MAY 2004
VOL. 15, NO. 1

SPIE's International Technical Group Newsletter

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HOLOGRAPHY

Special Issue:

Tribute to Professor Stephen A. Benton

Guest Editor
Sunny Bains
Imperial College London

Stephen A. Benton, 1941-2003.

Photo taken outside a conference hall in San Diego, 1977.
Photo courtesy of Richard D. Rallison.

NEWSLETTER NOW AVAILABLE ON-LINE

Technical Group members are being offered the option of receiving the Holography Newsletter electronically. An e-mail is being sent to all group members with the web location for this issue, and asking members to choose between the electronic and printed version for future issues. If you are a member and have not yet received this message, then SPIE does not have your correct e-mail address.

To receive future issues electronically, please send your e-mail address to: `spie-membership@spie.org` with the word holography in the subject line of the message and the words `electronic version` in the body of the message.

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Editorial

Many links to Steve Benton

This newsletter is dedicated to the memory of MIT Media Laboratory Professor Stephen A. Benton,[1] who had an impact on the lives of very many in the holographic community and beyond. In this issue I have tried to give a voice to as many people as possible who had something to say about why he was important: not just as a researcher but as mentor, friend, and someone who made you feel that you had to do better in both life and work. I'm going to keep this brief as I've already had my chance,[2] but I wanted to point you towards other resources in Benton's memory and, in effect, the many other voices that have been expressing their sadness at losing him, and their gratitude for having known him.

To start with, you may be aware that there have been three major sets of events organized to pay tribute to Steve. The first, *Benton Vision,* was a full-day celebration of his life and academic contribution. This was held at the Media Lab itself, and included many speakers from both the MIT and holographic communities. For those who were unable to attend, an archive of the webcast and many photographs are available online (as are press releases and other information),[3] and you can read about the experience of being there as told by holographic artist Andy Pepper.[4]

Steve Benton was known for being inclusive, making an effort to allow participation from people with unusual backgrounds. He is shown here with holographic artists Paula Dawson and Roberta Booth (far right, far left), collector and curator Eve Ritscher (second from right), and scientist/ journalist Sunny Bains (center), at the SPIE Holographics International '92 Conference at Imperial College London. Photo courtesy of Jonathan Ross.

In January, a string of events in conjunction with the SPIE/IS&T Holography meeting in Santa Clara took place. These included a sushi night organized by Steve's former student, Pierre St. Hilaire (sushi night was one of the many institutions that Steve had built up in his career), an evening session of tributes, and an exhibition organized by Steve Smith of the Media Lab. The tributes are currently being compiled into a special SPIE proceedings issue that will also include the technical sessions of the conference,[5] and the photographs of the exhibition are available online.[6]

Finally, an event has recently taken place in Japan. For further information on this, please see Masahiro Yamaguchi's piece at the beginning of the *Short Tributes* section.

Among other articles not included here or in other collections are Mark Kahan's tribute for *Mirror*, the organ of the New England Chapter of the OSA,[7] and Graham Saxby's piece for the newsletter of the Royal Photographic Society Holography Group.[8] Also, there have been many obituaries and death notices in the mainstream media, including the New York Times, Boston Globe, and the BBC.[9]

However, in my searches, one of the most interesting pieces I came across was one written by Steve Benton himself.[10] For those of you who did not get a chance to know him, this straightforward exposition about his work and interests is, to me, your best opportunity to get an inkling of what you've missed.

In editing this issue I have come to understand one of Steve's enormous gifts: to make people feel special and included. Reading here, you will see that everyone says the same thing: they felt valued, important, welcome. This is a *rare* gift, and perhaps even rarer in the macho, self-aggrandizing business that is academia at his worst. However, despite this generosity, Benton never made us feel like we could rest on our laurels. Like John Proctor in Arthur Miller's *The Crucible,* Steve was a man in whose presence, "a fool felt his foolishness instantly." We were the better for it. A light has truly gone out.

Sunny Bains

Sunny Bains is a scientist and journalist based at Imperial College London.

From Ray Kostuk

I first met Steve in 1986 at the OSA topical meeting on holography in Hawaii. I was in the process of finishing my graduate degree and remember being a bit nervous about my presentation. Steve was one of the organizers and made me feel right at home, inviting me to participate in many of the conference discussions and introducing me to many of the legends in holography. This was typical of Steve who always tried to make you feel welcome and part of things. Throughout the years he worked hard to strike a balance between the many diverse groups that make up the holography community and was one of the true statesmen of our field. I was deeply shocked to learn of his illness and passing and will greatly miss his guidance and friendship.

Professor Raymond Kostuk holds a joint appointment in the Electrical and Computer Engineering Department and The Optical Sciences Center at the University of Arizona, and specializes in holographic applications in imaging and optical communications.

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From Mark Lucente

What did Stephen A. Benton teach me?

One answer might include lots of shoptalk, equations, and technical terms: *reference beam ratio* and *triethanolamine* and *lateral geniculate body*, etc.. A comprehensive answer would necessitate several volumes.

What did Steve Benton—my doctoral supervisor—teach me?

Another answer might include an assortment of rules of thumb: how many lobsters one needs per party guest, or how to use an exclamation point, or when to use *which* and when to use *that*. (Steve knew grammar!).

However, I have a simpler answer.

What Steve taught me was this:

how to think…

and

…how to teach, how to know one's limitations, how to pursue an idea…

Creating the world's first interactive holographic imaging system was not easy; Steve often quipped that a commercially-viable system was only five Nobel prizes away. Using his mysterious Zen-like intuition, Steve sensed which of the big ideas to work on and which ones to save for later. It took years for me to absorb that Zen, but now I think I know.

…how to eat sushi,
how to avoid spilling a fresh cup of coffee while walking ("don't look at it"),
how to respect and cherish the extraordinary and the commonplace…

Steve once told the story of his days as a graduate student at Harvard, living in Somerville on Benton Road. He wrote to City Hall to request that the southern extent of this street—his block—be renamed 'South Benton Road' for various legitimate logistical reasons (of course). I wondered why anyone would take the time to contrive a home address of *S. Benton, S. Benton Rd.*; years later, I understand.

…how to hypnotize a rabbit,
how to behave, how to sleep well in a hotel ("pack your own pillow")
how to hold tight to the fantasy without suddenly believing it is real…

Research involves a confounding mixture of high expectations and frustratingly-frequent failure. Perhaps only a fool or a lunatic can fully embrace both. Somehow Steve made me feel that I could survive the failures while still dreaming of the big ideas to master.

…how to order pizza,
how to sign an email,
how to ride a roller coaster, the evils of "poor prior planning"…

In holography as in life, a tremendous amount of effort can fall to pieces simply because of poor prior planning. Steve insisted that we visualize laboratory procedure in detail, long before the safelights got switched on.

…balance…

But, in holography as in life, there are so many opportunities, challenges and surprises, and the excitement fuels a spirit of just-do-it. How to balance? Steve set the example, balancing prudence and pluck. He could make an experiment feel like the first moon shot: go for it… but first be certain that details and contingencies are preconceived and planned—from a fresh batch of bromine to a good pile of plasticine to a sign on the door saying 'genius at work.' There were many lessoned learned.

…how to use the whole brain,
how to kill a wart,
how to wonder,
how to see things in a new light…

One day, Steve was explaining optical refraction to his class of holography students. His description of the colors of the rainbow—the operatic way he said a few simple words—is burned into my brain: "red, yellow, green..." and, *sotto voce ritardando,* "a saturated blue…"; it was the way his eyes angled toward some higher dimension and his hand floated upward and his fingers twiddled some invisible knob. For over ten years now, I think of that moment each time I see a rainbow. Steve could do that: take a notion that we have all routinely wielded and pondered and suddenly turn it into an epiphany.

