

Figure 1. Holography pioneers Emmett Leith (*right*) and Juris Upatnieks at the Radar & Optics Lab, Willow Run Laboratories, 1964. [Bentley Historical Library, University of Michigan.]

HOLOGRAPHY From Science to Subcultures

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Holography has time and again been reconceived and retargeted by an unusually diverse succession of users with divergent perceptions, methods and goals. Two of the earliest and most dissimilar communities had origins in classified research and the counterculture movement.

conceived more than half a century ago by the Hungarian scientist Dennis Gabor at a British industrial laboratory, it exploded during the 1960s when lasers first made possible dramatic three-dimensional (3D) imagery and exquisitely sensitive measurements. Holography and its practitioners have been far from static in the intervening decades: holography has steadily evolved into a variety of applications, while the interests and vocations of practitioners have assumed the characteristics of bona fide scientific and artistic subcultures.

While many of the applications of holography are familiar to opticists, the subcultures of holography may not be immediately recognizable. Culture can be described as a collection of beliefs, practices, traditions, values and perspectives. We can distinguish a subculture by how its members think and by what they do, as well as by the products they create. With those broad definitions in mind, it becomes apparent that holography has engendered a number of subcultures having distinct goals and ways of perceiving the science itself. Among them are new breeds of scientists, hybrid engineers, technology-based artists, amateur holography enthusiasts and entrepreneurs.

Holography spawned these groups as it was being explored in new environments. The new communities were nurtured at schools of holography, art studios and startup businesses; they were reinforced and transmitted by periodicals, exhibitions and museums. Enthusiastic proselytizers propagated them further afield.



Figure 2. Margaret Benyon, 1970, behind her table-top holograms. Benyon was one of the first artists to learn holography and explore its aesthetic possibilities. [Benyon collection.]

The first influential community of holographers had its origins at the University of Michigan. When Emmett Leith and Juris Upatnieks at the Willow Run Laboratories there in the early 1960s announced improvements in what Gabor had called "wavefront reconstruction," they were straddling a professional no-man's land (Fig. 1). Since its origin in 1954, in fact, the operations of the Radar & Optics Lab of Willow Run Laboratories had been funded by classified research, a situation that was common to a significant portion of postwar science and technology. Indeed, Leith had been drawn to wavefront reconstruction as an outgrowth of his work on the development of a coherent optical processor for synthetic aperture radar data. The secrecy at Willow Run contrasted with traditional academic openness; the sponsors approved any publications cautiously, and the laboratory was located some 15 miles from the Ann Arbor campus, a factor which intellectually isolated its researchers.

Second, the workers at the Radar & Optics Lab were applying nontraditional optics to problems of electrical engineering. Indeed, most of the investigators at the lab had backgrounds in electrical engineering. Leith himself, having taken undergraduate courses in optics, was atypically well equipped to apply the ideas of coherent optics (using filtered mercury lamps, the most coherent sources then available) to the processing of electrical signals. The group combined these distinct disciplinary approaches to solve the problems it faced.

In recognition of the drawbacks of the intellectual segregation created by the

"Holography by itself is a somewhat narrow field, but combine it with others and it makes an area big enough to spend a lifetime in."

— Emmett Leith, 1986



Figure 3. "Public access holography," an illustration of a sandbox apparatus. [Unterseher et al., *The Holography Handbook: Making Holograms the Easy Way* (Ross Books, 1982).]

lab's location and the challenges posed by merging two such disparate disciplines, administrators integrated the laboratory with the University of Michigan campus during the early 1960s. At the same time, they appointed George Stroke the first professor of electro-optical sciences in the school's Electrical Engineering Department. (The Electrical Engineering Department itself had been a spinoff of the Physics Department a few years earlier.) Stroke touted electro-optical engineering as the most important discipline to emerge from modern optics. (Stroke's troubled relationship with his University of Michigan colleagues and his influence on the public history of holography are separate stories in and of themselves.)

