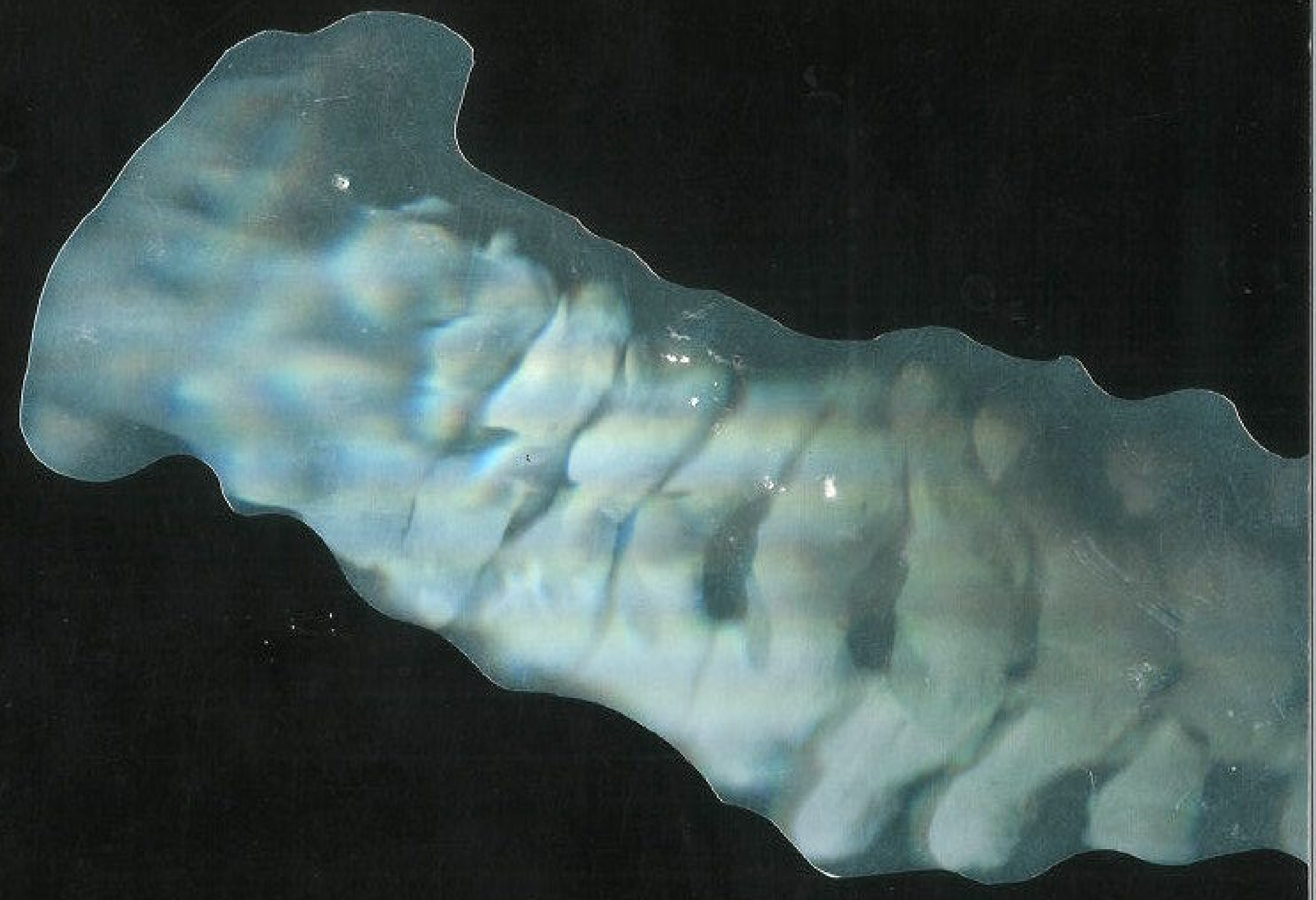
Museum of Holography
11 Mercer Street
New York, New York 10013

INTERNAL VIEWS: AMERICAN MEDICAL HOLOGRAPHY



MUSEUM OF HOLOGRAPHY

MEDICINE OVERCOMES GRAVITY
Model by Kathryn Ko, MD
Embossed Hologram produced by The Lasersmith, Chicago, Ill.
Hotstamping Foil provided by Transfer Print Foil, New Brunswick, NJ.
The hologram on the cover illustrates a human neck fracture repair with Songer® cables and a hip bone graft to fixate the first and second cervical vertebra.

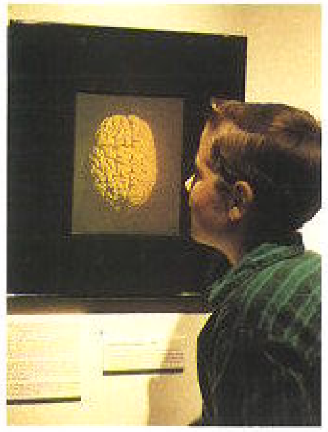
This Exhibition and Catalogue made possible by a generous grant from the **Richard Lounsbery Foundation,** NY.

DESIGN: NICHOLAS L. PLIAKIS
All Photos by RONALD R. ERICKSON except where indicated.

INTERNAL VIEWS: AMERICAN MEDICAL HOLOGRAPHY

MUSEUM OF HOLOGRAPHY

Table of Contents



Introduction

To help commemorate the fifteenth anniversary of the Museum of Holography, we have organized **INTERNAL VIEWS:** AMERICAN MEDICAL HOLOGRAPHY, a ground breaking exhibition of medical image holograms. Although not a comprehensive record of international holographic research and development, it is representative of current directions and potential applications of holography in the United States, stressing education and diagnosis, medical advertising, and display.

One of the significant advances in medical imaging has been the ability to render critical information in three dimensions. Previously all data was compiled in two dimensions using X-ray, photographs and CT Scans. Holographic imaging has provided doctors with the ability to diagnose patients without the need for invasive surgery and to dimensionally record diseases and physical abnormalities. Holograms aid in the teaching of medical students and eliminate the necessity of subjecting patients to repeated examination.

INTERNAL VIEWS: AMERICAN MEDICAL HOLOGRAPHY is the first exhibition in what we hope will be an ongoing examination of the synthesis between holography and advances in medical imaging. In a world where science has been used for so many destructive purposes, we are proud to present an exhibition highlighting the application of this technology toward a non-destructive and healthy future.

The Museum of Holography deeply appreciates the generous support of the Richard Lounsbery Foundation for making this exhibition possible. We would also like to thank our participants who have contributed their holograms to **INTERNAL VIEWS:** AMERICAN MEDICAL HOLOGRAPHY and their pioneering efforts in this critical area of medical research.

Sydney Dinsmore
Curator
1991

Essay

Holograms capture and reveal more anatomical information than any other visual medium. The medical community is learning to employ this capacity to create three-dimensional images for diagnosis and teaching. This catalogue, documenting the 1991 exhibition **INTERNAL VIEWS:** AMERICAN MEDICAL HOLOGRAPHY**,** examines the expanding use of holograms in medical research, diagnosis, documentation, and education. The exhibition presents convincing evidence that holographic technology has an important place in medicine.

Holograms are superior to the most detailed medical illustrations, even the unequaled work of the late Dr. Frank H. Netter, whose anatomical renderings are a standard for medical texts, because the hologram can provide an unobstructed three-dimensional view of anatomy.

The technology available to create three-dimensional images today is far better than it was a decade ago. Lasers and computers are already a part of the history of 20th century technology, but just as it took the invention of the laser in 1960 to make Dennis Gabor's 1947 theory of holography a reality; it is more and more the computer that now makes holography a practical medical instrument.

Increasingly, computers are used in medical technology to supply enhanced imagery to physicians, aiding in diagnosis and documentation. Now, computers are being used to integrate multiple views and alternate sources of data into a single hologram. With the aid of a computer in **Magnetic Resonance Image of Patient With Brain Tumor**, created by the Spatial Imaging Laboratory at the Massachusetts Institute of Technology (MIT), the initial 52 Magnetic Resonance Images were enhanced with color to differentiate the tumor from the healthy tissue. This series of images was then captured by a computer graphic system and a new series of 100 views of the tumor and healthy tissue was rendered in color. These views were combined holographically, with the color reproduced through a new *in-situ* holographic color process just developed at MIT. The credit information about the hologram, an alternate source of data, was also included in a single frame of the holographic image at the extreme right.

A good example of holography's ability to combine photographic views of an object is the cylindrical holographic stereogram, **Heart**, by Jason Sapan of Holographic Studios, New York. The cylindrical hologram containing these views stands between the observer and the apparent location of the heart image in the center. The stereogram of the heart is composed of more than 1,000 frames with each frame containing one view of the model of the heart. The hologram presents slightly different views of the heart to our left and right eyes, and we see a three-dimensional view of the heart — identical to the view seen if the actual heart model were present.

The Imaging Process

Creating a hologram involves a process of splitting and reflecting the beam of coherent light from a laser, illuminating the subject and the holographic emulsion with the laser light to produce a record of the light from the object. A portion of the laser light is used to illuminate the object while a different part of the beam is used to directly illuminate the holographic emulsion. Within the very high resolution holographic film the laser light from the object interacts with the portion of the light directly from the laser. This interaction records, within the emulsion, information about the amount of light reflected from the object (similar to a photograph) as well as the direction that this light from the object is traveling. It is the light's direction that carries the three-dimensional information about the object. While a photograph records a single view of the object, a hologram records thousands of possible views that the viewer can select while investigating the holographic image. Whether recording the surface of an organ, such as **Cerebral Hemispheres** by neurosurgeon Dr. Kathryn Ko, of Cornell Medical Center in New York, or integrating the multiple internal views of the brain provided by an X-ray angiogram in **Carotid Angiohologram** by Lee Lacey, of HoloSource in Southfield, Michigan, holograms provide a highly detailed medical record unmatched and even unattainable by any other technique.

Holography as a Teaching Tool

One of the most exciting uses of holography put forth by the participants in this exhibition is the use of holograms in teaching biology and medicine. Holography puts students one step closer to touching a real specimen, and allows medical students to examine a wide variety of tissue samples, disease examples, and unique malformations long before they work with human tissue directly. Dr. Bert Myers of the Veterans Hospital in New Orleans, and Dr. Kathryn Ko use different methods to preserve their tissue samples which requires them to use different holographic techniques. Dr. Myers uses a four-step technique known as Plastination to preserve and stabilize his tissue specimens. Plastination replaces the cellular liquids with a curable plastic. The result is a dry, stable specimen which Dr. Myers holographically records with the continuous beam from a helium-neon laser. The plastinated specimens preserve the physical form of the original tissue, and are more stable, but remain relatively fragile when subjected to repeated handling during study. The holograms of the specimens portray the essential physical form in three-dimensions, are superior to photographs and illustrations, and do not place the specimens at risk.

Dr. Ko preserves her specimens with formaldehyde, a standard preservation technique for animal tissue which leaves the unstable specimen with characteristics similar to live tissue. Because holography requires objects which do not move, even imperceptibly during the holographic exposure, Dr. Ko uses a 20-nanosecond pulsed beam from a Ruby laser to make her holograms. The very brief flash of laser light freezes any motion of the specimen in the hologram in the same way a flash photograph can freeze an athlete in mid-air, or stop a bullet in flight.

Dr. Myers has undertaken a project to create more than 100 medical images that he hopes will clearly demonstrate the value of such holograms in physician training. His long term goal is to have holographic intraoperative images widely available in medical journals and textbooks.

Dr. Ko is also committed to seeing holograms used as an integral part of the education of biology and medical students, as autopsy records, as a document of surgical procedures, and as a tool through which she can share her view of the wonders of the human brain with the public with exhibits of her holograms. Dr. Ko's hologram **Cerebral Hemispheres** will be on permanent display in the Hall of Human Biology and Evolution at the American Museum of Natural History (AMNH) in New York, when that hall reopens in 1993. In addition, **Hologram of DNA Molecule Chain**, and **Hologram of Visible Woman**, both under the art direction of Gerhard Schlanzky, AMNH, will be included in the new hall.

Hologram of DNA Molecule Chain presents an animated view in three-dimensions of fifteen base-pairs as rendered on a computer graphic system; and **Visible Woman** presents a life-size silhouette of a woman revealing her skeleton, organs, and nervous, circulatory and other systems as the viewer passes from right to left. **Visible Woman** is one of the world's largest holograms, combining four different views of anatomy and a graphic representation of the heart rhythm. Appealing to all ages, **Visible Woman** is colorful, educational, and memorable.

Holography portrays pathology and preserves the dignity of individuals. **Metastatic Tumor Left Frontal Cranium** by Dr. Ko is a holographic portrait of a patient whose cancer caused a tumor on her forehead. The hologram permits medical students to study the disease manifestation without submitting the patient to repeated examinations. Such documents can be used to record the unique variations of a disease, giving every physician the opportunity to become familiar with many diseases and their various appearances.

Non-Invasive Diagnosis

Apart from the documentary and educational uses in medicine, holographic technology is extending the reach and comprehensibility of the physician's diagnostic tools. The multiple images of Computer Assisted Tomography (CAT or CT) Scans, Magnetic Resonance Images (MRI), and Sonograms constitute the greatest advance in medical diagnosis of the last quarter century. In the same way that X-ray images have let physicians look inside the human body for most of this century, modern diagnostic imaging technology is using X-rays, sound waves, and magnetic resonance to produce multiple views of organs and tissues within the body captured without surgery or other invasive procedures. CT scans produce cross-sectional views of the body using X-rays — a series of such *slices* are used to provide the physician with information about joints, bones, the intestines, and blood vessels. Each of the views clearly shows relationships within the particular section, but much training is necessary to easily understand the relationships of features between different views.

Sonograms and MRI scans also provide cross-sectional views of the tissues under examination, subject to the same need to compare features between the section views to fully understand the information captured. The sound waves and especially the magnetic resonance images reveal a wealth of new information — information that the physician cannot easily see even if he holds the specific tissue in his hand. In **MRI Image of Patient With Brain Tumor**, the nature of the tumor tissue as seen by the surgeon is very similar to normal tissue, but the magnetic resonance character of the two tissues is significantly different, and this difference is critical to diagnosis and to successful treatment. Holography provides a unique tool to re-integrate the multiple views, providing a much more meaningful three-dimensional image.

At the request of the radiologists and neuro-surgeons at Indiana University Medical Center, Lee Lacey converted a series of angiogram images from a 34 year old patient into **Carotid Angiohologram**, in 1985. The holographic processing required about 36 hours, and proved beneficial to the physicians in making the decision that the anterio-venous malformation within her brain rendered additional brain surgery too dangerous to attempt. Mr. Lacey used a holographic stereogram technique to recombine the angiogram views into this hologram.

Dr. Roland Bagby of the University of Tennessee turned to holography to assist medical imaging, visualizing a damaged disk in a patient's lumbar vertebrae. A series of CT images were made prior to surgery as part of the diagnosis. Dr. Bagby used a multiple exposure, multi-planar technique to holographically recombine these X-ray images into **Venus' Looking Glass**, an accurate representation of the bone structure of the vertebrae in three-dimensions.

Dr. Bagby has made holograms of a wide range of objects. Using the multi-planar multiple exposure technique, Dr. Bagby has been able to work on microscopic as well as large objects. With Dr. David Dover of the Biophysics Department, King's College, London, he collaborated in making holograms from serial micrographs. They also produced holograms from CT scans at the Royal Sussex County Hospital in Brighton, England. With this experience, Dr. Bagby has built a multi-planar multiple exposure holographic printer for his continuing work similar to the one he used in England.

With the expanding range of non-invasive images created for medical diagnosis, holography becomes increasingly important in assisting radiologists and physicians to understand and use these images for the fullest benefit of their patients. Physicians require the holographic process to be available as quickly as an X-ray.

