laser light with matter is called stimulated Raman scattering, in which light is generated at wavelengths longer than the laser light travelling through the medium. Typically this wavelength shift requires huge laser powers (millions of watts). These high threshold-power requirements can be dramatically reduced if the laser light can interact with the matter (or gain medium) over long distances, as in an optical lightguide.

One of the materials commonly used to produce stimulated Raman scattering, because of its relatively large wavelength shift and its high conversion efficiency, is molecular hydrogen. However, hydrogen itself is not a waveguide medium.

Recently scientists at Bell Laboratories in Holmdel, N.J., have combined the desirable features of the large wavelength shift characteristic of hydrogen with the low threshold-power requirements of long silica optical fibers. When a silica fiber is placed in a hydrogen atmosphere some of the hydrogen gas diffuses into the fiber and is trapped in the voids or interstices of the silica network—a gas in glass. The wavelength of light propagating in such a hydrogen-charged silica fiber now can be shifted by the hydrogen gas at reasonably low power levels because of the confinement and interaction over hundreds of meters provided by the silica fiber. In this way power requirements are reduced by a factor of about 10,000 compared with previously used hydrogen gas-cell techniques.

A low-threshold-power large-wavelength-shift device has many possible applications. Nd:YAG laser radiation with a wavelength of 1.06 μm. Visible laser light can be efficiently shifted into the infrared using infrared-transmitting fibers; and different wavelengths can be generated by using other gases, such as deuterium and nitrogen.—**J. Stone, A. R. Chraplyvy** and **C. A. Burrus**, Crawford Hill Laboratory, Bell Laboratories

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Amplified surface plasma wave scattering

Researchers studying the use of intense laser beams to modify material properties have been perplexed by unexplained wavelike or ripple microstructures on surfaces following exposure to high-power laser radiation. The spatial scale of this ripple is equal to or shorter than the wavelength of the laser radiation and is too fine to be due to any aberrations on the input laser beam or to other conventional interference effects. Similar effects have been seen in a wide range of laser-material experiments including laser photodeposition of metals, laser annealing of semiconductors and laser damage of window materials.

MIT Lincoln Laboratory physicists have recently shown[1,2] that these ripples are the result of stimulated scattering of the incoming laser radiation into electromagnetic waves, known as surface plasma waves, which are strongly localized to the vicinity of the material surface in much the same way that waves in the ocean are localized to the water's surface. In a stimulated scattering process, both the surface plasma wave intensity and the ripple structure on the surface grow exponentially during the laser-material interaction. While properties of these surface plasma waves have previously been studied by conventional optical spectroscopic techniques using gratings and prisms to couple incident light into the plasma waves and by electron energy loss spectroscopy on metal surfaces, this is the first demonstration that these waves can be used to modify material structural characteristics.

In the initial stages of the interaction, a very small portion of the incoming laser light is scattered into a weak surface plasma wave due to the presence of some small imperfection, "noise", on the surface. The intensity of the light at the surface is modulated by the interference between the incident laser radiation and the surface wave. This modulation causes more ripple structure to build up due to the light-material interaction which, in turn, increases the scattering into the surface plasma wave. The result is positive feedback and exponential growth of both the surface wave and the ripple which continues until limiting processes occur.

For materials such as semiconductors, there is an additional preliminary step. Under the intense laser radiation the material characteristics are modified to produce the conditions which lead to the existence of the surface plasma wave. In particular, a very thin layer of semiconductors such as Si and Ge melt under pulsed-laser irradiation[3] and the resulting liquid state exhibits metallic optical properties which are necessary to support surface plasma waves. Time-resolved measurements of the dynamics of the microstructure growth have been used to confirm this relationship between the ripple formation and the melting of the semiconductor.

These ripple structures may be of use in the fabrication of semiconductor devices. As more devices of smaller dimensions have been placed on single chips as part of the ongoing semiconductor revolution, the demands on pattern generation processes to fabricate these structures have become more severe. Presently, one of the most commonly used techniques for fabricating submicron structures is to expose a photosensitive film on the semiconductor material using two interfering optical beams. This technique is limited to approximately half the wavelength of the laser source and, in practice, 1000 Å is a lower limit to the presently achievable spatial scale. As a result of the dispersion of the plasma waves, it is possible to generate structures considerably smaller than the wavelength of the laser source. Using an ultraviolet laser, the MIT researchers were able to produce 650 Å structures on a Ge sample.—**Steve Brueck, Dan Ehrlich** and **Jeff Tsao**, Lincoln Laboratory, Massachusetts Institute of Technology

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Scanning laser ophthamoscope

The scanning laser ophthalmoscope (SLO) has made it possible to present a view of the inside of the eye as a television image—accessible to computer manipulation—while actually decreasing the light falling on the sensitive retina during examination. At the Eye Research Institute of the Retina Foundation in Boston, Robert Webb and George Hughes have used lasers and electronics to turn the conventional instrument inside out.

A very weak (40 μW) laser beam is scanned over the retina at TV rates—so fast the raster (the TV line pattern) seems to be stationary. Because the laser beam is so small, only about one mm of the eye's pupil is used for its entrance. All the rest of the pupil (about 50 times this area) is used for exit of light reflected or backscattered from the retina. Conventional ophthalmoscopes use the large area to get light into the eye, and must make do with the smaller area for viewing it. The inversion of this pupil use in the SLO allows it to function with much less total light.

The emerging light is detected by photomultiplier tubes (one of each laser color used) and processed as a TV signal so that no true optical image need ever be formed. Such electronic imaging makes possible remote or group viewing (for consultation and teaching), as well as computer storage and manipulation of the image.

The raster pattern falling on the patient's retina is just like the view of a TV screen. So, by passing the laser beam through an Acousto-Optic Modulator, the beam can be turned on and off fast enough to put scenes on this view. Typically, simple text or merely dots (possibly flashing) are impressed on the raster. The