REVIEWS of MODERN PHYSICS

Volume 81 **Number 3** **July–September 2009**

959 ***Colloquium*: Field theoretic description of ultrarelativistic electron-positron plasmas** — Markus H. Thoma

Ultrastrong laser pulses can produce plasmas in which the thermal energy of electrons (say, 10 MeV) greatly exceeds their rest mass. The resulting ultrarelativistic electron-positron plasma mimics conditions in various astrophysical phenomena such as supernovae. This Colloquium uses perturbative QED for finite temperature to calculate, for such plasmas, equilibrium properties including the equation of state, photon dispersion relations of collective plasma modes, Debye screening, particle transport, and photon viscosity.

969 **The warm ionized medium in spiral galaxies** — L. M. Haffner, R.-J. Dettmar, J. E. Beckman, K. Wood, J. D. Slavin, C. Giammanco, G. J. Madsen, A. Zurita, R. J. Reynolds

Ionized as well as neutral gas components in the interstellar medium play a vital role in the cycle of stellar birth and death during galactic evolution. They govern the formation of new stars, while in turn stellar radiation, matter outflow, as well as kinetic energy release in winds and supernovae determine the properties of the interstellar medium. One of these feedback processes is the large-scale ionization by the youngest and most luminous (O-) stars. Their Lyman continuum radiation causes extensive ionization throughout the disk and the galactic halo. This article reviews the properties of this plasma, essential for the understanding of the dynamic interstellar processes in galaxies.

999 ***Colloquium*: Understanding ion motion in disordered solids from impedance spectroscopy scaling** — D. L. Sidebottom

Conduction of electricity within disordered solids involves motion of ions through the host matrix, in contrast to the mobile electrons that conduct in metals. ac impedance spectroscopy, measuring frequency dependence of conductivity, provides a direct connection, via Fourier analysis, to the mean square displacement of these ion charge carriers. This Colloquium discusses numerous examples of what may be learned from such measurements about the local ionic environment, and of simple scaling laws that describe the effects of temperature and ionic concentration.

1015 **Nobel Lecture: Spontaneous symmetry breaking in particle physics: A case of cross fertilization** — Yoichiro Nambu

1019 **Nobel Lecture: *CP* violation and flavor mixing** — Makoto Kobayashi

1027 **Nobel Lecture: What does *CP* violation tell us?** — Toshihide Maskawa

The 2008 Nobel Prize for Physics was shared by Yoichiro Nambu, Makoto Kobayashi, and Toshihide Maskawa. These papers are the text of the address given in conjunction with the award.

1031 ***Colloquium*: Phase diagram of strongly interacting matter** — P. Braun-Munzinger, J. Wambach

The behavior of matter compressed and heated to extreme conditions, as it occurred in the early Universe or as it is encountered in the interior of neutron stars, is studied in contemporary accelerator experiments. The results of these experiments find an explanation in the phase diagram of quark-gluon matter. This Colloquium discusses the salient features of the phase diagram in terms of the underlying theory of quantum chromodynamics and summarizes results from recent experiments of ultrarelativistic nucleus-nucleus collisions in which strongly interacting matter is created.

1051 **Optics and interferometry with atoms and molecules** — Alexander D. Cronin, Jörg Schmiedmayer, David E. Pritchard

Atom interferometry has emerged as a powerful tool for investigating fundamental quantum phenomena, for precision measurements and advanced metrology, and for studying basic properties of atoms and molecules. This review describes the tools of coherent atom optics, including diffraction by nanostructures, laser light, and double wells on atom chips. By clearly distinguishing interference of both the external (translational) modes of atoms and internal states, the review provides a unified view of the underlying physics. The review also presents a broad summary of applications. The focus is on single-particle interference in nondegenerate gases.

1131 **Dynamics and stability of thin liquid films** — R. V. Craster, O. K. Matar

The fluid mechanics of thin-film flow occupies a central place in an enormous variety of scientific and technological areas, from nanophysics to geophysics. The physical and mathematical description of such flows, and in particular their stability, is the subject of this review, which provides a comprehensive overview of fundamentals, scaling arguments, the nonlinear structure of the relevant partial differential equations, and the experimental study of these phenomena.

1199 **The physics of heavy Z' gauge bosons** — Paul Langacker

Extensions of the standard model allow for the existence of heavy neutral gauge bosons Z with different masses and couplings. This article focuses on the theory and phenomenology of the Z . Present limits from electroweak and collider experiments are presented, as are prospects for discovery at future colliders. Implications of existence of various Z particles on the extended Higgs sector, supersymmetry, and flavor changing neutral currents are discussed as well as the interplay with neutrino physics, implications for baryogenesis, and cold dark matter. With the start up of the LHC, this article serves as a reference for the theoretical underpinning of the searches for heavy neutral gauge bosons.

1229 **Physics of laser-driven plasma-based electron accelerators** — E. Esarey, C. B. Schroeder, W. P. Leemans

In the past decade, high intensity laser-driven particle accelerators have made significant progress. Recent results have shown relatively monoenergetic electron beams ($\sim$4% energy spread) with energies of $\sim$1 GeV . This article reviews the state of the art of laser-driven electron accelerators.

1287 ***Colloquium*: Laws controlling crystallization and melting in bulk polymers** — Gert Strobl

The discovery in the 1950s that long chain polymers can solidify into semicrystalline platelike structures soon led to a theoretical explanation, the Hoffman-Lauritzen model, for the relationship between controllable conditions and crystal growth. Measurements in the 1990s revealed, however, shortcomings of that "standard model." The present Colloquium discusses a subsequent multistage model in which growth proceeds through an intermediate metastable phase. Thereby a wealth of experimental results are explained and a detailed picture of the solidification of the observed structures are offered.

1301 **The security of practical quantum key distribution** — Valerio Scarani, Helle Bechmann-Pasquinucci, Nicolas J. Cerf, Miloslav Dušek, Norbert Lütkenhaus, Momtchil Peev

Quantum mechanics offers us a new way for secure communication. Photons prepared in certain quantum states can be used to distribute a key—a random string of bits—between two partners, which can be used to encode secret messages. Any eavesdropper who tries to obtain the key will distort the quantum states, something which can be detected. In practical applications, the noise induced by the environment will be indistinguishable from that coming from a potential eavesdropper, something which may compromise the security of the transmission. This paper reviews different methods to assess the security of most practical key distribution protocols in the presence of any kind of noise.

1351 **Erratum: Opportunities for mesoscopics in thermometry and refrigeration: Physics and applications [Rev. Mod. Phys. 78, 217 (2006)]** — Francesco Giazotto, Tero T. Heikkilä, Arttu Luukanen, Alexander M. Savin, Jukka P. Pekola

Forthcoming articles