LASERS, HOLOGRAMS, and MICROSCOPES

ABSTRACT

Two methods are examined for utilizing 3-dimensional laser holograms and microscopes:
(1) 3D object holograms viewed under micro-scopes, and (2) self-magnifying storage and retrieval holograms, where the microscope is optically stored in the holographic recording.

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Lasers, Holograms, and Microscopes

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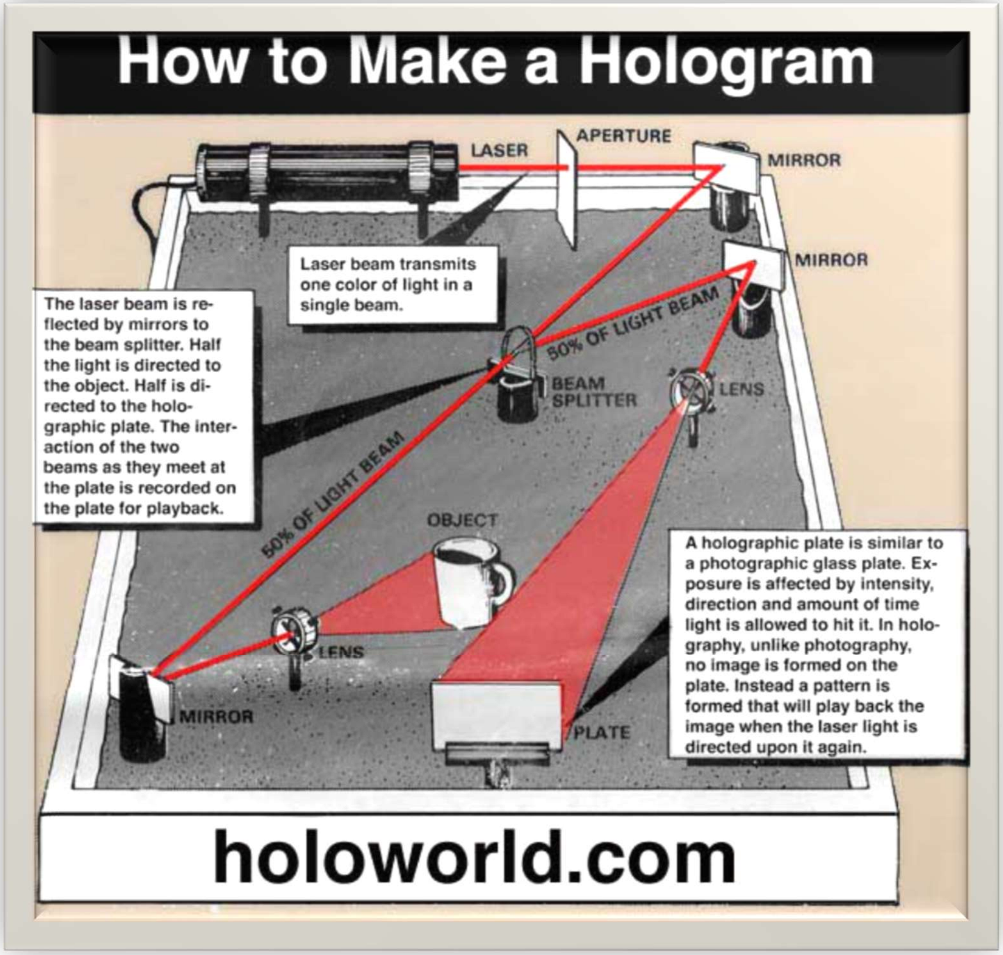
Holograms provide ultra high-definition recordings of three-dimensional objects and the storage of data. Resolutions can exceed 10,000 lines per mm, and detail well into the nanometer range. The author looks at the history of holograms and microscopes, and highlights a few projects of his own. Some of the most recent holograms have magnification optically encoded within the hologram itself. Therefore, no physical microscopes, lenses, sensors, computers, monitors or software are needed.

