

**307      Quantum error correction for quantum memories**

Barbara M. Terhal

It may seem inevitable that highly entangled quantum states are susceptible to disturbance through interaction with a decohering environment. However, certain multiqubit entangled states are well protected from common forms of decoherence as the quantum information is hidden in inherently nonlocal degrees of freedom. This review shows that this robustness is enabled by specific measurements on subsets of qubits, implementing a quantum version of an error-correction process. Beginning with the basics, the latest understanding of the relation between this form of error correction and the concept of two-dimensional topological order in many-body physics is reviewed.

**347      Interfacing single photons and single quantum dots with photonic nanostructures**Peter Lodahl  
Sahand Mahmoodian  
Søren Stobbe

Quantum dots embedded in photonic nanostructures provide unprecedented control over the interaction between light and matter. This review gives an overview of the theoretical principles involved, as well as applications ranging from high-precision quantum-electrodynamics experiments to quantum-information processing.

**401      *Colloquium:* Geometry and optimal packing of twisted columns and filaments**

Gregory M. Grason

Rope and biological bundles are examples of a broad class of filamentous matter. Incompatibility of filament twist and columnar ordering leads to geometric frustration, analogous to the frustration of objects packed on curved surfaces. This Colloquium presents recent theoretical progress in understanding the emergent properties of such twisted columnar and filamentous materials.

**421      Asymmetries in top quark pair production at hadron colliders**J. A. Aguilar-Saavedra  
D. Amidei  
A. Juste  
M. Pérez-Victoria

Several years ago measurements at the Fermilab Tevatron proton-antiproton collider showed top quarks to be produced preferably in the proton direction and the antitop quarks in the antiproton direction. The size of such asymmetries was not expected in the standard model and this sparked intensive effort. This article reviews the current theoretical and experimental progress in understanding the asymmetries. The revised measurements and calculations are now in relatively good agreement. The LHC now produces large quantities of top quarks and can study related, but different, measures of asymmetric top quark production. The prospects for the LHC to extend our understanding and to probe for new physics beyond the standard model paradigm are also discussed.

- 457 Colloquium: Theory of intertwined orders in high temperature superconductors**
- Eduardo Fradkin  
Steven A. Kivelson  
John M. Tranquada
- Understanding high temperature superconductors is a central problem in condensed matter physics. Many experiments have uncovered ordering tendencies which are responsible for the complex phase diagram of high temperature superconductors. This Colloquium discusses the interplay between different order parameters in these materials. Considering the intertwining of these orders leads to new experimentally observable consequences, shedding new light into the physics of these fascinating materials.
- 483 Lévy walks**
- V. Zaburdaev  
S. Denisov  
J. Klafter
- Lévy walks are random walks in which the distribution of step length does not decay exponentially and the velocity of the moving particle is finite. Building on earlier concepts, they reconcile anomalously fast diffusion with a finite propagation speed and have applications that range from basic statistical mechanics and transport theory to optics, cold atom dynamics, and biophysics. This review gives an introduction to this important class of models and discusses applications in both physics and biology.
- 531 Neutrino electromagnetic interactions: A window to new physics**
- Carlo Giunti  
Alexander Studenikin
- With the observation of neutrino masses and mixings, the study of their electromagnetic interactions has assumed greater relevance both as verification of the  $\nu$  standard model, and as a guide to new physics. After a standard description of massive neutrinos, this review assembles the present state of the art in the study of their electromagnetic interactions. Possible measurements of their static properties as test of new physics are described, as well as their behavior in strong magnetic fields. As such it should be helpful to both particle physicists and astrophysicists.
- 593 Macroscopic fluctuation theory**
- Lorenzo Bertini  
Alberto De Sole  
Davide Gabrielli  
Giovanni Jona-Lasinio  
Claudio Landim
- The statistical mechanics of systems out of equilibrium provides a formidable challenge. This review describes an approach to a subset of such problems, viz., stationary nonequilibrium states. The review includes what is known as the macroscopic fluctuation theory, which allows for the definition of nonequilibrium analogs of thermodynamics potentials, and is applied to various illustrative models.
- 637 Optical atomic clocks**
- Andrew D. Ludlow  
Martin M. Boyd  
Jun Ye  
E. Peik  
P. O. Schmidt
- Since 1967 the primary time standard is the cesium atomic clock, based on a hyperfine transition in the microwave domain. The development of ultrastable laser sources now allows one to operate on electronic transitions in the optical domain, corresponding to a 5-order-of-magnitude increase in the clock frequency. This article reviews the spectacular accuracy and stability gains that can be obtained when working with laser cooled ions or neutral atoms. It also discusses some important applications of these optical clocks, from geodesy to tests of fundamental theories to many-body physics.