# LASER CUTTING: THE ULTIMATE GUIDE

sculpteo

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**Welcome to Sculpteo's Ultimate Guide of Laser Cutting!**

In September 2016, **Sculpteo** will be launching its **new laser cutting online service.** While Sculpteo is specialized in 3D printing, we now offer our customers this digital manufacturing technique service that can be combined with 3D printing or uses on its own to cut various materials: cardboard, plywood, MDF and acrylics.

May you be an engineer, a company looking for a manufacturer, or just a curious reader, Sculpteo's team put its best in this guide to teach you **where the laser cutting technique comes from and how it works**.

And while you will get to know the **different uses** of laser-cutting, you will probably realize that laser-cutting is a process easy to master and easy to **associate to your own project**!

So keep an open mind, and, as you read our guide, you will probably find answers to your questions: which type of laser would be best for my project? how can I turn my project into a vector file that will - hopefully - one day become a real object? what material can I use?

Before diving into the mysteries of laser-cut, here is a brief summary of what you will find in our guide:

## Part I: Origins and operating of laser cutting

Laser cutting is a type of **digital manufacturing technique** known as "subtractive". It uses a large amount of energy generated by a laser, concentrated on a very small area, in order to **cut** or **engrave** a material. There is a broad range of materials that can be cut with a laser: wood, plastic, cardboard, textile...

Laser cutting works by directing the output of a high-power laser through **optics.** They direct the **laser beam** generated on a small zone of the material. The material then either melts, burns, vaporizes away, or is blown away by a **jet of gas**, leaving an edge with a good-quality surface finish. The laser can cut until a 20mm-thick material, depending on the type of laser.

## Part II: From design to object

Commonly used in the **industry**, laser cutting machines function from digital orders, based on the topographic information contained in a **vector file**. They cut or engrave the material plate in different locations, thus allowing an item's surface to be delineated and decorated. To use the laser as a cutting tool, you need a 2D vector file, created on a dedicated **software**. The designer enters all the informations about his pattern - material, thickness, shape - before sending it to the machine. When the pieces are ready, you just need to assemble!

## Part III: Applications of laser cutting

The laser-cutting technique is always evolving: **materials diversification,** increasing thickness of the cut, and a better-looking finished aspect made laser-cutting one of the most attractive industrial techniques of the past few years! It is now very common on the production line, to cut parts in **automotive and aeronautic factories**, but also to build **solar panels**, or to design pieces for **fashion** shows. It is widely used by architects, also in **sign-manufacturing**.

# PART ONE:
# ORIGINS AND OPERATING OF LASER CUTTING

**A. LASER AT ITS ORGINS**   **B. FROM LASER TO LASER-CUTTING**   **C. HOW DOES IT WORK?**

## 1) HOW WAS THE FIRST LASER INVENTED?

During World War II, the physicist Charles Townes worked at the **Bell Laboratories** on the radar assisted bombing systems and microwaves generators. In the 50's, following an Einstein theory, stimulated emission, where energy is extracted from a transition in an atom or molecule, Townes thought about creating a photon flux, all alike, thanks to the **amplification of a magnetic wave**. That's how he created the first device, called Microwaves Amplification by Stimulated Emission of Radiation, i.e. "MASER".

Masers were modestly useful, for scientific research mainly but not so much for military or industrial applications. Only a few scientists thought an infrared maser might be important. Moreover, infrared rays could not be manipulated like radar, and were hard to manage at all.

Yet, Townes thought about this idea intensively. And in 1957, studying the equations for amplifying radiation, he realized that it would be easier to make it happen with very short waves than with far-infrared waves.

He associated Arthur Schwalow, his friend and brother-in-law to his research, and Schawlow brought the solution: put the atoms you wanted to stimulate in a long, narrow cavity with **mirrors** at each end. The rays would shuttle back and forth inside so that atoms would be likelier to radiate. One of the mirrors would be only partly silvered so that some of the rays could leak out.

The same arrangement also occurred to Gordon Gould, a graduate student at Columbia University who had discussed the problem with Townes.

Even though Gould, Schawlow and Townes understood the principles of building a laser, none of them managed to build the device. In 1960, Thomas Maiman brought to life Townes' dream and made the first ruby laser, producing a perfectly straight red laser beam.

### Did you know...?

"LASER" is an acronym for "Light Amplification by Stimulated Emission of Radiation".
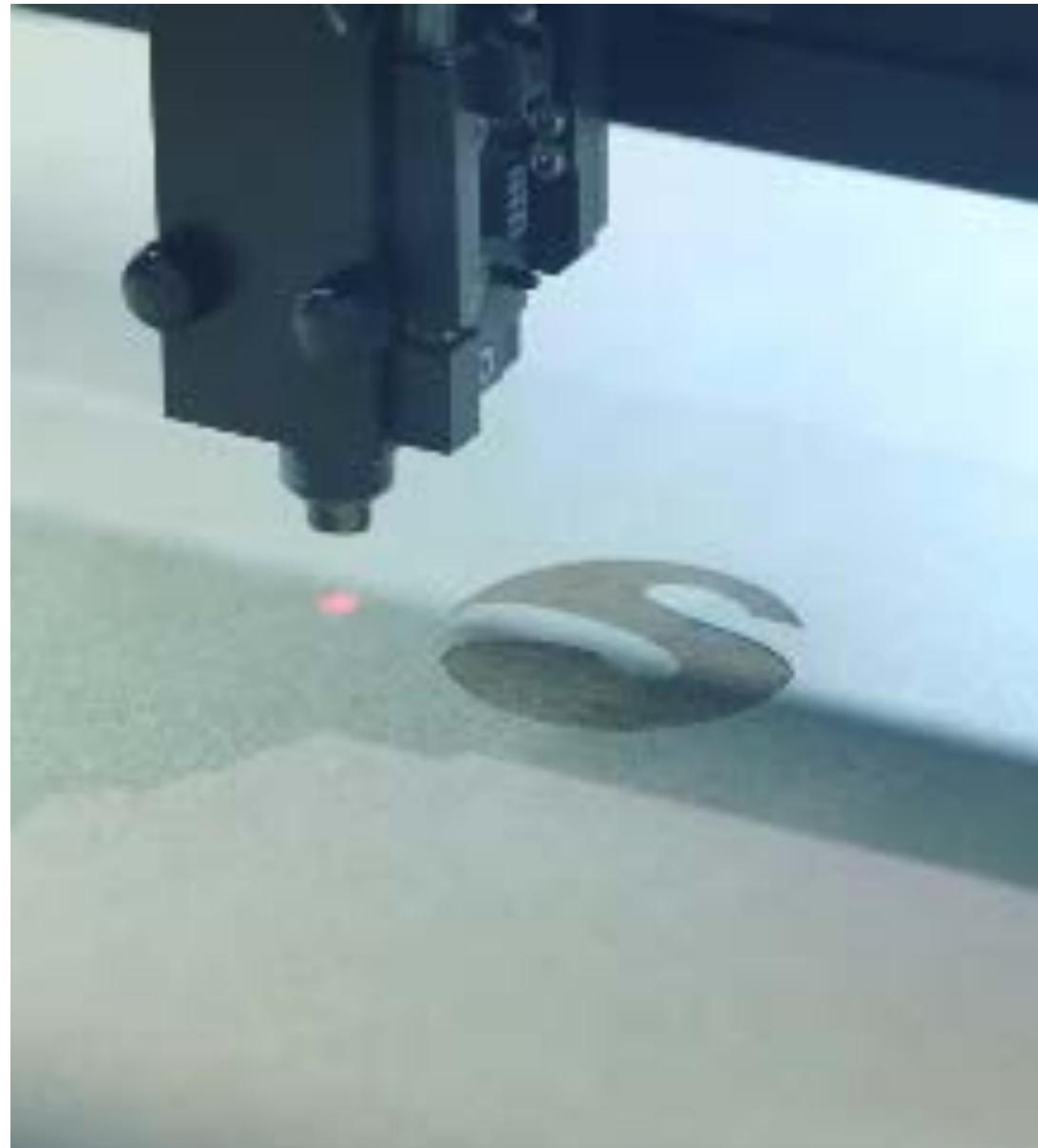
## A. LASER AT ITS ORGINS

### 2) HOW WAS IT USED?

Physicists were the first to use lasers in their research work thanks to **colored laser beams**, invented in 1966. Colored beams were a great progress for spectroscopy and enabled scientists to study properties of atoms and molecules, since radiant energy, in this case the laser beam, interacts differently with specific types of matter.

1966 was a good year for lasers! The very same year, the laboratory "Optical functions for information technologies" in Lannion, France, launched the first **transmission of information** through air with a laser. Thanks to this experiment, lasers are now massively used in **telecommunication**. Lasers are also employed to read informations engraved on CDs and DVDs, created respectively in 1982 and 1995.

Telecommunication is now the main market for lasers. The next ones would be **industry and micro-processing**, which use laser for its thermic properties as a cutting, welding and drilling tool.

### 1965 : Laser is used as a drilling tool

The **Western Engineering Research Center,** in Buffalo, USA, was the very first one to employ a laser as a cutting device. At this time, diamond dies were used to manufacture wire for electrical connections. Thousand of dies were required for this kind of operations, and piercing the dies or resizing them was both a costly and a slow process, up to 24 hours of making.

Instead of metal drill or diamond dust, used so far, engineers used a laser. Many of the conducted tests were **safety-testing**. The effects of laser beams on eyes and skin, or of the vaporized materials on the worker's health had not yet been established.

### 1967 : First gas assisted laser-cut

Peter Houldcroft, the Deputy Scientific Director at The Welding Institute, in Cambridge was one of the pioneers in experimenting with laser-cut in the 1960's. He realised that the combination of a focused laser beam and an **oxygen assist gas** had the potential to improve the precision and speed offered by thermal cutting processes.

In 1967, Houldcroft has the inspiring idea of adding a "laser cutting nozzle", with an oxygen pressure chamber which provides an assistant gas stream in the region of the laser beam focus. The results of the first experiments were published in August 1967 in the article "Gas-jet laser cutting" by Arthur Sullivan and Peter Houldcroft, in the British Welding Journal, and its conclusions are visionary!

