



Design for Manufacturability:  
Maximizing the Advantages of Laser Cutting

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# Design for Manufacturability: Overview

Succeeding in today's global marketplace requires more than just an innovative product design. To beat the competition and speed up time-to-market, you must control development costs while maintaining high levels of quality. Accomplishing these goals requires implementing efficient processes throughout the entire product development cycle.

Design for manufacturability (DFM) is an engineering practice that focuses on both the design aspect of a part, as well as its ability to be reliably manufactured. The design of a product and its components, including the raw material, dimensional tolerances and secondary processing, such as deburring and finishing, has an enormous effect on the cost of production. By validating design integrity and verifying manufacturability early in the development process, companies can save significant time and development costs, improve manufacturing productivity and accelerate time-to-market.

Companies typically commit to product lifecycle costs at the engineering stage. Depending on the various types of manufacturing processes, there are set DFM guidelines for optimizing functions such as procurement, fabrication, assembly and thorough testing to ensure cost, quality, reliability, regulatory compliance, safety and customer satisfaction. DFM encourages modular designs, standardization of component and reducing product complexity. Products that require fewer components are easier to build and can be assembled quickly. Commonality in part design and materials can also save time and money by allowing engineers to re-use proven design concepts.

# Designing Products for Manufacturability

The kick-off for any DFM project begins with assembling a multi-functional team of active participants early on in the product development process. Teams typically include industrial designers, manufacturing engineers, quality control professionals, marketing representatives, procurement specialists and compliance experts who all bring their specific "subject matter expertise" to the development table. Each individual's insight and their collective past experience support the creation of functional designs with optimized quality, reliability, manufacturability and cost.

**Along with specific technology-driven design guidelines, certain overall best practices have been established for DFM:**

- **Reduce the part count.**  
Fewer parts reduce the intensity of the manufacturing process. In addition to less complexity, inventory and handling, assembly is simpler and faster.
- **Design parts to serve multiple purposes.**  
This aligns closely with reducing part count, and allows functionality to be achieved through fabrication rather than assembly, such as a single part that serves as both a structural component and heat sink. Understanding the specific manufacturing process also allows designers to incorporate features that facilitate fixturing, assembly, or inspection.
- **Develop a modular design.**  
In addition to simplifying activities such as inspection, testing and assembly, modular designs add the versatility to easily create product variations.
- **Use standard components & material when feasible.**  
Standard materials are usually readily available and have established reliability factors.
- **Design for ease of fabrication.**  
By selecting the best combination of material and fabrication process, overall manufacturing costs are reduced. Examine tolerance requirements, and identify if a looser tolerance on certain features will still get the job done properly. Excessively tight tolerances lead to higher set up costs and rejection rates as well as longer lead times. Evaluate what final operations and finish choices are necessary for part functionality and compliance.
- **Minimize & simplify assembly.**  
Design parts so they can be positioned, oriented, and assembled only in one way—the correct way. This avoids possible errors during assembly operations due to variations in part dimensions or the accuracy of the positioning device. The more symmetrical the part, the easier it will be to install. Conversely, if a part cannot be designed with symmetry, it is best to make them very asymmetric to make their orientation more obvious.

# Advantages of Laser Technology

For parts that require extreme precision, laser technology is a very important manufacturing process. Lasers utilize an intense beam of coherent light to produce high quality cuts with extreme accuracy. Equipped with precise computer-controlled positioning systems, lasers are capable of creating complex geometrical shapes and small holes with consistent repeatability.




Lasers can operate at very high processing speeds. Tightly controlled beam profiles vaporize only a tiny amount of material, leaving very little kerf. The extremely low application of heat causes almost no deformation or "heat affected zone" in the cut area, preserving the intrinsic properties of the base material. With no direct contact between the material and focusing head, no force is applied to the workpiece, and easy adjustment of the laser power over the full 1 to 100% range allows smooth cutting transitions on tight or narrow curves.

The precision accuracy and edge quality achieved with laser cutting is superior to that of conventional cutting tools. Complex shapes can be cut with no need for tooling, and it is possible to drill tiny holes under 0.002" in diameter with clean cut edges and free from burr or dust formation.

Using lasers to cut material eliminates many secondary operations. Edges are smooth and burr free and there is no thermal stress or deformation of the workpiece. The very thin oxide layer from laser cutting is easily removed, while high-pressure laser cutting with inert assist gas eliminates oxide-formation entirely.



*Today's laser technology makes it possible to drill tiny, precise holes. Laser hole drilling can be used to modify plastic stents, as shown.*



**“Laser cutting is a powerful technology in the hands of skilled professionals. It is important to implement the right laser cutting strategy to achieve the highest accuracy, highest throughput, highest reliability and lowest cost.”**

## Laser Cutting: A Few Practical Facts for Consideration

Laser cutting is a powerful technology in the hands of skilled professionals. It is important to implement the right laser cutting strategy to achieve the highest accuracy, highest throughput, highest reliability and lowest cost.