INTRODUCTION

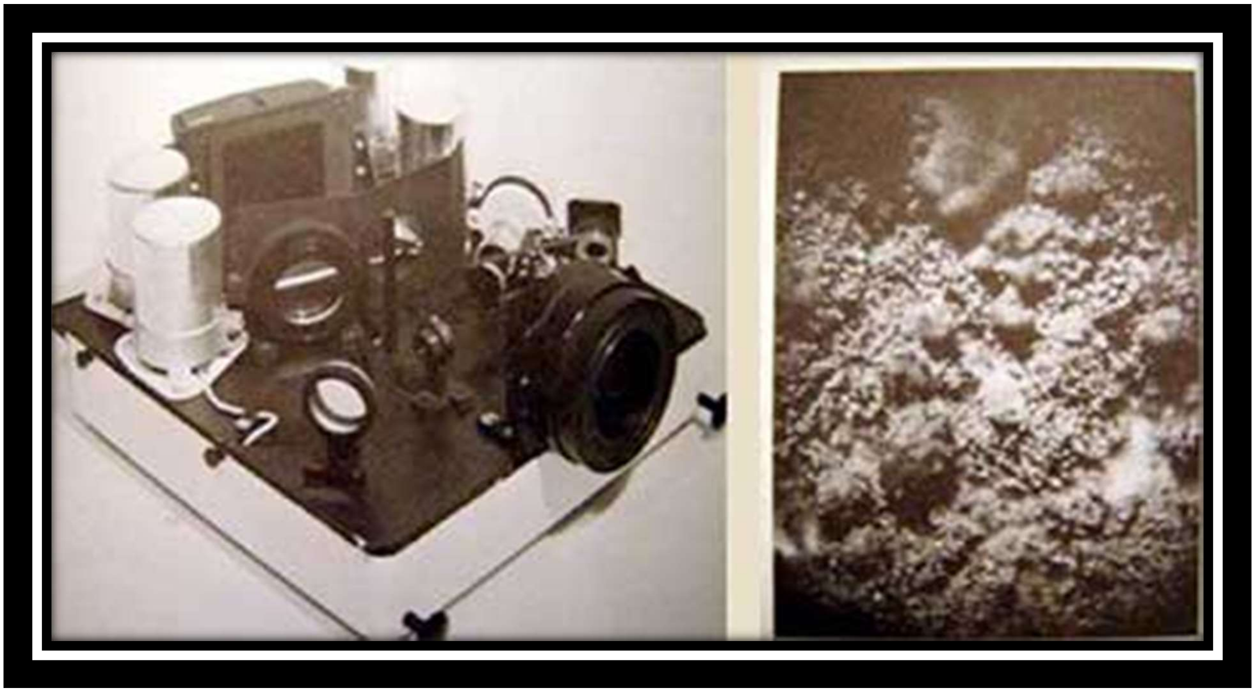
Microscopy was the original reason that holography was invented. Dennis Gabor developed holography in 1948 with the hope of improving the resolution and field depth of the electron microscope (A New Microscope Principle, Nature, May 1948). Relying on the light of a carefully filtered mercury vapor lamp, Gabor had mixed success with early holograms. It wasn't until the invention of the laser in the early 1960's that holography began to see its full potential.



HOLOGRAMS & THE MICRO WORLD

Holograms have been around for over a half-century now. While there are various forms of holographic microscopy, I will be addressing two forms in particular: display and data storage. These techniques can be (relatively) easy to duplicate in the modern classroom. Both bring renewed interest in the use and enjoyment of the microscope for students.

There are many things that a hologram can do well, and in some cases better than any other method on Earth. There are two techniques that are important to us: storing massive amounts of densely packed information, and giving the most realistic three-dimensional images in the world. Objects within a hologram not only look convincingly real, but inmany cases, they work as if they are real (a holographic lens functions the same as the 'real' lens that was used to record it). This leads many visitors to my presentations to ask: "What is real?" "What is a hologram?"



This portable holocamera, developed by Hughes Aerospace for NASA, was to fly on an Apollo mission to the moon. It would bring 3D laser holograms back to earth. The holocam is on the left, a simulated moon soil hologram taken with the camera on Earth is on the right.

