LINX

White Paper

UNDERSTANDING LASER MARKING TECHNOLOGIES

Which laser type is best for your application?

Laser coding and marking technology has been in existence for nearly 50 years. In this time, improvements in engineering have produced diverse laser marking systems for different applications.

This White Paper explains the technology behind laser marking systems and the options available to Production Managers. Through a better understanding, readers will be able to make an informed choice when it comes to selecting the right laser marking system for their application.

Contents

White Paper

1 Introduction

The word 'laser' has become so much a part of our everyday vocabulary that we tend to forget it is an acronym derived from the rather long-winded description Light Amplification by Stimulated Emission of Radiation.

Lasers are often thought of as a new technology but have in fact been in existence longer than many people realise. The theory of lasers was suggested in 1957 and the first laser was built in 1960. Long before that, at the turn of the century, Einstein produced equations which describe the main physical mechanism by which laser action occurs, although he didn't realise its potential at the time.

Many companies and government institutions became interested in lasers and started developing their own without any specific application in mind. As a result, lasers became known as 'a solution looking for a problem'. Nowadays lasers are developed for specific tasks and their characteristics are developed to meet the requirements of the application.

Lasers probably have one of the widest range of applications of any type of device, including cutting and welding metals, surgery, data reading and transmission, holography, accurate measurement of physical parameters, non-destructive testing, and marking products on the production line.

Laser marking systems came onto the market about 50 years ago. These early systems employed scientific lasers and were not designed to cope with the harsh dusty and wet environments found in many factories. Nor were they designed for continuous operation 24 hour per day, 7 days per week – something we take for granted today.

The initial focus was therefore on making these systems more rugged, rather than developing new technology formats to deal with changing market requirements.

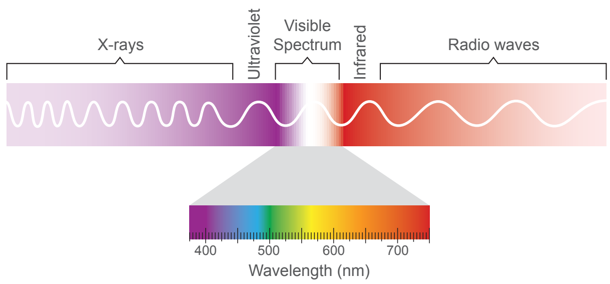
Laser marking system on a wine bottling line

2 How a laser works

All lasers share the same basic principles but are differentiated by the way the products are engineered, by the materials used and by the characteristics of the laser output beam.

Lasers for product marking occupy the infrared range of the electromagnetic spectrum from 10600 nm for CO_2 lasers to 1055 – 1070 nm for Ytterbium fibre lasers. By way of comparison, laser pocket pointers are diode lasers that occupy 671 nm.

Visible and invisible light



2.1 Components of a Laser

There are three main components to any laser:

The lasing medium. This can be a gas such as carbon dioxide (CO_2), a solid such as Neodymium: Yttrium Aluminium Garnet (Nd:YAG) or a liquid such as a dye. One of the properties of a lasing medium is that it can store energy in a specific way, known as a population inversion. The lasing medium will emit light (photons) as a way of removing excess stored energy.

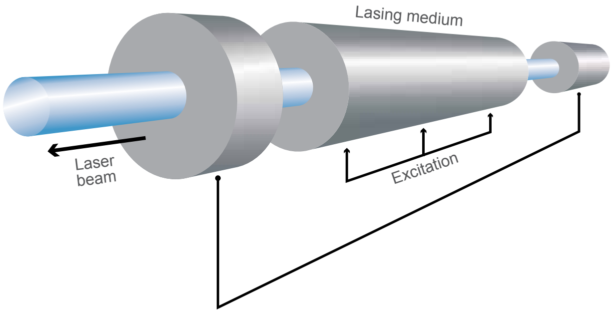
The excitation mechanism. The means by which energy is applied to excite the particles (atoms or molecules) of the lasing medium. Energy can be applied in the form of an electric current, electric discharge, light source, etc.

The optical resonator. The system that extracts the stored energy from the lasing medium in the form of a laser beam. In its simplest form the optical resonator consists of a mirror at either end of the lasing medium. These mirrors are parallel to each other so that photons travelling along the axis of the two mirrors are continuously reflected backwards and forwards (resonate) between the mirrors. One mirror is 100% reflective, the other is partially reflective, so that it only transmits some of the photons which hit it.

2.2 Generation of a Laser Beam

As the photons pass through the lasing medium they cause excited particles to release excess energy in the form of other photons by a process called stimulated emission. These new photons are identical to the original photons that caused the stimulated emission. They are the same colour (wavelength), they travel in the same direction and they are in phase. The photons transmitted by the partially reflective mirror form the laser beam. The remaining photons are reflected back through the lasing medium to continue the stimulated emission process.

Laser beam generation



3 The laser marking process

Laser marking is achieved by removing material from the substrate or by changing the surface of the substrate. The most important consideration is how well the material being coded absorbs the laser beam. This can determine the type of laser used as different wavelengths can have different absorption characteristics. If the laser beam is transmitted or reflected, then coding becomes more difficult or even impossible.

