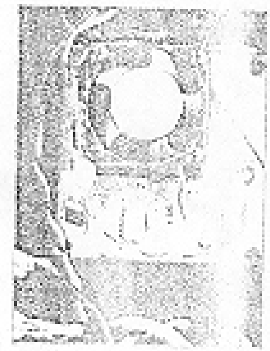
Is Holographic Storage A Viable Alternative for Space?



While it shines in rugged environments and offers gains in capacity and access speeds, holography still faces an uphill fight.

by Aaron J. Hand
Senior Editor/Technology

As space missions venture farther into the depths of the universe — and farther from Earth — engineers are pressed to devise data storage systems that will prove more capable and more reliable. While holographic storage hasn't been chosen yet as the answer to these problems, its large storage capacity, fast record and access times, and rugged design might someday be able to offer space applications what they need.

Developers of holographic storage already have their eyes on the general computing market, hoping to replace other optical discs such as CD-ROMs and digital video discs. But if the technology ever has a chance of coming down to a competitive price, it must find success in niche markets, such as archival applications requiring a huge capacity and very fast retrieval times.

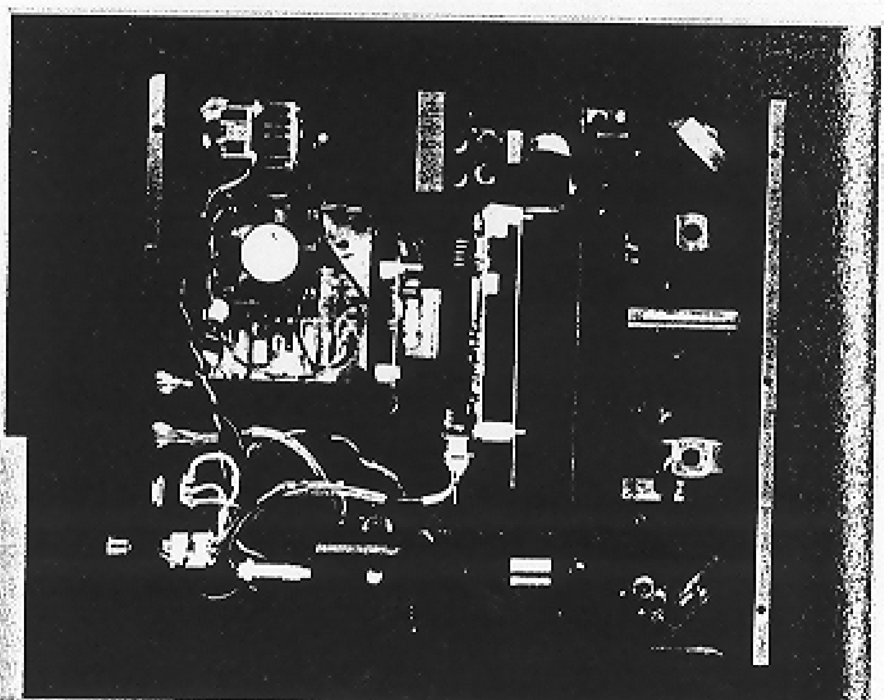
Space missions could make use of holographic storage capabilities. For its proposed mission to Pluto, NASA plans to boost the memory capabilities of the spacecraft, according to Tom Fraschetti, manager of the observational systems division at the Jet Propulsion Laboratory in Pasadena, Calif. Because the data rate from Pluto is so low, the mission will have to be able to store some data onboard while other data are being transmitted back to Earth. Conceivably, such needs will only continue to grow.

But the space industry is not going to jump on a new technology just because it's advanced. A technology must prove its worth, prove that it can offer something considerably more advantageous than the last design and that it can do so without forcing the players to spend much more money.

Holographic storage has its work cut out for it. It may be able to offer capacities 100 times that of other storage technologies and retrieve a billion bits of data in one second, but if it can't do so at a competitive price, and if designers can't convince users that they need these kinds of capabilities, then the technology will go nowhere.

How it works

Holographic storage actually has been around for decades, having been proposed first in the 1960s. But photonics technology has seen several advances, particularly in the last 10 years, that have enabled this storage system to be taken more seriously. Improvements in spatial light modulators, detector arrays and materials have helped holographic storage progress. Other components, such as laser diodes, will allow



[illegible] working on a system with [illegible] speed of 400 Mb/s and a [illegible] of 1 Gb/s. Rather than [illegible] the limits of holography, the [illegible] concentrating on [illegible] marketable system. [illegible] Engineer Yong Qiao.

designers to get the system down to a reasonable size.

Holographic storage uses volumetric holography, in which the information is stored throughout the volume of the material. Other storage systems such as CD-ROMs and magneto-optic systems store information only on the surface.

