EDITORIAL

Making Light Work

Optics, along with its cousins Heat, Electricity, and Magnetism, is for the typical physics undergraduate what *Piers Plowman* and *Le Morte d'Arthur* are to students of English literature: hallowed and worthy, but frankly a little dull. As the selection of articles in this special issue of *Science* shows, however, there is scope for ingenuity and innovation in even so well-studied a subject as the physics of light. The novelty is to be found at the margins of what is possible: from work with single photons to the most intense of laser pulses, from astronomical telescopes to optical microscopes of sub-wavelength resolution.

Direct visual observation remains the backbone of astronomy, and Hubin and Noethe describe how the techniques of active and adaptive optics have transformed the astronomical telescope from a passive collector of photons into an interactive instrument that can subtly change its optical characteristics to compensate, in real time, for mechanical distortions and the blurring effect of the Earth's atmosphere. These advances make possible a new generation of telescopes substantially bigger than the venerable Palomar 200-incher. At the other end of the resolution scale, Guerra, Srinivasarao, and Stein show how evanescent waves at the boundary between two refractive media can be used to perform imaging microscopy with resolution significantly better than the wavelength of the light used; the technique can be understood in strictly classical terms, but Huyghens would scarcely have recognized it.

And there is plenty to be done with photons besides imaging. Righini discusses the diagnostic uses of the optical Kerr effect, in which intense laser illumination generates anisotropic polarization in liquids and solids, which can then be measured by its effect on the passage of a second beam of light. The various electronic and nuclear responses contributing to the optical Kerr effect allow investigation of processes as distinct as the molecular dynamics leading to solid-state phase transitions in organic crystals and the electrooptic properties of solvated cations and anions. These experiments hold enormous potential, allowing the detailed investigation of the dynamics of molecules and ions in condensed phases.

Intense femtosecond laser pulses can put large amounts of energy very rapidly into a specific part of a molecule (the physics has much in common with the recent developments in multiple-pulse nuclear magnetic resonance). Nelson shows how ultra-short laser pulses of carefully designed amplitude and phase can be created by splitting a wavetrain into Fourier components, changing the relative amplitudes by means of a grating, and reassembling the components into a new pulse. These designer pulses can produce selective excited-state populations, and may eventually allow the long-sought goal of mode-selective chemistry to be achieved. Short laser pulses can also be used for their power alone, as Glanz describes in a news story: Tabletop devices are available that can create hot plasmas and may be used, in the laser wakefield technique, to power a new kind of particle accelerator. In a second news story, Freedman tells how individual atoms can be trapped for lengthy periods between opposed laser beams of the appropriate frequency and how, with the atoms maintained in almost stationary isolation, transition frequencies can be measured with extraordinary precision.

This issue includes three Reports in areas of optical science, testifying to the rapid pace of research in the field. Clays *et al.* present an example of the physics that Righini discusses, showing how the use of molecular orientation induced by an optical electric field will greatly increase our understanding of the electro-optic properties of, for example, solvated proteins. The other two Reports are examples of new kinds of microscopy: Berndt *et al.* induce fluorescence in a scanning tunneling microscope to create an indirect image of fullerene molecules, while Betzig and Chichester have made a direct image of isolated carbocyanine molecules using the near-field properties of an optical microscope. Kopelman and Tan describe the background to this innovation.

The physical laws derived from the classical study of optics are not confined to the world of photons. As Rauch explains, neutrons are quantum-mechanical objects with wave properties, and reflection and interferometry experiments can be performed with them. This is satisfying as an exercise in pure physics, but also allows some arcane aspects of quantum mechanics to be unequivocally demonstrated. The optics of neutrons reminds us of Query 29 of Newton's *Opticks*, "Are not the Rays of Light very small Bodies emitted from shining Substances?"—proving that in physics as well as literature, there is life in the classics yet.

David Lindley and Jeffrey Williams