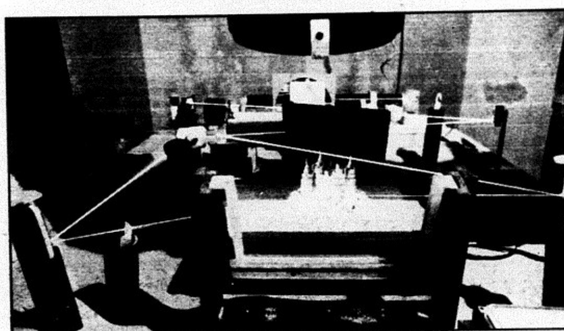
A STATE OF THE ART REPORT: HOLOGRAPHY

BY MICHAEL ROGERS

Deep in San Francisco's Mission District you will find a cavernous and underheated warehouse, dimly lit and crisscrossed by needle-narrow beams of laser light—crimson and rainbow arrows of distilled energy, watched over and manipulated by a band of nocturnal long-haired techno-freaks devoted to the art and science of holography: three-dimensional laser photography. The wanderer in this warehouse will find all the customary detritus of ongoing technology—machine tools and discarded electronics, scattered pages of notes and diagrams, well-thumbed catalogs and entirely unidentifiable bits of hardware. Stacked everywhere, however, is also something altogether unusual.



The do-it-yourself one-ton sandbox holographic set-up

They are holograms: flat rectangles of glass, usually four by five inches, that when held up to light appear to be covered solely by a random swirling pattern of grey emulsion, seeming no more sensible than the surface of a recently stirred mud puddle. But hold the plate at a certain angle, in a strong beam of light, and instantly the content becomes clear: You are suddenly looking past the shiny glass surface, directly through it, as if through a window, at a sharp three-dimensional image of a toy train or a model spaceman or the face of a pretty girl, apparently floating suspended in the air on the other side of the plate.

Move your head up a bit and you will be looking down on the top of the object; move your head down and you are looking up at its underside. Put your hand behind the hologram and the floating image will appear more real than your own flesh. It is, in short, as-life. Even at this stage of development, picked out of the clutter on a rough wooden workbench, it is as likely as anything technological to push your subliminal awe-and-wonder button and leave an ancient message flashing somewhere below the surface of consciousness: Here we have some Powerful Magic.

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Ten years ago holography was considered to be an impractical laboratory curiosity mostly useful for amusing bored first-year physics students. Today it is clear that, within a decade, holography will have impacted somehow on your own life. And the possibilities are limited only by the imagination.

Perhaps it will be a framed art hologram, with a built-in light source, that will hang on your wall and act as a perpetual window into some little world on the other side of the glass. Or a holographic portrait of friend or lover, a full 360° head shot displayed on a round cylinder of plastic so you can walk around and check out front, side and back all at once. (Salvador Dali and Alice Cooper, only a little ahead of their time, have already posed for the first of these.) Past that the possibilities begin to sound like classic science fiction. Holographic TV? Holographic movies? Definitely possible. With more advanced technique and a great deal of money—Sir Lawrence Olivier standing six feet tall and three-dimensional in your living room, emoting, perhaps, in quadraphonic sound. Pornoholography? A natural: The first holographic nude has already been commissioned.

Clearly, before any of us, lord willing, celebrates the turn of the century, we will have been presented with some thorny questions about the precise hierarchy of the real and the not-real—and maybe, the super-real. Spend a little time staring at good holograms and it is hard not to recall the future housewife in Ray Bradbury's *Fahrenheit 451*, who spends her day at home surrounded by four walls of nonstop super-real three-dimensional soap opera. Or the children in a Bradbury short story, who wander off into a nursery-wall hologram of the African veldt—where the lions are so real they even have appetites.

As far as the philosophical questions go, it may turn out to be every perceiver for himself. But the technique itself of holography is both interesting and rather straightforward—and a good example of a process that may initially appear quite mysterious, but which is in fact only a logical combination of a few curious natural properties.

