Laser engraving

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Laser engraving is the practice of using lasers to engrave or mark an object (it is also sometimes incorrectly described as *etching*, which involves the use of acid or a similar chemical). The technique can be very technical and complex, and often a computer system is used to drive the movements of the laser head. Despite this complexity, very precise and clean engravings can be achieved at a high rate. The technique does not involve tool bits which contact the engraving surface and wear out. This is considered an advantage over alternative engraving technologies where bit heads have to be replaced regularly.

The impact of laser engraving has been more pronounced for specially-designed "laserable" materials. These include polymer and novel metal alloys.

In situations where physical alteration of a surface by engraving is undesirable, an alternative such as "marking" is available. This is a generic term that covers a broad spectrum of surfacing techniques, including printing and hot-branding. In many instances, laser engraving machines are able to do marking that would have been done by other processes.

Contents

Laser engraving machines

A laser engraving machine can be thought of as three main parts: a laser, a controller, and a surface. The laser is like a pencil - the beam emitted from it allows the controller to trace patterns onto the surface. The controller (usually a computer) controls the direction, intensity, speed of movement, and spread of the laser beam aimed at the surface. The surface is picked to match what the laser can act on.

There are three main genres of engraving machines: The most common is the X-Y table where, usually, the workpiece (surface) is stationary and the laser moves around in X and Y directions drawing vectors. Sometimes the laser is stationary and the workpiece moves. Sometimes the workpiece moves in the Y axis and the laser in the X axis. A second genre is for cylindrical workpieces (or flat workpieces mounted around a cylinder) where the laser effectively traverses a fine helix and on/off laser pulsing produces the desired image on a raster basis. In the third method, both the laser and workpiece are stationary and galvo mirrors move the laser beam over the workpiece surface. Laser engravers using this technology can work in either raster or vector mode.

The point where the laser (the terms "laser" and "laser beam" may be used interchangeably) touches the surface should be on the focal plane of the laser's optical system, and is usually synonymous with its focal point. This point is typically small, perhaps less than a fraction of a millimeter (depending on the optical wavelength). Only the area inside this focal point is significantly affected when the laser beam passes over the surface. The energy delivered by the laser changes the surface of the material under the focal point. It may heat up the surface and subsequently vaporize the material, or perhaps the material may fracture (known as "glass" or "glass up") and flake off the surface. This is how material is removed from the surface to create an engraving.

If the surface material is vaporized during laser engraving, ventilation through the use of blowers or a vacuum pump are almost always required to remove the noxious fumes and smoke arising from this process, and for removal of debris on the surface to allow the laser to continue etching.

A laser can remove material very efficiently because the laser beam can be designed to deliver energy to the surface in a manner which converts a high percentage of the light energy into heat. The beam is highly focused and collimated - in most non-reflective materials like wood, plastics and enamel surfaces, the conversion of light energy to heat is more than {x%} efficient {example reference needed}. However, because of this efficiency, the equipment used in laser engraving may heat up rather quickly. Elaborate cooling systems are required for the laser. Alternatively, the laser beam may be pulsed to decrease the amount of excessive heating.

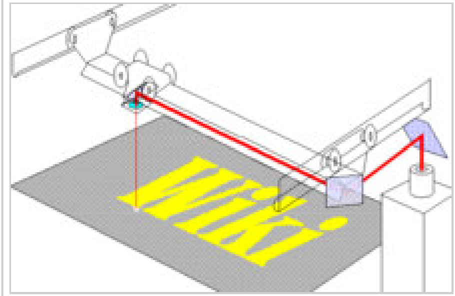
Different patterns can be engraved by programming the controller to traverse a particular path for the laser beam over time. The *trace* of the laser beam is carefully regulated to achieve a consistent removal depth of material. For example, criss-crossed paths are avoided to ensure that each etched surface is exposed to the laser only once, so the same amount of material is removed. The speed at which the beam moves across the material is also considered in creating engraving patterns. Changing the intensity and spread of the beam allows more flexibility in the design. For example, by changing the proportion of time (known as "duty-cycle") the laser is turned on during each pulse, the power delivered to the engraving surface can be controlled appropriately for the material.

