

Making computer –generated scratch holograms from three-dimensional virtual models

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Abstract—The scratch holography has been considered during many years by the optical community as a curiosity, being used only as an educational medium for teaching Optics. In this work we show the possibility of making more competitive the images that are obtained by this technique by means of *hologravure*. Hologravure is a way of making computer-generated scratch holograms from three-dimensional (3D) virtual models, represented as files in a 3D format by using appropriate software, and laser tracing on suitable material with a conventional computer driven CO₂ engraver-laser system. Some interesting applications of hologravures are introduced and the corresponding reconstructing images are shown.

The scratch holography has been considered for many years by the optical community only a curiosity or entertainment. Its main use has been educational, for teaching optics, or occasionally in artistic works. In 1995 Beaty [1] reported this technique and referred that some previous works mentioned the synthesis of 3D images by a "scratch" technique [2-6]. He shows how this phenomenon of generating 3D drawings from regular scratches on a piece of appropriate material was repeatedly discovered and received different names. However, we can probably consider that the first version of this technique was early patented by the artist and inventor Weil in 1934 [2]. An important Beaty's contribution was to clarify how 3D images could be created by varying the radius of scratches drawn on a two-dimensional (2D) soft support as transparent plastic sheets.

In the present work, the authors have considered using the term "scratch holograms" when referring to this technique of "scratches", able to encode three-dimensional information, and to the corresponding reconstructed images, which is a very common use. The basics of the theory for such displays have been explained from different points of view, by Plummer and Gardner [3] and Eichler, Dünkel and Gonçalves [7]. Also, an updated and more recent version of Beaty's paper can be found in [8], including some additional theoretical considerations, and highlighting that the optics of these "scratch holograms" is very similar to Rainbow Holography optics.

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Usually scratch holograms are directly drawn by hand upon an adequate material, by using an appropriate tool, as a compass with two points, although some ingenious instruments for drawing scratch holograms were also reported in Ref. [9]. In 1981 Garfield [10] described the work of the artist Lieberman entitled "World Brain" to produce 3D images, drawing circular scratches on metal surfaces. In all these cases a mechanically generated scratch-hologram is obtained.

Unlike these mentioned works, the present paper shows the possibility of making more competitive and useful the images obtained by this technique by means of *hologravure*, a generalization of scratch holography that we have introduced in a previous work [11]. Hologravure is not mechanically generated.

We named Hologravure a way of making computer-generated holograms from 3D virtual models, represented as input data files in a 3D format, and encoding it in a 2D multiple circular-scratch drawing by using a computer driven engraver-laser system.

A computing program was created for generating the holograms, and they are laser tracing onto a suitable material with a conventional computer driven CO₂ engraver-laser system. The reconstructed images can be observed using white light and appropriate illumination. Usually, to make computer-generated holograms [12-14], a diffraction pattern must be calculated and plotted on an expanded scale, and as high resolution is required, a photo-reduction process to a high resolution film plate is necessary. These holograms are of small size and generally are prepared to be used as elements of diffractive optics.

Hologravure allows a competitive use of the three-dimensional images obtained by the scratch technique in Art, Graphic Design, Visual Media for Education, teaching of Optics, Science, Information Processing, and others applications. In [11] we also have shown how, using the hologravure as a multiple image storage medium, a three-image computer-generated hologram was engraved, by varying the inclination angle of the laser-traces corresponding to each object. Also computer assisted and hand drawn scratch-holograms were shown. The quality of the lines traced by a CO₂ laser on sheets of several types of plastic materials was considered.

Coding a 3D virtual model as a 2D representation

The scratch holographic technique is precisely able to encode a 3D drawing, recorded as a 2D multiple circular-scratch drawing, by varying the radius of circular scratches for obtaining depth effects.

Due to its simplicity, a logical generalization of this type of holograms is to generate them by means of a computer, the possibility that was suggested in Ref. [1] as a way to reduce the amount of data required for computer-generated holography.

Usually, all techniques for making computer-generated holograms use a mathematical description of a virtual transparency, which constitutes the hologram. In all cases, a diffraction pattern must be calculated. No method can be easily achieved for producing this hologram directly because of high resolution required. The calculated diffraction pattern has to be first plotted on an expanded scale and later photographically reduced.

However, for making a hologravure, neither diffractive optics nor mask pattern or photo-reduction of a transparency onto a high resolution film plate are needed. The shape of a 3D virtual-object is directly encoded in a 2D multiple circular-scratch drawing.

A computer program, named *3D Silhouette*, was created. The initial purpose of this program was supplying an aid for the creation of hand-drawn scratch holograms, using the software as an assistant. A version of this software is freely available on the web [15]. An advanced version, briefly described in [11], was used here to generate the hologravures by a computer.

A polyhedron is a relatively simple geometric figure that allows to appreciate easily its three-dimensional form. Figures 1a)–c) show successive images of the same polyhedron in the creation of a hologravure.

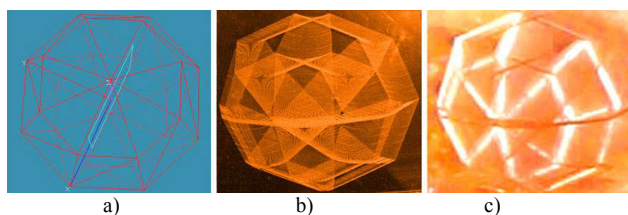


Fig. 1. a) Rendered 3D-format image from a polyhedron b) Photographic image of hologravure-laser traces of polyhedron on an orange acrylic surface sheet. c) Photograph of reconstructed image of polyhedron obtained in reflection mode using solar illumination.