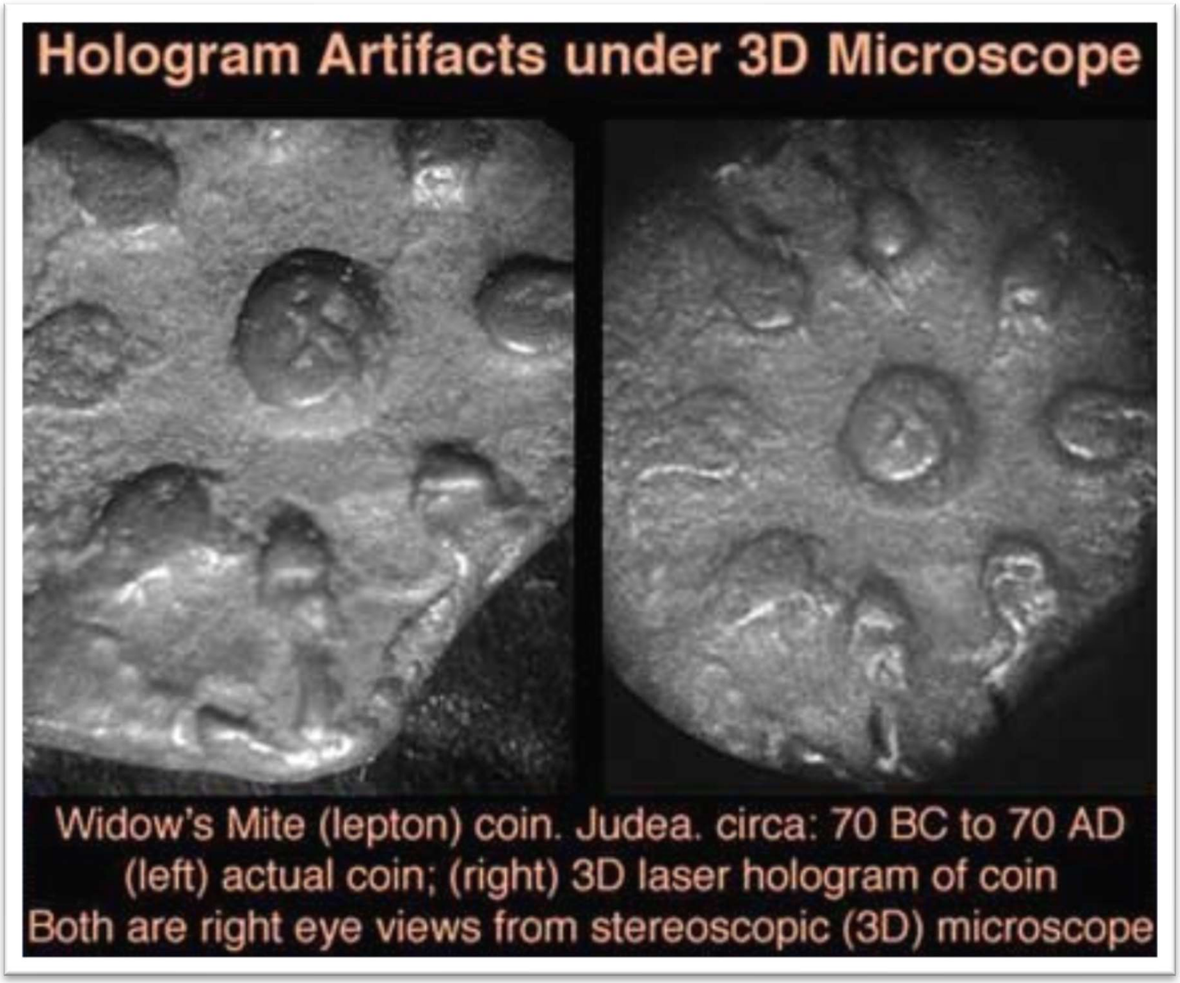
NASA APOLLO PROGRAM

Here is an example (above photo) of one of the earliest holographic microscopy projects. In the 1960's, Hughes Corporation developed a portable holocamera for inclusion for the National Aeronautics and Space Administration (NASA) Apollo program. This camera contained a pulsed ruby laser system, and its purpose was to take close-up laser holograms of moon rocks and soil. These samples would then be brought back to earth and taken into the laboratory for microscopic examination.

It is interesting to note that this early experimentation was viewed on a retrofitted microscope with a mono eyepiece, not stereo. Due to the hologram recording three-dimensional space, the entire field depth would still be available, albeit via a flat, 2- dimensional view, not 3D. The system never flew to the moon.

With traditional holographic microscopy, magnification is achieved by means of a wavelength change between recording and reconstruction. The field of view is a function of the resolution and size of the recording material. In the earliest days, silver halide emulsions were used. Modern recording now relies on very high-resolution photopolymer emulsions. Some of these materials can resolve up to 10,000 lines per mm, or greater.

I've been using holographic microscopy as a type of hybrid system: the creation of standard display holograms -- which are viewable under standard microscopes (and best with 3D stereo microscopes). This led to my most recent attempts to encode the magnification capabilities within the hologram itself, since a hologram can function as an optical element all on its own (a holographic lens system works just the same as the real).