Since the position of the laser is known exactly by the controller, it is not necessary to add barriers to the surface to prevent the laser from deviating from the prescribed engraving pattern. As a result, no resistive mask is needed in laser engraving. This is primarily why this technique is different from older engraving methods.

A good example of where laser engraving technology has been adopted into the industry norm is the production line. In this particular setup, the laser beam is directed towards a rotating or vibrating mirror. The mirror moves in a manner which may trace out numbers and letters onto the surface being marked. This is particularly useful for printing dates, expiry codes, and lot numbering of products travelling along a production line. Laser engraving has allowed materials made of plastic and glass to be marked "on the move". The location where the marking takes place is called a "marking laser station", an entity often found in packaging and bottling plants. Older, slower technologies such as hot-stamping and pad printing have largely been phased out and replaced with laser engraving.

For more precise and visually decorative engravings, a **laser table** is used. A laser table (or "X-Y table") is a sophisticated setup of equipment used to guide the laser beam more precisely. The laser is usually fixed permanently to the side of the table and emits light towards a pair of movable mirrors so that every point of the table surface can be swept by the laser. At the point of engraving, the laser beam is focused through a lens at the engraving surface, allowing very precise and intricate patterns to be traced out.

A typical setup of a laser table involves the fixed laser emitting light parallel to one axis of the table aimed at a mirror mounted on the end of an adjustable rail. The beam reflects off the mirror angled at 45 degrees so that the laser travels a path exactly along the length of the rail. This beam is then reflected by another mirror mounted to a movable trolley which directs the beam perpendicular to the original axis. In this scheme, two degrees of freedom (one vertical, and one horizontal) for etching can be represented.



Mirrors on both X and Y carriages allow exact positioning.

In other laser engraving devices such as *flat table* or *drum engraving*, the laser beam is controlled to direct most of its energy a fixed penetration depth into the material to be engraved. In this manner, only a particular depth of material is removed when the engraving takes place. A simple machined stick or angle-iron can be used as a tool to help trained technologists adjust the engraver to achieve the required focusing. This setup is preferred for surfaces which do not vary in height appreciably.

Fast Laser engraving.

For surfaces that vary in height, more elaborate focusing mechanisms have been developed. Some are known as *dynamic auto focus systems*. They adjust the lasering parameters in real time to adapt to the changes to the material as it is being etched. Typically, the height and depth of the surface is monitored with devices tracking changes to ultrasound, infrared, or visible light aimed at the engraving surface. These devices, known as *pilot beams* or *pilot lasers* (if a laser is used) help guide the adjustments made to the lens of the laser in determining the optimal spot to focus on the surface and remove material effectively.

"X-Y" laser engraving machines may operate in vector and raster mode.

Vector engraving follows the line and curve of the pattern to be engraved, much like a pen-based plotter draws by constructing line segments from a description of the outlines of a pattern. Much early engraving of signs and plaques (laser or otherwise) used pre-stored font outlines so that letters, numbers or even logos could be scaled to size and reproduced with exactly defined strokes. Unfortunately, "fill" areas were problematic, as cross-hatching patterns and dot-fills sometimes exhibited moiré effects or uber-patterns caused by the imprecise calculation of dot spacings. Moreover, rotations of a font or dynamic scaling often were beyond the capabilities of the font-rendering device. The introduction of the PostScript page-description language now allows much greater flexibility-- now virtually anything that can be described in vectors by PostScript-enabled software like CorelDRAW or Adobe Illustrator can be outlined, filled with suitable patterns, and laser-engraved.

