Laser Holograms and Microscopy

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Holograms provide ultra high-definition recordings of three-dimensional objects and storage of data. The author looks at the history of holograms under the microscope, and shows a few projects of his own. Some of the most recent holograms have magnification optically encoded within the hologram itself, therefore *no physical lenses, sensors, computers, monitors or software are needed for magnification.*

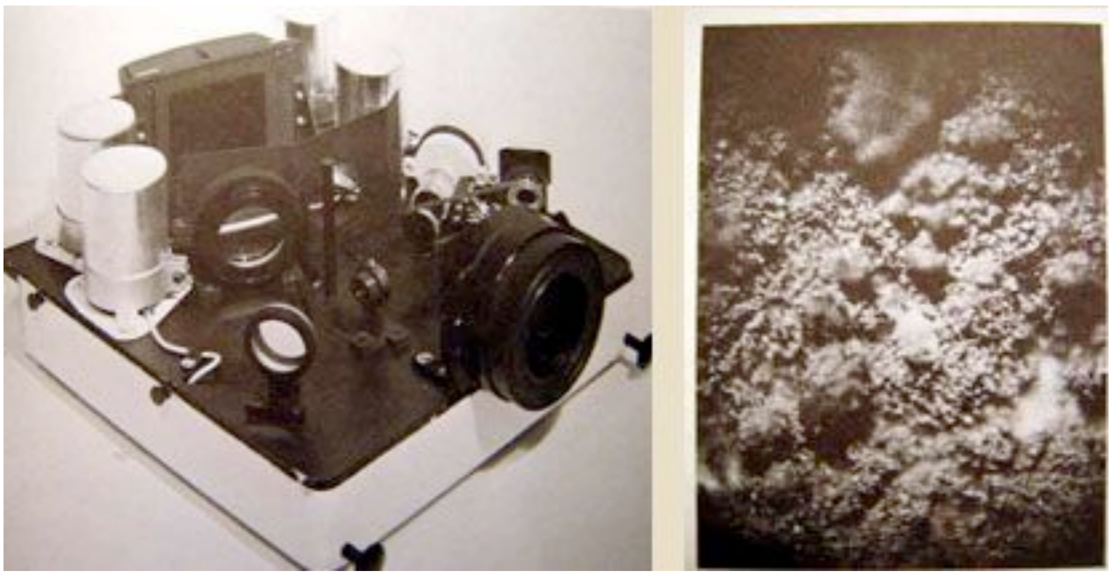
INTRODUCTION

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, those darlings of science fiction and museum gift shops, have been around for a half-century now. While there are various forms of holographic microscopy, I will be addressing two forms in particular: display holography and analog data storage. These techniques can be (relatively) easy to duplicate in the modern classroom, and 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 in many 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 holograms back to earth. The holocam is on the left, a simulated moon soil hologram is on the right.

APOLLO PROGRAM

Here is an example 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 rock 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.