Steve once told me *stay true to the dreams of your youth.*

Perhaps this is the most important lesson that he taught me.

However, I have a simpler answer.

Steve taught me *how to live.*

Dr. Mark Lucente (CLP Research Institute, Hong Kong) teaches, builds businesses, and conducts research in the fields of photonics, holography, energy services and information interactions.

Many holographers might never have tasted sushi were it not for Steve and his love of Japanese food and culture: every year, he organized a 'holography night out' for the SPIE/IS&T Electronic Imaging meeting. Pictured in the foreground with Benton at this 'sushi-scandal' in the early '90s are: Bill Molteni (left), Toshio Honda (right), and Mike Klug (partially occluded). Photo courtesy of Richard D. Rallison.

Contributions in memory of Steve can be made to:

American Brain Tumor Association
2720 River Road
Des Plaines, IL 60018
Tel: +1 800 886 2282
https://www.abta.org/donation

They will notify Jeanne Benton of the gift.

The legacy at MIT…

The passing of a prominent artist or scientist creates a sense of double loss, for tight-knit creative communities and circles of close friends often overlap. Professor Stephen A. Benton was both an artist and a scientist. He was much more: a tireless advocate for the continued importance of the arts in science, and vice versa, and a thoughtful mentor of younger aspiring professionals from undergraduates to graduate students to junior faculty. His presence at MIT for a period of over 20 years left an impressive volume of success stories, including spectacular research accomplishments, brilliant students who then moved on to successful careers of their own, and numerous initiatives and studies about student life and the arts at the Institute. To those of us who had the privilege of knowing Steve in person, he will be remembered for his warm and unassuming personality, his eagerness to be a meaningful contributor, and the spark in his eyes when the discussion found its way to a novel or challenging topic.

Steve was known for his "show me the hologram" approach to innovation: he wanted to see results, not read about them. Here he is doing just that around 1990 or 1991. Photo courtesy of Richard D. Rallison.

I first met Steve Benton when I arrived at MIT in the spring of '99. I did the usual thing of contacting the senior faculty in my field asking to meet them and introduce myself as a newcomer. It was one of the most pleasant surprises of my new job seeing how these legends of MIT were all willing to spend their time asking me what I do, showing me their labs, and offering their help with anything I needed. Steve was, of course, one of the first contacts that I attempted, and his warm welcome encouraged me to continue. It was easy for me to feel comfortable during his lab tour: not only was I between familiar holographic experiments on optical tables, but my host had the most amazing capacity to describe effortlessly and modestly an avalanche of ideas, past and ongoing, and present them in a way I could understand. I am sure that without Steve's special touch the experience would have been rather intimidating.

Steve Benton is best known for numerous inventions and contributions, including rainbow holography, large-format printed holograms, autostereoscopic displays, holographic and interactive 3D videos, and a unique set of laboratory classes on holography and spatial imaging. These accomplishments were the most significant pieces in a puzzle set to technologists by Nobel-winning physicist Andrew Lippman, whose integral photography method promised a three-dimensional 'window view upon reality. ' Steve Benton set out to prove that holography offers as much as any other technique towards seeing through that window.

In Steve's own words (from his class notes, soon to be published as a book—see next page), "For centuries, our culture has speculated on the future of visual communication, and has imagined that, as a matter of course, the resulting images would be three dimensional. […] One can only imagine the collective sense of betrayal when conventional photography turned out to be flat! […] Just when the ultimate limitations of traditional optical methods (such as lenticular photographs) seemed to be all too obvious, a completely new technique emerged in the early 1960s, one that promised an incredibly high quality of depth, detail, and tonal gradation; it was called 'holography.'"

In the fairly small community of holographers, it is a common joke that holography is like a siren: it is appealing with elegance and beauty, but few succeed in doing anything useful with it, which would start by selling holograms. Steve and his students not only made holographic products, they sold millions of them! So it is fair to say that Steve Benton actually turned Lippman's riddle into reality.

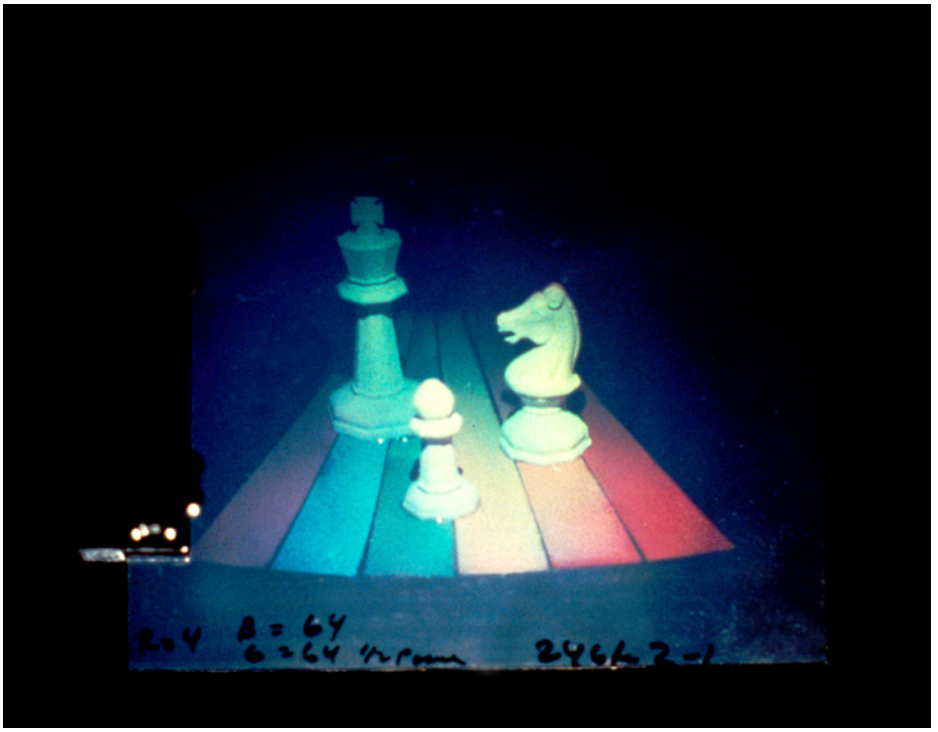
From a personal perspective, the Benton holograms (by which I mean collectively Steve's inventions, some of which undoubtedly I don't even know of) taught me the incredible power of holography in manipulating light. In less technical terms, if an application demands you to 'tell light where to go' in a complex way, then a hologram is the best way to do it, and often the only one. I could cite many examples of why this is true, but in the limited space of this article I will elaborate only on the use of color, which was the triumph of rainbow holography (see photo, right).

Color is important in vision not only because it provides a more faithful representation upon the 'window to reality' (at least as far as our visual sensory system perceives it.) Color, i.e. white light, also frees holography from the tyranny of attaching a high-powered laser to its every use, which adds danger to the users if not cost and weight as well. Again quoting from Steve's class notes, in the mid-60's, "holograms continued to be things that you had to go to basements and museums to see—they were simply not bright enough to survive the glare of daylight." Working at Polaroid Corporation during the early 70's, he thought of using transmission holograms to overcome the problem. "The key was the elimination of vertical parallax from the image, so that only side-to-side variations of the image's perspective were presented—this was found to be sufficient for producing strong dimensionality in the image." Rainbow holograms are also notoriously bright and detailed, when viewed with a white beam-like light source, and they produce a satisfying sense of parallax and color progression.

