IDEAS

Holograms – three-dimensional laser images – are replacing conventional optical devices, speeding up supermarket checkout lines, and creating more effective bifocal contact lenses.

Focus on lens with a future

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"WHEN is a lens not a lens?" asks a new generation of optical engineers.

"When it's a hologram," comes the reply.

Holograms – three-dimensional pictures made with lasers – are finding new uses as replacements for glass lenses. With a thickness of a few thousandths of an inch or less, holographic lenses can be stamped into plastic for a fraction of the cost of the heavy glass elements they replace. Because they are so thin, these holograms, called holographic optical elements, can dramatically reduce the weight and size of telescopes.

Furthermore, the holograms, also known as HOEs, can be programmed to direct light in ways that are impossible with conventional optics.

"The HOEs that most people have seen are supermarket scanners" that read the bar codes from the sides of packages, says Steven Benton, a professor of holography at the Massachusetts Institute of Technology. In conventional checkout line scanners, a laser beam is directed by a spinning six-sided mirror, which scans the bar code. In the holographic scanner, the spinning mirror is replaced by a spinning holographic disk.

"[The hologram] is lightweight and easy to make, so it's cheap," Dr. Benton says. "They can use a smaller motor to spin it," further lowering the price.

The hologram is "a disk, about eight inches in diameter, that has 20 pie-shaped sections," says LeRoy D. Dickson, an engineer at IBM who helped develop the device. "Each one of those 20 elements is a unique holographic element." As the laser beam strikes the disk, it is directed to a particular place where the bar code might be. "Then as the disk rotates, it brings the next sector over the laser beam. That sector focuses the beam to another distance, another elevation angle, and another skew angle," Dr. Dickson explains.

"In one rotation of the disk with 20 facets, you've created 20 different scan lines." If just one scan line crosses the bar code, he says, the computer "sees" the reflection and the product is tallied by the cash register.

Another kind of HOE was used in the movie "Top Gun" to display the F-14's instruments and computer readouts on the pilot's windshield. This "holographic combiner" was developed by Kaiser Optical Systems in Ann Arbor, Mich. The combiner has been in production for about a year, says B. Jin Chang, the company's vice-president. It is used on a variety of aircraft including the F-15E, one of the most advanced fighters in the American arsenal.

"The advantage of holographic combining is a wide field of view," Dr. Chang says. Although windshield display of instruments, called "heads-up displays," can be done without holograms, systems made with conventional optics have a substantially narrower field of view, he explains.

One of the most exciting applications to date for HOEs is not in supermarkets or in military aircraft, but in the human eye: Allen L. Cohen, a scientist at Allegran Hydron in Woodbury, N.Y., has developed a HOE that simultaneously focuses a beam of light into two images: one near, one far. The pattern for the hologram can be cut into a mold and used to make soft contact lenses. "Such a lens has two prescriptions, and two prescriptions are precisely what bifocal patients need," says Dr. Cohen, who himself wears bifocals.

He started work on the project in 1978; in 1980 he patented the idea. Mixing bifocals and contact lenses has never been an easy proposition, Cohen explains. In bifocal glasses, which are made with a lens that has one curvature on the top, another on the bottom, it is a simple matter for the wearer to look in one lens to see objects in the distance and the other to see objects up close. "But when you try to do that with a contact lens, the contact lens follows your eye," he explains.

The answer to the problem is to present the eye with two images at the same time: one that is in focus only for near objects, the other that is in focus only for ones that are far away. The eye focuses on the image that is in focus.

Until now, such split-focus contact lenses have employed two lenses, one around the other. Unfortunately, Cohen says, putting one lens inside the other made the lenses too small and prevented them from having sufficiently different prescriptions. The result: The image that was supposed to be out of focus was not. "When you superimpose those two images, you have to see them both at the same time – it causes blurry vision. It looks pretty bad," he said.