Raster engraving traces the laser across the surface in a back-and-forth slowly-advancing linear pattern that will remind one of the printhead on an inkjet or similar printer. The pattern is usually optimized by the controller/computer so that areas to either side of the pattern which aren't to be engraved are ignored and the trace across the material is thus shortened for better efficiency. The amount of advance of each line is normally less than the actual dot-size of the laser; the engraved lines overlap just slightly to create a continuity of engravure. As is true of all rasterized devices, curves and diagonals can sometimes suffer if the length or position of the raster lines varies even slightly in relation to the adjacent raster scan; therefore exact positioning and repeatability are critically important to the design of the machine. The advantage of rasterizing is the near effortless "fill" it produces. Most images to be engraved are bold letters or have large continuously-engraved areas, and these are well-rasterized. Photos are rasterized (as in printing), with dots larger than that of the laser's spot, and these also are best engraved as a raster image. Almost any page-layout software can be used to feed a raster driver for an X-Y or drum laser engraver. While traditional sign and plaque engraving tended to favor the solid strokes of vectors out of necessity, modern shops tend to run their laser engravers mostly in raster mode, reserving vector for a traditional outline "look" or for speedily marking out lines or "hatches" where a plate is to be cut.

Materials that can be engraved

Woods/Natural materials

Directly "burning" images on wood were some of the first uses of engraving lasers. The laser power required here is often less than 10 watts. Hardwoods like walnut, oak, mahogany and maple produce good results. Softwoods can be judiciously engraved but tend to vaporize at less-consistent depths. Burning a softwood with a fan blowing on it requires lowest power, quickest speed of cut, and enough airflow to extinguish what is trying meanwhile to ignite. Hard papers and fiberboard work well; linty papers and newsprint are like softwoods. Fur is not engraveable; finished leathers though can be laser-engraved with a look very similar to hot-branding. Certain latex rubber compounds can be laser engraved; for example these can be used to fabricate inking-stamps.

Paper masking tape is sometimes used as a pre-engraving overcoat on finished and resiny woods so that cleanup is a matter of picking the tape off and out of the unengraved areas, which is easier than removing the sticky and smoky surround "halos" (and requires no varnish-removing chemicals).

Plastics

Standard cast acrylic plastic, acrylic plastic sheet, and other cast resins generally laser very well. A commonly engraved award is a cast acrylic shape designed to be lasered from the back side. Styrene (as in compact disc cases) and many of the thermoforming plastics will tend to melt around the edge of the engraving spot. The result is usually "soft" and has no "etch" contrast. The surface may actually deform or "ripple" at the lip areas. In some applications this is acceptable; for example date markings on 2-litre soda bottles does not need to be sharp.

For signage and faceplates, etc., special laser-engraving plastics were developed. These incorporate silicate or other materials which conduct excess heat away from the material before it can deform. Outer laminates of this material vaporize easily to expose different colored material below.

Other plastics may be successfully engraved, but orderly experimentation on a sample piece is recommended. Bakelite is said to be easily laser-engraved; some hard engineering plastics work well. Expanded plastics, foams and vinyls however are generally candidates for routing rather than laser engraving. Urethane and silicone plastics usually don't work well--unless it is a formulation filled with cellulose, stone or some other stable insulator material.

Metals

The best traditional engraving materials started out to be the worst laser-engravable materials. This problem has now been solved using lasers at shorter wavelengths than the traditional 10,640nm wavelength CO_2 laser. Using Nd:YVO_4 technology at 1,064nm wavelength, or its harmonics at 532 and 355nm, metals can now easily be engraved using commercial systems.

Coated metals

However, the same conduction that works against the spot vaporization of metal is an asset if your objective is to vaporize some other coating away from the metal. Laser engraving metal plates are manufactured with a finely-polished metal, coated with an enamel paint made to be "burned off". At levels of 10-30 watts, excellent engravings are made as the enamel is removed quite cleanly. Much laser engraving is sold as exposed brass or silver-coated steel lettering on a black or dark-enamelled background. A wide variety of finishes is now available, including screen-printed marble effects on the enamel.

Stone and glass

Stone and glass do not turn gaseous very easily. As expected, this makes them generally a better candidate for other means of engraving, most notably sandblasting or cutting using diamond-wheels and water. But when a laser hits glass or stone, something else interesting happens: it fractures. Pores in the surface expose natural grains and crystalline "stubs" which, when heated very quickly, can separate a microscopic sized "chip" from the surface because the hot piece is expanding relative to its surround. So lasers are indeed used to engrave on glass, and if the power, speed and focus are just right, excellent results can be achieved. One should avoid large "fill" areas in glass engraving because the results across an expanse tend to be uneven; the glass ablation simply cannot be depended on for visual consistency, which may be a disadvantage or an advantage depending on the circumstances and the desired effect.

