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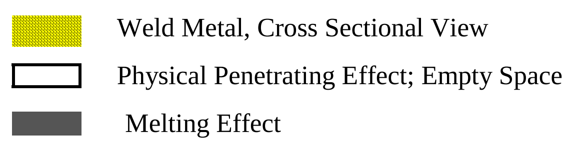
Laser Welding Basics
Primary Adjustable Welding Parameters

This article will run over multiple issues of Bench Magazine. I plan to start with the basics of welding and write about the characteristics of the beam and how we use those characteristics to weld. It is important to understand how the beam is focused. Equally important is, how the viewing system is focused in relation to the focus of the beam. I will have specific examples of jewelry related jobs that demonstrate the energy characteristics of the beam, as well as techniques and technologies, (some that are rather new), that help overcome challenges that we, as jewelers, have faced over the past 10 years of Laser Welding.

When learning laser welding, the jeweler should understand some basic principles of welding vs. the soldering technique most jewelers are familiar with. Anyone who has understanding for welding principles must only learn how the lasers adjustable energy characteristics can be used to accomplish welding, and then gain a small amount of eye hand coordination to work through magnification, using the characteristics of the beam, with some simple techniques to accomplish welding. Welding differs from Soldering. Solder melts at a lower temperature and flows, into a seam within metal of a different alloy content, that is not molten during the soldering process. I wont go into great detail about soldering. For an excellent article on soldering principles, pick up The Bench Magazine: Winter 2003, Volume 2, Issue 3 and read an article titled: The Secret Life of Solder, by: William Pellegrini. If you don't have that issue, contact me via lasers@mantech.info. I can e-mail the article to you. Welding is a different process from soldering; mainly because when welding the material being welded is also being melted. When melting the base material during welding it is important to penetrate into the seam with correct energy and energy distribution to join the two pieces together in a way that produces an adequately joined area. The lasers that are being used for welding in our industry have similar adjustable features that control various aspects of total laser energy and the way that energy is delivered.

The first thing that the laser must accomplish is physical penetration into the welding seam. The laser beam has a job to do, (join two pieces of metal), but before it can do the job, it must be able to reach the place that the job must be done. The job site that the laser must reach may require various characteristics of energy to allow the beam to best get to work. For example, a 3mm platinum ring shank would require different energy than a 18k YG earring post. The delivery of the beam into a welding seam is called penetration. Penetration is gained by controlling the physical force of the laser beam that most lasers on the market control through a variable parameter called Voltage. This parameter is usually expressed as Voltage as well. Voltage controls the physical force of Photons (Matter) in the light beam. Figure One shows examples of weld spot cross sections using various voltage settings. The figures are not to scale, and the listed parameters are not exact, they are only intended to show basic principles. Notice that when the voltage setting, alone, is increased greater physical penetration is achieved. The voltage parameter is one characteristic of the laser beam energy output. The laser must have enough energy to transport itself to the job site, meaning that it must overcome resistance of metal around the weld seam, penetrate through the resisting metal so that it can access the inner faces of the seam.



Changing Voltage:

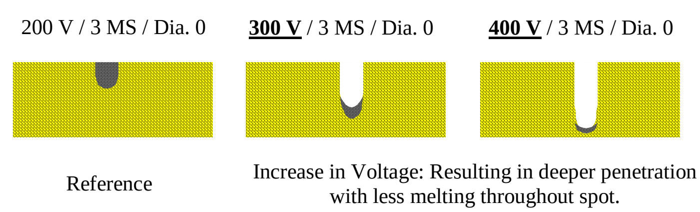


Figure 1.

Changing Pulse Duration:

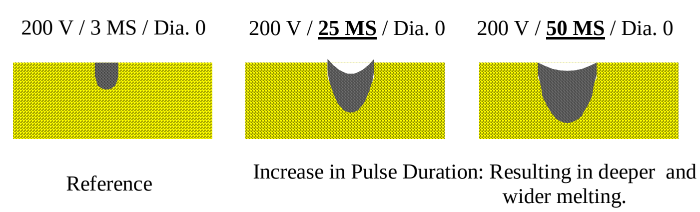


Figure 2

Once the laser beam has penetrated to the job site it must have enough energy left in it to do the work, (Melt the surrounding metal). Notice in Figure 1 how increased voltage, alone, creates an empty hole with little melting effect. Another controllable energy characteristic is the duration that that the beam stays exposed in the metal over a single laser pulse, (Pulse Duration). Some correctly refer to this as Beam Width,. I think Pulse Duration better describes what is happening. Pulse Duration is controllable, on most machines, in increments measured and expressed in milli-seconds, (Thousandths of a second). Leaving the laser energy exposed in the metal for longer heats the surrounding metal to it's melting point and collapses the metal upon itself, thus fusing it together in a way that seamlessly joins the metal. Notice in Figure 3 that longer Pulse Durations melt a spot that is wider and deeper. Pulse Duration can be used to gain penetration through melting rather than the forceful physical penetration that is the result of Voltage. However, longer pulse durations can burn certain metals leaving pits and brittleness. I plan to cover that in a later article.

Laser Welding Basics, Primary Adjustable Welding Parameters, Continued

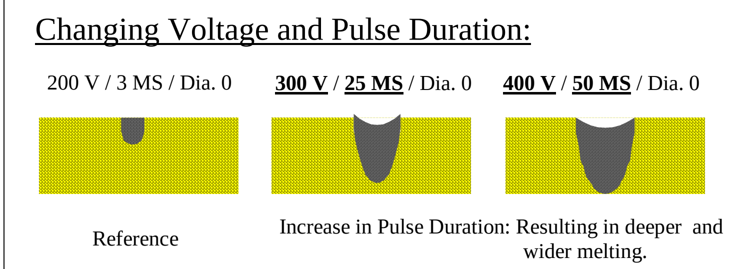


Figure 3.

