GRAVOTECH
by BRADY

EBOOK

Laser marking on thermoplastics: An advanced guide for marking

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To achieve a specific result when laser marking plastic parts, you need to understand **how the laser acts on plastics** based on their respective characteristics and the laser source. Are you considering acquiring a laser solution, changing technology, or implementing laser marking in a production process?

Gravotech is here to help you. Discover in detail the **types of reactions based on laser technologies and thermoplastics**.

Find all the information in this guide... and some advice from our experts!

Our experts

Dylan GARCIA
A photonic prototyping and validation engineer, Dylan is in charge of developing the testing strategy, technological monitoring and piloting innovation building blocks linked to laser technologies.

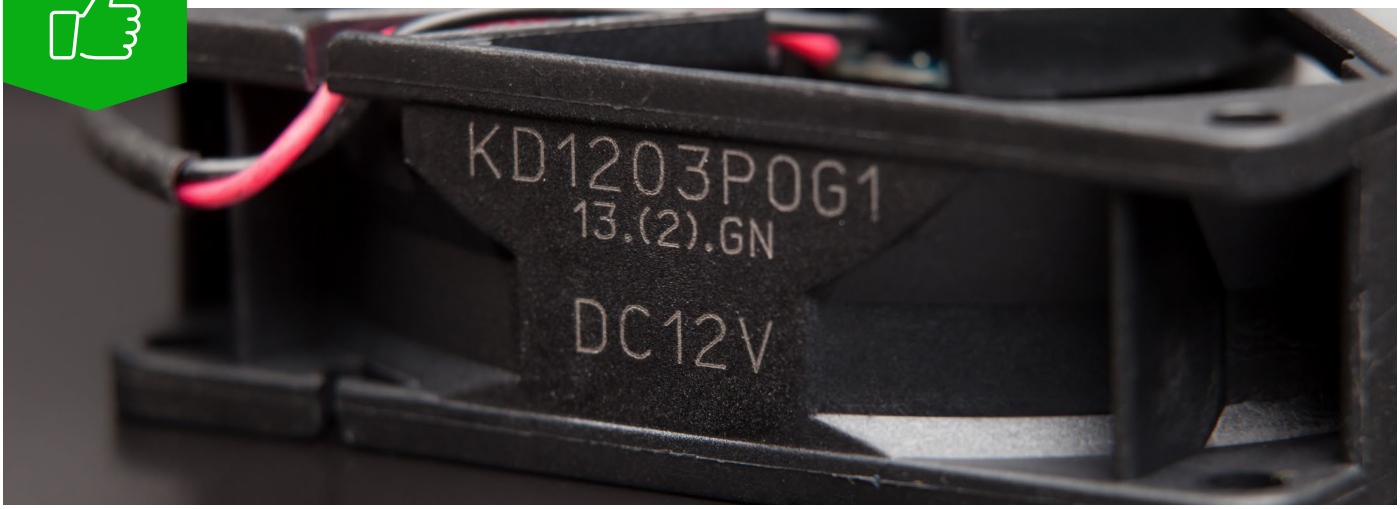
Prototype Testing and Validation Engineer

Juan José FRANCISCO DIEZ
Key Account Manager for the identification and traceability sector of the Gravotech group, Juan José ensures the strategic and commercial monitoring of major industrial clients.

Global Key Account Manager - Industry Segment

Watch our video!

Summary



[Preamble]
The advantages of laser marking

There are many technologies available for part identification in industrial sectors. But among them, laser marking has several **key advantages**.

Laser marking is **permanent**. The part identification is therefore as **durable** as the polymer. In addition, the marking is resistant to oils, aging and aggressive products to a certain extent - that is, until the polymer itself degrades.

This technology can be **faster than labeling or pad printing**. Your business gains productivity!

Today's laser machines are **reliable** and less prone to breakdowns. They also require **little maintenance**.

The laser **marks without coming into contact with the part**, which has several advantages: no tool wear, less debris and dust, and the ability to mark hard-to-reach or very small areas. It is **not necessary to hold** the part with a clamping or jaw system.

Laser machines do not require labels, ink or other consumables to operate, so **the identification cost per part is lower** than other technologies.

The 4 factors influencing the marking result

1. The polymer to be marked and its composition

The content of the components of the thermoplastic is the first criterion to take into account. This influences the interactions between the material and the laser, as well as the final rendering of the marking.

It is therefore necessary to have a good understanding **of the composition of the polymer you wish to mark** before choosing a laser solution.

Good to know

There are **thousands of types of thermoplastics**. Even within a given family, the composition of the material varies greatly depending on the manufacturer or the intended use. Added to this are the **plastics filled and recycled** or containing **organic materials**, these being increasingly present on the market.

The possibilities for laser marking plastic are therefore almost endless.