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Contributing Editor Michael Rogers recently published his first novel, 'Mindfogger.' He also writes the book section for Rolling Stone.

THEORY

For those familiar with conventional photography, holography will sound mysterious indeed. In holography there are no lenses between subject and film. There is no such thing as depth-of-field: Everything in front of the plate, at whatever distance, is in focus. A whole series of holographic images may be put on a single plate. There is no such thing as a "negative": If a hologram was copied by contact printing, the plate itself would come out reversed—dark lines where light ones had been—but the image produced would be exactly the same. And should you happen to drop a glass hologram on the floor and shatter it into a hundred pieces or so—the entire image, in two dimensions, can still be reconstructed from any single fragment. Information is conserved, as the holographer might say. Goddamn odd, the conventional photographer might say.

To explain holography we need to understand one property of light almost always entirely invisible to the eye. Light is a form of electromagnetic radiation—precisely the same form of energy as, say, radio waves or the electric current in your house—just at a vastly higher frequency to which the optic nerve, something like a radio, is tuned. Hence we can think of light as coming in waves, much like ocean waves—crest, trough, crest, trough. This is only, of course, a model. The primal reality of "what light is" will never fit entirely into this wave-model. But it works just fine for giving us a handle on the particular reality of holography.

Normal light, as emitted by the sun or incandescent light bulbs, is composed of a variety of frequencies (colors) of light, as well as many individual light waves that are out of phase. By out of phase we mean that while one wave is cresting, another is in its trough, and yet another may be halfway in between. Now there's nothing wrong with light like that—it's worked well enough for anthropoid primates for the last million years or so—but human beings have a tendency to screw around with everything. And thus the invention of the laser—Light Amplification by Stimulated Emission of Radiation, which distills normal light to a condition of high purity and high energy.

Laser light is *coherent*, which means that every wave that composes the beam is in phase; each wave crests, each wave troughs, at just the moment every other wave does. The product is a beam of light both powerful and highly directional. Even a weak laser may be capable of burning a blind spot into the retina of the eye, and more powerful beams, at least momentarily, can melt steel. A laser beam aimed at the surface of the moon will have spread only two miles by the time it has crossed 238,000 miles of space. Aimed across even the widest room, a laser beam remains a virtual pinpoint.

The coherence of laser light is of most importance in holography, because of a characteristic of light waves known as *interference*. If we continue with our assumption that a beam of light is made of many different wave-trains, then interference is easy to understand. Crest, trough, crest, trough—each individual wave follows this pattern. And when two isolated waves come together—say in striking the sensitized surface of a photographic plate—they will either agree (both cresting or both in their troughs) and hence reinforce each other, or else disagree (one is cresting, the other in a trough) and thus, like adding positive and negative quantities, they will cancel and leave no trace.

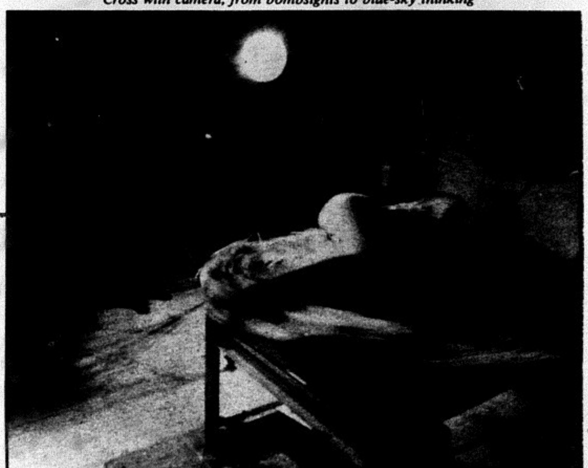
To make a hologram, we simply put together this property of interference with the coherent light output of a laser. We use one laser, with its beam split into two separate light sources. One half-beam (the object beam) bounces off a set of mirrors, through some lenses, and finally illuminates the subject, which is set directly in front of the photographic plate about to be exposed. The other half-beam (the reference beam) directly illuminates the plate. When the hologram is actually taken (usually the beam passes through a small electric shutter), the resultant image on the photographic plate comes from two sources: one, the reference beam, straight from the laser, just as produced. The other source is the laser light reflected off the subject onto the plate. And this is where the properties of coherence and interference come together. All of the laser beam, recall, started out in phase. But now the beam has taken two different paths, of differing lengths. And so the two have had a chance to get out of step, and the result, as captured on the photographic emulsion, is an interference pattern between object beam and reference beam that records, quite literally, every groove, wrinkle, bump and protrusion in the object being holographed.

