A GUIDE TO IDENTIFYING HOLOGRAMS IN THE FIELD

There are two broad categories of hologram types; transmission, or lit from the side opposite the observer, and reflection, lit from the same side as the observer. To complicate matters, the holograms mass-produced by embossing techniques are lit like reflection holograms, but they are actually transmission types with a mirror backing.

CLASSICAL TRANSMISSION HOLOGRAMS

The earliest types of transmission holograms were lit monochromatically, or with a laser. These are easy to identify, as the light in the image will have that distinctive laser speckle. They are the "Holographer's Hologram", as the scene in them can be very deep. Emmett Leith and Juris Upatnieks described this technique applied to the recording of diffusely reflecting objects in 1963. A company called Conductron made some impressive imagery in this mode circa early seventies, about a meter square, some of it pulsed, for instance a room full of people drinking beer and playing cards, or a deep sea scene with seven divers, with the reference beam emerging from one of their flashlights! Holex was a company producing large quantities of small holograms into the eighties.

WHITE LIGHT TRANSMISSION HOLOGRAMS

Dr. Stephen Benton made a major improvement in the reconstruction of transmission holograms when he introduced a slit into the imaging system. This slit eliminates vertical parallax, which is not all that necessary, since our eyes are oriented in a horizontal plane, but also eliminates the need for monochromatic light. A simple, unfrosted incandescent light bulb is all that is necessary to replay these holograms. The distinguishing characteristic of this type of hologram is the iridescence of the color of the image; it changes through all the hues of the rainbow as the viewer translates vertically while in front of it, or if the hologram is tilted. A bright one will project a rainbow onto the viewer's face, hence the name Rainbow Hologram. Multiple colors can be generated with this system, but the relative color hues will change as the vertical viewing angle changes. This technique is favored by the New York Holographic Artists. The typical mass-produced hologram is the Benton type of hologram embossed into a plastic backed with aluminum, which acts as a mirror backing, turning a light from the front into one which seems to be coming from behind the hologram. The holograms can then be attached to book covers, record jackets, clothing, cereal boxes, etc.

The real image of a laser lit hologram is usually used as the object wavefront in the production of the Benton hologram, so that most of these holograms exhibit an object which pierces the plane of the hologram.

Another type of White Light Transmission Hologram is a variation of Benton's slit technique which looks colorless, or black and white. These holograms are called

"Achromatic", and the technique is often used for holographic stereogram images of people.

It is possible to make true-color images with this technique, but color veracity is achieved only at a certain vertical viewing position.

REFLECTION HOLOGRAMS

The first reflection type of holograms were reported by Yuri Denisyuk in 1962, so they sometimes bear that name in holographic shop talk as well as the Lippmann or Bragg label. They are made by interfering the reference and object beams from opposite sides of the hologram during recording and they are reconstructed with the replay light on the same side of the hologram as the observer. They can be distinguished from the embossed hologram as they exhibit vertical as well as horizontal parallax and will not change color as the viewer moves up and down. As the hologram is tilted, a slight shift in color can be noticed, but it is only a small slice of the spectrum rather than the complete one of the Rainbow hologram. Many of these holograms are made in one step, where the hologram was exposed to the object in the scene, and their image is only virtual. But many more are made in a two-step process using the real image from a transmission hologram as the object for the second reflection one so that the object straddles both sides of the copy plate.

HOLOGRAMS OF LIVING PEOPLE

Since skin is constantly moving microscopically thanks to blood circulation and respiration,it presents a problem in the holographic recording of living subjects. Because of the fraction of a wavelength stability requirement in recording, holograms of living tissues are usually recorded with pulsed lasers whose short, strobe-like emissions do not allow the fringe pattern to be blurred by the moving subject wavefront. The choice of laser is limited to either ruby (694 nm) or frequency-doubled Nd:YAG (532 nm). The long ruby wavelength penetrates the surface of the skin, and returns to the hologram well-diffused, so that the subject acquires that all-too-familiar waxy or cadaver look. The green color of the YAG reflects directly off the surface, giving a much more real appearance. Holographers have not switched over to this type because there are not many YAG's out in the field that are capable of a single giant Q-switched pulse. Sometimes the portrait is reduced to smaller than actual size, and the people look flatter than pancakes because the minification in the z-axis is the product of the x- and y-axes, so if the person's face is reduced to 1/4 life size horizontally and vertically, their depth is 1/4 X 1/4 = 1/16! Extreme minification will make the subject look like they have been run over with a steamroller.