2. The wavelength of the laser

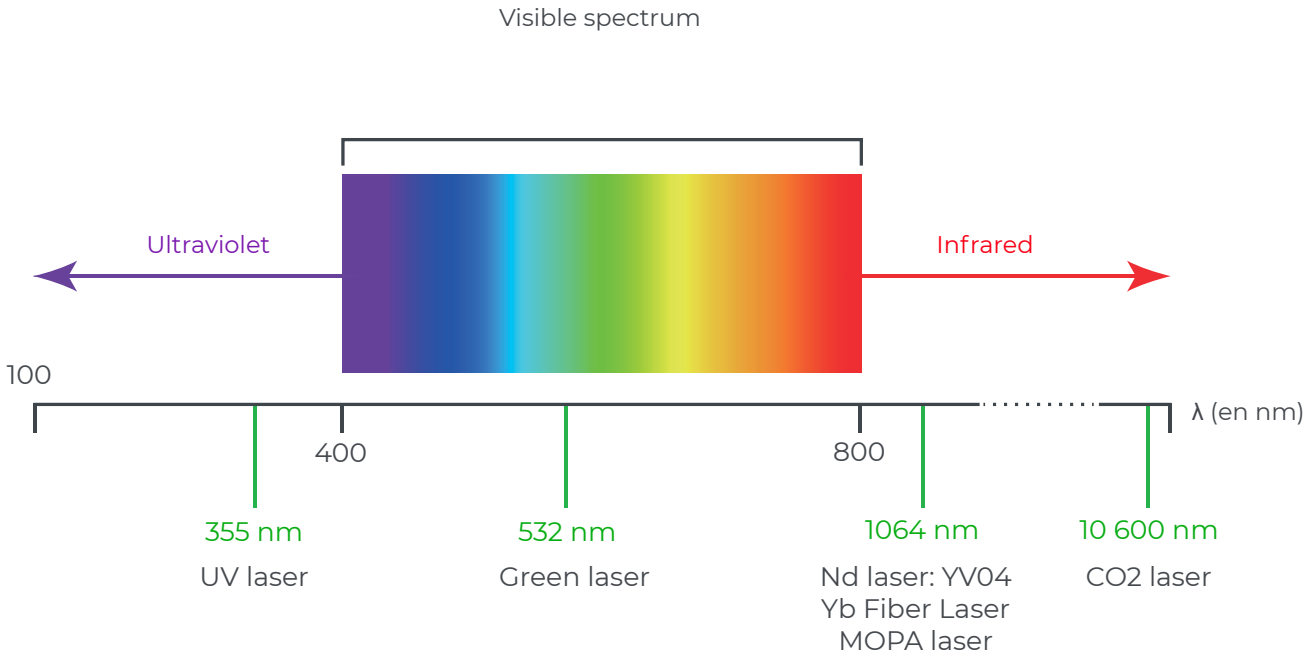
Of course, the characteristics of the laser are also to be taken into account when choosing a solution for marking plastic. While it is tempting to consider its power as the most important criterion, it is in fact its **wavelength** that takes precedence.

Reminder: the wavelength

It is expressed in nanometers and corresponds to **the distance between two successive peaks of a light wave** emitted by the laser.

It depends on the **speed of propagation** of the wave in the medium it passes through.

The wavelength of a laser influences the heat generated during interaction: the higher the wavelength (e.g., 10,600 nm), the hotter the point of contact of the laser on the plastic will be.



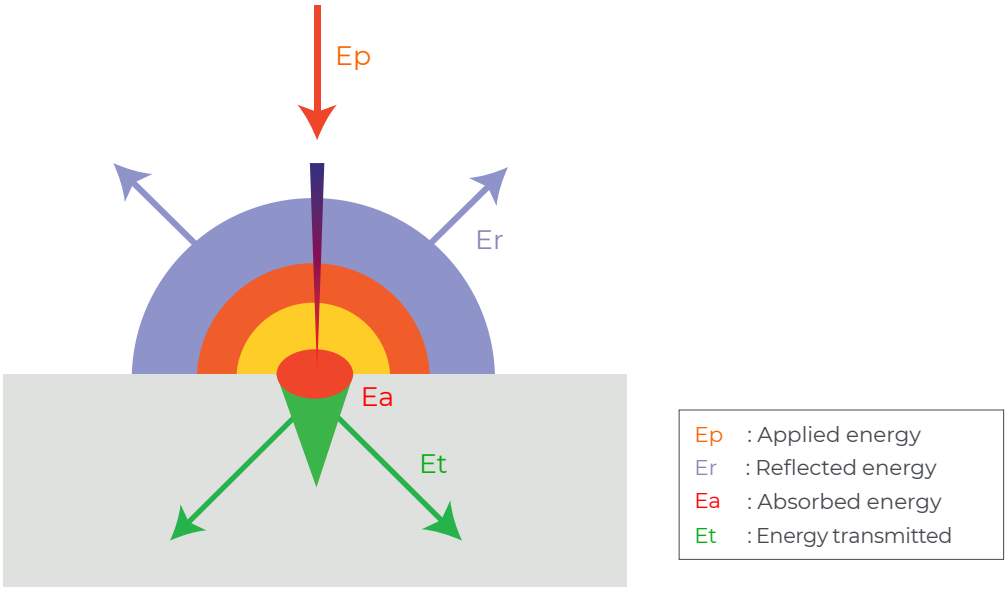
The wavelength value of a laser influences:

- the **power** of the laser;
- the **level of absorption** of the laser by the thermoplastic – which like all materials absorbs part of the laser beam at a more or less short wavelength;
- **the interaction** of the laser with the thermoplastic, i.e. how it **modifies or not the physico-chemical properties** of the material.

What is the link between laser absorption by plastics and the rendering of the marking?

When absorbed by the material, the laser can cause **thermal excitation**. This can cause **melting**, **sublimation** or **ablation** of the material.

