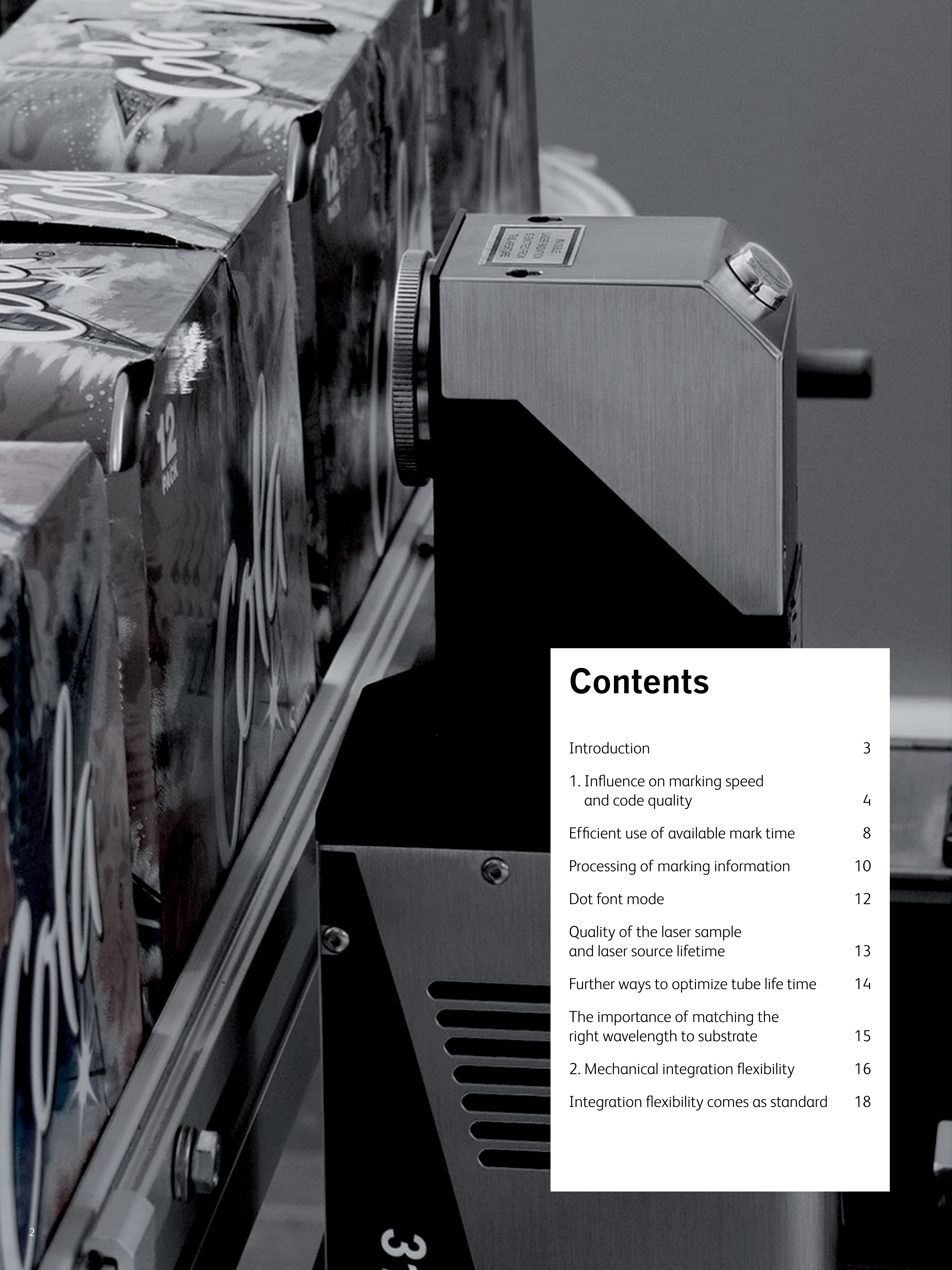
White paper

Maximizing productivity through intelligent CO_2 laser specification

A guide to configuring the optimum laser marking system for the exact application requirement

Laser marking systems are becoming more commonly selected as a solution for printing variable data onto packaging in many medium and large sized companies. As the use of laser marking increases in popularity, users may experience difficulties understanding how to differentiate between the various products and offerings.

This paper aims to demonstrate the definition of laser performance and how to get more from a CO_2 Laser through intelligent specification and application expertise. As a result, manufacturers can maximize efficiency and productivity by using a customized laser solution that meets their specific application needs.



Contents

Selecting the right technology for a marking or coding application can be a difficult task. Not only does the chosen technology need to be reliable, provide quality codes and help maximize production line uptime, it also needs to ensure high productivity.

Specifying a laser to an exact coding application typically requires careful consideration of a number of parameters, although a common misconception is that the laser power alone defines the suitability of a laser to a particular application. This paper examines the key parameters* that define laser productivity:

1.

Influence on marking speed and code quality

Laser power

- Efficient use of available mark time
- Processing of marking information
- Quality of laser sample and source lifetime
- Importance of wavelength selection

2.

Mechanical integration flexibility

(reduce downtime during mechanical install and changeover)

Laser marking systems are typically configured to meet a specific customer application.