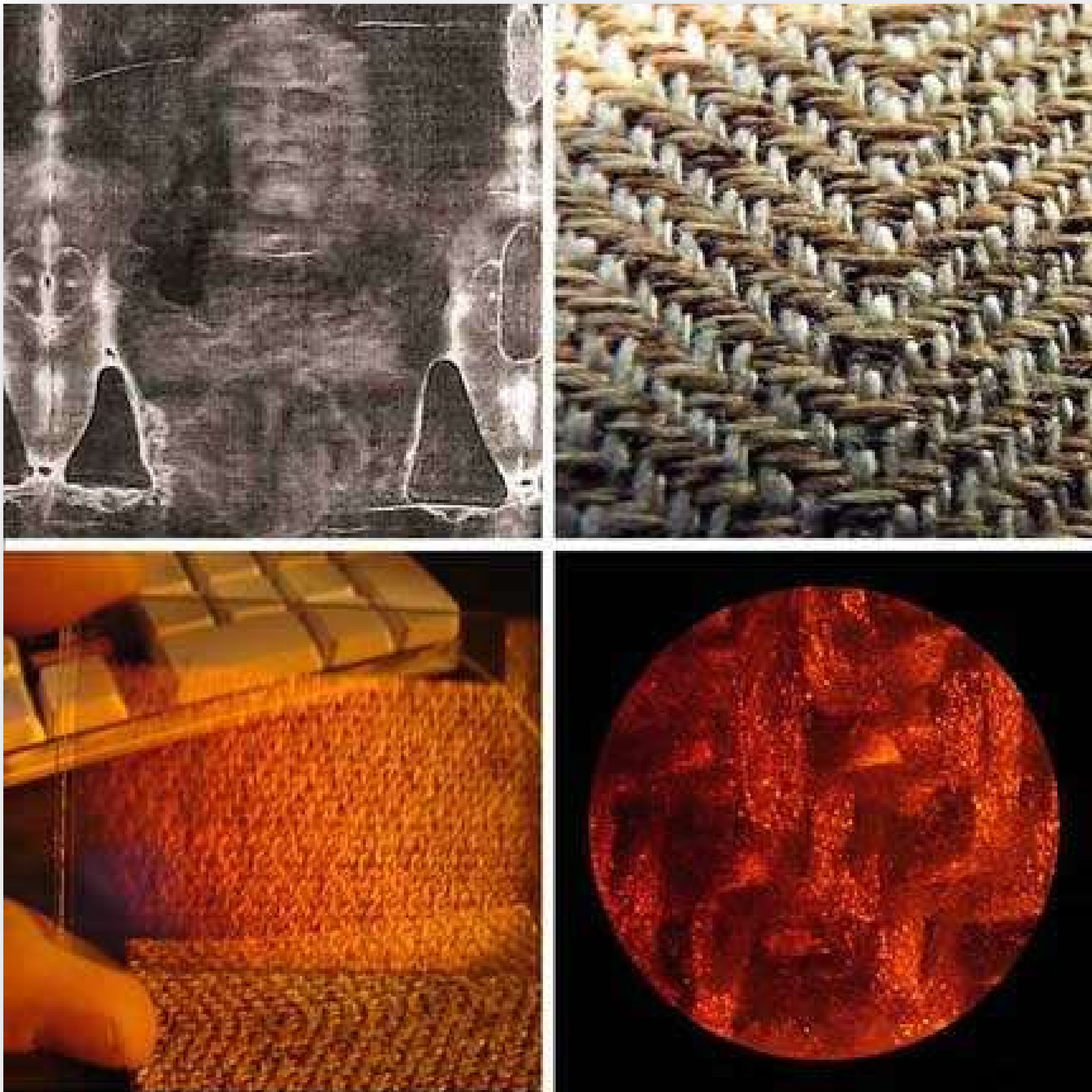


WIDOW'S MITE (Ancient Lepton Coin)

As we have read, since the 1960's it has been shown that a hologram can take the place of an actual object under the microscope. This includes stereo microscope reconstruction. In the above photo we see two images of a 2,000-year-old coin called a widow's mite. This coin was in use when Jesus Christ walked the earth. On the left, we have the actual coin viewed through an eyepiece of a stereoscopic microscope. On the right, we have the laser holographic image, reconstructed under the same microscope. Of course, the holographic coin on the right is not there physically. But it can be examined just as if the real coin were present.

