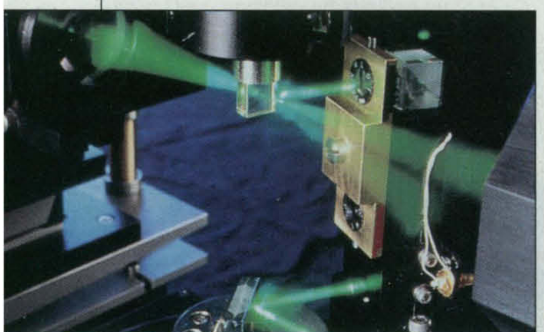
Making Light Work

Windows or eyeglasses that darken in bright light are examples of nonlinear optical materials, in which the response of the medium, in this case the refractive index, changes dramatically with the light intensity. However, the response time, typically seconds, of these materials is too slow to be of practical use for electro-optic or all-optical switching processes. The combination of intense coherent radiation available from lasers together with newly developed photorefractive materials is providing nonlinear optical response times on ultrafast time scales. Such systems allow photons to be added, subtracted, mixed, and manipulated in ways impossible in our familiar low-light–intensity environment. The Reviews in this special issue of *Science* look at some of those developments in the field of nonlinear optics and the applications they are finding.

To study the dynamics of an event too fast for our eyes to see, snapshots of the event are taken, pieced together, and then played back in slow motion. Cameras equipped with fast mechanical shutters allow us to view microsecond snippets of time. The detailed dynamics of chemical reactions or of electronic transitions in crystalline materials can be revealed in a similar manner by following processes with laser pulses on time scales of picoseconds (10^{-12} s) or femtoseconds (10^{-15} s). Steinmeyer *et al.* (p.1507) review the role of nonlinear optics in the generation of ultrafast laser pulses and focus on the role being played by direct laser oscillators.

It is necessary in spectroscopy to tune in to the energy scale that is relevant to the particular system under study. However, lasers generally emit light at very precise and fixed wavelengths. Dunn and Ebrahimzadeh (p. 1513) describe how high-quality monochromatic light can be generated with optical parametric oscillators in which the interaction between photons can be controlled. This approach achieves a flexibility in generating the output light that is not available to conventional lasers.

The past decade has seen an explosion in communication technology. The continuing challenge is to transfer ever-larger amounts of information from one point to another at as high a rate as possible without losing any data in the process. One proposal to overcome the transfer rate limitation of semiconductors is to use all-optical networks. Today, thousands of kilometers of optical fibers encircle the globe. As more information is transferred down a fiber, however, nonlinearities become important and can actually limit the information capacity. As a light pulse propagates through a medium, it disperses or broadens, and repeater stations are needed periodically to prevent pulses from smearing into one another. However, with sufficiently high light intensity, the refractive index of the medium is locally increased and the light is confined to that region by total internal reflection. The light then traverses the medium without loss of intensity and is described as a spatial soliton. Stegeman and Segev (p. 1518) review how such nonlinearities can be used to advantage in the generation and interaction of solitons in their role as information carriers, and Cotter *et al.* (p.1523) review the techniques required to implement processing of the optical signals at transfer rates in excess of 100 gigabits per second.



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A News story (p. 1502) examines the promise of storing such torrents of data in holograms: durable optical inscriptions written in nonlinear optical materials. And two other News stories (pp. 1500 and 1504) describe progress in other fields of optics: latticelike photonic crystals, which can trap or channel light; and adaptive optics technology, which helps telescopes undo the effects of atmospheric turbulence.

—IAN OSBORNE AND TIM APPENZELLER

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