Power consumption and efficiency depends on the type of laser used and the type of cut required. Different materials at various thicknesses require adjustments to output power and speed, and they both vary depending on the type of laser used. Smart laser processors find the right balance to minimize power consumption while optimizing cutting speed and efficiency.

As with any plant floor environment, specific safety measures must be observed to avoid worker injury. Workers must be protected from direct contact with beam profiles, and laser machining scenarios must also be adjusted to manage the beam interaction with plastics and the elimination of fumes caused by the subsequent chemical degradation.

## Laser Cutting Technologies

Laser cutting machines use stimulation and amplification techniques to convert electrical energy into a high-density beam of light. A source, called a resonator, produces light in waves of identical frequency, phase and polarization. There are several different types of laser delivery methods, each with their own distinct advantages. The technology choice largely depends on the type of material and the degree of thickness that must be cut.

## Laser Technologies: CO2

CO2 laser cutters have traditionally been the main workhorse in the laser cutting world. The cut quality of a CO2 laser remains consistent throughout a very wide range of material thickness—and it is an excellent choice for cutting through stainless steel, titanium, high performance alloys such as Hastolloy®, as well as other metals like aluminum and copper. CO2 lasers are also a suitable choice for welding.

CO2 lasers produce a beam of infrared light with the principal wavelength bands centering at 10.6 micrometers. They are also efficient — the ratio of output power to pump power can be as large as 20%. These extremely powerful beams are focused by a system of mirrors and lenses and assisted by the high-velocity flow of gases surrounding it until it is delivered through the cutting nozzle. Filling gases consist primarily of carbon dioxide, nitrogen and helium.

The basic construction of a laser incorporates a gas discharge with a total reflector at one end as well as a partially reflecting mirror at the output end. Generating continuous wave power anywhere between milliwatts (mW) to hundreds of kilowatts (kW), laser output may be edge-coupled in higher power systems to reduce optical heating issues. Sophisticated beam delivery systems allow fine tuning and focus.

CO2 lasers utilize a series of reflective optics between the laser source and the focus head. Low power CO2 lasers typically incorporate silvered mirrors as well as windows and lenses constructed from germanium or zinc selenide. High power applications usually incorporate gold mirrors, zinc selenide windows and lenses, and in some cases diamond windows and lenses are used to withstand the higher powers without degrading the beam quality.

## Laser Technologies: YAG

Solid-state lasers are those that use a gain medium that is a solid, rather than a liquid or gas, to amplify the source. YAG, short for yttrium aluminum garnet, is a host medium with very favorable properties for high power lasers and q-switched lasers that produce a pulsed output beam.

Specifically, Nd:YAG is the most commonly used host crystal because of its relatively high thermal conductivity, high mechanical strength, and good optical quality. Optically pumped using a flash tube or laser diodes, beams are easily transmitted through flexible quartz fibers. The wavelength of a Nd:YAG, is 1.064 microns, which is an order of magnitude smaller than the CO2 wavelength of 10.6 microns. This results in a spot size significantly smaller for very precise, tight tolerance cuts with very narrow kerf. The wavelength is absorbed more readily by metals when compared to CO2 laser radiation, which can help improve process efficiency. YAG equipment is widely used in micro cutting applications and is a good choice for large quantities of small components. In marking applications, YAG lasers are able to provide detailed graphics on small workpieces.

YAG lasers operate in both pulsed and continuous mode. Short pulses of extremely high peak power allow parts with small features to be created with precision accuracy, while low power requirements for continuous cutting allow faster rates to be achieved.

## Laser Technologies: Fiber

Another variation of a solid state laser is a fiber laser, where the active gain medium is an optical fiber doped with rare-earth elements such as erbium, ytterbium, neodymium, dysprosium, praseodymium, and thulium. Fiber lasers consist of an undoped cladding and a doped core of the active gain medium. Guided within the core, the laser light passes through the fiber, and because of the length of interaction, it achieves very high amplification. Fiber lasers are optically pumped, most commonly with laser diodes. The pump source can be a single diode, an array, or several separate pump diodes, each with a fiber going into the coupler.

Fiber lasers offer several advantages. The light propagating in the fibers is well shielded from the environment, and fiber lasers tend to be very compactly designed. They offer a large gain bandwidth, wide wavelength tuning ranges, and have the capacity to generate ultra-short pulses. Operating at high power with great efficiency, they are suitable for many types of cutting and welding procedures.

Fiber lasers can cut through thin materials at very high speeds. They also have the ability to cut reflective materials without risk of reflections causing damage to the machine, which allows metals such as copper, brass and aluminum, to be cut without issue.