Viewing the completed hologram is a

reversal of the above process. Laser light is directed at the surface of the plate from the same angle as was the reference beam. The interference pattern on the plate redirects the light so that it comes out of the plate exactly as it came in when the pattern was formed: The visual cues of the object are thus reconstructed, and, to the eye, it appears as if the object is still out there in space, reflecting the light of the object beam that is in reality long since gone.

While the details of this wave-front reconstruction may be difficult to visualize, it should be possible to sense how the interference of light waves allows one to record, on a flat surface, not only the variations in light and dark, but the distances and depths associated with a given scene. What is most interesting is that holography depends upon a property of light—that condition of crest, trough, crest, trough—almost always totally beyond our perception, yet which, when properly manipulated, can recreate a real object with unequaled fidelity.


Cross with camera; from bombsights to blue-sky thinking


One nude, rotating, and 1080 stills: the making of a 360° hologram


Science-freaking in progress at School of Holography

PRACTICE

Beyond the theory, of course, are more practical questions: If, intrigued, you want to learn holography yourself, is it even within the realm of possibility?

The best answer is back in that San Francisco warehouse. SAN FRANCISCO SCHOOL OF HOLOGRAPHY reads the small sign on the front door, and inside is a phenomenon increasingly common at the frontiers of new technology: a collection of science-freaks, generally long-haired and blue-sky thinking, who have discovered a toy of immense interest in a scientific process once restricted to the pages of esoteric scientific journals.

The classic example of the phenomenon is computer science—see Stewart Brand's "Spacewar" in ROLLING STONE Issue No. 123. But holography—which has a stony, mind- and dimension-bending potential almost unique in frontier technology—is clearly a prime candidate for concerted science-freaking.

"Look at this," says Lon, a ponytailed holographer of 18 months or so, surrounded by a group of aspiring student holographers. He is placing an 8"-by-10" hologram in the diffused beam of a bright red helium-neon laser. "If you look at it this way"—he holds it up, the image of a steam locomotive appearing suddenly, clear and three-dimensional, floating somewhere behind the plate—"it's *orthoscopic*, which means it's accurate in all three dimensions. But if you turn it this way"—he flips it over in the laser beam, turns it upside down, the image of the locomotive now appearing to emerge right out from the glass—"it's *pseudoscopic*. Anybody know what pseudoscopic means?"

No one knows except Lon. "It's accurate in two dimensions," he says, "but reversed in the third. It's as if the whole thing has been turned inside out—and there's almost no way the human eye can ever understand that."

The students look more closely. Sure enough: The longer one looks, the stranger the image. How did someone reach inside that locomotive, grab it by the headlight, and pull it inside out?

"Pseudoscopic," Lon says again. "It sounds complex, but it's not."

Pseudoscopicity is only the beginning of the mental trips afloat at the School of Holography. Science-freaks tend to approach technology as if a toy. If there is a nine-to-five involved it is likely to be nine at night until five in the morning. And the problems are rarely formulated in terms of this-is-what-we-think-will-sell; more likely, this-is-what-we-think-will-be-far-out—and if the far-out just happens to be saleable as well, so much the better.