It also influences, just like laser power, the **depth of penetration** of the laser into the plastic.



Absorption level diagram

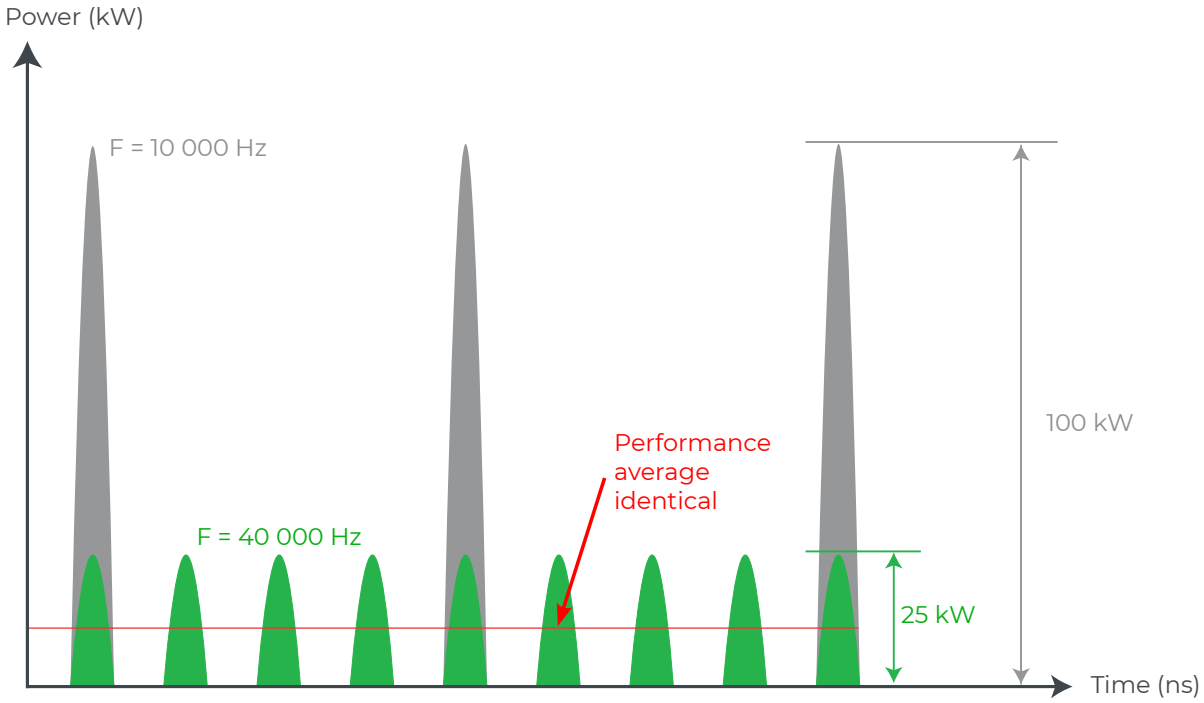
Gravotech expert advice

«For optimal interaction with matter - i.e. a conflict-free absorption level - it is recommended to use a laser with a wavelength between 355 and 532 nanometers.»

Juan José FRANCISCO DIEZ
Global Key Account Manager - Industry Segment

3. The laser pulse frequency

A laser set to a **high frequency** (between 70 and 200 kHz) emits many closely spaced pulses. Those of a laser set to a **low frequency** (between 2 and 70 kHz), on the contrary, are fewer in number and therefore more spaced out.



Graph showing two waves with different frequencies and powers, as a function of time

Gravotech expert advice

*«Low frequency lasers (30 kHz) can cause **thermal shocks** that damage plastic parts. In practice, it is better to opt for a **high frequency laser**.»*

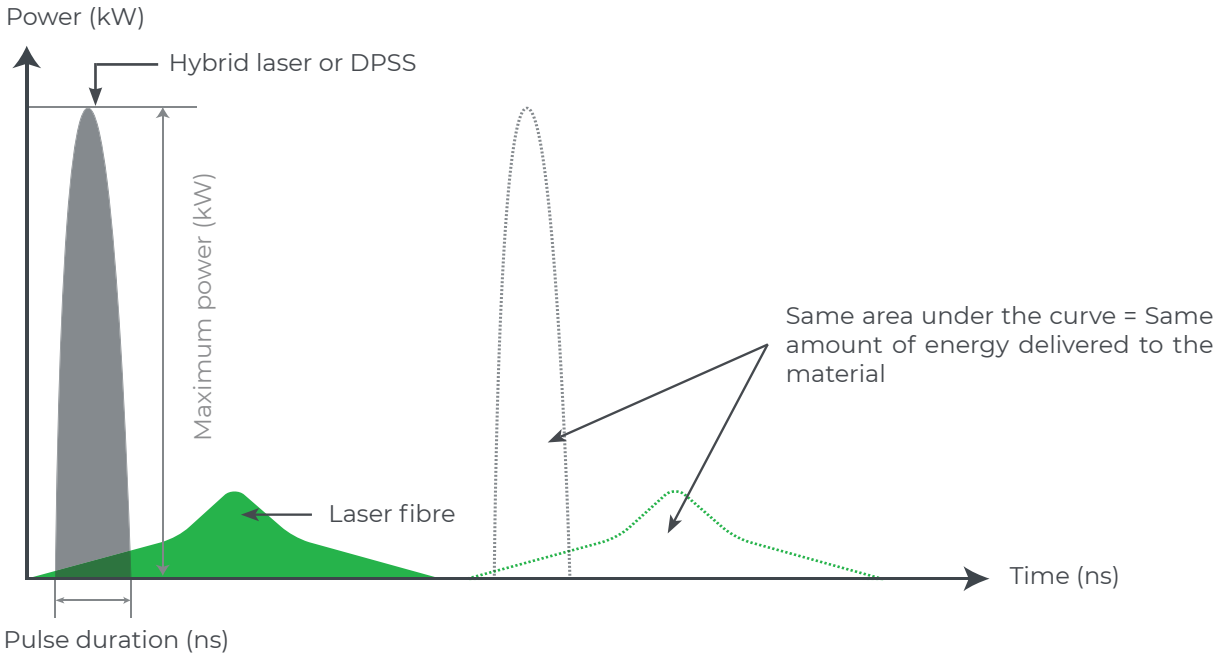
Dylan GARCIA
Prototype Testing and Validation Engineer