*'With the development of higher power lasers it should be possible to cut thicker and different materials including non metals.'*

*'The narrowness of the cut promises a precision not previously obtained with thermal cutting techniques.'*

- Peter Houldcroft

## B. FROM LASER TO LASER-CUTTING

### 1969: First industrial use in Boeing factories

The American company **Boeing** is the first one to integrate laser-cutting on its production lines. In August 1969, three employees from the Boeing Company produced a paper on the [CO2 laser cutting](#) of "hard" materials - titanium, Hastelloy and ceramic - using the assist gas technique. They concluded that the laser "could be an effective and economical cutting tool, but a great deal of research and development may be required before such a machine could be put on the production line". In the 1970's, Boeing patented the **multi-beams laser-cutting** and was among the pioneering companies cutting titanium with a laser.

### 1979: 3D laser-cut

In 1979, the Italian company Prima Industrie invented the first **3D laser-cutting** process with a 5 axes rotation system.

### Laser-cut today

Forty years after the invention of Houldcroft, laser-cutting is everywhere! And it's not only for metals anymore: plastic, wood, paper, cardboard, textile, ceramic. Our lasers now have good-quality and **high-precision beams** which can cut through materials thick up to 20 mm, with a clean and narrow [kerf](#), and no need to resize or polish the material.
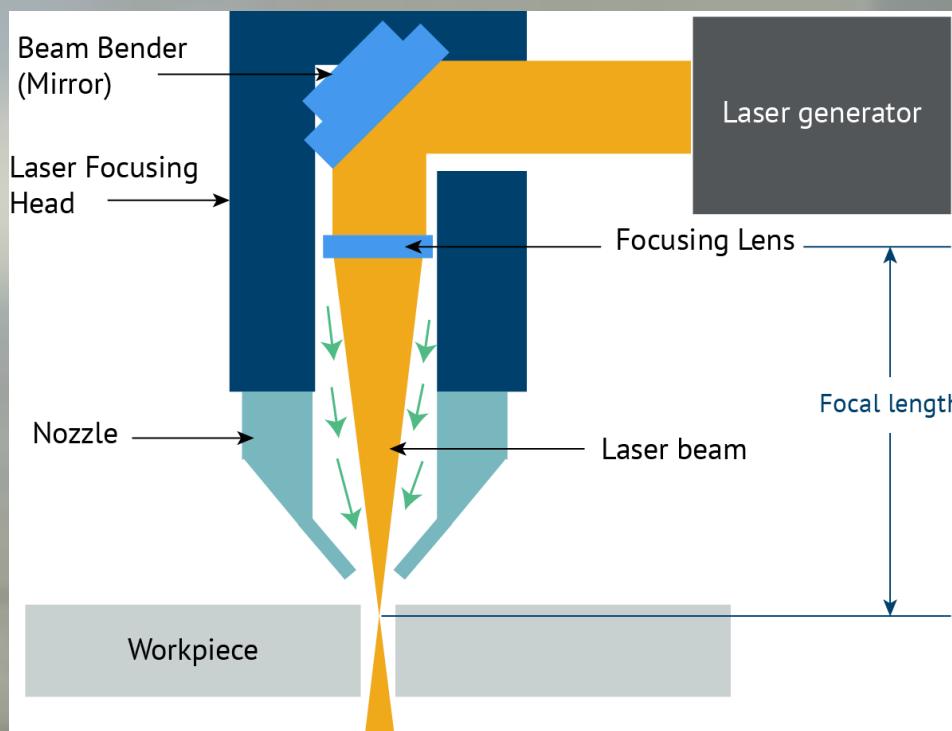
Industry stays the biggest buyer. **Automobile companies** especially, but lasers are also employed to create **solar panels** by cutting photovoltaic cells in silicon slabs, or to drill holes in the blades of turbines in order to cool **aerospace** constructions. Engraving objects, for example letters on keyboards, the brand on the side of your phone or your pen, is also a frequent use for lasers. Paired with **3D-print**, laser-cut opens up the field of possibilities in industry!

## A. LASER AT ITS ORIGINS    B. FROM LASER TO LASER-CUTTING    C. HOW DOES IT WORK?

The laser originates from a **laser resonator**, which sends out a **beam** of intense light that reflects through a system of **mirrors** to the **cutting head**. Within the cutting head, the laser is focused through a **lens** and narrowed down to an extremely thin, concentrated beam.

The active laser medium can be:
- **a solid**, such as a crystal. Maiman actually built his first laser using a crystal, a ruby in his case;
- **a gas mixture**. The oxygen is the most common type, with a mixture of composing of carbon dioxide ($CO_2$);
- **fiber**, most of the time glass fibers.

The laser resonator creates the energy at the origin of the beam. It can be:
- **light**, thanks to diodes or lamps ;
- **an electric discharge**.

This beam is projected down at the material to cut it thanks to an **optical system** which is composed of mirrors and lenses.

Beam Bender (Mirror)

Laser Focusing Head

Laser generator

Focusing Lens

Focal length

Nozzle

Laser beam

Workpiece

## C. HOW DOES IT WORK?

When the resonator generates lasers, **mirrors** guide the beam in the required direction and **lenses** focus it at the necessary point. The crystal or the gas helps giving a more **precise direction** and amplifying the laser beam. The **focusing** also multiplies its cutting power. Most laser-cutters employ capacitive height control to maintain an accurate gap between the workpiece and the nozzle-end, which is the exit point for the laser beam. This gap will determine the cut quality.

Laser cutters cut by a melting, vaporizing, or burning action. **Compressed gases** such as oxygen and nitrogen exit as well from the nozzle-end and flush the molten debris off the kerf.

**SAFETY FIRST!**
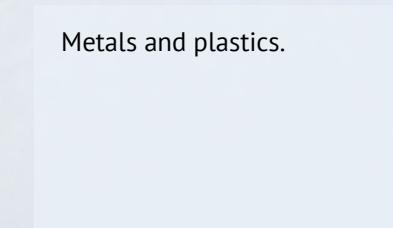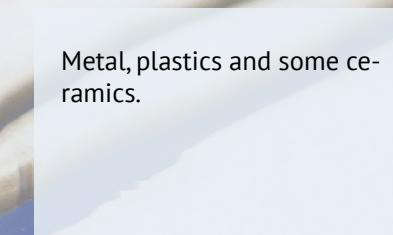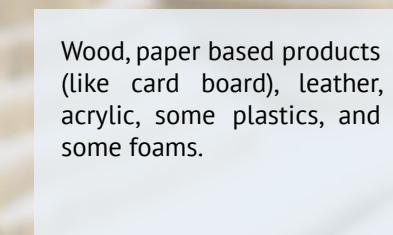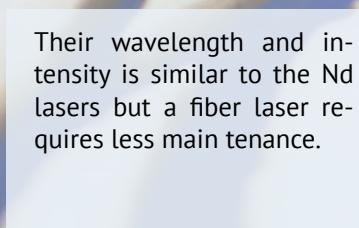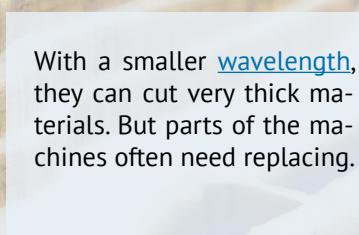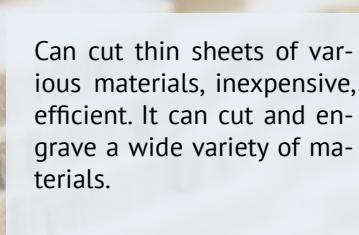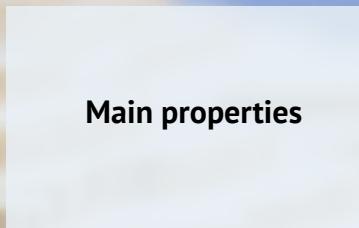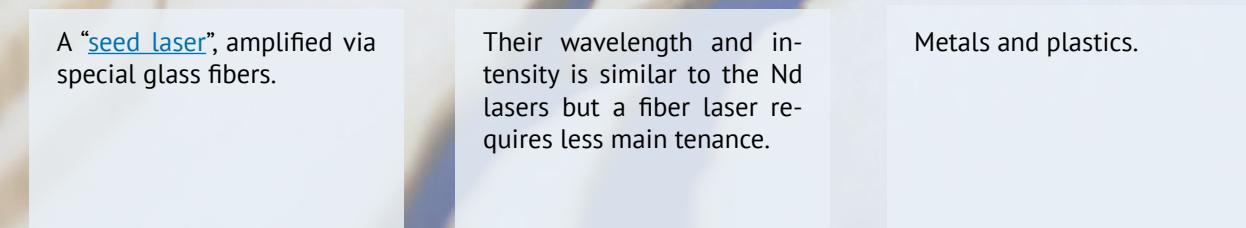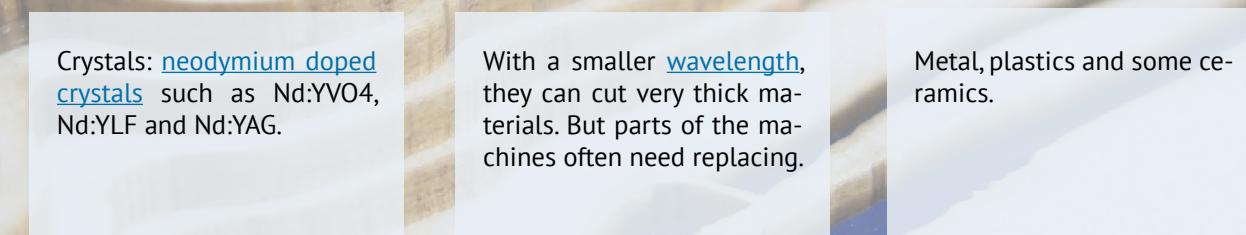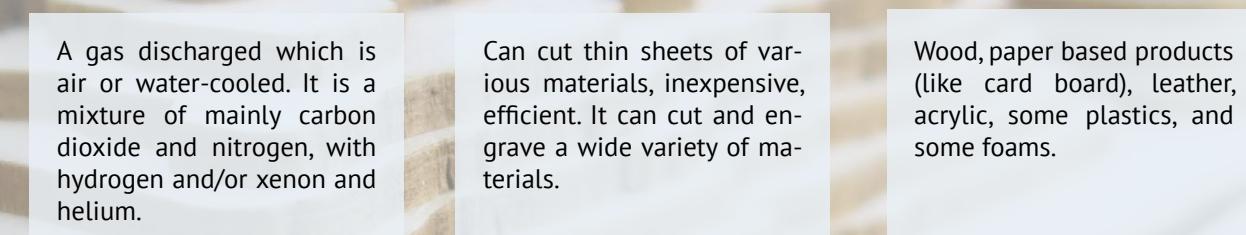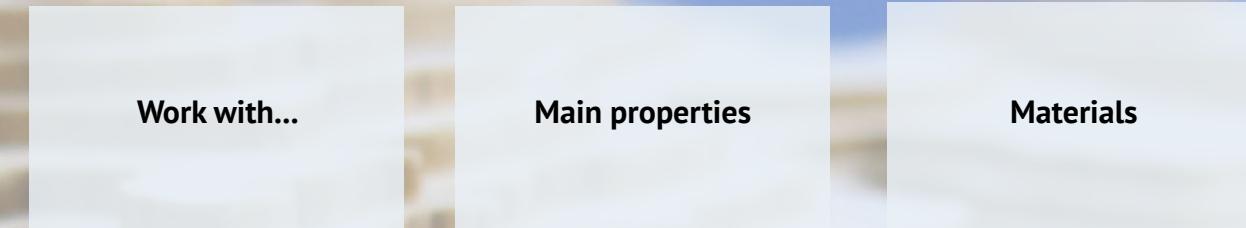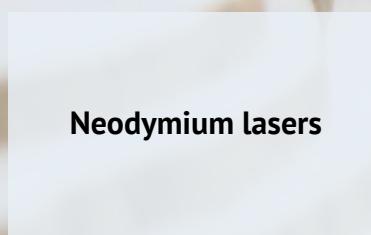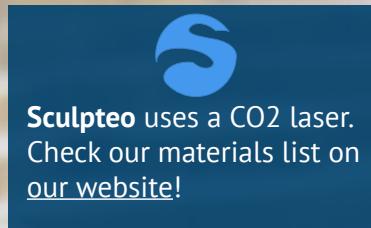
**During such operations, the laser beam is sometimes invisible to the human eye and yet extremely powerful. Therefore, safety glasses are mandatory during the process. Would the laser beam cross your eye, your retina would melt in less than the time needed for pain to reach your brain!**