Optical engineering as a career path had become more appealing in the United States after World War II, when missile and nuclear tests raised requirements for rapid cameras and tracking systems. Until the early 1960s, however, unlike their Willow Run counterparts, most optical engineers concentrated on combining skills in geometrical optics with expertise in mechanical integration. Adolf Lohmann, one of the few researchers studying holography during the 1950s, recalls the problems optical physicists and electrical engineers of the era had in communicating with each other:

In 1954, two radio and TV engineers came to our optics lab in Braunschweig. They asked: "How many dB has a typical lens?" [I replied] "A lens has aberrations and a bit of diffraction, but no dB," (and I thought to myself 'you'd better learn what aberrations are before you come back and steal our time').¹

At coherent optics laboratories such as Willow Run and the Vavilov State Optical Institute in Leningrad, where researcher Yury Denisyuk was engaged in separate but parallel research, optical engineering came to embody a synthesis of communications theory and wave optics. The new subject also flourished among researchers of microwave electronics, lasers and radio astronomy.

At first, the Optical Society of America (OSA) and what was then known as the Society of Photo-Optical Instrumentation Engineers (SPIE) adapted awkwardly to this new field, which was still dominated by military funding. Existing journals seemed poorly suited to the hybrid. Although the *Journal* of the Optical Society of America was joined by Applied Optics in 1962, through the 1960s holography papers were as likely to be published in journals of general science or those of the IEEE as in those of the optical societies. Interestingly, Dennis Gabor, Reader in Electrical Engineering at Imperial College from 1949, had not been a member of OSA before 1971, when he won the Nobel Prize for his invention of holography.

Holography required disparate skills that seemed best suited to groups of investigators having complementary backgrounds. But by 1966, two years after 3D holography had first been demonstrated at the OSA spring meeting, "the holographer" existed as a recognized specialist. Gabor suggested that the ideal individual to pursue holography at the CBS Laboratories would be "a young first degree physicist [italics added], say 22-26, who would be willing to learn and whom I could train myself. If he had a course in modern optics all the better, but it is not absolutely necessary."2 Jim Burch at the National Physical Laboratory in Britain defined him (holographers were then almost exclusively male) as a hands-on investigator concerned with engineering analysis; Ralph Wuerker of TRW in California facetiously noted that the scars inflicted from holographic plates broken in the dark would be the mark of the holographer.³ This emerging identity was promoted by dedicated conferences, such as those organized for acoustical holography in Huntington Beach, Calif., in 1967, and for holographic interferometry in Glasgow starting in 1968. The Gordon Research Conferences on Holography and Optical Information Processing, held in association with the American Association for the Advancement of Science (AAAS), starting in 1972, even more closely ascribed the community of scientific holographers; the chairman himself traditionally selected all speakers and invited participants.

Gabor's emphasis on the need to pursue holography with malleable young practitioners is significant; by the late 1960s, most holographers were, indeed, newly trained scientists or engineers, able and eager to absorb the new subject fully. Charles Vest, later president of the Massachusetts Institute of Technology (MIT), entered the field of holographic interferometry as a newly qualified assistant professor of mechanical engineering at Michigan.

Young practitioners had careers to forge and fresh perspectives to contribute. This was particularly true by the late 1960s, when holography was taken up in new contexts. Enthusiasts had been drawn to the subject by a wide range of popular articles and a handful of how-to explanations in magazines such as Scientific American. The readers of such articles now included "would-be" scientists rather than young professionals already employed in the sciences. The amateurs were motivated by the same interests and ideals, although their enthusiasm about improvising with limited resources contrasted with the way research was carried out by professional scientists working in well-funded laboratories. While the professionals increasingly focused on optical image processing and holographic memories, the amateurs were drawn to the excitement of visual displays.

The seeds of two distinctly different perspectives were planted at this time. The first was the attraction of artists to the new medium during a period in which new connections between art and technology were being actively pursued.

In 1968, artist Bruce Nauman approached the Conductron Corporation in Ann Arbor, Mich., which was energetically exploring markets-and seeking investors-for display holography. He produced a number of holographic selfportraits, which were exhibited in small galleries. At about the same time, painter Margaret Benyon, supported by a fellowship in art history, produced her own holograms in a lab in the Mechanical Engineering Department of the University of Nottingham (Fig. 2). When she displayed them in Bristol, she found the public, like herself, both disoriented and captivated by the viewing experience.