PERSIAN VASE

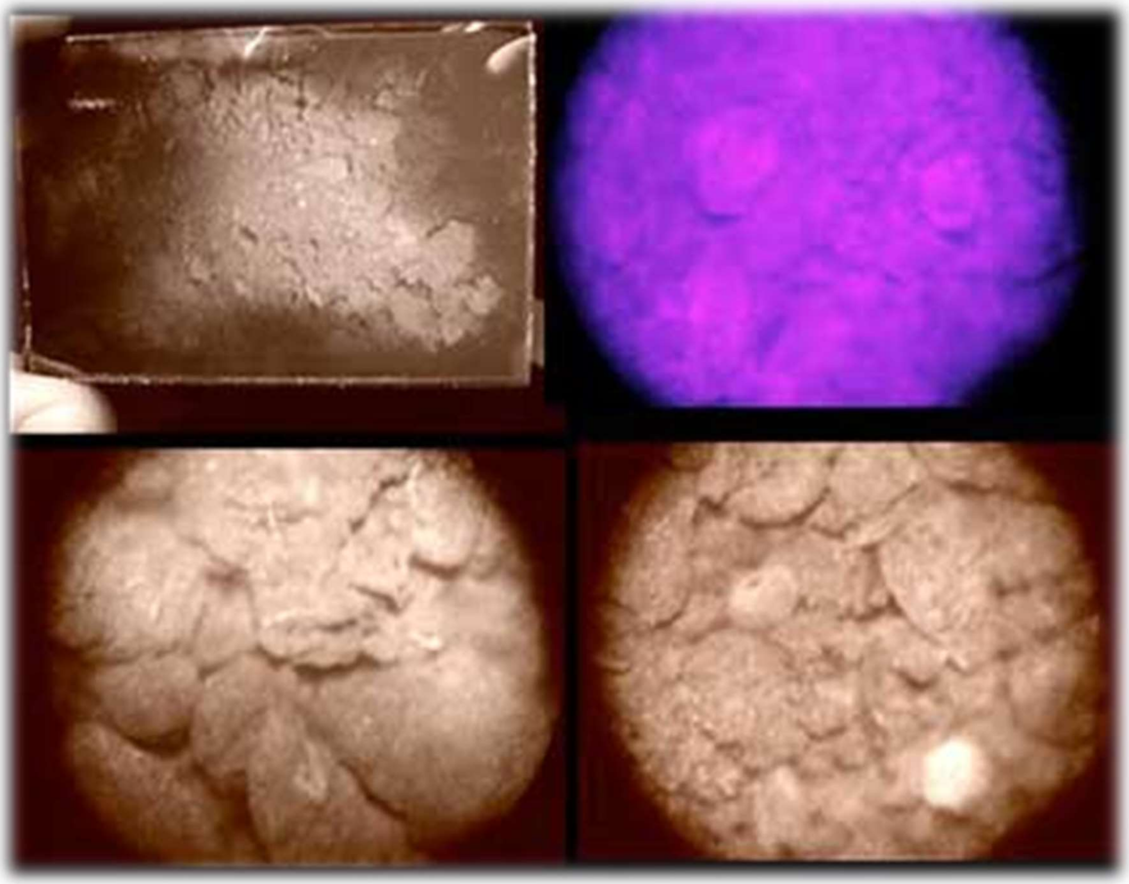
Note how this Persian vase (photo above) can be recorded as a thin film laser hologram. The thin film can then be placed under the 3D stereoscopic microscope for magnified examination. This particular experiment shows that a 3-dimensional laser hologram of a large object can be a substitute for the actual object itself. The holographic image provides the examiner with the very same features of the original, except that the actual object is not there, nor does it consume the same space (its entire volume of space is stored on thin film). I have been referring to this process as “Zero Mass 3D Printing”. The quality of a hologram image is determined in part by the qualities of the light used to reconstruct it. ‘Playback’ or reconstruction, must be taken into consideration when recording the hologram.



Utilizing 3D laser holograms in duplicate, combined with stereo microscopes, the Shroud of Turin fabric can be visually examined in 3D by researchers, anywhere in the world.

SHROUD OF TURIN FABRIC

This proof-of-concept research project (photo below) shows how the fabric from the Shroud of Turin could be recorded as a thin film laser hologram for viewing under 3D stereoscopic microscopes. Since the recording is holographic, the image of the fibers would remain three dimensional. The holographic recordings can then be duplicated and sent to researchers around the world -- without the Shroud ever leaving its protective storage. The holographic recording media (photopolymer) can be suspended slightly above the fabric, therefore nothing will ever touch the Shroud itself. It is a completely non-invasive, non-destructive way to send "samples" of the Shroud to laboratories around the world.