Laser-cutter systems can be:

- **Gantry system** with a laser beam always placed perpendicularly to the cut materials, tahnks to a plotter associated to three mirrors: one fix mirror, and two mobile ones.

- **Galvanometer system** with a laser beam placed at various angles to the materials, using angled mirrors. It can speed up to 1 meter-per-second, but this system is mostly used as an engraving tool since it doesn't provide clean cuts. The laser beam, which is placed at the center of the device, is oriented with mirrors on the material and cuts it in bias. Especially if the object is wide and its edges are far from the laser beam.

## C. HOW DOES IT WORK?

Although the laser cutters are all built and work similarly, they are **distinct** in that each type of laser has a **specific power range.** Each can be used to cut through different **material types** and **thicknesses**. There are three main types of lasers used in laser cutting:

**Sculpteo** uses a CO2 laser. Check our materials list on our website!

| | Work with... | Main properties | Materials |
|---|---|---|---|
| **CO2 lasers** | A gas discharged which is air or water-cooled. It is a mixture of mainly carbon dioxide and nitrogen, with hydrogen and/or xenon and helium. | Can cut thin sheets of various materials, inexpensive, efficient. It can cut and engrave a wide variety of materials. | Wood, paper based products (like card board), leather, acrylic, some plastics, and some foams. |
| **Neodymium lasers** | Crystals: neodymium doped crystals such as Nd:YVO4, Nd:YLF and Nd:YAG. | With a smaller wavelength, they can cut very thick materials. But parts of the machines often need replacing. | Metal, plastics and some ceramics. |
| **Fiber lasers** | A "seed laser", amplified via special glass fibers. | Their wavelength and intensity is similar to the Nd lasers but a fiber laser requires less main tenance. | Metals and plastics. |

## C. HOW DOES IT WORK?

## WHY DO I NEED TO USE LASER CUTTING?

Laser-cutting is very efficient in many fields where **manufacturing speed** is essential.

Another good reason to adopt laser-cutting is the **wide range of materials** you can cut with only one machine, especially with CO2 lasers.

The cut is always **precise**, neat and the kerf is **clean**, without important deterioration on your material.

**LASER IS AN IDEAL TOOL FOR CUTTING BECAUSE:**
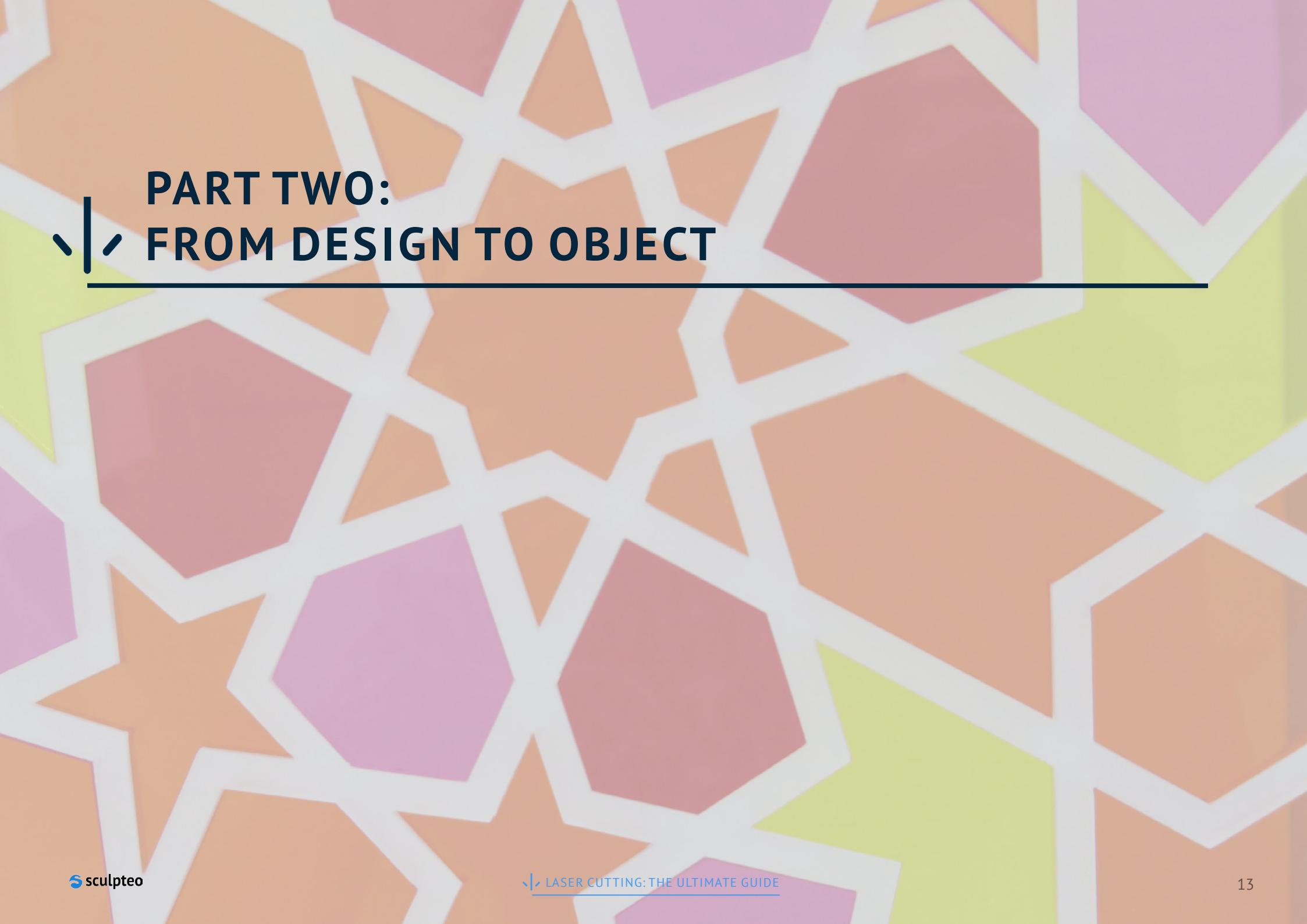
ITS POWER IS ENTIRELY ADJUSTABLE AND PRECISELY FOCUSED ON THE MATERIAL

THE HIGH FOCUS AND THE GOOD COHERENCE BETWEEN THE ELECTRIC AND MAGNETIC COMPONENTS GIVES THE LASER BEAM GREATER ENERGY

THE MINIMUM DIFFRACTION OR BENDING AROUND SHARP CORNERS MAINTAINS ITS ENERGY LEVELS OVER A DISTANCE

Traditional manufacturing devices have a limited use and technical constraints that you will not find with laser-cut, permitting also a **wider freedom of design**. Laser-cutting offers:
- top cutting precision and positional accuracy,
- improved edge quality and surface finish,
- strong repeatability,
- the use of materials not cut by traditional devices,
- drilling and engraving in addition to cutting,
- negligible workpiece degradation,
- cost-effectiveness,
- minimal thermal stress zone,
- cuts of complex shapes

# PART TWO:
# FROM DESIGN TO OBJECT

## A. WHICH MATERIALS CAN BE CUT?

## B. HOW CAN I CREATE MY OWN LASER CUT MODEL?

Many materials can be cut by a laser: from wood to plastic, from steel to ceramic. Depending on the material, there is usually **no limit to the thinnest sheet that can be cut, and the thickest sheet is usually 20 mm.** The following materials can be cut:

**Plastics:**

- ABS (acrylonitrile butadiene styrene)
- Acrylic (also known as Plexiglas, Lucite, PMMA)
- Delrin (POM, acetal) – for a supplier, try McMaster-Carr.
- High density polyethylene (HDPE) – melts badly
- Kapton tape (Polyimide)
- Mylar (polyester)
- Nylon – melts badly
- PETG (polyethylene terephthalate glycol)
- Polyethylene (PE) – melts badly
- Polypropylene (PP) – melts somewhat
- Styrene
- Two-tone acrylic – top color different than core material, usually for custom instrumentation panels, signs, and plaques.