Within a year artists Karl Fredrik Reutersward in Stockholm and Harriet Casdin-Silver in Boston were also exploring the medium and exhibiting their works to small audiences. These artistic



Figure 4. Creative chaos: Lloyd Cross and colleagues at the Multiplex Company, San Francisco, circa 1975. [New York Museum of Holography Collection, MIT Museum.]

"If you think about the amount of struggle, and the amount of energy, that has gone into this collectively, it's pretty interesting. It's clearly addictive, and ... it's equally destructive to the personality!"

— Fred Unterseher, 2003

interactions with holography added, quite literally, a new dimension to the work being carried out in the field. Until then, holograms had usually recorded mundane and readily recognizable objects; Leith and Upatnieks, like most holographers, had recorded models of trains, tanks and tools—objects sufficiently stable to remain motionless to within a fraction of a wavelength during exposure. Artists, too, started with representational art. The loose-knit artistic community began to branch into abstract variants and more experimental forms during the 1970s to figuratively "sculpt with light." Some 500 shows—including big exhibitions in New York (to largely negative critical reviews), Stockholm, London, Berlin, Rome and Canberra brought the subject to hundreds of thousands of people over the following two decades. In the Soviet Union, this type of non-scientific artistic community did not develop; instead, starting in the early 1970s, Soviet institutes of the Academy of Sciences established programs to holographically record valuable art objects to make them available to audiences in the provinces.

The second perspective to appear during the late 1960s was a more general, countercultural trend that initially rejected aspects of holography and then absorbed and modified them. Coincidentally, the University of Michigan at Ann Arbor was home to both the rebirth of holography and the genesis of the youth movement: the influential Students for a Democratic Society (SDS) was organized there in 1960. While these two events had no initial correlation, they intersected from 1965 onwards when student protests over the Vietnam War began to focus on



Figure 5. Creating new communities: Tung Hon Jeong (*sixth from left, front row*) organized the first International Symposium on Display Holography, Lake Forest College, III., in 1982. The symposium brought together scientists, artists, entrepreneurs and enthusiasts. [New York Museum of Holography Collection, MIT Museum.]

institutions involved in military contract research. The Willow Run Laboratories became an eventual target. Centrally funded professional science and its perceived underlying ideals—such as notions of progress and materialism -attracted increasing criticism. Holography itself was suspect among the protesting students because of its sources of funding. The association between military sponsorship and Willow Run activities became contentious enough to convince the University of Michigan to devolve the lab in 1972 as an independent non-profit research organization, the Environmental Research Institute of Michigan, half a mile from the campus.

Willow Run also spun off numerous startup companies and entrepreneurs. Perhaps the most significant of them was Lloyd G. Cross, who had worked as a research associate in the maser laboratory of Chihiro Kikuchi from the mid 1950s. In the year after Ted Maiman at Hughes

Research Laboratories invented the ruby laser in 1960, Cross and his group, working without funding and after hours, became the third team to develop such a device. He co-founded Trion Instruments to manufacture ruby lasers and later joined KMS Industries, another Willow Run spinoff firm. By the late 1960s, however, increasingly disenchanted with the applications of his work, he began encountering artists interested in taking up holography. During a peripatetic three years, he collaborated with artist Jerry Pethick and others in setting up small holography labs, displaying holograms and attracting a coterie of followers. By 1971, their entourage had resettled in San Francisco, where they established the first School of Holography. Members of the group scoured the Bay Area in the search for permanent premises. They found their special requirements for a quiet laboratory did not seem well-suited to their demeanor:

They had to 'check the vibrations in your building' and owners thought they were totally nuts. One guy said, 'You guys aren't going to make drugs are you?' And of course we looked the part.⁴

The school, which was run as a loosely organized community, made holography accessible not only to amateurs, but also to artists and other enthusiasts with no background at all in science. The key was their invention of the "sand table," a low-cost, low-tech solution for isolating the holographic apparatus from vibration (Fig. 3).

