Take Your Product Quality to the Next Level

Select the correct lens and see the difference

By David Stevens

David Stevens is a Sr. Global Technology Specialist at Universal Laser Systems (ULS). Through more than 15 years of experience and his passion for technology, Dave has become a trailblazer in laser material processing. Dave travels worldwide educating audiences about laser technology and providing them insight on how to maximize and expand their business.

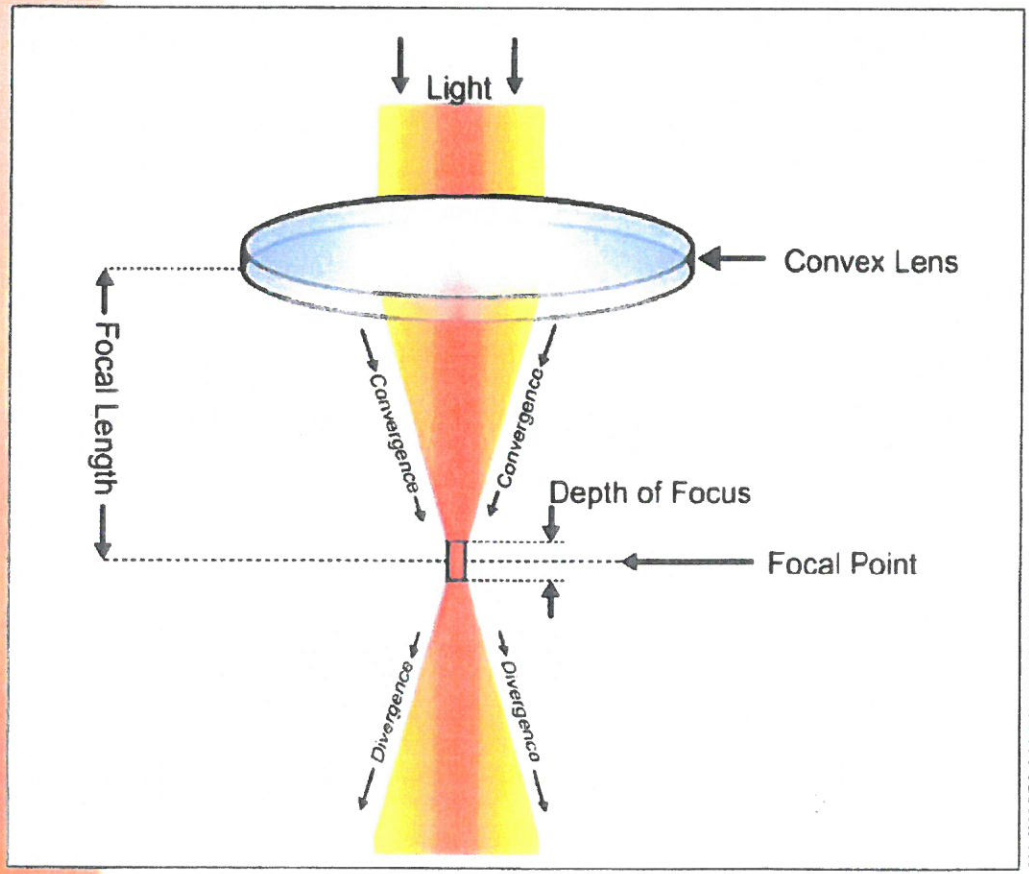
One of the fundamental components of your laser system essential to producing quality engraving are the focusing optics or lenses that concentrate the laser light to deliver detail and sharpness to every product you produce.

The first consideration when choosing focusing optics is the application. What type of material processing are you doing: engraving, marking or cutting? Knowing this helps determine the best focusing optics for the task at hand. This article describes how focusing optics work and compares the different focusing optics available for a typical laser material processing system. Some important characteristics of focusing optics include focal spot size, focal length and depth of focus. Most laser manufacturers offer a range of focusing optics in increments that step from 1.5 inches to 4.0 inches for processing substrates in a variety of ways.

HOW LASER FOCUSING OPTICS WORK

Laser systems typically use Plano-convex lenses to focus laser light. Laser light enters the lens and begins to converge to a focal point. Upon crossing the focal point, the light diverges again. In the illustration below, note the light takes on an hourglass shape.

The area on either side of the focal point where the beam remains focused enough to be useful is called the depth of focus. The shorter the focal length, the more quickly the laser light will converge and diverge. A shorter focal length produces a smaller focal spot. The shorter



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the focal length, the smaller the depth of focus. Shorter focal length optics require more precise focusing than longer focal length optics. Focusing optics with shorter focal lengths are more sensitive to the flatness of material. Focusing optics with longer focal lengths are more forgiving and able to perform even if the material has some curvature to the surface.