4. The laser wave amplitude

Reminder: definition of wave amplitude

It is the **time distance between its maximum energy emission and its resting position** (where the energy emitted is zero). It is therefore closely linked to the notions of energy and time.

Amplitude is to be considered in tandem with marking time. Let's compare a hybrid or DPSS (Diode-pumped Solid-state) laser and a fiber laser in the same operation.



Pulse duration and power delivered by two laser sources

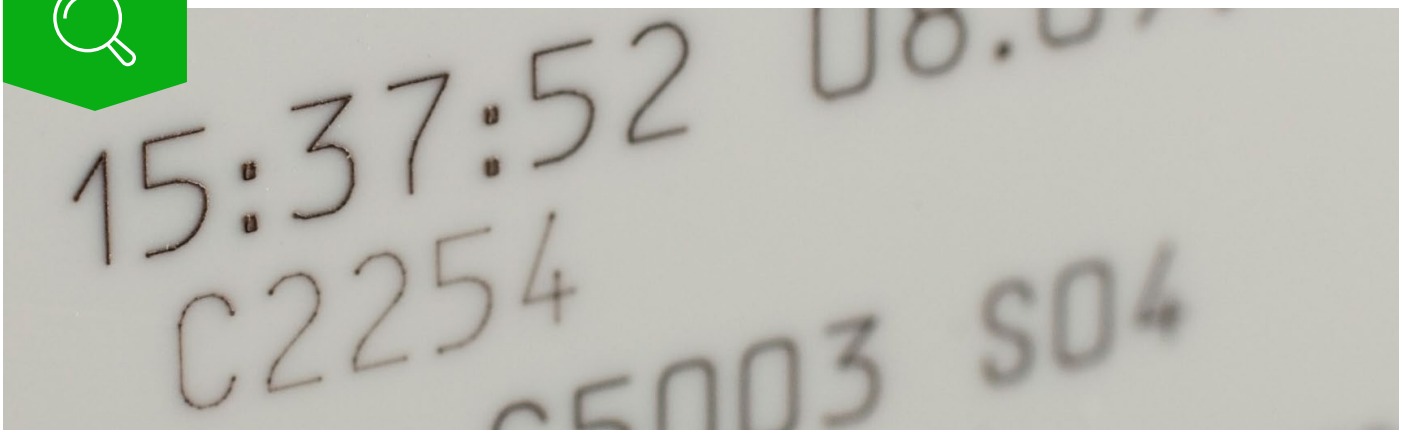
In the case illustrated above, both lasers transmit the same amount of energy to the polymer. But the fiber laser, with its lower amplitude, applies it less intensely, over a **longer period of time**. This presents a **risk of thermal heating** of the plastic part.

It is then better to opt for hybrid or DPSS technology, with its capacity to quickly deliver high energy intensity.

Gravotech expert advice

*«In principle, it is better to mark thermoplastics with a laser with a higher **wave amplitude** over a **short period of time**, to avoid damaging the material.»*

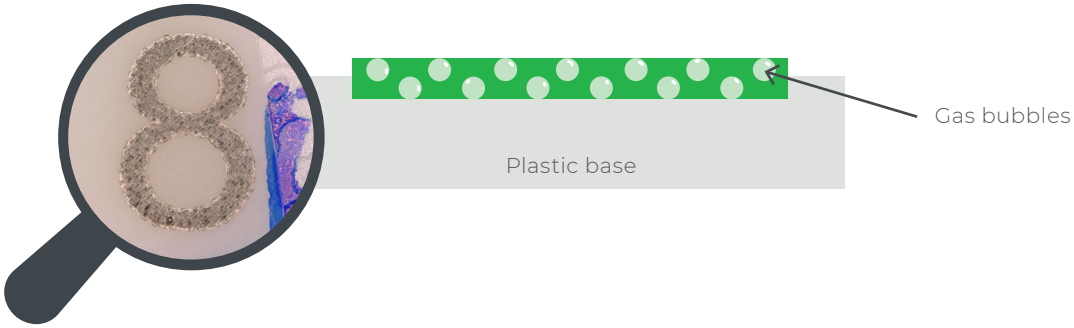
Juan José FRANCISCO DIEZ
Global Key Account Manager - Industry Segment



5 most common interactions between laser and thermoplastics

The French plastics union **Polyvia** and the Gravotech teams worked together to carry out a series of laser marking tests on polymers supplied by the organization. These tests made it possible to establish the following results:

1. Gas bubbles or foaming



Following the irradiation of the thermoplastic by the laser, **gas bubbles** form in the marked area under the effect of heat.