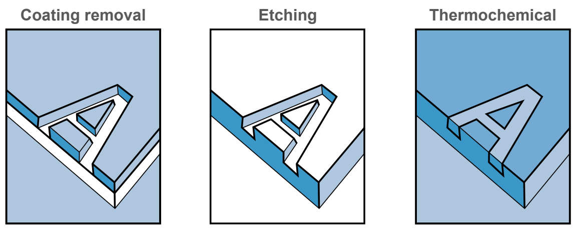
For optimum results the focussed laser beam has to be absorbed in the top few microns of the material surface, so that sufficient energy density is produced to modify the surface by one of the following three processes:

Coating removal. The laser is absorbed by the substrate or surface coating, vaporising the coating to reveal a contrasting substrate. An example of this process is the removal of coloured ink printed on to white paper or card.

Laser marking on beverage label

Etching. The laser vaporises material from the surface of the substrate without necessarily producing any colour change. (This is the process which occurs in the laser marking of polymers such as PET.)

Laser marking on beverage PET



These marks look similar to an embossed print. On glass the laser induces thermal stress, causing microcracks in the surface and resulting in tiny glass crystals being ejected from the surface to produce a mark.

Laser marking on glass

Thermochemical. The laser changes the material by heating it to a sufficiently high temperature to break molecular bonds. The new material formed by this process may have a different colour, thus producing a discernible mark.

Laser marking on pharmaceutical PVC

4 Marking system technologies

4.1 Laser Types

The majority of laser marking systems use one of three types of laser:

CO_2 uses a mixture of gasses which are excited by an electric discharge. These lasers have a typical infrared output of 9.3 µm, 10.2 µm or 10.6 µm wavelength.

Fibre lasers are a special class of solid state lasers. Instead of a gas as the lasing medium, an optical fibre is used. The laser beam is generated and confined inside the core of the fibre, which is doped with ions such as yterrbium that is typically excited by a diode laser. This technological setup leads to an emission wavelength band of 1.05 µm to 1.08 µm with its centre at 1.06 µm.

Nd:YAG this is a crystal which is commonly excited by a flash lamp (an intense light source) or by a diode laser. It yields an infrared laser output of 1.064 µm wavelength.

4.2 Beam Delivery

There are three main laser beam delivery systems used to produce a mark on the surface of an object:

Mask lasers

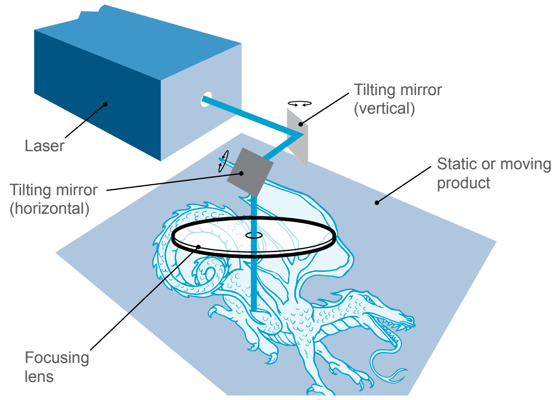
Were first introduced in the early 1970s. These systems used a pulsed laser beam that is expanded to a large profile. The beam illuminates a thin metal mask through which the required image or code has been etched. This method can be very fast, as only a short moment of illumination is needed. The drawback is the relatively small marking area, as it is limited by the laser beam diameter in combination with the focus optics and the power density. In addition, this type of code generation is very inflexible as it uses a fixed mask that needs to be manually replaced with every code change.

Dot matrix

The term dot matrix for laser marking encompasses different principles of beam delivery that generate a pattern of marked dots on a material, forming characters or graphics. One beam delivery system is an array of lasers that are oriented in a vertical arc which send their beams through a common focusing lens onto the product. This array (of e.g. eight lasers) can generate a vertical line pattern of dots, depending on which laser is switched on. This method uses a whole laser source for every dot printed in a column, therefore it is a relatively resource and cost intensive technology.

Both mask and dot matrix beam delivery systems have the major disadvantage that they are all very static in the codes they can generate. In contrast, a scribing laser beam that writes like a pen on the surface of a product is a more versatile principle of beam delivery. Therefore, this technology now has become the most popular.

Scribing Lasers



These systems write like a pen. The first systems, based on pulsed Nd:YAG lasers, were introduced in 1969. Systems using Continuous Wave (CW) CO_2 lasers were not introduced until the early 1980s. But in the first years this principle was rarely used, as the mirrors for each direction need a very fast and robust control algorithm that could only be realised with high performance signal processors.

A lens is used to focus the laser beam to a small spot on the surface of the product. Two galvanometer-driven mirrors move the spot over the surface of the product to draw the required mark or image. The laser beam is turned on when coding is required and off when not. The rotation of the two galvanometer-driven mirrors is computer controlled. The computers are often based on desktop PCs and will accept marking information from a wide range of software packages including word processors, CAD systems, databases etc.

