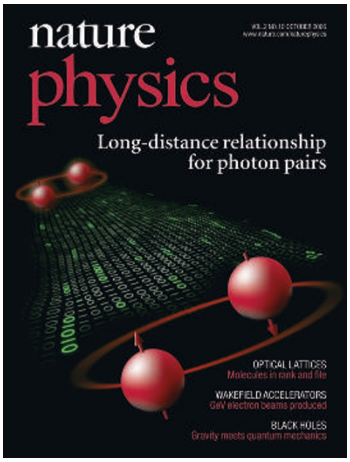


COVER STORY

Vol.2 No.10 October 2006

Quantum teleportation describes the transfer of a quantum state from one place to another, by a sender who knows neither the state to be teleported nor the location of the receiver. The phenomenon is one of the most intriguing examples of how quantum entanglement can assist in realizing practical tasks, and is involved in numerous quantum communication and quantum computation schemes. Quantum teleportation of single bits of quantum information has been demonstrated before, but large-scale applications require the transfer of composite systems. Now Qiang Zhang and colleagues report the teleportation of combined polarization states — including entanglement — of two photons, the key to their success being the development of an efficient six-photon interferometer.
[Letter p678; News & Views p655]

DRIVING ELECTRON BEAMS TO 1 GEV

Progress continues apace in the development of laser wakefield accelerators, which produce high-energy beams of electrons, atoms and molecules using the extreme fields generated in a plasma by high-power lasers. But for the potential of these devices to be realized — in practical applications that range from studying the behaviour of matter under extreme conditions to proton therapy for the treatment of deep-seated tumours — the energy of the particle beams they produce must reach the giga-electronvolt range. Initial estimates had suggested that reaching such energies would require lasers capable of producing pulse powers of the order of petawatts. But Wim Leemans and colleagues have proved the predictions wrong by producing 1-GeV electron beams using only 40 terrawatts of laser power — the trick being to focus the laser into a 3.3-cm-long gas-filled capillary discharge tube. **[Letter p696]**

RADIOFREQUENCY ATOM TRAP

Traps using magnetic fields and optical dipole potentials have revolutionized ultracold atomic physics. Atoms can also be manipulated using radiofrequency fields, which couple hyperfine components of the electronic ground state (whereas optical dipole potentials couple ground and electronically excited states). But radiofrequency-field-based potentials were not considered practical. However, in a detailed theoretical analysis and a series of experiments, Sebastian Hofferberth and colleagues show how these so-called radiofrequency-dressed-state potentials, implemented on a microfabricated atom chip, can provide a versatile means for manipulating neutral atoms, without adverse effects such as substantial heating or particle loss. **[Article p710; News & Views p661]**

TINY STEPS IN X-RAY IMAGING

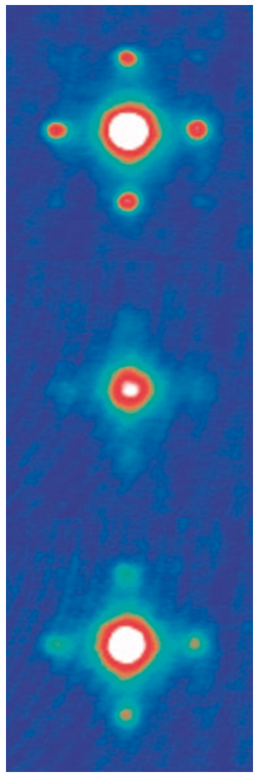
The ability of X-ray radiation to penetrate deep into an object is one of its practical strengths, and the basis of medical X-ray imaging. The other is its short wavelength, which is the basis of X-ray crystallography. Exploiting both attributes at the same time, however, presents a challenge. Although the subatomic wavelength of X-rays makes them attractive for imaging atomic-scale features, their poor absorption means that extreme X-ray intensities are needed to have any hope of resolving such features above the noise. But by using a technique that generates an image from variations in the phase of X-rays reflected from a sample, Paul Fenter and colleagues can resolve subnanometre-high steps in the topology of an otherwise atomically smooth surface. The technique could enable the study of surface processes that occur under harsh conditions, in which electron or atomic-force microscopy is not feasible.
[Letter p700; News & Views p657]

WELL-PLACED MOLECULES

Particles trapped in optical lattices can be arranged in nearly perfect crystal-like configurations. Several states of matter have been realized with atoms using this approach, but arrays of molecules — with long-range interactions between them — would represent a whole new playground for physicists. Towards this goal, Thomas Volz *et al.* report the preparation of a quantum state in which each site of an optical lattice is occupied by exactly one molecule, made of two rubidium atoms. Their method might be extended to prepare heteronuclear molecules with large permanent electric dipole moments. Such polar molecules feature in several proposals for applications in the fields of quantum information processing and quantum simulation. **[Letter p692]**

CLASH OF THE TITANS

On one side there is gravity, in the guise of general relativity, and on the other, quantum mechanics — both profoundly successful theories, describing a wealth of physical phenomena, but seemingly incompatible. Nowhere is that conflict more acute than in the physics of black holes. Emerging from a solution to Einstein's field equations, even classical black holes have apparently brain-bending properties. But add quantum mechanics to the mix, and the situation descends into paradox. Drawing on basic physical principles, such as entropy, temperature and information, Leonard Susskind reviews the development of the black-hole crisis, and reveals how ideas from string theory may now have effected a reconciliation.
[Review p665]



Interference patterns herald the nature — atomic or molecular — of quantum states in optical lattices.
p692