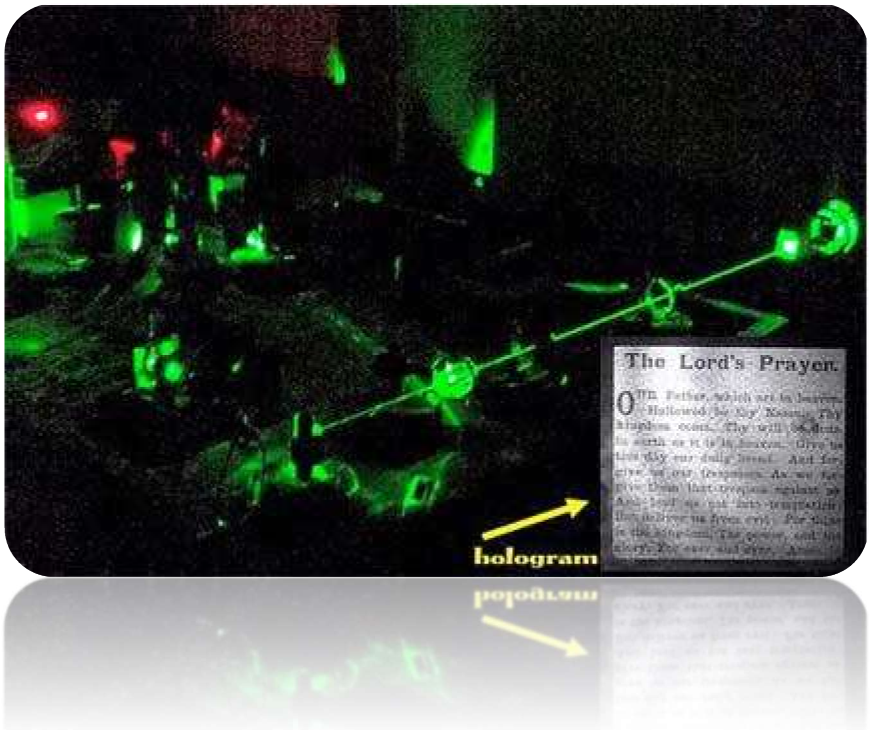


Space missions can bring back soil samples from the moon and mars for 3D visual examination … without having to compensate for the extra weight that "real" samples would add to the return mission.

MOUNT OF OLIVES SOIL

The results of this experiment were very close to what NASA achieved with their Apollo holocamera. This is soil from the Mount of Olives. It shows that soil samples from the moon, mars or other body can be recorded onto lightweight photopolymer film. That film can then be visually examined in its entire 3-dimensional fidelity back on earth – far in excess of any current electronic resolution capabilities . . . without the need for the storage space or weight associated with bringing additional 'real' samples back.

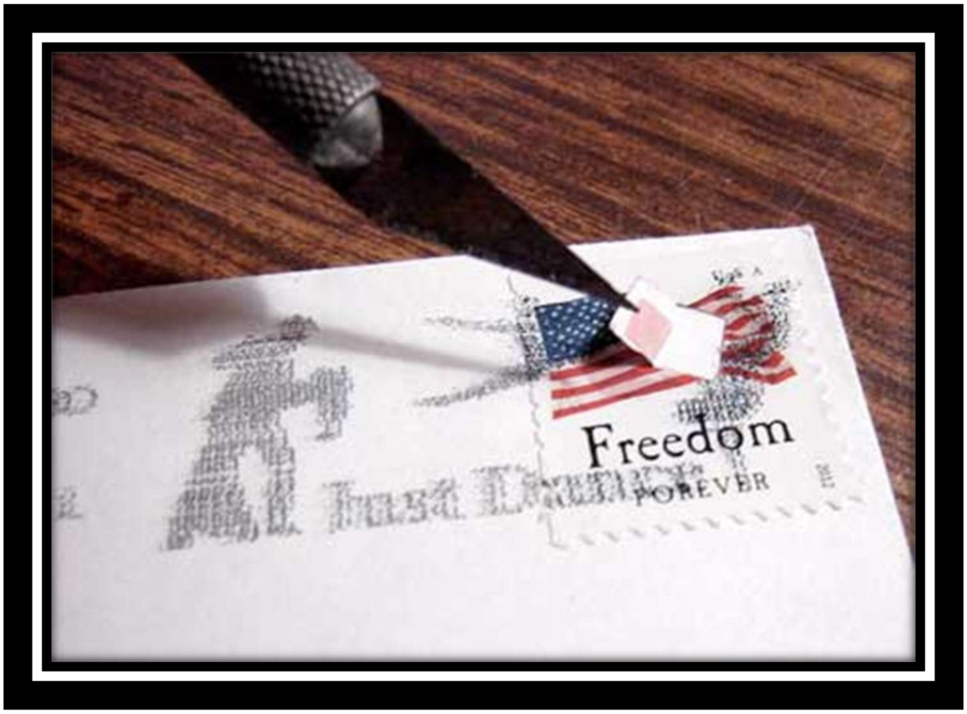
Self-Magnification Holograms



LORD'S PRAYER (Self-Magnification Type)

I am proposing that this is the smallest Lord's Prayer in the world today. Its imaging area size is smaller than the width of a human hair -- or less than 100-microns in diameter. We see it here greatly magnified from its original size in my laser studio / lab. If the size of the imaging area were enlarged to the size of a U.S. dime, the holographic image would be the height of a 16-story office building. It exists in a realm that is difficult to comprehend. Its detail is in the nanometer range.

