Lenticular printing

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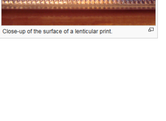
Lenticular printing is a technology in which lenticular lenses (a technology that is also used for 3D displays) are used to produce printed images with an illusion of depth, or the ability to change or move as the image is viewed from different angles.

Examples of lenticular printing include flip and animation effects such as winking eyes, and modern advertising graphics that change their message depending on the viewing angle. This technology was created in the 1940s but was involved in recent years to show more motion and increased depth. Originally used mostly in novelty items and commonly called "flicker pictures" or "wiggle pictures," lenticular prints are now being used as a marketing tool to show products in motion. Recent advances in large-format presses have allowed for oversized lenses to be used in lithographic lenticular printing.



Close-up of the surface of a lenticular print.

Process

Lenticular printing is a multi-step process consisting of creating a lenticular image from at least two images, and combining it with a lenticular lens. This process can be used to create various frames of animation (for a motion effect), offsetting the various layers at different increments (for a 3D effect), or simply to show a set of alternate images which may appear to transform into each other. Once the various images are collected, they are flattened into individual, different frame files, and then digitally combined into a single final file in a process called interlacing.

From there the interlaced image can be printed directly to the back (smooth side) of the lens or it can be printed to a substrate (ideally a synthetic paper) and laminated to the lens. When printing to the backside of the lens, the critical registration of the fine "slices" of interlaced images must be absolutely correct during the lithographic or screen printing process or "ghosting" and poor imagery might result. Ghosting also occurs on choosing the wrong set of images for flip.

The combined lenticular print will show two or more different images simply by changing the angle from which the print is viewed. If more (3D+) images are used, taken in a sequence, one can even show a short video of about one second. Though normally produced in sheet form, by interlacing simple images or different colors throughout the artwork, lenticular images can also be created in roll form with 3D effects or multi-color changes. Alternatively, one can use several images of the same object, taken from slightly different angles, and then create a lenticular print which shows a stereoscopic 3D effect. 3D effects can only be achieved in a side to side (left to right) direction, as the viewer's left eye needs to be seeing from a slightly different angle than the right to achieve the stereoscopic effect. Other effects, like morphs, motion, and zooms work better (less ghosting or latent effects) as top-to-bottom effects, but can be achieved in both directions.

There are several film processors that will take two or more pictures and create lenticular prints for hobbyists, at a reasonable cost. For slightly more money one can buy the equipment to make lenticular prints at home. This is in addition to the many corporate services that provide high volume lenticular printing.

There are many commercial end uses for lenticular images, which can be made from PVC, APET, acrylic, and PETG, as well as other materials. While PETG and APET are the most common, other materials are becoming popular to accommodate outdoor use and special forming due to the increasing use of lenticular images on cups and gift cards. Lithographic lenticular printing allows for the flat side of the lenticular sheet to have ink placed directly onto the lens, while high-resolution photographic lenticulars typically have the image laminated to the lens.

Recently, large format (over 2m) lenticular images have been used in bus shelters and movie theaters. These are printed using an oversized lithographic press. Many advances have been made to the extrusion of lenticular lens and the way it is printed which has led to a decrease in cost and an increase in quality. Lenticular images have recently seen a surge in activity, from gracing the cover of the May 2006 issue of *Rolling Stone* to trading cards, sports posters and signs in stores that help to attract buyers.

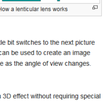
The newest lenticular technology is manufacturing lenses with flexo, inkjet and screen-printing techniques. The lens material comes in a roll or sheet which is fed through flexo or offset printing systems at high speed, or printed with UV inkjet machines (usually flat-beds that enable a precise registration). This technology allows high volume 3D lenticular production at low cost.

Lenticular printing has been used to produce movie posters, such as this advert for *Species II*, which morphs between two different character appearances when the angle of viewing changes.

Construction

Each image is arranged (slicing) into strips, which are then interlaced with one or more similarly arranged images (splicing). These are printed on the back of a piece of plastic, with a series of thin lenses molded into the opposite side. Alternatively, the images can be printed on paper, which is then bonded to the plastic. With the new technology, lenses are printed in the same printing operation as the interlaced image, either on both sides of a flat sheet of transparent material, or on the same side of a sheet of paper, the image being covered with a transparent sheet of plastic or with a layer of transparent, which in turn is printed with several layers of varnish to create the lenses.

The lenses are accurately aligned with the interlaces of the image, so that light reflected off each strip is refracted in a slightly different direction, but the light from all pixels originating from the same original image is sent in the same direction. The end result is that a single eye looking at the print sees a single whole image, but two eyes will see different images, which leads to stereoscopic 3D perception.



Images are interlaced on the substrate

Types of lenticular prints

There are three distinct types of lenticular prints, distinguished by how great a change in angle of view is required to change the image:

Transforming prints

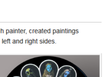
Here two or more very different pictures are used, and the lenses are designed to require a relatively large change in angle of view to switch from one image to another. This allows viewers to easily see the original images, since small movements cause no change. Larger movement of the viewer or the print causes the image to flip from one image to another. (The "flip effect".)