The School abounds with examples of science-freak straight-line problem-solving. Since holography depends on the interference of specific wavelengths of light, any vibration of the holographic plate—even one-quarter wavelength of light, unthinkably minute—will blur or destroy the image during a long exposure. And much holography these days must be done with long exposures. Even university laboratories have reported difficulties achieving a high level of stability in the holographic setup. The technique used at the School is to ignore the traditional notions of elaborate metal optical benches, and instead, use simply built huge concrete block containers filled with about a ton of fine white sand, floating atop a base of partially inflated inner tubes. All optical components are mounted on long tubes and simply buried in the sand wherever required. The result is great flexibility, maximum stability, and the distinctly pleasant sensation that the experimenter is playing in a massive waist-high sandbox.

There seems to be nothing wrong with the survival potential of sandbox thinking. Lloyd Cross—an Ann Arbor laser genius who departed the conventional technology-biz when the laser bombsight went into R&D—has financed the wattage for the School's lasers through regular courses, given nights and weekends, that will make anyone a reasonably competent holographer in only a dozen hours or so. But the plans of Cross and company go a good deal past the simply pedagogic.

One area where the School has concentrated attention is perfection of the image-plane hologram. Conventional holograms, of course, must be viewed either with a laser or a rather specialized source of filtered, highly monochromatic light. The image-plane hologram, however, has in a sense a built-in filter, and thus may be viewed with almost any bright, reasonably narrow source of light—a desk lamp, a spotlight, even the sun. The quality of the image-plane holograms made at the School has increased rapidly and already they sell as many as they can produce. With only a bit more development, the era of the art hologram, glowing in some dim corner of the living room, will be with us.

Just beyond that is the holographic portrait. The first 360° holographic portraits—those posed by Salvador and Alice—were made at the School of Holography. The technique—a remarkable breakthrough in holographic technology—involves taking a large number of separate still photographs of the subject and then transferring them to a cylindrical hologram via a complex method of multiplexing. In its final form the process will probably involve a small movie camera, mounted on a boom that swings in a wide circle around the subject's head, snapping three pictures for each degree of movement. All 1080 pictures will be multiplexed onto the head-sized plastic cylinder and the result will be, quite literally, a walk-around representation from ear to crown to forehead. And that's only the beginning of the possibilities. Cross is already at work on 360° holographic x-rays. In one of the prototype portraits on display at the School, the subject was instructed to smile for the last few frames of the picture. Transferred to a flat hologram, this means that as you move the plate, you see the girl's head turning, turning, turning—and then suddenly grinning, almost as smoothly as in life.

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FUTURE

It is late afternoon at the School of Holography. A group of holographers sit around the small cluttered teaching space, discussing a recent television special that explored the possibility of ancient earth junkets by extraterrestrial astronauts. Quite suddenly, the discussion segues into prehistoric lasers.

One of the holographers—a quiet long-haired Oriental named Michael, who started his electronic career repairing radios and who has just finished his second homemade continuous-wave gas laser—starts to describe a pre-Columbian South American laser culture. "They used solid gold mirrors," he says, "mounted on marble and jade, high up on the tops of mountains, for defense. They had huge pits dug between the mirrors where they kept bonfires of big logs burning." The gold, he explains, was highly reflectant of infrared wavelengths, so the infrared energy generated by the burning logs would bounce around between the two solid-gold mirrors until it finally built up enough energy to zap out, down from the mountaintop, incinerating or at least badly frightening whomever was threatening the mountain-laser Indians. The reason that no trace of laser-culture has been found, he claims, is that when the Spaniards invaded and defeat was imminent, the laser Indians chose to melt down their magical solid-gold mirrors.

He describes the giant primitive lasers in great detail, evoking the power and glory of those solid-gold mirrors atop the marble stands, and when he finishes, there is a moment of respectful silence in the room.

"Jesus," one of the veteran holographers finally says. "Where did you hear about that?"

The storyteller shrugs modestly. "Oh, on the radio," he says. "You know. Around." He shrugs again. "And I added to it some myself."