When cooling, these bubbles become **trapped in the upper layer** of the material. This results in a **whitish swelling**.

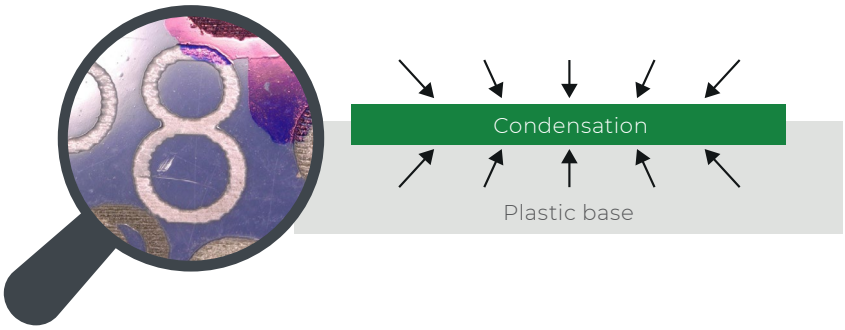
Gravotech expert advice

«This reaction produces a kind of discoloration. It is therefore particularly visible on dark thermoplastics.»

Dylan GARCIA
Prototype Testing and Validation Engineer

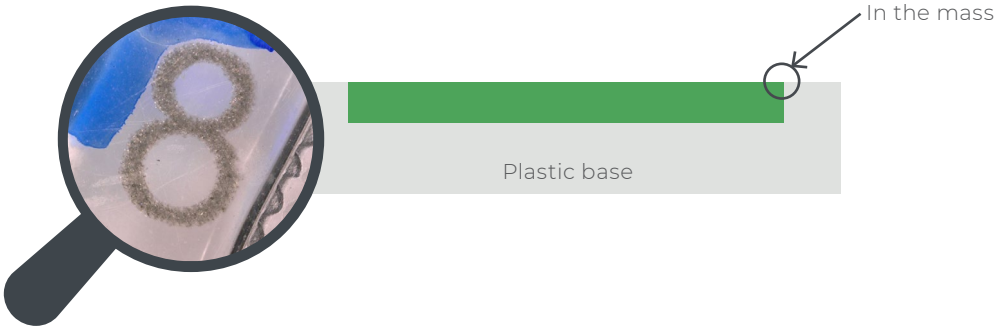
Foaming can be coupled with **carbonization**, producing a gray or black swelling.

2. Surface coloring



Here, the material absorbs the energy provided by the laser radiation. The resulting series of thermal reactions leads to an **increase in the molecular density** of the marked area. This then visibly **swells**.

3. Body coloring

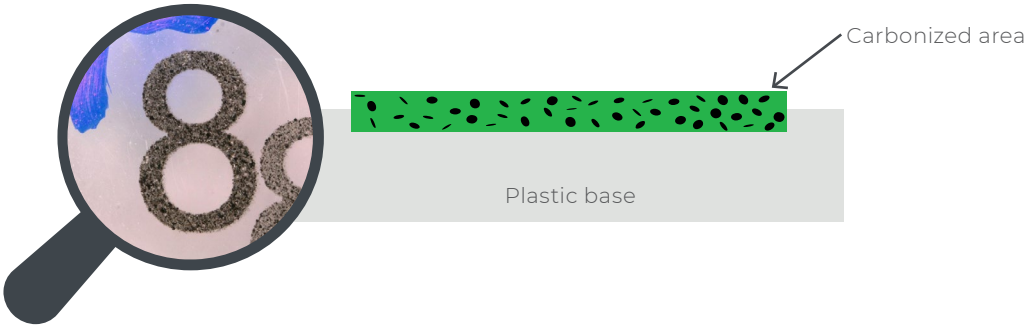


Here, the laser **changes the chemical composition** of the material's constituents.

More precisely, it modifies the «**pigments**» of the thermoplastic. These generally contain metal ions. The laser induces a modification of the crystalline structure of these ions, as well as the degree of hydration of the crystal.

These "pigments" then become **more intense** and the material undergoes coloring.

4. Carbonization



This reaction occurs when the area facing the laser is **continuously irradiated**. The macromolecules of the material are carbonized, which produces a **black tint**.

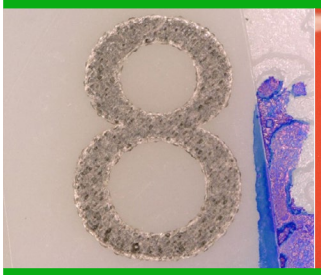
Foaming can occur in conjunction with this interaction. You then get **carbonized foam**.

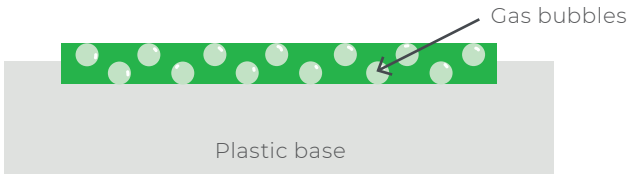
5. Sublimation

The laser causes the material to «sublimate» by thermal effect and creates a **depression** in the irradiated area. This «cavity» is revealed by reflection of ambient light.