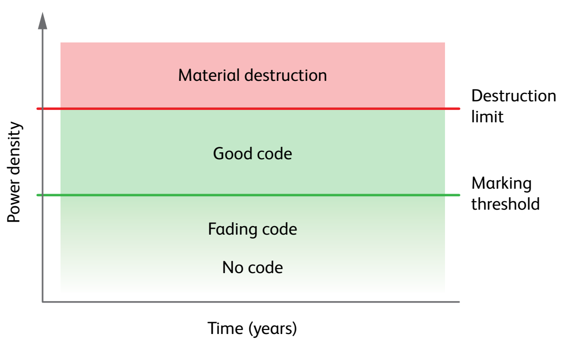
The first thought that comes to mind is: “can it mark the material in question? And does it achieve a sufficient contrast to read the code?” Once this is clarified it comes down to understanding which total laser solution best fits a customer needs.

*Parameters may vary based on customer and application

1 Influence on marking speed and code quality

There are several factors influencing marking speed and code quality.

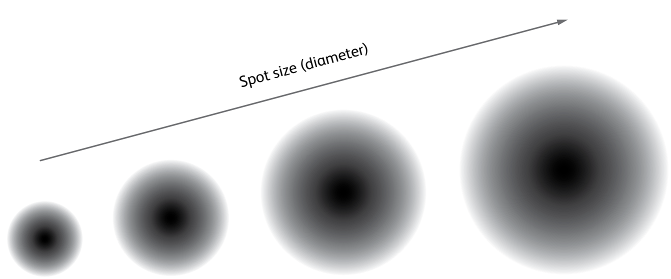
Typically laser power is considered to be the number one factor, however, it is not the laser power emitted by the printer that determines the marking quality but the power density on the product itself. Every substrate has two individual power density thresholds as shown below:



Power density below the marking threshold may result in weak or faded codes, however, increasing the power density too much could exceed the second threshold (destruction limit) and potentially damage the material. Only if the right amount of power density is applied, will consistent, high contrast codes be achieved.

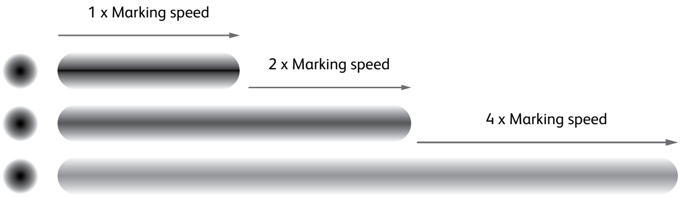
Depending on the exact substrate material, the marking threshold may provide a very distinct mark, for example; ablation, where a colored layer is removed to make the background material visible or on laser sensitive coated materials where the color pigments suddenly change color when a certain power density is exceeded.

For other materials where carbonization takes place, the code color may vary from low contrast brown to high contrast black codes when exceeding the marking threshold.



The spot size is determined by the combination of marking head aperture (6, 10,12mm) and lens. The laser 'power' is distributed over the spot's area which results in a certain 'power density' for a given laser power and the spot size. It is important to understand that the spot's area increases with the square of its diameter. Consequently, if the spot size is increased by a factor of two, the power density is reduced by a factor of 4 (down to a quarter).

The second important factor influencing the power density is the marking speed - the speed at which the marking head scribes the lines forming characters or other symbols.



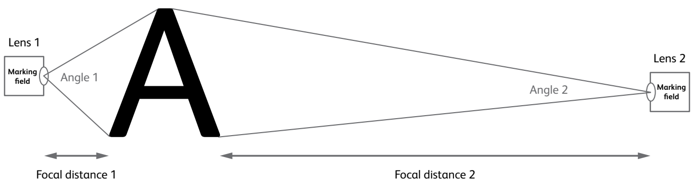
The power emitted by the laser is spread over an area forming a line. If the marking speed is doubled, the area will double that is covered by the laser beam in the same time. Hence the power density shrinks to half. Similarly, if the marking speed is increased by a factor of four, the power density will shrink to a quarter.

Marking head performance can also be dramatically influenced by the chosen lens – or to be more precise, the focal distance of the lens. Why?

It appears obvious that scribing large characters takes more time than scribing smaller characters. This is because the galvanometer motors need to turn the mirrors by a larger angle to scribe larger characters. So the reason for marking head performance limitation is the need to turn mirrors, which takes time. The smaller the characters to scribe, the smaller the required angles and the higher the performance. However, it is not always possible to design smaller characters to decrease the angles if a customer application requires characters of a specific height.

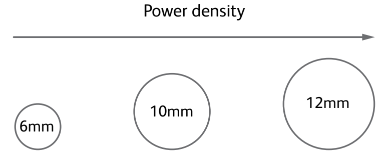
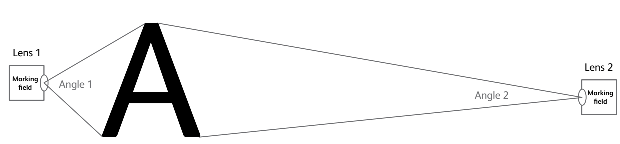
This is where selecting a lens with a larger focal distance, as shown below, can have an advantage.

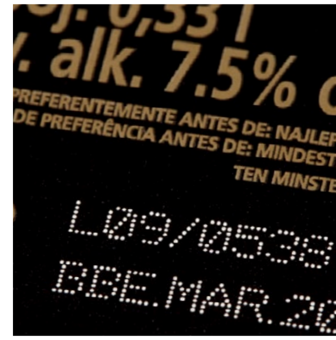
The left lens (1) having a shorter focal distance requires a substantially larger angle (1) than the right lens 2() which results in a smaller angle 2() for the same resulting character height A:



Therefore a marking head using larger focal distance lenses will show a substantially higher performance than using small focal distance lenses. The downside here is that the larger focal distance will result in a larger spot diameter which in turn requires increased laser power.