When I describe rainbow holography in my basic optics class, I sometimes pretend that its simplicity should be obvious to the students. "Well, the slit used in the master hologram serves to limit vertical parallax and reserve the vertical direction for dispersion by the multiple colors in the white light beam so they don't get in each other's way," I might say. Yet, like all

beautiful inventions, it is the very simplicity of the rainbow two-step recording process that made it non-obvious at the beginning. Of course, in the years since, Steve's research group at MIT has succeeded in producing full-color full-parallax holograms by using a pixel-wise rendering approach. In my own work, I have confronted the issue of color in the use of volume holographic lenses for image acquisition, and exploited it to extract spectral and spatial information in conjunction from objects; the simplicity and elegance of the rainbow hologram have been an invaluable guiding principle in these efforts.

The passing of Steve Benton, a prominent artist and scientist and valued colleague, created a strong sense of double loss to his fellow holographers and all his friends; it also created a strong urge to honor and continue his legacy. We are fortunate that the numbers of his former students and colleagues are great, and we are all committed to his memory. We will soon announce formally our plans to preserve Steve's multifaceted presence at MIT, the institution that he loved and devoted so much of his professional life to improving. We will not forget about any of the numerous creative professionals, artists, scientists, and technologists around the world who have been empowered by Steve's inventions, and we will make sure that new members will keep getting added to their ranks. Above all, we are counting on the holographers' community to reinforce Steve Benton's intellectual legacy, or what we have come to call the 'Benton Vision': making the visual window to reality richer, stronger, and clearer.



The first ever rainbow hologram: made by Steve Benton in 1969. Photo courtesy of MIT.

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George Barbastathis works on 3D optical systems for imaging and other information-processing applications as a professor at MIT.

...And an important project in the works

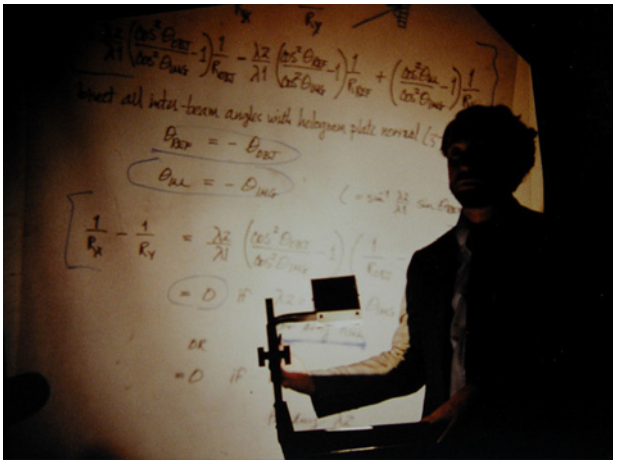
This is part of a piece written by Betsy Connors for the SPIE volume paying tribute to Benton and his work. See the 'Links…' article on page 2 for further information.

Late last summer, Steve and Jeannie asked Mike Halle, Julie Walker, and myself to help Steve complete a book he had worked on for years and had nearly finished. This was his long-awaited academic text, based on his rigorous 'Holographic Imaging' class, MAS 450, taught at MIT and including the latest installment of his revolutionary math. We spent time with him during a wonderful week at their summer house, and helped to organize some of his materials. We are also in the planning stages of creating another, visually-based, book looking at Steve's life through his work.

His family has been so generous to us, it is an honor to work on his books. At MIT, there is a plan in the works, to continue holography, and as my class continues this semester, I can't help but notice... As I walk around the Media Lab, I can see it in people's eyes, and body language, some have even expressed, how much they miss Steve and feel the loss of his presence. He connected to so many people, and will continue to. Through his work, his books, he will educate others about the incredible gifts he gave us, through holography.

Betsy Connors

Betsy Connors has been teaching Holography at MIT's Spatial Imaging Group since 1990, and owns ACME Holography, where she does her art and commercial work.



Benton with some of his famous mathematics at an OSA meeting in 1982. Photo courtesy of Richard D. Rallison.

From Mary Lou Jepsen

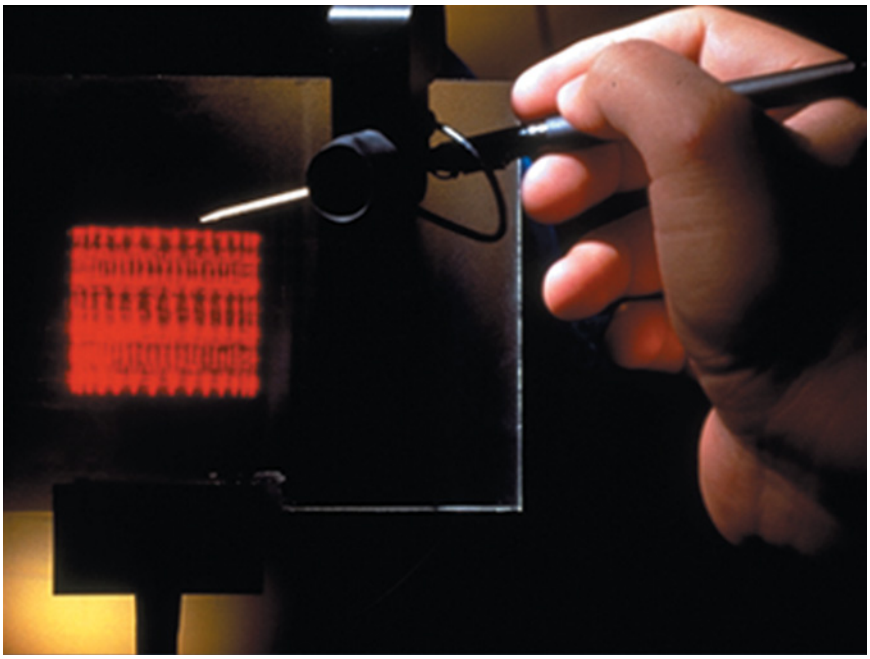
I had dinner at a French fin-de-siecle-ish restaurant called Boulevard in San Francisco last night. I had been there only once before: Steve had taken me there in summer of 2002. I couldn't help but think of him: the conversations he and I had that night replayed in my mind. We spoke of life, of work, of relationships, of our respective health situations.

Steve had a dinner strategy: order just appetizers so that we had plenty of room for a full dessert. I replicated that strategy last night, as I have so much of what he taught me.

I met him first in 1987, as a college senior who never ever imagined herself going to graduate school, but who—after making my first hologram as a freshman—knew what she wanted to do with her life. If one wanted to make holograms, it was clear that Steve Benton's lab was *the* place to be. He said he knew that he would admit me when I sent a hand written thank-you note after my interview at the lab: I thought it would have been my grades, or my holograms, but the clincher was my using the manners my mom taught me.

He liked to say he taught as if he was teaching to a one-room school. He wanted it to work on multiple levels so people could sit and catch one-level in the first year, and then access a deeper level in the second year, and so on. Of all the courses I took in college and graduate school I have the notes to only one course still on my shelf—Steve Benton's Holography class. I still learn from it, and find myself dusting it off about twice a year to this day.

People use the word 'intuitive' to describe Steve's way. It doesn't do it justice. Steve was visual: he could see a solution and then explain it with a diagram or an analogy that made it clear and concrete. I suspect this visual way allowed him to access the really deep neural pathways in himself and others. His communication was especially direct, clear, and concise with visual people, like artists. Steve would drill down to the key, relevant, issue at hand in the confusion of the complex discussion and make the necessary tweak so quickly—it seemed to those around him so effortless.



Benton pioneered interactive holography or holovideo (see article on page 12), including (depicted) the holographic lathe (depicted) where a haptic interface is used to 'carve' the holographic image. Mary Lou Jepsen (article above) and Mark Lucente (see page 3) were among the many of Steve's students who worked on the project over its development. Photo courtesy of MIT.