Use of laser engraving in industrial applications

Cutting

It should be mentioned, though outside the scope of this article, that lasers of high power have the capability of not only engraving, but cutting material. The same basic techniques and considerations are used in fabrication of many cut shapes, whether in wood or in stacked fabric for apparel manufacture, or even metals (plasma-cutting). It is just all done at power levels which allow the laser to penetrate quickly *through* the piece rather than only at the surface level. Evacuation of released gases is often provided by a forced-air "snout" trained directly on the laser cutting area. The process is also referred as laser converting in some industies.

Printing

Direct laser engraving of flexo photopolymer plates or sleeves (which fit over a mandrel) is attracting wider interest following some recent technical developments and mergers of vendors. Up to now the process has been associated with wide-web flexo printing of, for example, film or paper packaging (flexible packaging). Here it competes with rotary gravure, although direct laser engraving is also being introduced. For the less expensive flexo process, the technology is being adapted for smaller formats suitable for engraving flexo plates or sleeves mounted on the actual printing cylinders.

This includes narrow and mid-web flexo presses (up to 20-24 inches wide), which could open up the market for self-adhesive label and packaging converters interested in the digital - that is filmless - route. With this process there is no integral ablation mask as with direct laser imaging (see below). Instead a high-power carbon dioxide laser head burns away, or ablates, unwanted material. The aim is to form sharp, relief images with steep, smooth edges to give a high standard of process color reproduction. A short water wash and dry cycle follows, which is a lot less involved than in the post-processing stages for direct laser imaging or conventional flexo platemaking using photopolymer plates.

Direct laser imaging

Closely related is the direct imaging of a digital flexo plates or sleeves 'in-the-round' on a fast-rotating drum, or cylinder. This is carried out on a platesetter integrated within a digital prepress workflow, that also supports digital proofing. Again, this is a filmless process, which removes one of the variables in obtaining the fine and sharp dots for screened affects, including process color printing.

With this process the electronically-generated image is scanned at speed to a photopolymer plate material that carries a thin black mask layer on the surface. The infrared laser-imaging head, which runs parallel to the drum axis, ablates the integral mask to reveal the uncured polymer underneath. A main ultraviolet exposure follows to form the image through the mask. The remaining black layer absorbs the ultraviolet radiation, which polymerizes the underlying photopolymer where the black layer has been removed. The exposed digital plate still needs to be processed like a conventional flexo plate. That is, using solvent-based washout with the necessary waste recovery techniques, although some water-washable digital plates are in development. This technology has been used since 1995 and is only now becoming more widely used around the world as more affordable equipment becomes available. Trade sources say there are around 650 digital platesetters installed in label, packaging and trade platemaking houses.

In flexo direct laser engraving can be done using a CO2-laser. This makes it possible to direct ablate the non-printing area. This way steps like UV-exposing, chemical washing and drying are not necessary anymore. Before the year 2000 lasers only produced lower quality in rubber-like materials. In these rubber-like materials, which had a rough structure, higher quality was impossible. At the Drupa 2004 the direct engraving of polymer plates was introduced. This had also an effect on the rubber-developers who, in order to stay competitive, came with new high quality rubber-like materials. Since then direct laser engraving of flexo-printingforms is seen by many as the modern way to make printing-forms for it is the first real digital way.

Sub Surface Laser Engraving (SSLE)

The process of engraving an image below the surface of a solid material, usually glass with an optical clarity to minimize distortion of the laser.

A fairly comprehensive overview of this medium is best described from a designer that specializes in implementing SSLE into custom designs: (following text copied with permission of SharpeAwards [1] (http://www.sharpeawards.com/))

Sub-Surface Laser Engraving or SSLE as it is being termed nowadays, is a technique "discovered" in Russia in the early 1980's. Originally the creation of these "dots" in optical glass was a problem known as "Laser Induced Damage" and was exhaustingly studied.

