

The background of the entire page is a detailed, light gray technical line drawing of a mechanical assembly, likely a laser welding system. It features various components such as nozzles, guides, and structural frames, all rendered in a clean, engineering-style line art.

DUKANE

THE ENGINEER'S DESIGN MANUAL

for **LASER PLASTIC WELDING**

PART 1 - THROUGH TRANSMISSION LASER WELDING

TABLE OF CONTENTS

Contents

<i>Introduction.</i>	<i>1</i>
<i>Overview of Traditional Joining Technologies</i>	<i>2</i>
<i>Advantages of Laser Plastic Welding.</i>	<i>4</i>
<i>TTLW Method</i>	<i>5</i>
<i>The 4 Pillars of TTLW.</i>	<i>7</i>
<i>Materials</i>	<i>12</i>
<i>Joint Design</i>	<i>15</i>
<i>Clamping Technology</i>	<i>20</i>
<i>Beam Properties and Delivery.</i>	<i>25</i>
<i>Mirrors and Beam Guidance</i>	<i>29</i>
<i>General Design Guidelines</i>	<i>31</i>
<i>Common Pitfalls.</i>	<i>36</i>
<i>Typical Project Roadmap.</i>	<i>37</i>
<i>FAQ</i>	<i>38</i>
<i>Material Selection Chart.</i>	<i>40</i>

INTRODUCTION

THE GOAL OF THIS MANUAL

The goal of this Design Manual is to educate designers and engineers on through-transmission laser welding technology, give them the keys to design their products for the Laser Plastic Welding method, and to disseminate general knowledge about this technology in an *unbiased* approach.

This manual is Part 1 of a 2 Part series: Part 1 - Through Transmission Laser Welding (TTLW) and Part 2 - Transparent Polymer Laser Welding (TPLW). The two technologies are somewhat similar but have enough differences to create the need for a separate approach. It is highly recommended to read through the TTLW manual before moving onto the TPLW manual as only the differences in the TPLW method will be covered.

IMPORTANT - please keep in mind this is purely a set of guidelines. Every application will require its own, nuanced approach and some - or all - of your application's requirements may fall outside of the scope of this guide.

Before you make any design adaptations or changes to mold tooling, etc., I highly recommend you consult a laser welding expert for a complete review of your application design and production needs. You can find out more about this service here: www.dukane.com.

OVERVIEW OF TRADITIONAL JOINING TECHNOLOGIES

Joining Technologies

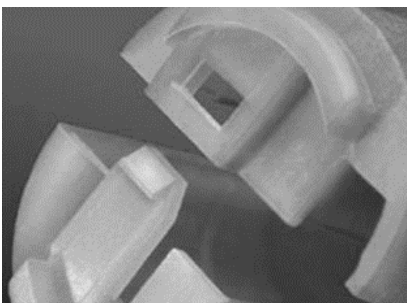
While Laser Polymer (Plastic) Welding really isn't a new technology, it is still not quite as well-known or widely adopted as legacy joining solutions, such as gluing, fasteners, snap fits, and ultrasonic welding. It is interesting to note that the German automotive industry was one of the first to adopt this technology around 19 years ago. In spite of the fact that it was - and still is - a revolutionary technology, it took many years for other industries to adopt it.

While traditional methods have their place, it is a good idea to look at how implementing laser plastic welding could be beneficial and overcome some of the highlighted issues. The below list is only a few of the most common methods that laser welding has its advantages over:

COMMON WELDING PRACTICES

SNAP FEATURES

- Require complex injection mold tooling
- Extra space is typically required in the part



FASTENERS

- Require Added Cost
- Creates extra, superfluous features in part



GLUE

- Messy and difficult to automate
- Lacks precision
- Often requires lengthy drying periods



ULTRASONIC WELDING

- High rate of particulate
- Not as suitable for sensitive electronics
- Potential to mar visible surfaces



With that being said, if the current joining technology is working well for the application and there are no specific issues that are prevalent, then laser welding may not be the best approach due to the relatively high cost to implement it over one of the traditional bonding methods. As system builders become more advanced, the cost to implement will go down.

ADVANTAGES OF LASER PLASTIC WELDING

LASER POLYMER WELDING ADVANTAGES

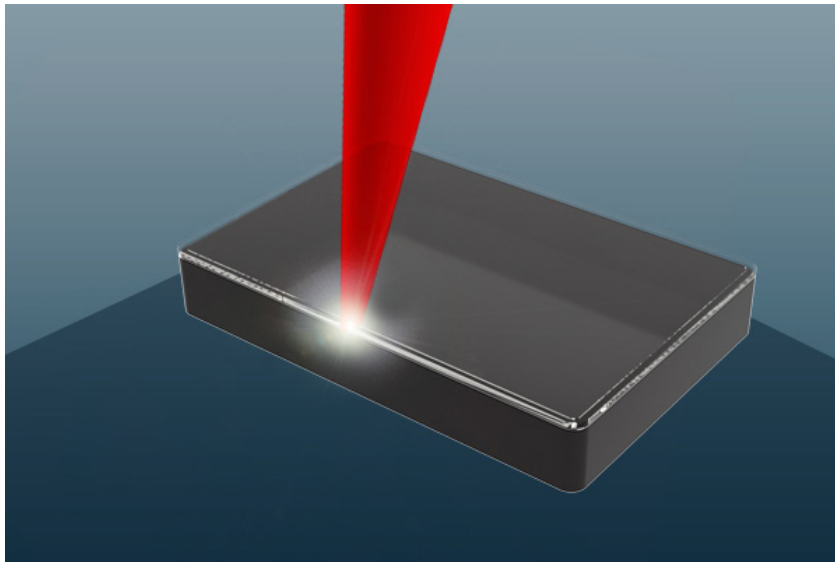
Laser Polymer Welding delivers the following advantages:

- ➞ Precise control of the welding area
- ➞ Aesthetically pleasing weld seams - visually OK on “class A’ surfaces
- ➞ Ability to hold tighter tolerances in the joining process
- ➞ No damage to surrounding materials or sensitive electronics
- ➞ A perfectly hygienic method of bonding - no particulates generated
- ➞ Ability to miniaturize designs
- ➞ Joining of 3D and complex shapes
- ➞ Removal of costly and cumbersome part features
- ➞ Eliminate consumables - fasteners, glue, etc.
- ➞ Drastically improve quality
- ➞ Bonding strength virtually as strong as the base material
- ➞ Lower total cost of ownership - thinking holistically

Laser Polymer Welding picks up where other joining technologies leave off...

If there is a need to eliminate quality problems and miniaturize designs, all while avoiding damage to sensitive electronics then Laser Polymer Welding is the right choice for your design!

THROUGH TRANSMISSION LASER WELDING



There are several terms that have been coined for this subject-to-date; “laser plastic welding”, “plastic laser welding”, “through transmission welding”, laser transmission welding, and “laser polymer welding”, (which will all be referred to synonymously throughout this manual), however, the main concept is the same... *A method of joining two plastics by subsequent transmission and absorption of laser energy.*

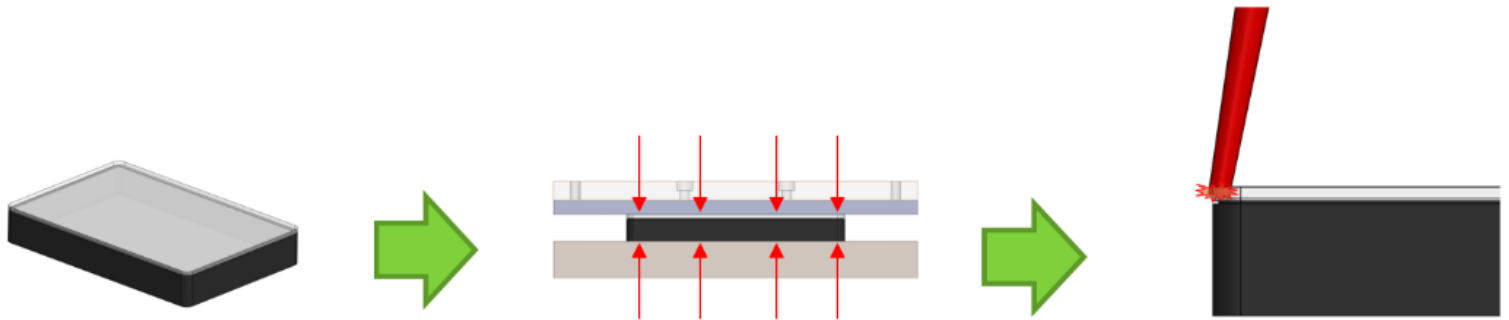
Another way to describe it: laser plastic welding is a cutting-edge means of joining two thermoplastics together via a laser beam in the near-infrared spectrum.