In holographic storage, each bit of data is stored as an interference pattern throughout the storage medium. First, the data — whether images or bit arrays — are put onto spatial light modulators, typically liquid crystal display devices, represented in crossword-puzzlelike patterns of on and off pixels. One laser beam takes on the data when it shines through the spatial light modulator. This beam interferes with a reference beam to create interference on the storage material, thereby storing the data. The stored data then can be retrieved by shining the reference beam onto the storage material at the same angle at which it created the hologram.

Page at a time

What makes recording and retrieval times so fast (about 1 Gb/s) is the fact that the information is stored a page at a time. The more pages a system can store in one spot, the faster the access times and the greater the storage capacity. So developers are using angle multiplexing, in which the reference beam shifts about 0.001° for each page written.

Still, holographic storage systems face a significant challenge because the areal density of the squares of a spatial light modulator is about 400 times less than that of today's hard drives, according to Eric Elias, senior industry analyst with SRI Consulting in Menlo Park, Calif.

"In order to be exciting, this technology needs to be able to put several thousand pages in one spot, and so far I haven't seen anyone demonstrate this level of performance," Elias said.

Rockwell Science Center in Thousand Oaks, Calif., has developed a holographic system that can put 1000 pages onto one spot, according to John Hong, manager of the microwave and photonics department.

At the Massachusetts Institute of Technology in Cambridge, Mass., researchers are hoping their system will be able to place 15,000 pages on one spot, said Selim Shahriar, research scientist at the institute's Research Laboratory of Electronics.

What makes the MIT system's capabilities so high is a new holographic material, called photopolymer with diffusion amplification, that was developed by Russian scientists and improved by Shahriar and other MIT researchers.

The major stumbling block in holographic storage involves finding and exploiting the right storage material. Lithium niobate crystals previously were thought to be the answer, but several developers have abandoned them in favor of polymers. The difficult search is on for a material that will hold the data indefinitely, that will be consistently reliable and that won't be too expensive.

Photopolymers last a reasonably long time, according to Yong Qiao, chief engineer at Holoplex Inc. in Pasadena, Calif. After the holographic system exposes the material with an interference pattern, ultraviolet techniques fix the pattern onto the material. Although some crystals last a long time, others decay quickly.

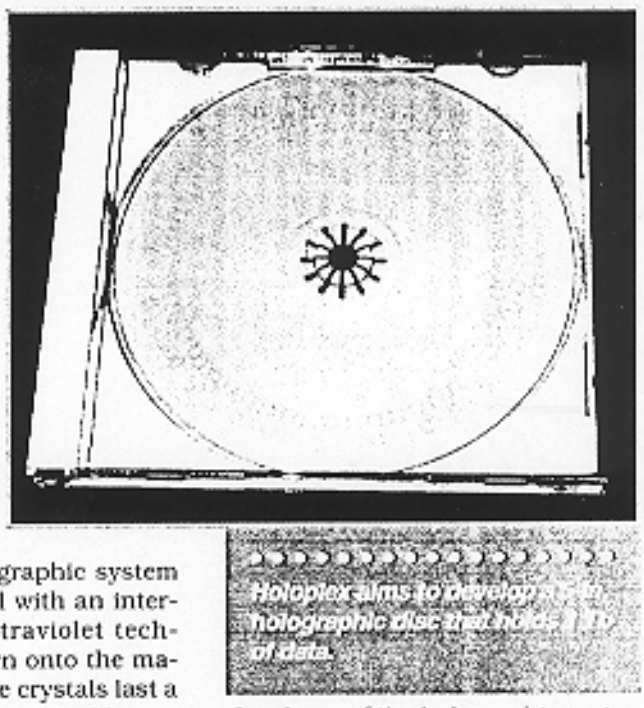
The availability of commercially viable materials is still an obstacle, Qiao said. "It's almost there, but not quite," he said. "There are a lot of parameters to consider, with the three main ones being sensitivity, storage time and dynamic range. For commercial applications, the materials need to be very reliable."

Although photopolymers look interesting, SRI's Elias said, shrinkage of the films could limit the number of holograms that can be stored. "These films shrink during exposure, and may also move around due to changes in temperature or humidity, and that could be a problem," he said.

Rockwell still uses lithium niobate because it offers an attractive thickness (which affects how close together holograms can be stored), but Hong said the company is still looking for a more viable alternative. The photorefractive crystals, he said, are still too variable from source to source, and too expensive.

MIT's material is a Plexiglas substrate with a special dye put into it. The development process for this material is dry, which allows researchers to use a very thick hologram. "Once we've made the hologram and fixed it, there's no shrinkage," Shahriar said.