Here is an overview of the system components and parameters that we can configure, along with their impact on performance in terms of marking head speed versus required laser power and code quality.

Decrease	System parameter/system component	Increase
Pro: Smaller mirrors will result in higher marking head performance due to higher mirror acceleration rates, smaller required delay times and less character distortions. **Con:** Spot size will increase and more laser power is required. May result in hard to read code if used with small characters.	**Marking head aperture**  	**Pro:** Larger aperture will result in a smaller spot size. This reduces the required laser power and hence improves performance if laser power is limiting factor. **Con:** Larger mirrors reduce the marking head performance. Small spots may result in hard to read code if used with larger characters.
Pro: Smaller focal distances will result sin smaller spots increasing the power density. Less laser power required or processing of hard-to-mark materials. **Con:** Less marking head performance as character writing requires larger angles to cover. Smaller spots may result in hard to read code especially with larger character sizes.	**Lens/focal distance**  	**Pro:** Marking head performance increases - more cps may be achieved. Also good if large filled areas such as logos are threatening throughput. Larger spots will result in good readable codes for larger characters. **Con:** Large spot size may result in hard-to-read codes for smaller characters and lower power density which in turn requires more laser power.



Summary:

Maximizing marking head performance comes from optimally utilizing the resulting power density and character qualities.

Decrease	System parameter/system component	Increase

Mark and jump speed

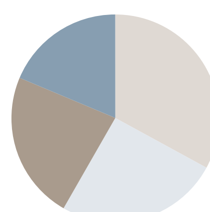
Decrease

Pro: Higher power density - less laser power required. High quality characters as galvo mirrors have enough time to 'form' desired characters. Lines are homogeneous (not chopped) and hard-to-mark materials can be processed.

Con: High power densities may require less than 100% laser power, which in turn might result in chopped lines.

Timing:

Marking time:	26 ms	23.21%
Jumping time:	21 ms	18.75%
Jump delays:	37 ms	33.04%
Stroke delays:	28 ms	25.00%
Mark delays:	0 ms	0.00%
Total:	**112 ms**	**100%**



Increase

Pro: Faster jump and marking speeds directly result in more characters per second (cps) - higher performance.

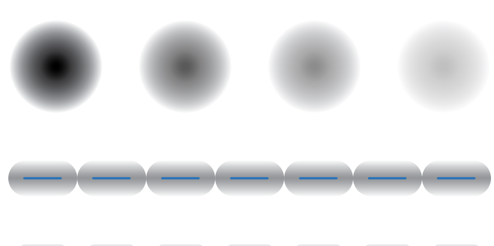
Cons: Characters may be distorted which in turn requires increased delay times which in turn reduces throughput. Relative net time to mark reduces which requires more laser power. High marking speeds at less than 100% laser power may result in chopped lines due to laser modulation.

Laser power (duty cycle)

Decrease

Pro: Average laser power can be matched to substrate requirements at given marking speed and spot size. Laser source will experience less extreme thermal conditions - lifetime may increase.

Con: Does not work for high marking speeds as laser modulation will break up lines into distinct line segments. Unreadable codes may result as a consequence.



Increase

Pro: Average laser power can be matched to substrate requirements at given speed and spot size. The higher the duty cycle the more homogeneous the lines will get as modulation gaps get smaller

Con: High duty cycles may increase thermal stress to the laser tube which may result in shorter lifetime. May not be feasible in high temperature environments at all.

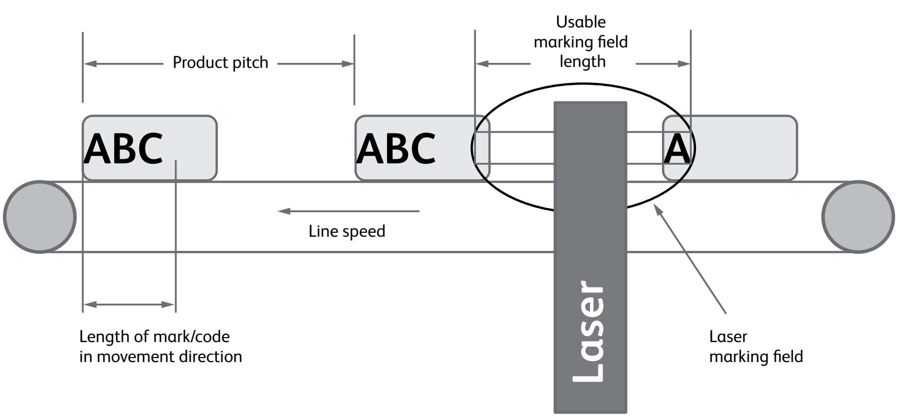
Optimal use of power density

Efficient use of available mark time

Case 1

Mark on the fly (MOTF), being marked while moving

Available marking time is typically defined by the number of products marked in a given time and the product pitch (or distance between them)