The truth is: not only was Steve brilliant, but he worked very hard to make it all seem so effortless. His insight didn't come for free, but through long hours in the lab, and at his desk. Yet, despite that work ethic, what also always bled through all interactions with Steve was his strong desire to have fun.

He was everyone's mentor it seems, but he was my mentor too.

He really became my mentor after my graduation from the Media Lab. I think that he preferred not having direct responsibility for his minions of mentorees. Steve and I emailed each other on average of once a month since my graduation from MIT in 1989. We also saw each other on average a couple times a year. There is no other professor with whom I've had as close a relationship. And yet, somehow Steve seemed to maintain these type of relationships with so many. How did he do it?

When I found out over a year ago that Steve had had a brain tumor I felt different than most. I knew some of what he was facing: I survived a brain tumor in 1995 and take about 12(+) meds a day to maintain my health; it's never far from my thoughts. And yet I thought that Steve would work through it—modern medicine and all—and that it would be treatable. I had no idea he was so sick. I think that many of us that don't live in Boston didn't realize. It was Steve's way. Had we known we would have made more of an effort to get to the summer volleyball game and other get-togethers. Now, there is no more Steve. Our minds know it, but our hearts still believe he's here with us. I have Akira's hologram sitting on my desk with Steve staring back at me every day. I miss him. We all miss him so.

Those of you reading might wonder what he was like to work with. I remember watching him tune a spatial filter for the first time. He stared right into the spatial filter output (e.g. he stared right into the laser beam) while he adjusted the micrometers to maximize the brightness. I thought—wow—he's tough. This is how the big-boys tune spatial filters. He told me not to do it that way, but that really you could, it's not that much light. I thought it was pretty edgy and tried. When I couldn't do it as fast as he could he told me to keep plugging away at it. It was often his advice to me—and it was good advice. It always made me feel that I could get there someday and be good enough but was never quite there. He was quite fatherly in that way.

At that dinner we had in the fancy French restaurant in 2002, I felt that I was finally getting a little closer to his approval—but that the 'there there' was actually someplace different—it was really some form of contentedness with one's life. He seemed really happy to get to see the inside of my life and that it had grown and developed into something more complex than he had seen in me back in grad school. I think that he loved following and coaching the lives of so many of us in this way. That night I asked him why he did it—why he choose this path of being Uncle Steve to the world, and he said simply it was the only thing at all that made sense to do and it's what he learned from Doc Edgerton, Dr. Land, and others. He felt it was the most rewarding way to live one's life.

Thank you Steve. We love and miss you.

Mary Lou Jepsen is the Director of Technology Development for Intel's Display Technologies Operation. She is also a founder and former CTO of the MicroDisplay Corporation.

From Setsuko Ishii

Left to right: Yuri Denisyuk, Setsuko Ishii, and Stephen Benton at a beer hall in Tokyo, 1991. Photo courtesy of Setsuko Ishii.

It was the autumn of 1979 when I met Prof. Benton for the first time at his welcome party in Japan. The day before that day, I had just come back home via New York from Brazil, where I attended the international art exhibition, the Sao Paulo Bienniale. When I heard about the party, I was very excited because the chance to meet the inventor of rainbow hologram had come sooner than I expected. I hastened to the party despite my jet lag. In those days, I was studying holography as a research student at Prof. Jumpei Tsujiuchi's laboratory in Tokyo Institute of Technology'(TIT), where I had heard much about Prof. Benton.

I had encountered holography for the first time few years before. I meandered around for several years until I came back to TIT to study holography. I studied applied physics and, after graduating, I made my way from science to art and studied painting for three years. For several years after art school, I was active in painting, nevertheless, I was not satisfied with this media and groped for something new that fitted me better. It was around this time that I chanced upon a multiplex hologram in the street. I found them shocking: objects that could not be held despite looking like they really existed in 3D space. So, I went back to my old school to study holography. It had been almost ten years since I got my bachelor's degree.

As an art medium, holography has several attractive features. In my case, rainbow holograms came first. *Crystal beginnings* (see page 11*),* in particular, had a great influence on me. It demonstrated the medium's ability to express new objects and inspired me with its creative power. No medium except holography could have realized such images: dots of light in 3D space. Until this piece, the point of holography seemed to be to record actual objects in 3D. However, *Crystal beginnings* was not a representation of reality, it was a creative work in itself. This showed me that holographic images could be original artistic works. I saw this hologram in 1979 and, since then, my ideas for artistic holographic imagery have always been based on this viewpoint.

Prof. Benton worked not only as a scientist but also helped, supported, and encouraged artists to make better creative holograms. His advice was as valuable on the artistic side as on the technical side and inspired new expression in many artists. I was one of those artists who was lucky enough to receive such advice.

In 1981, I was a research fellow at the Center for Advanced Visual Studies, MIT, and lived in Boston for one year on a Japanese government scholarship. In those days, Prof. Benton was working at the research lab at Polaroid Corporation, next to MIT. The following year, I worked as an artist in residence of Museum of Holography (MoH), New York, for one month. Pieces were finished and in good condition but, on the day I planned to bring them back to Boston, I was shocked to find myself a victim of theft. All of my final holograms were stolen from the locker at Penn station in New York, where I had left them the day before. Fortunately, my master holograms had a narrow escape, but most of my efforts for the month had ended in vain. I went back, heartbroken, to Boston.

Prof. Benton had heard of this incident and offered to let me make holograms in his own lab at Polaroid. I appreciated his heartwarming thoughtfulness: it cheered me up enormously. I accepted his offer, and his advice, with many thanks, and made color-controlled silver-halide reflection holograms with his kind guidance. At the time, color control was a new technique that had just recently been developed. The hologram thus represented a new stage of my work.

Prof. Benton supported and collaborated with many artists. For instance, Margaret Benyon—a pioneer of British holographic art—worked with him around the same time as I did. Although most of her works were reflection holograms, she made a beautiful, creative, rainbow hologram by following his advice. Harriet Casdin-Silver, a pioneer in American holographic art, also made many of her early works in collaboration with him. This demonstrated how open-minded he was: he worked with artists, and often advised them to challenge themselves technically to extend their abilities. In fact, his technical advice—with his great artistic sense—inspired many artists to create something new.

Looking back on how Prof. Benton supported my own activities, I could always find him attending my important exhibitions. In 1985, I had a sole show at MoH, New York, planned by curator René Paul Barilleaux. It was my first large-scale exhibition in USA. At the reception, it was a wonderful surprise to find him among the many guests from the holography community: he had just flown in from Boston. Ten years later, I had an opportunity to have a big solo exhibition at Takasaki City Art Museum in Japan, 200km north of Tokyo. At that time, he was in Japan on business and managed to find time to visit my exhibition in spite of his tight schedule.

Prof. Benton was always for art and artists. How encouraged we were by him!

I am deeply grateful to him. I pray his soul may rest in peace.

Setsuko Ishii is a holographic artist in Tokyo.

Chasing the holoprinter

Stephen Benton worked on many topics with both coworkers and students[1] but, as I'm involved with the development of holoprinters, I wanted to write about the parts of Steve Benton's work that are particularly relevant to this area.

Benton, in 1986, demonstrating how the concave shape of this one-step, computer-graphic hologram makes it appear as though it is floating over his hand. This gives the viewer a much larger field of view. Photo courtesy of MIT Media Laboratory.

From the rainbow to the Media Lab

To tell this story, we must start with Steve Benton's first patent[2] and publication.[3] The original idea in 1969 was to limit the amount of data in a hologram so it could be used in future television systems or low-resolution films. There was no mention of the effect for which it became the best known—and which gave it it's name—the rainbow. As it turned out, the rainbow technique became the basis for the mechanical reproduction used in the production of embossed holograms: the core of the holographic security market. Artists also used this technique because it was less vibration-sensitive than reflection holography and therefore easier to implement. Now they were able to make colorful images that could be shown to the public with normal light bulbs. Steve's *Crystal Beginnings (see page 11)* and *Rind II* were excellent examples of the rainbow technique, and clearly underlined his aesthetic sense.