**Thin metals:**

- Stainless steel
- Spring steel

**Foam:**

- Depron foam – often used for RC planes.
- EPM
- Gator foam – foam core gets burned and eaten away compared to the top and bottom hard shell.

**Other:**

- Cloths (leather, suede, felt, hemp, cotton)
- Magnetic sheets
- Papers
- Rubbers (only if they do not contain chlorine)
- Teflon (PTFE, Polytetrafluoroethylene)
- Cork
- Woods (MDF, balsa, birch, poplar, red oak, cherry, holly, etc.)

On the contrary, **any materials containing chlorine cannot be cut**: polycarbonate, PVC, vinyl, for example. **Glass cannot be cut** as well, it can only be engraved. Finally, most **metals** cannot be cut or need a **special laser cut**, either a powerful fiber laser or a very powerful $CO_2$ laser, except from stainless or spring steel.

## A. WHICH MATERIALS CAN BE CUT?

Let's have a closer look at four commonly used materials: **cardboard**, **acrylic**, **plywood**, and **medium-density fibreboard** (MDF).

### CARDBOARD

Cardboard is **a light yet rigid material.** It is made by gluing several sheets of paper of different thicknesses, both flat, corrugated and wavy. Cardboard is a generic term for a heavy-duty paper of various strengths, from a single thick sheet of paper to complex configurations with multiple layers.

➕ Cardboard is **inexpensive** and very easy to work with. It is both **light and very stiff,** can be folded, taped, glued, cut, stapled. It is also very easy to paint. Made from **natural fibers**, cardboard is recycled, recyclable and biodegradable.

➖ Cardboard is **not suited to resist fire nor water**, unless treated for wet-strength.

❓ Creating structures from corrugated cardboard can be a great way to test out complex designs. Slotting, stacking and folding shapes all work well to create 3D form. Therefore, cardboard is typically used for **early prototypes, package design, crafts, or kids projects**. You can also make outstanding **business cards** in compact cardboard.

## A. WHICH MATERIALS CAN BE CUT?

## ACRYLIC

Acrylic is a type of **plastic** with a variety of brand name manufacturers, including Plexiglas, Lucite, Acrylite, Perspex, and Optix.

Seen as **attractive** because of its **glossy surface**, it comes in a variety of thicknesses and colors, and the edges of laser-cut acrylic have a "laser-polished" look. It is also available in transparent, translucent, and opaque colors, including neons, fluorescents, and mirrored colors.

It is possible to create **two-tone acrylic** with a thin, top layer that is a different color than the core material, and it is usually used for parts that require **high-contrast engraving** such as instrumentation panels, signs, and plaques.

Acrylic is an **affordable** material with a **high quality look and finish.** Its texture enables also **good engravure** with a high level of details. Many ranges of thickness and colors can be used.

Acrylic can be **brittle**. For example, you have to be careful not to crack if you want to drill holes after laser cutting; it is better to have us laser-cut all screw holes and mounting holes. Acrylic parts can also **crack or chip** - especially at sharp corners - if you drop them on a hard surface. **Scratches** can appear on the material if not careful.

Acrylic is used for both industrial and artistic purposes. **Robot parts and chassis, computer case parts and fan grills** are often laser-cut in acrylic. But it can also be used to create **jewelry, trophies, furnitures and art pieces**.

# A. WHICH MATERIALS CAN BE CUT?

## PLYWOOD

**+** Like paper or cardboard, plywood is an **affordable** support, from **natural** extraction. Wood can also give a unique character to the furniture or the piece created thanks to its **fibers** and its **knots**. It **engraves well** and is very **easy to stain or to paint**.

**—** Plywood can present a slightly **rough surface**. Laser **burnt edges** can slightly blacken the objects they are in contact with (or your hand). Plywood can be more or less thick (+- 1mm) depending of the supply batch.

**?** **Craftsmen** use and love laser cut for plywood. No finishing, no splits, it is a perfect technique to create **furnitures**. The heat of laser beam even adds a little something on the side of the cut.

Plywood is a **sheet material manufactured from thin layers (or "plies") of wood veneer** that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another.

All plywoods are a mix of resin and wood fiber sheets. This alternation of the grain, known as "cross-graining" reduces the tendency of wood to split when nailed at the edges.

**Light and waterproof,** plywood is used by designers and manufacturers for its resistance and its flexibility. Laser cut and plywood often go together: **no need of finishing** the material thanks to the precise cut of the laser beam!

Plywood is also a **good engraving support for pictures, symbols or typewriting**.

## A. WHICH MATERIALS CAN BE CUT?

### MDF

MDF stands for **Medium Density Fiberboard**. It is an engineered wood product made by breaking down hardwood or softwood residuals into wood fibres, combining it with wax and a resin binder, and forming panels. It is is generally **denser than plywood** but can be used as a building material similar in application.

Available in **many colors and thicknesses**, MDF is **isotropic**, i.e. it is homogeneous and has the same properties in all dimensions. It is also quite **inexpensive**, cheaper than wood but with similar properties. Just like plywood, MDF does not present splits or splinters when cut with a laser. It doesn't have fibers which means there is no specific direction to follow when you cut MDF. It can also be **painted, tainted, varnished, waterproofed**...

MDF is **not water resistant**. It does not have really strong mechanical properties.

MDF is commonly used for making **prototypes, furniture**, but also **ornaments, puzzles and coasters**.

# A. WHICH MATERIALS CAN BE CUT?

| | Cardboard | Acrylic | Plywood | MDF |
|---|---|---|---|---|
| ➕ | Inexpensive, recyclable, easy to paint, easy to join | High quality look and finish, high level of detail possible, engraves well, affordable. | Affordable, engrave well, easy to stain, natural material giving a unique surface aspect, good mechanical properties. | High quality look and finish, engraves well, solid/substantial feel. Recommended to create 3D objects from laser cut. |
| ➖ | Low durability. | Can crack under stress, can scratch. | Inconsistent thickness between supply batches. | Does not like humidity, not really resistant in small thickness. |
| **Used by...** | Point to paper, a dutch company specialized in luxury packaging and greeting cards. | The italian furniture brand Kartell. | Architects for models. | Furniture designers. |

## A. WHICH MATERIALS CAN BE CUT?

## B. HOW CAN I CREATE MY OWN LASER CUT MODEL?

### 1. GUIDELINES

### 2. SCULPTEO TOOLS AND HOW TO CONFIGURE YOUR VECTOR FILE

Simple pictures or non vectorized drawings are not enough to create an object with laser cut because they do not contain the information necessary to enable the machines to cut or engrave it. What you need is a vector file.

**A. HOW CAN I GET A VECTOR FILE?**
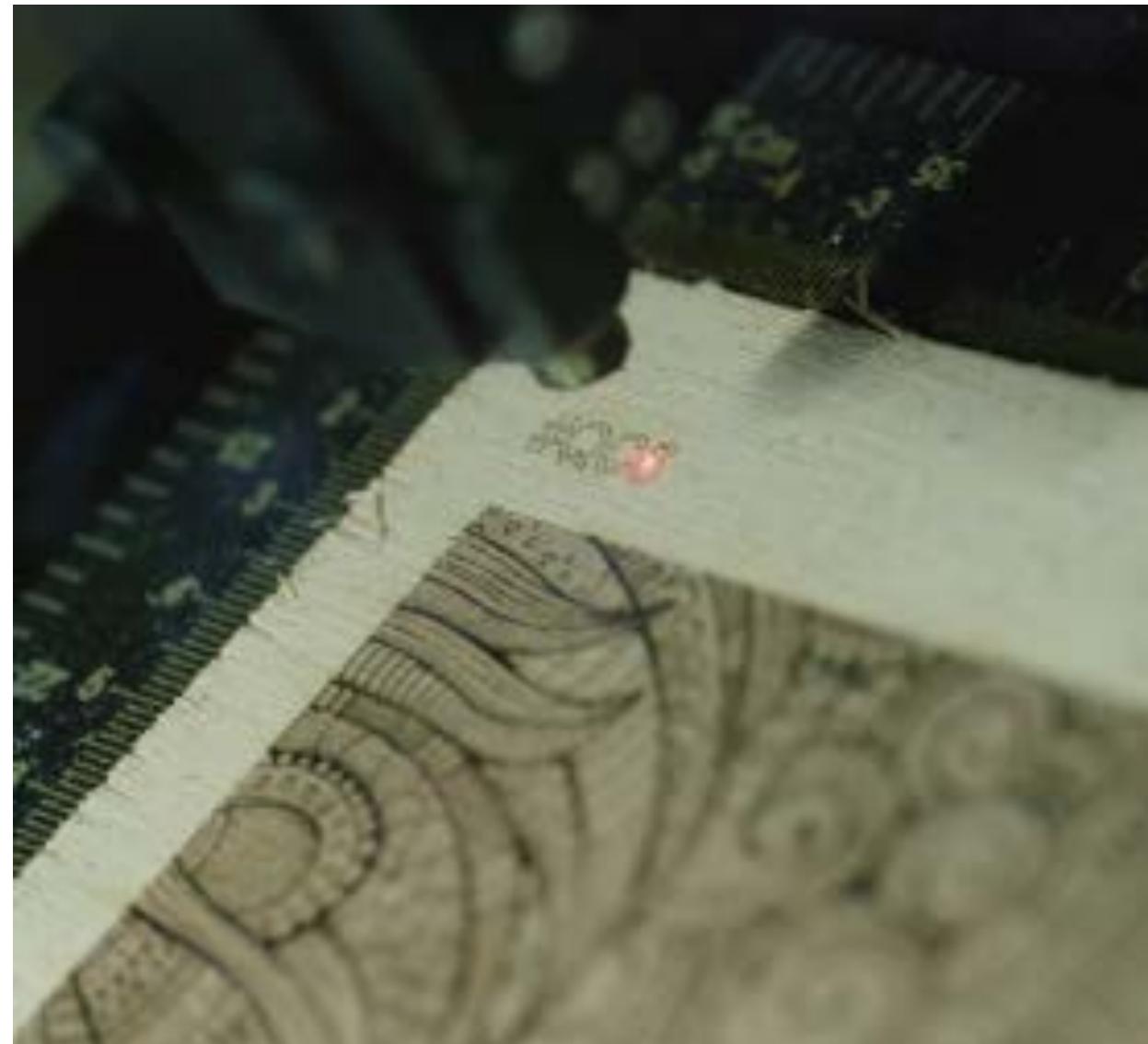
**B. IS IT THE RIGHT FORMAT?**

**C. HOW CAN I SEND IT TO SCULPTEO?**

**D. HOW DO I FIND THE PRICE OF MY DESIGN?**

**1. GUIDELINES**

**2. SCULPTEO TOOLS AND HOW TO CONFIGURE YOUR VECTOR FILE**

## A. HOW CAN I GET A VECTOR FILE?

Here are three options available to you:

- **Option 1:** Create **your own vector file**: it's way easier to create your own vector file with a **dedicated software**, which can be understood in a few hours. On the contrary, a 3D file requires more complex software, and at least a week to get the basics.
- **Option 2:** Ask a **designer** to create a vector file for you.
- **Option 3:** Use **free vector files** on websites such as Noun Project.