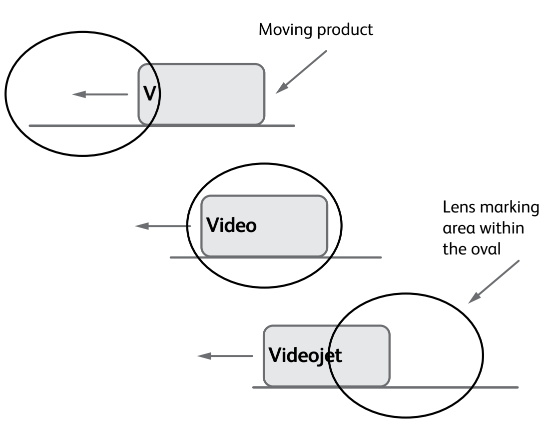


The picture opposite shows a row of products moving right to left. The oval area demonstrates the mark field, sometimes referred to as the mark window, i.e. the window of opportunity where the laser can mark on the product. The optimal combination between mark window and production line is achieved when the mark window can be used to its maximum.
That is the case when:

Mark field length= product pitch + message length (length of mark)

The available field defines, together with the speed of the product moving, the available mark time.

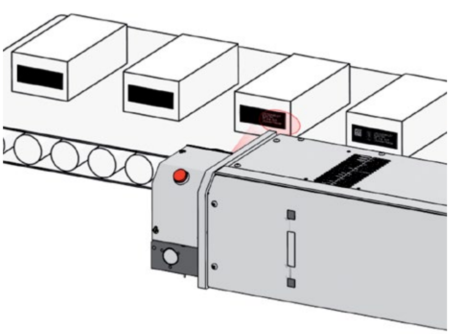
By marking on the fly, the laser can perform the required operation using minimal power. Using less power keeps the laser source cooler which extends laser tube life (we will discuss benefits of this later in the paper). When marking moving products, a sales consultant can match the best lens and marking head combination to maximize the marking time available for the particular production line set up. This is done simply by matching the best lens to the size of the product pitch. For example, if an application is mark on the fly (MOTF) and has product of 6" pitch, a sales consultant can specify a CO_2 laser with the appropriate scan head and lens combination to allow one product in the mark field over the full pitch. This maximizes how much time is available to mark the product.

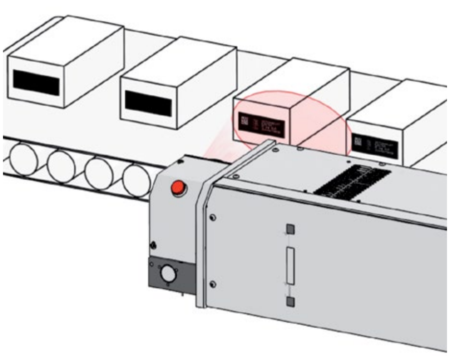


The real available time to mark:

T1 = Mark window length in time
T2 = Time it takes to make the mark.

With the correct sized mark field, you get T1+T2 as the real time to make a mark on your product. Using the entire mark field plus the time to make the mark enables faster marking, hence faster throughput or mark more content in the same time.





Despite many laser suppliers suggesting characters per second (CPS) is the most important measure for laser efficiency, the reality for most producers is that volume of correctly coded products, i.e. maximized throughput is what really matters.

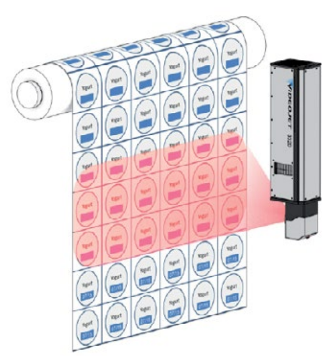
Case 2

Static/intermittent application

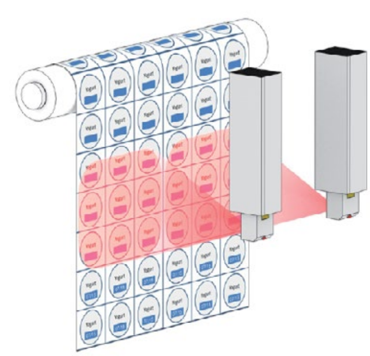
If running a wide web application (continuous or intermittent), a sales consultant can specify a Videojet CO_2 laser with the appropriate scan head and lens combination to perform the work on your product in the most efficient way.

This includes the potential to use one laser (due to an industry leading; 21 mark windows / focal length options) where many companies with less mark window options would need to specify more than one laser. For example, it is quite possible that if two lasers are currently required by company X, the same application could be achieved with one Videojet laser as shown below:

Code more efficiently and faster



One Videojet laser with 485mm wide mark window



Two lasers using 340mm wide mark window

Since there is no homogeneous world outside, each line configuration is different. Hence, the more mark window options a supplier offers, the better the laser can be configured to the specific needs of an application. With mark fields from as small as 25x20mm to as large as 485x351mm, and a total of 21 choices in between, Videojet offers the largest range of mark fields in the industry. This enables matching the optimum laser system to fit the exact application so as to be the most efficient and cost effective.