Holograms for Analysis

Holographic interferometry, also known as non-destructive testing, can reveal the strengths and weaknesses of prostheses in medicine. Applying the holographic processes used to examine new engineering design, the designed prosthesis can be placed under the same forces it will be required to carry when implanted in a patient. The structural design can then be adjusted to give the patient the full range of function, closely duplicating the normal human structure, and providing an efficient, comfortable attachment to the healthy tissue. In industry, holograms have been used to examine the microscopic movements in manufactured parts, revealing the way that they deform before they break, or to locate flaws in the structure of the material itself. Engineers use holographic interferometry to test new structural designs, looking for stress and weakness before the full scale project is begun. Heat or pressure is applied to the object under study to induce microscopic changes in the structure that can reveal flaws in the material, or points of high stress in the form. The characteristics that make industrial holography an ideal diagnostic tool are now being used by physicians.

Prosthodontic construction — fixed bridgework that replaces missing teeth can now be built to be both comfortable and durable. Using a double-pulsed ruby laser, in **Dynamics of Human Teeth,** Drs. P. R. Wedendal and H. I. Bjelkhagen, of Holicon and Northwestern University, have created analytical images of the chewing function. The series of lines that appear on the image of the teeth and jaw are known as fringe lines, and measure the extremely small changes in the shape of the surface as the forces of chewing are applied. The fringe lines are similar to the altitude lines in a topographic map, except they mark the change in surface height in nanometers which occurs between the two pulses of laser light that record the holographic image. By measuring these fringes, the doctors were able to locate precisely where teeth move, and the magnitude and direction of forces during mastication. This method of studying the dynamics of human teeth and the prosthetic bridgework can detect deformation and stress points as clearly as it has in metal parts and engineering models of highway bridges.

Conclusion

Patients facing surgery can now be provided with essential information about the procedures and treatments they will receive by looking at accurate and realistic holographic images. Lacey's 1984 hologram of the placement of an implanted pacemaker electrode relative to the heart and chest wall, has been used in this way hundreds of times. Physicians have used medical holograms to aid in decisions about surgery, and to diagnose medical conditions using non-invasive imaging technology. Prostheses designs have been tested using holographic analysis to duplicate the function and strength of the healthy tissue they replace. Diseased tissue has been recorded with amazing fidelity and shared with other physicians and medical students. The public has been allowed a unique view of the wondrous human brain, one previously reserved for neuro-surgeons.

Medical holography has a bright future. Holograms provide great detail, are easily understood by even untrained observers, and can represent information and relationships inaccessible by any other means. Medical holograms will find more extensive use in operating rooms, doctor's offices, class rooms, textbooks and journals as the medical community finds additional uses for the information that holograms record and make available in three-dimensions. **INTERNAL VIEWS:** AMERICAN MEDICAL HOLOGRAPHY is the first chapter.

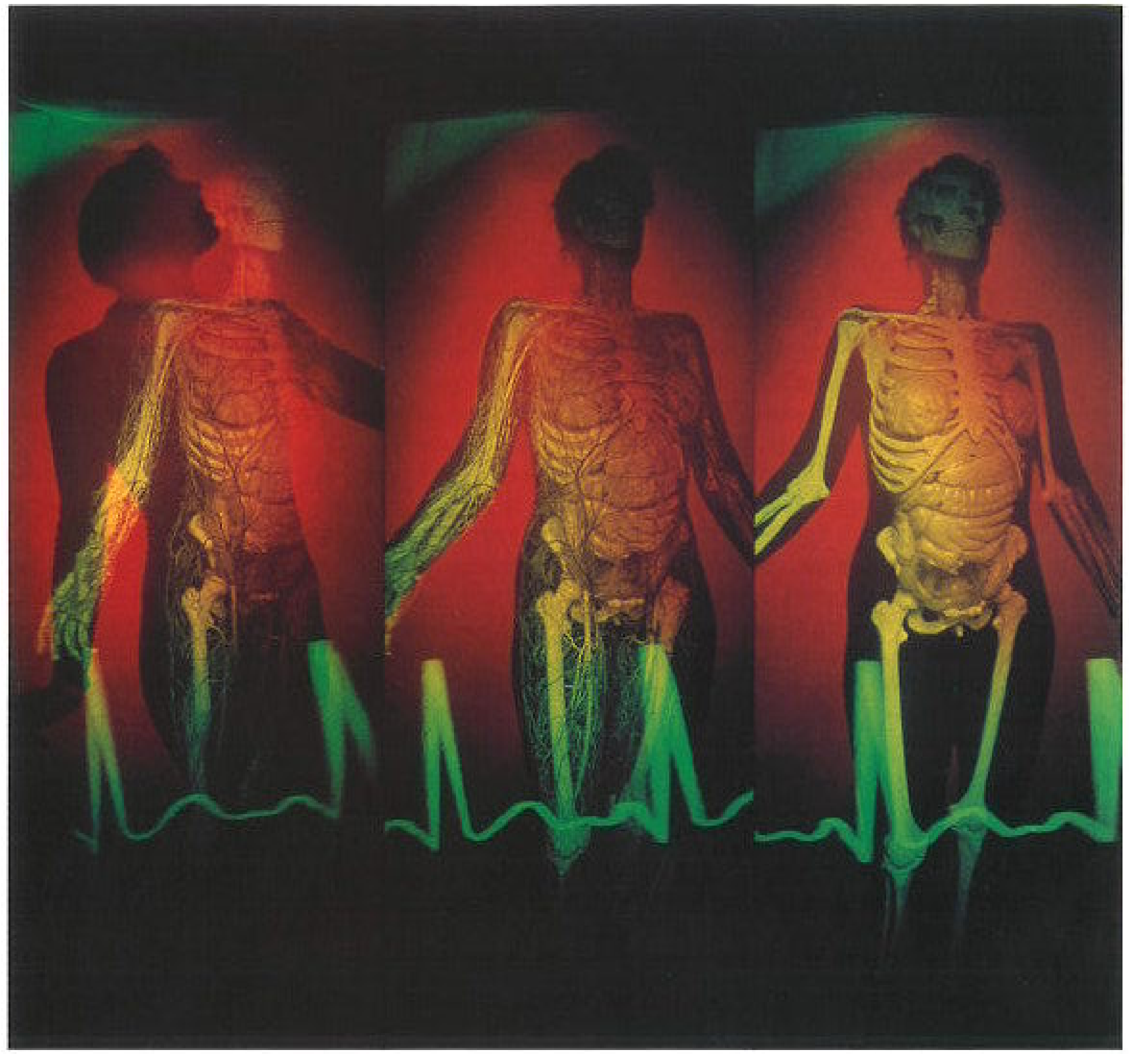
Martha Palubniak

Hologram of Visible Woman
1991

White Light Transmission Hologram
39 x 68 in.

Hologram of Visible Woman © 1991, AMNH, New York

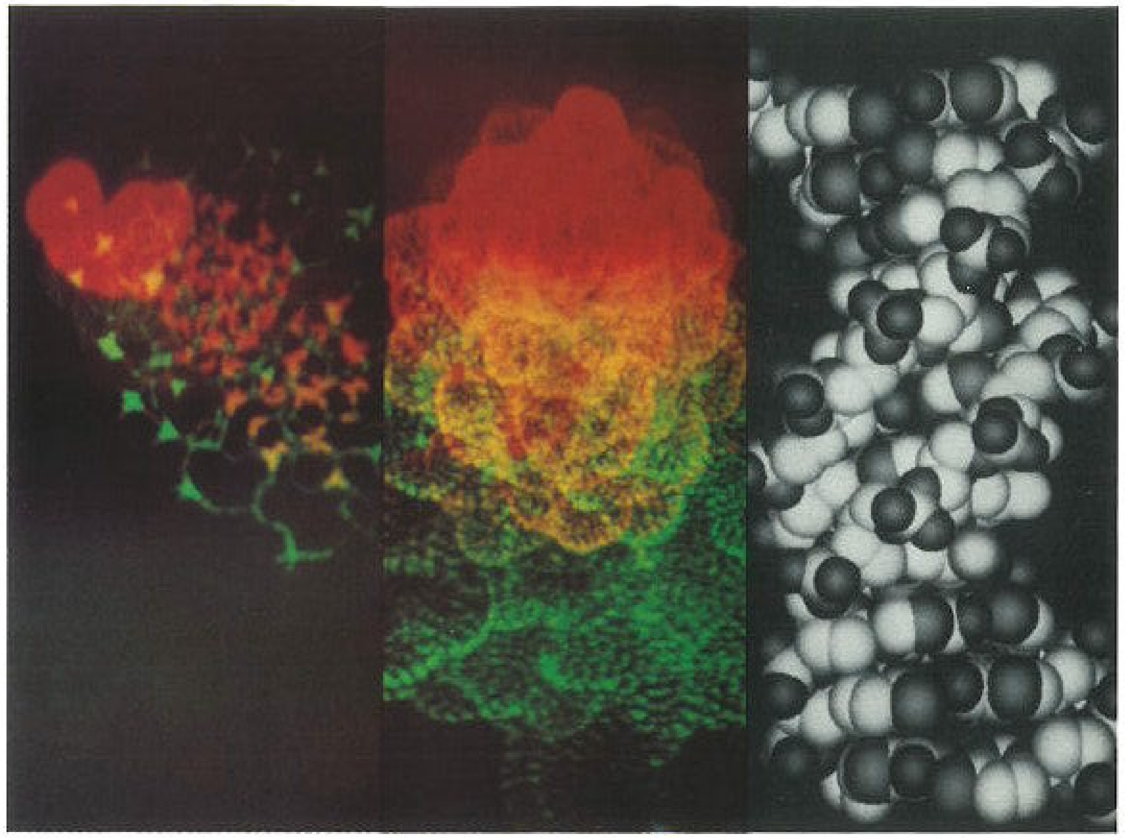
Produced by the American Museum of Natural History for its new Hall of Human Biology and Evolution, scheduled to open in 1993. Pulsed Holographic Mastering Produced by Gerard Allon, Montreal, Canada. Holographic Production by Holographics North, Burlington, Vermont. Art Direction by Gerhard Schlanzky, AMNH, New York.



Within the Animal Kingdom, humans belong in the diverse group of animals with backbones that includes fish, amphibians, reptiles, birds and mammals. The earliest vertebrates appeared in the seas around 500 million years ago. Their four-legged descendants invaded the land 150 million years later.

The major attributes of vertebrates are that they possess a circulatory system, nervous system, urinary system, digestive system, endocrine system, respiratory system, musculo-skeletal system and six senses, those being sight, smell, taste, touch, hearing and balance.

This hologram has been created so that each of these systems can be seen in one or more holographic views.



Hologram of DNA Molecule Chain
1990

White Light Transmission Hologram
24 x 36 in.

Computer generated hologram of DNA Molecule, © 1991, AMNH, New York

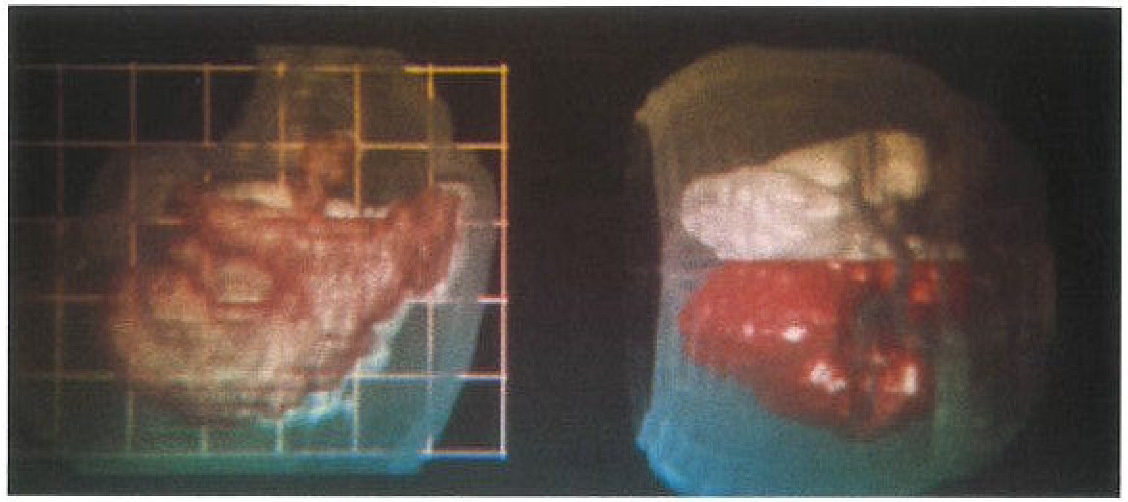
Produced by the American Museum of Natural History for its new Hall of Human Biology and Evolution, scheduled to open in 1993.Computer graphic program by Jim Phlugrath, Cold Springs Harbor Laboratories, New York.Filmed by Jason Sapan, Holographic Studios, New York. Holographic Production by Applied Holographics, Oxnard, California. Art Direction by Gerhard Schlanzky, AMNH, New York.

All existing life on earth descended from a single-celled ancestor. So it is not surprising that, in order to discover what it is that humans have in common with every other living thing, we have to look inside the cells of which all the tissues of our bodies are composed.

Within the nuclei of our cells we find the nucleic acids DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid). These transmit from generation to generation the hereditary information needed to build each new individual, and supervise the building process. From viruses and the simplest bacteria on, all living organisms possess nucleic acids; these represent the central element whose common possession binds all life forms together.

This image is of a DNA double helix that is fifteen base pairs in length. The image was generated on a Digital VT 105 computer which was interfaced with an Evans and Sutherland computer with high definition scanning vector PS 300 monitor. The image was filmed with a Mitchell R-35 movie camera with a stop motion motor using a 55 mm lens on 35 mm color high speed 5294 negative film by Eastman Kodak.

The view you are seeing in the DNA hologram is an end view, as opposed to the traditional side view seen in the accompanying illustration.



Ventricles of a Patient with NPH
1991
White Light Transmission Hologram
8 x 10 in.

Dr. Stephen Benton, Michael Halle & Julie Walker, Spatial Imaging Group of the Massachusetts Institute of Technology and the Brigham and Women's Hospital, Boston.

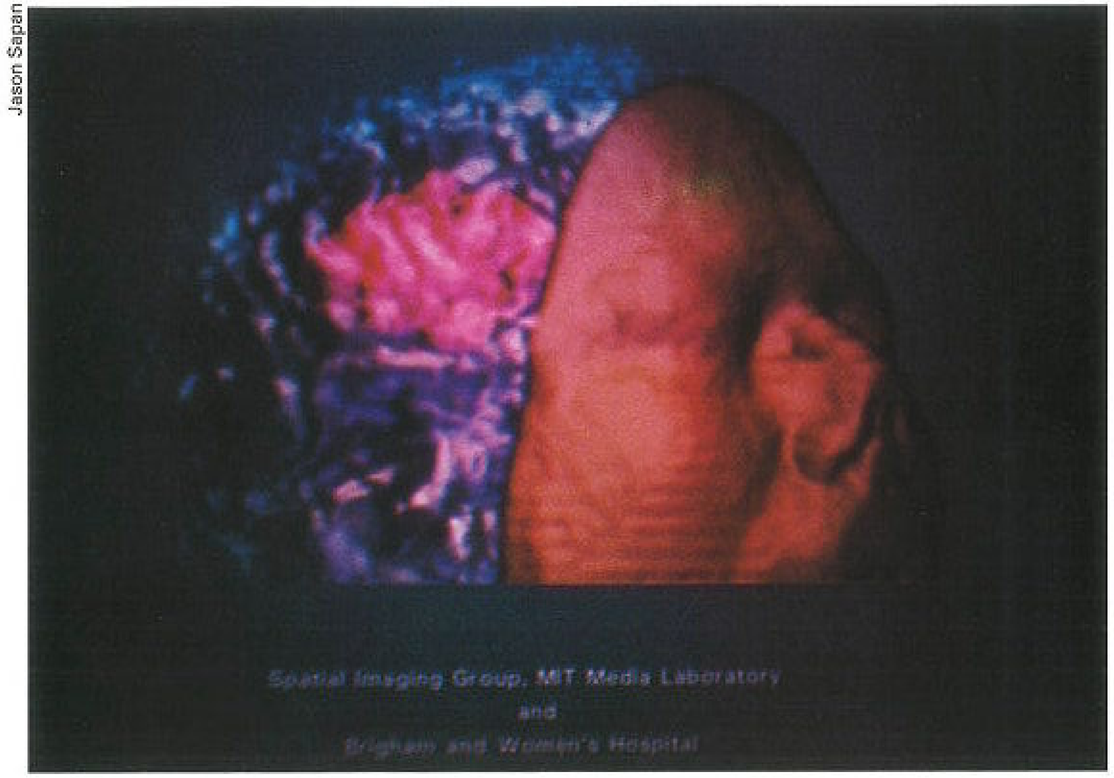
The Spatial Imaging Group of the Media Lab at the Massachusetts Institute of Technology has been established by Prof. Stephen A. Benton to develop a teaching and research program in all aspects of 3-D and holography, with special emphasis on electronic and computational imaging. The Group's charter is to explore and understand the technical, perceptual and aesthetic bases of high quality three-dimensional imaging. All three factors play important roles on the progress and work of the Group.