**You picked option 1? Here is how can you can create your own vector file for laser cutting and engraving.**
There are several ways to create a vector file. You can use a wide range of software, either for modeling or design, professional or not, priced or free, more or less complete and easy to use. Whatever software you use, you should not forget **the design guidelines that must be respected**.

You should always follow the design guidelines of the material you want to use, since each material has **specific constraints** which are necessary to take into account. For example, you must take into account **the kerf that the laser creates** as it passes over the material, and check that **the size of the object does not exceed the size of the cutting table of our machines**.

At **Sculpteo**, we have our favorites softwares for each digital manufacturing techniques.

**Take a look at 6 of our best softwares for laser cutting!**

## 1. GUIDELINES

## A. HOW CAN I GET A VECTOR FILE?

### ADOBE ILLUSTRATOR

**+** Very **versatile**, it will let you work with vector graphics.
So many artistic opportunities!
You can use it with **other software**, to check and repair other files.

**−** Needs **some time to understand** how to use it and to handle the tools...

**Do I need to pay?** Yes

**Format:** SVG

### SOLIDWORKS

**+** SolidWorks is a **2D modeling software**.
Going from a 2D model to a 3D design with it is super easy, and allows for **neat and cohesive results**.
Lots of tools, whether it is for architectural plans or products' designs.

**−** You will need to go through **some trials before handling all the options properly**.
You **can't import a SVG file** in SolidWorks. You have to export the drawings with a format such as IA, and open the files in Adobe Illustrator or Inkscape, to convert them into SVG.

**Do I need to pay?** Yes

**Format:** DXF, PDF

### INKSCAPE

**+** An **open-source** alternative to Adobe Illustrator!
You can create a new design from scratch, or repair an existing one.

**−** Needs **some time to understand** how to use it and to handle the tools...
The functions don't have the same name as in Adobe Illustrator. Be careful!

**Do I need to pay?** No

**Format:** SVG

### ONSHAPE

**+** A **free** equivalent of SolidWorks with many good functionalities.
OnShape is available for **tablets and smartphones** too, so you can work on your models wherever you go!
You can give OnShape a try on their website.

**−** You need an **Internet connection** to work on it and to download your design.
**No SVG format.** You will need to export your file to the DXF format again, before going through Illustrator/Inkscape to

**Do I need to pay?** No

**Format:** DXF

### SKETCHUP

**+** One of the **easiest software**! Very intuitive to use.
You can add **plugins** and discover new functionalities.

**−** SketchUp **can't handle spheres and circles**, and will transform them into polygons.
Avoid this software for any curvy design if you need high precision.

**Do I need to pay?** Yes and no.
There is a free version but you need to pay to access the entire functionalities.

**Format:** 3DS, DEM, DWG, DXF
SVG if you have the right plugin.

### SOLVESPACE

**+** **Free and open-source**.
Many functionalities, from basic forms to fully functional constraints, just like SolidWorks or OnShape.
Very **fast to download** (less than 10MB).

**−** A bit **tricky to use** and not very good-looking.
**You can't export your design directly into SVG.**

**Do I need to pay?** No

**Format:** Files need to be **SolveSpace Models** (*.slvs) format. Various export formats are provided, including 2D vector drawing as DXF, EPS, PDF, SVG, HPGL, STEP.

**1. GUIDELINES**

**A. HOW CAN I GET A VECTOR FILE?**

## FOUR TIPS FOR OPTIMIZING YOUR VECTOR FILE

The **price of your design** depends on the **time spent by the machine to cut the material**. If you optimise the line work, you will achieve faster cuts and save money! Check these four elements on your pattern:

### 1) Design

Remember "**more is less**"!

Clever designers will figure out the best way to maximise the use of materials and processes they undergo.

Look carefully at your design and **get rid of anything that could be considered superfluous**.

### 2) Watch out for double lines!

The laser is no human being and doesn't know you don't want to cut the same line twice!

It may sound obvious, but **be careful when you duplicate or copy and paste linework** on top of each other.

In extreme cases this will **double your cutting time and cost**, and increase the chances of **burning the material**.

### 3) Reduce Raster engraving

Raster engraving is the **most time consuming operation.**

Considering that manufacturing time is an important price factor, we recommend you limit your surface engraving to **a few cm²**.

### 4) Pay attention to your text

Dont't forget to **vectorized anything you want to write on your design**.

If not, fonts could be misinterpreted at upload.

Check **Sculpteo**'s website to find our tutorials on how to prepare your vector file!

## 1. GUIDELINES

## A. HOW CAN I GET A VECTOR FILE?

These **software** are among the best to **create a vector file** according to the Sculpteo team but remember that you can always **enhance the capacities of your software** or **upload new functionalities** thanks to **plugins**. You can also use **online services** to create ready-to-use vector files.
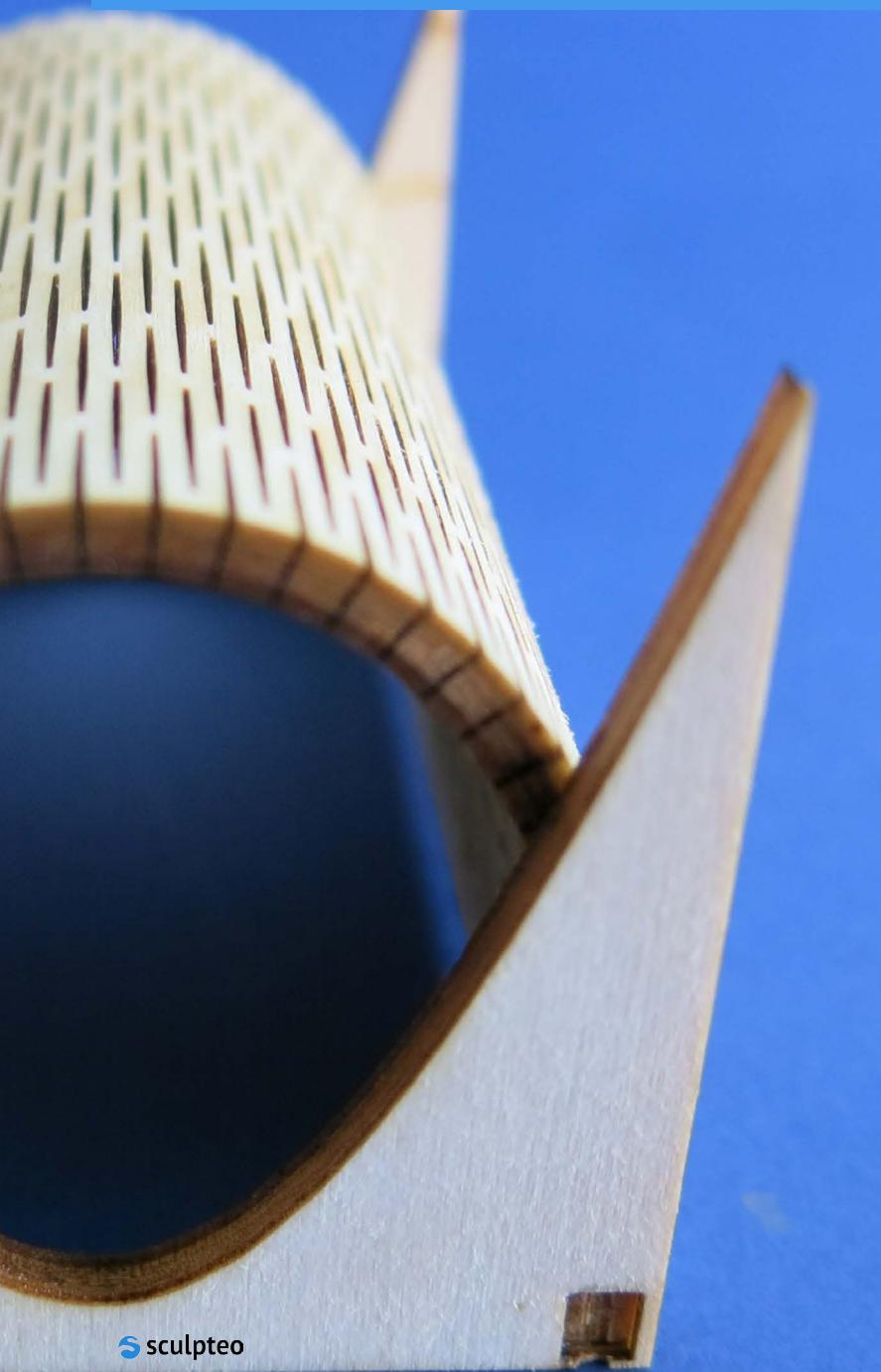
### SOME USEFUL PLUGINS...

- **The Flights of Ideas:** this **SketchUp plugin** for anyone that needs to **export faces from their 3D model into the 2D SVG format**. This allows you to use editors like Inkscape or Adobe Illustrator and to create 2D layouts for laser cutting.