At the end of the 70s, while still at Polaroid, he investigated the possibilities of black and white transmission (achromatic) images. The first experiments used HOE diffractor plates and were tedious.[4] The result of all the work was the invention of the 'achromatic angle'.[5] Compared to all the different corrector plates used in the earlier experiments, it was a marvelous and simple concept: the achromatic angle is still the current basis for all 3D, full-color, embossed work.[6]

Around 1980 Steve was approached by MIT to setup the Media Laboratory: MIT happened to be located just around the corner from Polaroid Lab in Cambridge, Massachusetts. His leadership, vision, and artistic sensibility made him the right man for the job.[7]

Towards the Ultragram

Steve started by initiating the production of computer-generated holograms. The first two-step computer-generated image-plane holograms had been made in 1970 by King.[8] Steve added new techniques and developed new equipment and at about that time, 3D software and computer power slowly started to become available. The images were black and white—the H1 holograms were positioned at achromatic angle[5]—and showed enormous depth (60-80cm).[9]

At the Lake Forest conference in 1985, Steve showed me two of these computer-generated holograms in private, outside in the sun. These two holograms inspired me to pursue computer-generated holography.

While our team started with very primitive 3D computer-graphics experiments[10] Steve and his group were working on anamorphic rendering.[11-13] Two different pre-distortion methods for the alcove stereogram system were developed at almost the same time by his students: Mike Teitel and Mark Holzbach. It was soon clear that the 'slice and dice' method[13] had the edge due to the fact that it required less computer power (though more memory), this work was the key to the production of image-plane one-step holograms. At first, straddling the plane was problematic, but this all changed with the alcove-hologram.[14]

When I saw this (see photo) while visiting MIT in 1988, I was impressed with the quality of the floating image. The distortion corrections definitely worked. Still, the cumbersome reconstruction—using a gigantic curved mirror—stood in the way of its commercial usefulness. The reflection configuration, with the light bulb in the center, would solve all this but, unfortunately, I never saw a reflection alcove.

The knowledge built up through understanding the anamorphic and alcove holograms was incorporated into the Ultragram concept. The typical property of the Ultragram was that the placement of the original 3D image and the final image-plane 3D image became totally controlled[15-17] and the placement of the image carrier relative to the hologram became irrelevant. The technique was first applied to large-scale H1-H2 holograms: with a relatively small setup, a large CGH hologram could be recorded.

Holoprinter success

In 1993 the first attempt to scale the Ultragram to a compact one-step printer was presented.[18] This system was subsequently expanded to be able to make full-color images.[19] Then, around 1996, three former MIT-students—Mark Holzbach, Mike Klug, and Alex Ferdman—started up Zebra Imaging. They produced some stunning large-size images using a next-generation one-step printer (see their holographic image of Stephen Benton on page 9).[20]

There have been others working towards the same goal: at the 1999 Photonics West conference, Sony engineers Akira Shirakura and Nobuhiro Kihara[21] demonstrated their version of instant desktop holoprinter. And, of course, we are working in this area.[22]

Steve had a zest for holography. He knew how to generate interest and create momentum. Whenever Steve would touch a subject and turn it into a project, international interest would rise quickly, research groups all over the world would become interested in the subject, and we would all try to catch up: in our case benefiting from the MIT work directly by referring to it in order to get funding for our own research.

The holography world is going to miss Steve's leadership.

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This striking photograph of Rich Rallison in front of Zebra Imaging's holographic portrait of Stephen Benton was taken at the Benton Vision event on 11 November 2003. The hologram is horizontal-parallax only, full color, 16"x24", and was made using footage taken around the year 2000. A copy was presented to Benton by Mike Klug in August 2003. Rallison—photon plumber, pilot, and Ph.D—says he owes much of his success to constant and reliable support from Steve Benton. Photo courtesy of Paul Barefoot.

From Masahiro Yamaguchi

Steve Benton has encouraged many young people like me working in holography. Here is my experience: I first met him at SPIE Practical Holography IV, Los Angeles, in 1990. It was my first participation in an international conference. Just one minute after we introduced ourselves, he asked me to show my hologram, which was a full-parallax holographic stereogram generated from a computer image. He stared the hologram and said it was great, and it greatly pushed me to work more in the field of holography. Every year or two since then, I reported my progress to him. At Practical Holography XVII in 2003, it was again time for my progress report; it was a final chance. His reaction was again positive.

The Holographic Display Artists and Engineers Club (HODIC), a holographer's community in Japan, held an 'Benton Vision Japan' event jointly with 3D Forum on March 19, 2004. Speakers were Hiroshi Yoshikawa, Jumpei Tsujiuchi, Fujio Iwata, Iwao Sakane, Toshio Honda, Mitsuo Kodera, Toshihiro Kubota (see page 14), Setsuko Ishii (see article on page 7), Hiroyuki Hagura, and Akira Shirakura. A special issue dedicated to this event is also published as HODIC Circular Volume 24 (1), 2004. This includes articles by the above speakers as well as others memories of Steve Benton; additional contributors are Nobuhiro Kihara, Nobuyuki Hashimoto, Jun Ishikawa, Shunsuke Mitamura, Michio Horiuchi, and myself. Many among them described his encouragement, and we suspect there are many more people to whom his encouragement was extremely important.

Young holographers are also indebted to the excellent and open community that he built, including institutions such as the Holography Working (now Technical) Group, sushi-scandal party, and so on. Those wonderful meetings were possible only because of his open-minded character. It reminds me of a comment he once made: "We have to be very open-minded in this society not to exclude any possibility just because it's not true holography." (He said this at a panel discussion at Electro-holography '92, Hayama Marina, Japan, 29 June.) I would like to express my great appreciation to him for fostering, in young people like me, a desire to engage deeply with the holographic world.

Masahiro Yamaguchi is an Associate Professor of Tokyo Institute of Technology, Yokohama, Japan.

From Nils Abramson

The first time I met Steve in his home, I was slightly surprised and very impressed. He told me that in the evening he was having a meeting with some friends. Some ten people arrived and they sat down at a large table and it turned out that they belonged to a society that regularly had meetings to discuss the literature of Shakespeare. This evening they were discussing Henry VIII and I was very impressed by the depth and knowledge in that discussion. So, I had found one, rather unknown, interest Steve had besides holography.

Later on I found out that he and his family bought a farm far outside the city where he, among other things, specialized in rabbit farming and worked on breeding techniques that created special patterns on their fur. I also heard that he won prestigious competitions in this business and that he competed with Richard Allison in this game: Richard is also famous for his holograms and diffraction gratings. Charles Vest, holographer and MIT Director, also published, *Holographic Interferometry used to demonstrate a theory of pattern formation in animal coats*. Thus we see a strange coupling between interests in holography and in animal patterning.

Among the greatest experiences of my life were seeing the Transmission hologram of a train by Emmett Leith and Juris Upatnieks, the reflection hologram of a great lion head by Yuri Denisyuk, and the rainbow hologram of fifteen cubes by Steve Benton. The rainbow hologram, or Benton hologram, has nowadays become perhaps the greatest business as in all holography in the form of embossed holograms on credit cards, banknotes, stamps and for other security uses.