At the time, the idea was to avoid these problems by selecting specific material compositions and laser optics to improve laboratory use. In the process, a list of material compositions was created that provided good transparency with minimal heat absorption. There was also another list, which included materials that didn't, and it was somewhere there that laser technicians found it "neat" to write their name in these materials.

Needless to say, someone decided there might be some commercial applications for this and began writing dissertations about the controlled placement of these dots inside of the crystal. Over the years, the science of this process from a purist view has become more of an art form that balances the technical aspects of high-powered lasers and delicate balance of image design within them.

A much more technical overview

The creation of 3D laser crystals utilize high-energy laser beams to produce a phenomenon known as "Multi-photon Absorption (http://webphysics.davidson.edu/alumni/jimn/Final/Pages/FinalMPA.htm)" within optically perfect crystal. This phenomenon, which uses the electromagnetic wave of the laser beam known as coherent light creates an electric field greater than 10 million volts per centimeter. When the laser beam is focused within the interior of the subject crystal the energy creates unattached electrons also known as "free" electrons. These "free" electrons, accelerated by the electric field created by the laser beam causes the high energy electrons to collide with atoms and ions in the focus area. As the process continues it causes a chain reaction and produces about 1 million trillion free electrons per cubic centimeter in *about 1 trillionth of a second. The laser then emits a short pulse beam of a few billionths per second and produces a tiny micro crack. The laser head then align and position tens of thousands of additional micro cracks to create 2 or 3 dimensional images. Although, the laser generates power densities of 10 billion watts per square centimeter, the surface of the crystal is not damaged due to the highly transparent nature of optically perfect crystal. The resulting images appear to be suspended within the crystal.*

Techniques used in SSLE

There are basically three different techniques in use by sub-surface engraving houses, each of which vary in their approach but all fall into similar categories. Regardless of the technique, the palette is the same - white or shades of white. Another important thing to know is the objects in the design will rarely ever look like a solid white object because they cast no shadow on themselves. With white being the primary "color" and no ability for shadows to enforce contours, the designer should have a working knowledge of negative space, spatial juxtaposition and a basic understanding of good design. Here is an example of a BAD use of SSLE Too Many Layers of White are Confusing (http://sharpeawards.com/images/_points.jpg) – to see what the designer is referring to 3D WHAT? (http://sharpeawards.com/3d_what.htm)

NOTE: Color SSLE has been developed using furnaces to reheat the crystal that has be engraved (changing the color of the points). After cooling, the crystal is engraved in other areas to create a "contrast" with its original white palette. Heating and annealing is a time intensive process with larger blocks taken as long as 70 days to cool properly. Therefore, this process is only cost effective in small sized crystal done in batch run designs used exclusively for limited editions or collectors.

3d modeling - A scene, logo, or product is designed completely in 3D cad system - ideally, different components may have differing shades of white. This approach works well with simple shapes that are easily identifiable for the viewer. Complex shapes that create numerous overlapping surfaces will confuse the viewer with dense white regions and hide the actual shape. Best used sparingly by a designer that understands "less is more" for a better result - cad file drops from the client rarely provide satisfactory results out of the box.

2d bitmap - One of the most common methods of laser engraving for both sub-surface and surface engravers. Images are converted into a "halftone" which is a pattern of dots spaced to evoke a sense of tone across the varying intensity of the image. The brighter (whiter) the area, the closer the dots are placed to one another. Less dense areas appear less bright creating tonal changes in the image. Look at newspaper print of an image - same idea - different medium. This approach works well with photographs that have good contrast in them as well as single or two color logos or text. There is some size limitations though since images, symbols and text need enough dots to be recognizable.

2.5d bitmap - This is an interesting approach which combines the advantages of 2D bitmaps and some of the dimensionality of 3D modeling. This techniques builds as many as seven to eight layers of points over one another to create a whiter "white" than is available with the basic 2D approach. This approach works really well with logos and a certain amount of text - photographs of heads are commonly done but tend to look "spiky" when viewed from subtle angles and quickly loose the visual effect desired if not viewed from the front.