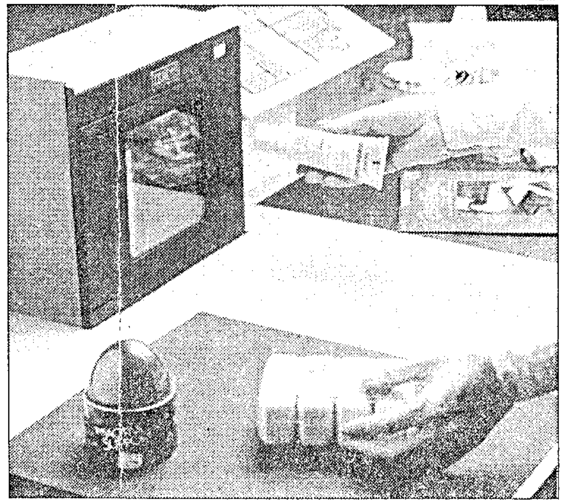
The new contact lens uses a HOE that produces two images for every object that the wearer looks at. For near objects, the first image is in focus and the second image is blurred beyond recognition. For objects in the distance, it is the second image that is in focus, and the first that is ignored. The contacts "are now in trial studies with several hundred people," he says. "The indications from the trials have been very good."

The only problem reported with the lens, Cohen says, is that "patients will say that sometimes in dark illumination, their vision is greatly reduced."

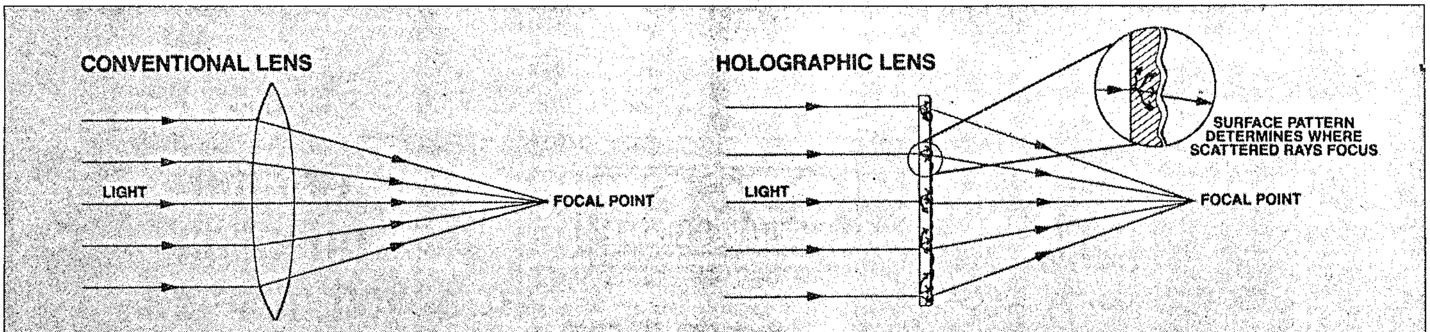
Beyond eye applications, a number of holographers have proposed using HOEs in space-based telescopes, where reducing the telescope's weight would lower the cost of getting it into orbit.

And a project recently done for the United States Postal Service discovered a way to use HOEs to assist in "the automatic location of address blocks on what the Postal Service calls flats – magazines and newspapers," says John Garvey, a project manager at the Battelle Memorial Institute in Columbus, Ohio, a contract research organization, which did the study.

IBM



This vertical holographic checkout scanner can also be mounted horizontally. It is smaller and faster than conventional units.



How a holographic lens works

The difference between holographic and conventional optics is similar to the difference between thinking about light as a wave and as a particle.

Traditional glass lenses work by refraction, treating light as a particle: "Whenever light moves from one medium, such as air, and strikes another medium, such as glass or plastic," it is bent at an angle, says scientist Allen L. Cohen of Allegran Hydron in Woodbury, N.Y. It is as if the light was composed of rays of particles, entering the lens at one side, being bent by the glass, and leaving the lens on the other side, he explains.

Holography is based on diffraction. Think of light not as a particle, Dr. Cohen says, "but as a wave. When you imagine waves striking objects, all sorts of wave patterns and interference patterns can be set up." When light enters a holographic lens, which is nothing more than a block of plastic covered with microscopic valleys and ridges, the light forms an interference pattern and is sent off in one or more directions.

By using computers to calculate the pattern for the lens's surface features, it is possible to make one that will manipulate light in any way that can be imagined, Cohen says. Once the pattern is decided upon, a variety of techniques can be used to put the holographic pattern onto the plastic. The most common is to etch the block lithographically, using the same techniques that are used to create electronic microchips. The pattern can also be directly cut into the block "with a million-dollar lathe that's mounted on tons of stabilizing foundation," Cohen says. Such a lathe has to be able to cut a pattern accurately "to within a fraction of a micron," he adds.

– S. G.