A DIGITAL PRINTING SYSTEM FOR THE COMMERCIAL PRODUCTION OF HIGH-RESOLUTION TRUE-COLOUR REFLECTION HOLOGRAMS

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ABSTRACT

A digital printing system for the commercial production of high resolution reflection holograms is presented. The printer is capable of printing high-quality reflection holograms in true colour from digital data in a dot-matrix fashion using RGB pulsed laser technology. Data for the holograms may be prepared either by standard 3D modeling programs or by using a specialized Holocam system that is able to rapidly digitize real world scenes at high resolution. XYZ Imaging Inc and the Geola group explain their objectives and show recent work.

1. DEVELOPMENT OF DIGITAL HOLOGRAPHY AT GEOLA

In 1998 the Lithuanian company Geola UAB (short for General Optics Laboratory) commenced an intensive programme of research and development into digital holography using pulsed Neodymium lasers. Geola, which was originally a spin-off company of Australian Holographics Pty Ltd, had built up considerable expertise since its birth in 1992 in the domain of pulsed lasers and large format pulsed analogue holography systems.

As an integral part of its R&D programme into digital holography Geola developed a unique prototype RGB pulsed laser. The company had felt from the start of the programme that the only feasible solution towards a real commercial holographic printer would be one based on pulsed rather than CW laser technology. By 1999 Geola had developed both 1-step and 2-step digital hologram printing technologies based around their pulsed lasers.

2. DEVELOPMENT OF A COMMERCIAL PRINTER AT XYZ

In 2001 Geola UAB became a major shareholder of the Canadian company XYZ Imaging Inc which had offered to raise the finance required to take Geola's prototype 1-step printing technology and develop it into a real commercial printer.

By early 2002 Geola had delivered a working RGB prototype dot-matrix printer to Montreal. This printer (see Fig. 1) was able to generate full-colour reflection holograms by printing 15 RGB holopixels each second onto glass holoplates.

Over the next few years XYZ Imaging Inc radically improved the printer technology in various ways. Working with Geola's UK parent company, Geola

Technologies Ltd, the laser repetition rate was increased from 3x15 to 3x30Hz and the laser stability significantly improved. An automatic vacuum driven film advance system, designed to work with 1m wide film rolls, replaced the original two-dimensional translation stage. Automatic processing of the film was added. Software was completely rewritten and many functions of the printer were now adaptively controlled by software. Finally, working with Geola UAB and the Russian companies BIT AO and Sfera AO, a new panchromatic Silver Halide emulsion was produced. This emulsion was tailored to the requirements of the printer. Fig. 2 shows a picture of the latest generation printer.