One additional note regarding SSLE should be made regarding these "points". Points generated by the laser are relatively small usually .1mm and slightly eggshapped. Perhaps more importantly, they are spaced typically no closer than 1.5X their size (across x/y/z planes). This is due largely by the fact that the entire lasered image is held together by the internal stress of the glass itself - tighter spacing increases the probability of creating a fissure between points resulting in damaging the crystal and/or design. This enforced spacing also reveals why SSLE objects lack the ability to cast shadows on themselves.

Since its inception in the late 90's, SSLE has become more cost effective with a number of different sized machines ranging from small (~$35-60KUS) to large production sized tables (>$250KUS) - still although these machines are becoming more available there is estimated only a few hundred in operation worldwide. Many machines require very expensive cooling, maintenance and calibration for proper use. The primary component being the laser diode can easily cost 1/3rd of the machine cost itself that has a limited number of hours.

In past 5 years the use of SSLE has become more cost effective to produce 3D images in souvenir 'crystal' or promotional items with only a few designers concentrating on designs incorporating large or monolithic sized crystal. A number of companies offer custom made souvenirs by taking 3D pictures or photos and engraving them into the crystal. Quality of the designs and images varies greatly between vendors in the promotional and personal services sector (photo engravers) - the mass producing curio vendors have the habit of reducing resolution of the points and lowering output to maximize their laser diodes lifespan. When properly produced, designs in this medium can be striking and mesmerizing.

External links

- *Laser Engraving: The Basics* (http://www.signindustry.com/ada/articles/01-08-2001-LaserEngraving.php3)
- *Laser Engraving: Systems and Machines* (http://www.engravinglaser.info/)
- *Laser Engraving: High-speed Laser Engraving* (http://www.lasx.com/)
- *Laser Engraving: Flatbed- and Galvosystems* (http://www.trotec.net/_en-US/040+Laser+Engraving.htm)
- *Laser Engraving: Large Sized Flatbed Systems* (http://www.eurolaser.com/)
- *Laser Engraving: Movies* (http://www.evright.com/movies.asp)
- *Lasers Engraving from metal, glass and plastics* (http://www.lasercut24.de/prod03.htm)

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Bakelite	http://en.wikipedia.org/wiki/Bakelite
foams	http://en.wikipedia.org/wiki/Foam
vinyls	http://en.wikipedia.org/wiki/Vinyl
Urethane	http://en.wikipedia.org/wiki/Urethane
silicone	http://en.wikipedia.org/wiki/Silicone
cellulose	http://en.wikipedia.org/wiki/Cellulose
insulator	http://en.wikipedia.org/wiki/Thermal_insulation
edit	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit§ic
edit	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit§ic
enamel	http://en.wikipedia.org/wiki/Enamel_paint
silver	http://en.wikipedia.org/wiki/Silver

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steel	http://en.wikipedia.org/wiki/Steel
marble	http://en.wikipedia.org/wiki/Marbling
edit	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit§ic
Stone	http://en.wikipedia.org/wiki/Rock_(geology)
glass	http://en.wikipedia.org/wiki/Glass
sandblasting	http://en.wikipedia.org/wiki/Sandblasting
diamond	http://en.wikipedia.org/wiki/Diamond
water	http://en.wikipedia.org/wiki/Water
Pores	http://en.wikipedia.org/wiki/Pore
grains	http://en.wikipedia.org/wiki/Grain
edit	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit§ic
edit	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit§ic
cutting	http://en.wikipedia.org/wiki/Laser_cutting
fabric	http://en.wikipedia.org/wiki/Textile
laser converting	http://en.wikipedia.org/wiki/Laser_converting
edit	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit§ic
flexo	http://en.wikipedia.org/wiki/Flexo
photopolymer	http://en.wikipedia.org/wiki/Photopolymer
mandrel	http://en.wikipedia.org/wiki/Mandrel
gravure	http://en.wikipedia.org/wiki/Gravure
adhesive	http://en.wikipedia.org/wiki/Adhesive
digital	http://en.wikipedia.org/wiki/Digital
carbon dioxide laser	http://en.wikipedia.org/wiki/Carbon_dioxide_laser
edit	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit§ic
edit	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit§ic
[1]	http://www.sharpeawards.com/
Multi-photon Absorption	http://webphysics.davidson.edu/alumni/jimn/Final/Pages/FinalMPA.htm
Too Many Layers of White are Confusing	http://sharpeawards.com/images/_points.jpg
3D WHAT?	http://sharpeawards.com/3d_what.htm
edit	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit§ic
Laser Engraving: The Basics	http://www.signindustry.com/ada/articles/01-08-2001-LaserEngraving.php
Laser Engraving: Systems and Machines	http://www.engravinglaser.info/
Laser Engraving: High-speed Laser Engraving	http://www.lasx.com/
Laser Engraving: Flatbed- and Galvosystems	http://www.trotec.net/_en-US/040+Laser+Engraving.htm
Laser Engraving: Large Sized Flatbed	

