized a variety of techniques to characterize the composite media in terms of the bulk material parameters epsilon and mu. Typically, we perform finite-difference or finite-element simulations of either a finite or infinite structure, and then interpret the results by either averaging the local fields to find the "macroscopic" fields (for an infinite structure), or performing an S-parameters inversion (for a finite structure). Both methods provide a means of characterization, and produce results in agreement with each other and experimentally obtained data.

Abstract

Femtosecond Energy Concentration in Nanosystems: Coherent Control

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We predict that excitation of a nanosystem with a correspondingly phase-modulated femtosecond pulse can cause concentration of the excitation energy at a small part of that nanosystem [1]. The location of the excited site is coherently controlled by the distribution of the phase along that pulse, distinct from the "Ninth Wave" effect [2]. We discuss unique possibilities of using this in applications, in particular, for nanoscale ultrafast computing and nano-lithography. The theory is based on the Green's function method in the spectral representation [3,4] employed as an analytical approach and implemented as a high-efficiency numerical method in the real 3D space.

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[4] M. I. Stockman, S. V. Faleev, and D. J. Bergman, Phys. Rev. Lett., 87, 167401 (2001).

[¶] Presenter

Abstract

Control of nano- and micro-scale inhomogeneities using surfactants in III/V alloys

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Thin films of semiconductor alloys are subject to spinodal decomposition due to the atomic-level-strain-energy induced deviations from thermodynamic ideality. This gives rise to micro-scale inhomogeneities that are controlled by kinetic factors during epitaxial growth. For (001) films, anisotropic surface diffusion coefficients give rise to a one-dimensional compositional modulation (CM) that is reflected in the surface morphology of the epitaxial layer. The nature of the inhomogeneities and the magnitude of the compositional fluctuations in GaInP grown by organometallic vapor phase epitaxy can be determined by controlling the surface diffusion kinetics during growth. This CM has profound effects on the optical properties of the material. In particular the effects on the low temperature photoluminescence energy, anisotropy, and decay lifetime are dramatic. Surface thermodynamic effects can produce an entirely different form of inhomogeneity, namely ordering. This phenomenon, occurring on the sub nanometer scale, also has a large effect on the bandgap energy as well as the polarization and lifetime. This paper describes how both of these phenomena, ordering and compositional modulation, can be controlled in GaInP via the addition of surfactants isoelectronic with P, most notably Sb and Bi, during the epitaxial growth process. This leads to a new level of control of the materials properties of an alloy without affecting the average solid composition or the Fermi level. It also allows the possibility of deliberately and controllably introducing bandgap inhomogeneities in grown structures to produce, e.g., heterostructures and quantum wells.

more
note:poster

Abstract

Absorption in Multiple Scattering Systems of Coated Spheres

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We present formulae for rigorous, numerically stable T-matrix type calculations of absorption in multiple dependent scattering systems in which the scatterers are multiply coated spheres (not necessarily concentric). This method permits reliable calculations for situations in which any of the spherical coatings, cores, or host media are composed of absorbing materials.

For a non-absorbing host media, the total absorption may be deduced from overall energy conservation. A more detailed description of the absorption is obtained through formulae yielding the absorption within individual scatterers and/or coatings. This more complete description is particularly useful when treating absorbing host media.

Results will be presented illustrating the utility of these methods in optimizing the design parameters of inhomogeneous absorbing media. Particular attention will be paid to the numeric stability of our results. We shall also illustrate the utility of analytic orientation averages in calculating transport properties of multiple scattering systems.

¶Presenter

Abstract

Single Component, Multiphase Lattice Boltzmann Models (LBM) in Invasion Percolation

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Single component, multiphase LBM (e.g., models that simulate water and its vapor) offer a unique opportunity for computing invasion percolation-like fluid advance in realistic porous media (derived from imaging techniques) by simulating the physical behavior and configuration of liquid/vapor and liquid/solid interfaces. Applied to typical percolation domains, where the assignment of size/invasion probability to each site in a regular network is random, the proposed approach retains the simplicity and qualities of percolation models and enhances the treatment of fluid physics, including vapor flow and the potential for simulations at relatively high capillary numbers. The complex geometry of connected paths in such percolation models arises solely from the random spatial arrangement of simple elements on a lattice. In reality, fluid interfaces and connectivity in porous media are naturally controlled by the details of the pore geometry and its interaction with the fluid and the ambient fluid potential. The multiphase LBM approach admits realistic pore geometry derived from imaging techniques and incorporation of realistic hydrodynamics into invasion percolation models, and advances our understanding of constitutive transport properties in multiphase systems.