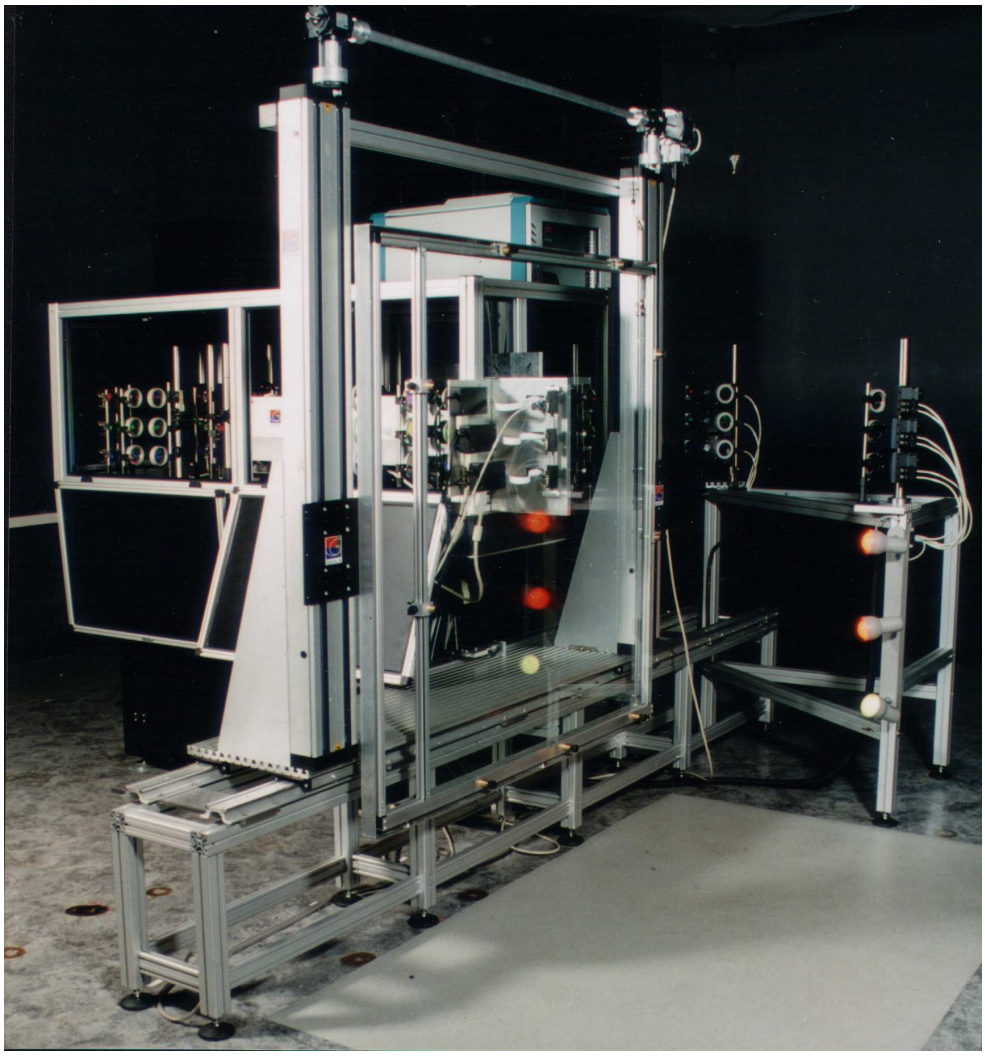

Fig 1. Original RGB dot-matrix prototype printer. Note the large 2-dimensional translation stage that holds the glass holoplate. The RGB pulsed laser and object beam conditioning systems are located in the box to the rear; the reference beam systems are mounted on a triangular stand to the right; all control electronics are mounted in the rack to the rear right.

2. HOW DOES IT WORK?

The XYZ printer is a one-step dot-matrix holographic printer. The printer produces white-light reflection holograms by writing contiguously a plurality of

very small square micro-holograms or holopixels onto a Silver Halide film using a pulsed laser which emits in the red, green and blue. The size of the small micro-holograms is usually set at either 0.8mm or 1.6mm diameter (software selectable).

Each micro-hologram is written using red, green and blue reference beams and red, green and blue object beams. The object beams are prepared using individual specialized optical systems of high numerical aperture and digital data is encoded onto each object beam using a spatial light modulator. The numerical aperture of the object beam conditioning system effectively determines the final maximum field of view of the holograms. Typically this is around 85 degrees.