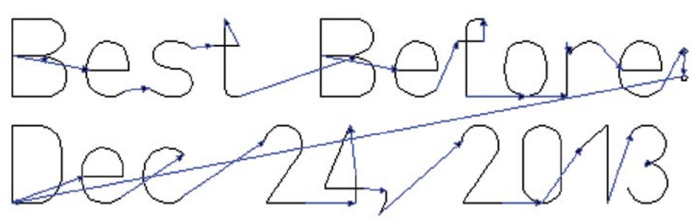
Optimal use of power density

Processing of marking information

Column vs. row writing

Optimizing the beam control helps to furthermore effectively use the available mark time. For example, there are a number of ways to write a two line code on a bottle:

Row writing

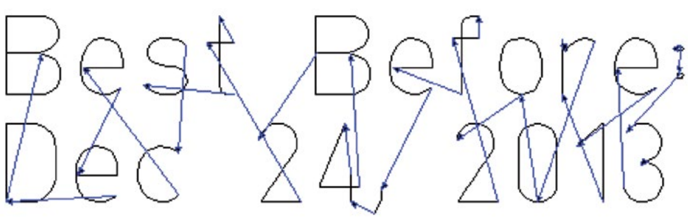


Firstly, row by row. By writing one line at a time the product has already moved within the available marking area by the time the laser needs to write the second line. The laser has to waste valuable time to jump back into position to write the second line, during which the available marking area is reduced.
To compensate for this inefficiency the laser would have to mark faster (if it can) and use more power to mark the product in time.

To illustrate this, imagine moving your hand past a candle flame – when this is done quickly you are not burnt – to feel more heat from the candle the flame would need to be bigger (more energy) or you would need to move your hand slower.

This means loss of valuable time as the product may have already passed the mark field or does not have enough time left inside the mark field to write the second row of text on the product.

Column



An alternative approach is writing column by column. This in fact makes most effective use of the marking time providing up to 50% speed advantage over conventional row writing.

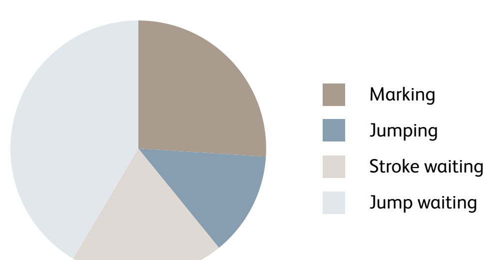
If you and a colleague were traveling from A-B you would not contemplate making the driver make two separate journeys.

It is much more efficient to make the journey once and this is similar to the column marking method. Column writing marks the first digit of the first and second line of the message together as soon as they enter the mark field, then moves on to mark the second digit of both lines in the message.

In this case, you do not loose valuable time to mark and do not risk the product traveling out of the mark window before it is able to start writing on the second row.

The mark time typically consists of actual time the laser marks in addition to the time it jumps from one character to the next. Optimizing the actual mark time vs. the jump time is another method to maximize the available time for marking. Jump time is idle and consists of jumping, waiting plus decelerating and accelerating time for the galvos.

The below chart demonstrates the average distribution of each element:



Dot font mode

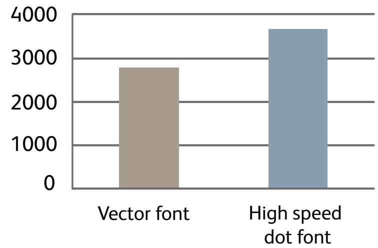
Advanced Videojet laser systems typically calculate the most efficient way of marking, in particular for long or complex codes, to achieve faster marking.

Additional software features can help to further optimize the use of time to mark, such as dot font mode to increase mark speed capabilities.

Marking with dot font software compared to traditional vector fonts can increase marking speeds by up to 30%. This allows manufacturers to increase throughput or add more code content without compromising their line speeds.

best by: 07/28/2016

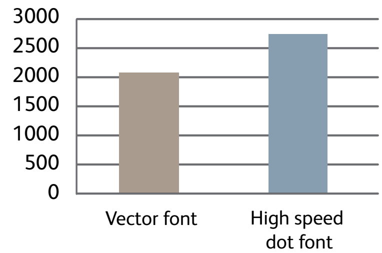
Single line best by: 07/28/2016



28% faster

best by: 07/28/2016
358710

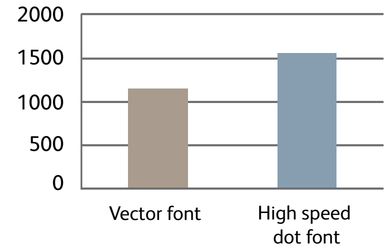
Dual line best by: 07/28/2016 358710



29% faster

born on: 03/31/2014
best by: 07/28/2016
358710

Tri-line born on: 03/31/2014 best by: 07/28/2016 358710

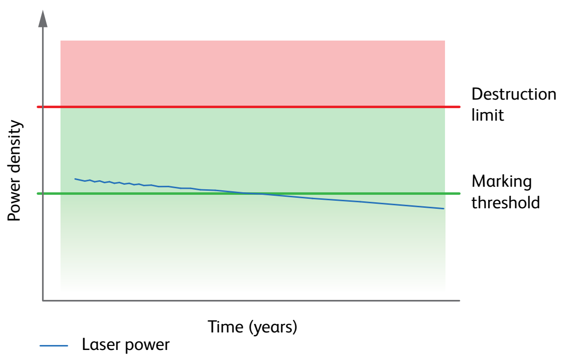


30% faster

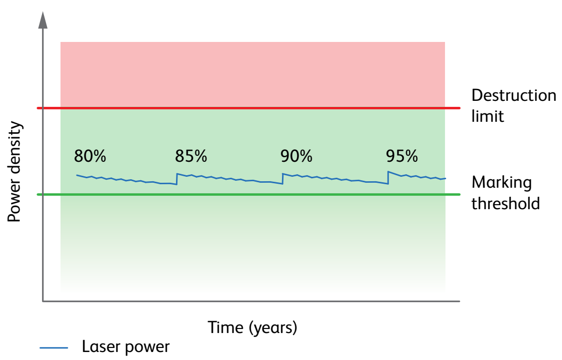
Quality of the laser sample and laser source lifetime

When it comes to analyzing sample quality, typically the first task is to look at the mark quality and contrast on the packaging substrate. If this is acceptable, the customer is happy.