Animated prints

Here the distance between different angles of view is "medium", so that while both eyes usually see the same picture, moving a little bit switches to the next picture in the series. Usually many sequential images would be used, with only small differences between each image and the next. This can be used to create an image that moves ("motion effect"), or can create a "zoom" or "morph" effect, in which part of the image expands in size or changes shape as the angle of view changes. The movie poster of the film Species II, shown in this article, is an example of this technique.

Stereoscopic effects

Here the change in viewing angle needed to change images is small, so that each eye sees a slightly different view. This creates a 3D effect without requiring special glasses, using many images. For example, the Dolby-Phillips Lenticular 3D display produces 28 different images.[1]



How a lenticular lens works

Motorized lenticular

With static (non-motorized) lenticular, the viewer either moves the piece or moves past the piece in order to see the graphic effects. With motorized lenticular, a motor moves the graphics behind the lens, enabling the graphic effects while both the viewer and the display remain stationary.

History of lenticular image technology

Images that change when viewed from different angles predate the development of lenticular lenses. In 1692 G. A. Bois-Clair, a French painter, created paintings containing two distinct images, with a grid of vertical laths in front.[2] Different images were visible when the work was viewed from the left and right sides.

Lenticular images were popularized from the late 1940s to the mid-1960s by the Van-Vue company.[3] Early products included animated political campaign badges with the slogan "I Like Ike!" and animated cards that were stuck on boxes of Cheerios.[4] By the late sixties the company marketed about two thousand stock products including twelve inch square drawing and coloring card sheets, large images (many religious), and a huge range of novelties including badges. The badge products included the Rolling Stones' tongue logo and an early Beatles badge with pictures of the 'fab four' on a red background.

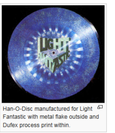
Some notable lenticular prints include the limited-edition album cover for the Rolling Stones' *Their Satanic Majesties Request*, and Saturnalia's *Magical Love*, a picture disk with a lenticular center. Several magazines including *Look* and *Venture* published issues in the 1960s that contained lenticular images. Many of the magazine images were produced by Crowle Communications (also known as Visual Panographics). Images produced by the company ranged from just a few millimeters to 28 by 19.5 inches.

The panoramic cameras used for most of the early lenticular prints were French-made and weighed about 300 pounds. In the 1930s they were known as "auto-stereo cameras". These wood and brass cameras had a motorized lens that moved in a semicircle around the lens' nodal point. Sheet transparency film with the lenticular lens overlay was loaded into special dark slides (about 10×15 inches) and these were then inserted into the camera. The exposure time was several seconds long, giving time for the motor drive to power the lens around in an arc. [citation needed]

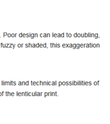
A related product produced by a small company in New Jersey was Rowlux. Unlike the Van-Vue product, Rowlux used a microplastic lens structure made by a process they patented in 1972,[4] and no paper print. Instead, the plastic (Polycarbonate, flexible PVC and later PETG) was dyed with translucent colors and the film was usually thin and flexible (from 0.002" in thickness).

Lenticular arrays are also used for 3D "autostereoscopic" television which produces the illusion of 3D without the use of special glasses. A number of prototypes were shown in 2009/2010 by companies such as Philips and LG. These systems use cylindrical lenses slanted from the vertical, or spherical lenses arranged in a honeycomb pattern - which provides a better resolution.

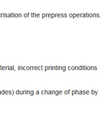
While not a true lenticular process, the Dufex Process (Manufactured by F.J. Warren Ltd.)[5] does use a form of lens structure to animate the image. The process consists of imprinting a metallic foil with an image. The foil is then laminated to a thin sheet of card stock that has been coated with a thick layer of wax. The heated lamination press has the Dufex embossing plate on its upper platen, which has been engraved with 'lenses' at different angles, designed to match the artwork and reflect light at different intensities depending on angle of view.



Saturnalia record with lenticular label that switches from "Magical love" to a logo.



Han-O-Disc record with diffraction grating 'Rainbow' film (outside ring), color shifting Rowlux (middle ring) and "silver balls" Rowlux film (center of record).



Han-O-Disc manufactured for Light Fantastic with metal flake outside and Dufex process print within.

Manufacturing process

Printing

Creation of lenticular images in volume requires printing presses that are adapted to print on sensitive thermoplastic materials. Lithographic offset printing is typically used, to ensure the images are good quality. Printing presses for lenticulars must be capable of adjusting image placement in 10 µm steps, to allow good alignment of the image to the lens array.

Typically, ultraviolet-cured inks are used. These dry very quickly by direct conversion of the liquid ink to a solid form, rather than by evaporation of liquid solvents from a mixture. Powerful (400W per sq. in) ultraviolet (UV) lamps are used to rapidly cure the ink. This allows lenticular images to be printed at high speed.