In 1974 the school mutated into the Multiplex Company, which went on to produce thousands of cylindrical animated holograms that could be viewed in white light (Fig. 4). These became the most widely seen holograms of the 1970s and had an unprecedented influence in raising public awareness of the medium. Other private schools appeared soon afterwards in New York, Chicago and,

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by the early 1980s, different locations in Europe.

Besides espousing low-cost self-sufficiency in the style of the Whole Earth Catalog, the San Francisco School of Holography absorbed wider meanings for holography itself. Since the late 1960s physicist David Bohm had mused publicly about the analogy between holography, human perception and physical reality itself. Psychophysiologist Karl Pribram similarly had promoted the analogy of memory as holographic. These links between holism and holography resonated with Eastern and mystical elements in counterculture thinking. By promoting ideals popularized by the wider youth culture, the San Francisco School nurtured a new contingent of holographers who were distinctly at odds with their Department of Defense-funded counterparts. Cross recalls that his orientation "was not so much anti-technology as against the process and procedures of technical innovation which separate and isolate the technical specialities."5

Graduates of the school became artists and teachers of holography who promoted the subject as a means of personal expression rather than as a rejection of established values. From this counterculture group came a stream of entrepreneurs eager to exploit the medium as a cottage industry. The emerging sense of community was reinforced through specialist publications; the best known of these was holosphere, published from 1972 as a trade newsletter and then from 1977 to 1990 by the Museum of Holography in New York, which sought to become an international focus for holographers. Other shorterlived publications (notably Wavefront, by artists and entrepreneurs in Vancouver; Image Plane in Providence, R.I.; Real Image by the Royal Photographic Society in Bath, U.K.; and Holographics International by physics students at Imperial College London) attempted to promote particular definitions of their holographic communities.

In 1982, Tung Hon Jeong organized the first International Symposium on Display Holography at Lake Forest, Ill., as an outgrowth of his summer classes (Fig. 5). Attendees recall it as seminal in



"Matrix 18R," 1985. Off-axis Fourier transform lens matrix hologram produced by Fred Unterseher at the Dennis Gabor Holography Laboratory, Museum of Holography, New York. Unterseher, a scientist, artist and teacher, was a cofounder of the first independent school of holography and is a co-author of The Holography Handbook. He says the hologram pictured here "involves my exploration of light and spatial relationships in kinetic form, blending inspiration from ancient sacred geometry with technological media." Unterseher is currently an instructor in a photonic laser technology program for high school students in Columbia, Mo.

bringing coherence to the increasingly fragmented subcultures of holographers.

More recently, the expansion and proliferation of holographic groups has taken a pause. The New York Museum of Holography, like the schools and cottage industry that appeared during the late 1970s and early 1980s, gradually discovered that communicating this sense of community was ephemeral. The general public absorbed the ideas and enthusiasms of holographers with difficulty. The nascent organizations mounted educational campaigns that sapped more traditional profit-making activities. Yet public awareness of holography increasingly was shaped and dominated by the film portravals of Star Wars and Star Trek, a factor which introduced a bifurcation between the technical realities and the imagined future of the medium. Popular culture became diverted by a "virtual image" of the subject that could not be realized by any community of holographers then existing.

The subcultures of holography have continued to evolve as the public engagement and occupations of holographers have themselves undergone transformation. Holography did not develop applications that generated a distinct occupation supported by universitytaught courses (although higher degrees in creative aspects of holography became available, notably at the Royal College of Art in London and, with the creative guidance of the late Stephen Benton, at the MIT Media Lab). Even the broader and richly supported field of optical engineering experienced a significant downturn in funding at the end of the Cold War. The growth of stable occupations and accredited teaching programs is usually deemed crucial for the consolidation of a new profession or a new discipline. The initial niche applications of optical signal processing and non-destructive testing declined in importance during the 1970s, only to be replaced by holographic packaging and security devices from the mid-1980s.

Holographic artists, although they continue to struggle for recognition in the wider art world, still enlist new and enthusiastic adherents attracted by the sublime qualities of holograms and by their seemingly endless possibilities. As a result, albeit in the shadows, such shifting communities have sustained their numbers and nurtured their self-identities—perhaps the most important characteristics of any subculture.

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