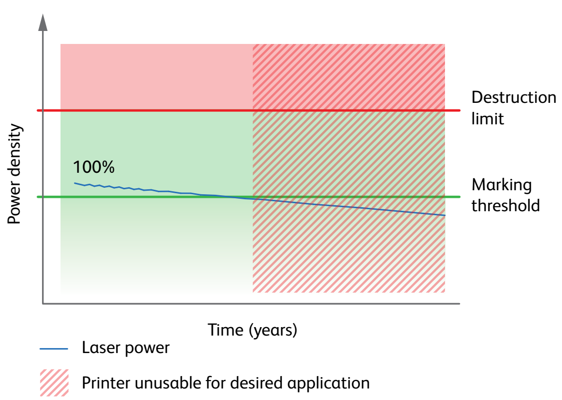
What is often not considered is exactly how a sample had been achieved. When comparing sample marks completed using a 30-Watt laser you have to ask the question: **has the sample been done using the full 30-Watt or less? Why?** Although being a sealed off CO_2 laser, there is a slight degradation of power over time. This is the result of gas deterioration due to diffusion of helium into the gas chamber and will happen in all laser sources.



1-2% degradation typically happens per annum.



To compensate the loss of power and assure that even after 5-7 years of operation the laser is still fully capable of achieving the desired performance, all initial marking tests should be done with less than 100% output power. This allows additional power to be available for adjustment over time.



As an example, typical specification for a Videojet 30W laser is an 80% setting which equals to 24W.

The main factor affecting tube life is heat. Excess heat is produced during the marking process, which in turn increases as the laser power is set higher.

The heat causes expansion at the near perfect seals, accelerating any gas loss. To maximize laser life, the tube needs to be effectively cooled. The optimum condition is to have a high performing laser that uses the minimum amount of power to achieve the desired marking result – lower duty laser needs less cooling.

Further ways to optimize tube life time

Cooling and wear on the tube are key elements to ensure a laser source lasts as long as possible. In particular, uniform cooling around the tube helps to extend source life time. The tube is not overheating on one side vs. the other, avoiding the cause of thermal stress.

There are multiple ways to keep lasers cool

Compressed air

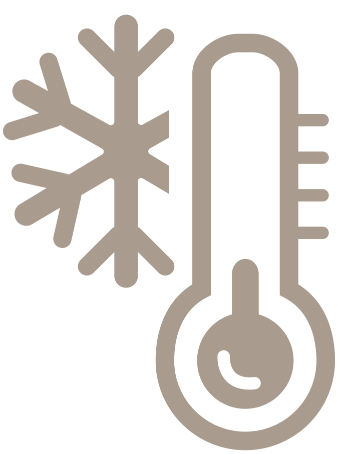
Compressed air cooling is the most expensive way to cool a laser when taking into account the energy to drive the compressor, efficiency of the compressor, leaks in the system, etc.

Fans

Fan cooling draws ambient air through the laser housing and across the laser heat-sinks to remove heat much like a PC at home cooling the processor. Another way to move air through the laser body is to use a blower to move a high volume of air through the laser housing and across the laser heat-sinks.

Liquid cooled systems

Lastly, a liquid cooling system can be used much like your automobile. Like your automobile, there can be additional maintenance associated with liquid cooling.



A laser tube is happy to run at high power, and as long as it is effectively cooled, the degradation of power is within the anticipated natural range.

In summary a laser which is being effectively cooled, and a laser meeting the application with the least amount of power is going to help maximize the laser source life time.

The importance of matching the right wavelength to substrate

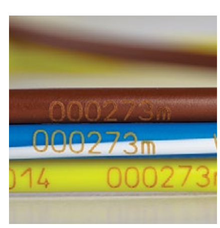
As brand marketing departments develop new packaging and artwork to entice consumers to purchase their brand, different packaging materials are brought to market. With all these materials and artwork, having multiple wavelengths to choose from in specifying a laser marker helps give marketing departments the freedom to use new materials, inks, and coatings on their products.

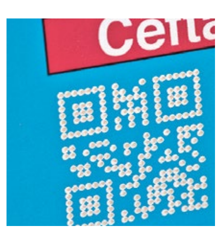
Having the option of 9,300nm, 10,200nm, and 10,600nm wavelengths allows a sales consultant to specify a Videojet CO_2 laser with the appropriate wavelength to make a high quality, permanent mark on a product without distracting from the customer's brand image.

Certain materials react differently to each wavelength and therefore matching the correct wavelength is an integral part of the specification process.

