dition is more physically realistic because, unlike in the prior boundary condition, the connected-bond energy of the surface atoms is kept unchanged and, hence, there is no extra energy penalty for electrons to occupy the connected bonds of surface atoms. The other prior boundary condition is a periodic one and, hence, not well suited to modeling a nanodevice that has an irregular shape or is subjected to a non-periodic externally applied potential.

This work was done by Seungwon Lee, Fabiano Oyafuso, Paul von Allmen, and Gerhard Klimeck of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-41155

Miniature Distillation Column for Producing LOX From Air

This column is only about a hundredth as high as an industrial one.

John H. Glenn Research Center, Cleveland, Ohio

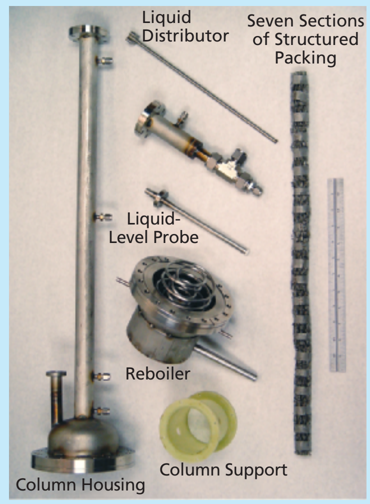
The figure shows components of a distillation column intended for use as part of a system that produces high-purity liquid oxygen (LOX) from air by distillation. (The column could be easily modified to produce high-purity liquid nitrogen.) Whereas typical industrial distillation columns for producing high-purity liquid oxygen and/or nitrogen are hundreds of feet tall, this distillation column is less than 3 ft (less than about 0.9 m) tall. This column was developed to trickle-charge a LOX-based emergency oxygen system (EOS) for a large commercial aircraft.

A description of the industrial production of liquid oxygen and liquid nitrogen by distillation is prerequisite to a meaningful description of the present miniaturized distillation column. Typically, such industrial production takes place in a chemical processing plant in which large quantities of high-pressure air are expanded in a turboexpander to (1) recover a portion of the electrical power required to compress the air and (2) partially liquefy the air. The resulting two-phase flow of air is sent to the middle of a distillation column. The liquid phase is oxygen-rich, and its oxygen purity increases as it flows down the column. The vapor phase is nitrogen-rich and its nitrogen purity increases as it flows up the column. A heater or heat exchanger, commonly denoted a reboiler, is at the bottom of the column. The reboiler is so named because its role is to reboil some of the liquid oxygen collected at the bottom of the column to provide a flow of oxygen-rich vapor. As the oxygen-rich vapor flows up the column, it absorbs the nitrogen in the down-flowing liquid by mass transfer. Once the vapor leaves the lower portion of the column, it interacts with down-flowing nitrogen liquid that has been condensed in a heat exchanger, commonly denoted a condenser, at the top of the column. Liquid oxygen and liquid nitrogen products are obtained by draining some of the purified product at the bottom and top of the column, respectively.

Because distillation is a mass-transfer process, the purity of the product(s) can be increased by increasing the effectiveness of the mass-transfer process (increasing the mass-transfer coefficient) and/or by increasing the available surface area for mass transfer through increased column height. The diameter of a distillation column is fixed by pressure-drop and mass-flow requirements. The approach taken in designing the present distillation column to be short yet capable of yielding a product of acceptably high purity was to pay careful attention to design details that affect mass-transfer processes.

The key components in this column are the structured packing and the distributor. The structured packing is highly compact. Each section of packing is about 1 in. (about 2.5 cm) in diameter and 3 in. (about 7.6 cm) long. The column contains a total of seven sections of packing, so the total length of packing in the column is 21 in. (about 53 cm). The packing promotes transfer of mass between the up-flowing vapor and the down-flowing liquid. The liquid distributor, as its name suggests, helps to distribute the liquid as nearly evenly as possible throughout the cross section of the column so as to utilize the packing to the fullest extent possible and thereby maximize the mass-transfer effectiveness of the column.

In operation, saturated air at a pressure of 70 psia (absolute pressure of 0.48 MPa) enters the reboiler and partially condenses. The air is then fully condensed by an external refrigeration source, such as a small cryocooler. The air then goes through a pressure drop of about 50 psi (about 0.34 MPa) in a throttling valve and thereby becomes partially vaporized. This pressure drop sets the column pressure at about 20 psia (about 0.14 MPa). This column pressure is required to obtain a significant temperature difference in the reboiler. The two-phase flow then enters a separator, where the vapor is vented, and the liquid is sent to the distributor. Once operation has reached a steady state, mass transfer between the down-flowing liquid and the up-flowing vapor



COMPONENTS OF DISTILLATION COLUMN

MAGNIFIED VIEW OF ONE SECTION OF STRUCTURED PACKING

The **Components of the Distillation Column** are designed to maximize mass transfer in a small space.

results in the collection of 99-percent-pure LOX in the reboiler. The nitrogen-rich vapor is vented as waste at the top of the column. The structured packing enables the column operation to be insensitive to tilt angles of up to 20°, with respect to the local gravity vector. We are currently working to further miniaturize the distillation technology to provide a portable, lightweight, and low-power source of high-purity nitrogen and oxygen for other applications.