- **VectorScribe:** VectorScribe is a plugin for Adobe Illustrator that allows designers to **create geometric shapes with more refinement and control**.

- **InkScribe:** InkScribe is both an alternative and a complement to Adobe Illustrator's **pen tool**. It will enable you to **create paths, or draw vectors**, more quickly and intuitively.

### ...AND SOME HELPFUL ON-LINE SERVICES

- **Box Designer**: enter the dimensions and thickness of your box online and the software will generate a PDF you can use to cut **a notched box on a laser-cutter**.

- **Template Maker:** the page contains a good number of **templates for gift boxes and many other things that can be made out of paper**. The templates are completely free and all dynamic: you can customize almost all dimensions.

- **Gear Generator:** this online tool creates **involute spur gears that you can download in SVG format**. In addition it lets you compose full gear layouts with connected gears to design multiple gears system with control of the input/output ratio and rotation speed.

## 1. GUIDELINES

## B. IS IT THE RIGHT FORMAT?

**Check our format list!**

The vector-format file types used by Sculpteo are:
- **SVG is the most commonly used. We recommend this format for our machines.**
- PDF
- CDR (CorelDRAW)
- AI (Adobe Illustrator)
- EPS (Adobe Illustrator)
- DXF compatible with AutoCAD version 2011 or earlier
- DWG compatible with AutoCAD version 2011 or earlier

You can use the software of your choice as long as you **export your file in a correct format**.

**Sculpteo** works usually with SVG. Most software can export directly into it.

When this is not the case, you can use a 2D design software like Illustrator or Inskape, which generally can transform other file formats into SVG.
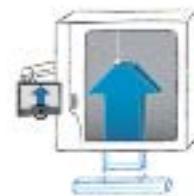
**1. GUIDELINES**

**C. HOW CAN I SEND IT TO SCULPTEO?**

**No e-mails, just upload your vector file on our website!**
When you are ready to upload your vector file, you can go to the Upload page.

## Upload a file

From there, you can select a file from your computer or Drag and Drop a vector file.

Select File for Upload

Or Drag and Drop a File

**Visibility:** Private ▾ ❔     **Units:** mm ▾

By uploading content to Sculpteo, you agree to our Terms of Service.

**1. GUIDELINES**

**C. HOW CAN I SEND IT TO SCULPTEO?**

**While you are waiting for the upload to complete, you can:**

## Upload a file

| Complete | 1.6 KiB ✓ 🗑 |

**Design name ***
arabesque

Name your design

**Description**

Add a description

Choose who can access your file with the link to be able to purchase the model or not.

**Visibility** ❓   **Let people with a link:**   **Units**
Private ▾   ☐ Order a copy of this design   mm ▾
☐ Customize this design

Change the visibili-

Allow people to customise the model

**Category**   **Tags**
--- ▾   Rocket, robot, rebel

*Required   **Next**

Select a category

Add tags

**1. GUIDELINES**

**C. HOW CAN I SEND IT TO SCULPTEO?**

**Once uploaded, our algorithms will analyse and automatically repair your file if some design errors remain.**

## Upload a file

| Complete | 1.6 KiB ✓ 🗑 |
|---|---|

**Success!**
You'll soon be redirected to your design.
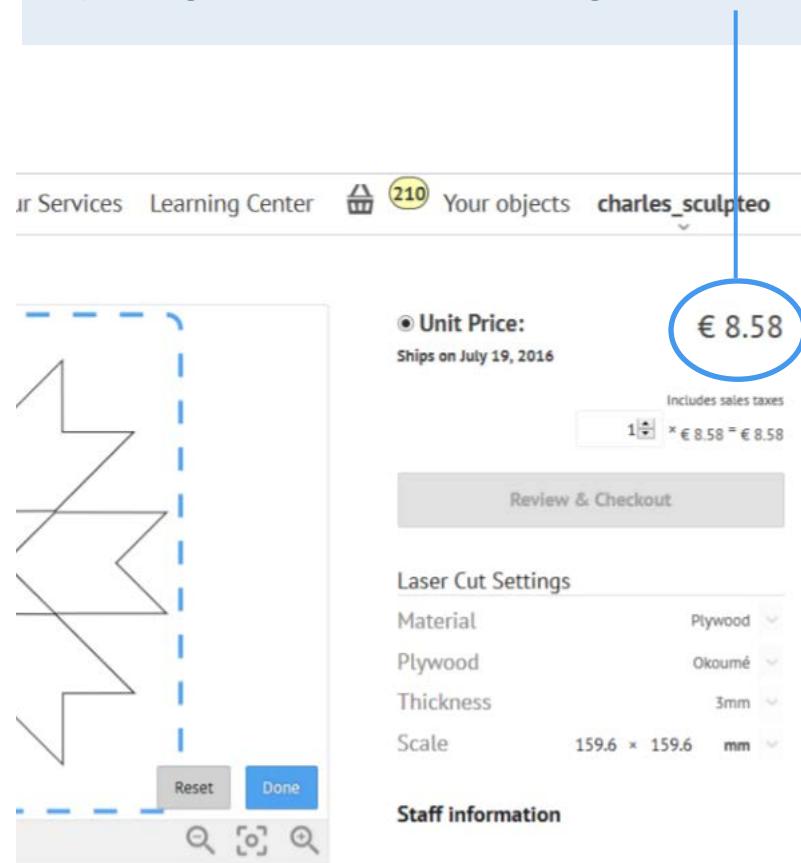
**Sculpteo**'s offer is revolutionnizing laser cutting with a rapid and easy access to this digital manufacturing service! As easy as 1, 2, 3.

1. **You upload it:** laser cutting has never been so reachable! Just go online, upload your vector file and follow our guidelines.
2. **We laser cut it:** depending on your project, its size, the material you picked, 3 to 9 days are required to manufacture it.
3. **You receive it:** unpack, assemble and be proud of your product!

## 1. GUIDELINES

## D. HOW CAN I FIND THE PRICE OF MY DESIGN?

The **price** will be displayed on the right of your screen and it will be **updated in real time automatically** depending on modifications you bring to it.



**Sculpteo's tips: Pay attention to the size!**

It is always a good practice to ensure that your model is the **proper size** before exporting in any file format. After uploading your file, our website could think that your model is in inches or millimetres when your model should actually be in centimeters! This is because some file formats do not contain unit information.

Whichever measurement unit you need your model to be in, ensure that the **proper measurement unit is attached to your model in the Laser Cut Settings**.

**And don't forget to use our Verification Tool!**

**1. GUIDELINES**

**2. SCULPTEO TOOLS AND HOW TO CONFIGURE YOUR VECTOR FILE**

**Sculpteo**'s tools offer you to use different 'styles', depending on your wish to engrave or cut your vectorial paths and fills. Each style has a special color code.

By default, **our algorithm detects the colors you defined for your paths and suggests corresponding styles**. If you haven't defined colors for your file, you can do it once it is uploaded on our website. **You can assign an outline and fill for each style**. The style will be applied to all the vectorial paths and fills selected for the style.

For the outline and the fill, you can choose different engraving types:

**Vector engraving**: it is the same operation than laser cutting, with lower power. It can only be associated to an outline. One level of depth for vector engraving is available on our website.

**Raster engraving**: we offer two levels of depth : light and deep. The light raster engraving is barely perceptible to the touch, compared to the deep raster engraving. It can be associated to filled or >0.1mm outlines (we recommend 0.3).

**1. GUIDELINES**

**2. SCULPTEO TOOLS AND HOW TO CONFIGURE YOUR VECTOR FILE**

Automatically, the 'Laser Cut Settings' space and the price in the right corner will update when choosing your material.
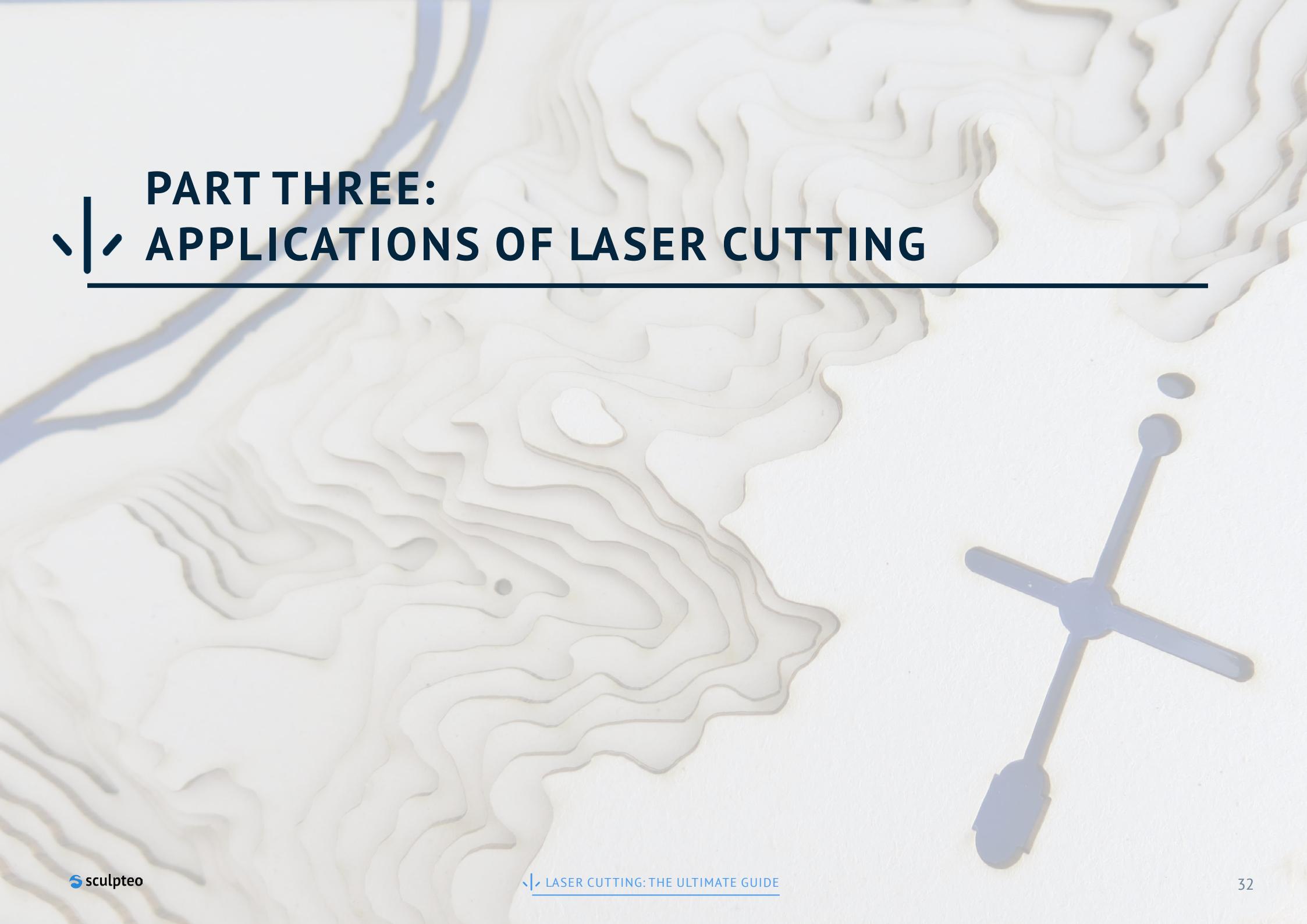
You can choose what material you want to use for laser cutting or engraving, as well as thickness.