In some cases, electron beam lithography is used instead. The curing of the ink is then initiated directly by an electron beam scanned across the surface.

Defects

Design defects

Double images on the relief and in depth

Double images are usually caused by an exaggeration of the 3-D effect from some angles of view, or an insufficient number of frames. Poor design can lead to doubling, small jumps, or a fuzzy image, especially on objects in relief or in depth. For some visuals, where the foreground and background are fuzzy or shaded, this exaggeration can prove to be an advantage. In most cases, the detail and precision required do not allow this.

Image ghosting

Ghosting occurs due to poor treatment of the source images, and also due to transitions where demand for an effect goes beyond the limits and technical possibilities of the system. This causes some of the images to remain visible when they should disappear. These effects can depend on the lighting of the lenticular print.

Prepress defects

Synchronisation of the print (master) with the pitch

Also known as "Banding". Poor calibration of the material can cause the passage from one image to another to not be simultaneous over the entire print. The image transition progresses from one side of the print to the other, giving the impression of a veil or curtain crossing the visual. This phenomenon is felt less for the 3-D effects, but is manifested by a jump of the transverse image. In some cases, the transition starts in several places and progresses from each starting point towards the next, giving the impression of several curtains crossing the visual, as described above.

Discordant harmonics

This phenomenon is unfortunately very common, and is explained either by incorrect calibration of the support or by incorrect parametrisation of the prepress operations. It is manifested in particular by streaks that appear parallel to the lenticules during transitions from one visual to the other.

Printing defects

Colour synchronisation

One of the main difficulties in lenticular printing is colour synchronisation. The causes are varied, they may come from a malleable material, incorrect printing conditions and adjustments, or again a dimensional differential of the engraving of the offset plates in each colour.

This poor marking is shown by doubling of the visual, a lack of clarity; a streak of colour or wavy colours (especially for four-colour shades) during a change of phase by inclination of the visual.

Synchronisation of parallelism of the printing to the lenticules

The origin of this problem is a fault in the printing and forcibly generates a phase defect. The passage from one visual to another must be simultaneous over the entire format. But when this problem occurs, there is a lag in the effects on the diagonals. At the end of one diagonal of the visual, we have one effect, and at the other end we have another.

Phasing

In most cases, the problem comes from imprecise cutting of the material, as explained below. Nevertheless, poor printing and rectification conditions may also be behind it.

In theory, for a given angle of observation, one and the same visual must appear, for the entire batch. As a general rule, the angle of vision is around 45°, and this angle must be in agreement with the sequence provided by the master. If the images have a tendency to double perpendicularly (for 3-D) or if the images provided for observation to the left appear to the right (top/bottom), there is a phasing problem.

Cutting defects

Defects in the way the lenticular lens is cut lead to phase errors between the lens and the image.

Two examples, taken from the same production batch:

First image

Second image

The first image shows a cut which removed about 150 µm of the first lens, and which shows irregular cutting of the lenticular lenses. The second image shows a cut which removed about 30 µm of the first lens. Defects in cutting such as these lead to a serious phase problem. In the printing press the image being printed is aligned relative to the edges of the sheet of material. If the sheet is not always cut in the same place relative to the first lenticule, a phase error is introduced between the lenses and the image slices.

See also

- Lenticular lens, the technology used in lenticular printing and for 3D displays
- Integral imaging, a broader concept that includes lenticular printing
- Autostereoscopy, any method of displaying stereoscopic images without the use of glasses
- Parallax barrier, another technology for displaying stereoscopic images without the use of glasses

Notes and references

1. ^ Lelyveld, Philip (2013), *NAB - Dolby/Phillips autostereo 3D display*, retrieved July 5, 2013
2. ^ Oster, Gerald (1965). "Optical Art". *Applied Optics* **4** (11): 1359–69. doi:10.1364/AO.4.001359 (subscription required (help)).
3. ^ a b Lake, Matt (1999-05-20). "An art form that's precise but friendly enough to work". *New York Times*. Retrieved 2008-06-04.
4. ^ US patent 3695346, Rowland, William P., "Method for producing retroreflective material", issued 1972-09-05, assigned to Rowland Development Corp.
5. ^ "F.J. Warren Ltd". *Kompass UK*. Retrieved 2008-06-04.

- *Bordas Encyclopedia*. Organic Chemistry (French).
- Sirost, Jean-Claude (2007). L'Offset : *Principes, Technologies, Pratiques* (in French) (2nd ed.). Dunod. ISBN 2-10-051366-4.
- Okoshi, Takanori *Three-Dimensional Imaging Techniques* Atara Press (2011), ISBN 978-0-9822251-4-1

External links

- Patent 2063985. *Apparatus for Making a Composite Stereograph* filed May 24, 1935, issued Dec 15, 1936, by Douglas Fredwill Winnek Coffey.
- Lecture slides covering lenticular lenses (PowerPoint) by John Canny