To appreciate the effects of depth of these images, Fig. 2 shows photographic-stereoscopic pairs obtained from hologravure 3D-reconstructed images in reflection mode, at two different angles. The images correspond to the word LASER encoded on a polycarbonate sheet, and to a dodecahedron engraved on the surface of an acrylic transparent sheet. The quality of reconstructed images from hologravures engraved on several suitable materials

was considered. The maximum size of each of the engraved pieces is limited by the dimensions of the engraver-laser workspace.

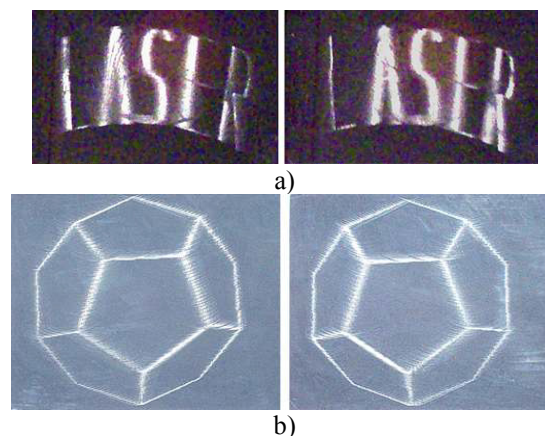


Fig. 2. Photographic-stereoscopic pairs from the hologravure 3D-reconstructed images in reflection mode observed at two different angles: a) Word LASER encoded in a polycarbonate sheet. Image obtained using a 20 Watt halogenous lamp like the light source. b) Dodecahedron engraved on a transparent 11x14 inches acrylic sheet. Image obtained with solar illumination.

Assembled hologravures and holographic logos

A very interesting possibility of making hologravures of bigger size is recording the coded image in separate parts and then assembling it, as the pieces of a puzzle, controlling the effects of depth in the obtained reconstructed images. This type of hologravure can be observed indoors, with appropriate illumination, or outside under sun illumination. In Fig. 3 we show a version of *holographic poster*, or *holoposter* as a simple example of this way of engraving. Many types of 3D modeler software exist at present. By using one of them, the original design was made with the necessary size in a compatible digital format, as the *.3ds (3D Studio) and after being coded, using adequate software, it was recorded separately in three polycarbonate pieces, by using the CO₂ laser engraver.



Fig. 3. Photographic version of image from a holographic poster, obtained outside under solar illumination. Holoposter was assembled of three 8x10 inches transparent polycarbonate pieces, separately laser-engraved. The pieces were painted of black on the back after engraving poster.

Another interesting application of hologravure is making holographic logos, which we have named

hologologos. These holographic versions of essentially bidimensional elements, require a new 3D design from original idea.

Figure 4 shows the 2D original logo of the Bralax Laser Labs, as well as the photographic image of its reconstructed hologo 3D version. In this 3D design, the word "bralax" and the text "LASER LABS" below, are observed in two different planes, out of the acrylic sheet.

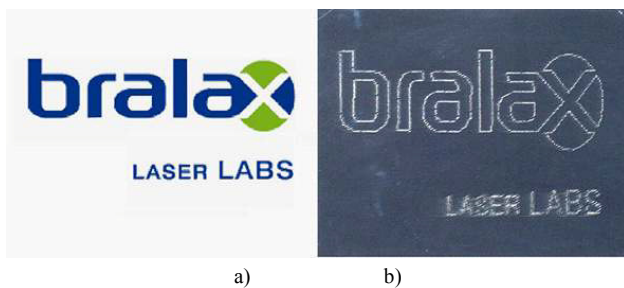


Fig. 4. a) Bralax Laser Labs original logo. b) Photographic image of its hologo version, obtained using solar illumination. The hologravure was engraved on a transparent 11x14 inches acrylic sheet.

A way of making computer generated holograms from 3D virtual models was shown. We have named *hologravure* the generalization of scratch holograms, computer generated from a 3D virtual-object by using an appropriate software, and direct laser tracing onto a suitable material with a laser engraver system. Hologravure allows a competitive use of the three-dimensional images obtained by this technique in Art, Graphic Design, Visual Media for Education, including the teaching of Optics, Sciences, Information Processing and other applications, demonstrating the possibilities of images obtained using this type of holograms.

Software was created for generating the holograms, and several plastic materials were used as engraving-medium. Hologravures representing some 3D virtual models, including some interesting applications, were engraved on sheets of acrylic and polycarbonate and the reconstructed images were shown.

A holographic poster as a simple version of assembled hologravure was shown. Using the adequate software and the CO₂ laser engraver it was recorded separately in three pieces, and later assembling.

Assembled hologravures could allow for making very interesting gigantic engraved holograms, recorded in separated parts and then assembled as the pieces of a puzzle, controlling the effect of depth in the obtained reconstructed images. These type of images could be observed from a convenient distance, indoor with appropriate illumination, or outside under solar illumination.

Holographic version from the original Bralax Laser Labs logo was shown, extending the possibilities of this type of design to a three-dimensional space.

Hologravure considerably widens the possibilities of scratch holography, as well as its quality, reducing drawing time and allowing the performance of relatively more high density complicated drawings.

Further development of this work should be aimed to find more efficiency, simplification in the edition and treatment of the used 3D virtual models and a way of increasing the hologram complexity without damaging the recording medium.

Suitable materials, looking for optimal laser parameters in each case, scratch shape and its quality will be the subjects of future research, as well as a more complete study of reconstructed images.

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