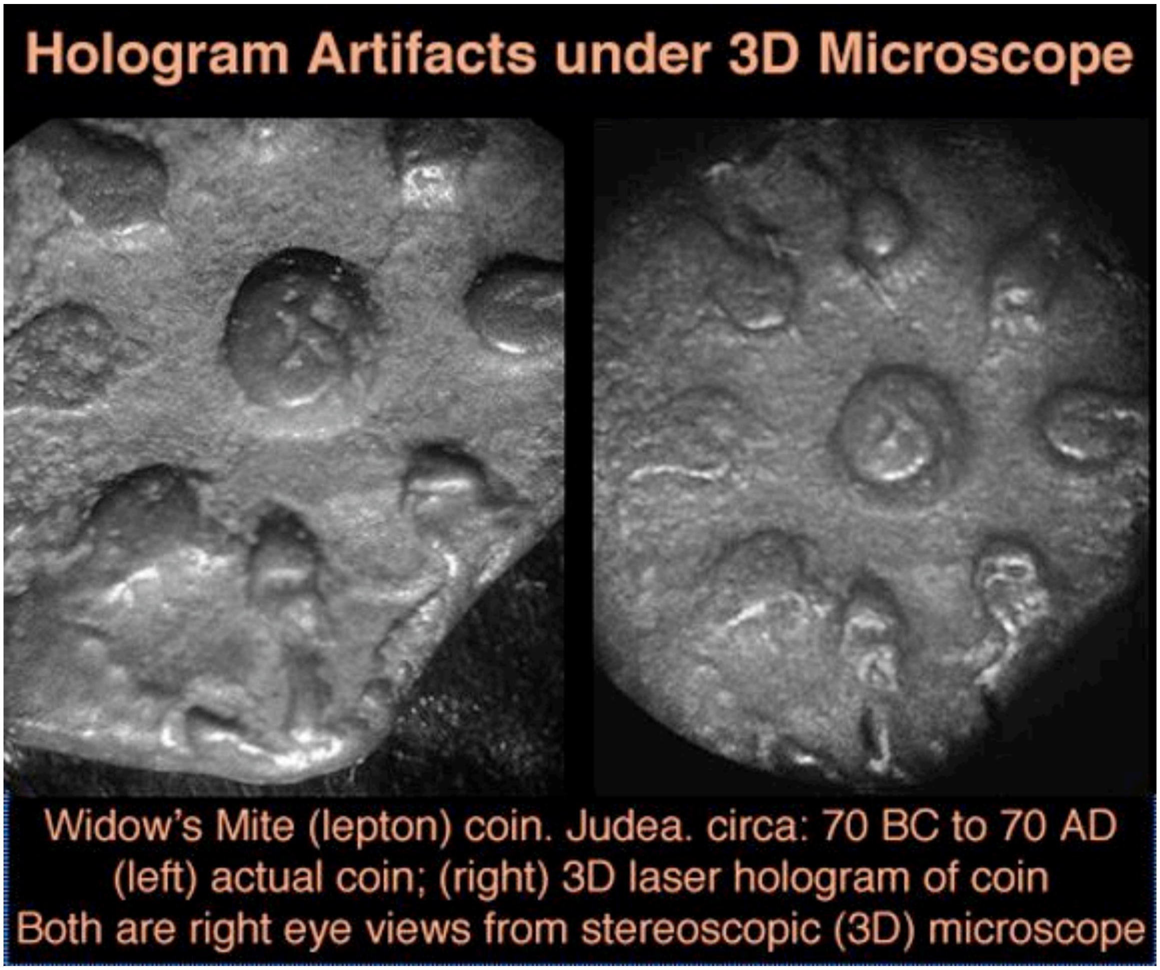
With traditional holographic microscopy, magnification is achieved by means of a wavelength change between recording and reconstruction. The field of view is a function of the resolution and size of the recording material. In the earliest days, silver halide emulsions were used. Modern recording now 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 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 on its own.

MY RESTORED MICROSCOPE

I obtained my own Leitz-Wetzlar prism stereo microscope at an antiques market. It was in rather poor visual condition, but the optics were acceptable. It took a lot of care to bring it back to nearly pristine condition, and it now accompanies me to my holography presentations.

It was important that the holographic objects viewed under the microscope would appear three dimensional to the viewer. Especially since the objects themselves were no longer physically present. I would like to introduce the reader to several of my projects:



Widow's Mite (lepton) coin. Judea. circa: 70 BC to 70 AD
(left) actual coin; (right) 3D laser hologram of coin
Both are right eye views from stereoscopic (3D) microscope

WIDOW'S MITE

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 widows 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 holographic image of the coin on the left, also shown under the same microscope.