This work was done by Jay C. Rozzi of Creare, Inc., for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17593-1.

Even Illumination From Fiber-Optic-Coupled Laser Diodes

Emerging light beams would be shaped by diffractive fiber-optic tips.

Marshall Space Flight Center, Alabama

A method of equipping fiber-optic-coupled laser diodes to evenly illuminate specified fields of view has been proposed. The essence of the method is to shape the tips of the optical fibers into suitably designed diffractive optical elements. One of the main benefits afforded by the method would be more nearly complete utilization of the available light.

As shown in Figure 1, the light beam emerging from the flat tip of an optical fiber coupled to a laser diode has a Gaussian distribution of intensity across a circular cross section, whereas what is typically desired is to concentrate the light into a beam characterized by a "top-hat" distribution (even illumination in a specified field of view, zero illumination outside the field of view). In order to obtain an acceptably close approximation of even illumination in the field of view, the Gaussian beam must be significantly wider, so that much or most of the light is wasted outside the field of view. A conventional lens can be used to partially shape the beam, but the beam does not lose its basic Gaussian character; this is true whether the lens is placed at a focal distance from the tip, in contact with the tip, or formed onto the tip surface as an integral part of the optical fiber.

Diffractive optics is a relatively new field of optics in which laser beams are shaped by use of diffraction instead of refraction. There exist ways to produce diffractive lens elements that shape laser beams into desired arbitrary cross sections (for example, the arrow shapes of the beams generated by many laser pointers). In a fiber-optic-coupled laser diode according to the proposal, the optical fiber would be tipped with a diffractive surface such that the diffraction pattern imposed on light leaving the fiber would, at a desired distance from the tip, concentrate the beam at nearly even intensity into a cross section of specified shape. Usually, the desired illuminated area would be rectangular or circular, but in principle, the diffractive surface could be designed to shape the beam to almost any specified cross section. In one version of the proposal, the diffractive shape would be etched directly onto the initially flat tip surface of the fiber. In another version, the diffractive surface would be molded onto a transparent piece of plastic that would be bonded to the tip, the mold having been previously etched or otherwise formed to the diffractive shape.

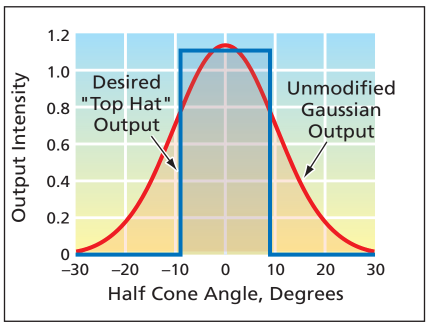


Figure 1. The **Distribution of Laser Light** emerging from an optical fiber is typically Gaussian, whereas often a "top hat" distribution is desired.

A diffractive fiber-tip surface that would function in this way has not yet been designed. However, it has been estimated, for example, that such a pattern on the tip of an optical fiber of 110-μm diameter would consist of about 300 prisms of various heights resembling buildings on 5-μm-square city blocks (see Figure 2), fabricated by etching the square areas to different depths from an initial flat tip surface. A small developmental problem is posed by the difficulty of etching such a pattern.

As in the case of any diffractive optic, some light would pass through undiffracted; hence, the output light pattern that would be mostly the desired pattern with a slight superimposed Gaussian pattern.

This work was done by Richard T. Howard of **Marshall Space Flight Center**. *Further information is contained in a TSP (see page 1).*

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31843-1.

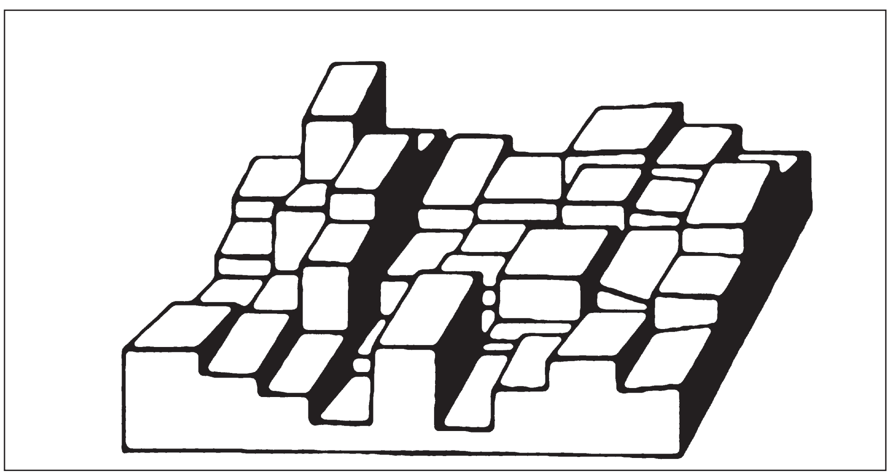


Figure 2. This **Diffractive Optic** was formed in plastic. Optical performance is affected by the widths and depths of steps and the sharpness of edges. Although a rectangular floor plan is shown in this example, the floor plan for application to the tip of a round optical fiber would be circular, even if the optic were to be used to illuminate a rectangular area.