In the case that two plastics are clamped tightly together, the laser beam penetrates the upper layer and is absorbed by the lower layer which in turn is heated by the laser energy and transfers this heat to the upper layer which results in both of the plastics melting and mixing to form a bond that is virtually as strong as the base material.



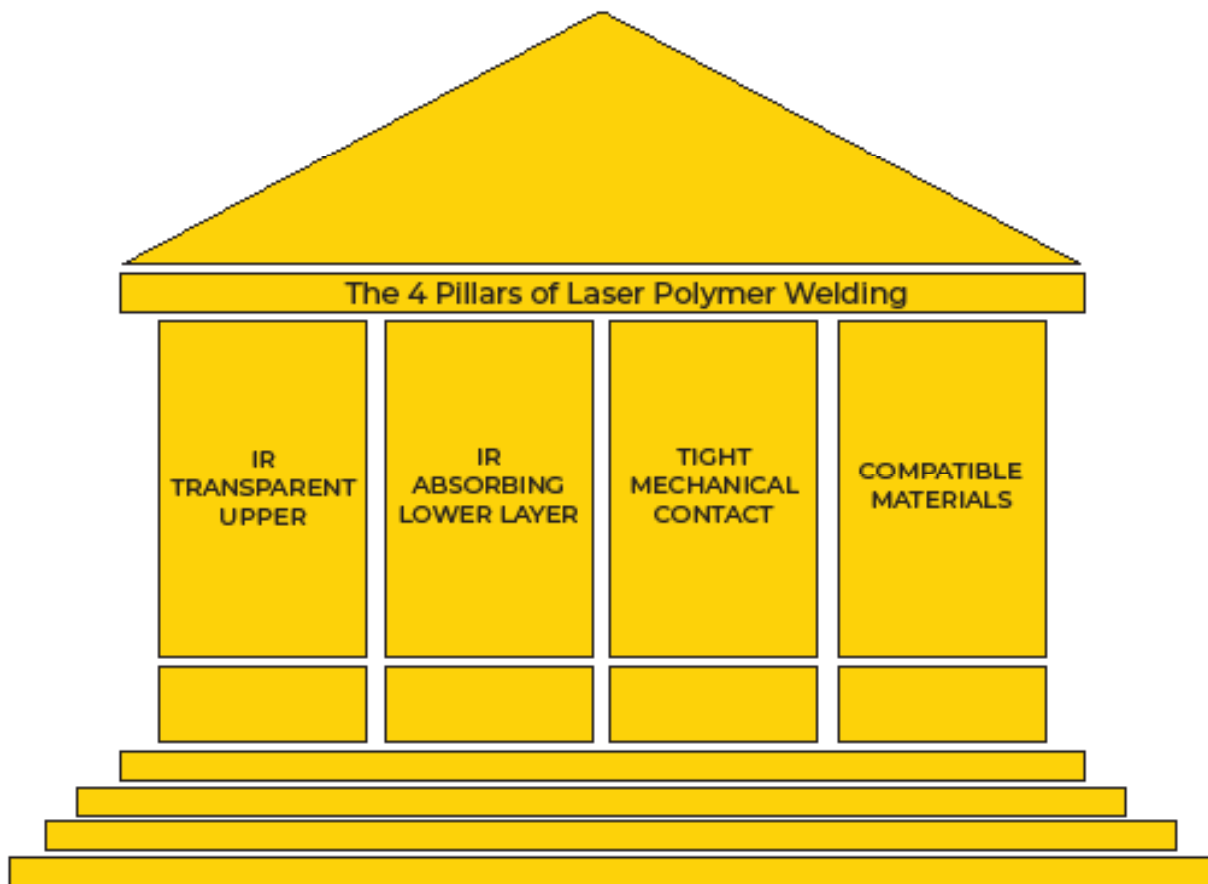
HOW IT WORKS

When two plastics are clamped tightly together, a laser beam in the 1000nm range penetrates the upper layer and is absorbed by the lower layer which in turn is heated by the laser energy and transfers this heat to the upper layer resulting in both of the plastics melting and mixing to form a bond that is virtually as strong as the base material.



THE 4 PILLARS OF TTLW

There are four, main guiding principles to this method of laser plastic welding. While many other design and engineering factors can affect the ability to laser weld a component, these four pillars are absolute requirements for all laser plastic welded applications.



PILLAR #1

IR TRANSPARENT UPPER LAYER



The first layer of material that the laser beam shines through (IR Transparent Layer) must allow a certain portion of the laser energy to pass through. It is widely recommended that at the very least, about 5% of this energy passes through to be able to effectively heat the lower absorbing layer before degradation or burning occurs in the IR Transparent Layer.

Pro Tip:

To provide the widest flexibility in weld parameters - and therefore ease of success - a transmission rate of at least 5% is recommended. However, it is possible to go as low as 1% in certain circumstances.

There have been some applications where less than 1% of the energy passes through but special welding parameters need to be used in order to create a stable process and avoid surface degradation or burning.

Of course, there are various misconceptions about the term “transmissive and/or transparent” when it concerns laser plastic welding. The first is that the material does not have to be clear or transparent to the human eye, it just needs to pass the respective wavelength of the laser. Most consumer electronics devices and automotive components don’t employ the luxury of having a “clear” transparent layer and need to be opaque in whatever color the designer/stylist/marketer selects. In most common laser polymer welding applications, the wavelength used is around 980nm, (1 micron) which is supplied by a solid state semiconductor diode laser source.

PILLAR #2

IR ABSORBING LOWER LAYER

The absorbing layer of plastic serves as the most important layer of the two. This is because the inception of the welding process happens at this layer. As the laser contacts this layer, the plastic heats up to the point where this heat is transferred to the upper layer and both plastics melt and mix as long as there is tight mechanical contact between the two. Part of this is due to thermal expansion of both plastics as they heat and expand into each other, ensuring a good mixing of the materials at the joint interface.

In order for the process to work, the absorbing layer needs to be doped with a compound that absorbs the infrared laser energy. The most common dopant is carbon black, and is doped in at 0.5% - 1% by volume depending on the base resin as well as joint geometry. It is cheap and easy to come by but the resulting plastic in most cases is either grey or black.

Titanium dioxide is also used in conjunction with carbon black when colors other than black or grey are desired. Certain pigments can be added with the right mixtures of TiO_2 and carbon black to be able to get virtually any color desired. If a translucent absorbing layer is required, there are a couple of different suppliers of a compound which is doped into the plastic and absorbs the infrared energy but still allows the plastic to be somewhat clear (translucent).