The Lords Prayer hologram that you see above is made entirely of light. If you reach for it, your fingers pass right through it. It was created with a 100mw DPSS 532nm laser system on a vibration isolation table. It can be reconstructed, however, with a simple, inexpensive laser pointer. Its magnification optics are 'built in" to the holographic encoding. It can be projected onto a wall, screen or ceiling. It can be (and has been) sent secretly through the mail to anyone, anywhere in the world (see below

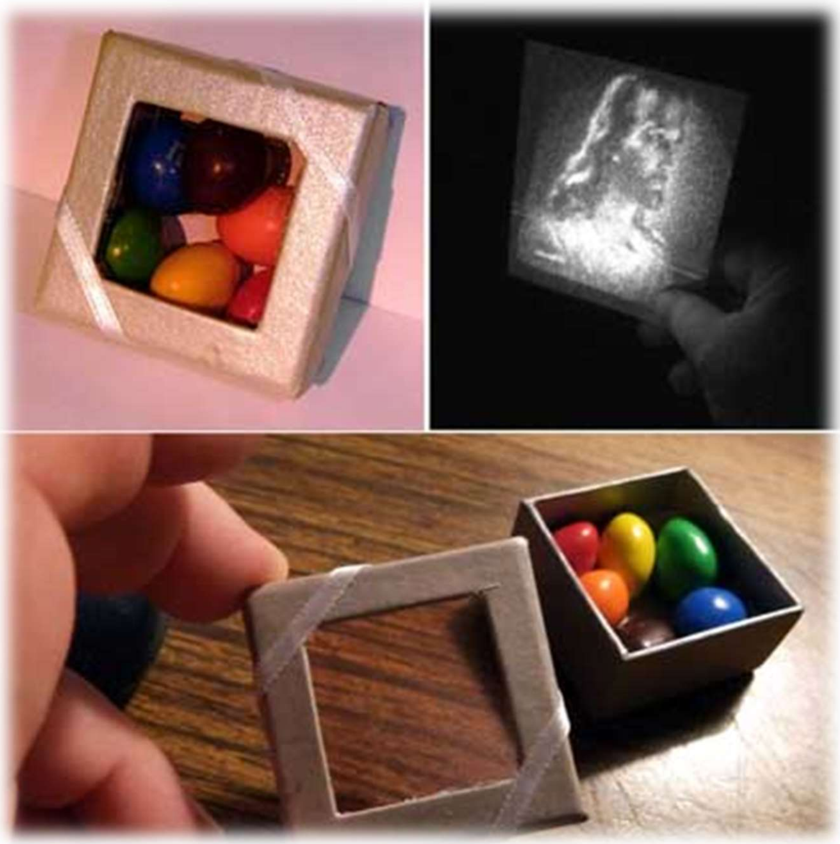


All 1,245 pages / 773,746 words of the King James Bible are optically stored inside a laser hologram, with a surface area of only 2mm square.

This is what I refer to as “stealth holography”. Relying on long-standing, common properties of holography, this micro text and image hologram (above) was placed under a postage stamp and mailed successfully. It can be 'read' with a simple laser pointer, but only by the recipient(s) knowing the proper laser beam tohologram orientation / geometry. As an example, the Holy Bible and Scripture can be sent to areas of the world where the Bible is banned.

This particular type of hologram was recorded so that its magnification takes place without any external optical system components. In essence, the ‘microscope’ is built into the hologram itself.

Again, text and images can be 'projected' out into space onto a wall, screen or ceiling by passing a laser pointer beam through the hologram area. The hologram is ‘self magnifying’, i.e. while the recorded image can be measured in microns, the reconstructed image can be easily read. If there is no physical microscope, is it still a microscope?



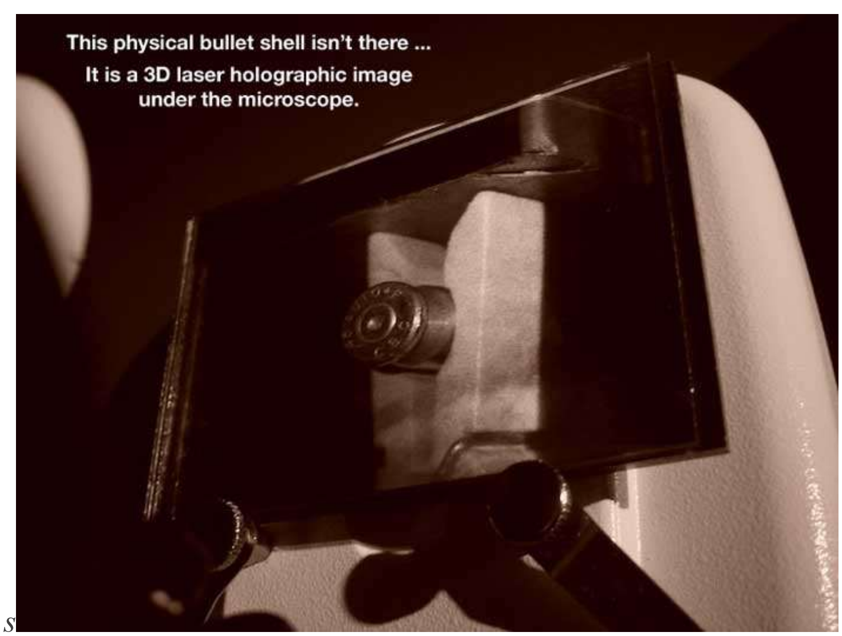
Candy Box Stealth Hologram of Jesus Christ