The laser beam requires different aspects of energy in order to penetrate than the energy required to melt. Voltage and Pulse Duration are directly related to the amount of energy (measured in Joules) that is in the laser beam. Without discussing formulas of laser physics, I want to show the relationship between Voltage, Pulse Duration and Total Energy. A direct relationship means that increased Voltage or Pulse Duration equals more energy (Joules) output in the beam, and a decrease in either two of those parameters equals less total energy in the beam. It is important not to forget that Voltage and Pulse Dation are related to the energy directly, but the two individual parameters create different results. Voltage is physical pressure that requires energy, and results in physical forceful penetration. Pulse Duration is beam exposure time, that also requires energy, and results in melting. Many machines have a display reading that shows a calculated Total Energy in Joules. based on the selected Voltage and Pulse Duration. I find that having a Total Energy reading on the display is not necessary, but very helpful in understanding the characteristics and relationship of Voltage and Pulse Duration. I commonly refer to Voltage and Pulse Duration as the Energy Settings. Often, when figuring out the best welding parameters for a particular job, I will note, or comment, that energy must be increased, or decreased. One must then go one step further and ask what specific result of the energy should be different (Penetration, or Melting, or both?).

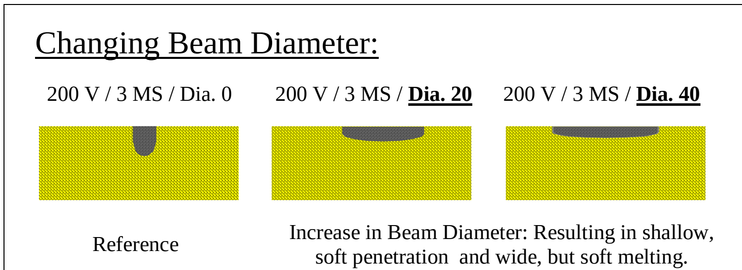


Figure 4.

The area in which the total energy is spread is a function of controlling the Beam Diameter. Some correctly refer to this parameter as Focus. I like to call it Beam Diameter because a change in Beam Diameter at the viewing system focal plane is the effect that is has on the laser beam, as it applies to us jewelers with our application. It is important to understand the difference between the laser beam focus and the viewing system focus and how they relate to the parameters that I am discussing here. In fact, understanding the energy characteristics of the beam at the operators viewing system focal plain, goes hand-in-hand with learning the effect of the individual parameters. I will discuss that in the next article. For now, I want to write about what effect changing the beam diameter has at the weld spot when the item being welded is held correctly and consistently in correct focus of the operator in the viewing system. Changing Beam Diameter changes the size of space that the lasers total energy is focused into. As seen in Figure 4, a given (Voltage & MS) energy in a narrow space or Beam Diameter will have a deeper effect in that small area than the same energy that is spread over a larger diameter. Changing Beam Diameter changes the Joules per square area. Some machines display a calculated Joule per sq. cm., based on the selected energy at a given Beam Diameter. I find that helpful in understanding the relationship between Total Energy and Beam Diameter.

Figures 1, 2, and 4 show results from the three primary adjustable parameters: Voltage, Pulse Duration, and Beam Diameter, while they are being adjusted individually in an extreme manner. Figures 3 & 5 show results of adjusting two or more of these parameters simultaneously. All of these examples are not to any specific scale and are only intended to help explain basic principles.

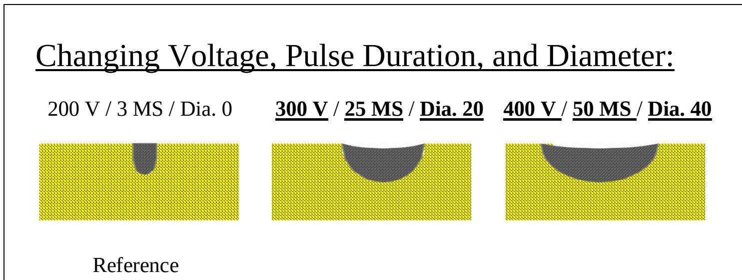


Figure 5.

I consider Voltage, Pulse Duration, and Beam Diameter to be the primary controllable parameters. Secondary to these three parameters is Pulse Frequency. A single laser pulse is initiated by depressing a foot pedal one time. Selecting a faster Pulse Frequency allows the operator to keep the foot pedal depressed and continue making laser pulses. Pulse Frequency is usually measured and expressed in Hertz (Hz). Hz. In this case, is the measurement of how frequently the laser pulses in one second. Machines that are available on the market currently range in Hz capability from 5 Hz max. up to 20 Hz max. Increasing Hz delivers the pre-selected primary parameters at a faster rate per second. The results of a faster frequency will tend to be more aggressive than the same set of parameters in a single pulse, because the weld metal has less time to conduct the laser energy away from the weld joint between pulses.

These are the basics, that can be learned through a small amount of experience working with a machine. Included in the basics are knowing the relationship of the beam focus and viewing system focal plain, gaining eye-hand coordination, and learning how to make a continuous weld with and without filler metal. I will be discussing these in the next article to finish the basics before we start looking at individual jobs that require all or a combination of: special adjustments of the parameters, various techniques, and or available technologies.