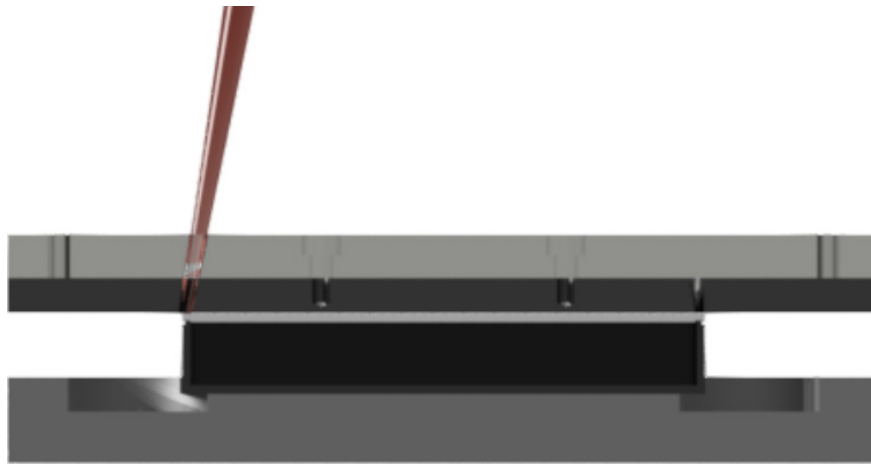
BASF has a product called Lumogen and Crystalyn has a product called Clearweld, both of which have a greenish hue which might be a prohibitive factor for some. There is also a product that is virtually clear when doped into the base resin, from a supplier called Brilliance Laser Inks.



PILLAR #3

TIGHT MECHANICAL CONTACT

Tight mechanical contact between the parts that are to be welded is probably the most critical factor when it concerns getting a good and stable process. The importance of clamping cannot be stressed enough.



It is vital to select the correct clamping style for the design of the part, whether it be a glass plate, all metal clamping mask, or a combination of the two. The part itself needs to be able to handle the resulting forces applied while clamping to avoid issues with deflection which may result in sporadic un-welded areas along the weld seam.

In some cases, a thin transparent silicone sheet in between the part and the clamping fixture might mitigate any non-planar surfaces and allow for full contact between the two pieces. The fixture or part nest is also a key item in the package as the fixture needs to provide rigidity under the part to allow proper transfer of clamping forces through the part to the fixture. It is absolutely essential that the fixture contacts the underside of the part in all areas where there is a weld seam.

PILLAR #4

MATERIAL COMPATABILITY

	ABS	ASA	COC	EVA	LCP	MABS	PA 11	PA 12	PA 6	PA 66	PBT	PBT/ ASA	PC	PC/ ABS
ABS														
ASA														
COC														
EVA														
LCP														
MABS														
PA 11														
PA 12														
PA 6														
PA 66														
PBT														
PBT/ ASA														

In general, *like* thermoplastics weld very well to themselves and there shouldn't be any issues with weldability in this case. Most laser plastic welding applications are able to use like materials. However, there are cases that call for two different materials to be welded together.

CHEMICAL COMPATABILITY

The first factor is that the two plastics need to have relatively similar chemical compatability (surface energy and polymer chains). For example, silicone is not going to weld to polycarbonate as their chemical compatibility is just too different, let alone their melt temperatures.

PROCESS WINDOW (MELT TEMPERATURE OVERLAP)

The next factor is the "process window" of the plastic. This process window needs to have at least a 50° C overlap with the process window of the other plastic you intend to weld. To clarify this, there is a point at which the plastic begins to melt called the glass transition temperature, and then a point at which the plastic degrades or decomposes. The goal here is when selecting the materials, the two plastics have a 50° C process window overlap in order to sustain a good and stable process. The greater the process window overlap the more stable the process will be.

MATERIALS

Selecting the proper materials for your project can be a daunting task and there are many factors to consider with respect to laser plastic welding. In most cases however, it is recommended to test the desired materials for their relative weldability before continuing with full part design.

As mentioned before, *like* thermoplastics will typically weld well to each other. The Material Matrix chart will show the weldability of some common dissimilar materials but it is best to obtain actual same coupons and test them in the lab to verify compatability.

The masterbatch and compound suppliers can produce resin grade that are laser welding compatible for both the transparent and absorbing component, as well as color-matched to your specific application. Some are listed below for you:

- RTP Company
- PolyOne
- A. Schulman
- Clariant



COLOR MATCHING

Virtually any color can be set up to work for laser plastic welding. Companies such as the ones listed above can help you dial in your color preferences to be absorbing to the laser as well as transmissive. Even black to black and white to white are possible.



Orient Corporation
Black to Black

Please keep in mind that IR Transparent dyes or pigments are not recommended for semi-crystalline materials such as PEEK or LCP. These materials should only be used in their natural state (IR Transparent layer only).

Glass fills (beads or fibers) also drastically reduce the transmissive properties of the material. For example, PBT can have up to 30% glass fill, however, the transparent layer shouldn't be thicker than about 2mm. One thing to note is that with this material in particular injection mold temperatures have a drastic effect on the transmissivity (such as cooling too fast or too slow, etc.). If you are specifying a grade of polyamide (Nylon), no more than about 30% GF should be used.

If an IR transparent black or other color is desired in a glass filled part, the transmissivity will need to be checked as the dye + the glass fills drastically reduce the transmissivity. Again, semi crystalline materials should not be dyed or pigmented.

ADDITIVE SELECTION CHART

Reference the below chart when selecting additives

AMORPHOUS			SEMI-CRYSTALLINE	
MATERIAL STATE	LASER WELDABLE?		MATERIAL STATE	LASER WELDABLE?
NATURAL	YES		NATURAL	YES
CLEAR	YES		CLEAR	YES
GLASS FILL	<40%		GLASS FILL	<20%
DYES OR PIGMENTS	YES, MINIMUM 3% LET		DYES OR PIGMENTS	NO
OTHER ADDITIVES	<5% LOADING		OTHER ADDITIVES	NO

MATERIAL COMPABILITY CHART

	ABS	ASA	COC	EVA	LCP	MABS	PA 11	PA 12	PA 6	PA 66	PBT	PBT/ ASA	PC	PC/ ABS	PE-HD	PE-LD	PEEK	PEI
ABS																		
ASA																		
COC																		
EVA																		
LCP																		
MABS																		
PA 11																		
PA 12																		
PA 6																		
PA 66																		
PBT																		
PBT/ ASA																		
PC																		
PC/ ABS																		
PE-HD																		
PE-LD																		
PEEK																		
PEI																		
PES																		
PET																		
PI																		

JOINT DESIGN

The first step in designing for laser plastic welding is to identify what major constraints you have in developing your product.

Asking the below questions can help you with the design process:

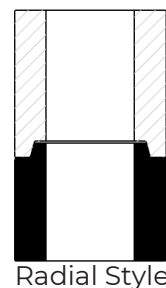
Are you locked into certain types of material considerations such as biocompatibility or structural?

Does the product you are designing have to withstand a certain mechanical fatigue or pressure?

Is your product highly visual, or perhaps the colors or styling are dictated by the marketing team?

Are there UV or other material properties that will influence the mechanical structure and selection of materials?

It is important to answer these questions before venturing down the path of joint design for laser plastic welding as you could end up backing yourself into a corner quite easily.



Typical Joint Profiles for Plastics Bonding

DESIGNING FOR STRENGTH

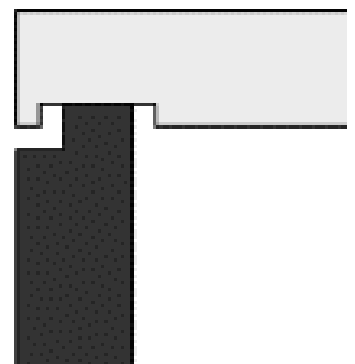
The first subject this design guide will tackle is designing for strength. When the main object is to design for mechanical integrity and strength of the part, this will trump most of the visual criteria.

Mechanical Design Considerations:

- ➔ Structural - Thick absorbing and transparent layer, relatively wide (>2mm) side walls, ribs or other stiffening features in both the absorbing and transparent layers
- ➔ Leak integrity - Does the part need to pass a standard such as the IP66 salt spray or other harsh environment testing?
- ➔ Burst pressure - Is a specific burst pressure necessary for hermetic integrity?
- ➔ What forces are acting on the part? Burst, chemical, thermal cycling, etc.
- ➔ Where is the part seam or joining line going to be?
- ➔ Is melt flash going to be an issue if it protrudes outside the edges of the part?
- ➔ Typically with large welding ribs and a large amount of collapse during welding. there tends to be some flash that will be visible after welding.
- ➔ It is recommended to use as wide of a sacrificial rib as possible without giving up wall thickness of the housing

For Example:

100mm x 75mm housing to lid application requiring an IP rated "tightness" specification, and a flash hiding feature...