¶Presenter

Abstract

Bistable Behavior of a Photonic Crystal Non-Linear Cavity

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A Fabry-Perot cavity can be closed with reflecting slabs made with different types of materials. An interesting situation occurs when the slabs are constructed from a photonic crystal in the non-propagating regime, i.e. with an incident frequency tuned to an evanescent mode. The situation is even more interesting when the cavity itself is filled with a non-linear Kerr medium, i.e. a material which changes its index of refraction with the transiting intensity. The response of this system to high-intensity incident waves falling normal to the interferometer is studied in detail. It is shown that (1) the photonic-crystal slabs are able to concentrate the energy density in the cavity so that non-linear effects are enhanced; (2) the index of refraction of the material which fills the cavity changes in a significant way as a function of the incident power; (3) in specific intensity ranges, the index of refraction in the cavity is multi-valued, leading to a bistable behaviour of the Fabry-Perot filter. The hysteresis cycle of the index of refraction, the transmission coefficient and reflection coefficient is described for a system using arsenic sulfide glass as a cavity-filling medium, and gallium arsenide - vacuum structure as photonic crystal slabs.

[¶]Presenter

Abstract

The Frequency Dependence of the Localization Length in One-Dimensional System

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The effect of localization both quantum and classical waves has been intensively studied thorough the last decade. The apparent simplicity of the one-dimensional system attracts the investigators but does not give simple answers. This concerns the frequency dependence of the localization length. In spite of the Herbert-Jones-Thouless theorem that there should be a high frequency limit, which is equal either to zero or to a constant, and of theoretical investigations that connect the zero limit with smooth interface between layers and the non-zero valued limit with sharp one [1], there are systems in which there is neither the limit nor even localization [1].

Is shown that the zero-valued limit is observed in a delta- correlated-process only [2] where there is no reference scale of length, and the scaling could be applied. According to scaling the localization length is inversely proportional to the square of frequency [2].

Any system with final thickness of layers exhibits non-zero limit if such a limit exists at all. Moreover, is shown that the existence of high frequency limit is connected with a presence of an infinite set of incommensurable optical path in the system (the merge of layers with commensurable optical paths should be equal to zero). The value of the limit is determined by the mean thickness of the layer. While dealing with electromagnetic waves the existence of localization demands the impedance distribution. However this requirement is feebler than the requirement of optical path distribution. For example, two different values of impedance are enough for existence both of localization and of limit of localization length in the system where there are the merge of layers with identical optical paths is equal to zero.

The literature.

1. P. Sheng “Introduction to wave scattering, localization and mesoscopic” Academic Press, London (1995)

2. V. I. Klyatskin and A. I. Saichev UFN 162 161 (1992)

¶Presenter

Abstract

A New Method of Homogenization of the Maxwell Equations

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A new method of homogenization of the Maxwell equations is proposed. This method is based on newly proved mathematical lemma that any vector field can be presented as a sum of its “electrical dipole”, “electrical quadrupole” and “magnetic dipole” moments. The responding “moments” have a well-known form of the common moments as if the vector field is a current density. This presentation of the vector field is exact and connects neither to multipole expansion nor to the Helmholtz theorem. This lemma permits consequently introduce a concept of magnetic permeability at high frequencies even in the case of impermeable ingredients. The deduced renormalization group equations result in effective fields, which are governed by the usual material Maxwell equations, but differ from the mean values of the same-named fields. As illustrations of the method are presented (1) the derivation of the known EMA formula that takes into account the skin effect, this derivation emphasizes the role of anapole moment of currents, (2) consideration of the properties of q-media (media where the quadrupole interaction of fields with matter is prevalent) are considered.