When I first met Steve he was working at Polaroid Land where he had just developed the rainbow hologram. Then Steve returned to MIT where he became founding head of the Spatial Imaging Group, and later faculty member of the Media Lab. While Dr. Edwin Land's Polaroid camera fought a hopeless fight against electronic imaging, Steve and his group instead modified the holographic technique so that it could utilize the fantastic evolution of electronics and computers. One reason why Steve was so successful in his work was that he was so enthusiastic about holography: and he was able to transfer this enthusiasm to his collaborators and friends.

Steven Benton on his rabbit farm in Massachussetts, around 1979/1980. Photo courtesy of Richard D. Rallison.

Another reason for his success, and perhaps the most ingenious part of Steve's work, was that—while most of us tried to squeeze as much information as possible into the hologram—Steve instead worked to reduce the amount of information as much as possible while maintaining a high-quality image. A classical hologram carries a fantastic amount of information, most of which is unnecessary to produce a good image. The resolution is diffraction limited and thus much higher than is usually needed: it is, for instance, possible to measure movements as small as a fraction of thousand of a millimeter using holography.

In the rainbow or Benton hologram, the horizontal parallax is preserved while the vertical is eliminated. The result is that the needed information content is halved, and as an extra bonus the image light intensity is greatly increased. After reducing other unimportant information Steve finally reached his goal: a live hologram that in real time could display three-dimensional moving images produced directly from a computer, holographic video (see article on page 12). No doubt this work will go on and develop further, finally to become the most important 3D video of the future.

Nils Abramson is holographer and retired professor at the Royal Institute of Technology, Stockholm, Sweden.

From Carole Brisson and Georges Dyens

Our world is crowded with millions and millions of human beings, who were born, are living, and will die without even being aware of their mission on earth. These people may suffer from a lack of culture and from living in poor environments, and as a result can be selfish, indifferent, or socially disabled.

However, thousands of healthy people living in our wealthy and democratic world do not act or behave in a better way...

When I encounter a man or a woman of stature—devoted, intelligent, open-minded and highly-creative—such as Stephen Benton, my heart fills up with hope for our mankind… He *rediscovered* light, in the shape of a universal rainbow that he spread all over humanity.

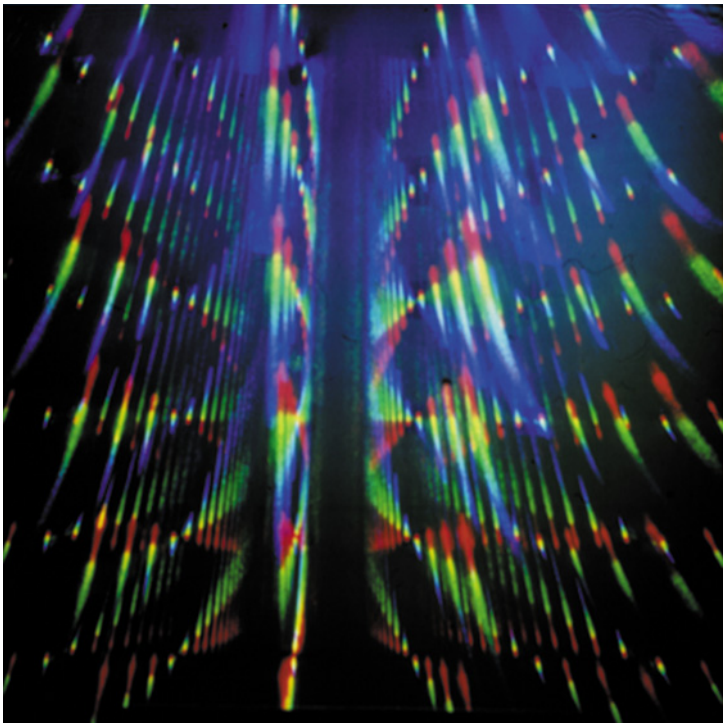
Thank you, Stephen!

Georges Dyens is a sculptor, holographer and professor at the Université du Québec à Montréal. Carole Brisson is a painter and holographer also based in Montréal.

From Jonathan Ross

I first met Steve Benton in 1978, shortly after becoming involved with holography. I was on a photo shoot for Multiplex-style holograms and had been persuaded that it would make an amusing image if I shaved off half my beard (I think I had probably grown it after seeing a picture of Steve and deciding that it was the cool holographer's look). As it happened, Steve was in London at the time and turned up at the studio, which was in the bowels of Goldsmith's College. I was dispatched to meet him at the main gate and the look of astonishment on his face at being greeted by a half-bearded Englishman was worth quite a lot. (Naturally he had a Polaroid camera with him and took some photos, but I only have an out-of-focus one.) Whenever we met subsequently there would always be an exchange of facial-hair jokes.

I remember going to visit him at Polaroid shortly after embossed holograms came on the market and asking him what he thought of this new development. I found his comment extremely succinct: "It's like seeing your first girl selling it on the street."



Crystal Beginnings, *an early test pattern to measure various qualities inherent in any rainbow hologram, and an early indication of the promise of holographic art.* Photo courtesy of MIT Media Laboratory.

On the same occasion he coined the expression 'stereopath' to describe obsessive 3D enthusiasts (which I was subsequently to become) and I have found it extremely useful ever since as a means of defining myself and others.

I looked Steve up on several of my American trips and, though I am far from a techy and could only offer a bit of UK hologossip in exchange for his time, he always took the trouble to show me round MIT and buy me a beer. E-mail enquiries were always responded to with similar courtesy and charm.

Rind II was one of the first holograms I ever acquired and, along with the immaculate copy of *Crystal Beginnings* I bought some years later, remains one of the treasures of my collection. Like its author, it is quite simply irreplaceable.

Jonathan Ross is an art dealer and collector based in London. He has been involved with holography since 1978 when he opened The Hologram Place, the first gallery in Europe specializing in holography.

From Fred Unterseher and Rebecca Deem

Stephen Benton, as we all know, was an extraordinary innovator. We can all appreciate the contributions he made to the field of holography: in particular the 'rainbow hologram'. Perhaps this invention is a case in point. It was invented in 1968. We now have generations that do not remember life without holograms (or computers for that matter). Holograms are commonplace thanks to Benton's invention: one can only imagine the numbers of holographic credit card doves or magazine covers that have been produced over the past twenty some years.

The other side of this coin is the impact of such wide-ranging exposure on human perception. 'Seeing the light' has greater meaning after one 'experiences' a good hologram. 'Experience' because holograms seem to offer a broader range of impact than other types of imagery. Benton considered viewing a good hologram to be a 'magical experience'. He created one suited to print media, allowing great numbers of people to carry holograms in their pockets and in turn set many on a path of exploration. We are certain this was not lost on Steve, who was an authority on the history of 3D imaging media.

We all know that the Spatial Imaging group at MIT develops new technology and interfaces for high-quality 3D displays that are viewable without glasses, using a variety of holographic and other optical techniques. Research includes holographic video, hardcopy and haptic holography, spatial interaction, rapid image generation for 3D displays, edge-lit and autostereo-scopic displays. It is well recognized that spatial intelligence predominates in the arts and sciences. It may be little known however that the Media Lab, of which Steve was a founder, is one of the first institutions to commit to interdisciplinary education. He described holography as a true, "intersection of art, science, and technology."[1]

As the Harvard educator Howard Gardner, writes, "It is already a cliché to remark that our time is one of tremendous breakthroughs… It is also a cliché to note that education is becoming increasingly important. Anything predictable and rule-governed will be automated. Only those persons who are broadly and flexibly educated will be able to function productively in this new world. Around the world, education leads the list of public concerns."[2] The projects Steve undertook with students and colleagues continue to break ground in *21st century media in ways that advance thinking, decision-making, communication, and learning.* Perhaps one of Steve's greatest gifts was to human spatial literacy. We can only begin to wonder to what extent it will impact our future.