BY SMALL MEANS, GREAT THINGS ARE ACHIEVED

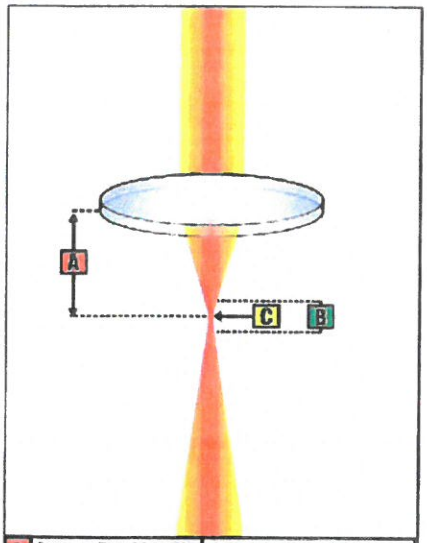
The focal point is the point where the laser light is concentrated into a small area typically referred to as a focal spot. The size of this focal spot is what determines the ultimate resolution and quality that can be achieved with each focusing optic. Each focusing optic or lens will have a distinct spot size, depth of focus or focus tolerance, and focal length. As a result, each will produce differing effects. 18

The effect of three different lenses is apparent in the engraving of the same image at the bottom of the page. The laser image appears brighter and with more visible detail as the focal spot gets smaller.

The image was laser processed on black anodized aluminum with the same laser system at the same laser wattage. Identical laser processing settings were used with three different focusing optics, 2.0 inches, 1.5 inches, and High Power Density Focusing Optics (HPDFO).

THE 1.5-INCH DETAIL DYNAMO

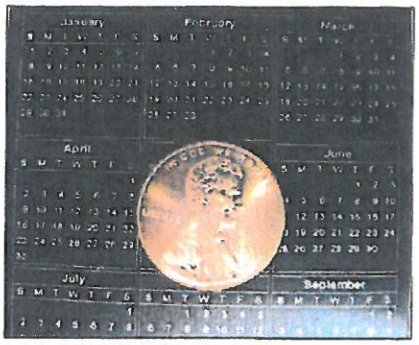
The 1.5-inch lens assembly is designed for high-resolution engraving of extremely small fonts and detailed photos. Depending on the type of material being processed, the spot size produced by this option can be as much as 30 percent smaller than a standard 2.0-inch focusing lens. This size difference enables an increase in detail and quality but comes with some tradeoffs.



A	Average Focal Length:	1.5" (38,1mm)
B	Tolerance:	+/- 0.075" (+/- 1,905mm)
C	Average Focus point:	0.003"(0,076mm)

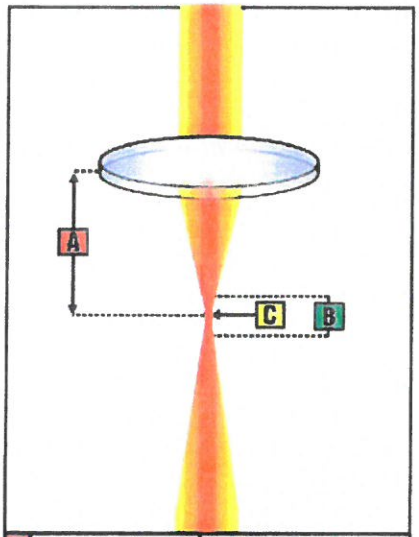
A shorter focal length gives you an additional 1/2" (12,7mm) of Z-axis travel, allowing taller parts to be processed, but this lens is close to the work area. In this proximity, the lens stands a greater chance of being contaminated by smoke or debris.

Additionally, the lens tolerance is small and cannot handle much deviation from the focus point. High divergence limits its usefulness in cutting materials over 0.2" (5,08 mm) in thickness, but on thin material cutting applications, it can maintain an acceptable kerf or cutline. See the example of the penny below.



2.0-INCH WORKHORSE

If there is a question of what lens to use, this lens is the most practical choice.



A	Average Focal Length:	2.0" (50,8mm)
B	Tolerance:	+/- 0.1" (+/- 2,54mm)
C	Average Focus point:	0.005"(0,127mm)

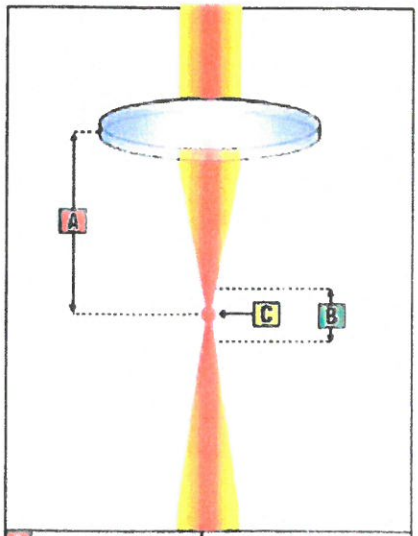
The 2.0-inch lens produces excellent engraving and marking detail combined with superb cutting quality. Because of this flexibility, the 2.0-inch lens is the most common lens and comes standard with most laser systems.