Normal Pressure Hydrocephalus (NPH) is a disease that causes the fluid filled spaces of the brain, called ventricles, to swell because of the increased pressure of the cerebral spinal fluid inside. This disease can be treated by removing fluid from the ventricles, but diagnosis is not very easy. Up until the early 1970's, NPH was diagnosed by draining the fluid from the ventricles and filling them with air so that they could be imaged with X-rays. The process usually involved inverting the patient so that all the fluid could be removed: obviously, the treatment was awkward and painful.

Magnetic Resonance Imaging (MRI) offers a less invasive and more appealing alternative to X-ray diagnosis of NPH. Data about the patient's entire head can be acquired using a single MRI scan. But because the data is usually viewed slice-by-slice, the subtle shape variations caused by the disease are difficult to see. Three-dimensional reconstruction of the data and display by holography allows the radiologist to better understand the shape of the ventricles with respect to the surrounding brain, resulting in a more accurate diagnosis.

This image was made from clinical multi-slice spin echo MR data acquired at the Brigham and Women's Hospital in Boston. The 26 slices of data were reconstructed using a computer graphics technique known as volume rendering. The computer calculated 100 different full-color views of the data, which were then recorded as a two-step transmission hologram. The hologram shows two different views of the patient: one view from the side of the head, the other from the front as if the patient were sleeping. The transparent region represents the inside of the patient's skull. Simple measurements can be made using the measurement grid inlaid into one of the images.

Jason Sapan



Magnetic Resonance Image of Patient With Brain Tumor
1991
White Light Reflection Hologram
8 x 10 in.

Dr. Stephen Benton, Michael Klug & Michael Halle, Spatial Imaging Group of the Massachusetts Institute of Technology and the Brigham and Women's Hospital of Boston.

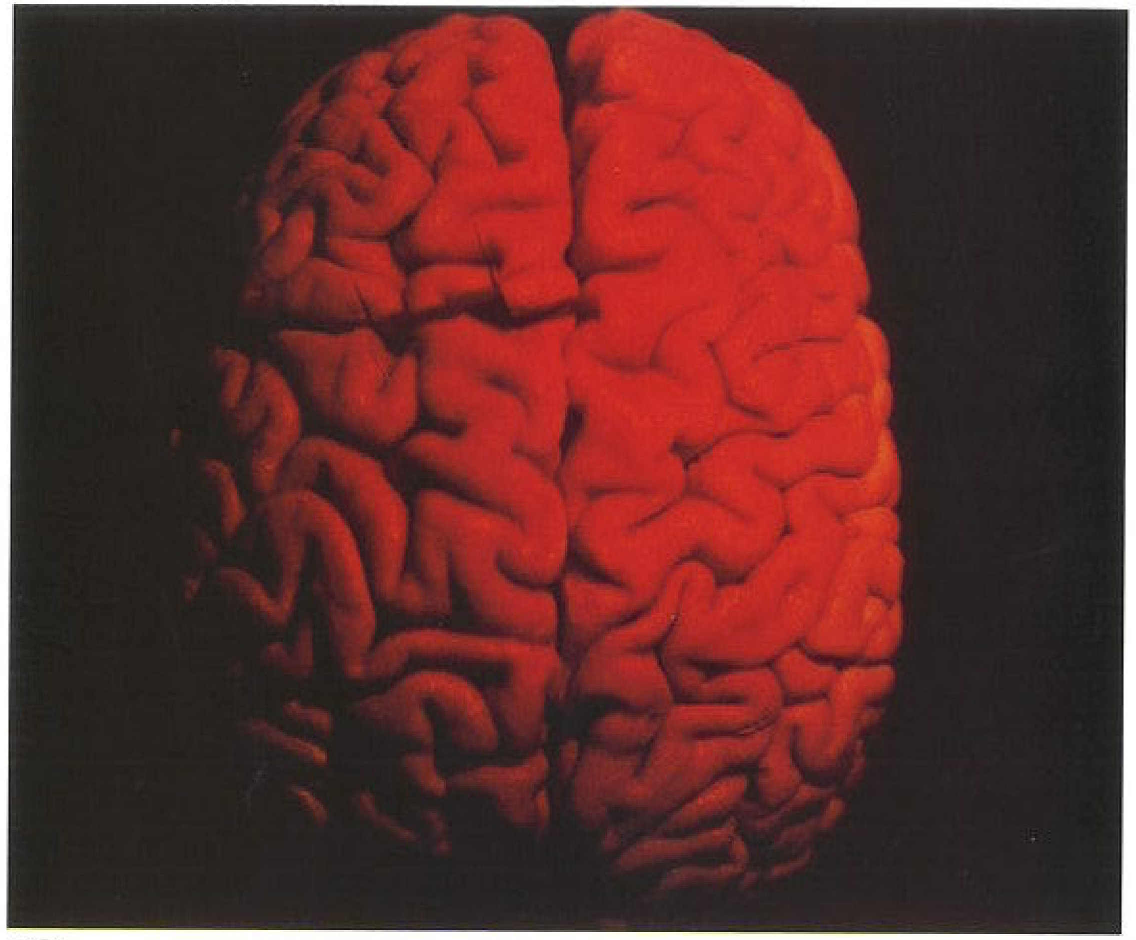
The current generation of medical imaging scanners, such as computed tomography (CT) and magnetic resonance imaging (MRI) devices, produce more information that a radiologist or doctor can comfortably and thoroughly view at once. Computer generated holograms offer a way to conveniently view this wealth of medical information, permitting better anatomical understanding and more accurate patient diagnosis.

This image is made from a clinical MRI scan (multiple spin echo, 52 slice multi-slice acquisition) of a living patient with a large brain tumor, imaged at Brigham and Women's Hospital in Boston. The skin, brain, and tumor tissues of the patient's head can be differentiated from this data. The surfaces of these tissues are colored by the computer as if they were lit by imaginary light sources, producing an understandable, intuitive and solid-looking image. The brain surface is transparent to show the underlying tumor, but the surface is shiny so its position in space can be easily seen. The patient's nose is missing from the image because it was located outside the scanned volume.

The three-dimensional effect of the display is created by computing 100 slightly different full-color images of the patient, taken from a range of different horizontal camera positions. The display itself is a two-step holographic stereogram, recorded on a silver halide emulsion. The vivid color of the holographic display was created using the *in-situ* color process developed at MIT.

Cerebral Hemispheres
1990
White Light Reflection Hologram
30 x 40 cm

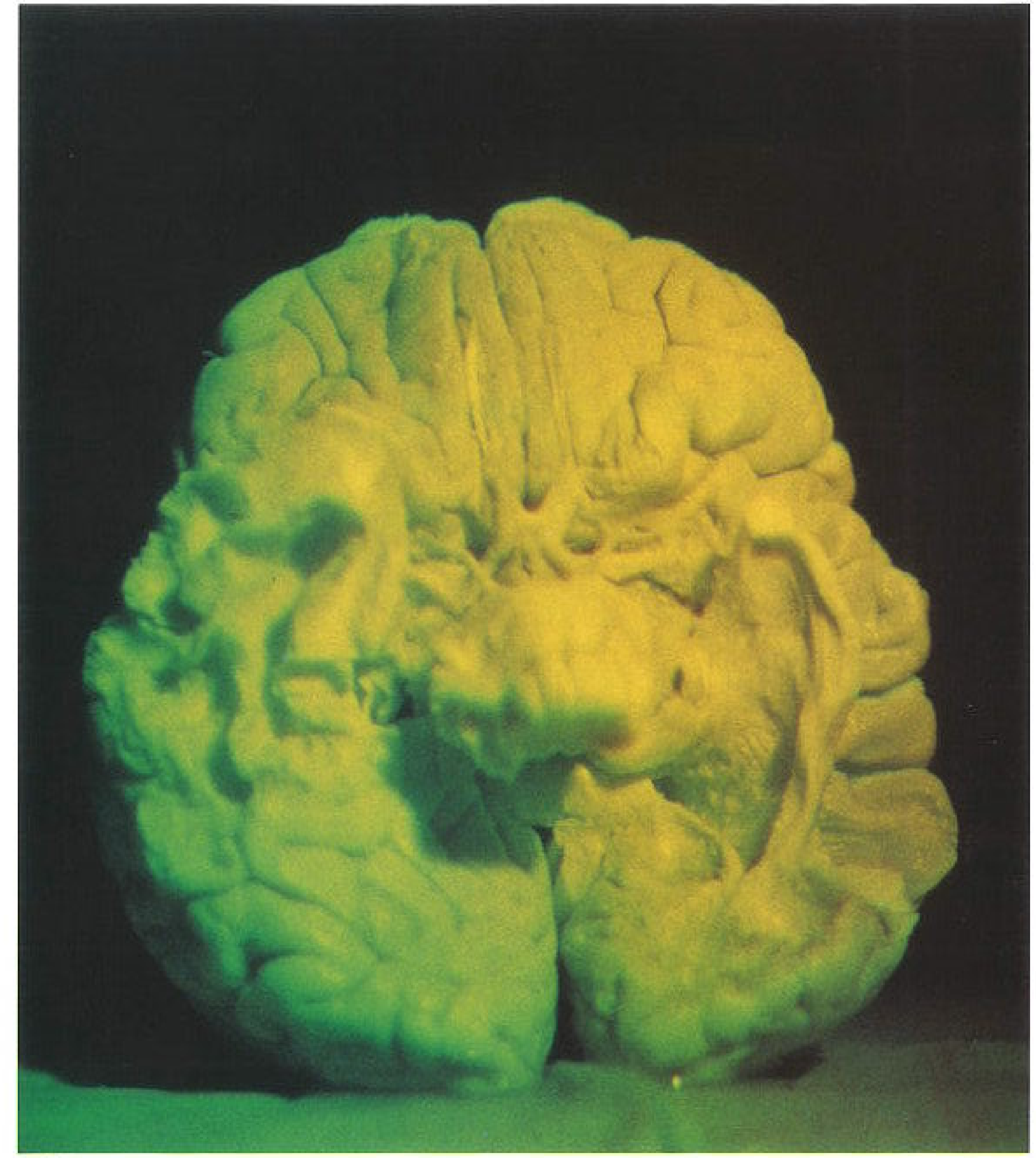
Produced by Kathryn Ko, MD and Holographics, Inc., New York



Kathryn Ko, MD is Assistant Professor of Neurosurgery at Cornell University Medical Center, New York. She is a practicing neurosurgeon engaged in research and teaching. A graduate of the University of Hawaii School of Medicine, and a Resident at Mount Sinai Medical Center in New York, Dr. Ko has studied the brain for a decade. Her learning process involved the transformation of two-dimensional study aids — photographs, drawings, and diagrams into the three-dimensional reality of the anatomy she now operates upon. In an attempt to hasten the essential understanding that must be mastered, she turned to holography to record the complex reality that no other medium can record.

BRAIN — *the portion of the vertebrate central nervous system that constitutes the organ of thought and neural coordination, including all the higher nervous centers; and that is enclosed within the skull.*

The left hemisphere occupies the seat of human consciousness. The right hemisphere provides artistic and spatial thought.



Vision
1990
White Light Reflection Hologram
8 x 10 in.

Produced by Kathryn Ko, MD and Holographics, Inc., New York

The vision pathways extend from the eyes to the posterior occipital lobe. These same visual structures in your brain are active as you look at this picture of the hologram.

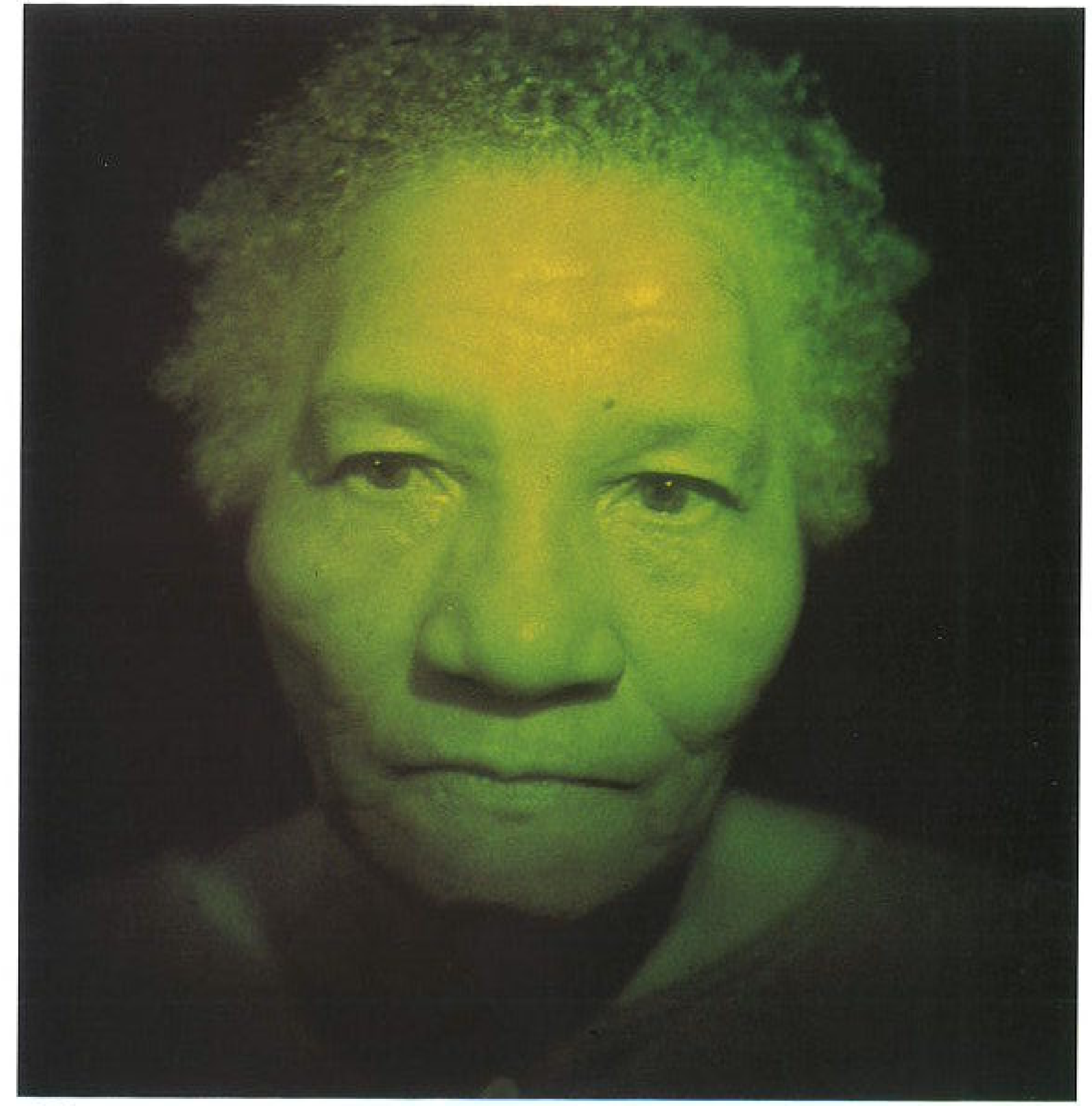
Hippocampus
1990
White Light
Reflection Hologram
8 x 10 in.