Cross-Section of Standard Sacrificial Rib and Flash Hiding Feature

A recommended design form factor could be a 2mm-3mm wide sacrificial rib with 0.3-0.4mm of collapse during the welding process to ensure a good connection and material transfer between both joining partners.

AESTHETIC DESIGN CONSIDERATIONS

Once strength and integrity have been considered we can then turn out attention to the visual form and “looks” of the component.

Some things to consider:

- ➔ Color selections - are my parts required to meet a color matching standard?
- ➔ 3 D profile of part - is there some contour that i cannot deviate from such as radii in the potential weld area?
- ➔ Are sink marks OK? Sometimes sink marks occur after the welding process that are visible to the trained eye.
- ➔ Coatings, paint, etc? Are there any coatings that get applied either before or after the laser welding process?
- ➔ Damage to part during clamping - could there be potential for parts to get scratched or blemished in some way during clamping?
- ➔ Hide the flash or excess material - is there a visual requirement for the part to hide or eliminate any excess material ooze or flash from the outside environment?



Actual Laser Plastic Welded Car Taillight
Image courtesy of Motortrend

Sometimes *both* aesthetic and structural properties must be considered and compromise between the two will have to be made.

JOINT PROFILES

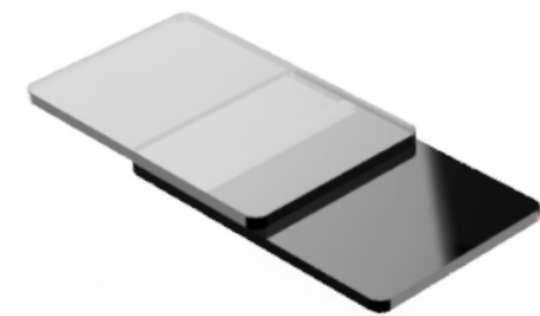
When designing a part for laser plastic welding, the designer must decide if a “sacrificial welding rib” is needed or not. If so, special care must be taken when including this feature.

You can compare the sacrificial rib to that of the energy director for those of you familiar with ultrasonic welding, with the exception that the rib needs to be flat at the top instead of pointed. There are many different ways to design the joint for optimal process.

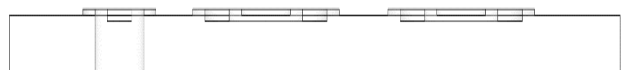
The first thing to take into consideration when selecting a joint profile is to fully understand if the goal is structural or aesthetic. If the part needs to withstand a certain burst pressure or has structural demands such as an actuator or electromechanical device, in almost every case, a weld rib is needed to overcome any variations from the injection molding process and ensure a good, strong, and hermetic bond. This is especially true with parts that have a complex labyrinth of fluid channels.

FLAT-TO-FLAT (LAP JOINT)

Then joining flat to flat parts, no sacrificial rib is needed, or in some special cases a much smaller rib can be designed into the absorbing part... 0.1mm or less.



Lap Joint Examples



RADIAL WELD - INTERFERENCE FIT

When designing for a radial style weld interference, typically just a good interference fit will suffice. A 1%-2% interference fit on diameter should be a good rule of thumb to start with. For example, a 10mm diameter round part should have 0.01mm-0.02mm of interference to get a good weld.

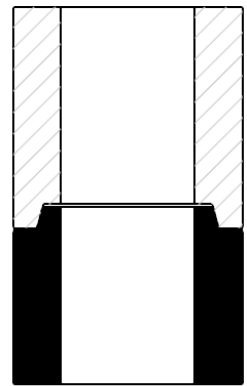
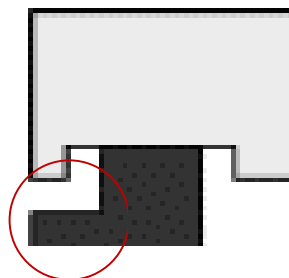
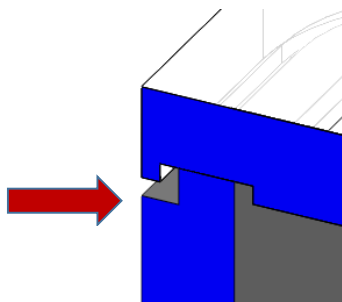
NO BUTT JOINTS!

With TTLW, butt joints do not work. This is due to clamping constraints but most importantly due to the absorbing layer degrading under laser energy before transferring any usable heat to the transparent layer. Further, two absorbing layers would not work because there is no way to ensure a good transfer of material after heating between the two, referring to TTLW, with clamping and subsequent heat transfer.

In certain cases, if you have two absorbing resins, butt welding is possible (see image at right, courtesy of Orient Corporation).

HIDING FLASH

There are certain features that can be designed into the part on the transparent layer to hide any excess material or flash that is a result of the welding process. The most common is to add a flange that shields the welding area from view. See below:



Radial Joint Cross Section



Butt Welding Example
Courtesy of Orient Corporation

CLAMPING TECHNOLOGY

Clamping and contact of the two parts to be joined is a vast area with many facets and is by far the most important aspect of laser plastic welding. Clamping will have far reaching effects on your process both in development as well as in high-volume production.

The goal of clamping in laser plastic welding is to provide a tight mechanical connection ensuring contacting between the two components that are to be joined, thus eliminating any potential gaps. As mentioned before, one of the 4 pillars of Laser Plastic Welding is a tight mechanical connection. Without the parts being clamped tightly together, the laser energy would burn and degrade the absorbing layer before it transferred the heat to the upper transparent layer.

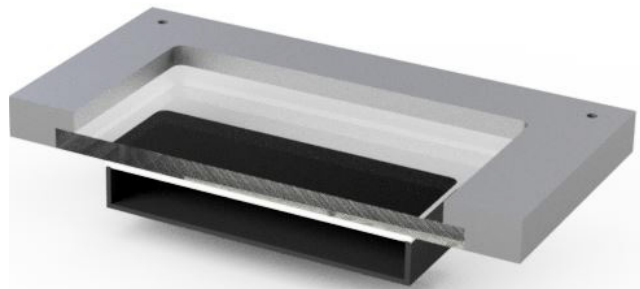
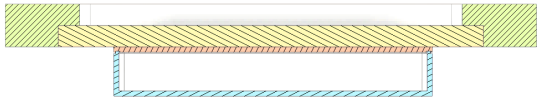
Clamping is everything in laser plastic welding, it will make or break your process, every time and needs serious consideration. The part must be able to handle the mechanical force that is transferred by the clamping system. If not designed properly, warping will occur resulting in an imperfect weld seam.

An important point to consider when selecting a clamping method is that anything in between the laser aperture (F-Theta lens, Beam Expander, Diffractive Optic) and the welding surface (glass or plastic) has a tendency to attract impurities from the air which settle on the surface and superheat and burn when hit by the laser. This causes micro fractures on the surface which gradually decreases the amount of laser energy that gets through. With that being said, there are several different clamping methods known to laser plastic welding and each have their advantages and disadvantages.

WINDOW CLAMP TOOLING

The first clamping technology is also the simplest. It is mainly used for prototyping in a lab scenario. It involves the use of a flat piece of clear acrylic PMMA, PC, or glass to exert mechanical force on the surface of the part to be welded.

Laser access is, for the most part, unobstructed and this concept makes for a great and inexpensive means of testing parts in the lab and even in some limited batch run scenarios. If using plastic, it can also be easily machined to conform to the part surface anomalies whether it be 3D contours or other features.