Indirect recording of people can be achieved by **Holographic Stereograms**, which integrate a variety of photographic views into a hologram which acts as a Viewmaster, except that there are many stereo pairs of the object. The earliest experiments were

performed in the late sixties, but the commercialization of the technique was achieved in the mid-seventies by Lloyd Cross and his Multiplex Company's holograms, which used 1080 motion picture frames holographically printed onto a cylindrical piece of holographic film. Nowadays the technique has been perfected to encompass flat, white light transmission and reflection image plane copies, in formats from tiny embossed ones to meter squares. Because it is based on stereophotographic principles, magnification as well as minification of images can be quite convincing. Computer generated images can also be used, so holograms of things that never existed can now be made. True color rendering is possible in this technique, with some images available in the embossed format, for instance Shakespeare, Michael Jackson, children in a toy store, etc., from Applied Holographics.

HOLOGRAMS THAT ARE NOT FLAT

The earliest curved film holograms were made in a cylindrical shape. ("If you're going to go 3-D, why not go 360!" quote the inventor.) They are true transmission holograms, and are lit monochromatically. Flattened out, they transform the objects in them quite wonderfully. The record for largest one in this format is about a meter in diameter.

Multiplex is the trademark of the company which made cylindrical stereograms. They are about 30 to 35 cm in diameter, sometimes on rotating displays, white light transmission types lit with an unfrosted 100 Watt light bulb from below. Some images were produced that are less than a full cylinder. The most widely distributed one is "The Kiss", which shows a woman blowing a kiss and winking.

An Alcove hologram is basically an inside out Multiplex. A real image of the object floats in front of a concave semi-cylinder, as opposed to a virtual image floating behind a convex semi-cylinder. The Alcove hologram is lit with a laser, but the reference beam must be shaped by a concave plexiglass semi-cylindrical mirror larger than the hologram itself to focus the light below and in front of the hologram. The prototypes were made at M.I.T. by Benton in the mid-eighties.

HOLOGRAPHIC RECORDING MATERIALS

The different types of recording materials influence the quality of the holographic image and its cost. Some materials are industrially produced, and are either commercially available (Agfa, DuPont, Ilford, Kodak) and the holographer uses and processes the holograms himself, or the holographer can have the mass production done by the producer of the material in their own labs (Polaroid). Sometimes holographers coat their own brews on glass plates (Dichromated Gelatin, Photopolymers, Other Experimental Layers), or buys plates coated with Photo-Resist from a specialist.

SILVER HALIDE: The most popular recording material amongst holographers, due to its high sensitivity and ready availability compared to all the others below. Handling of the media is well enough understood nowadays so that high quality results can be achieved consistently. Gabor and Denisyuk made their first recordings on silver halide plates. Agfa dominates the market with their Holotest line up of products, while Ilford is coming on strong with their Hotec series of films, plates and chemicals. Apparently the field is too small for Kodak to even think of competing, and they market a variety of materials that have essentially remained unchanged for 15 years.

Each hologram is individually exposed and processed, and equipment for high volume production has been utilized, for instance the "Holocopier" of Applied Holographics which cranked out the "Supernaturals" series of holographic toys. But the silver halide holograms for sale in the galleries are mainly produced by a "Cottage Industry" of small (>10 employees) businesses.

DICHROMATED GELATIN: For many years the dichromated gelatin holographic pendant was the mainstay of the mass-produced holo-trinket market. Each hologram was individually coated with gelatin layer containing ammonium dichromate to make it light-sensitive, exposed to laser light, (The material has sensitivity to violet and blue but starts losing it in the green and is totally blind to the red end of the spectrum, and it needs about 100 times the light exposure as silver halide under the same circumstances.), then processed in Kodak Rapid Fixer, Kodak Photo-Flo, and baths of hot isopropyl alcohol. The hologram can be destroyed by high humidity, so they are sealed under glass with either epoxy or an Ultraviolet curing adhesive. Older dichromates, (as they are known in the trade), have been observed to be disappearing as water penetrates the seal around the edge. They were produced by the thousands by several companies, (Electric Umbrella/International Dichromate/Dikrotek/Holographic Products, Holo-Source, Holo-Crafts, Portson, Holographic Design, etc.) mainly in the 38 mm diameter pendant format, but 4 by 5 and larger have been made, with anything larger than 8 by 10 inches pretty rare.