Shortcut Text	Internet Address
Systems	http://www.eurolaser.com/
Laser Engraving: Movies	http://www.evright.com/movies.asp
Lasers Engraving from metal, glass and plastics	http://www.lasercut24.de/prod03.htm
http://en.wikipedia.org/wiki/Laser_engraving	http://en.wikipedia.org/wiki/Laser_engraving
Categories	http://en.wikipedia.org/wiki/Special:Categories
Lasers	http://en.wikipedia.org/wiki/Category:Lasers
Printing	http://en.wikipedia.org/wiki/Category:Printing
Engraving	http://en.wikipedia.org/wiki/Category:Engraving
Discussion	http://en.wikipedia.org/wiki/Talk:Laser_engraving
Edit this page	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=edit
History	http://en.wikipedia.org/w/index.php?title=Laser_engraving&action=history
Sign in / create account	http://en.wikipedia.org/w/index.php?title=Special:Userlogin&returnto=Las
	http://en.wikipedia.org/wiki/Main_Page
Contents	http://en.wikipedia.org/wiki/Wikipedia:Contents
Featured content	http://en.wikipedia.org/wiki/Wikipedia:Featured_content
Current events	http://en.wikipedia.org/wiki/Portal:Current_events
Random article	http://en.wikipedia.org/wiki/Special:Random
About Wikipedia	http://en.wikipedia.org/wiki/Wikipedia:About
Community portal	http://en.wikipedia.org/wiki/Wikipedia:Community_Portal
Recent changes	http://en.wikipedia.org/wiki/Special:Recentchanges
File upload wizard	http://en.wikipedia.org/wiki/Wikipedia:Upload
Contact us	http://en.wikipedia.org/wiki/Wikipedia:Contact_us
Help	http://en.wikipedia.org/wiki/Help:Contents
What links here	http://en.wikipedia.org/wiki/Special:Whatlinkshere/Laser_engraving
Related changes	http://en.wikipedia.org/wiki/Special:Recentchangeslinked/Laser_engraving
Upload file	http://en.wikipedia.org/wiki/Special:Upload
Special pages	http://en.wikipedia.org/wiki/Special:Specialpages
Printable version	http://en.wikipedia.org/w/index.php?title=Laser_engraving&printable=yes
Permanent link	http://en.wikipedia.org/w/index.php?title=Laser_engraving&oldid=138392
Cite this article	http://en.wikipedia.org/w/index.php?title=Special:Cite&page=Laser_engra
Deutsch	http://de.wikipedia.org/wiki/Laserbeschriftung
	http://www.mediawiki.org/
	http://wikimediafoundation.org/
GNU Free Documentation License	http://en.wikipedia.org/wiki/Wikipedia:Text_of_the_GNU_Free_Documen
Copyrights	http://en.wikipedia.org/wiki/Wikipedia:Copyrights

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Wikimedia Foundation, Inc	http://www.wikimediafoundation.org/
501(c)(3)	http://en.wikipedia.org/wiki/501(c)#501.28c.29.283.29
tax-deductible	http://wikimediafoundation.org/wiki/Deductibility_of_donations
nonprofit	http://en.wikipedia.org/wiki/Non-profit_organization
charity	http://en.wikipedia.org/wiki/Charitable_organization
Privacy policy	http://wikimediafoundation.org/wiki/Privacy_policy
Disclaimers	http://en.wikipedia.org/wiki/Wikipedia:General_disclaimer