Produced by Kathryn Ko, MD and Holographics, Inc., New York

Motor Cortex
1990
White Light
Reflection Hologram
8 x 10 in.

Produced by Kathryn Ko, MD and Holographics, Inc., New York

This is a complex structure in the brain which may contribute to memory processing. The hippocampus is also included in the limbic system, believed to be the source of emotion. Motion is a fundamental characteristic of life. From the motor cortex, shown here, the corticospinal system descends within the spinal cord controlling voluntary activity.



Woman with
Metastatic Tumor
Left Frontal Cranium
1990
White Light
Reflection Hologram
30 x 40 cm.

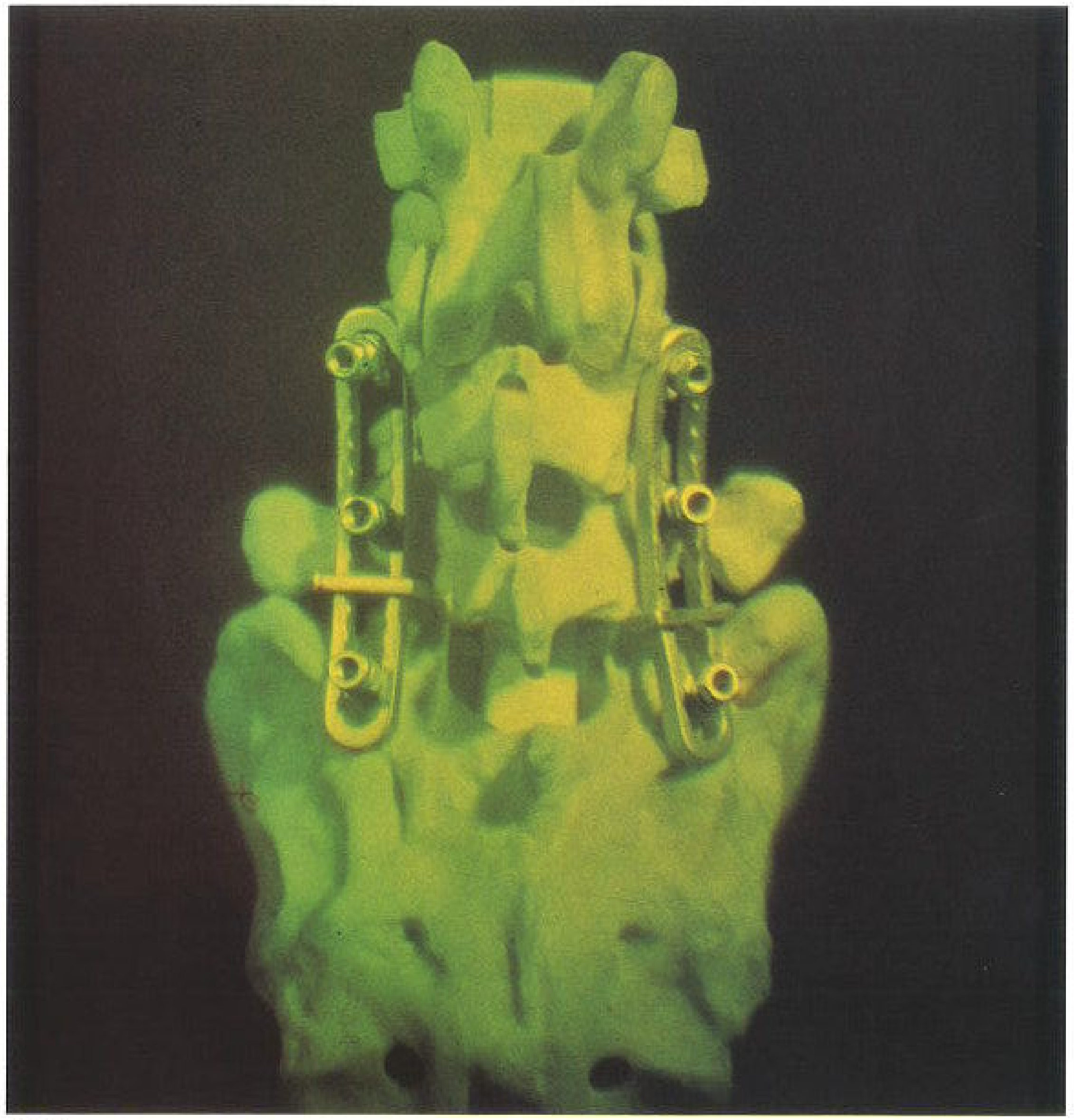
Portrait by Ana Maria Nicholson
Produced by Kathryn Ko, MD and Holographics, Inc., New York

The first manifestation of this patient's disease was the mass on the left forehead which represented metastatic or widely dispersed cancer.

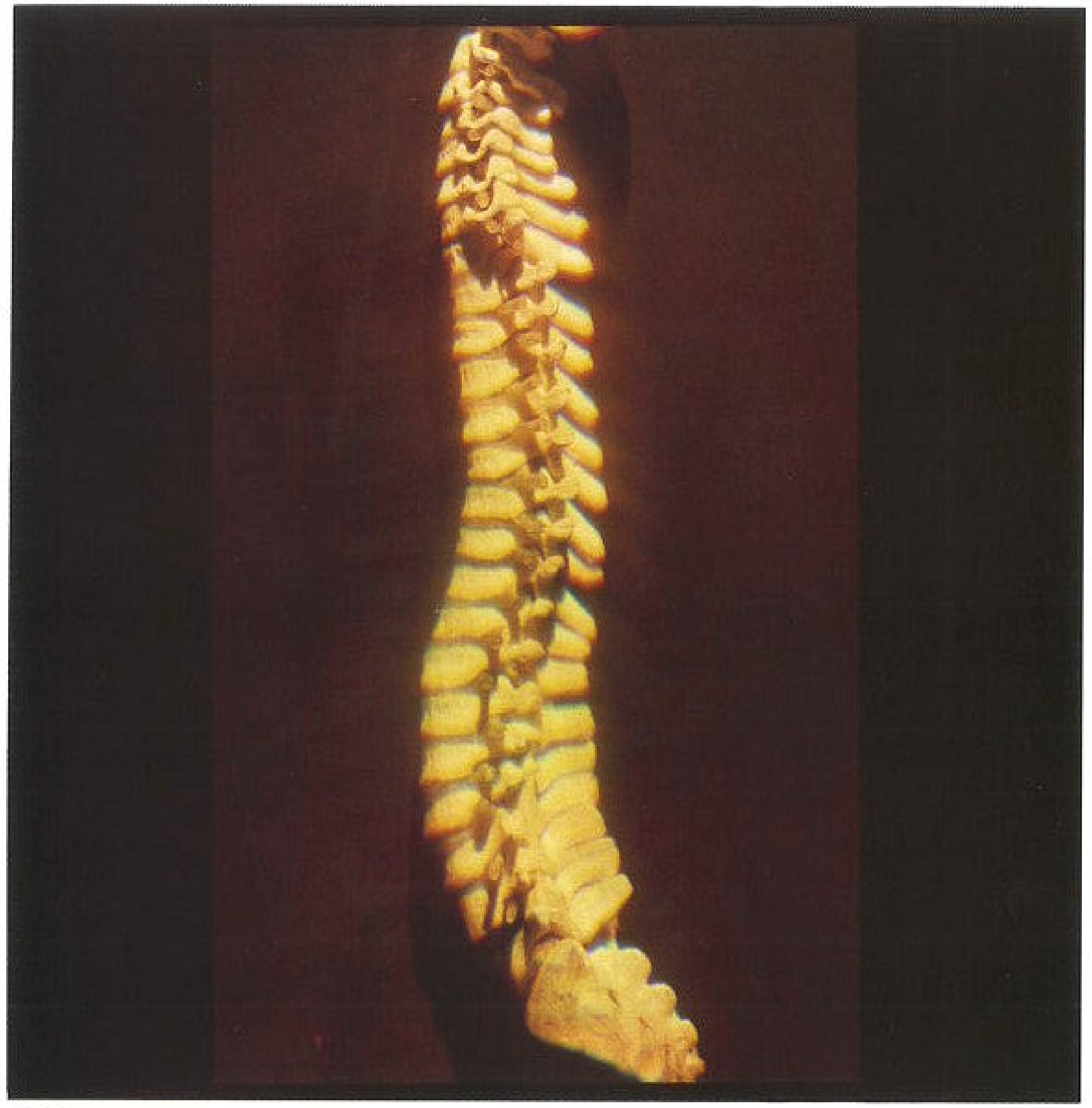
A greater number of students will be able to study this hologram than can meet and examine the patient. A hologram increases the dissemination of medical information, providing a more accurate and effective method of recording a patient's visible disease. A holographic recording will extend beyond the physical life of the patient.

Spine Repair
1991
White Light Reflection Hologram
8 x 10 in.

Produced by Kathryn Ko, MD and Holographics, Inc., New York



This example of a low back spine repair provides information beyond that of an ordinary two-dimensional photograph. A hologram is the only medium capable of accurately rendering three-dimensional objects. This hologram duplicates the correct depth and angle of the plates required for the spinal repair. Three-dimensionality is essential to the surgeon's understanding of the complex relationships between the patient's spine and the precise placement of the plates and pins for a successful repair.



Spine
1990
White Light Reflection Hologram DCG
8 x 10 in.

Produced by Dr. Bernard Furshpan and AD 2000, Connecticut

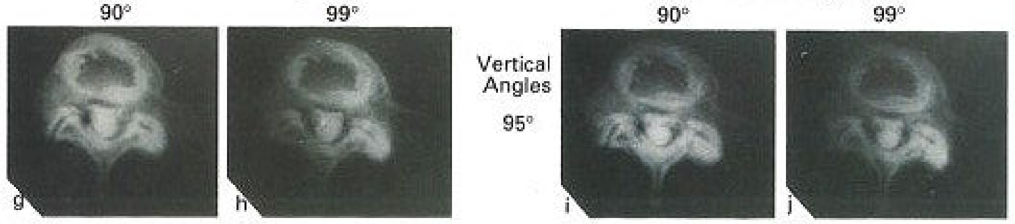
Created from a model, this anatomically accurate chiropractic and medical holographic illustration demonstrates the natural curves and intricate structure of the spine. The holographic image contains the base of the skull, the twenty-four movable vertebrae and the sacrum (base of the spine). Providing support, protection for the nerves in the spinal column, and flexibility, the spine is one of natures engineering wonders. Dichromated Gelatin (DCG) is a holographic emulsion noted for its very bright reflection holograms.

Venus' Looking Glass
1988

White Light Reflection Hologram
5 x 7 in.

Dr. Roland Bagby,
Department of Zoology,
University of Tennessee

Roland Bagby and Ronald R. Erickson



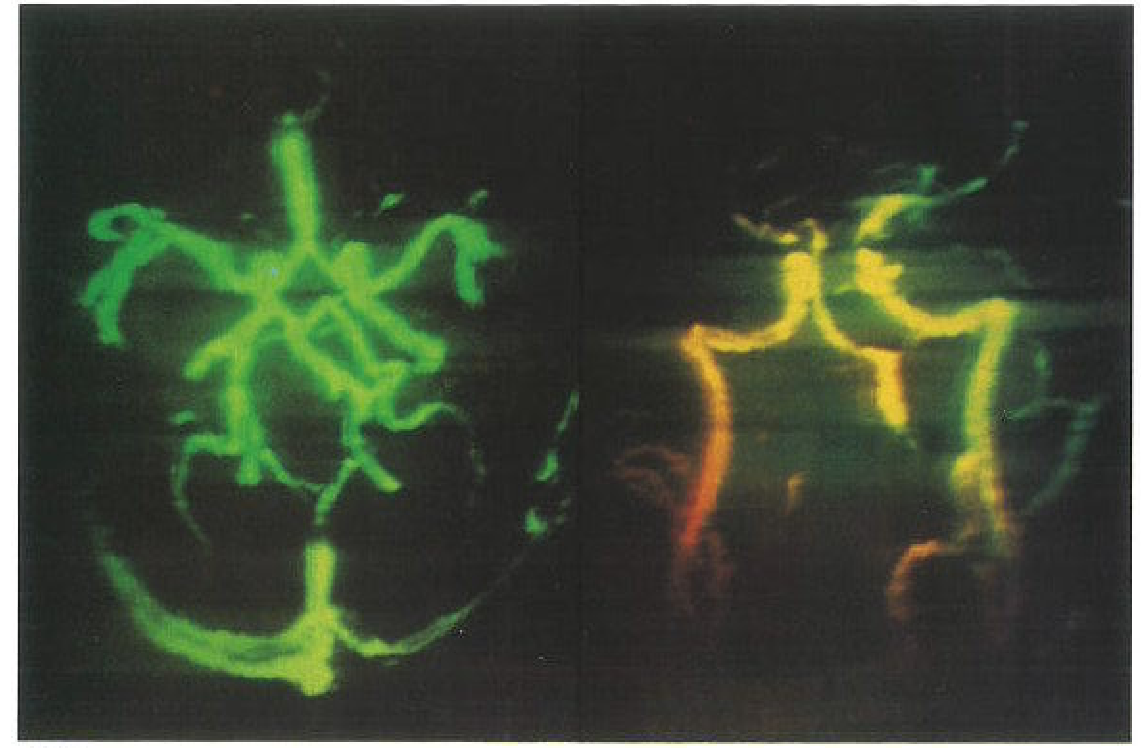
The hologram was made by multiple exposure of carefully spaced CT scan films of Dr. Bagby's wife's lumbar vertebrae prior to surgery to correct a damaged disk.

Dr. Roland Bagby has been actively working on multi-planar multi-exposure holography (also known as Z-multiplex holography) since 1985 he has worked with Dr. David Dover of the Biophysics Department, King's College, London; and Laurie Wright of the Royal Sussex County Hospital in Brighton, England, and has produced Z-multiplex holograms of microscopic serial sections as well as the CT scans exhibited here. Based at the Zoology Department of the University of Tennessee, Knoxville, he has constructed one of the few Z-multiplex holographic cameras in the United States.

Non-Invasive Holographic Magnetic Resonance Angiography
1990

White Light Transmission Stereogram
2 Frames - 9 x 9 in.