## Maximize the Advantages of Laser Technology

The goal of a DFM initiative is to achieve a simple solution rather than a complex one. Complex designs are harder to manage, increase the chances of defects, and generate waste in the form of materials, energy, labor and time. As one of the most efficient and cost effective fabrication methods, laser technology is a suitable tool for creating all shapes and sizes of components.

Complex cuts with superior edge quality can be accomplished easily and accurately on laser cutting equipment. Precision laser beams are capable of creating close tolerance components quickly, cleanly, and with minimal operator intervention. No stress is put on the workpiece, and no heat affected zone preserves the intrinsic properties of the base material. Sophisticated software and minimal kerf allow tight nesting of parts to maximize yield and minimize material waste.

## Metals

Metal components are regularly produced using laser cutting equipment. When assessing laser processing as a viable solution to component manufacturing, consider that the thicker the material, the more output power is required and the kerf, although still being considerably narrow, gets larger.

*Metal components are regularly produced using laser cutting equipment*



## Titanium & Nitinol

Titanium, a material often used for applications in aerospace engineering and medical device manufacturing, is slow and difficult to process by mechanical means, which makes laser cutting an excellent alternative. Pulsed lasers work well with titanium due to significantly reduced heat affected zones. Use of oxygen and nitrogen as cutting gases is avoided because they absorb into the surface, which could cause cracks and component failure. High-purity argon and argon-helium mixtures avoid this risk entirely.

Nitinol is a nickel and titanium alloy utilized in the medical device industry. Lasers process Nitinol like other titanium components. High quality laser cuts and Nitinol to Nitinol welds are achievable.

## Stainless Steel & Steel Alloys

All steels and alloys respond well to the cutting action of a laser. Intricate cuts are made with very high accuracy and consistent repeatability. When cutting alloy and tool steels, lasers rapidly create cut edges that are smooth, square, and clean. Typical cutting speeds, depending on energy density, for carbon and mild steel are 18 m/min for 1 mm thick, 4.5 m/min for 3 mm, and 1.5 m/min for 8 mm thick material. The heat affected zone in carbon steel is negligible, and kerfs as narrow as 0.1 mm are possible. Oxygen is typically used as cutting gas for low-alloyed steels

Both CO<sub>2</sub> and solid-state lasers are suited for stainless steel applications. CO<sub>2</sub> lasers cut stainless steel at speeds of 18 m/min at a material thickness of 1 mm. Careful control over the applied heat requires slower cutting speeds, but this minimizes the heat affected zone helps maintain its natural corrosion resistance. Edges are also smooth and oxide free.

In micro material processing, solid-state lasers are commonly applied to create intricate features down to 20 microns in very thin gauge materials. Excellent quality cut edges and low heat affected zones also enable 2D laser cutting of fine diameter tubing. Excellent cutting edge qualities can be achieved both with dry and wet cutting, and non-radial cuts are easily generated.

## Aluminum

Non-ferrous metals, such as aluminum, can also be cut with a laser. Aluminum is challenging to cut because of its ability to reflect light as well as absorb and conduct heat. It is preferable to cut aluminum with a solid state laser using a process called sublimation. In this process, the laser vaporizes the material with as little melting as possible. The material vapor creates high pressure that expels the molten material from the top and bottom of the kerf. Since more energy is needed to vaporize metal than to melt it, sublimation cutting requires high energy intensity and it is slower than other cutting processes. However, it produces very high-quality cuts.

## Copper, Copper Alloys & Brass

As with aluminum, copper, copper alloys, and brass present unique challenges because of their ability to reflect light as well as absorb and conduct heat. The maximum sheet thickness that can be cut is 4–5 mm, and when using CO<sub>2</sub> technology, precautions must be taken to avoid reflection of the laser beam and subsequent damage to the resonator. Oxygen is a suitable cutting gas since the oxide layer in the cutting edge improves absorption of beam energy. Both low oxygen pressures of up to 85 psi and high pressures of up to 300 psi are used depending on the application.

## Other Metals

Many other metals can be processed using laser technology. Gold and silver are typically cut using pulsed or q-switched YAG lasers since the wavelengths of solid-state lasers is better absorbed, while platinum is easily cut using either CO<sub>2</sub> or solid-state lasers. Low pressure oxygen cutting is used to obtain high speeds for cutting through nickel, although the cut edges may accumulate dross as the cut surfaces are oxidized.

Other materials in the aerospace and medical industries that can be laser cut include cadmium, zinc, magnesium, tin, and chromium.

## Plastics

The effect of the CO<sub>2</sub> laser on plastic substrates causes it to either vaporize the material, melt, or chemically degrade it. The condition of the cut surfaces is completely dependant on the material composition and its behavior under thermal stress. Laser cutting plastic and polymer substrates produces edge-cut quality that ranges from a smooth, finely polished edge with no discoloration to edges with minimal striations, some charring, or some discoloration.