Scribing laser systems are capable of producing high quality marking over large areas, up to 600 x 400 mm. Because of the size of the area to be marked, special flat field lenses are used. This is to prevent degradation of print quality which would otherwise occur as marking moves progressively further away from the centre line of the lens, causing the optimum position for the focal spot to be shifted away from the surface to be marked.

Since these systems are only drawing lines where required, they make very efficient use of the laser beam. This allows the use of low power (10 – 20 W), air cooled CO_2 lasers in the relatively low priced entry level systems.

With developing technology, increasing galvanometer speeds and reductions in the cost of computing power, scribing laser systems are able to apply highly complex codes onto products at high production line speeds.

5 Marking criteria and performance

Many parameters affect both the ability of a product to be coded and the speed at which it can be coded.

Absorption. Bare metals reflect CO_2 laser light and therefore cannot be coded by CO_2 lasers. An absorbent coating will enable marking by a CO_2 laser, or alternatively a fibre laser can be used.

Fibre laser marking on bare metal

Some plastics transmit CO_2 laser light and cannot be coded; therefore it is necessary to include additives in the plastic which absorb the light or to use a laser with a different wavelength, e.g. a Nd:YAG laser.

Dwell time. Defined as the time a beam of focused laser light is applied to the substrate. Different materials require different energy densities to produce a code. The longer the dwell time required to produce a code the slower the maximum coding speed. For example, on recycled board, printed ink is generally absorbed further into the surface and the laser therefore requires a longer dwell time to remove it. Similarly, a fast-moving production line will provide a shorter dwell time for the laser to make a mark, so under these conditions it may be necessary to use a high-powered laser, or a material that reacts quickly to laser light.

Surface treatments. If a surface has a varnished coating the laser has to remove the varnish before it can code the surface, and this will require a higher energy density.

Amount of data to be coded. A complex or large code will take longer to apply than a small code with the same laser, on the same material and in the same conditions.

Product Pitch. The distance between the consecutive products to be marked. If this is smaller than the laser's marking area, the laser will have less time to print each message.

6 Safety

No document on lasers would be complete without mentioning safety. The lasers that are used for marking in an industrial environment are all classified as laser class 4 according to the standard EN 60825-1. Therefore, safeguarding must be integrated into a production facility to prevent potentially unsafe situations. By using a few simple engineering design rules for guarding, interlocking, etc., similar to those used for other types of machinery, it is relatively easy to gain a safe overall system setup.

Performance Level. Local industrial regulatory requirements (e.g. the Machinery Directive 2006/42/EC) will determine the level of safety required. Today's laser marking machines can fulfil the highest "performance level 'e' (PLe), which means an emergency circuit switches off the laser immediately.

For example, if an emergency switch connected to the interlock circuit opens, then marking stops immediately. Marking cannot be continued until all emergency switches are closed and the Start button is pressed. Door lock switches operate in a similar fashion: if one opens then marking stops.

Guarding. Although laser light is not visible, it behaves the same as visible light. A beam is only emitted in a straight direction and does not travel on curved paths – but the directed rays can go around corners by reflection off surfaces and objects. The reflected laser light from the product surface can still contain sufficient energy to be harmful to eyesight and skin. The access to the laser beam should therefore be restricted by a housing that reduces the possible laser radiation from laser class 4 to laser class 1 (eyesafe emission). The wavelength that is emitted by a fibre laser needs a guarding, so no light can exit the location were a product is marked.

Restricted access. If areas and rooms containing running lasers cannot have direct guarding installed, then access must be restricted to persons specially trained for laser radiation. These persons must wear laser safety goggles which protect the eyes from the wavelength of the emitted laser radiation in that area.

7 Benefits of laser marking

- **Indelible codes.** Codes are etched into the surface which prevents unauthorised removal and aids anti-counterfeiting
- **High quality codes.** Scribing laser systems deliver quality codes which can match product branding, for discreet coding
- **Clean codes.** No additional materials required, just extraction of by-products generated during the laser marking process
- **Low maintenance.** Only a visual inspection every month; long service intervals compared to other coding technologies
- **Low running costs.** No consumables cost
- **High reliability.** With coding a legal requirement in most industries, equipment reliability is key. With minimal consumables and efficient use of laser power, laser marking systems are among the most reliable coding and marking devices on the market
- **Non-contact.** Enables high-speed printing as there is no physical contact with the surface to be printed
- **Programmability.** Enables variable information to be printed
- **Complex codes.** Barcodes and 2D codes containing a large amount of information can be generated

Laser marking on cosmetics painted card

8 The future

Although laser technology as a whole is moving forward very quickly, the relevance of these advances to coding and marking applications is limited. In other words, changes are likely to be of an evolutionary rather than a revolutionary nature. Nevertheless, developers of laser marking systems are always in search of improvements in the form of systems which:

- Are capable of marking faster and on a wider range of substrates
- Are more compact
- Cost less to produce.

For users, achievement of these goals will ultimately translate into more powerful and flexible systems at a lower price.

LINX THINKING ALONG YOUR LINES

For more information, please contact:

Graphic Solid Inks, Inc. 5790 Shiloh Rd, STE 100, Alpharetta GA 30005

Email: info@gsinks.com Phone: 678.264.4008 www.gsinks.com

MP40090