Although requiring large Argon lasers for exposures, the process itself is inexpensive in materials but labor-intensive, which is why the pendants would list for $20.

PHOTOPOLYMERS: This class of chemicals are totally artificially prepared from industrial materials so quality is more consistent than that of dichromates. Plus they don't seem to have the need to be hermetically sealed like the above.

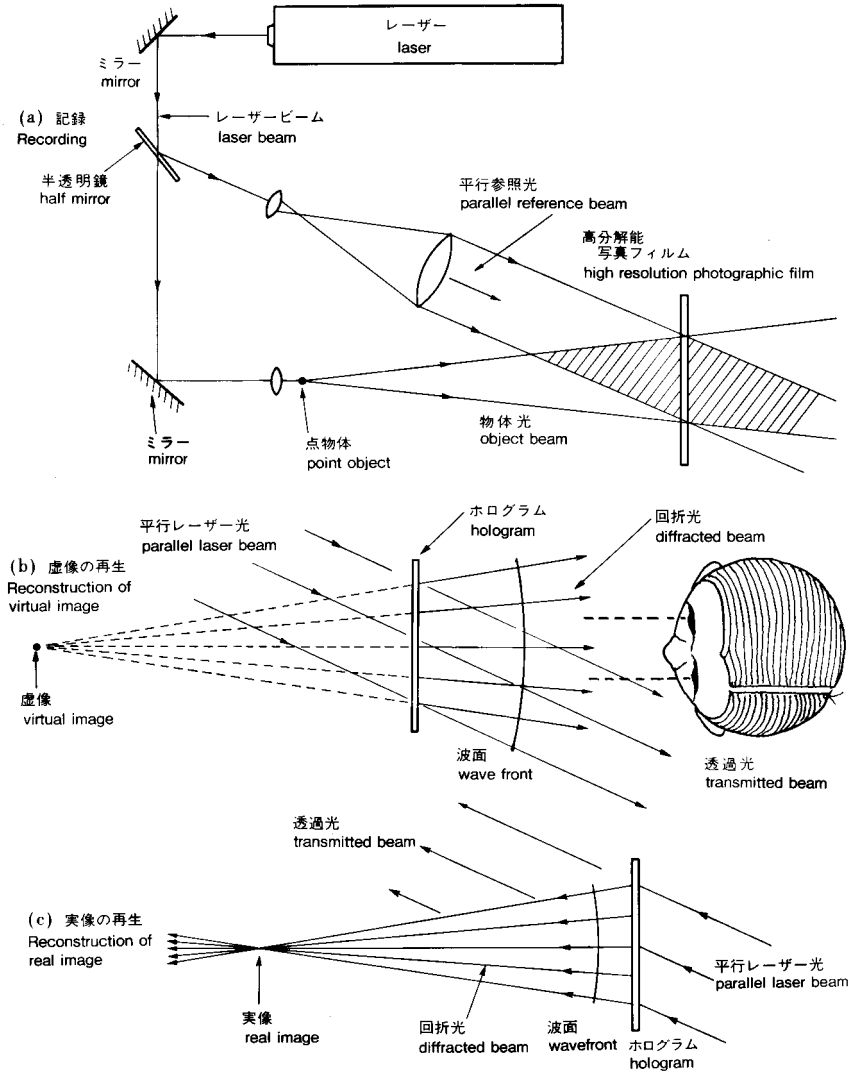
Polaroid manufactures DMP-128, but it is very fussy about its environment before it is exposed and processed that Polaroid only uses it in-house to mass produce holograms. The "Red Beam" series of images are made on this material.

DuPont makes their own variety of photopolymer that is available to the holographer. It has the potential of true color recording of reflection holograms. Applications of this material have not surfaced yet.