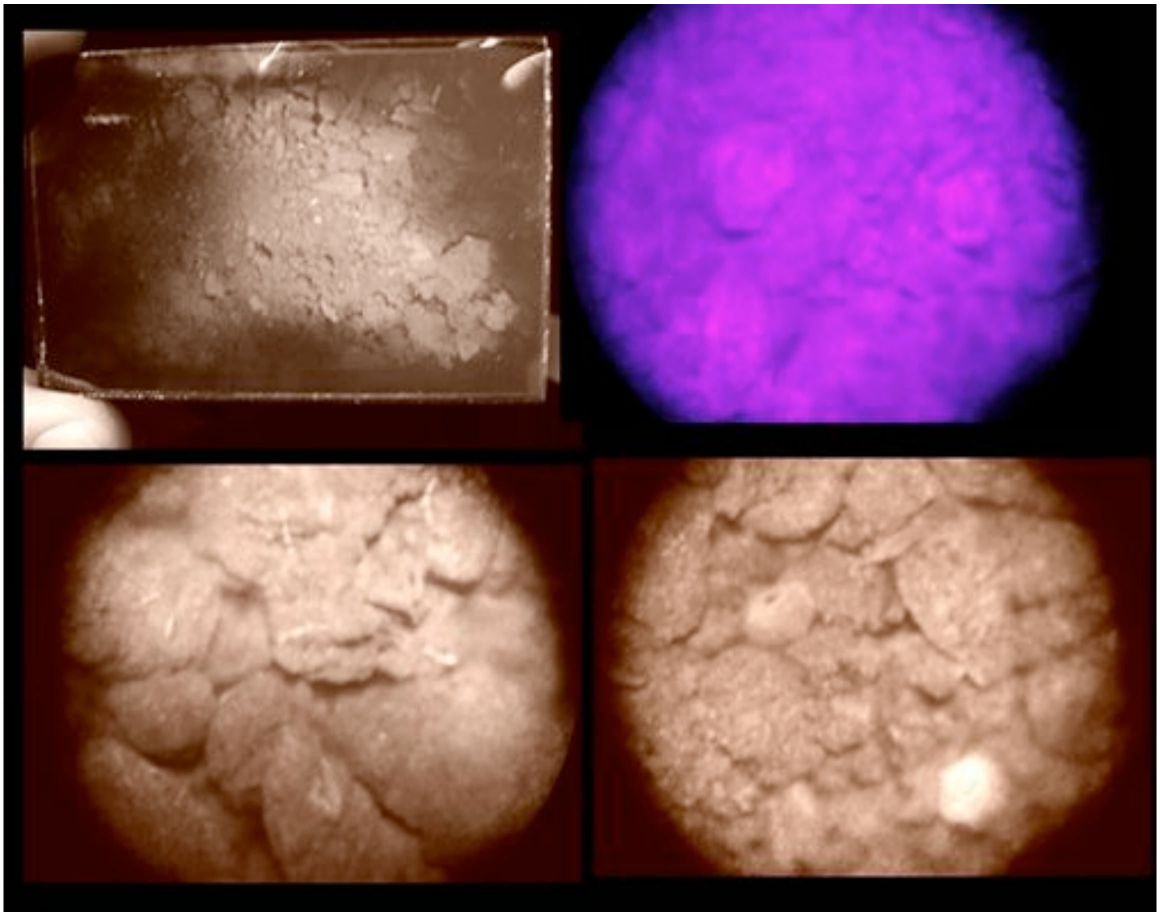
Of course, the holographic coin on the right is not there physically. But it can be examined just as if the real coin were present.

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.

PERSIAN VASE

Note how this Persian vase can be recorded as a thin film laser hologram. The thin film can then be placed under the 3D stereoscopic microscope for close examination.

This particular experiment shows that a 3-dimensional laser hologram of a large object can be a substitute for the actual object itself. It provides the examiner with the very same features, except that the actual object is not there, nor does it consume the same space.