Fred Unterseher and Rebecca Deem are artists, holographers, and instructors currently based in Columbia Missouri, teaching the first high school photonics program in the US.

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Electronic holography: progress towards practical electroholography for interactive 3D

One of the areas of holography that Professor Steve Benton pioneered was electroholography[1]—the use of computer-generated holograms to synthesize reconfigurable 3D images of computer-held data. Steve, with his students and international collaborators,[2] developed the technology to the point where a wide range of issues associated with this powerful approach to visualization could be studied. Major and fundamental advances were made in the algorithms, computing architectures, modulator systems, and human interaction with the resulting 3D images.

We believe this research was Steve's main aim, rather than to develop an electroholography system as a product having practical utility in a variety of real-world applications. However, work at QinetiQ and elsewhere has attempted to build on these significant underpinnings and scale the technology to the point where it can be used as a viable visualization tool. This short article summarizes the results of QinetiQ's activities in electroholography. See Reference 3 for more details.

In many ways, electroholography is the ultimate 3D visualization technology, being the only approach capable of generating very high resolution 3D images and with all the depth cues used by the human visual system. The images are optically real and can be accessed by viewers, allowing intuitive image interaction. Unlike conventional holography, electroholography allows reconfigurable 3D images of synthetic data to be produced and manipulated.

However, to produce 3D images which are both of large enough size and field of view to be useful, computer generated holograms having pixel counts in excess of 10^9 are required—and even with such CGHs (compuer generated holograms), it is difficult to generate images larger than 0.5m wide. These pixel counts are orders of magnitude beyond the capabilities of the most advanced display technologies. The two main technical obstacles to be overcome are associated with the efficient calculation of these large CGH fringe patterns and their display on suitable modulators. Ideally both of these tasks need to be performed at interactive rates.

Whilst advances in computing power mean that clusters of commodity PCs can offer cost-effective and scalable calculation of CGH patterns, it is crucial to have an efficient design algorithm. Inspired by the capabilities of the MIT diffraction specific (DS1) approach[4]—in particular, DS1's ability to calculate fringe patterns that can diffract light to produce 3D images with predetermined resolution and information content—a modified algorithm known as DS2 was developed at QinetiQ.

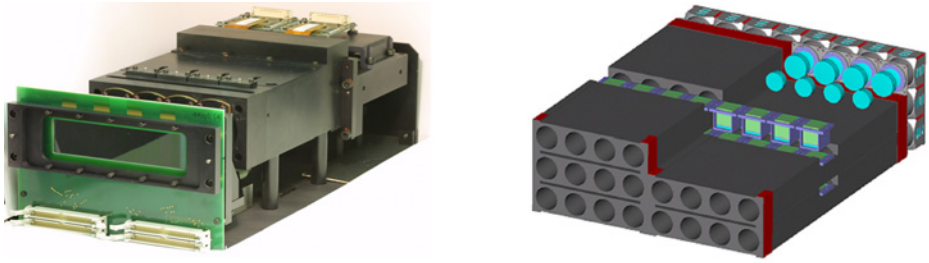

Figure 1. Left: Photograph of a 1×4 channel Active Tiling *unit, delivering 10^8 pixels in an active area of 140×35mm². Right: The AT system can be scaled in both height and width; example design shown with cutaway.*

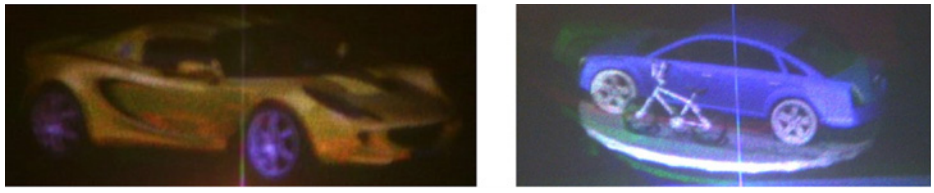

Figure 2. Photographs of color, 3D animations from full-parallax replays from the 10^8pixel AT system.

DS2 has improved wavefront control, avoids the need for the basis-fringe decoding step used by DS1, and produces good-quality 3D images in the Fourier-replay geometry. Following the calculation of the grayscale CGH pattern using DS2, either single-pass or iterative techniques are used to binarize this pattern. This extra computational step is required to allow high-quality CGH replay on the QinetiQ *Active Tiling'* (AT) system, which is a binary spatial-light-modulator technology. Binarization of the very-large fringe patterns is possible using a novel partitioned approach. This allows efficient implementation on highly-parallel cluster computing architectures.

Once calculated, the 2D holographic pixel pattern must be displayed and replayed by a coherent reference to yield the required 3D image. The leading scalable solution, capable of the required pixel counts, is the AT system. This spatial light modulator (SLM) technology exploits the existing and projected strengths of both electrically-addressed binary SLM (EASLM) and optically-addressed SLM (OASLM) in an optimal way, trading the high temporal bandwidth of the former for the large spatial bandwidth of the latter.

The EASLM used is typically a binary microdisplay from a video projection application, that is a device having ~1 million pixels and a binary refresh rate >1kHz. A number of microdisplay technologies and solutions from different manufacturers can be exploited. At the heart of an AT system is a set of replication optics that produce and focus multiple images of the EASLM onto an OASLM. The replication optics provide a route to passive demultiplexing of the high-frame-rate binary data stream from the binary EASLMs, and transfers the information into higher spatial bandwidth at lower frame rates. Typically, a 25-fold transfer of information from the temporal to the spatial domain can be achieved using a 5×5 passive-replication optics system. The OASLM permits optical memory, incoherent to coherent conversion, optical gain, and multiwavelength readout. In one configuration, shutters are opened in turn to build up the pattern on the write side of the OASLM, the shutters being synchronized to the appropriate frames of the EASLM. In this way, the whole of the OASLM can be updated at faster than video rates.

A typical configuration consists of: a binary 1024×1024-pixel ferroelectric-crystal-on-silicon EASLM operating at 2.5 kHz frame rate; a binary-phase diffractive optical element and associated refractive optics performing the 5×5 replication; and an OASLM using an amorphous silicon photosensor, light-blocking layers, dielectric mirror and a ferroelectric-liquid-crystal output layer. Each AT channel is modular and carefully designed such that multiple channels can be stacked together in parallel in two dimensions to deliver the required pixel counts. This parallel approach also minimizes the required data feed rates for each channel and

matches well with the capabilities of cluster-based rendering architectures.

Current attributes of the system (Figure 1, left) include: a high pixel areal density of more than 2.2×10^6 pixels/cm^2; a compact system volume of better than 2.4×10^9 pixels/m^3; binary pixels, with a pixel spacing of 6.6μm; successful demonstration of an updateable 1×4 AT channel arrangement (5120×20480 pixels = 104 Mpixels) in both monochromatic and frame-sequential color operation; and designs for scalable channel tilings in both height and width to deliver systems with pixel counts in excess of 10^9 (Figure 1, right). Animated horizontal-parallax-only and full-parallax 3D monochrome and color images have been generated using this system (Figure 2). To the authors' knowledge, this is the first and only electroholography modulator system which has exceeded the 36 Mpixel performance of the MIT's pioneering Holovideo system.

Various chrome-on-quartz, binary, fixed CGHs have also been calculated and fabricated using optical plotter technology. These fixed CGHs have been used to test, verify and optimize other aspects QinetiQ's electroholography technology. In addition to the frame-sequential color 3D images produced by the AT system, carrier-frequency multiplexing and spatial multiplexing have been used to generate full-parallax, color, 3D images. CGH systems with up to 24 billion (24×10^9) pixels have been built and tested. Figure 3 shows some photographs of images from one of the QinetiQ fixed CGH demonstrators.