The kerf and hole size range will increase with material thickness, and it is important to remember that tolerance requirements must be in line with achievable precision. The minimum size of cutting a slit is 0.004", depending on cutting speed, and processing tolerances are typically  $\pm 0.001$ ". Pressure is applied to the workpieces in the direction of the gas jet, which may present challenges with thin gauge materials.

Lasers are also a practical method for creating small holes and intricate features in small diameter polymer tubing, especially in applications with a large depth-to-diameter ratio.

MATERIAL	HEAT EFFECTED ZONES
Acrylic	Cuts good with good finish
Polyoxymethylene (POM)	Some melting
Polyester (PES)	Some melting
Polyimide (PI)	Some charring
Polystyrene (PS)	Moderate melting & residue
Polymethyl-Methacrylate (PMMA)	Edges are burned
Polycarbonate (PC)	Leaves a charred or powder edge
Polypropylene (PP)	Some melting & discoloration
Acrylonitrile Butadiene Styrene Co0Polymerisate (ABS)	Discoloration of cut edges
High Density Polyethylene (HDPE)	Moderate to large melting
Nylon	Melts badly
Polyethylene (PE)	Melts badly
Styrene	Moderate melting
Polycarbonate	Brown/yellow charring
PVC	Brown/yellow charring
Bakelite	Some charring
Fluoro-Polymers	Some melting
Polysulfone	Moderate melting & residue
Polyurethane	Moderate melting & residue

## Tube & Precision Tube Cutting

Laser technology is an excellent choice for precision tube cutting. High powered, automated equipment allows accurate, repeatable burr-free cuts in both large and small production volumes. Multiple operations can be consolidated into one cycle, and there are plenty of opportunities to conserve material by nesting several parts into the length of a single tube. There are no tooling expenses, and laser cutting is a coolant-free process that leaves no residue to be cleaned off.

The minimum hole diameter is 0.001" in metal but is also material thickness dependent. Tubes with diameters as small as 0.010" or as large as 15.0" can be processed using laser methods. With their precision, non-contact and high speed processing capabilities, lasers have been quickly adopted for use in microtubing applications.

# Benefits of Partnering on Design for Manufacturability

Design for Manufacturability is a proven methodology that works for any size company in any marketplace. Product design establishes the feature set, how well the features work, and the marketability of the product. Since the design determines the majority of the product's cost and has a significant influence on quality, an understanding of manufacturing processes and how they impact design choices helps to condense product development time and expense while ensuring a smooth transition into production.

The key to obtaining the best results from a Design for Manufacturability initiative begins by partnering with a manufacturing company that will engage in an open and productive dialog about what it takes to meet the objectives. The right partner should have relevant industry experience and insight into materials and processes as well as related standards and compliance issues. Invested in a truly collaborative effort, partners understand the implications of design choices and make significant contributions to improve and optimize both the product and the process.

## Improve Manufacturability with Lasers

Evolving to a viable production alternative during the past twenty-five years, the laser is a technically advanced fabrication method for the 21st century. Laser energy, which is many times the intensity of the sun's surface, enables manufacturers to process materials ranging from the hardest ceramic or super alloy to soft rubber or plastic with comparable ease.

Laser cutting is ideal for creating complex shapes because there are no constraints on part geometry. The laser cutting tool does not touch the part, so it can be oriented to make any shape or form. Superior cut quality along high resolution cut paths enables the production of precision components that require little if any post-processing. Intense beams of coherent light can be precisely directed to heat, melt, or vaporize select areas of heavy gauge sheet metal as well as cut fine, micro-sized features in delicate, thin gauge polymers.





## About Laserage

Through more than 45 years of experience, Laserage has become the expert in precision laser contract manufacturing. We have state-of-the-art facilities in the Midwest, in order to better meet our customers' engineered laser solution and production laser processing requirements.

We have the experience and resources to help you reap the cost and quality benefits that laser processing has to offer. Our Design for Manufacturability methodologies help reduce the cost and number of components, as well as streamline and simplify assembly operations.

We have a deep understanding of materials, both metals and polymers, and employ design guidelines that ensure the most robust performance at minimum cost. As a full-service manufacturer, our technical competencies encompass a broad range of secondary and finishing operations, such as laser welding, passivating, shape setting and electro-polishing, with an emphasis on the specific needs of the medical, aerospace, industrial and microelectronics industries.

*"Our priority has always been to build relationships with our customers based on honesty and integrity. In addition, we have always been committed to excellence at every level of our operation."*

*Dan Capp, Director Technology Programs, AMETEK Paragon Medical.*

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