# PART THREE:
# APPLICATIONS OF LASER CUTTING

**A. AERONAUTIC AND AEROSPACE**    B. PHOTOVOLTAIC PANELS    C. FASHION    D. ROBOTS, DRONES AND ELECTRONIC FABRICATIONS

**Aeronautic** and laser-cutting technology have always been closely linked. Remember, **Boeing** was among the first companies to use laser cutting technology for its engines in the 1970's!

Aviation and space travel place indeed the highest demands on materials and technology: **modern engines need to achieve an ever higher performance while, at the same time, reducing fuel consumption**. Utilizing materials with improved strength and reduced density is by far the most efficient way to achieve this goal, and laser material processing has been proved suitable for these ambitions.

- Improves the **strength** of the material but reduces its **density**.
- The processing is highly **versatile**: by tuning laser parameters, multiple tasks can be achieved such as cutting, drilling, welding and cladding with a single machine.

In aeronautic and aerospace, the powers of the lasers are in the order of **few hundreds of watts to few thousands of watts**. They are employed for the cutting and fusion welding of alloy and superalloy sheets, turbine engine deep hole drilling, repair of blades for gas turbines aircraft engines, on-the-fly drilling of de-icing panels and heat treatment of surfaces. Thanks to these techniques, the engines can **operate efficiently at high temperatures**.

Aeronautic and aerospace now even use **ultrafast lasers**. There are two types of ultrafast lasers: picoseconds (1x10-12 second) and femtosecond (1x10-12 second). Their **extreme short pulse duration** provides peak power reaching giga watts, enabling almost all kinds of materials to break down instantaneously under laser irradiation.

**A. AERONAUTIC AND AEROSPACE**  **B. PHOTOVOLTAIC PANELS**  **C. FASHION**  **D. ROBOTS, DRONES AND ELECTRONIC FABRICATIONS**

The making of **photovoltaic panels** requires several thin layers of conductive and photoactive materials. These layers are then structured, drilled and cabled together.

Lasers are used for **edge deletion on thin film solar cells**. To protect thin film solar modules from corrosion and long-term short circuits, the layering system at the edge of the module is removed and laminated. In the 2000's, the **entire solar industry converted to lasers** in order to remove this few millimeters fraction of semiconductor material from the edges of the silicon wafer, which would otherwise lead to undesired **short-circuiting around the edges**.

During this process, the laser beam works at a speed of more than 700 mm per second, with a **very low risk of short-circuiting**. It is much more **reliable** than any other techniques on the market so far, better than sand blasting for example.

A second operation successfully accomplished by lasers when building solar panels is **drilling solar cells**. The laser works **contactless** and can get into position very quickly, without producing any mechanical charge. **Thousands of holes can be drilled in a second**.

- Creates extremely **small and precise** solar cells.
- **Inexpensive**.
- Very few time consuming.
- Easy to integrate in the production line.
- **Contactless**, precise and process-safe.
- There is a very **low risk of short-circuiting**.
- Much more reliable than any other techniques on the market so far.
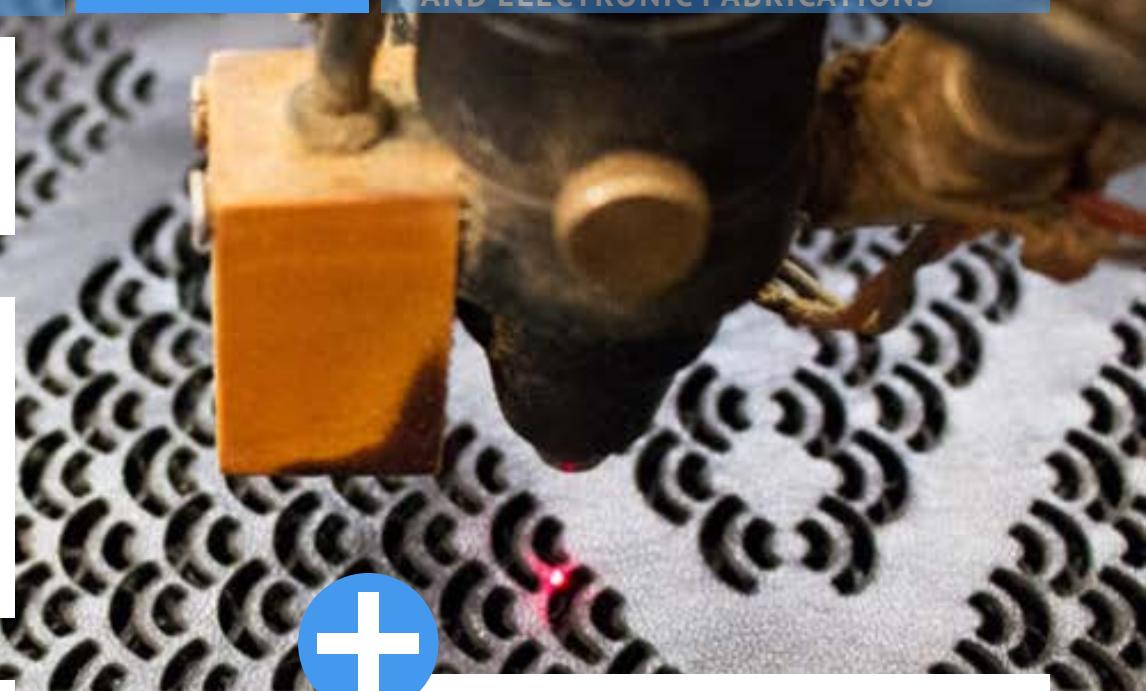
**A. AERONAUTIC AND AEROSPACE**   **B. PHOTOVOLTAIC PANELS**   **C. FASHION**   **D. ROBOTS, DRONES AND ELECTRONIC FABRICATIONS**

Laser cutting used to be reserved for **haute couture** designs, but the technology is now more readily available to manufacturers. It is now more common to see **laser-cut silk and leather** in **ready-to-wear** runway collections or at retailers such as **Topshop** or **ASOS**.

In general, laser-cutting works best on **synthetic fabrics**; the plastics in these textiles melt during the process, resulting in a sealed, perfect edge that will not fray. **Natural fabrics** on the other hand, are slightly spoiled by the heat of the laser, holding the fibers in place. This generally results in a discoloration at the edge of the cut, even if adjustments can be made depending on the fabric and the strength of the laser to potentially eliminate any marks.

Laser works also really well on **leather.** For example, the French saddler and designer **Hermès** has acquired several lasers in its workshops, and uses them to cut pieces in leather skin. The craftsmen can now cut four to five bags in one skin thanks to this precise technology, without losing as much of their precious and expensive material as they did when cutting with blades.

- **Accuracy.**
- **Clean cuts.**
- Sealed fabric edges to **prevent fraying**.
- A unique machine can cut many different materials: silk, nylon, leather, neoprene, polyester, cotton…
- Cuts are made **without any pressure on the fabric**, no part of the cutting process requires anything else to touch the garment.
- **No unintended marks** left on the fabric, which is particularly beneficial for delicate fabrics like silk and lace.
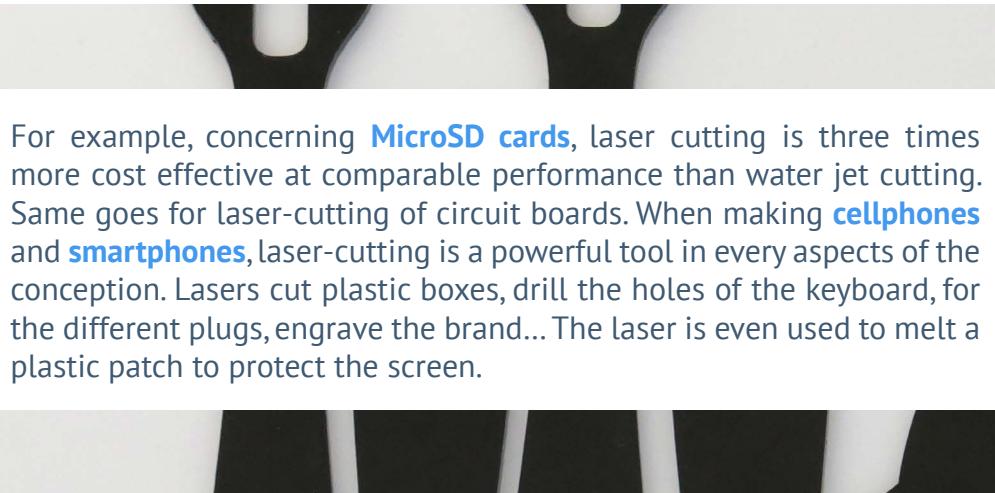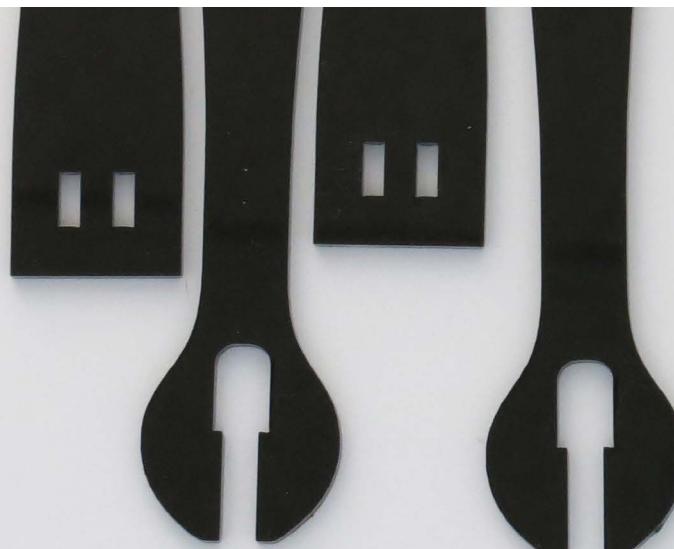
**A. AERONAUTIC AND AEROSPACE**     **B. PHOTOVOLTAIC PANELS**     **C. FASHION**     **D. ROBOTS, DRONES AND ELECTRONIC FABRICATIONS**