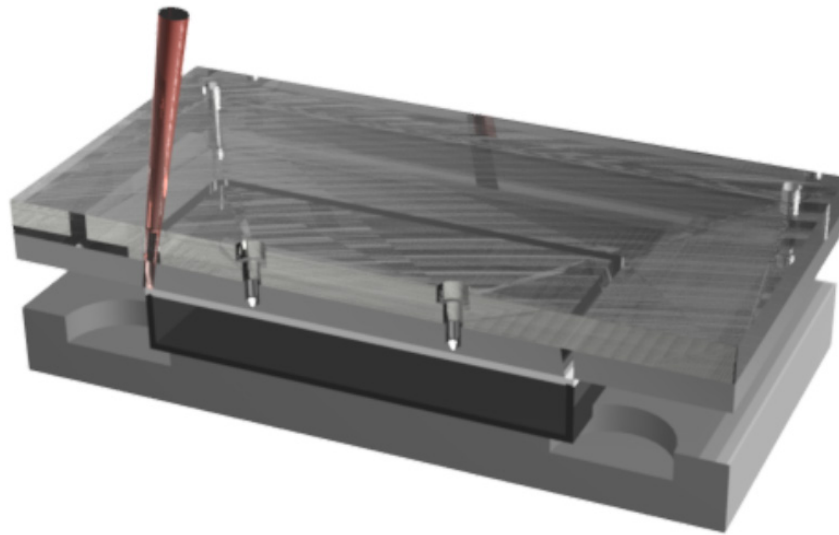
Window Clamping Tool Example - Cross Section

Glass can also be used in clamping. Quartz glass is machinable with diamond coated tools and borosilicate glass is typically ground to shape and in certain cases this can provide a cost-effective, limited-life production solution. You could expect to get around 500-1000 parts with each new piece of glass if you have a good preventative maintenance (cleaning) schedule. In the case where glue is used, certain coatings can also be applied to limit back-reflection and aid in the laser transmission.

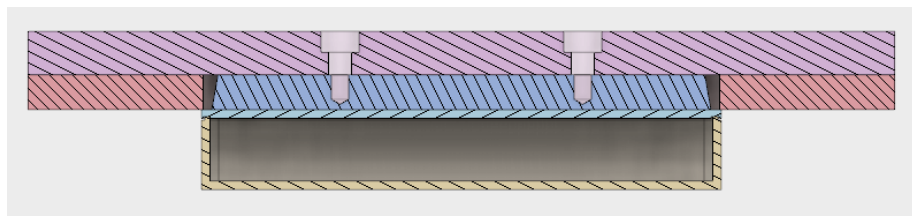
HYBRID TOOLING

The next clamping technology is a somewhat of a hybrid between full production tooling and prototype tooling. It consists of mounting an inner metal clamping mask and an outer metal clamping mask to a piece of clear PMMA or PC. This leaves a channel that is open for the laser to pass through.

This acts as a sort of hybrid production clamping technology. While the warping issues of the outer profile metal clamp are overcome, there is still the surface for dust to settle and become burned by the laser. This type of clamping is best suited for ramp up prototype runs where the intent is to go into production with the part but a low-cost upfront tooling investment is desired. Later a full metal production clamping device can be developed.



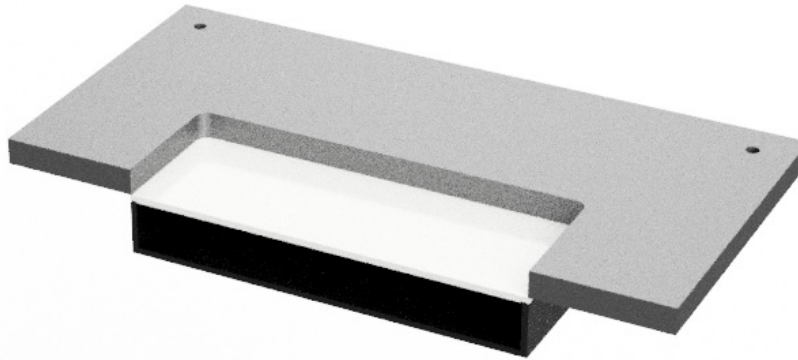
Hybrid Clamping Tool Example - Cross Section A



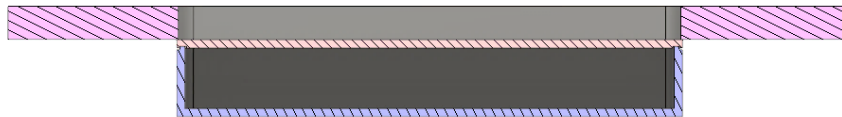
Hybrid Clamping Tool Example - Cross Section B

ALL METAL CLAMPING - OUTER ONLY

The next type of clamping involves using an all metal outer clamping mask which contacts between 0.5mm and 1mm of the outer perimeter of the part to be welded. Typically these types of clamps are made from tool steel or stainless steel.



Metal Outer Clamping Tool Example - Cross Section A



Metal Outer Clamping Tool Example - Cross Section B

For a production scenario, this clamping method is a step up from having an acrylic or glass clamp in-between the laser and the welding surface that can potentially be contaminated. However, the drawback of this type of clamping method is that as the plastic heats up, it tends to warp. Since the clamp is only on the perimeter of the part, the inner area of the part stays put and the outer perimeter where the clamp contacts, moves down and warps the edges, see illustration below:

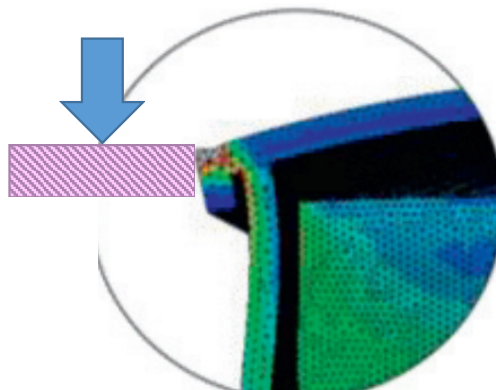


Image Courtesy of:

<http://www.sciencedirect.com/science/article/pii/S1875389213000679>

The next factor is similar to what happens when TIG welding metal, the object is to push the molten bead along during the welding process with the TIG torch. This also happens while welding plastics, the molten plastic is “pushed” under the metal rib as the beam is guided around the profile of the weld path - especially when using the quasi-simultaneous welding technique, where the beam is directed around the weld path many times in a short period of time. These factors combined with some optimization of the weld parameters will virtually eliminate any effect of shadowing caused by the metal rib in the laser path.



TIG Welding Bead
Image courtesy of: www.hotrod.com

CLAMPING FORCE

A very important point to consider is that the parts must be structurally sound enough to handle the forces being applied and transmitted through the part during clamping. The typical range of clamping force applied is between 2-3 Newtons per square millimeter of welding joint surface area.

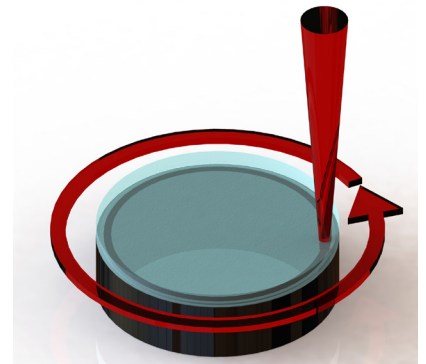
BEAM PROPERTIES AND DELIVERY

Several optical components work together in a laser plastic welding system to form and focus the laser beam. With that result, there are 4 different methods of beam delivery and ways to get the laser to the part.

They are summarized below.

CONTOUR WELDING

Method of beam delivery utilizing a galvanometer scanning unit, or CNC control, where the laser is directed along a programmed 2D (X and Y axis) welding path one time with enough energy to heat the materials and properly weld at the joint interface. There is no collapse or movement of the transparent part. This method is feasible for flat to flat (lap joint) style parts where an energy director is not required.