There remains a great deal to add to the story of holography, as well, but most of it lies in the same approximate realm of speculation, possibility, the half-connection. Unlike the past, however, the future shows an increasing tendency to grow to fit the myths of the present—so perhaps the speculation is the most important part of the story.

Moving holography is the process that could revolutionize not only the media but all heads that input media. Right now a moving hologram is technically feasible, but monstrously expensive, although it is already attracting attention from big-money participants. Most holography today is done with continuous-wave lasers that provide a constant beam, but little power, necessitating long exposure times. A more sophisticated variety is pulsed, putting out an extremely bright beam for only a few ten-thousandths of a second, in the manner of an electronic flashgun. Already pulsed lasers exist that are capable of flashing and recharging up to ten times a second—and as any filmmaker knows, even ten frames a second can provide a decent illusion of motion. And as long as we're speculating, there's no reason why those moving holograms can't be full-color, too. Processes have been developed to produce color holograms, much like the three-step techniques used in the first attempts at color photography.

How soon until commercially broadcast motion holography? Well, it's still a bit early to sell your color TV. The difficulties are immense—recording method, transmission mode, display system—although, of course, not that many decades ago, something the same was said of color television. Still holography, certainly, will be commonplace by the time holographic television is implemented. The advertising potential alone of good still holography is, needless to say, considerable. A milestone in holography, in fact, may be when a national magazine first includes an inexpensive mass-produced image-plane hologram.

And what about those philosophic implications of highly sophisticated holography? In the broadest sense, it may mean that in this nation of media-junkies, we'll find that the distinction between illusion and reality grows increasingly fine—conceivably, even, to become almost a matter of taste. A trifle far-fetched? Already, for certain purposes, a hologram of an object can be more useful than the object itself. When viewing a biological specimen under a high-power microscope, for example, there are difficulties involved in keeping the subject in focus—particularly if, like many biologic specimens, it is suspended in fluid. Previously it was necessary for the scientist to either slice the subject down almost to two dimensions, or else freeze it solid.

Now it is possible to make a short-exposure hologram of the specimen, freeze its motion without distorting its structure, and thus be free to examine the subject three-dimensionally at one's leisure. The illusion, in this case, is altogether more useful than the reality. In non-rigorous terms, it may even recall Werner Heisenberg's inescapable old Uncertainty Principle—the principle that formulates, in a sense, our expulsion from the Garden, condemning us forever to be unable to watch nature without somehow altering its flow. Holography may at least give us better seats in the theater.

Past all this, however, is one more consideration. If the nature of a medium acts to alter the thinking of the perceiver, then with holography we're closer to home than ever before. Holography comes from the same Greek root as holistic, a word which refers, worthily, to an analysis that takes into account all facets—the depth and breadth—of a situation. Whether or not one thinks holistically, there is increasing evidence to suggest that the physical brain stores information holographically. Nothing, of course, to do with lasers or photographic plates, but the principle of conservation of information—that example of the shattered holographic plate—seems, within limits, to hold true in the structure of a brain. Holographic storage implies the storage of patterns, rather than bits: The obvious comparison is a normal photographic negative—where the image is stored on discrete bits of silver, each meaningless when taken individually—against a holographic plate, where the entire scene is recorded at each point. Recently much attention has been given to the development of holographic memory storage in computer science; appropriate enough, considering that the computers between our ears seem to have been doing it already for the last few million years.

The precise directions holography takes from here will depend on the imagination of those who work within the medium, and the appetites of the public. The existence of a strong human desire for increasingly real media is, at this point, hardly debatable. It is reminiscent, in fact, of the Russian writer Tolstoy, who near the end of his life had a chance to view one of the first successful moving pictures—a steam locomotive rushing jerkily past the camera, causing many in the audience to shrink back involuntarily in their seats. Afterwards storyteller Tolstoy had only one comment: "I was born 50 years too soon." Thank to technological acceleration, the chances are that almost no one reading this need say the same about holography. The only question remaining is precisely how ready we'll be when it gets here.