

SCIENCE

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Atomic, Molecular, and Optical Science

A recently issued National Research Council report* with the above title is of interest to natural scientists, engineers, and physicians. Powerful experimental equipment coupled with computer-aided theoretical approaches have been yielding insights relevant to many fields of science and to numerous practical applications in industry and medicine. Atoms, molecules, gases, clusters, and surfaces are being studied by instrumentation that includes scanning tunneling microscopes, atomic force microscopes, and electronic devices of many kinds.

One of the key advances of this century, the laser continues to be increasingly employed in research and applications. Different forms of it are being developed. Today, lasers have dimensions varying between a micrometer and tens of meters. Variants of them can emit sharply defined radiation with wavelengths that include the middle of the infrared, visible, and ultraviolet. Some of them are tunable. Intensity can range over seven orders of magnitude. Pulse lengths can be as short as a millionth of a billionth of a second. Lasers are especially notable in their relevance to other sciences and their societal impact. With lasers it is possible to control and manipulate individual neutral atoms and molecules. Among other accomplishments it is possible to cool atoms to temperatures as low as 10^{-6} kelvin. With the use of fast pulsed lasers, detailed events occurring in molecular reactions can be monitored. Infrared light can be employed as "optical tweezers" to study the mechanical properties of the molecular motor that propels the bacterium *Escherichia coli* through water. A laser beam has cut chromosomes within the nucleus of a cell undergoing mitosis, and the fragments have been moved into different locations using the optical tweezers.

The formation and study of clusters of atoms is an important frontier of science. The behavior of clusters of a small number of atoms is quite different than that of either a simple atom or atoms in a bulk solid. The first molecules of the C_{60} cluster were observed after laser ablation of graphite. Clusters of varying numbers of atoms, for example, 10 to 200, of other refractory substances have been also produced by ablation. Laser spectroscopic methods are used to investigate the resultant structures. Many unexpected, potentially exploitable phenomena have been observed.

Lasers are having an increasing number of practical applications in medicine, communications, manufacturing, remote sensing, and other fields. Lasers are being used in numerous therapeutic and diagnostic procedures. Laser light can be directed to visible lesions and through flexible optical fibers into body organs where it can have beneficial effects. A broad range of lasers provides the radiation needed to match particular clinical circumstances. A common problem following cataract surgery is that the membrane holding the implanted intraocular lens becomes opaque. A specific laser is used to remove part of the opaque material, thus providing a window through the membrane.

Telecommunications networks are rapidly becoming an optical fiber-based system that has higher performance and lower cost than a copper-based network. The attenuation of signals in high-quality quartz fibers is minimal but nevertheless a problem. The needed periodic amplification of signals is now being provided by erbium-doped fiber optic amplifiers that boost signals by a factor of 1000.

Lasers are finding many applications in industry. With an appropriate choice of wavelength, lasers can be used to process metals, ceramics, plastics, wood, and cloth at high rates. The ability to control lasers with computers makes them compatible with automated manufacturing facilities and permits on-line design and processing changes. One of the largest roles of atomic, molecular, and optical science in industrial applications has been in the area of measurement. On-line monitoring, process optimization, quality control, pollution control, and nondestructive testing are essential to acceptable industrial practice. Fiber optics and lasers can measure a wide range of physical observables with high sensibility, immunity to electromagnetic noise, and usefulness in hostile environments.

The items presented above represent only a small fraction of the significant material in the report. A comparatively low level of federal support of research in atomic, molecular, and optical science is producing enormous benefits for society.

Philip H. Abelson

* National Research Council, *Atomic, Molecular, and Optical Science* (National Academy Press, Washington, DC, 1994).