Contour Welding Concept

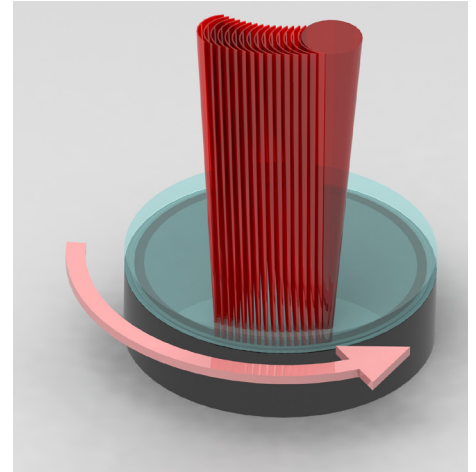
3D CONTOUR

Method of beam delivery where the laser is directed along a programmed 3D (X, Y, and Z axis) welding path one time with enough energy to heat the materials and properly weld at the joint interface. This can be achieved by either using a multi-axis robotic arm to move the laser along the path, by means of a 3D galvanometer scanning unit, or even CNC motion control (a car taillight is a good example of this).

In some cases, a 2D galvanometer scanning unit can be used if certain guidelines are met. This type of beam delivery method is used on larger free-form curved parts where geometry would inhibit the beam access.

QUASI-SIMULTANEOUS

Method of beam delivery utilizing a galvanometer scanning unit similar to Contour Welding except that the laser is directed along the programmed 2D path at a high rate of speed, enough times to achieve a preset collapse or melting travel distance of the transparent part. This simulates the entire weld profile being lased - simultaneously.



This is a good place to start when doing your structural analysis. Good support is needed directly under the weld joint both in the part itself as well as the fixture the part is placed in for the welding process. Proper support will ensure minimal warping or bowing of internal features and thus resulting in an inconsistent welding seam. This is one of the most important aspects to laser plastic welding and is often overlooked when designing for this technology.

Pro Tip:

A layer of silicone sheet (1mm thick or so) can be applied in between the glass or plastic clamping window when welding large complex patterned welds (2D only). This helps overcome any warping issues and allows for an even clamping force over the whole surface of the part. The same silicone layer can be added to the part nest to allow for free-alignment.

TOOLING TYPE APPLICATIONS

Quick prototyping of sample coupons & flat surfaced parts

- ➔ Acrylic or glass upper clamp
- ➔ Universal part nest - modular fixture

Prototyping of most parts - contoured surface or not

- ➔ Acrylic or glass upper clamp
- ➔ Custom machine part nest or 3D printed

Prototyping and multi part runs

- ➔ Hybrid upper clamp
- ➔ Custom machined part nest

Production

- ➔ All metal style upper clamp
- ➔ Custom machined part nest

1940nm welding (Transparent Polymer)

- ➔ Borosilicate glass upper clamp
- ➔ Custom machined part nest

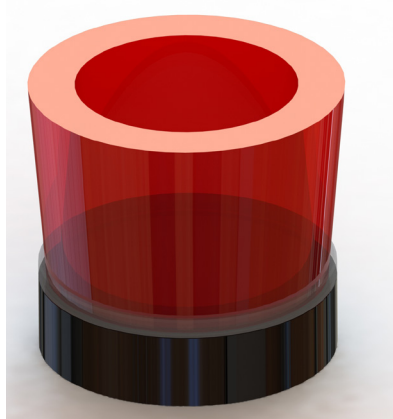
Radial welding

- ➔ Use mirror tooling
- ➔ Fixturing either in rotary device or nested

When a welding rib or “energy director” is needed, this is the only type of beam delivery that can be used aside from simultaneous. The reason for this is that as one section of the part begins to heat enough to start melting, the clamping mechanism cannot collapse that area because the remaining majority of the part is not melted and will not allow the clamp to travel downward in the Z direction.

SIMULTANEOUS

This is a method where the laser energy is delivered by multiple optical fibers placed strategically around the profile to be welded. To ensure a homogenous blending of the individual fibers, the laser energy projecting from the fibers is diffused by means of wave guide to the welding surface of the part.



Simultaneous Welding Concept

SHAPED BEAM - DIFFRACTIVE OPTICAL ELEMENT

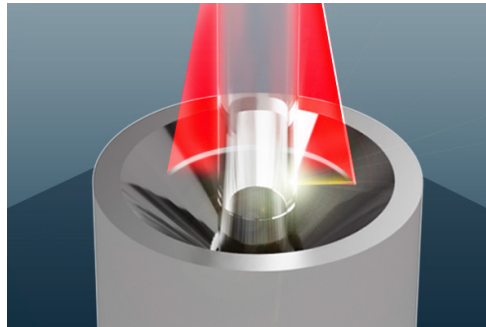
The laser can be focused into certain shapes or profiles by means of a “Diffractive Optical Element” to allow a more efficient coverage of the welding area. This is achieved by means of precision optics such as prisms, lenses, light guides, etc. DOE’s are now being used to create a “top hat” profile which greatly decreases burning potential in low transmissive materials.

MIRRORS AND BEAM GUIDANCE

The laser beam itself is a very interesting phenomena in that it can be directed, channeled, focused and guided to a precise position, in a perfectly repeatable manner. In the event where features on a part cannot be accessed by conventional means, IE (2D scanner, 3D scanner, CNC motion control, or robot, etc.) then precisely placed mirrors can be used to direct the beam to access that particular feature.

CONICAL MIRRORS FOR RADIAL WELDS

Mirrors also make a great, robust, and quick way to weld around a circular part in a radial style weld joint. The mirror would be in a conical shape and a conventional 2D scanner could be used to direct the beam around the conic and eventually mirrored to the part. This works well for radial welding applications.



Radial Style Welding With Mirror

When welding round contoured parts or radial style weld joints, the use of mirrors in conjunction with clamping and fixturing can be very valuable.

RADIAL WELD TOOLING

When it comes to radial welds the clamping force is provided not by tooling, but actually the interference fit designed into the parts themselves.

Radial welds can be done in 2 different ways:

- 1 Parts held horizontal and mechanically spun while the laser is held stationary, as seen below
- 2 The parts are fixtured vertically and a conical mirror, acting like a collar around the part, is used to direct the laser around the joining area.



DIRECTED MIRRORS FOR WELDING UNDER OBSTRUCTIONS

In certain cases, parts may have features that restrict laser access from the top, shadow the beam path, or even obstruct it completely. In these instances, mirrors with particular shapes and strategically placed, can be used to direct the beam around or even under such obstructions.

GENERAL DESIGN GUIDELINES

UNIFORM LID THICKNESS

It is recommended that the transparent layer is of uniform thickness around the profile of the weld joint. If multiple or varying thicknesses are used, the chance for varied laser power at the welding surfaces is increased, which can cause an unstable process. Granted, there is some level of programmable control at specific areas around the weld profile that can alleviate some of these affects, however, it is best to keep thicknesses uniform.

- Uniform transparent layer thickness



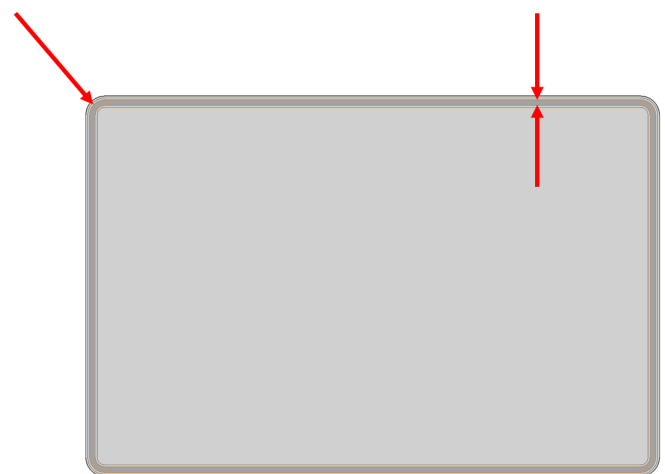
Transparent layer as thin as possible

MINIMUM POSSIBLE THICKNESS

As the thickness of the transmissive layer increases, the less the percentage of laser energy gets through. It is recommended that the transmissive layer stays as thin as possible taking into consideration injection molding constraints as well as structural needs. Typical thickness of the transmissive layer is between 1mm-3mm. If additives such as glass fills are used or IR transparent pigments, this greatly reduces the amount of laser energy able to pass through the part and therefore reduces the thickness this layer can be.