PHOTO-RESIST: A Photo-Resist Master Hologram is the first step of many in the replication of embossed holograms. A nickel shim (the "Mother") from which ultimately thousands of copies will be formed in plastic is electro-formed on the Photo-Resist hologram, which usually results in the master's destruction. This accounts for the scarcity of actual photo-resist holograms in the field, although their descendants are many. Typically Shipley AZ-1350 positive working photo-resist is coated by a micro-electronics pattern producing house onto glass plates for the holographer, although some spin-coat it themselves. The resist is clear, but is usually coated onto a layer of ferric oxide on top of the glass substrate to prevent back reflections from the resist/glass plate boundary causing a troublesome standing wave pattern, so that the plates themselves have a rusty red color. The resist is not very sensitive to ultraviolet, the violet and not much else, so its use is restricted to holographers who can supply copious amounts of the expensive blue photons.

EMBOSSED HOLOGRAMS: "Daughter" holograms are grown from the "Mother" from above and those are placed on presses which smash the holographic pattern into plastic. The characteristic tin foil appearance of the embossed hologram comes from the back of the plastic which is aluminized to reflect the reference beam so that they can be displayed in a reflective mode. (Embossed holograms reconstructed in a pure transmission mode are very rare.) Sometimes an adhesive backing with a peel-off release cover is applied for the sticker trade, or the foil is "hot-stamped" with an electrically warmed die onto a magazine or package. Millions of holograms have been made using this technique, viz. the National Geographic magazine covers, credit card and bus pass holograms, stamps, foreign currency, album covers, cereal boxes, raffle tickets, liquor packages, kids' stickers, ad nauseum.

図4　ホログラフィーの原理
Principles of holography.