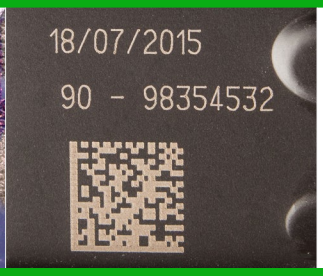
The 5 interactions in pictures

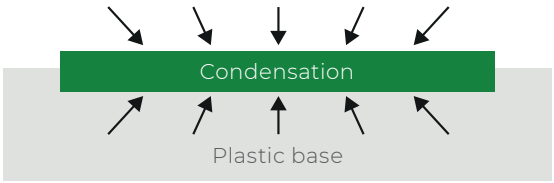
Gas bubbles or foaming



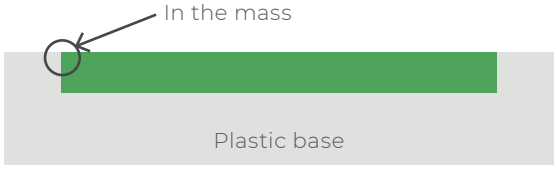


Surface coloring

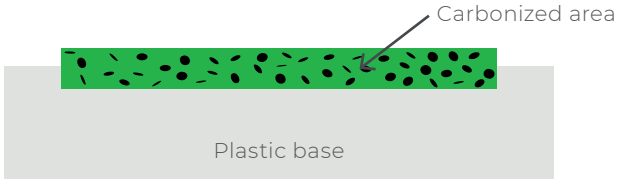




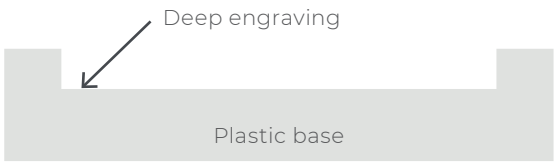
Body coloring



Carbonization



Sublimation



The reactions of plastics to different laser technologies

The green DPSS laser

The green DPSS laser provides e**xcellent results for marking plastic**.

Thanks to a wavelength of 532 nm, it ensures **optimal absorption** by polymers, especially transparent or clear plastics.

Of the polymers tested, 30% showed satisfactory results, 45% showed excellent quality markings and only 15% did not react.

With a power of 5 W and a peak power of 95 W, this laser operates cold, thus reducing the thermal stress suffered by the materials. This feature is particularly sought after for the **identification of sensitive materials**.

Its short pulse duration, ranging from 7 to 50 ns, and small beam spot size ensure superior marking accuracy and resolution. It offers a marking area from 65 x 65 mm to 150 x 150 mm (2.6 x 2.6'' to 5.91 x 5.91'').

Is the green DPSS laser the optimal solution?

The answer depends on your project. To ensure high-quality marking, two fundamental aspects must be taken into consideration:

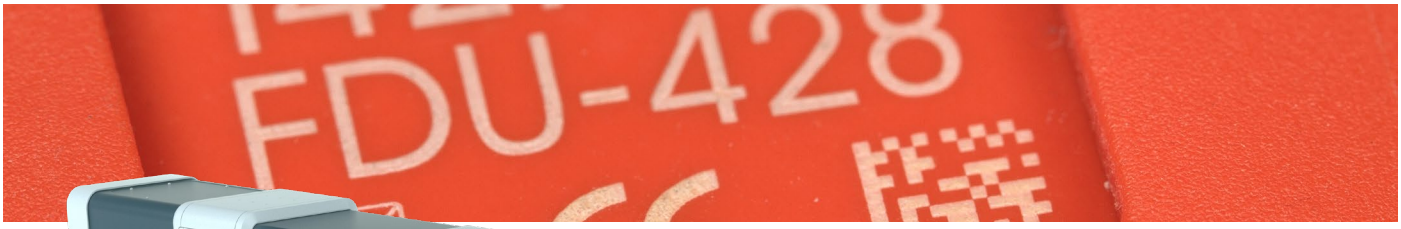
- **Nature of the material** : The green DPSS laser is not universally suitable, with some plastics reacting more favourably to alternative wavelengths.
- **Operating parameters** : Laser performance is determined by factors such as emitted power, scanning speed and energy density.

The DPSS laser involves a larger **investment** compared to other sources but with an extraordinary yield. Nevertheless, the selection of a fiber or hybrid laser can be well justified if the tests made on the plastic material are satisfactory.

The fiber laser

It operates at a wavelength of 1064 nm and offers marking areas ranging from 65 x 65 mm to 300 x 300 mm (2.56 x 2.56'' to 11.81 x 11.81''), with available powers of 20, 30 or 50 W, for peak powers of 10 kW and a pulse frequency ranging from 2 to 200 KHz.

It stands out for its power and exceptional ability to mark metals with great precision. Fiber laser technology is also **capable of marking most plastics**, although the rendering can vary considerably depending on the type of polymer used. In fact, the contrast of the marking is **optimal** for **42%** of polymers and **16%** show **excellent results**.



The hybrid DPSS laser

It has a wavelength of 1064 nm, with marking areas from 65 x 65 mm to 205 x 205 mm (2.56 x 2.56'' to 8.07 x 8.07''), powers of 10 or 20 W, peak powers of up to 150 kW, and a pulse frequency ranging from 10 to 100 Khz.