Radius all corners

Uniform joint width



UNIFORM JOINT WIDTH

It is required in laser plastic welding that the width of the welding rib around the part stay uniform. This means no dimensional changes or variation. All sharp corners must be filleted so that the rib width stays uniform. The laser beam must overlap the welding joint by a minimum of 0.5mm on either side. If the joint width was to vary or get wider, the laser would potentially not be able to fully melt the plastic in one pass. The same holds true for sharp corners.

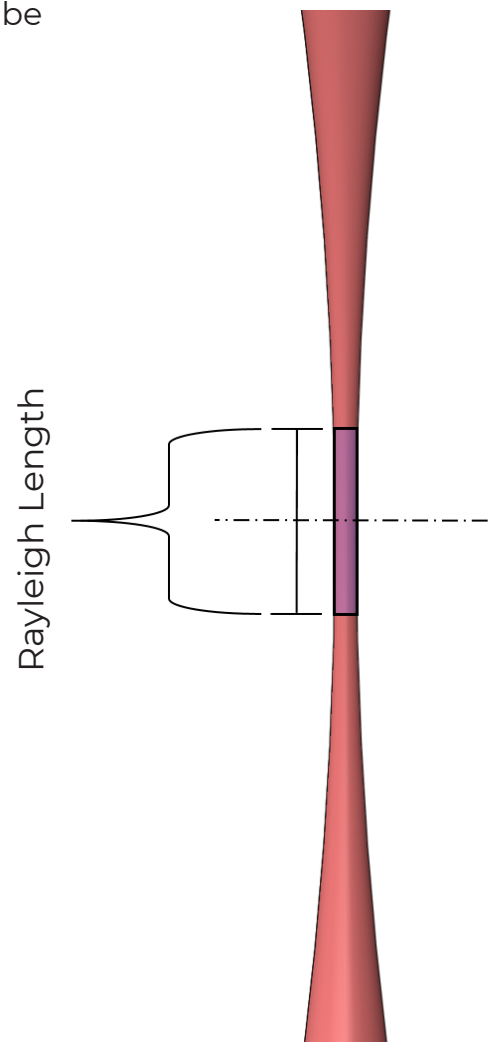
PLANAR JOINTS

It is highly recommended that the welding profile lies on a single plane. When design or styling requirements demand a profiled or curved surface and resulting weld joint, certain criteria must be taken into consideration which will be covered later in this guide.

RAYLEIGH LENGTH AND MAXIMUM DEVIATION

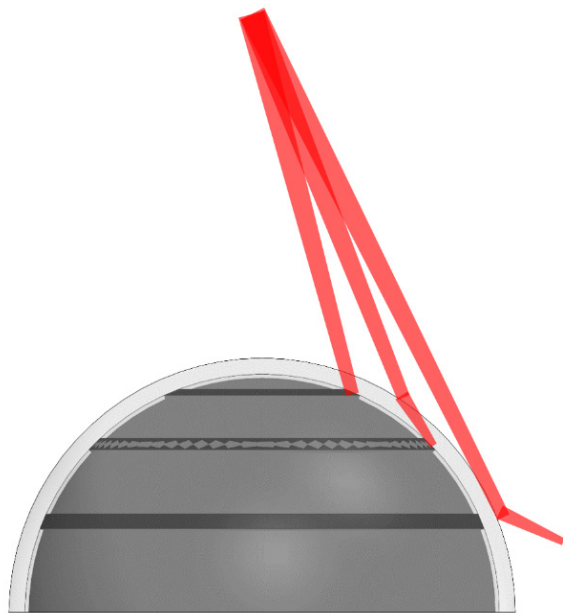
Since the beam is in the shape of an hourglass when focused there exists a certain region at the center of the beam waist which is called the Rayleigh length. Inside of this area the laser beam is effectively still focused enough to properly weld. This can to certain extents allow some 3D or non-planar welding.

"In optics and especially laser science, the Rayleigh length or Rayleigh range is the distance along the propagation direction of a beam from the waist to the place where the area of the cross section is doubled." (source: Wikipedia)



CURVED UPPER SURFACES AND REFRACTION/ REFLECTION

When welding 3D or non-planar parts, too aggressive of a radius or curve will act as a mirror and the laser will not penetrate due to redirection of the light - think of the spoon in a glass of water optical effect.



Reflection Effect
Image for Reference Only



Refraction Example

MUCH TIGHTER CONTROL OF INJECTION MOLD TOLERANCES

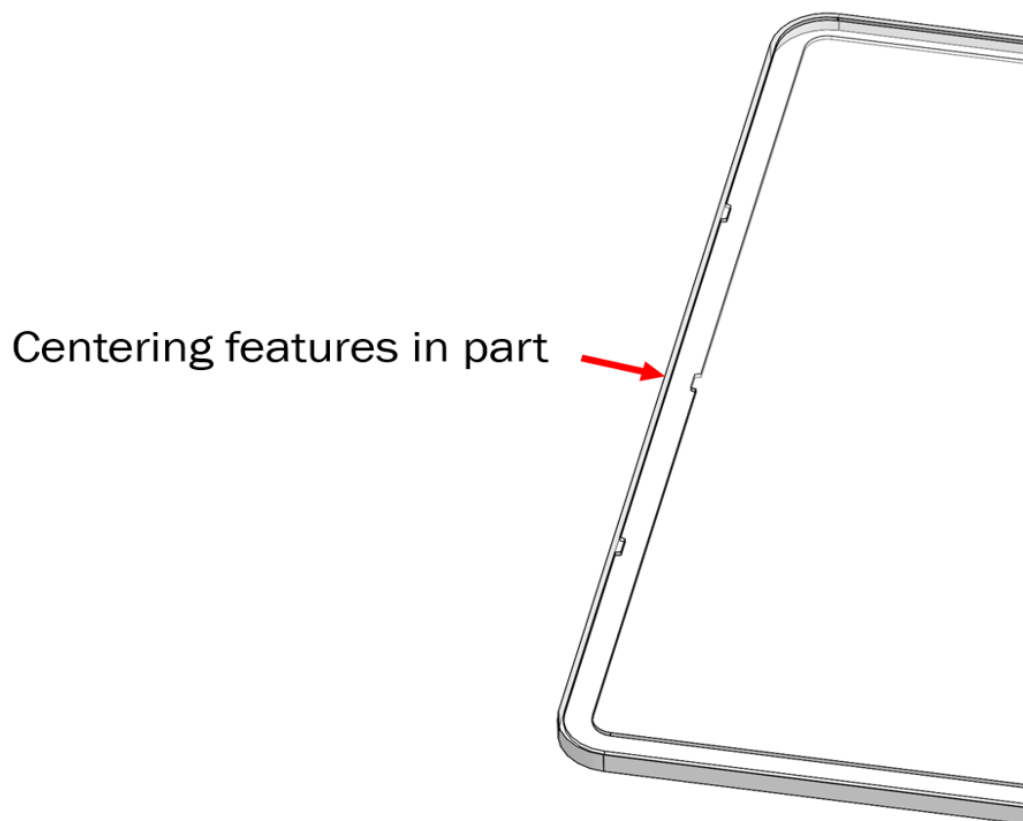
One critical term to consider when implementing laser plastic welding is the need for much tighter control of the injection molding process. This means that tolerances need to get smaller! It is recommended that the tolerance stack up is no greater than 0.2mm for flatness. Dimensionally the parts can vary a bit but no greater than about 0.5mm. Gaps between the two pieces need to be less than 0.1mm in order to create a stable welding process.