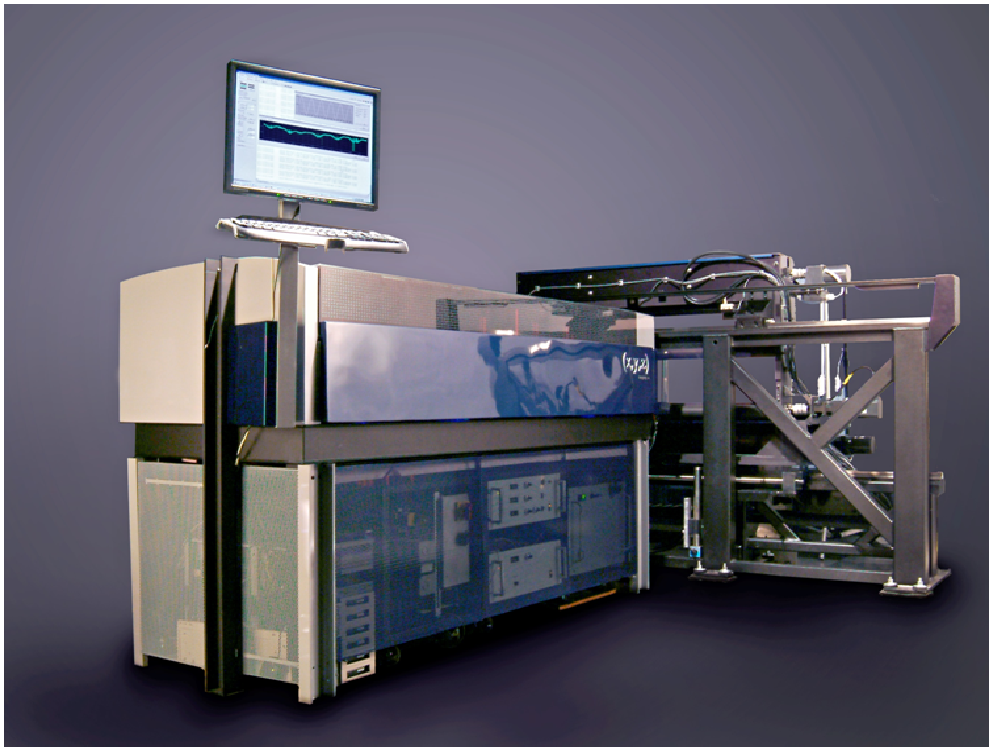

Fig 2. A modern XYZ dot-matrix holographic printer. Note the film advance system to the rear. All electronics are now located underneath the main optics and laser table.

The XYZ printer is designed to use film rolls of 1m diameter. In the current commercial models the reference beams and object beams are static and the film is pulled by motors and vacuum, in a two-dimensional fashion, over the red, green and blue write-heads. A more complex design is planned to be put into production in the future using a dynamic reference beam. With the current static reference beam system, the printer can produce holograms up to 1m (vertical) x 1.5m (horizontal) with standard lighting rigs. By using more complex lighting individual holograms may potentially be tiled together to form ultra-large displays.

In order to assure pixel-to-pixel brightness stability, the RGB laser has been engineered to produce exceptionally stable SLM emission. This translates into a very high fidelity digital hologram.

The printer currently operates at 30Hz and is designed to run 24 hours per day. It therefore prints one red, one green and one blue pixel every $1/30^{th}$ of a second. Typically a high resolution (0.8mm pixel) 1mx1m hologram takes around 12 hours to write. A lower resolution 1.6mm pixel hologram takes 4 times less – i.e. 3 hours. Software allows the scheduling of multiple jobs of different sizes. Processing of the exposed film is handled by an automatic chemical processor and dryer. The film is then cut and cold laminated to black plexiglass before shipping to clients.

Since the XYZ printer is based on pulsed laser technology the reliability and sensitivity to environmental conditions are exceptionally good. Latent image fading of the holographic film does put some constraints on batch printing. But visible effects only appear after around four days, meaning that over-the-weekend and overnight printing runs are not a problem.

Currently the XYZ printer is configured to produce horizontal parallax only (HPO) holograms. This is largely because the targeted market is perceived not to require full parallax holography; better lighting options are also available with HPO holograms. XYZ have however tested their technology with full-parallax holograms and may in future release this option if there was demand.

3. LIGHTING REQUIREMENTS

The major market targeted by XYZ for the placement of their holograms is the advertising sector. Typically this sector requires high brightness images that are able to stand out in a high-ambient light environment. Consequently, for larger format (>1mx1m) holograms, either 500W theatre projectors or stacks of multiple halogen lamps are used. Fig.3 shows an example of how a large format hologram can be lit using 6 x 50W tungsten halogen spotlamps. Note that this type of lighting is only possible with HPO holograms. An additional advantage of this type of lighting is that it produces a larger viewing window in the vertical dimension. The individual halogen bulbs are generally each offset vertically such that they all point towards the centre of the hologram. The median angle is usually set to 45 degrees. The lamp divergence is chosen according to the illumination distance which is itself chosen by the required image depth and projection.

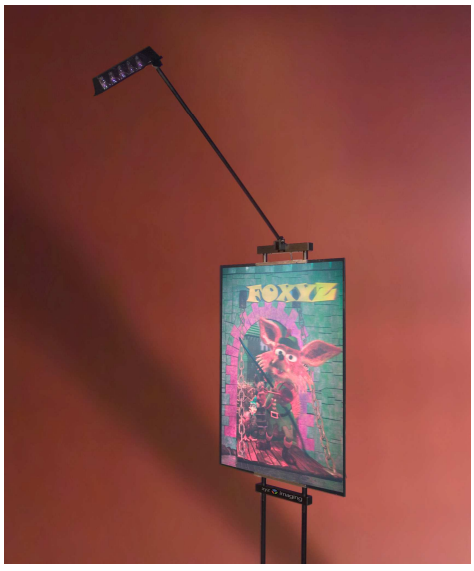

Fig 3. Example of a digital HPO hologram being illuminated using a stack of 6 x 50W halogen spotlamps

4. IMAGE ORIGINATION

The XYZ printer requires digital data in the form of multiple perspective views encoded as bmp files. Since the current software only permits generation of HPO holograms only perspective views taken with a virtual or real camera along a single line in space are required. All leading 3D modeling programs can generate this data from a virtual 3D model. Hence programs such as 3D Studio Max ®, LightWave ®, or Softimage ® can be used to make any 3D model or scene and then to generate the required bmp perspective view files. For a large format hologram of 1m x 1.5m typically over a thousand such images are required by the printer. A small rendering farm of between five and ten high performance PCs is usually necessary to produce these bmp files.