This all purpose lens engraves and marks in high quality and provides consistent cutting quality up to 1/2 inch (12,7mm) or more in thickness depending on the type of material being processed.

However, it does have its limits. It's not the best lens for achieving the highest resolution detail, and when cutting substrates over 1/2 inch (12,7mm), it creates edges that are tapered, which for some applications may be unacceptable. See the example above.

ADDED CLEARANCE WITH 2.5, 3.0 AND 4.0 INCHES

There are several lens options available that can be successfully used when cutting thicker materials greater than 1/2 inch (12,7mm). These lenses are also an option when dealing with materials that have a curvature to the surface or cannot be held flat. When your application exceeds the capabilities of the 2.0-inch lens, the 2.5-inch, 3.0-inch and 4.0-inch are viable choices. But as the focus spot gets larger, engraving detail is reduced.



A	Average Focal Length:	2.5" (63,5mm)
B	Tolerance:	+/- 0.15" (+/- 3,81mm)
C	Average Focus point:	0.007"(0,178mm)

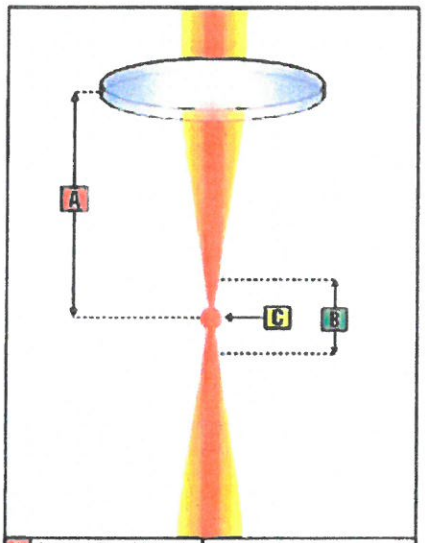
The 2.5-Inch Lens

The 2.5-inch lens gives you an additional 1/2 inch (12,7mm) of clearance over the standard 2.0-inch lens, so your project does not interfere with the carriage. However, it also reduces Z-axis travel by that same 1/2 inch (12,7mm). In some cases, this can limit the size of your project.

This lens has a longer focal length and greater focal tolerance but still provides good engraving detail, although not as good as shorter lenses due to the slightly larger spot size. This lens is at its best when cutting. Depending on the material, this lens is capable of cutting thicker materials up to 5/8 of an inch (15,875mm). See river rock example below.

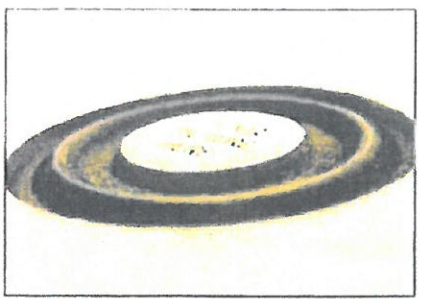
The 3.0-Inch Lens

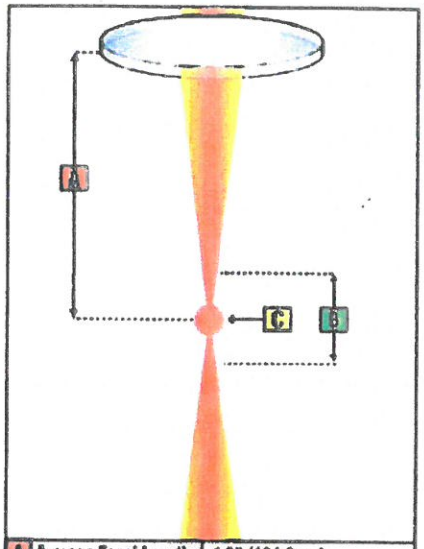
A step-down, the 3.0-inch lens provides you an additional 1 inch (25,4mm) clearance over the standard 2.0-inch lens. However, Z-axis travel is reduced by 1 inch (25,4mm) from the standard 2.0-inch lens.