Abstract

Nonlinear Polaritons of Antiferromagnetic Superlattices

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We investigate nonlinear polaritons of antiferromagnetic superlattices, or antiferromagnetic multilayers. In the third-order approximation, an effective-medium theory and a coordinate system with the y axis normal the interfaces, and sublattice magnetization and anisotropy axis parallel to the z axis, are applied to obtained the dispersion equations for the polaritons in different geometries. These equations show that the nonlinearity does not influence the polaritons propagating in the x-y plane or along the three axes, but influences clearly the polaritons with wave vector in the x-z and y-z planes. Numerical results tell us that the nonlinear wavenumber shift versus frequency is always positive for those polaritons in the bulk continuum above the antiferromagnetic resonant frequency, but in the continuum below this resonant frequency, the nonlinear shift is negative in most of the frequency region and is positive in a small region. Combine linear dispersion curves, these results also show that the relevant envelope solitons can exist in most of the bulk continua, and cannot appear in the small region mentioned above. The parameters for numerical calculations come from the FeF_2/ZnF_2 superlattice.

[¶]Presenter

Abstract

Numerical Computation of Wave Motion through Dynamic Materials

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Dynamic materials are spatio-temporal composites formed from materials which are distributed on a microscale in space and in time. These materials are of particular interest when we want to affect the influences of long wave disturbances. A dynamic disturbance on a scale much greater than the scale of a spatio-temporal microstructure will perceive this formation as a new material with its own effective properties. With spatio-temporal variability in the material constituents, we shall be able to effectively control the dynamic processes by creating effects that are unachievable through purely spatial (static) material design. For example, by appropriately controlling the design factors of a dynamic composite, it is possible to selectively screen large domains in space-time from the invasion of long wave disturbances. One is also able to eliminate the existence of the cut-off frequency in electromagnetic waveguides.

In this talk, we focus on the direct numerical simulation of wave motion through dynamic composites. Work is presented for laminated materials where the material properties are periodic and move with constant velocity. We present numerical results and the numerical and analytical challenges that arise in various scenarios.

Abstract

Homogenization Study of Resonances in Photonic Structures

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Using the ideas of homogenization theory we study the leakage rates or scattering resonances associated with certain classes of optical waveguides with transverse microstructure. We derive and prove the validity of an effective (averaged) potential model. We further show how homogenization theory yields higher order corrections to the resonances and fields due to microstructure. Finally, we implement our theory numerically for various microstructure waveguides.

¶Presenter

Abstract

Homogenization of Maxwell's Equations

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Abstract: If the typical spatial length scale in a heterogeneous material is much smaller than the wavelength of an electromagnetic field then the field can not resolve the fine scales. In numerical implementations the fine scales require a numerical mesh which is far too large for any computer. One way to take care of that problem is to homogenize the Maxwell equations, i.e. to find the effective material properties of the heterogeneous material. The effective properties correspond to a homogeneous material which is a good approximation of the heterogeneous material in the sense that the solutions of the homogenized equations are good approximations of the solutions of the original equations. The effective material properties are obtained by solving local problems on the unit cell and taking suitable averages. I will give examples of how the Maxwell equations can be homogenized, using two-scale convergence, in some linear and nonlinear cases. In particular I will address homogenization of varistor ceramics, nonlinear resistors used as devices for protection against surges in power lines.

Abstract

Two and Three Dimensional Ordered Structures in Electro-magneto-rheological Fluid[10]

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We have observed both two dimensional [1] and three dimensional [2] ordered structures in electromagnetorheological (EMR) fluids by using uniform-sized microspheres coated with a inner layer of nickel and outer insulating materials. For the 2D structures, the magnetic microspheres floating on a liquid meniscus were seen to form planar crystal structures with lattice constant which is variable as a function of applied normal magnetic field. Other symmetries, such as oblique, centered rectangular, square, and even local formations of quasicrystals with five-fold symmetry, were also obtained under a tilted external magnetic field, where the structural transition from 2D to 1D can be also observed. Here the balance between the repulsive magnetic interaction and the “attractive” interaction, due to the weight of the particles projected along the surface tangent, is the basic underlying physical mechanism. Three dimensional ordered structures with body-centered tetragonal (BCT) or face centered cubic (FCC) symmetries were obtained by dispersing the coated microspheres in liquid and applying crossed electric and magnetic fields.