Hybrid DPSS lasers are more precise thanks to their short laser pulse duration, thus offering **better marking results on polymers**. Among 60% of polymers offering a contrast that meets Gravotech's expectations, **30%** offer an **excellent marking result**.

Good to know

These two technologies make it possible to largely address industrial constraints such as traceability challenges.

The CO2 laser

Operating at a wavelength of 10,600 nm, the CO2 laser offers a marking area ranging from 70 x 70 mm to 210 x 210 mm (2.8 x 2.8'' to 8.3 x 8.3''), with a power of 30 W and a continuous pulse frequency.

A CO2 laser source causes **ablation or sublimation** of the marked area on most polymers, typically resulting in a **low-contrast** marking, where a cavity is created. It is the reflection of light in this cavity that allows the marking to be seen.

However, some materials, especially **clear plastics**, may react differently, producing a **white mark on the surface** of the material.

Gravotech expert advice

*«Does your polymer's properties prevent it from being marked with one of these sources? You can usually get around this problem with an **additive**, such as color pigments, or an appropriate **masterbatch**.*

These allow the polymer, in most cases, to react to laser irradiation and to mark the part. »

Juan José FRANCISCO DIEZ
Global Key Account Manager - Industry Segment

Summary of possible interactions for each laser technology

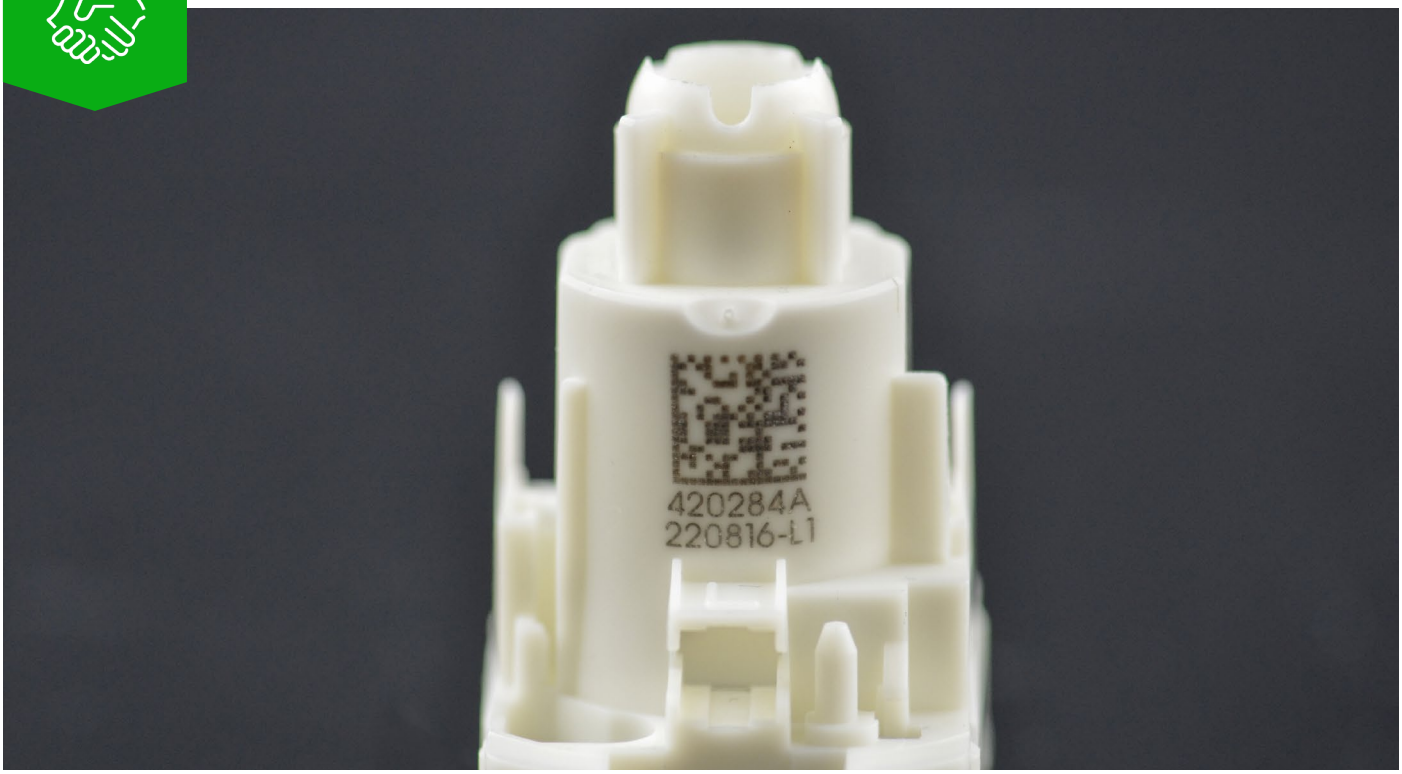
Thermoplastic families	Materials	Possible interactions				
		Foaming / Bubbles	Surface coloring	Carbonization	Coloring in the mass	Ablation
Polyolefins	HD PE		Green/ Hybrid	Green		CO2*
	PP	Hybrid	Green/ Hybrid		Hybrid/ Fiber	CO2*
Polystyrenes	ABS	Fiber***	Fiber	Fiber***	Green	CO2*
Linear polyesters	PET		Green		Green	CO2*
	PBT	Fiber		Green/ Fiber	Hybrid	CO2
Polyacetals	POM		Green			CO2*
Polymethacrylics	PMMA	Green			Green	CO2*
Polyamides	PA		CO2**	Green	Green/ Hybrid	CO2*
Polycarbonates	PC	Green/ Hybrid/ Fiber	Green/ Hybrid	Green/ Hybrid/ Fiber		CO2*
Others	PPE		Green/ Hybrid			CO2*
	PPS		Green/ Hybrid			CO2*
	TPU			Green		CO2*
	PPA				Green	CO2