The clear cover on this box of M&M candies is actually a laser hologram. It contains the image of a painting of Jesus Christ encoded into a matrix within its clear photopolymer emulsion. The information is projected in a darkened room using the beam from any standard laser pointer. The enlarging / magnification optics are recorded in the hologram itself, so no microscope is needed. The only person that can reconstruct the holographic information is the person that the candy gift box is sent to: the only person who would know the correct geometric angle and orientation of the hologram to the beam of laser light. Once the laser beam is turned off, everything disappears completely, and all that is left is a box of candies.

Forensic Investigative Micro Holograms

Finally, here we will take a look at how 3-dimensional laser holographic imaging can be utilized in the investigation of crime. In this particular instance, we will examine a .45 caliber bullet shell after it has been fired. The 3D laser hologram of the bullet shell can be used in place of the actual shell, and examined under 3D stereoscopic microscopes as if the shell were physically present under the microscope. In addition, the holograms can be easily duplicated, allowing holographic images to be sent to any additional laboratories anywhere in the world.

(above photo): The "real" bullet shell (left) cannot be distinguished from the holographic image of it (right). The hologram is just as dimensional as the actual object.



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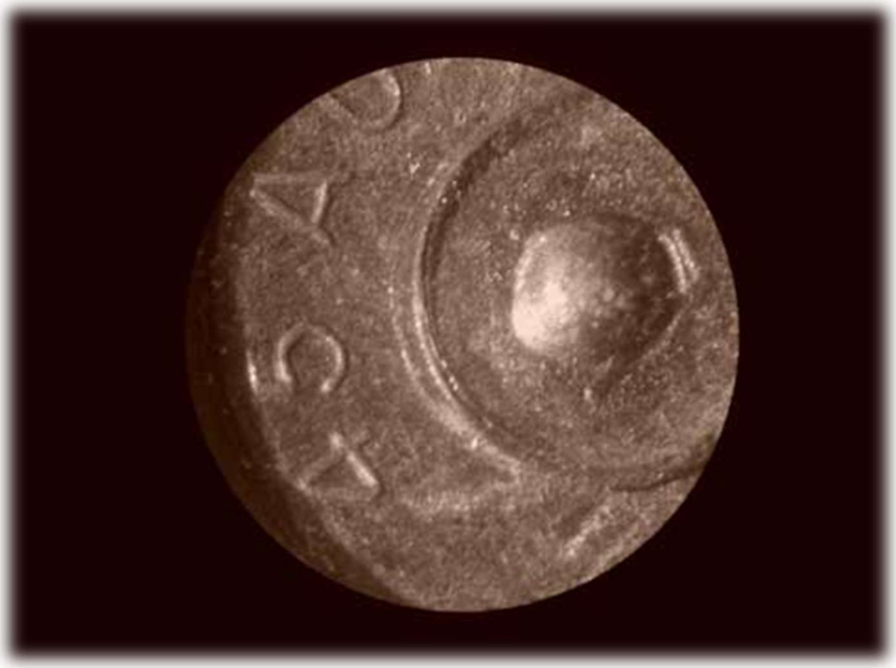

Viewing the hologram of the spent bullet shell through one of the eyepieces of the 3D stereo microscope. Through the microscope one can see the depth that would be present if the actual bullet shell were there instead of the hologram.

These holograms are relatively easy to make in a classroom setting for educational purposes, and have a very strong real world application (and future) in forensic sciences.

Once again I must point to the feature of “zero mass 3D printing” with this application as well. The bullet shell is stored onto thin flat film and does not require the physical space that the actual bullet shell would require. The same would hold true for any other object as well.

This was one of several examples that I presented to the New York Microscopical Society by invitation in October of 2017.

THE FUTURE:

After 35 active years in the field of holography, I am now retired.

Microscopy gained my interest due to a fascination with just how small I could go.

It has not been common for standard holograms to be combined with microscopes in the classroom or in public, although it has been done (as noted). Mostly, large display holograms are shown in museums, galleries and shops. As with many items today, larger is considered better. I didn't want to get caught up in the "biggest hologram' race. I decided to go in the opposite direction: making the smallest.

On final important thing to remember is this: these micro holograms are not reduced images. In fact, there are no "images" recorded in holograms at all. It is beyond the scope of this report to go into exactly what the hologram does contain, its structure, or to even begin the discussion of how to make them. There is plenty of information available online, just type 'holography' in to any search engine … and please get your information from someone who is actually a holographer. There is so much misinformation about holograms "out there".

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