Three standard wavelengths for broadest substrate coverage

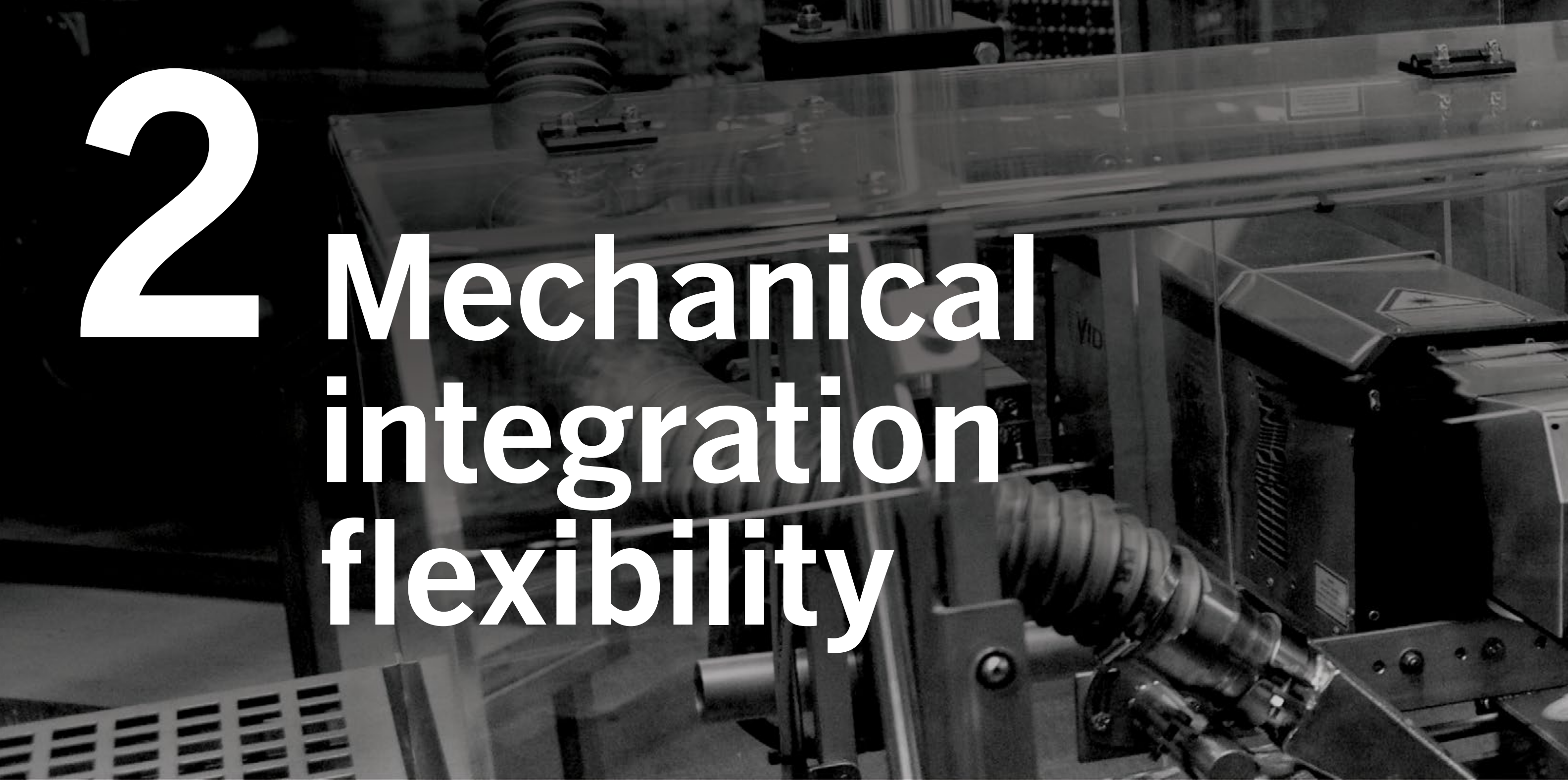
10.6µm	10.2µm*	9.3µm
Standard consumer packaging including paperboard, cardboard, various plastics and labels, as well as wood, glass and painted metal products	Laminated cartons typical in cosmetic and Life Sciences applications, PVC and other plastics	PET bottling, plastic labels and Biaxially Oriented Polypropylene films (BOPP)





*10.2µm only available in 30 Watt model



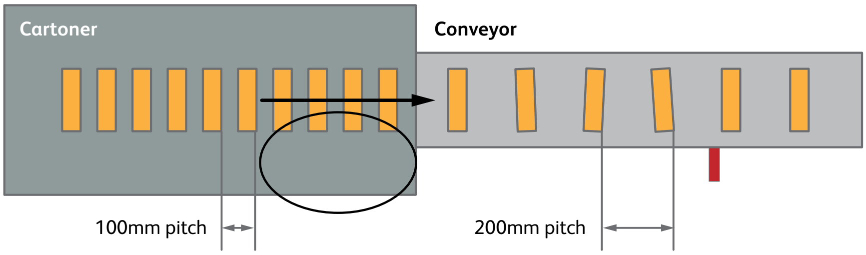
2 Mechanical integration flexibility

Besides choosing the best laser configuration, the laser also has to fit into the specific line configuration of the customer.

This can cause customer pain points not obvious at the beginning, like downtime due to line modifications to fit the laser in, sub-optimal marking position resulting in ripple or other negative mark effects, or potential safety hazards and hence non-acceptance.

The reality is that in most instances, the best place to mount a coding device is inside a piece of equipment where your product will be marked to ensure maximum control. Marking product while under control provides the best code possible and helps ensure the code complements the brand image.

Such concerns can be avoided when line integration is part of the laser selection. Understanding the production line environment and having mechanical options available (how to deliver the beam as well as configurations of the laser) can help to ensure a smooth integration into customer's existing packaging line.



Picture above: Best mounting position is inside the cartoner (oval circle) as the product to be marked is guided. In contrast, marking on the conveyor belt (although seems the most obvious) induces the risk of product movement and hence possibility of lower mark quality.

