A round-up of recent papers in the field of photonics published by the physical sciences division of the Nature Publishing Group.

Parallel and selective trapping in a patterned plasmonic landscape

Nature Phys. **3,** 477–480 (2007)

The implementation of optical tweezers at a surface opens a huge potential towards the elaboration of future lab-on-a-chip devices entirely operated with light. The transition from conventional three-dimensional (3D) tweezers to 2D is made possible by exploiting evanescent fields bound at interfaces. In particular, surface plasmons (SP) at metal/dielectric interfaces are expected to be excellent candidates to relax the requirements on incident power and to achieve subwavelength trapping volumes. Here, we report on novel 2D SP-based optical tweezers formed by finite gold areas fabricated at a glass surface. We demonstrate that SP enable stable trapping of single dielectric beads under non-focused illumination with considerably reduced laser intensity compared with conventional optical tweezers. We show that the method can be extended to parallel trapping over any predefined pattern. Finally, we demonstrate how SP tweezers can be designed to selectively trap one type of particles out of a mixture, acting as an efficient optical sieve.

Entanglement-based quantum communication over 144 km

Nature Phys. **3,** 481–486 (2007)

Quantum entanglement is the main resource to endow the field of quantum information processing with powers that exceed those of classical communication and computation. In view of applications such as quantum cryptography or quantum teleportation, extension of quantum-entanglement-based protocols to global distances is of considerable practical interest. Here we experimentally demonstrate entanglement-based quantum key distribution over 144 km. One photon is measured locally at the Canary Island of La Palma, whereas the other is sent over an optical free-space link to Tenerife, where the Optical Ground Station of the European Space Agency acts as the receiver. This exceeds previous free-space experiments by more than an order of magnitude in distance, and is an essential step towards future satellite-based quantum communication and experimental tests on quantum physics in space.

Efficiency enhancement in low-bandgap polymer solar cells by processing with alkane dithiols

Nature Mater. **6,** 497–500 (2007)

High charge-separation efficiency combined with the reduced fabrication costs associated with solution processing and the potential for implementation on flexible substrates make 'plastic' solar cells a compelling option for tomorrow's photovoltaics. Attempts to control the donor/acceptor morphology in bulk heterojunction materials as required for achieving high power-conversion efficiency have, however, met with limited success. By incorporating a few volume per cent of alkanedithiols in the solution used to spin-cast films comprising a low-bandgap polymer and a fullerene derivative, the power-conversion efficiency of photovoltaic cells (air-mass 1.5 global conditions) is increased from 2.8% to 5.5% through altering the bulk heterojunction morphology. This discovery can potentially enable morphological control in bulk heterojunction materials where thermal annealing is either undesirable or ineffective.

Metallated conjugated polymers as a new avenue towards high-efficiency polymer solar cells

Nature Mater. **6,** 521–527 (2007)

Bulk heterojunction solar cells have been extensively studied owing to their great potential for cost-effective photovoltaic devices. Although recent advances resulted in the fabrication of poly(3-hexylthiophene) (P3HT)/fullerene derivative based solar cells with efficiencies in the range 4.4–5.0%, theoretical calculations predict that the development of novel donor materials with a lower bandgap is required to exceed the power-conversion efficiency of 10%. However, all of the lower bandgap polymers developed so far have failed to reach the efficiency of P3HT-based cells. To address this issue, we synthesized a soluble, intensely coloured platinum metallopolyyne with a low bandgap of 1.85 eV. The solar cells, containing metallopolyyne/fullerene derivative blends as the photoactive material, showed a power-conversion efficiency with an average of 4.1%, without annealing or the use of spacer layers needed to achieve comparable efficiency with P3HT. This clearly demonstrates the potential of metallated conjugated polymers for efficient photovoltaic devices.

