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Announcement: Anthony Starace Retires

Announcement: Bruce Shore Assumes Position as RMP Colloquia Editor

309 **Optics in the relativistic regime** — Gerard A. Mourou, Toshiki Tajima, Sergei V. Bulanov

With advances in laser technology, peak field intensities have increased to the point where electrons are accelerated to relativistic velocities within a single optical cycle. This article reviews the techniques for producing ultrahigh intensities highlighting the fundamental and technological limitations. The ultimate conceivable goal with present laser media is the zettawatt laser, which would have a peak intensity of 10^{29} W/cm^2. Also a description of present and future scientific and technological applications extending the realm of optics from the eV to conceivably the TeV range is presented.

373 **Impurity-induced states in conventional and unconventional superconductors** — A. V. Balatsky, I. Vekhter, Jian-Xin Zhu

Impurities in materials are not just a source of scattering and resistance, but can yield precise spectroscopic information about the electronic states, and on the symmetry and energetics of the ground state. In conventional superconductors, this topic has a long history, but it has become reinvigorated with the developments in high resolution scanning tunneling measurements applied to unconventional superconductors. This review is firmly based in the theory of *s*-wave superconductors established in the 1960s, and then focuses on recent developments in unconventional and high-temperature superconductors.

435 **String gas cosmology** — Thorsten Battefeld, Scott Watson

In recent years the study of string-theory-based approaches to cosmology has become a very active field. This paper reviews one of these approaches, called string gas cosmology. It concerns the role of a gas of extended strings in the very early Universe. These strings can wrap compact dimensions and influence their expansion. Attention is also turned to late time cosmology and it is found that string gases even provide a framework to explore dark matter.

455 **Photonic crystal heterostructures and interfaces**

Emanuel Istrate
Edward H. Sargent

"Photonics" has become a household name in analogy to "electronics." This review discusses photonic crystal heterostructures, that is, devices with a periodic modulation of their dielectric constant, and hence their optical properties. An overview is given of both the experimental realization of such materials, which has led to functional devices, and the theoretical methods used to model these systems.

483 **Ultracold photoassociation spectroscopy: Long-range molecules and atomic scattering**

Kevin M. Jones
Eite Tiesinga
Paul D. Lett
Paul S. Julienne

Photoassociation is the process in which two colliding atoms absorb a photon to form an excited molecule. Normally, photoassociation absorption lines are broad because of the spread of thermal energy of the colliding atoms. For ultracold atoms, however, the spectral lines are sharp, permitting high-resolution spectroscopy. The spectra of very long-range molecular states are of particular interest because their properties can be related with high precision to the properties of the constituent atoms. This review describes how photoassociation spectroscopy is performed and how it has been applied to determine scattering lengths, the control of scattering lengths via optical Feshbach resonances, precision determinations of atomic lifetimes from molecular species, and the production of cold molecules. The review also describes possible limits on photoassociation rates in a Bose-Einstein condensate.

537 **Inflation dynamics and reheating**

Bruce A. Bassett
Shinji Tsujikawa
David Wands

The paradigm of inflation solves several fundamental problems such as the horizon and flatness of the Universe. This article discusses specific models that implement inflation and examines their observational consequences. In particular, the theory of inflation for models with single and multiple fields is reviewed. Furthermore, the dynamics of adiabatic and isocurvature perturbations, which can be used to test various inflationary models, is treated in detail. More speculative scenarios such as extra dimensional models and modulated reheating are also mentioned.

591 **Nonlinear collective effects in photon-photon and photon-plasma interactions**

Mattias Marklund
Padma K. Shukla

Under most conditions, photons do not interact with one another in vacuum. At sufficiently high field strengths, however, the vacuum becomes nonlinear mediated by virtual electron-positron pairs. High electric field sources (short-pulse lasers, x-ray free electron lasers, and high Q cavities) will soon approach these field strengths. This article describes the effects of these nonlinear quantum electrodynamics effects on photon-photon and photon-plasma interactions and also discusses applications to laser-plasma systems and astrophysical environments.

641 **Patterns and collective behavior in granular media: Theoretical concepts** Igor S. Aranson, Lev S. Tsimring

Though driven granular matter is far from thermodynamic equilibrium, there is a remarkably rich theoretical tapestry used to explain the appearance of pattern formation in these systems. In this review, we are treated to illustrations of order in these nonequilibrium systems along with their theoretical descriptions. The connections between the macroscopic models, models for equilibrium fluids, and microscopic models for particle interactions are made and described.

693 **Forthcoming articles**