Having mechanical integration options available allows the best solution for the customer.

Mechanical options typically refer to separating the beam delivery from the marking head. This can be achieved via beam extensions or beam turning. Beam Turning Units (BTUs), or so called ‘optical plumbing’, allow for clean placement of a scan head (Marking head) inside a piece of equipment like a cartoner, flow wrapper, bagger, etc. while mounting the laser body somewhere out of the way from hazards like lift trucks, pallet jacks, careless operators, and so on.

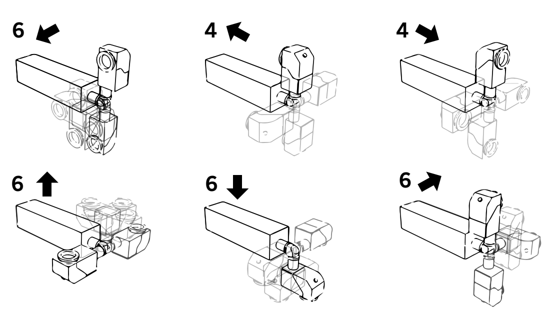
Integration flexibility comes as standard

Over 20,000 standard configurations deliver flexibility to fit your line with minimal disruption:

Option selections make it simple to configure the right beam delivery for the application. Again, the more choices available, the better the laser system can be fitted to meet the individual integration requirements.

Positioning the beam where needed

= 32 Standard beam delivery options for marking head positioning



Videojet offers 32 base configurations plus additional special application solutions.

Understanding above parameters and interaction is typically what you want to expect from an experienced laser sales expert visiting your factory.

Additional factors to consider are the design of the laser and the simplicity of the user interface.

A laser typically consists of a control unit (supply unit) and a marking unit.

Having both units connected via quick disconnects (vs. static connectors) speeds up the installation (or redeployment time) since the units can be integrated first and only then be connected with each other.

This removes the sometimes time consuming fiddling of wires and cables through the packaging line where the laser is to be integrated. In addition, various options in main umbilical length (Videojet offers 3 options, 3, 5 and 10m) will help to use the right length for the individual application.

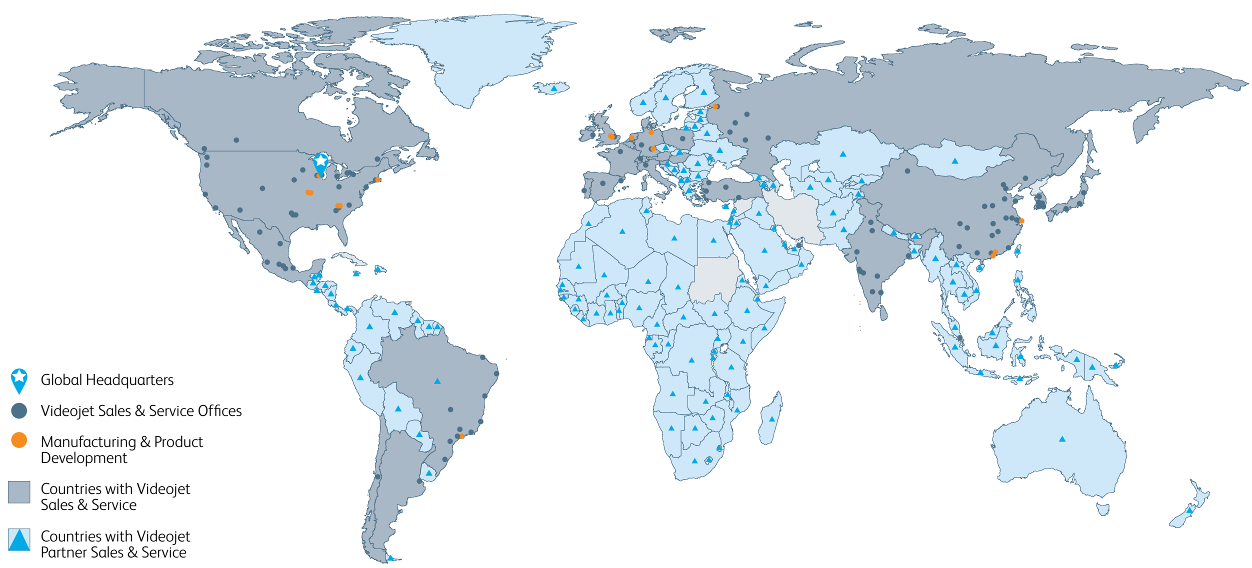
The consultation process, combined with the right laser configuration at the optimum duty, will not only provide the customer with the best solution with maximum longevity, but also one that they fully understand.

Peace of mind comes as standard

Videojet Technologies is a world-leader in the product identification market, providing in-line printing, coding, and marking products, application specific fluids, and product life cycle services.

Our goal is to partner with our customers in the consumer packaged goods, pharmaceutical, and industrial goods industries to improve their productivity, to protect and grow their brands, and to stay ahead of industry trends and regulations. With our customer application experts and technology leadership in Continuous Ink Jet (CIJ), Thermal Ink Jet (TIJ), Laser Marking, Thermal Transfer Overprinting (TTO), case coding and labeling, and wide array printing, Videojet has more than 325,000 printers installed worldwide.

Our customers rely on Videojet products to print on over ten billion products daily. Customer sales, application, service and training support is provided by direct operations with over 3,000 team member in 26 countries worldwide. In addition, Videojet's distribution network includes more than 400 distributors and OEMs, serving 135 countries.



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