The progress briefly summarized here confirms that the technology now exists to make electroholographic display systems of practical utility. Work at QinetiQ, MIT, and elsewhere has demonstrated the viability of the component subsystems. Integration of these subsystems together into a prototype, and scaling them to the required pixel counts, is now possible.

However, the cost of such sophisticated systems has to be justified by return-on-investment arguments when they are used in specific real world applications. The novelty of the technology dictates that performance benefits have yet to be quantified. Additionally, there are several other impressive visualization technologies being developed and that are in the process of commercialization. Whilst not having the image quality that electroholography may ultimately offer, they do have other advantages. These include being closer to product, having lower system complexity and providing larger image sizes and/or fields of view. Ultimately, choice of appropriate visualization technology will be dependent on the requirements of the application.

The authors gratefully acknowledge the work of all members of the HI project team at QinetiQ and our academic and commercial collaborators. Funding from Holographic Imaging LLC is also acknowledged.

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Figure 3. Photographs of the replay of a spatially-multiplexed, 3×8-billion-pixel, full-parallax, color, 3D system and image.

From Doris Vila

For me Steve is a beacon showing how to make difficult things light in every sense of the word. Many times I've seen him listening to problems, clearly taking things in, then making some wry comment that lifts the weight off people's shoulders. Even when I think about diffraction, I hear Steve's voice saying, "red rotates radically."

I first met him in the NY Holography Lab basement on 13th Street, I think in 1980, on one of his many visits there. He seemed bigger than life to me. He impressed me as an over-the-top-smart trailblazing scientist, but at the same time interested in checking out what a newbie with an off-center attitude might be asking and showing. His talks at the Museum of Holography were an inspiration. And when a handful of us were on the beach one summer at Amagansett and up in the sky there was a sun dog, a circular rainbow around the sun, Steve declared, "It's rare, that's a good omen."

Later, in 1983 when I ran into him at the MIT Regional Laser Center, he generously offered to be of help—I was both comforted and awestruck.

I remember parsing over the Benton math with other holographers. The diagrams and equations were like secret runes. I would study them to tweak my midnight rituals of hologram-making. It felt like those calculations and re-calculations were invoking some mystic power of the bright rainbow. I told Steve about how I would pass on the lore it to my art students in Chicago, and getting his wry corrections and confirmation.

Thanks, Steve, for your words of encouragement about my work over the years. And for the banter that told me that you shared my teasing relationship with science. Maybe you remember the rap about the League of Enlightened Pseudo-Scientists-you joined in wholeheartedly. (The League held that art and science will never really meet and instead a whole new field of pseudo-science must be created to fill the gap. And we should be overdressed for any experiment we conduct. And that chocolate makes you smarter. Well, the theories just go on from there, not to mention the research.)

And thanks Steve, for getting me to SPIE meetings as an artist-speaker, and for making me laugh when I was getting nervous before a talk in front of all those real scientists. And for all those high-flying idea-bouncing events, those sushi bashes, sneaking margaritas into the back of a long evening lecture, and late-night parties, that brought everyone together. And most of all, for shining a bright light with all the colors into the future.

In her studio in Brooklyn, New York, artist Doris Vila creates holograms, installations, and 3D video where stories stretch out in space as well as over time.

From Toshihiro Kubota

Professor Benton invited me to spend two months as a Visiting Associate Professor in his laboratory starting September 1993. I was able to soak in the atmosphere of the latest research there, one of the most active centers of holography research, and spent time with many exciting young researchers. I am deeply thankful to him for giving me this chance. The discussions at the meetings on Monday mornings and exchange of information at the sushi party on Thursday were precious experiences for me. I am now doing research on the design and fabrication of HOEs using hologram CAD tools, observation of light propagation using ultrashort pulsed lasers, and so on. Those two months I spent at MIT were very important to the initial stages of these projects.

I remember his smiling face as he shook hands and said, "Oh Kubota sensei," whenever I met him. We cannot but pray for the bliss of the dead, as we mourn the much-to-early death of Professor Benton.

Toshihiro Kubota is a scientist based at Kyoto Institute of Technology.

In memory of Stephen A. Benton

SPIE and IS&T will publish the Stephen A. Benton Commemorative Edition of

Practical Holography XVIII Materials and Applications

Tung H. Jeong
Hans I. Bjelkhagen
Chairs/Editors

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http://www.aivela.org/index6.html

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Optical Science and Technology
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HOLOGRAPHY ONLINE

Holography Web Discussion Forum

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You'll find our forums well-designed and easy to use, with many helpful features such as automated email notifications, easy-to-follow "threads," and searchability. There is a full FAQ for more details on how to use the forums.

Main link to the Holography forum: http://spie.org/app/forums/tech/

Related questions or suggestions can be sent to forums@spie.org.

The International Society for Optical Engineering

Holography

This newsletter is published semi-annually by SPIE—The International Society for Optical Engineering, for its International Technical Group on Holography.

Editors and Technical Group Chairs Hans Bjelkhagen, Raymond Kostuk
Technical Editor Sunny Bains
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From Miguel Angel Rolfo and Cintia Luz Peralta

We are a holography researchers at Buenos Aires University. Five years ago, one of our students had trouble attaching a holographic film to glass. To learn more about the different techniques, he sent e-mail to several different holographers around the world, asking for advice. Among them was Dr. Steve Benton. Great was our surprise when, soon after, Natan, our student, received an answer from Dr. Benton.

Here is a copy of that e-mail:

Dear Natan:
It is a pleasure to know that there is a holographic artist in Argentina! While I am happy to try to help you, I have to admit that I am probably not a good source of details most relevant to you.

In particular, we have very little experience with films in general (we much prefer glass plates) and with any of the GEOLA materials in particular.

But based on experience a long time ago, we find that if the film base is a polyester material (Mylar, Estar, etc.), then simply using the capillary action of xylene (an organic solvent) is adequate, provided that the film is not curled. If the film base is an acetate type material (polyvinl acetate, etc.), and soluble in xylene, then some other material such as glycerine should be useful, but messy. If you only make transmission holograms, then spreading on with printer's ink (blue or black color) with a heavy brayer roller works well, Make sure that the thick ink will dissolve in water, though, or cleanup becomes very difficult.

Tung Jeong, Steve Benton, and Jim Cowan on a visit to Holospectra in 1986. This laser-optics resale company run by the Arkin brothers not only made holograms and produced laser effects for entertainment, but they also worked in repair, development, and consultancy. Their factory included laser repair facilities, holography production spaces, storage for many different kinds of plasma tubes and accessories, and a display area, and became a regular side-trip for holographers attending O/E LASE (where Steve Benton's Practical Holography meetings used to take place). Photo courtesy of Rich Rallison.

Good luck with your project. If you have more questions, you can often get answers from the SPIE mailing list…

Best wishes,

…Steve Benton …

To receive a reply to our inquiry, was a great honor and encouragement. Today it continues to be a source of inspiration for us. It is morally reassuring to know that such a personality had the kindness to answer the inquire of a humble student from a distant country.

We can only cite Lao Tse from his *Tao Te Ching*, first book:

27—Perfection
A good traveler has no fixed plans and is not intent upon arriving. A good artist lets his intuition lead him wherever it wants. A good scientist has freed himself of concepts and keeps his mind open to what is. Thus the Master is available to all people and doesn't reject anyone. He is ready to use all situations and doesn't waste anything. This is called embodying the light. What is a good man but a bad man's teacher? What is a bad man but a good man's job? If you don't understand this, you will get lost, however intelligent you are. It is the great secret.

Miguel Angel Rolfo is a professor, researcher, and director of the Holography laboratory at the Architecture, Design and Urbanism Faculty, Buenos Aires University, Argentina. Cintia Luz Peralta is a researcher based at the same faculty.

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