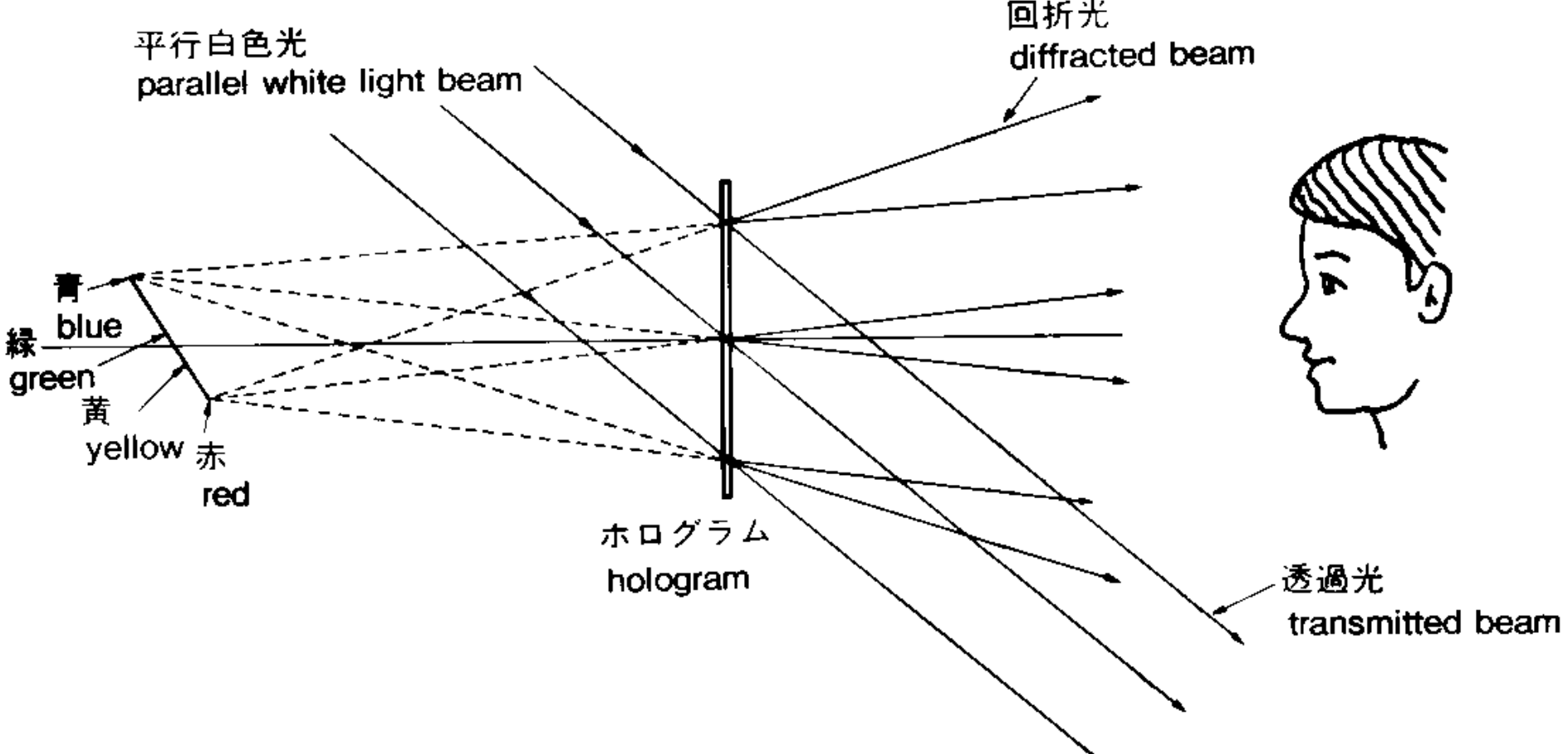

回折光
diffracted beam
平行白色光
parallel white light beam
青
blue
緑
green
黄
yellow
赤
red
ホログラム
hologram
透過光
transmitted beam

図6　ワンステップ・レインボウ・ホログラム
One step raimbow hologram

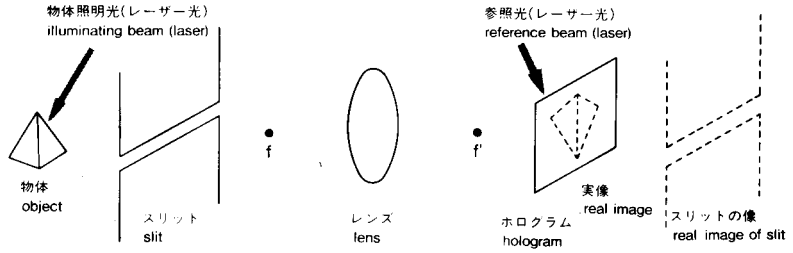


図7　レインボウ・ホログラム
Rainbow hologram.

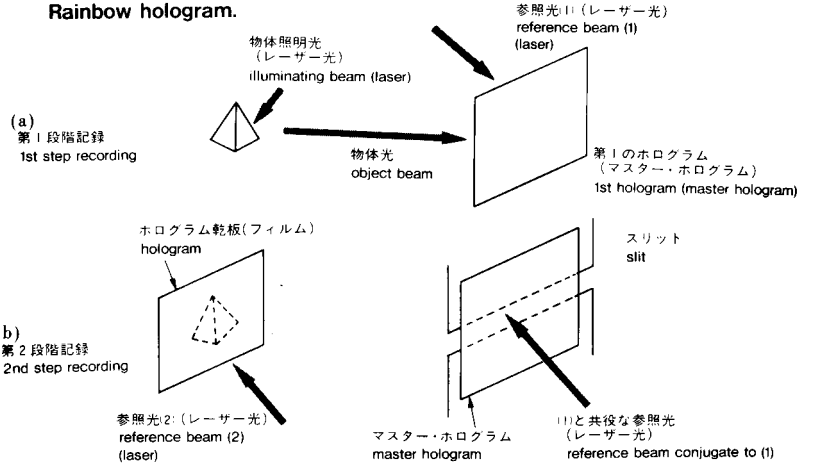


図8　レインボウ・ホログラムの再生
Reconstruction of rainbow hologram.

