

REVIEWS of MODERN PHYSICS

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041001 *Colloquium: Protecting quantum information against environmental noise*

Dieter Suter
Gonzalo A. Álvarez

Quantum mechanical systems retain their properties so long as the phase of quantum superpositions evolves stably over time. Contact with an environment can disrupt this phase evolution. But for environments that do not exchange energy with the quantum system, strategies exist where the controlled driving of the system can recover or maintain the quantum phase. This Colloquium surveys the host of techniques that are available to “refocus” the phase when disturbed by various forms of classical or quantum environment. While the first such techniques were developed long ago, ideas from quantum information theory have introduced new strategies for accomplishing this goal.

041002 *Colloquium: Herbertsmithite and the search for the quantum spin liquid*

M. R. Norman

As the temperature slowly goes down to absolute zero all the thermal motion ceases and only quantum effects are possible. At these low temperatures most materials will order in well-defined structures. Nevertheless, there is a class of materials called quantum spin liquids that even at the lowest temperatures they refuse to order because of frustration, that is, the impossibility of satisfying all participating elements. This Colloquium reviews this fascinating topic.

045001 *Alternatives to an elementary Higgs*

Csaba Csáki
Christophe Grojean
John Terning

Experiments point to the Higgs particle being the excitation of an elementary scalar field, as originally proposed in the standard model. To many theorists, however, its low mass suggests it may be more than that. This article provides a comprehensive review of these alternative Higgs models. The current run of the LHC will test the nature of the Higgs with greater precision. Particle physicists will find this review to serve as a guide to interpret the experimental results to come.

045002 *CP violation in the B_s^0 system*

Marina Artuso
Guennadi Borissov
Alexander Lenz

Sources of CP violation beyond those of the standard model of particle physics are needed to explain the dominance of matter over antimatter in the Universe. The bound state of a bottom antiquark and a strange quark and its charge conjugate is a fertile hunting ground, as standard model CP violating effects are typically small. This article reviews the many studies of CP violation in B_s decays, the quantum mixing of B_s and anti- B_s , and their interference.

- 045003 Materials perspective on Casimir and van der Waals interactions**
- Electromagnetic fluctuation-induced interactions known as van der Waals, Casimir, and Casimir-Polder forces are an active and exciting area of research. This review summarizes recent progress in this field with emphasis on theoretical and computational developments and their applications to materials including molecular structures, Dirac-like systems, optical metamaterials, composites with nontrivial boundary conditions, and biological matter.
- L. M. Woods
D. A. R. Dalvit
A. Tkatchenko
P. Rodriguez-Lopez
A. W. Rodriguez
R. Podgornik
- 045004 Time-dependent density-functional description of nuclear dynamics**
- Many excitation modes of atomic nuclei and their reactions can be described as time-dependent processes, in which nuclei oscillate, rotate, collide, and split. A theoretical framework to describe nuclear dynamics at low energy is the time-dependent density-functional theory. This reviews the foundations and extensions of this theory and its applications to nuclear collective motion, including giant resonances, heavy-ion collisions, and shape coexistence. Conceptual differences between nuclear and electronic applications are also discussed.
- Takashi Nakatsukasa
Kenichi Matsuyanagi
Masayuki Matsuo
Kazuhiro Yabana
- 045005 Quantum memories at finite temperature**
- While the typical scenario for quantum error correction involves active intervention there are advantages to a passive quantum memory, for which a suitably designed interaction Hamiltonian will naturally protect the coherence of low-lying states from decoherence induced by a thermal environment. This review summarizes and discusses the various theoretical attempts to find a workable scenario for a passive quantum memory.
- Benjamin J. Brown
Daniel Loss
Giannis K. Pachos
Chris N. Self
James R. Wootton
- 045006 Active particles in complex and crowded environments**
- This article reviews both experimental and theoretical advances in the field of active matter which consists of natural and artificial objects capable of self-propulsion. Prime examples of active particles are Brownian particles, biological or man-made microscopic and nanoscopic objects, that can propel themselves by taking up energy from their environment and converting it into directed motion. The review provides a guided tour through the basic principles and fabrication of active particles and also discusses many interesting future directions these man-made micromachines and nanomachines could take as autonomous agents for health care, sustainability, and security applications.
- Clemens Bechinger
Roberto Di Leonardo
Hartmut Löwen
Charles Reichhardt
Giorgio Volpe
Giovanni Volpe
- 045007 Particle and nuclear physics instrumentation and its broad connections**
- Progress in the physical sciences depends as much on innovations in instrumentation that enable more refined experiments as on new theoretical ideas. This article reviews the instrumentation developments in particle and nuclear physics that have brought new understanding in those fields, their impact upon broader societal issues, and their interdependence with commercial advances.
- M. Demarteau
R. Lipton
H. Nicholson
I. Shipsey

045008 Nonlinear optical signals and spectroscopy with quantum light

Konstantin E. Dorfman
Frank Schlawin
Shaul Mukamel

By variation of the photon statistics and the entanglement between time and frequency components, quantum states of light feature spectroscopy signals which are not subject to classical Fourier limitations on temporal and spectral resolution. This review surveys the properties of entangled photon pairs relevant to spectroscopic applications and it presents an intuitive diagrammatic approach which allows calculation of a variety of ultrafast, nonlinear spectroscopy signals from multilevel model systems exposed to quantum light.