These results are based on internal tests with thermoplastics following a Gravotech study. Please note that not all colors are represented, and some laser technologies will cause different reactions. To ensure the rendering of your plastic markings, **Get in touch with Gravotech experts** to carry out sampling and testing phases.

**: Marking without contrast on non-transparent thermoplastics.*

***: Contrasting marking.*

****: Marking producing a carbonized foam.*



Why choose Gravotech

Hybrid, fiber, green or CO2 laser? The in-depth study conducted by experts from Gravotech and Polyvia has enabled a panel of tests to be carried out to facilitate the choice of laser and its configuration, depending on the type of thermoplastic and the desired rendering.

By turning to Gravotech to choose the solution best suited to your projects, you will benefit from comprehensive support including in particular:

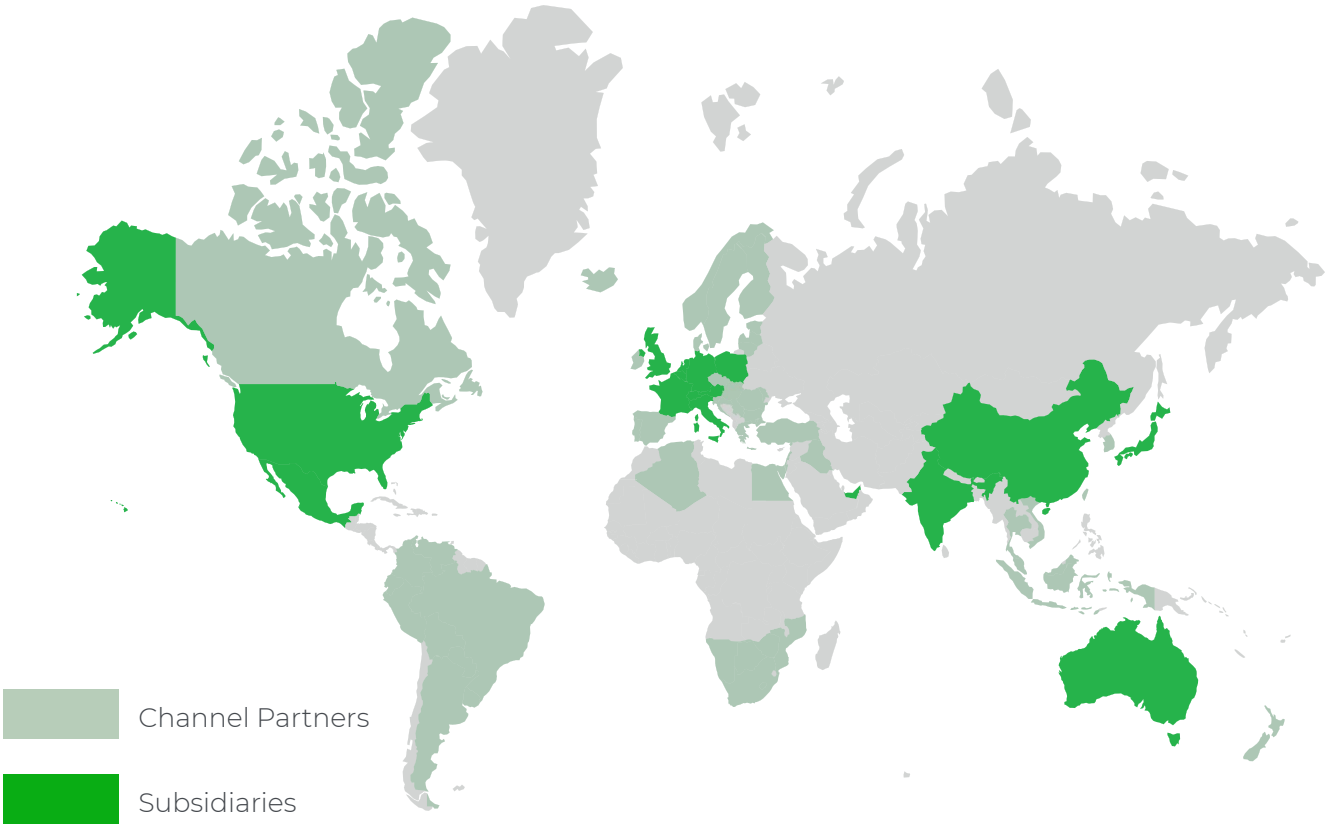
• testing phases, to determine the most suitable technology, depending on the desired result;

• the configuration of your machines according to your needs.

Contact the Gravotech teams to guide you!

Contact an expert

Gravotech, leader in permanent marking solutions



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