[10]Work done in collaboration with L. Zhang, P. Sheng, N. Wang, H. Ma, Z. Lin, W. Y. Tam, and C. T. Chan.

Abstract

Liquid Crystal Infiltrated Random Media: From the Optical NTC-Resistor to Temperature Tunable Random Lasers

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We will discuss experiments on various disordered dielectric systems that are infiltrated with liquid crystals. An example of such a material is liquid crystal infiltrated macro porous glass. The diffusion of light in such a system depends strongly on temperature, which allows to tune the diffusion constant of a single sample. This is a new feature in multiple light scattering studies and opens up interesting possibilities. For instance, it allows to create a random laser with a laser threshold that depends on temperature. This tunable random laser was realized by introducing optical amplification in a liquid crystal infiltrated sintered glass. It represents a new type of light source with an emission spectrum that can be controlled via environment temperature and switched via an external electric field. [See also: wiersma et al., Nature 414, 708 (2001).]

¶Presenter

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Abstract

Light transport in cold atoms: the fate of coherent backscattering in the weak localization regime

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After a few mean free paths, a wave propagating in a strongly scattering medium rapidly looses the memory of its initial direction. At this scale, propagation can be described by a diffusion process. However this description discards an important phenomenon : interference between multiply scattered waves. It is now known that interference can profoundly alter the wave transport. An extreme situation is that of the Anderson (or strong) localization regime, where diffusion vanishes. In the intermediate regime of weak localization, light diffusion is hampered by interference. A hallmark of interference effects in multiple scattering is provided by the so-called coherent backscattering effect (CBS), an interferential enhancement of diffuse reflection of light off a disordered sample. CBS has been widely studied with classical samples like semi-conductor powders, white paint, teflon, etc. The use of atoms as scatterers gives rise to new possibilities. They indeed exhibit some peculiar light scattering properties (internal structure, optical pumping, saturation effects, resonant scattering, etc) and the now well-established techniques of laser cooling allow one to fully exploit the potentialities of this atomic scattering medium. For example wave effects in the external motion of atoms as well as statistical aspects (BEC condensates) should open new areas in the field. The purpose of this talk is to describe our experiments on coherent backscattering and to present various aspects of quasi-resonant light scattering in optically thick samples of laser cooled atoms. In particular, we shall stress the dramatic impact of the atomic internal structure on weak localization, a role which may be of importance in the search for strong localization of light in cold atoms.

¶Presenter

Abstract

Measurements of Spin-Dependent Exciton Formation Cross-Sections in pi-Conjugated Oligomers and Polymers

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The spin dependent exciton formation cross-sections are directly related to the singlet exciton yield in organic LEDs (OLED), which determines the maximum quantum efficiency for OLEDs. We report on an experimental study of the ratio $r = \sigma_S/\sigma_T$. Here σ_S is the formation cross-section of the singlet exciton channel and σ_T is the cross-section of any one of the three triplet exciton channels in the charge-transfer reaction between spin $1/2$ positive and negative polarons. We developed an all-optical technique for measuring r, which combines steady state photoinduced absorption (PA) and a spin-dependent recombination technique, namely PA-detected magnetic resonance (PADMR). Upon magnetic resonance the PADMR spectra generally show a reduction of polaron and triplet populations, and a single positive band that we assign to enhanced singlet population. This directly demonstrates that $r > 1$ in pi-conjugated polymers. Moreover the fractional reduction, d_n/n in polaron density, n is directly related to r. We have obtained r for a large variety of pi-conjugated oligomers and polymers and studied the dependencies of r on optical gap and conjugation length, CL. We use a direct and universal spectroscopic method, which we developed, to determine the average CL of a polymer. Our main result is the discovery of a universal relationship between r and CL largely independent of backbone and sidegroup structure. Our results also show that polymers have an advantage over small molecules for their use in OLED. We advance possible explanations for the universal dependence r(CL).