The self-organizing properties of squid reflectin protein

Nature Mater. **6,** 533–538 (2007)

Reflectins, a recently identified protein family that is enriched in aromatic and sulphur-containing amino acids, are used by certain cephalopods to manage and manipulate incident light in their environment. These proteins are the predominant constituent of nanoscaled photonic structures that function in static and adaptive colouration, extending visual performance and intra-species communication. Our investigation into recombinantly expressed reflectin has revealed unanticipated self-assembling and behavioural properties, and we demonstrate that reflectin can be easily processed into thin films, photonic grating structures and fibres. Our findings represent a key step in our understanding of the property–function relationships of this unique family of reflective proteins.

Tunable nanowire nonlinear optical probe

Nature **447,** 1098–1101 (2007)

One crucial challenge for subwavelength optics has been the development of a tunable source of coherent laser radiation for use in the physical, information and biological sciences that is stable at room temperature and physiological conditions. Current advanced near-field imaging techniques using fibre-optic scattering probes have already achieved spatial resolution down to the 20-nm range. Recently reported far-field approaches for optical microscopy, including stimulated emission depletion, structured illumination, and photoactivated localization microscopy, have enabled impressive, theoretically unlimited spatial resolution of fluorescent biomolecular complexes. Previous work with laser tweezers has suggested that optical traps could be used to create novel spatial probes and sensors. Inorganic nanowires have diameters substantially below the wavelength of visible light and have electronic and optical properties that make them ideal for subwavelength laser and imaging technology. Here we report the development of an electrode-free, continuously tunable coherent visible light source compatible with physiological environments, from individual potassium niobate ($KNbO_3$) nanowires. These wires exhibit efficient second harmonic generation, and act as frequency converters, allowing the local synthesis of a wide range of colours via sum and difference frequency generation. We use this tunable nanometric light source to implement a novel form of subwavelength microscopy, in which an infrared laser is used to optically trap and scan a nanowire over a sample, suggesting a wide range of potential applications in physics, chemistry, materials science and biology.

Surface plasmon polariton analogue to Young's double-slit experiment

Nature Nanotech. **2,** 426–429 (2007)

When a light wave strikes a metal film it can, under appropriate conditions, excite a surface plasmon polariton (SPP)—a surface electromagnetic wave that is coupled to the free electrons in the metal. Such SPPs are involved in a wide range of phenomena, including nanoscale optical waveguiding, perfect lensing, extraordinary optical transmission, subwavelength lithography and ultrahigh-sensitivity biosensing. However, before the full potential of technology based on SPPs (termed 'plasmonics') can be realized, many fundamental questions regarding the interaction between light and matter at the nanoscale need to be answered. For over 200 years, Young's double-slit experiment has been a valuable pedagogical tool for demonstrating the wave nature of light. Here, we perform a double-slit experiment with SPPs to reveal the strong analogy between SPP propagation along the surface of metallic structures and light propagation in conventional dielectric components (such as glass waveguides). This allows us to construct a general framework to describe the propagation, diffraction and interference of SPPs. It also suggests that there is an effective diffraction limit for the lateral confinement of SPPs on metal stripe waveguides, and justifies the use of well-developed concepts from conventional optics and photonics in the design of new plasmonic devices.

Tunable plasmonic lattices of silver nanocrystals

Nature Nanotech. **2,** 435–440 (2007)

Silver nanocrystals are ideal building blocks for plasmonic materials that exhibit a wide range of unique and potentially useful optical phenomena. Individual nanocrystals display distinct optical scattering spectra and can be assembled into hierarchical structures that couple strongly to external electromagnetic fields. This coupling, which is mediated by surface plasmons, depends on the shape and arrangement of the nanocrystals. Here we demonstrate the bottom-up assembly of polyhedral silver nanocrystals into macroscopic two-dimensional superlattices using the Langmuir–Blodgett technique. Our ability to control interparticle spacing, density and packing symmetry allows for tunability of the optical response over the entire visible range. This assembly strategy offers a new, practical approach to making novel plasmonic materials for application in spectroscopic sensors, subwavelength optics and integrated devices that utilize field-enhancement effects.

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