Fig 4. The Geola Holocam system for digitising real-world scenes.

In order to convert a real-world scene, as opposed to a virtual computer generated scene, into a digital hologram Geola has recently launched a unique Holocam system for use in conjunction with the XYZ dot-matrix printer. This system uses a standard high-end high-resolution high-speed CMOS digital camera on a fast translation stage in order to grab up to a thousand images within 4-10 seconds. The camera rotates in a programmed non-linear fashion as well as translating; this allows the use of a normal low-FOV lens with no image distortion. The images are then processed numerically to order to produce the bmp files required by the XYZ printer. This system, when used in conjunction with the XYZ printer, is capable of the production of near-analogue quality full-colour holographic portraits. The current model uses a 4m long rail and is able to produce data for any format of hologram up to 1m x 1.5m. The technology can be extended easily to virtually any size.

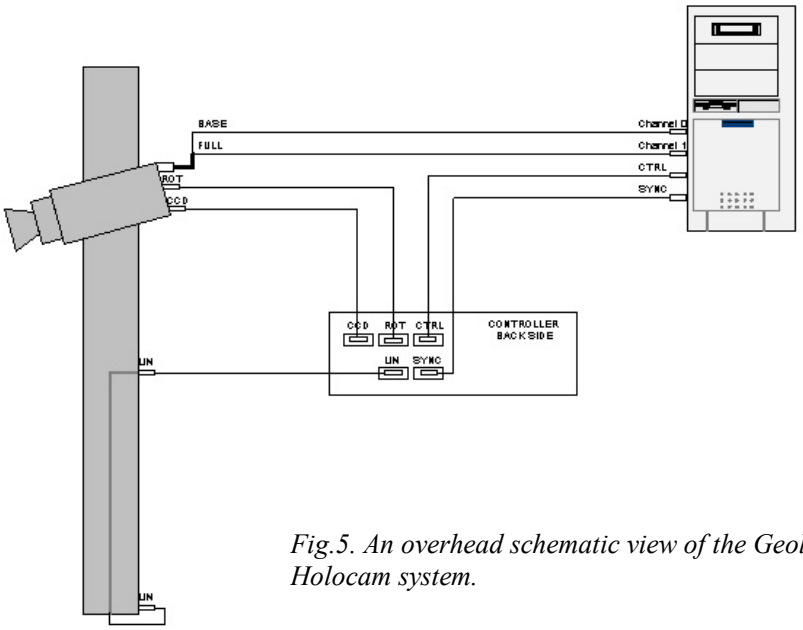

Fig.5. An overhead schematic view of the Geola Holocam system.

Both techniques described above can be used simultaneously to produce mixed real-world/virtual world holograms using standard cinema post-production software. Where the absence of distortion in a holographic image is not so critical various other sources of image data can also be employed; for example standard video camera footage or motion picture material can be converted into a format acceptable for the XYZ printer.

5. A CASE STUDY OF HOLOGRAMS CREATED FOR PUMA

In order to illustrate the application of our digital holograms within the advertising industry we present here a detailed study of a recent campaign used during the grand-prix in Montreal.

A preliminary meeting was held with Puma Canada on the 6th of May at XYZ's Montreal showroom where our holograms were presented. Puma were impressed and indicated they would be interested in using our holograms for an up-coming campaign of their Ferrari branded foot wear during the Montreal Grand Prix in June.

We received shoes and other athletes wear from Puma in the days that followed the initial meeting. We used pictures and Adobe Photoshop ® to prepare a few 2D previews of what our suggested artwork concept would be. These pictures were then sent via email to the client for comments. Subsequently we then prepared digital movies of what these concepts would look like in 3D and these were then sent to the client for his/her comments.

