# XIV Introduction to Holography

## ① What is Holography?

Holography represents a class of techniques which capture 3-D information about a scene as an interference pattern on or in an extremely high resolution 2-D film. When the film is developed and viewed under the right conditions (some require a laser for viewing while others can use a suitable white light source), the result is a recreation in every detail of the original including the ability to move your viewpoint and look around objects, proper hidden surface removal (solid objects appear solid), shadows and highlights, and so forth. In principle, the hologram is optically indistinguishable from the original. A normal photo of a hologram would look the same as a photo of the scene itself.

However, in so far as the technology exists today, holography is NOT what is often depicted in Sci-Fi and other movies and TV shows. Some of this deficiency is due to fundamental principles of what holography is and how it works while much of it is due to the inadequacy of present technology:

- The hologram itself (film or plate) must be in the view. In other words, it isn't possible to project a hologram into empty space and view it from the side. With a suitable setup when the hologram is created, the perspective can be arranged such that the scene *appears* in front of the film but it must be bounded by it. The effect in this case is that of looking into a window but with the scene appearing in front of the window based on depth cues.
- The quality of holographic reproduction is currently far far below that of conventional photographic techniques simply because so much information must be captured on film with limited resolution and almost everything else affects the final outcome including the slightest wavelength of the light used) and even air currents in the studio.
- Although progress is being made constantly, there are still much that needs to be done to perfect the quality and resolution when viewing holograms without using lasers and in producing true full color holograms (not the 'rainbow' holograms seen on credit cards and logos).

(Portions from: Rick Poulin (rpoulin@rohcg.on.ca).)

While holography is really still in it's infancy it already has many other fascinating applications. Just a few of these include:

- 3-D representations of rare and delicate artifacts, carvings, and paintings. By capturing every nuance of the original, the actual object can be put away for safe keeping under ideal conditions of temperature, humidity, darkness, etc.
- Analysis of vibrational modes or deformation due to stress on a microscopic scale. A hologram of the object being tested is made in the usual way. Then, without moving the object, the developed hologram is replaced in exactly the same position as it had originally and the laser is turned back on. Any displacement of the object's surface – even on the scale of a fraction of a wavelength of the laser light being used – will show up as a visible interference pattern. This is being used to

evaluate everything from priceless 300 year old violins and jet engines to scale models of proposed buildings, bridges, and other structures subject to vibration or stress.

- Multiple 2–D images from a medical CT or MRI scanner may be stacked by recording them successively onto a single displaying the orignal slice data using a like an LCD panel which becomes the 'object' for a normal hologram. After each exposure, the SLM is moved a small distance relative to the holographic film and the next slice in the sequence (separated by the slice thickness) is displayed and recorded. When the film is 'reprojected' or 'look–through' image with anatomy appearing semi–transparent that is more meaningful to someone not trained to read 2–D scans or normal X–rays 'plane' films. By preprocessing the images on a conventional medical workstation, structures of interest can be enhanced and others can be removed. These "Voxgrams" (from voxel – the 3–D analogy to pixel) can be used for surgery planning or to explain a problem to the patient! (Note, however, that this is not the true 3–D possible using holography directly.) Using advanced techniques, the hologram may be viewed with a simple low cost white light display box without requiring a laser. See: Holorad: Holograms from CT and MRI Data. (Unfortunately, while the technology works and is impressive, VOXEL, the original company, was just a bit overly optimistic about their ability to develop and market a holographic printer, and had other legal problems as well. Perhaps Holorad has overcome those obstacles.)
- Holographic recording methods are being developed to store massive amounts of data throughout the volume of tiny crystals – the true–life version of the standard Star Trek memory device. The information is converted to a 2–D array of bits using a SLM and multiple such 'planes' can be stored within the same holocrystal by varying the angle of the crystal relative to the optics. The challenge now is to be able to do this in without erasing what was there before!
- Holographic methods may be used to optically sort data elements that form building blocks for true optical computers and for data selection in optical communications networks. These may be pregenerated and optically selected or generated in real–time.