

REVIEWS of MODERN PHYSICS

Volume 83

Number 2

April–June 2011

307 *Colloquium: Physics of the Riemann hypothesis*

Dániel Schumayer
David A. Hutchinson

Mathematics has been a guide for physicists since the time of Newton. Eugene Wigner spoke of the “unreasonable effectiveness of mathematics in the natural sciences.” But is this always the case? Can physics be a guide to mathematicians instead? In this Colloquium this problem is addressed from the perspective of one of the most famous mathematical problems, the Riemann hypothesis.

331 *Colloquium: Physics of optical lattice clocks*

Andrei Derevianko
Hidetoshi Katori

The accurate measurement of time is fundamental in many different areas in physics and engineering. In this Colloquium, a way to measure time with high accuracy is discussed which is based on clocks made out of cold atoms trapped in optical lattices. Within this method a clock “would neither lose or gain a fraction of a second over an estimated age of the Universe.”

349 *Continuous-time Monte Carlo methods for quantum impurity models*

Emanuel Gull
Andrew J. Millis
Alexander I. Lichtenstein
Alexey N. Rubtsov
Matthias Troyer
Philipp Werner

Quantum impurity models were introduced to describe atoms or molecules embedded in a host material and are now understood to be a central concept in condensed matter physics with applications ranging from modeling the conductance and other properties of quantum dots to auxiliary problems whose solutions help reveal the physics of complex heavy fermion and oxide materials. This review describes a new family of numerically exact methods solving quantum impurity problems. The methods are based on continuous-time quantum Monte Carlo algorithms which are free from the time discretization errors which occur in standard quantum Monte Carlo approaches. They enable solutions of broader classes of models, over wider parameter regimes, than previously possible. A description of the new methods is given, along with a review of the systems to which the new methods have so far been applied, with a goal of enabling the readers to implement and use the algorithms described.

405 *Publisher’s Note: Solitons in nonlinear lattices [Rev. Mod. Phys. 83, 247 (2011)]*

Yaroslav V. Kartashov
Boris A. Malomed
Lluís Torner

407 *Electronic transport in two-dimensional graphene*

S. Das Sarma
Shaffique Adam
E. H. Hwang
Enrico Rossi

Graphene, a single layer of carbon atoms forming a hexagonal lattice, has many remarkable properties, including an electron spectrum that is a realization of nonrelativistic Dirac fermions. This review focuses on the transport properties of this extraordinary material, which are contrasted with those of two-dimensional semiconductor systems. A thorough understanding of these issues will be essential for any future use of graphene in electronic devices.

- 471 Electrodynamics of correlated electron materials**
- Correlated electron materials, which include transition metal oxides, organic and molecular conductors, intermetallic compounds with and electrons and magnetic semiconductors, are dominated by strong Coulomb interactions which have spin and orbital components. This review discusses the use of optical methods as a primary experimental probe of correlations. The examination of electromagnetic response over a broad frequency range reveals energy scales associated with elementary excitations and collective modes and, in addition, gives insight into the physics of metal-insulator transitions.
- D. N. Basov
Richard D. Averitt
Dirk van der Marel
Martin Dressel
Kristjan Haule
-
- 543 Carrier dynamics in semiconductors studied with time-resolved terahertz spectroscopy**
- Time domain terahertz spectroscopy is particularly well suited for the study of carrier dynamics in bulk semiconductors and semiconductor nanostructures. This review discusses the generation and detection of terahertz radiation and the advantages of utilizing all optical noninvasive contact-free techniques. Sensitivity to the response of free carriers, polarons, and excitons together with results on phonon resonances and intraband transitions in low-dimensional systems (with and without quantum confinement) provide an insightful perspective on the use of these time-resolved techniques compared to other methods of measuring conductivity.
- Ronald Ulbricht
Euan Hendry
Jie Shan
Tony F. Heinz
Mischa Bonn
-
- 587 Theoretical perspective on the glass transition and amorphous materials**
- It is hard to imagine a world without glass and it is even more difficult to understand the fundamentals of this ubiquitous material. In this review, the authors outline and refine the problem and note the subtleties in defining the glassy state. In addition they argue that computing power has progressed to a level where useful and profound insights can be made through simulation. Multipoint correlation functions are also discussed as a means to identifying the glass transition.
- Ludovic Berthier
Giulio Biroli
-
- 647 Microscale acoustofluidics: Microfluidics driven via acoustics and ultrasonics**
- Though the study of acoustics and ultrasound may conjure images of concert halls and cardiograms, the exquisite control of ultrasonic waves enables microfluidic and nanofluidic technologies. In this review, a consolidated overview of the old and ramified field of acoustics is presented. Not only is the reader led through the complexities of the variety of flow rates and geometries, but a plethora of applications are also described and explored. We learn how to pump fluid, drag colloids, and mix chemicals in a micron-sized environment.
- James Friend
Leslie Y. Yeo

Resonant inelastic x-ray scattering (RIXS) is a rapidly developing experimental technique in which one utilizes the inelastic scattering of x-ray photons in resonance with atomic x-ray transitions to probe elementary excitations in complex materials by measuring their energy, momentum, and polarization dependence. This review describes the experimental and theoretical advances of RIXS arising from the availability of high-brilliance synchrotron x-ray sources and advanced photon detection instrumentation. The resonant enhancement of RIXS cross sections offers a unique way to probe charge, magnetic, and orbital degrees of freedom in correlated electron systems.

Luuk J. Ament
Michel van Veenendaal
Thomas P. Devereaux
John P. Hill
Jeroen van den Brink

Dániel Schumayer
David A. Hutchinson