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021001 ***Colloquium*: Excitons in atomically thin transition metal dichalcogenides**

Gang Wang, Alexey Chernikov, Mikhail M. Glazov, Tony F. Heinz, Xavier Marie, Thierry Amand, Bernhard Urbaszek

Most two-dimensional (2D) semiconductors are interesting materials as quantum confinement enhances the Coulomb interaction between carriers, leading to a strong attraction between conduction electrons and valence holes, forming stable excitons and the optical response of 2D semiconductors can be extraordinary. In this Colloquium the progress and open questions in the study of excitons in 2D semiconductors from both the experimental and theoretical perspectives are reviewed.

021002 ***Colloquium*: Strong-field phenomena in periodic systems**

Stanislav Yu. Kruchinin, Ferenc Krausz, Vladislav S. Yakovlev

This Colloquium presents an introduction to the interaction of strong laser fields with electrons in periodic potentials and reviews recent results on extremely nonlinear processes in crystalline solids. A classification of the field-matter interaction regimes is discussed and a research framework for extending the frontiers of optoelectronic signal processing and metrology is outlined.

025001 **Scattering processes and resonances from lattice QCD**

Raúl A. Briceño, Jozef J. Dudek, Ross D. Young

Hadrons and their interactions arise via the coupling between quarks and gluons, as dictated by quantum chromodynamics (QCD), the theory of strong interactions. Unlike protons and neutrons, very few hadrons observed in nature are stable under the strong interaction: the majority of them appear as resonances in scattering experiments. This work reviews progress and prospects in the studies of few-hadron reactions and resonance properties using lattice QCD techniques.

025002 **Dual-readout calorimetry**

Sehwook Lee, Michele Livan, Richard Wigmans

The measurement of the energies of collections of particles in jets resulting from quarks or gluons produced in high-energy collisions is a key element in the analyses of events at particle colliders. Good energy resolution requires that the different responses to hadrons and electrons or photons be corrected for in an event-by-event way. Measurements using the dual-readout technique show that by recording separate measurements that depend differently on the electromagnetic and hadronic components one can achieve excellent energy resolution.

025003 **Diagrammatic routes to nonlocal correlations beyond dynamical mean field theory**

G. Rohringer, H. Hafermann, A. Toschi, A. A. Katanin, A. E. Antipov, M. I. Katsnelson, A. I. Lichtenstein, A. N. Rubtsov, K. Held

The inclusion of strong electronic correlations into a theoretical description of solids is a notoriously hard problem. This review describes various recent schemes to improve on dynamical mean field theory, which includes only local correlations, by systematically incorporating nonlocal correlations as well and discusses applications to standard models of strongly correlated electrons.

025004 **Macroscopic quantum states: Measures, fragility, and implementations**

Florian Fröwis
Pavel Sekatski
Wolfgang Dür
Nicolas Gisin
Nicolas Sangouard

It should not be possible for a cat to be in a quantum superposition of alive and dead. But why? "Because it is classical" is not a good answer; when is a physical object classical? This requires an effort to formulate the quantitative criteria for classicality. Here a whole set of such criteria are reviewed, experimental limits are explored for observing quantum properties in macroscopic states, and implications for quantum metrology and computing are discussed.

025005 **Jet measurements in heavy ion physics**

Megan Connors
Christine Nattrass
Rosi Reed
Sevil Salur

The hottest matter that existed in the early Universe after the big bang, the quark gluon plasma, is created in ultrarelativistic collisions of heavy nuclei. By studying narrow streams of fast-moving particles coming from the collisions, nuclear physicists learn about properties of this hot, dense medium. This work reviews current experimental evidence and related theoretical descriptions of the plasma's constituents and properties.

025006 **Looking at cosmic near-infrared background radiation anisotropies**

A. Kashlinsky
R. G. Arendt
F. Atrio-Barandela
N. Cappelluti
A. Ferrara
G. Hasinger

While the cosmic microwave background originates from the very early Universe, the cosmic infrared background contains the cumulative emission of sources from the earliest epochs to the present time. It is generated from nucleosynthetic sources and gravitational sources. The source-subtracted spatial fluctuations of the cosmic infrared background provide information on the brightness and clustering of sources too faint to detect individually. Among these are the very first stars in the Universe and an unexpectedly large fraction of black holes. Observational and theoretical efforts at decoding the cosmic infrared background are presented together with possible future tests and prospects.

025007 **Materials characterization by synchrotron x-ray microprobes and nanoprobes**

Lorenzo Mino
Elisa Borfecchia
Jaime Segura-Ruiz
Cinzia Giannini
Gema Martinez-Criado
Carlo Lamberti

The Moore's law trajectory of hard x-ray spatial resolution extrapolates to a few nanometers within the next few years, thereby promising critical space-resolved structural, electronic, and compositional nanoscale characterizations for a wide variety of materials. This review addresses the capabilities and advantages of x-ray microbeam and nanobeam techniques compared to photon, electron, neutron, and ion probes through selected applications including semiconductors, superconductors, metals, and nanostructured devices.

025008 **Search for new physics with atoms and molecules**

M. S. Safronova
D. Budker
D. DeMille
Derek F. Jackson
Kimball
A. Derevianko
Charles W. Clark

Advances in atomic physics, such as cooling and trapping of atoms and molecules and developments in frequency metrology, have added orders of magnitude to the precision of atom-based clocks and sensors. Applications extend beyond atomic physics and this article reviews using these new techniques to address important challenges in physics and to look for variations in the fundamental constants, search for interactions beyond the standard model of particle physics, and test the principles of general relativity.