MOUNT OF OLIVES SOIL

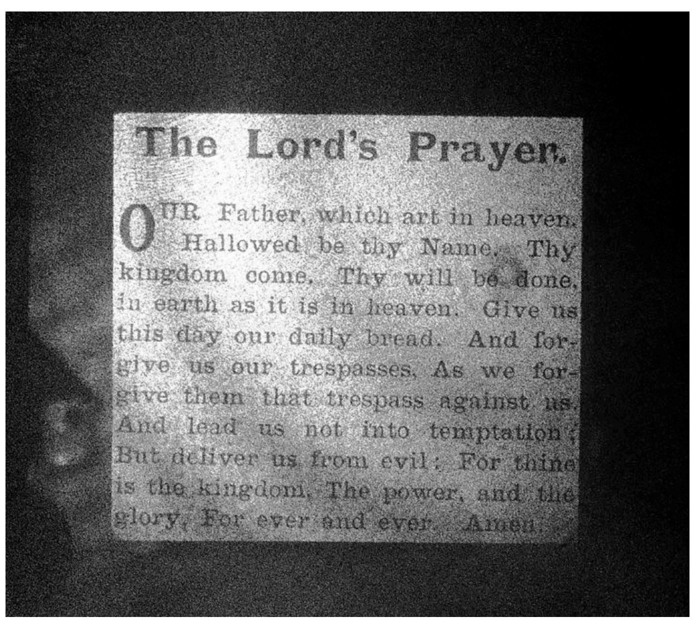
The results of this experiment were very close to what NASA achieved with their Apollo holocamera. This is soil from the Mount of Olives. It shows that soil samples from the moon, mars or other body can be recorded onto lightweight photopolymer film. That film can then be examined in its entire 3-dimensional 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.

With the advent of small, yet high-powered diode laser systems, a 21st century holocamera could be very compact and lightweight.

Today it is more likely for some sort of digital system to be employed. As with most imaging technologies, holography continues to move into the digital realm – although at a much slower pace than standard photography has. Today's digital holograms are still exposed onto very high resolution emulsions, notably photopolymer materials.

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 from Wal-Mart. 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).

WHAT'S THE POINT?

Actually, the bottom line is what I'm referring 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 to hologram orientation / geometry. As an example, the Holy Bible and Scripture can be sent to areas of the world where the Bible is banned.

The next self-magnifying micro hologram (below) has been embedded within an everyday greeting card. The information can be retrieved by a simple laser pointer. This particular hologram contains the Lords Prayer, and was recorded so that its magnification takes place without any external optical system components. In essence, the 'microscope' is built into the hologram itself. Can you find the hologram embedded in the card?

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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?

Otherwise, it remains camouflaged, calling no attention to itself, with no information whatsoever revealed under inspection.

This particular hologram (shown below in tweezers) contains the entire contents of the King James Holy Bible (1,245 pages / 773,000+ words):

THE FUTURE

After 30 years in the field of holography, I continue to work on varying projects. Microscopy has gained my interest due to a fascination with just how small I can go. Public interest is moderate. So far, I've been invited to be a guest on several radio shows and I have been including micro holography during my presentations (from local groups to the Smithsonian and New York Hall of Science). I've participated in a web cast to Europe via Skype. All of this helps to promote both holography and microscopy.

It has not been common for standard holograms to be combined with microscopes in the classroom or in public, although it has been done. Mostly, holograms are shown in museums, galleries and shops as displays. As with many items today, larger is considered better. I didn't want to get caught up in the "biggest hologram' race. So 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. That is, taking a normal sized image and making it smaller and smaller. In fact, *there are no "images" in the 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 (they're no longer very difficult to make). There is plenty of information available online, just type 'holography' in to any search engine. If there is enough interest, perhaps I can submit a step-by-step primer sometime in the future.

More detailed information is available at my holoworld.com web site.

In closing, if you happen to have a pair of 3D anaglyph glasses, put them on and view this final photo of my microscope (below). It should project out of your computer monitor or hand-held device. Left eye: red / Right eye: cyan.

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Published in the September 2013 edition of Micscape Magazine.
http://www.micscape.org