Holographer: Les Folio



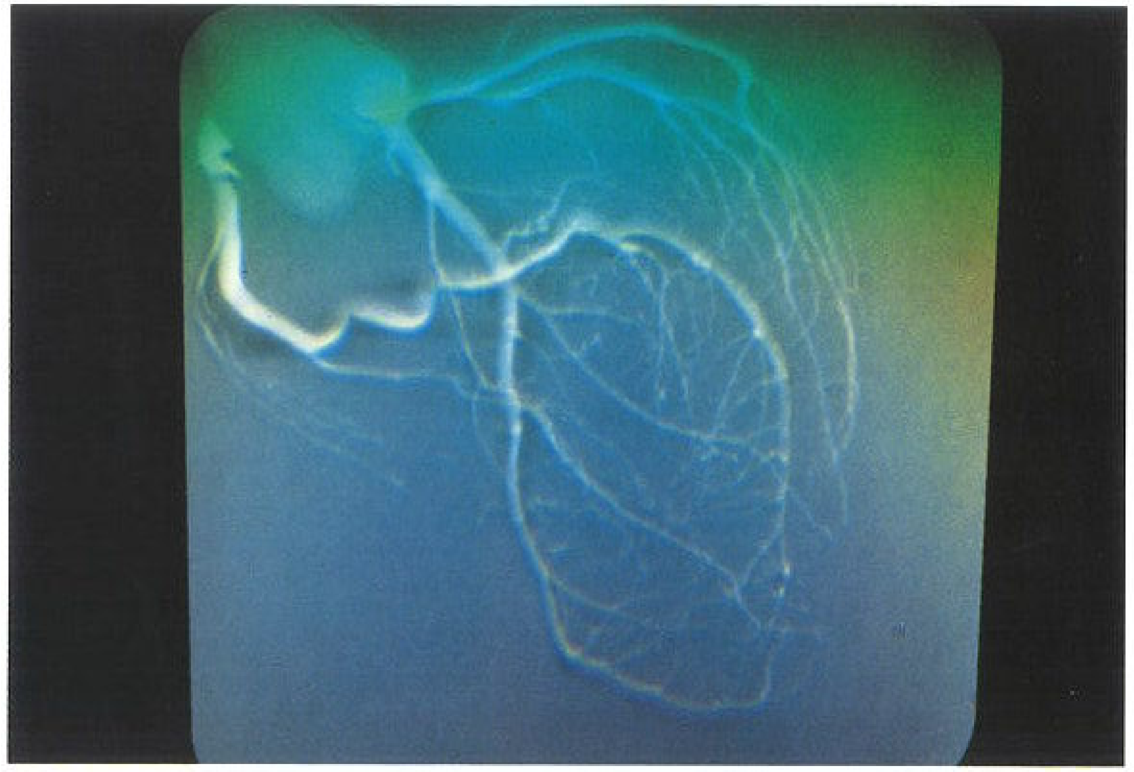
Les Folio has been Chief Radiology Resident at the Osteopathic Medical Center of Philadelphia. He is a Captain in the US Air Force and will be continuing his early career in an Academic Air Force Hospital. He obtained a degree as a Registered Technologist in Radiologic Technology from Crozer-Chester Medical Center in 1983 and a Doctor of Osteopathic Medicine from Philadelphia College of Osteopathic Medicine in 1987.

Holographic Magnetic Resonance imaging is a new method of displaying magnetic resonance data. Magnetic Resonance Angiography (MRA) is a non-invasive way of imaging vasculature throughout the body and has been utilized most in imaging the brain.

Produced at the Children's Hospital of Philadelphia, these two different stereograms show the vasculature of a living child's brain. The carotid arteries travel up the neck towards the top of the head sending many branches out into the brain. During the recording of the MRA, the child was awake and had received no injections nor exposure to any radiation.

The three-dimensional effect of the display is created by computing 100 slightly different images of the patient, taken from a range of different horizontal camera positions. The display itself is a two-step holographic stereogram, recorded on a silver halide emulsion.

The left stereogram shows the blood vessels of the child's brain as seen from under the chin looking toward the top of the head. The right stereogram shows the blood vessels as seen from the front of the face looking toward the back of the head.



Radiologic IPI Holograms

Coronary Arteries Stereogram 1983

White Light Transmission Hologram 8 x 10 in.

Holographer: Lee Lacey
HOLO/SOURCE, INC.,
Southfield, Michigan.

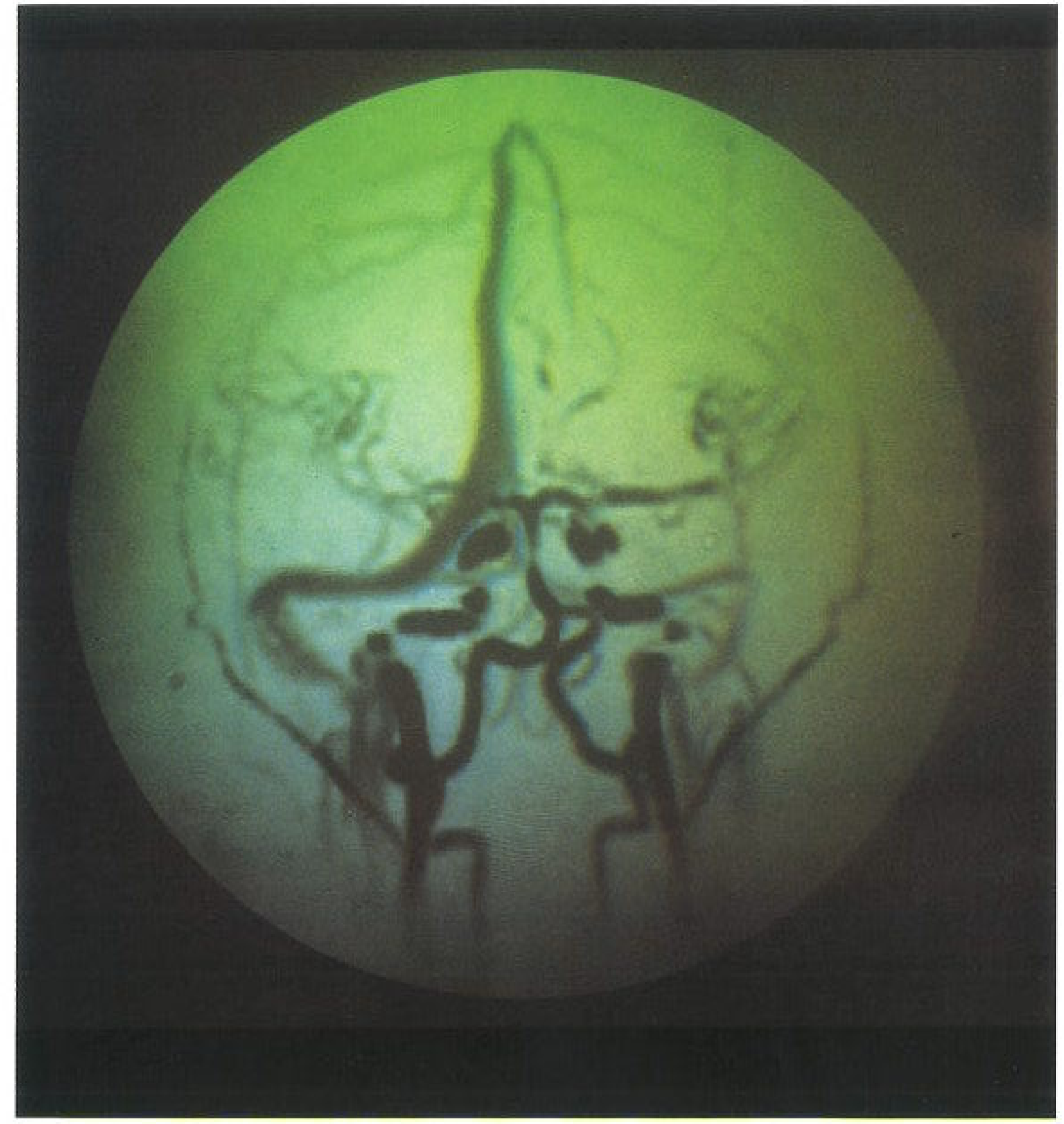
Client:
G.E. Medical Systems

Lee Lacey received a BS degree in Engineering Operations from North Carolina University in 1969. In early 1977 he became Chief Engineer for the Holographic Arts Company in Niles, Illinois. In 1979 Mr. Lacey first developed a holographic technique now referred to as Image Plane Integral (IPI) holography. His company, Dimension Research, was purchased in March 1984 by HOLO/CAD Systems, the predecessor to HOLO/SOURCE, Inc. Currently, HOLO/SOURCE is involved in medical applications of IPI holography, image synthesis from computer graphic images, and allied computer/holographic applications.

Image Plane Integral (IPI) holography, a stereogram technique first documented by Lee Lacey in 1984, uses a series of 35 mm cine two-dimensional views to create a white-light viewable stereogram.

IPI holography may become a useful method for providing three-dimensional viewing for conventional cine angiography. The 35 mm cine views are collected about a single rotational axis at regularly spaced angles and are recorded on filmstrips which are used for subsequent conversion into IPI holograms. A high quality hologram can be made with 120 views.

The hologram shows the arteries of the heart as seen by X-rays with the arteries filled with material opaque to X-rays. Only the general shape of the heart is suggested from the pattern of the arteries.



Radiologic IPI Holograms

Carotid Angiohologram 1985

White Light Transmission Hologram 10 x 10 in.

Holographer: Lee Lacey
HOLO/SOURCE, INC.,
Southfield, Michigan.

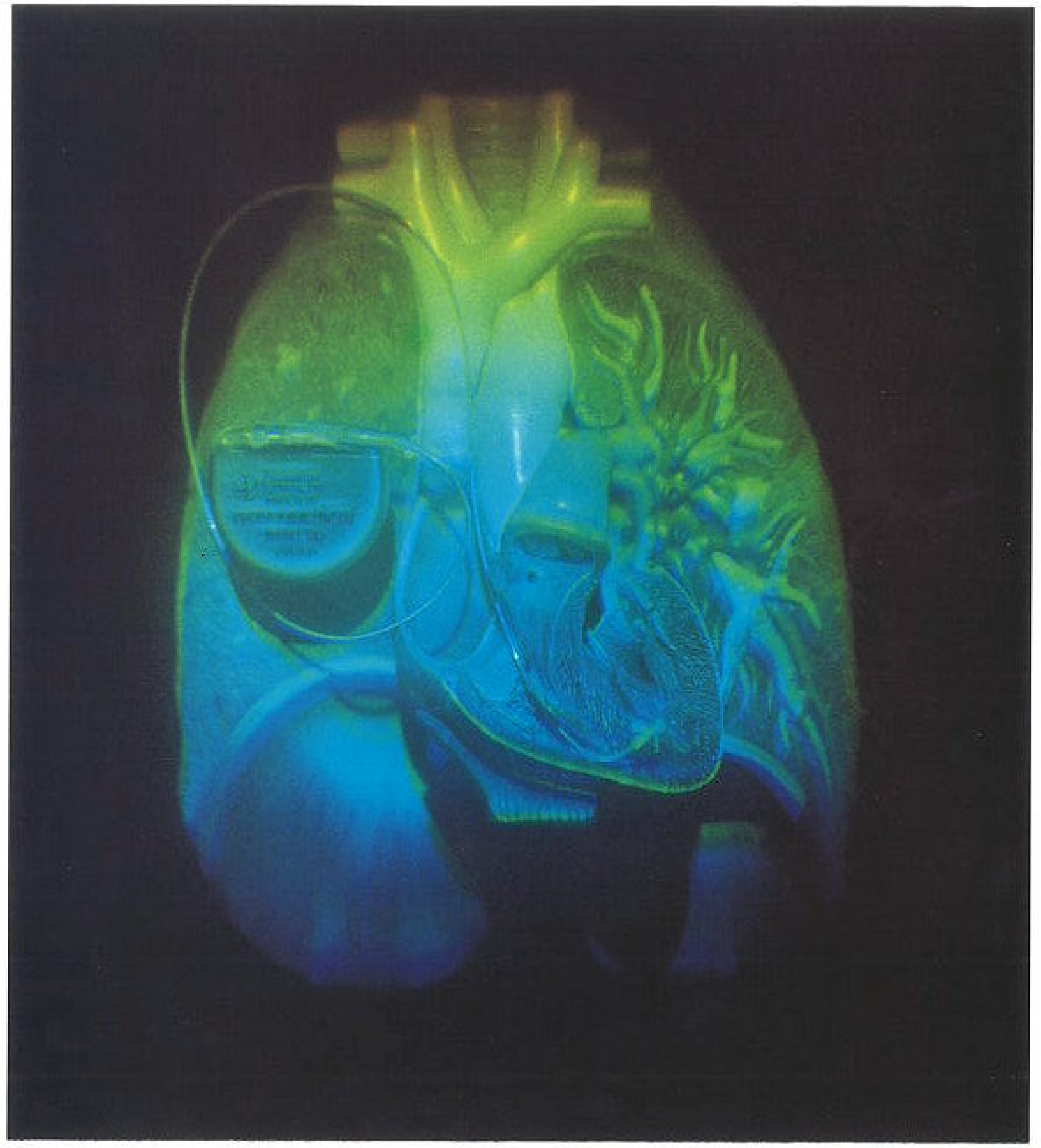
Client:
Indiana University
Medical Center

This hologram is among the first actually requested for use as a diagnostic aid to the radiologists and physicians. The angiography was obtained from a live patient, and the completed hologram was produced in about 36 hours. The hologram revealed the details of a serious malformation of the carotid artery leading to the decision that further surgery was too dangerous for this 34 year old woman.

Thoracic Anatomy Model
1984
White Light Transmission Hologram
30 x 40 cm.

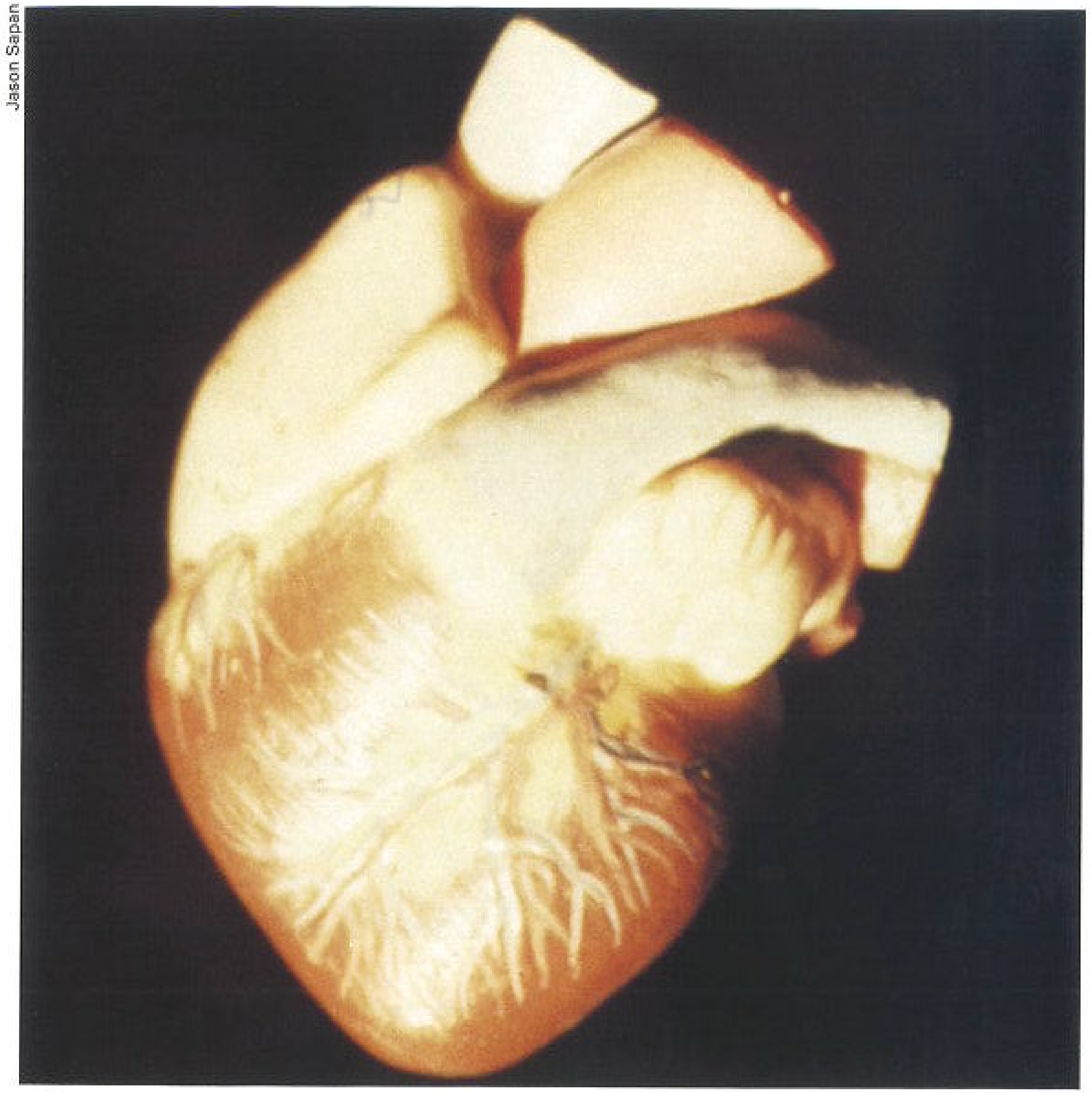
Holographer: Lee Lacey
HOLO/SOURCE, INC.,
Southfield, Michigan.