Laser offers an efficient cutting solution for **almost every material in the electronic industry.**

For example, concerning **MicroSD cards**, laser cutting is three times more cost effective at comparable performance than water jet cutting. Same goes for laser-cutting of circuit boards. When making **cellphones** and **smartphones**, laser-cutting is a powerful tool in every aspects of the conception. Lasers cut plastic boxes, drill the holes of the keyboard, for the different plugs, engrave the brand... The laser is even used to melt a plastic patch to protect the screen.

**Drones and robots** often require the use of laser-cutting as well, for the electronic components as for the pieces of the device. Sculpteo's team created its own drone combining laser-cutting and 3D printing, cutting and sculpting all the pieces through plastic and wood.

- Beam deflection with scanning heads allows **any complex contours** that can be reprogrammed to be cut in a **short time**.
- As opposed to other cutting processes, the laser cannot wear out, which assures the **continuous processing quality**.
- Sealed and **neat edges**.

sculpteo

**Why do you need to use laser-cutting?**

• **A wide range of options:**
Sculpteo currently offers more than 60 materials and thicknesses available. We'll be expanding the range as the time goes on. These materials can be used for various projects: packaging, business cards, puzzles, furnitures... Sculpteo's team imagined a drone combining acrylic and wood! What's your idea?

• **At a small cost:**
Laser-cutting is an **unexpensive digital manufacturing technique with good finishing results**. You can take a look at our price range on Sculpteo's website and upload your vector file to find the exact price of your project.

• **Laser cutting made simple:**
Our service is one of the **quickest** ones on the market! Just upload your file on our website and press "send"!

**Remember, laser-cutting can be combined with other digital manufacturing techniques**

• **3D printing:** it is Sculpteo's main field of expertise. **Laser cutters and 3D printers work well together** and have a very wide range of applications. While laser cutters are very versatile when it comes to 2D geometries, 3D printers build up 3D geometries layer by layer to create intricate models, prototypes, art, and more. Sculpteo's team imagined a pyramid, combining 3D printing and laser cutting, what's your idea? If you want to know more about 3D printing, have a look at Sculpteo's page.

• **water-jet cutting:** waterjets are high power and have a huge bed size, so they are great for cutting out large, thick pieces of metal and wood.

• **plasma cutting:** another example of high power 2D cutting machines. Plasma cutters use a plasma beam to cut metal by melting it away.

• **vinyl cutting:** vinyl cutters have a pointed cutting tool used to cut through thin materials like paper,

**Contact Sculpteo and we will help you figure out how laser cutting can advance your project!**

**Digital manufacturing** is the use of an integrated, computer-based system comprised of simulation, three-dimensional (3D) visualization, analytics and various collaboration tools to create product and manufacturing process definitions simultaneously.

A **vector file**, or a vector graphics file, stores the lines, shapes and colors that make up an image as mathematical formulae. A vector graphics software uses mathematical formulae to construct the screen image since it determines where the dots that make up the image should be placed for the best results when displaying the image.

**Charles Townes** (1915-2015) is an American physicist and inventor. He is known for his work on the theory and application of the maser, on which he got the fundamental patent, and other work in quantum electronics connected with both maser and laser devices. He shared the Nobel Prize in Physics in 1964 with Nikolay Basov and Alexander Prokhorov.

**Arthur Schawlow** (1921-1999) is an American physicist. His research focused mainly on optics, in particular, lasers and their use in spectroscopy. He also investigated the areas of superconductivity and nuclear resonance. He shared the 1981 Nobel Prize in Physics with Nicolaas Bloembergen and Kai Siegbahn for their contributions to the development of laser spectroscopy.

**Theodore Maiman** (1927-2007) is an American engineer and physicist known for the invention of the first working laser. Following his invention of the laser, he created several companies specialized in the manufacturing of ruby lasers. He continued his research in laser developments and applications as an industrial consultant and a scientist and authored a number of patents on masers, lasers, laser displays, optical scanning, and modulation.

**Albert Einstein** (1879-1955) is a German physicist. He developed the general theory of relativity and his work is also known for its influence on the philosophy of science. Einstein is best known in popular culture for his mass–energy equivalence formula $E = mc2$ and received the 1921 Nobel Prize in Physics for his "services to theoretical physics", in particular his discovery of the law of the photoelectric effect. In 1917, Einstein published an article that proposed the possibility of stimulated emission, the physical process that makes possible the maser and the laser. This paper was enormously influential in the later development of quantum mechanics, because it was the first paper to show that the statistics of atomic transitions had simple laws.

**Stimulated emission** is the process by which an incoming photon of a specific frequency can interact with an excited atomic electron (or other excited molecular state), causing it to drop to a lower energy level. The liberated energy transfers to the electromagnetic field, creating a new photon with a phase, frequency, polarization, and direction of travel that are all identical to the photons of the incident wave. This is in contrast to spontaneous emission, which occurs at random intervals without regard to the ambient electromagnetic field.

**MASER**, or "microwave amplification by stimulated emission of radiation", is a device that produces coherent electromagnetic waves through amplification by stimulated emission. The maser is based on the principle of stimulated emission proposed by Albert Einstein: when atoms have been induced into an excited energy state, they can amplify radiation at the proper frequency. By putting such an amplifying medium in a resonant cavity, feedback is created that can produce coherent radiation.

**Gordon Gould** (1920-2005) is an american physicist, known for the invention of laser. He is best known for his thirty-year fight with the United States Patent and Trademark Office to obtain patents for the laser and related technologies.

A **ruby laser** is a solid-state laser that uses a ruby crystal. The active laser medium, a synthetic ruby rod, is energized through optical pumping. Ruby has very broad and powerful absorption bands in the visual spectrum, at 400 and 550 nm, and a very long fluorescence lifetime of 3 milliseconds. This allows for very high energy pumping. The first working laser was a ruby laser made by Theodore Maiman in 1960. One of the first applications for the ruby laser was military rangefinding.

**Spectroscopy** is the study of the absorption and emission of light and other radiation by matter. It measures light that is emitted, absorbed, or scattered by materials and can be used to study, identify and quantify those materials. The definition has been expanded to include the study of the interactions between particles such as electrons, protons and ions, as well as their interaction with other particles as a function of their collision energy.

**Peter Houldcroft** is a British engineer and inventor. He is known as the first person to perform a gas assisted laser cutting experiment in an industrial context. He was Deputy Scientific Director at TWI (The Welding Institute) in Cambridge in 1965, when he visited the British Motor Company, where he was told some cutting trials had been undertaken using a plasma torch and an articulated arm robot. The problem was that the system was not accurate enough and produced burning. He was asked to imagine an alternative cutting process.That's how he had the idea of combining an oxygen-jet with a focused laser beam began to form. Peter Houldcroft was the first winner of the Association of Industrial Laser Users (AILU)'s award in 1997.

The **laser cutting nozzle** or the **nozzle end** is a part of the laser used to direct the beam on the workpiece. The nozzle drives clean, dry compressed air to the material that is being processed during the cutting procedure at a preset pressure. The cutting nozzle, which has different opening cross-sections, is easy to change and optimises the cutting results considerably.

The **kerf** designates the portion of material burnt away by the laser when it cuts through. It usually ranges from 0.08mm – 1mm depending on the material type and other factors. Kerves above 0.45mm are only experienced when cutting thicker foams since any areas in your design where cut lines come closer than 0.5mm together could burn away entirely. Kerf is determined by material properties and thickness, but other factors also have an impact on it as well: the focal length of the lens, the pressure of compressed air.

**Neodymium doped crystal:** Neodymium (chemical symbol: Nd) is a chemical element belonging to the group of rare earth metals. In laser technology, it is widely used in the form of the trivalent ion Nd3+ as the laser-active dopant of gain media based on various host materials, including crystals and glasses. The most common neodymium-doped gain media are:
* Nd:YAG = Nd:Y3Al5O12 or yttrium aluminum garnet, used for YAG lasers.
* Nd:YVO4 or yttrium vanadate
* Nd:YLF = Nd:YLiF4 or yttrium lithium fluoride
* Nd:glass: various glasses, mostly silicates and phosphates

The **wavelength** of the laser in a vacuum is used to characterize the laser. It depends on the medium used to generate the laser beam. Depending on the wavelength of the laser, the color of the beam will also change. This visible light corresponds to a wavelength range of 400 - 700nm and a color range of violet through red. For example, ruby lasers produce a beam at a wavelength of 694.3nm and CO2 lasers produce a beam at wavelength between 9.4 and 10.6μm.

A **seed laser** is a laser combined with or injected into another laser. It can be used with an amplifier to form a master oscillator power amplifier used to increase the power of the laser. It can also be sent into another, bigger, laser or into an optical parametric oscillator. This latter process is called injection seeding and it helps stabilize the output of the bigger laser.

![sculpteo logo]

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