Subsequently we printed a few 3D concepts onto actual holograms that were presented to the client; at this stage we obtained their final comments, signed the purchase order and finalized the number and size of prints. We were also given the location where the holograms were to be displayed (two Foot Locker stores in downtown Montreal) - We then scouted out the 2 stores and prepared the

display structures and lighting while we finalized the artwork in high resolution and printed the holograms. Installation occurred on the 6th of June, in time for the start of the week of the Grand Prix festivities - a market study was done by a third-party firm in order to measure the success of the campaign; the results of this, which were highly positive, will be reported below.

5.1 Hologram Images

In total four holograms were produced for the campaign. Two holograms (high resolution 0.8mm pixel) of 1mx1.2m were produced of a red racing car that morphed into a 3D Ferrari/Puma shoe and then back into a racing car.

Fig. 6. One of the Puma holograms displayed during the Grand Prix in Montreal.

One hologram (high resolution 0.8mm pixel) of 1mx1.2m was produced of a video clip of a racing car moving on a racetrack with 3D shoes in front.

One hologram (high resolution 0.8mm pixel) of 1mx1.5m was produced of a close-up of a different pair of 3D shoes with the Gilles Villeneuve racetrack in the background.

5.2 Image Origination

All the holograms contained 3D shoes that rotated in space in front of the hologram film plane when the viewer moved side to side. These were done by taking many pictures of the shoes from different viewpoints with a digital camera. Some holograms contained 3D elements created in Lightwave and some had video clips and/or pictures that were worked on using Photoshop ® and/or After-Effects ®

5.3 Installation and Lighting

The largest hologram was installed in the back of one Foot Locker store behind and above the counter. It was visible from the counter all the way to the entrance (60 ft) and even from across the street. The other 3 prints were in the front of the stores behind the window displays facing inside the store (towards the centre of the store). Lighting for all holograms employed theater projectors (500w halogens).

A similar campaign to the Puma campaign was subsequently carried out in London for Nike through Exhibits International (Amsterdam) and Geola's UK digital printing subsidiary, Power Imaging Ltd. Again four large format holograms printed using XYZ technology were produced and installed in Niketown on Oxford street in London.

Fig 7. Example of one of the XYZ holograms produced for Nike in London through Exhibits International and Power Imaging Ltd.

5.4 Market Study

The main objectives of this independent marketing study were to determine:

- a measure of the awareness generated by this 3D medium and the awareness generated of the product advertised;
- a judgement of this 3D medium as an advertising medium as well as a specific judgement of the concept proposed for Puma;

- the advertising impact and effects of the campaign including any associations with the brand which were generated by the campaign and any increase in interest in the brand.

Approximately 200 people leaving the store at 954 rue Ste-Catherine Ouest were interviewed and asked to fill out a questionnaire over a period of three days from Friday to Sunday. The results were processed and statistically analyzed using the STAT-XP package.

The principle results of this analysis were as follows: During the latter part of the Montreal Grand Prix F1 week the Puma-Ferrari holographic displays situated at 954 Ste-Catherine Ouest were able to capture the attention of visitors to the Foot Locker store despite the fact that the average time that a given individual spent in the store was less than 15 minutes. More precisely, the displays were capable of generating a spontaneous awareness of 37% of one or several elements of the concept advertised. In addition the displays generated a total awareness (including spontaneous and cued) of 41%. To put this in context, comparable figures for standard 2D displays are usually in the range 8-10%.

The results of this study confirm that the displays produced a positive perception of the brand and reinforced the idea that Puma is a quality brand and is popular; the displays also enhanced the impression of a dynamic brand and of an international look. Statistically one can observe that there is a positive correlation between the clarity of recall of the holograms and more positive impressions of the brand.

The vast majority of those respondents who noticed the 3D character of the displays clarified specifically that they particularly appreciated this type of display. In addition most respondents underlined the value of this type of display to capture the attention.

6. COMMERCIAL PLANS

Currently XYZ operates a printing bureau in Montreal where three production holographic printing machines are installed. Geola group operates a further production printer in Europe that provides an international printing service through the companies Power Imaging Ltd (UK), Geola UAB (Lithuania) and Sfera AO (Russia).

XYZ are currently building awareness of their printing technology and evaluating the global digital hologram market with a view to determining when and how to roll out their printing technology. Currently all printers are operated in house either at XYZ or Geola.

A variety of hologram copying technologies based on pulsed lasers have also been trialed at both XYZ and Geola. In the case that the market requires higher volumes these technologies may be introduced in due course.