Client:
The Toledo Hospital



This holographic image provides a detailed view of the location of the heart pacemaker and the electrode positioning to inform patients of aspects of the pacemaker implant prior to surgery.

Jason Sapan



Heart
1989
White Light Transmission Integral Hologram, 14 x 36 in. diameter.

Integral Hologram by
Jason Sapan,
Holographic Studios, Inc.,
New York City.
Client:
G. D. Searle Pharmaceuticals, Inc.

The hologram was produced as a commercial image for the advertising campaign for CALAN, a calcium blocker for hypertension.

Integral holography is often used for point of purchase advertisements and trade show display as it is a stand alone, animated, three-dimensional view of the product or theme element. The integral hologram provides greater impact than two-dimensional full color photography as the holographic presentation attracts and holds attention, while the 45 seconds of action relates a brief story.

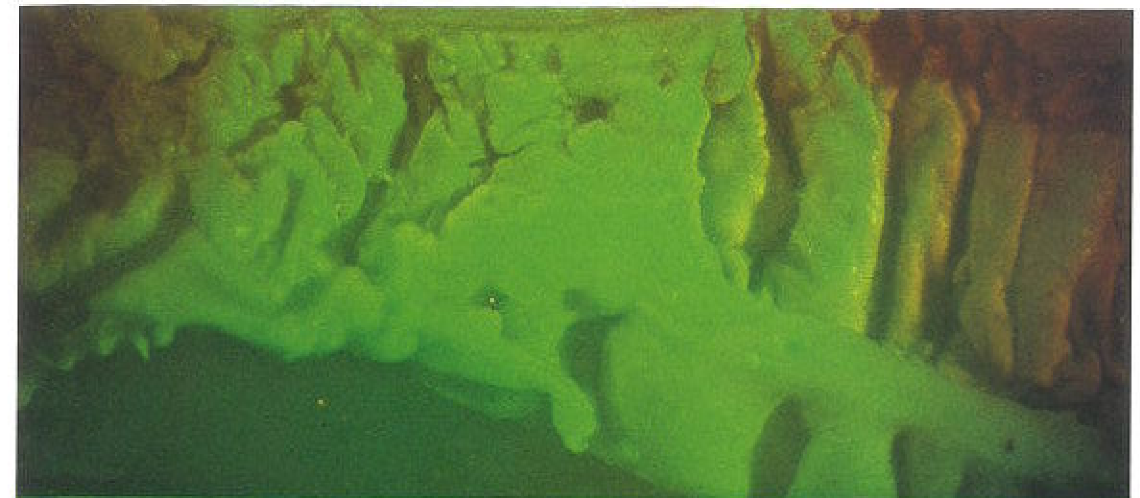
Bert Myers, M.D.
Professor of Surgery, Louisiana State University Medical Center
Director, Holography Research Laboratory
Veterans Affairs Medical Center
New Orleans, Louisiana

My interest is to develop holography as a teaching tool. I believe that holograms will prove to be better than conventional two-dimensional images. The added dimension makes it easier to understand complex structures and their greater impact will lead to better memory retention.

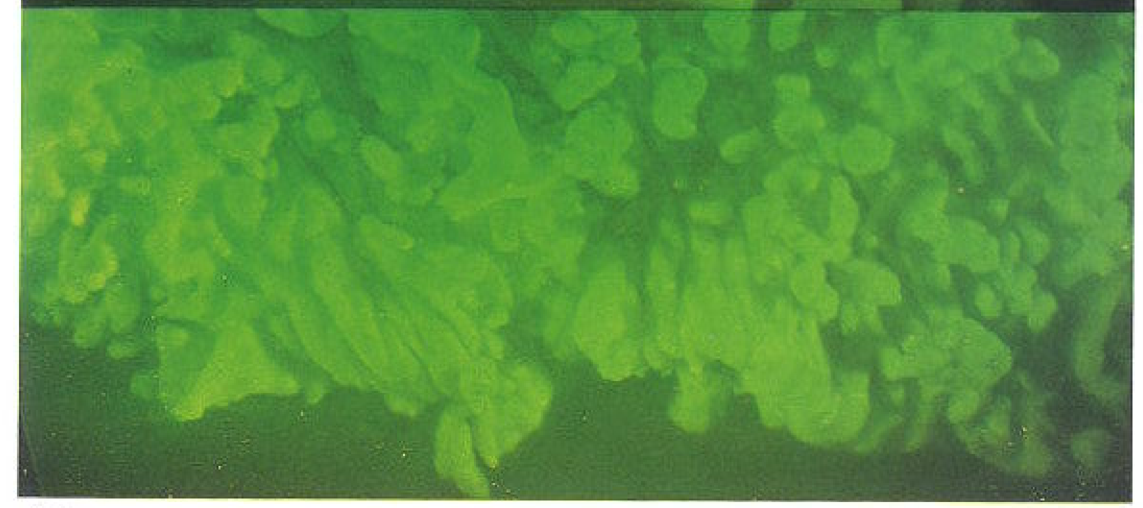
Dr. Myers' long range goal is to make intraoperative images and have them published in a medical text. To do this will require a pulsed laser. His short range goal is to make about 100 high quality medical images and to use them in a controlled study to scientifically determine the value, if any, of holograms over conventional images as teaching instruments.

Holography of Human Pathologic Specimens with Continuous Beam Lasers through Plastination

Since evaporation of cellular water leads to shrinkage and motion, holography of human tissue samples is generally possible only with pulsed lasers. Plastination is a preservation technique in which cellular water is replaced with a curable polymer. This preserves the tissue, including even the cellular anatomy, and renders the specimen rigid enough for holography with continuous beam lasers.



Human Colon Adenocarcinoma
White Light Transmission Hologram
4 x 5 in.

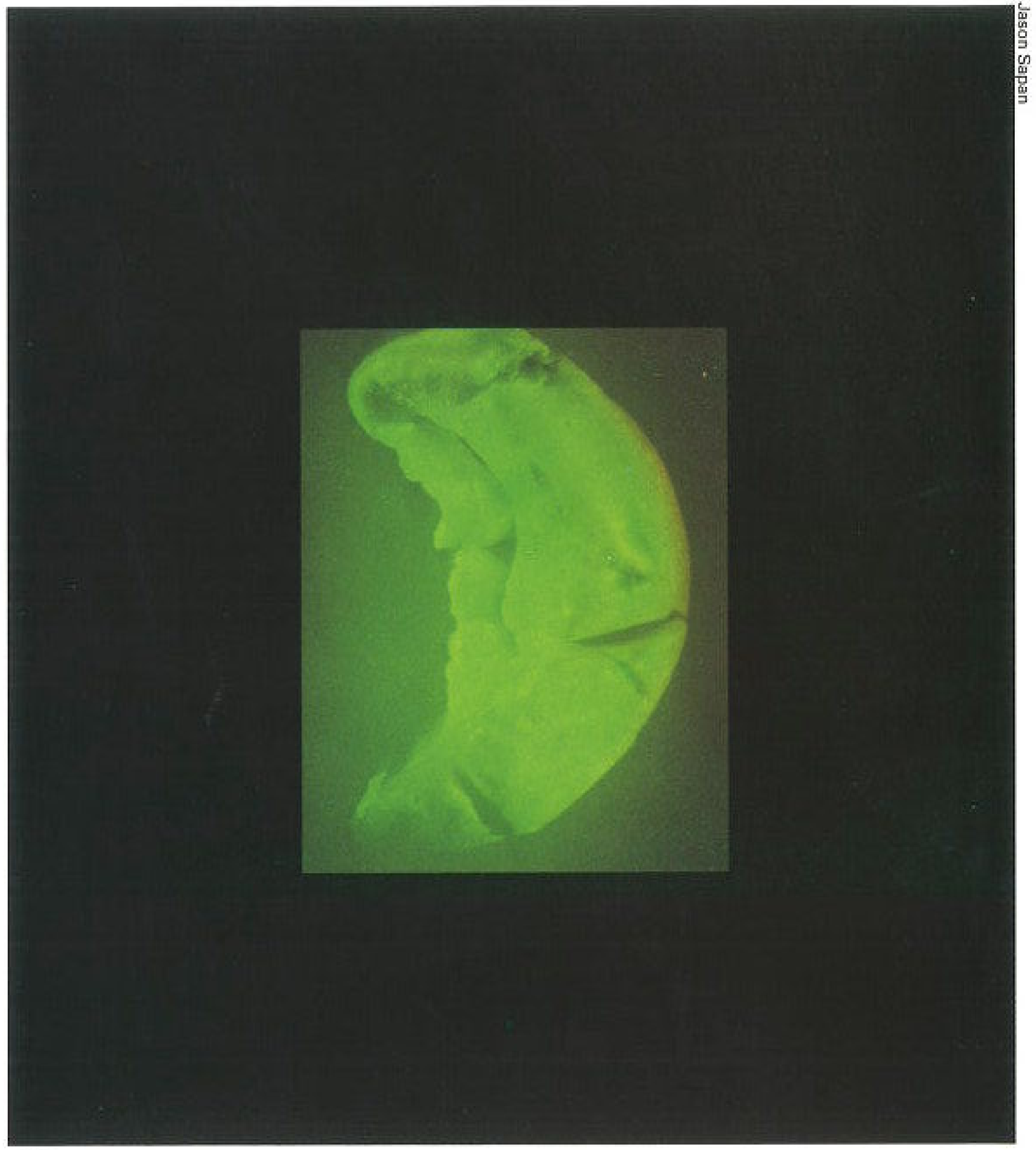


Human Colon with Familial Polyposis
White Light Reflection Hologram
4 x 5 in.

This is the most common cancer in the colon and the same type that patients with familial polyposis get. As the tumor grows it blocks the organ, often leading to complete obstruction. The body tries to force feces through the constricted area leading to stretching of the organ before (proximal to) the lesion. This is the reason that the diameter of the part on the right is bigger that on the left.

This is an inherited disease in which the entire colon is filled with polyps. If left alone, the polyps become malignant at an early age and almost all of these patients are dead of cancer by age forty. The present treatment is to remove the entire colon and rectum before a cancer develops. This is very radical surgery. There is some experimental work which shows that treatment with Sulindac, a non-steroidal, anti-inflammatory agent (an aspirin like drug), causes the polyps to disappear, but whether the treatment with the drug reduces the likelihood of cancer remains to be proven.

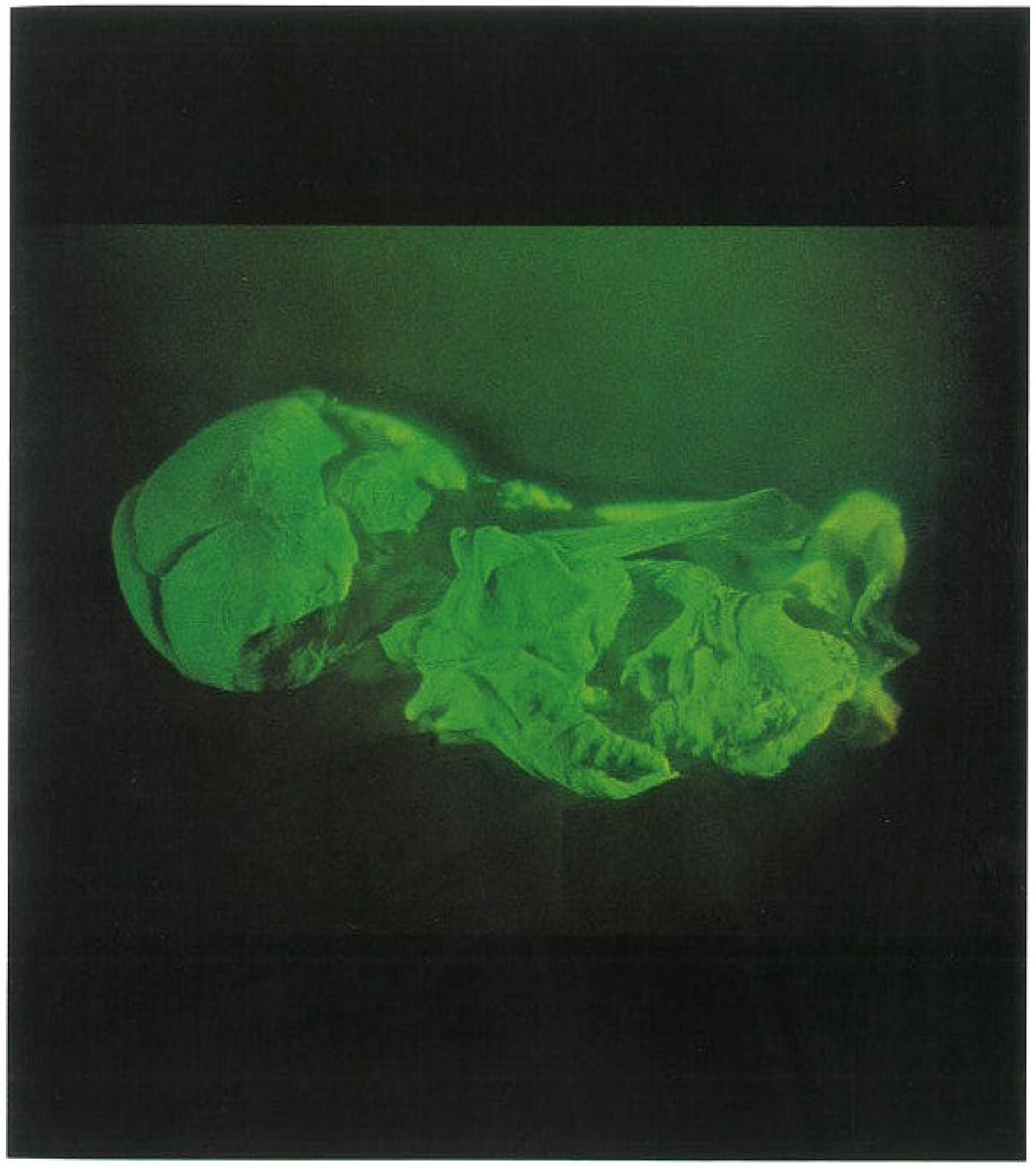
Human Spleen
White Light Reflection Hologram
4 x 5 in.



Jason Sapan

The light colored area on the specimen is an infarct, an area of the organ which was deprived of its blood supply and then went on to die. This does not show in the hologram.

Human Fetus Spina Bifida
White Light Reflection Hologram
4 x 5 in.