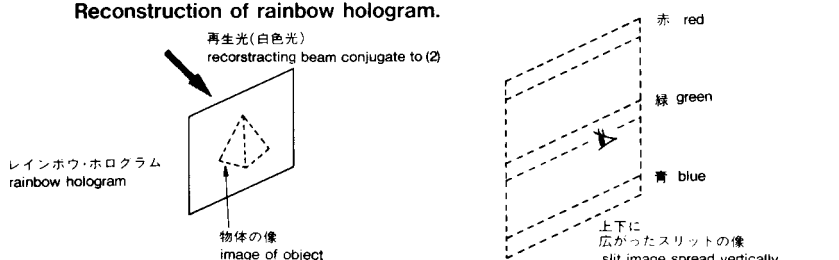


図9　デニシウク・ホログラム
Denisyuk hologram

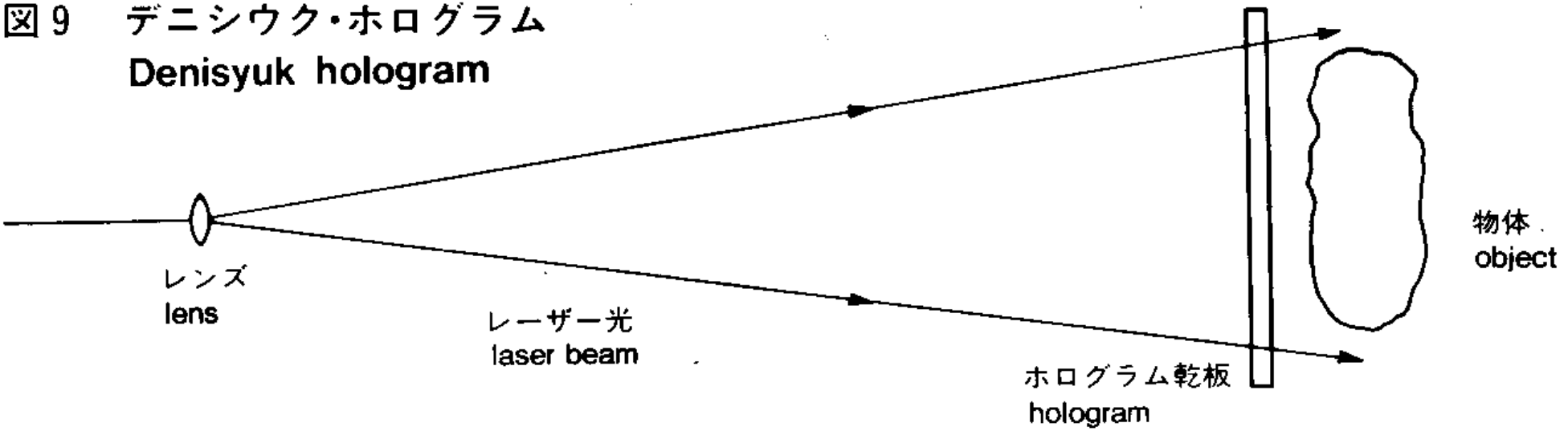


図10　リップマン・ホログラムの干渉縞
Interference fringes of Lippmann hologram.