¶Presenter

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Abstract

Photoinduced Electronic Interaction Between a Poly(p-phenylene vinylene)-derivative and Single Wall Carbon Nanotubes

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It is known that charge separation upon photoexcitation is very inefficient in pi-conjugated polymers, preventing applications such as organic photovoltaic. Much research effort has therefore concentrated on doping polymer films with electron acceptors that promote photoinduced charge separation. Here we report on a study of photoexcitation of single-wall carbon nanotubes (SWNT) as well as C_{60} polymer composites. We have studied the photoinduced electronic interaction between a poly(p-phenylene vinylene)-derivative (MEH-PPV) and SWNT as well as C_{60}. In our study we used various continuous wave spectroscopies such as photoluminescence (PL) and photoinduced absorption (PA). We have found evidence for electronic interaction of the photoexcited MEH-PPV and the SWNT or C_{60}, whereas there is no significant interaction in the ground state. The PL emission that originates from the polymer is considerably quenched in the composite films and the polaron PA band dramatically increases. These indicate that efficient photoinduced charge separation occurs in the composites.

¶Presenter

Abstract

Dielectric Behavior of Corrugated Membranes[11]

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We have employed a Green's function formalism to study the dielectric behavior of a model membrane, formed by two periodic interfaces separating two media of different dielectric constants. It is known that lipid bilayers, which abound in living cells membranes, exhibit a ripple phase of the bilayer-water interface, in a narrow temperature range. The ripple phase is characterized by permanent wave-like deformations of the interfaces. We solve the Maxwell's equations by a surface integral equation thus it greatly simplifies the solutions and yields accurate results for membranes of arbitrary shape. The integral equation is solved and dielectric dispersion spectrum is obtained for a model corrugated membrane. We report a giant dielectric dispersion as the amplitude of corrugation becomes large.

[11]Work in collaboration with Prof. G. Q. Gu, Prof. Hong Sun and Dr. Jones T. K. Wan.

Abstract

Estimation of the Permeability of a Porous Medium Using the Geometric Structural Function

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Permeability or hydraulic conductivity of porous geological media are the most important properties of reservoir engineering and the most difficult to measure on a reservoir scale. Although many works are devoted to the problem of relating electric and hydraulic conductivity based on Kozeni-Carman relations, network models, or experimental data fitting, definite progress has been sporadic. A link between electrical and flow properties of a porous medium has been developed recently based on a structural function which is associated with the spectral measure in analytic representation of the effective complex permittivity of a two-component composite medium. We demonstrate the use of this relationship in interpreting the electric response of a geologic formation due to applied sources in a borehole to characterize the microstructural geometry of the medium outside the well. This microstructural information is recovered in a form which allows us to use it for characterizing other transport and physical properties of the rocks. This approach might provide an alternative indirect method of measuring permeability in a geological setting.unfl

¶Presenter

Abstract

Dynamics of Damage in Two-Dimensional Structures with Waiting Elements

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We consider the dynamics of the damage of a bridge-like 2-D structure made from specially constructed waiting elements. Each element consists of two elastic links of different equilibrium lengths. Whenever the elongation of the shorter link accedes some critical value, it undergoes an irreversible damage process which eventually leads to the breakage. Thereafter the second (longer) link assumes the stress.

Let α be a portion of material used for the first link and $1-\alpha$ be a portion of material used for the second link. We compare the waiting element model with the usual structure, consisting of only one link (of shorter length). In the waiting element model the usual structure corresponds to $\alpha = 1$. By performing various numerical experiments when the structure is impacted by a projectile modeled as an "elastic ball," we show that in some cases the waiting element structure can spread the damage over a large area and therefore withstand larger stresses than the usual structure. Several movies will be shown to illustrate this phenomenon. We also address the question of the optimum choice of parameter α.

¶Presenter

Abstract

The Study of 5CB Absorbed On Nano-Roughened Ag and Au Electrodes by Surface-Enhanced Raman Scattering

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We studied the orientation of inhomogeneous media 5CB absorbed on nano-roughened Ag and Au Electrodes by using Surface-Enhanced Raman Scattering. Our results first suggest that the orientation of 5CB absorbed on nano-roughened Ag electrode is different from that of Au electrode. This implies that the interaction between inhomogeneous media 5CB and Ag is different from the interaction between inhomogeneous media 5CB and Au. The conclusion is that the orientation of 5CB absorbed on nano-roughened Ag electrode is perpendicular, and the orientation of 5CB absorbed on nano-roughened Au electrode is more complicated, including parallel, perpendicular and tilted.

Keywords: Surface-Enhanced Raman Scattering, 5CB

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