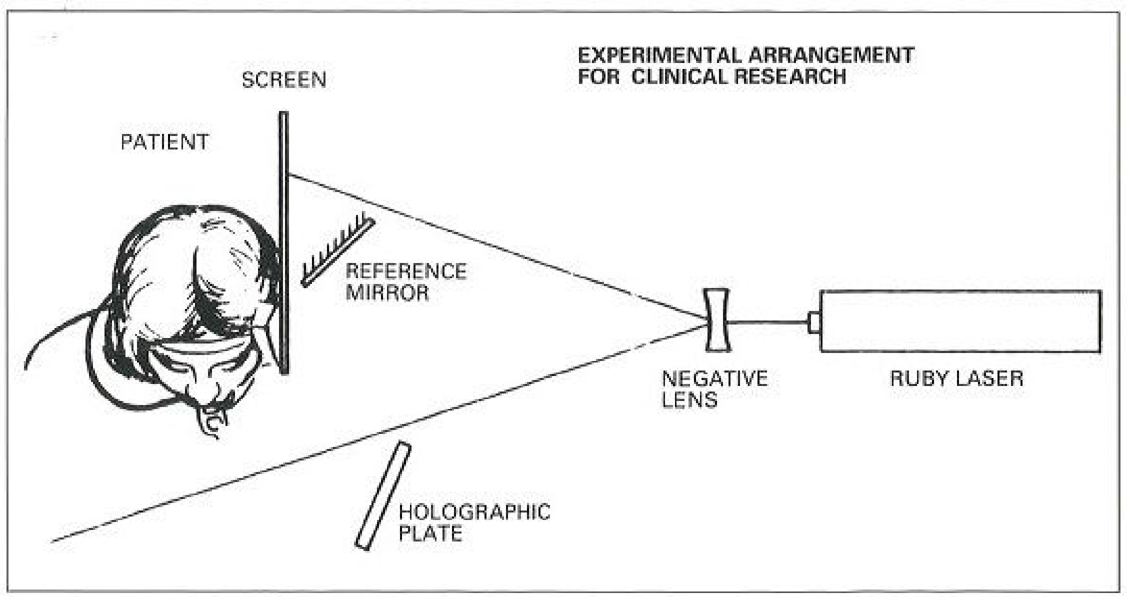
The fetus is about 11 weeks old and did not live because it had a severe congenital malformation. The end of the vertebral column did not form properly and the spinal column was exposed to the elements.

Dynamics of Human Teeth in Function by means of Double Pulsed Holography: an Experimental Investigation.
by P.R. Wedendal and H.I. Bjelkhagen

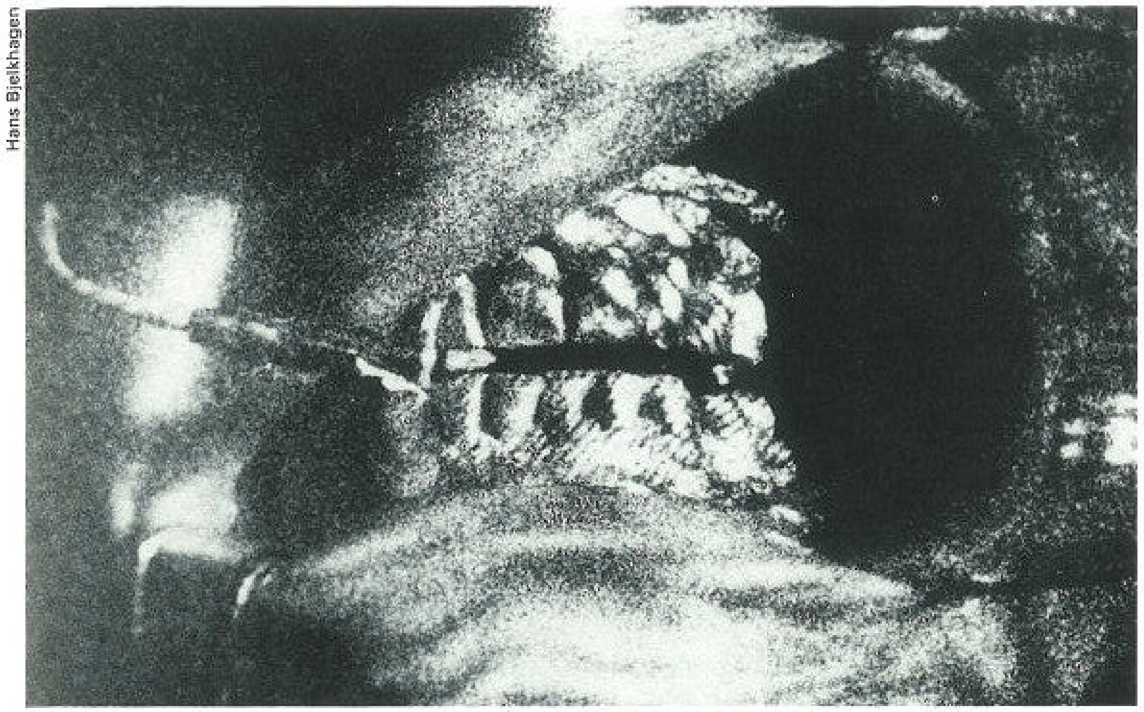
Hans Bjelkhagen is currently Associate Professor of Engineering in the Pre-Medical Engineering Department, Northwestern University, Evanston, Illinois; and is a partner in Holicon Corporation, a pulsed portrait studio in Evanston, Illinois.

Paul R. Wedendal, DDS, is currently in the Department of Stomatognathic Physiology, Royal Caroline Institute, Stockholm, Sweden; and is an international expert in prosthodontics and oral surgery.

Investigation *in vivo* of small deformation and mobility processes in the masticatory system of man has been until now a very intricate problem. Mechanical as well as non-contact methods have been utilized earlier in order to record the mobility pattern of teeth and prosthodontic appliances. Holographic interferometry can be a solution to some odontological measurement problems. The method was first tested in a simulator arrangement and then used in a number of clinical experiments. A special, totally reflecting paint was used for surface preparation prior to holography. A Q-switched double-pulsed ruby laser was combined with an electronic subminiature force sensor for pulse triggering, which was actuated by the masticatory force of the patient. Force increases and pulse positions were registered synchronously on the screen of an oscilloscope. The applied force exerted by the patient's masticatory muscles could thus be defined according to its point of application, direction, amplitude, and duration. The corresponding surface deformation was evaluated by means of a synchronized, double-exposed hologram. Conclusions could be drawn regarding the relative and absolute mobility of the teeth and related structures of the holographed jaw section.

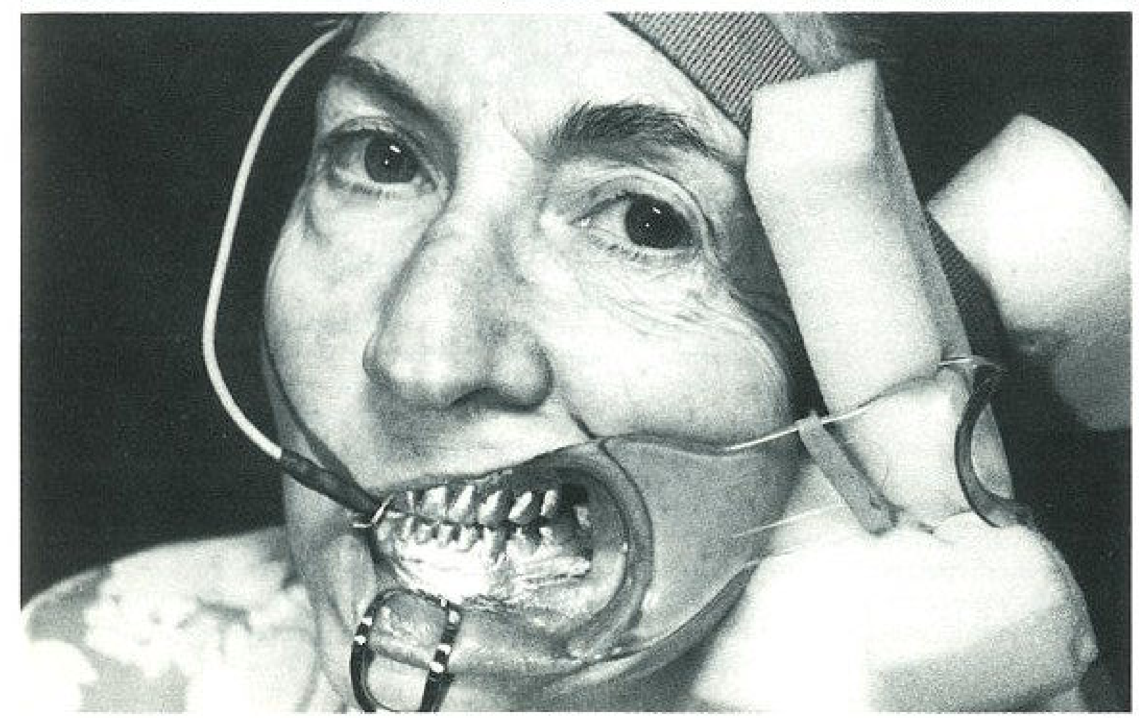


Hans Bjelkhagen



Dynamics in Human Teeth
P.R. Wedendal and H.I. Bjelkhagen
Laser Transmission Hologram
4x5 in.

Holographic reconstruction of the exposed jaw section.



Photograph:
Patient prepared for holography. The region to be exposed is painted with a special gold paint for total reflection of the laser light., The subminiature force sensor is positioned between 24 and its opposing teeth. During the registration of the hologram the eyes of the patient are protected by means of black glasses.

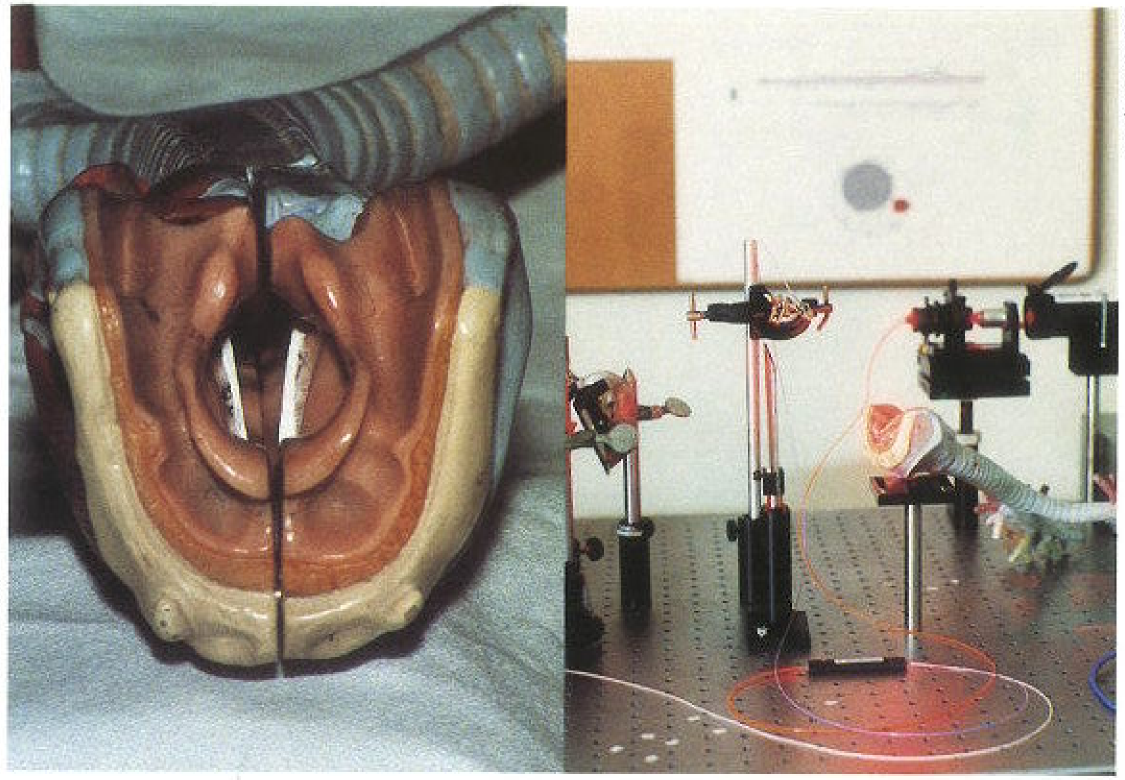
Model of the Human Throat and Larynx 1991

White Light Reflection Hologram, 4 x 5 in.

InterScience, Inc.
New York
James Castracane
and Michelle Conerty

Left:
Photograph of anatomically correct model of the human throat and larynx, used to test the fiber-optic holographic apparatus prior to clinical work with human patients.

Right:
Fiber-optic holographic apparatus showing separate fibers used to illuminate the subject (larynx) and provide the reference beam for the holographic recording.



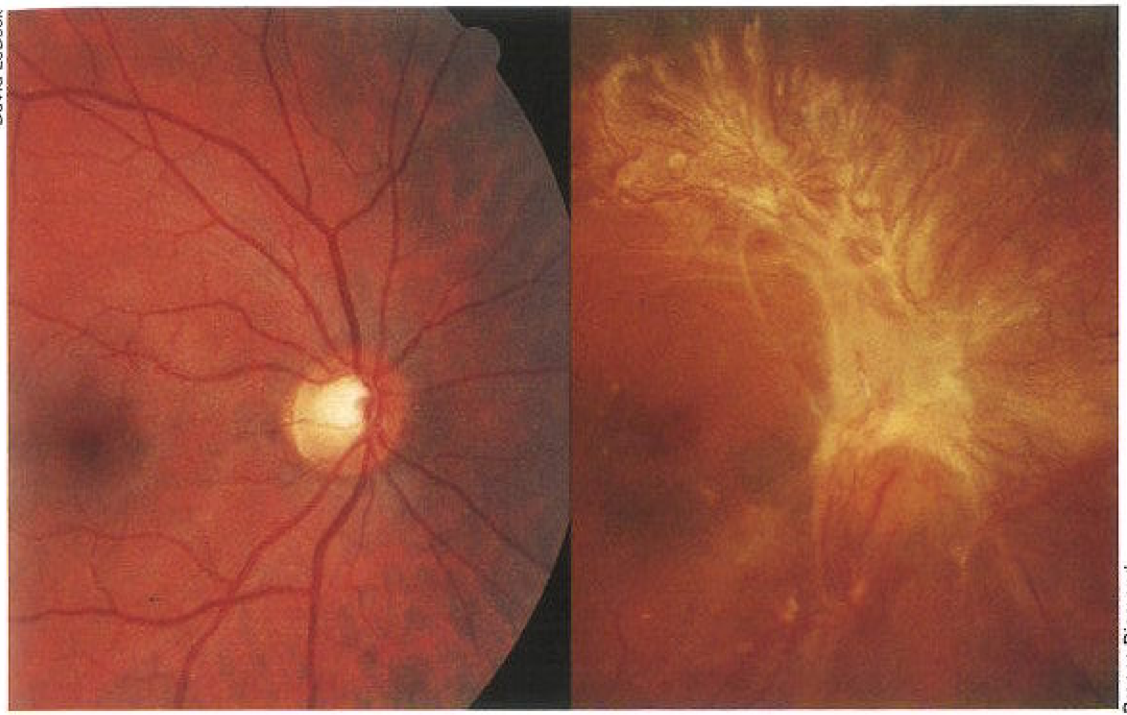
InterScience, Inc.

InterScience, Inc. is involved in basic research of vocal and hearing dynamics, and is developing fiber optic instruments for endoscopic holography and interferometry. This work is supported by the National Institute of Health. They are working in collaboration with the Otolaryngology Department of the Albany Medical College. The goal of the project is to perfect a new instrument for the measurement of abnormalities in the vibration patterns of the vocal cords and tympanic membranes.