A	Average Focal Length:	3.0" (76,2mm)
B	Tolerance:	+/- 0.18" (+/- 4,57mm)
C	Average Focus point:	0.010"(0,25mm)

This lens has an increased focal length and greater focal tolerance than the 2.5-inch lens. It excels in cutting thick substrates up to 3/4 of an inch (19,5mm) or more depending on the material. The lens still maintains adequate engraving and marking quality, especially on simple patterns and designs. However, is not recommended for detailed engraving. See example below.





A	Average Focal Length:	4.0" (101,6mm)
B	Tolerance:	+/- 0.20" (+/- 5,08mm)
C	Average Focus point:	0.012"(0,304mm)

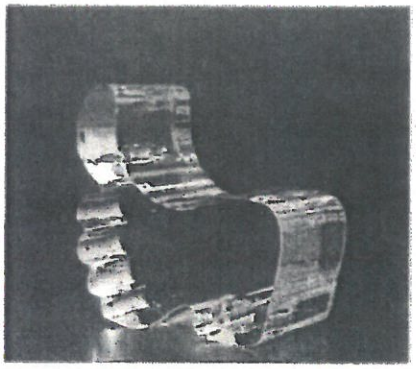
4.0-Inch Lens

This lens has a long focal length and offers great focal tolerances. When clearance and focal tolerance issues prevent shorter lenses from working, this lens will do the job.

The 4.0-inch lens produces a focused beam over a longer vertical distance, which makes it ideal when engraving within a recessed area of a product, such as inside a bowl or box. This lens is still able to mark and engrave for some applications though the quality and detail is reduced due to its large focal spot size.

This lens gives you an additional 2-inch (50,8mm) clearance from the carriage over the standard 2.0-inch lens. At the same time, it reduces Z-axis travel by 2 inches (50,8mm), so the size of the project that fits in your system will be reduced.

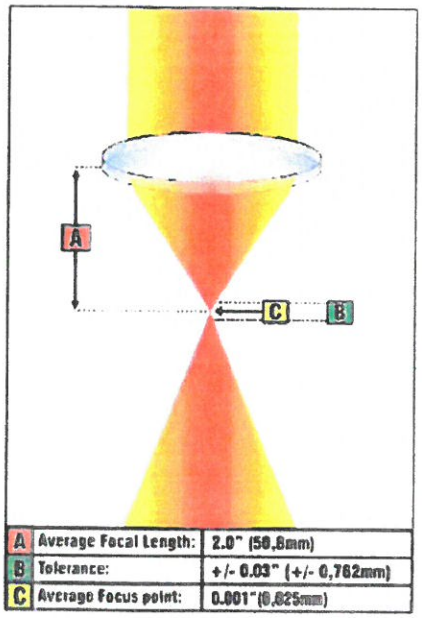
The large focal tolerance is ideal for cutting thick materials up to 1 inch (25,4mm) or more depending on the substrate. This is your best option for thick materials. It is also a good choice for parts with some curvature to the surface. See above example.



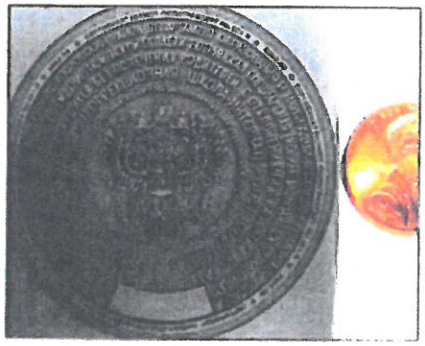
EXTREME DETAIL AND HIGH POWER

The High Power Density Focusing Optics (HPDFO) from Universal Laser Systems is a unique, patented focusing lens assembly. It produces a spot size that can be as small as 1/5th the size of a standard 2.0-inch focusing lens, but with the focal length of the standard 2.0-inch lens. The HPDFO dramatically increases the power density of the focused laser energy to achieve the effects of a laser of much higher power, permitting materials like steel to be directly marked.

The small spot size generated by this lens assembly makes it possible to produce intricate, tight-tolerance engraving, the sharpest marking images, and the finest kerf when cutting thin material. However, it does have reduced focal tolerance over the standard 2.0-inch lens. Its cutting ability on substrates thicker than 1/8 of an inch (3,18 mm) is limited. See both examples on this page.



A	Average Focal Length:	2.0" (50,8mm)
B	Tolerance:	+/- 0.03" (+/- 0,762mm)
C	Average Focus point:	0.001"(0,025mm)



OPTIONS

The number of lens options available today provides solutions for a broad range of applications for cutting, engraving and marking on thousands of materials that come in many shapes and sizes. Understanding the characteristics of each lens and effects each produces will help you to choose a lens option that will help you elevate the quality of your products. **LER**