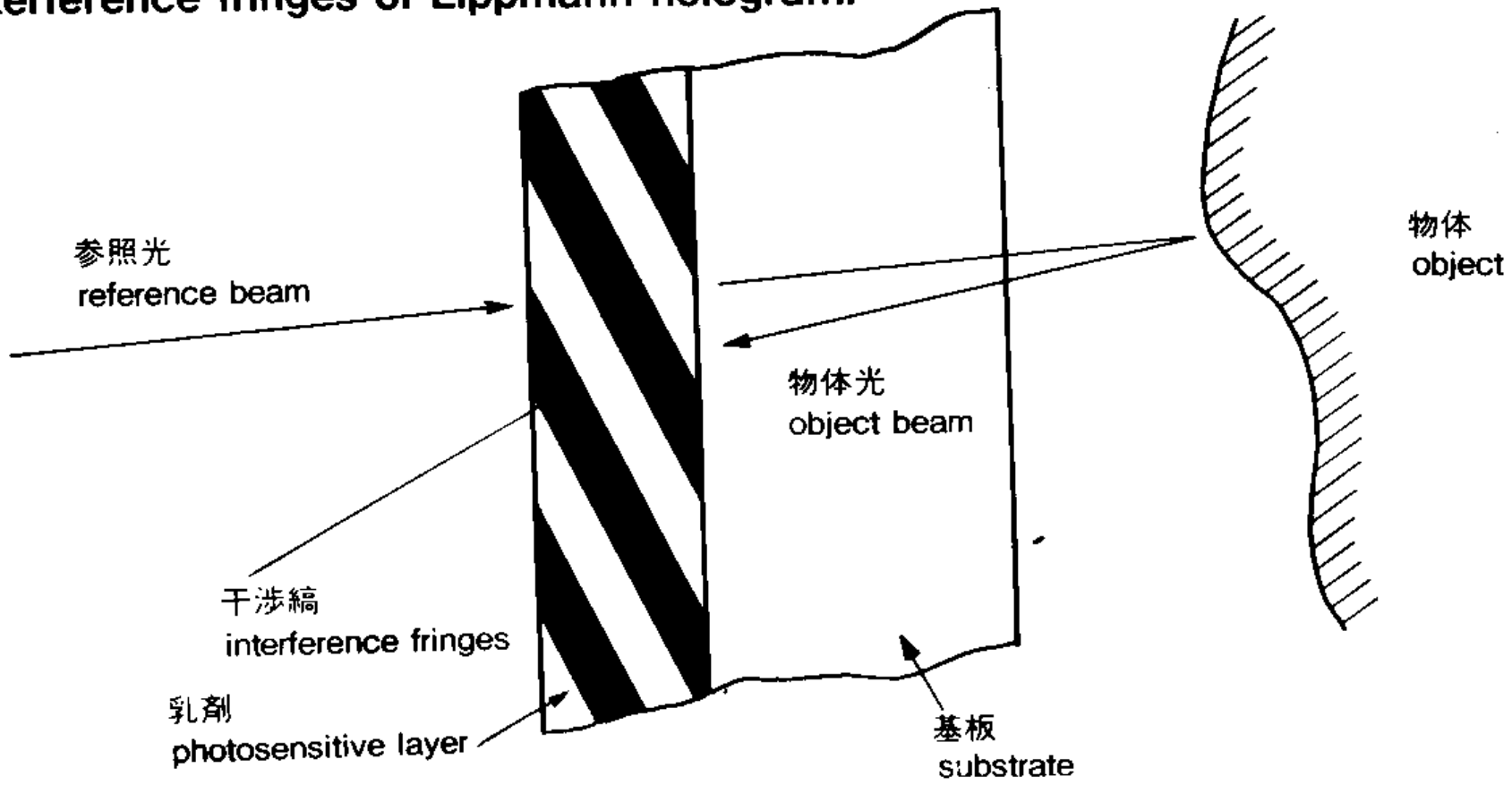


図12　マルチプレックス・ホログラムの原画撮影
Taking original film of multiplex hologram.

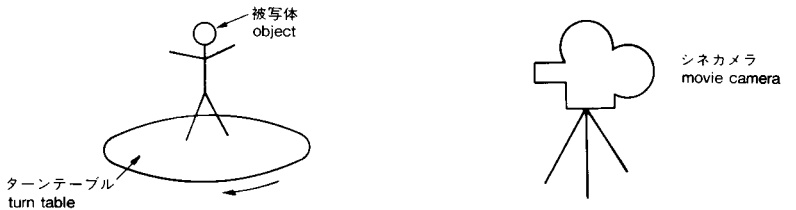


図13　マルチプレックス・ホログラムの合成
Synthesis of multiplex hologram.

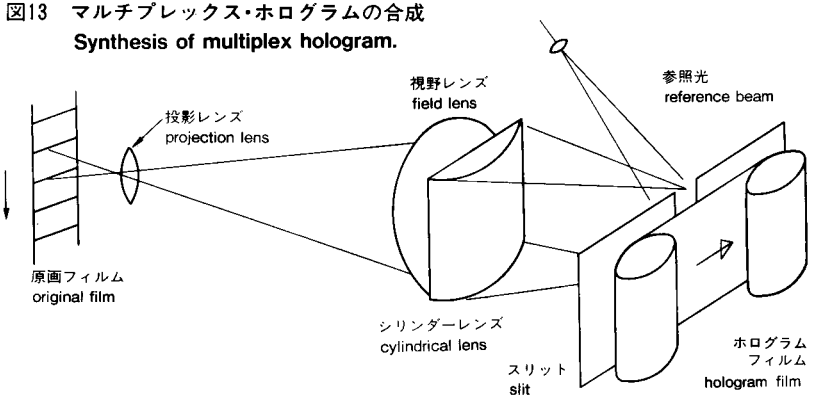


図14　マルチプレックス・ホログラムの再生
Reconstruction of multiplex hologram.