NO EJECTOR PIN MARKS OR GATES IN WELD AREAS

It is recommended that no mark reside in the area where the weld is to take place. This includes material gates, ejector pin marks, injection mold slide marks and other surface irregularities. Some of these instances are unavoidable and should therefore be relocated to another area where they won't interfere with the welding. The main thing is that there are no gaps between the parts caused by these surface irregularities, which will cause burning in the welding area and not allow heat transfer and the two plastics to join properly.

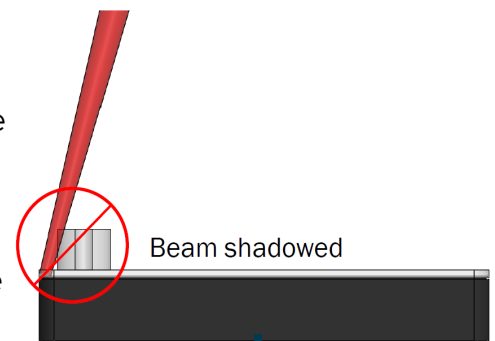
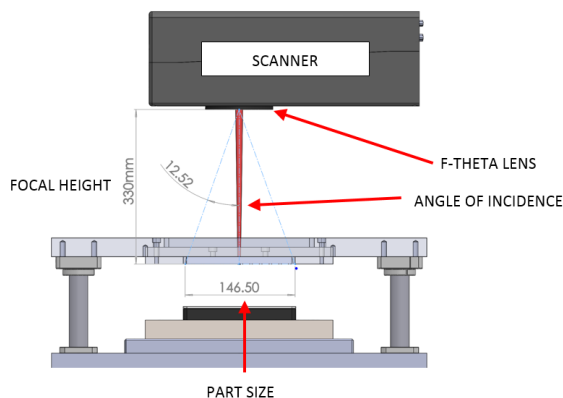
CENTERING FEATURES IN PART

It is important to design certain features into the transparent part that will locate it to the absorbing side. This will help the two parts locate to each other and avoid misalignment. Centering features will also help to keep the transparent part on the absorbing part during the manufacturing process. Sometimes during the part-transfer step in a fully automated production line, the parts could shift and separate from each other before welding can occur. This technique can also be designed into the welding joint itself.



BEAM ANGLES AND REFRACTION

When designing for laser plastic welding, care must be taken if a part has features that protrude off of the welding plane. This includes bosses and other features that could potentially shadow the laser and keep it from reaching the welding area. In addition to beam shadowing, one must take into consideration the angle of incidence of the laser. See diagram below. This will vary with the type of laser and optics and is a result of the distance between the focal plane of the laser and the aperture or F Theta lens as well as the size of the scan field. This can be calculated with some simple trig or in the CAD system using the below concept.

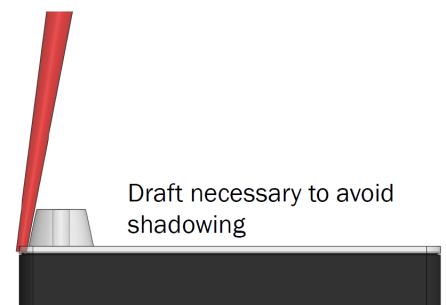


CALCULATE ANGLE OF INCIDENCE

The angle of incidence is calculated with the following steps:

- ➡ Figure out the focal height of the laser beam (Use F-Theta specification)
- ➡ Figure out the maximum dimensions of the part
- ➡ Solve for angle of incidence

Calculating the angle of incidence allows for figuring out the draft necessary and positioning for protruding part features. It is also necessary when designing inner-stamp tooling or all metal style tooling to calculate the draft allowing for laser clearance.



COMMON PITFALLS

COMMON PITFALLS

By following the recommendations in this guide you will avoid most problems with laser plastic welding, however, here is a list of common pitfalls to avoid:

- ➞ Non compatible or non weldable material section
- ➞ Poorly transmissive upper layer - fills (glass, TiO₂) or dyes, etc.
- ➞ Bad injection molded components - loose tolerances
- ➞ Parts deform under clamping pressure
- ➞ Internal part features obstructing welding collapse
- ➞ Internal/external features refracting beam
- ➞ 3D surfaces refracting laser

A TYPICAL PROJECT ROADMAP

PROJECT ROADMAP

PHASE 1

- ✓ Select materials - verify OK
- ✓ Joint design recommendation (this typically takes 2-3 iterations)
- ✓ Proto tooling concept

PHASE 2

- ✓ Sample coupons test welded in lab
- ✓ Proto tooling designed and built
- ✓ Proto welding and DOE - (typically less than 200 parts)
- ✓ Lock in materials and joint design
- ✓ Research laser welding system supplier that is best suited for the application

PHASE 3

- ✓ Purchase system and production tooling
- ✓ Supplier acceptance testing of production system
- ✓ Installation and commissioning at manufacturing site
- ✓ Ramp up of production line
- ✓ Follow up service and support

FREQUENTLY ASKED QUESTIONS

COMMON QUESTIONS

Can i use my existing joint geometry, for example... Ultrasonic welding?

- ➔ No, because the apex of the triangular energy director used in US welding will tend to burn first before effectively transferring the heat needed to melt the opposing layer of plastic. A new joint profile is needed and consists of flat top profile as pictured earlier in this design guide.

How can i inspect my laser plastic welded component for joint integrity?

- ➔ By using an Infrared system either integrated into the welding process or in a standalone form factor. An IR inspection system specifically set up for inspecting plastic welded components can "see thru" the laser transparent layer and effectively analyze the bonding area with special software.
More info at: www.dukane.com

Will the laser damage the plastic or components inside or outside of the welding rib area?

- ➔ No, this is one of the major advantages of laser plastic welding, LPW has a very small heat affected zone and since the beam is precisely controlled, it stays within the set boundary.

What is the maximum thickness the transparent layer can be?

- ➔ The transparent layer should be as thin as possible, however, when structural cases or other design constraints present themselves, the maximum thickness depends ultimately on the transmissivity of the material

Can you weld opaque plastics?

- ➔ Yes, as long as the plastic transmits the laser energy in the appropriate wavelength. RTP Company and others can compound virtually any color desired to be laser transmissive.

How much clamping force is needed?

- ➔ 2-3 Newtons per square millimeter of weld joint surface area.

For more information, speak with your Dukane representative or contact your Dukane regional office.

United States
St. Charles, Illinois
+1.630.797.4900 Phone

Czech Republic
Prague
+420.220.970.509 Phone

China
Changzhou, Jiangsu
+86.519.85966719 Phone

Japan
Kashiwa, Chiba
+81.4.7136.2165 Phone

India
Chennai, Tamil Nadu
+91.44.2478.3448 Phone

Germany
Bielefeld, Ostwestfalen-Lippe
+49.521.932070 Phone

Mexico
Santa Catarina, Querétaro
+52.442.198.0206 Phone

For additional information visit us at: www.Dukane.com

MATERIAL SELECTION CHART

	ABS	ASA	COC	EVA	LCP	MABS	PA 11	PA 12	PA 6	PA 66	PBT	PBT/ASA	PC	PC/ABS	PE-HD	PE-LD	PEEK	PEI	PES	PET	PI	PMMA	POM	PP	PPS	PPSU	PS	PSU	PTFE	PUR	PVC	SAN	SB	TPE
ABS																																		
ASA																																		
COC																																		
EVA																																		
LCP																																		
MABS																																		
PA 11																																		
PA 12																																		
PA 6																																		
PA 66																																		
PBT																																		
PBT/ASA																																		
PC																																		
PC/ABS																																		
PE-HD																																		
PE-LD																																		
PEEK																																		
PEI																																		
PES																																		
PET																																		
PI																																		
PMMA																																		
POM																																		
PP																																		
PPS																																		
PPSU																																		
PS																																		
PSU																																		
PTFE																																		
PUR																																		
PVC																																		
SAN																																		
SB																																		
TPE																																		

Good Weld

Adequate Weld – testing recommended

Good Weld Adequate Weld - testing recommended