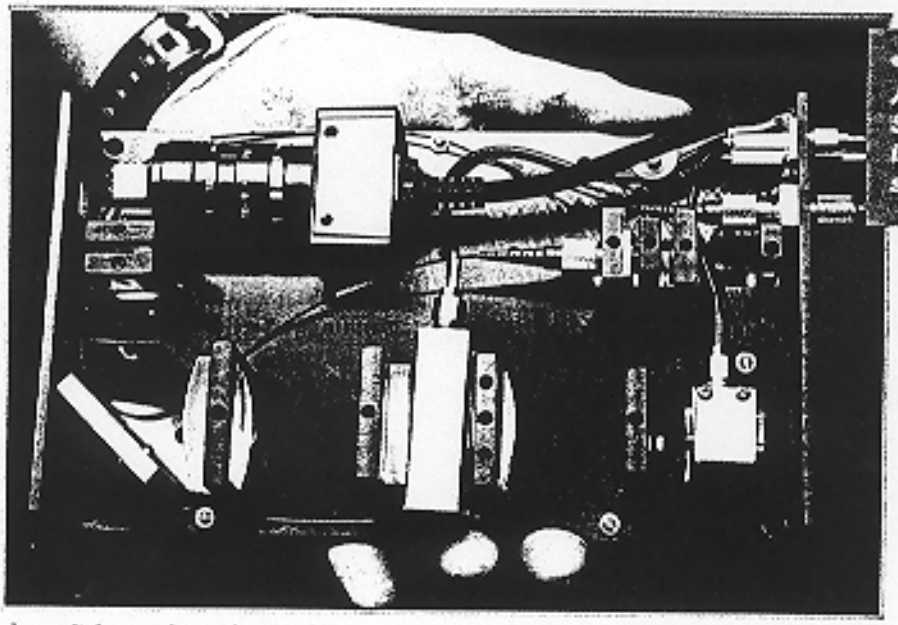
There are several approaches to the shape of the holographic material. One approach involves a cube of material that uses an electro-optic scanning technique to access each location. Another is a disc, a bit thicker than a CD-ROM, that allows storing information along the depths of the disc.



Holoplex aims to develop a holographic disc that holds [illegible] of data.

Finding a niche

How materials research develops could make or break holographic storage's entrance into the marketplace. Qiao estimates that it will be several years before it is commonly marketed, noting that its price tag will keep it in niche markets at first. "It's a relatively new technology, so it



As a member of the Holographic Data Storage System Consortium, Rocky is developing a holographic storage system for rugged environments.

doesn't have the volume that other storage systems have," he said.

The space industry is one niche that could make use of holography's capabilities, according to Qiao. With all the data and images that get downloaded from satellite links or planetary missions, the industry could use a storage device with a large capacity. Also, holography's high recording rate could help the data move across those links at a higher speed.

Although developers are still searching for the perfect material, the nature of volumetric storage makes it inherently robust, which makes it suitable for rugged environments. When information is stored in a hologram, it is distributed throughout the volume of the material. Each bit of information may be stored over thousands of bit locations. If you scratch the surface, you still can retrieve the information. Conversely, if you scratch the surface of a CD, you lose the information stored at that spot.

Rockwell is part of the Holographic Data Storage System Consortium, a university/industry/government venture including IBM, GTE, Kodak, Optitek, Rochester Photonics, SDL, Stanford University, the University of Arizona and the University of Dayton. Rockwell's role is to develop finished systems for rugged environments. The storage medium is more radiation hard than semiconductor memory, so it doesn't suffer as much from a single-event upset. But holographic storage's capabilities in rugged environments come more from the system's configuration as a solid-state system, with no moving parts, Hong said. "We don't have to spend as much time ruggedizing our system as you would with a hard disk drive," he said.

Holographic storage faces not only obstacles with materials and price, but also competition from existing technologies. "The big problem that this technology faces is that it's fighting a moving target," said SRI's Elias, who thinks the window for holographic storage could close within five years.

Good enough for most

Magnetic storage is a perfectly good solution for most applications and continues to improve at a rapid pace. It has its own Moore's Law, he said, similar to that in the semiconductor industry, with capacity doubling about every year and a half.

Holographic storage capacities are often listed at 1 Tb, which is the equivalent of 125 GB. Holoplex is working on this capacity on a 5-in. disc, with a recording speed of 100 Mb/s and a transfer rate of 1 Gb/s. Although that may sound high, it's no longer high enough to warrant investing in a whole new technology, Elias said. Hard drives are in the 10-GB range now. Seagate recently came out with a 50-GB box, incorporating 14 discs. It's becoming possible to envision a 100-GB hard drive with 100-MB/s transfer rates, Elias said.

MIT, however, aims for a storage capacity of 1 TB, with recording and readout speeds at 1 Gb/s. Five years ago, MIT researchers thought they could reach a capacity of 100 GB. But thanks primarily to its photopolymer material, they have much higher hopes. They know, in fact, that they must do much better than 100 GB if they are to get users to switch to the new technology.

And they are going to have to move fast to stay ahead of magnetic storage. "We feel very pressed to bring something to the market as quickly as possible," Shahriar said. "The magnetic memory industry is growing so fast, we have to keep pace with the rate of growth there. If we try to do it slowly, we will always be behind. Three years is all we have to demonstrate something; otherwise, we might as well forget it." □