The larynx is located along the midsection of the neck and is externally known as the Adam's Apple. It is the organ in the human body responsible for phonation. The vocal cords are the primary structures within the larynx whose sole function is voice production. These five-layered structures produce sound as they vibrate due to air forced up between them by contraction of the expiratory muscles in the abdomen. The pitch and intensity of the tone produced is dictated by the vibratory pattern of the vocal cords. The position, shape, elasticity, and tension of the vocal cords are controlled by the intrinsic muscles of the larynx and define the vibratory pattern produced.

The holographic apparatus uses single-mode optical fiber (10 micron diameter) and integral beamsplitters. By avoiding the use of conventional optical components, the technique can be made very small and extended to the interior of the human body for routine clinical applications.

David LeBeck



Brenna Diamond

Left:
Retina With No Apparent Pathology
1990
35mm Stereo-Photographic Pair

Right:
Traction Retinal Detachment
1990
35mm Stereo-Photographic Pair

Brenna Diamond
New York Hospital
Cornell Medical Center

Brenna Diamond has a BFA degree in Photography and Fine Arts from the University of Colorado. As a Medical and Ophthalmic photographer for 10 years, she has worked in Tel Aviv, Israel and New York. She is also involved in photojournalism and portraiture.

This patient is diabetic and has a severe case of diabetic retinopathy. The optical repercussion of diabetes is the progressive closure of capillary circulation with severe consequences. There is localized infarction of blood vessels, leakage of fluid and proteins into the retina, proliferation of neovascular membranes, traction of the retina and hemorrhages of the blood vessels. There can also be accelerated formation of cataracts and rubeosis and glaucoma. Rubeosis is new blood vessels on the iris that cause severe glaucoma — a painful condition. Diabetes is the number one cause of blindness in the United States.

Almost all of the above complications are evident in Traction Retinal Detachment (right photograph) which is the pulling up of the retina into the vitreous by a membrane that shrinks (blood vessels are lifted with the membrane.) The result is stretching of the retina (the area in bright yellow with red blood vessels.) There are exudates in the macula (to the left of the macula is a macular hole (the red oval) in the retina affecting the area of critical focus or central vision. The orange fuzzy disk peeking out under the white traction is the optic nerve. Around the edge are light brown or yellow circular marks which are laser scars, the result of laser treatment to cauterize the leaking blood vessels.

Exhibit Checklist

American Museum of Natural History
Hologram of Visible Woman
Hologram of DNA Molecule Chain

Hans Bjelkhagen and P.R. Wedendal
Dynamics of Human Teeth

Roland Bagby
Venus' Looking Glass

Stephen Benton & MIT Spatial Imaging Group
Magnetic Resonance Image of Patient with Brain Tumor
Ventricles of a Patient with NPH

Brenna Diamond
Macular Degeneration
Malignant Melanoma
Optic Pit
Pseudo Tumor
Retinal Detachment with Diabetic Retinopathy
Traction Retinal Detachment
Traction Retinal Detachment Caused by Diabetes
Virtual Separation with Retinal Edema

Les Folio
Non-Invasive Holographic Magnetic Resonance Angiography left and right view

Bernard Furshpan
Model of Human Spine

Kathryn Ko
Cerebral Hemispheres
Hippocampus
Motor Cortext
Vision
Woman With Metastatic Tumor Left Frontal Cranium
Human Spine in Zero Gravity
Spine Repair

InterScience, Inc.
Anatomically Correct Model of the Human Throat and Larynx

Lee Lacey
Blood Flow in Cerebral Arteries
Carotid Arteries
Cerebral Vasculature
Coronary Arteries Stereogram
Thoracic Anatomy Model

Bert Myers
Human Colon: Adenocarcinoma
Human Colon: Familial Polyposis
Human Fetus: Spina Bifida
Human Lumbar Vertebrum: angled view
Human Lumbar Vertebrum: view from above
Head of Humerus
Human Temporal Bone: Radical Mastoidectomy
Normal Human Larynx
Larynx: Prone View
Human Spleen
Tulane Hip

Jason Sapan
Heart

Glossary Of Terms

Angiogram a non-invasive diagnostic imaging technique, often using X-rays, to produce an image of the blood vessels and any malformations that may be associated with disease. Angiograms are often enhanced with the aid of computers to reveal more subtle details, as in a CAT or CT scan.

Coherent Light A very pure beam of light emitted by a laser and essential in the creation of a hologram. Ordinary light is made up of many different colors of light. The coherent light from a laser is made up of a single color of light, and this light's waves are all in step as the beam emerges from the laser.

Computer Assisted Tomography (CAT or CT) Tomography is the general term applied to non-invasive diagnostic imagery often presenting information related to the specific tissue densities relative to some probe beam (X-rays or sound waves), and now applied to the wide range of imagery representative of a view within the body. The increased sensitivity of detection materials used to register the image and the application of computer technology to enhance and interpret the imagery has lead to Computer Assisted Tomography and Computerized Tomography. For instance, the computer has allowed very low amounts of X-ray radiation to be registered on a detector surface and transformed into a video image; much less radiation is used than with the most sensitive film, and several images can be recorded to enhance the image while reducing the noise created by stray radiation.

Computer Synthesized Holographic Image a series of images created by a computer graphic system based on a three-dimensional object that has been reintegrated into a holographic image. The source of the computer's rendering of the three-dimensional object can be from measurements taken from a real object, as in CAT scans, or totally fabricated as in the case of computer modeling or computer graphic artistry.

Continuous Wave Laser a laser that produces a beam of coherent light that is of constant amplitude over time — as opposed to a pulsed laser that produces a burst of coherent light periodically or on demand.

Dichromated Gelatin (DCG) Hologram a white light reflection hologram recorded in a light sensitive gelatin emulsion. These holograms are very bright and can be created in multi-colors. The DCG emulsion is very sensitive to moisture (humidity) and must be sealed behind glass to be preserved.

Fringe Lines the pattern of light and dark lines imposed on an object or image created by the interference of coherent light — usually created by some surface change in the object or by the optical comparison of the surface of one object with another. See also Non-Destructive Testing.

Hologram a record of the light from an object made with laser light and appearing as a three-dimensional image identical in form with the original object. Holograms which are illuminated from a light on the same side as the viewer are *Reflection Holograms* except for those that appear silvery and are known as *Embossed Holograms.* Holograms which are illuminated from the opposite side from the viewer, and are hung some distance from the wall to allow the illuminating light to strike the back side are *Transmission Holograms.* Embossed holograms are transmission holograms which have been mass-produced and appear mirror-like.

Holograph a testament or written document in the handwriting of the author. This is often a diary, journal or will.

Holographic Film the light sensitive material specially designed to be sensitive to the laser light color, and to have very high resolution in order to record the very fine interference lines of the hologram. High resolution photographic film might be able to resolve 200 line pairs per millimeter while holographic film must be able to resolve more than 2000 line pairs per millimeter.

Holographic Interferometry a technique used to measure and record the microscopic deformation of objects by making a hologram of the object and either comparing that image with the object under a deformed condition, or holographically recording the object a second time under changed conditions. The interference lines in the holographic image reveal the microscopic changes in the surface of the object between the two exposures as small as 1/10 the wavelength of the laser light used — one millionth of an inch.

Glossary Of Terms

Holographic Stereogram a hologram created by reintegrating a series of photographic views of an object; the series created by taking a succession of photographs moving from left to right of the object. These individual views are then recorded holographically so that the viewer's left eye sees views of the object which were to the left of those views seen by the right eye when viewing the finished hologram. The name is derived from the photographic technique of stereo-viewing, such as the three-dimensional postcards viewed with a *stereopticon*, popular at the turn of the century, and the more contemporary *ViewMaster* viewer. The holographic version records a continuous series of stereo views and duplicates the function of the viewing apparatus all within a single hologram. Also known as a stereogram or integral holography.

Holography the technique of recording the three-dimensional light from an object on a photo-sensitive material by means of coherent light. Hungarian scientist, Dennis Gabor received the Nobel Prize in Physics in 1971 for his discovery of transmission holography, and Yuri Denisyuk in the USSR received the Lenin Prize in 1970 for his discovery of reflection holography.

***In Situ* Holographic Color** a technical innovation created at Massachusetts Institute of Technology, Spatial Imaging Lab, that allows the holographic emulsion to be selectively treated prior to an exposure allowing that portion of the image to be reconstructed in the desired color after development.

Interference the optical phenomenon where two or more beams of light of identical wavelength meet at a point in space and produce the vector sum of the energy of the photons. This can result in two beams of light meeting to produce a very bright point of light, or to produce a dark spot. Laser light is sufficiently coherent to demonstrate this property easily. It is the property of interference which allows holography to record not only the amplitude of the light from an object, but the direction that the light is traveling as well.

Integral Holography an alternate name for holographic stereogram.

Interferometry a technique of measuring microscopic distances and changes using coherent light and the optical phenomenon of interference. The fringe lines produced in interferometry are a precise measure of these microscopic distances and a function of the wavelength of the coherent light used. The transition from a dark fringe line to an adjacent bright fringe line represents a difference of half the wavelength of the light.

Laser the acronym stands for Light Amplification by the Stimulated Emission of Radiation. The laser is a source of coherent light that is essential in the creation of a hologram. Lasers produce the purest single color light achieved and can emit their light continuously (CW) or in very brief pulses. Many different materials are able to be used in lasers; helium-neon, ruby, argon, and krypton are materials that can emit laser light.

Laser Transmission Hologram See Transmission Master.

Magnetic Resonance Imaging (MRI) a diagnostic imaging technique that uses the natural radio waves emitted by the atoms that make up a particular tissue to reveal the location of that tissue. Because these radio signals are very weak, the MRI machine must shield the detectors from external signals, and stimulate the atoms to emit the signal in a way that allows the detection system to create an image of the location of the particular signal.

Metastatic a medical term used to describe the transfer of a disease producing agent (such as cells, bacteria or virus) from an original site of disease to another part of the body with the development of a similar lesion in the new location. Metastatic tumors are sometimes associated with advanced cancer.

Micrographs the photographs made of microscopic objects. Micrographs represent an enlarged image of something, often animal or plant tissue specimens. Because the micrograph is a photograph, its eventual size is up to the optics used to create the final image.

Multiplex a term used in holography to describe a hologram that combines multiple images. The most common type of multiplex hologram is the stereogram, however multiple exposures and multi-color holograms are also multiplex holograms.

Non-Destructive Testing (NDT) an industrial technique using coherent light to examine a material or object in comparison with some reference — usually the material or object itself prior to the test condition. NDT can measure surface deformations as small as 1/10 of the wavelength of the light used. The fringes created by the microscopic deformations can reveal material flaws and indicate weaknesses in engineering designs as well.

Non-Invasive a medical term often used to describe a diagnostic technique which does not require the patient to undergo surgery nor to submit to probes that enter the body cavities, or break the skin during the procedure.

Plastination a specimen preservation technique that replaces the liquids within the tissue with a curable polymer which leaves the specimen dry and much more rigid than the original tissue. Plastination is being used by Dr. Bert Myers to prepare specimens for holography using a continuous wave laser (CW).

Prosthesis a mechanical replacement for a damaged tissue segment. Bridgework in dentistry and replacement joints in medicine are common prosthetic devices.

Pulsed Laser a laser that emits coherent light in very brief pulses, often used to make holograms of high speed phenomena and of people and objects that cannot be stabilized to allow for holographic recording with the continuous beam of a CW laser.

Reflection Hologram a type of hologram, discovered in the USSR by Yuri Denisyuk, where the illuminating light is on the same side of the hologram as the viewer, allowing the hologram to be displayed flat against the wall like a picture. Reflection holograms are viewable in white light.

Ruby Laser a laser using a ruby crystal as the source of coherent light. The ruby laser is a type of pulsed laser.

Serial Sections a series of tissue samples or images of tissue which have been created like slices from a loaf of bread. Each *section* or slice represents one plane through the tissue, and the series of planes are parallel to each other but displaced through the specimen. Serial sections of 10 to 36 samples can reveal much of the three-dimensional detail in the specimen if properly interpreted.

Sonogram a diagnostic technique that uses sound waves (in a manner similar to radar) to create images of tissues within the body. Sonography is a non-invasive diagnostic procedure. The sonogram probe creates a series of sound pulses which reflect from the various tissues in the body back to the probe where their direction and delay (distance) are detected. From this information an image of the tissues can be displayed.

Stereogram See Holographic Stereogram.

Transmission Hologram a record of the light from an object made with laser light and appearing as a three-dimensional image identical in form with the original object. A hologram which is illuminated from the opposite side from the viewer, and hung some distance from the wall to allow the illuminating light to strike the back side.

Transmission Master a laser transmission hologram created specifically for use as a master image in the process of making a display hologram viewable with white light. The master is viewable only in laser light and is created so that the light from its reconstructed image can be used in a subsequent hologram. The display hologram will be a hologram of a hologram (rather than of the original object or image) with the result that the final image can be more precisely controlled by the holographer.

White Light Hologram a hologram created to be viewed when illuminated with the light from ordinary light bulbs, called white light. This is a distinction drawn because most transmission holograms made of objects are viewable only in laser light, unless specially created to be viewed in white light. Reflection holograms are usually viewable in white light.

References

1. Bagby, Roland M., *Reconstruction of 3-D biological images from serial sections using multiplane/multiplex holography*, Proceedings, SPIE Vol. 1212, Practical Holography IV (1990)

2. Bowins, Toni-Sue, *Interferometry in Orthopedics Research*, holosphere, Vol. 12, No. 6, Winter, 1984

3. Cline, H.E., et al, *Two algorithms for the three-dimensional reconstruction of tomograms*, Med. Physics 15 (3), May-June 1988, pp. 320-327

4. Eskridge, Joseph M.; Lacey, D.C. Lee; Gilmor, Richard L.; and Klatte, Eugene C. *Holographic Cerebral Angiography Using Image Plane (IPI) Integral Holography*, Presented at the American Society of Neuroradiology, New Orleans, La., 1985

5. Folio, Les; Meals, Robert L; and Boggin, Andrew. *Non-Invasive Holographic Magnetic Resonance Angiography*, International Conference of Lasers and Electroptics, Boston, Ma., Nov. 1990

6. Kulick, J.H.; Benton, S.A.; Halle, M.; and Klug, M. *Volumetric Display of Soft Tissue Via Holography*, Proceedings, SPIE, Medical Imaging II, 1988

7. Lacey, D.C. Lee, *Geometric Modeling with Image Plane Integral (IPI) Holography*, Proceedings, Society of Photo-Optical Instrumentation Engineers, Vol. 507-18, August 1984

8. Lacey, D.C. Lee, *Radiologic Applications of Holography*, Proceedings, SPIE Vol. 761, True 3-D Imaging Techniques and Display Technologies (1987)

9. Myers, Bert and Binkley, Harmon. *Holography of Human Pathologic Specimens With Continuous Beam Lasers Through Plastination*, Veterans Affairs Medical Center, New Orleans, La., 70146

Special Thanks to our Sponsors:

Lasersmith, Chicago, IL
Steve Smith

Transfer Print Foils, Inc., East Brunswick, NJ

Potlatch Corporation, Northwest Paper Division

Media Interface, Ltd., Brooklyn, NY
Ronald R. Erickson

Meredith-Webb Printing, Inc., Burlington, NC
Lou Jewell

Richard Lounsbery Foundation, New York, NY
Alan F. McHenry

Potlatch White Vintage Gloss Cover, 120 lb.
Potlatch White Vintage Gloss Text, 100 lb.
(Potlatch Vintage Gloss Cover is noted for its quality and consistency. The Vintage exclusive blade coating gives a smooth uniform surface perfect for hot stamped hologram application.)