Unitek Miyachi Lasers
Connections

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Technical Application Brief

Understanding Laser Parameters for Weld Development

Nd:YAG lasers produced by Unitek Miyachi are pulsed. The weld created by each pulse is determined by the peak power density and duration of that pulse. The number of pulses per second and the welding speed additionally defines a seam weld. This tech brief introduces these parameters and associated terminology

- The peak power density controls the weld penetration and is a function of the fiber type and core diameter, focus optics, and laser peak power output.
- The pulse width controls the heat into the part, weld width and thermal heat cycle.
- The pulse repetition rate or pulse frequency controls the heat into the part and thermal heat cycle.

Glossary of Terminology

Peak Power

A direct parameter that can be selected on the laser. It controls the maximum power of each pulse. The units of peak power are watts (W).

Pulse Energy

The energy contained within a pulse and is a product of peak power and pulse width. $E = Pp \times t$, units are joules (J).

Average Power

Used when more than one pulse is used for welding. It represents the power averaged over the period of the pulse, and is the product of the pulse energy and the pulse repetition rate (frequency). $P_{ave} = E \times prr$, units are watts (W)

Peak Power Density

Concentration of the power at the part, and is determined by dividing the peak power by the focus spot size area. Spot size is given by fiber core diameter x focus head magnification. Units are W/cm^2.

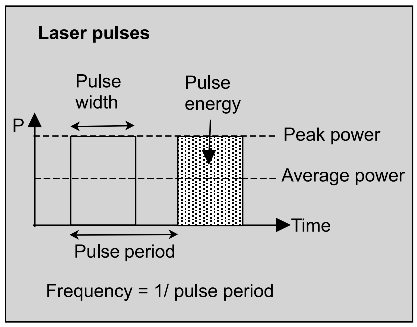

Figure 1 Shows the important parameters of the laser pulse, including peak power, average power, pulse width, pulse energy and frequency or pulse repetition rate.

Fiber Optic Cable

The laser is delivered from the laser to the focus head via a fiber optic cable. The core diameter of the fiber directly affects the final focus spot size, and therefore the peak power density. This effect is a square scaling, for example a 300 micron core fiber has half the focused spot size of a 600 micron core fiber, but has four times the peak power density. The core diameter is selected for reasons of focus spot size and power handling capability.

The fibers come in two types, stepped index (SI) and graded index (GI). The difference between the two is that the graded index fibers tend to maintain the mode structure of the laser through the fiber length, whereas the stepped index tend to homogenize the beam structure. The practical implication of these differences in beam propagation is that for the same energy the GI fibers show about twice the penetration of the SI fibers.

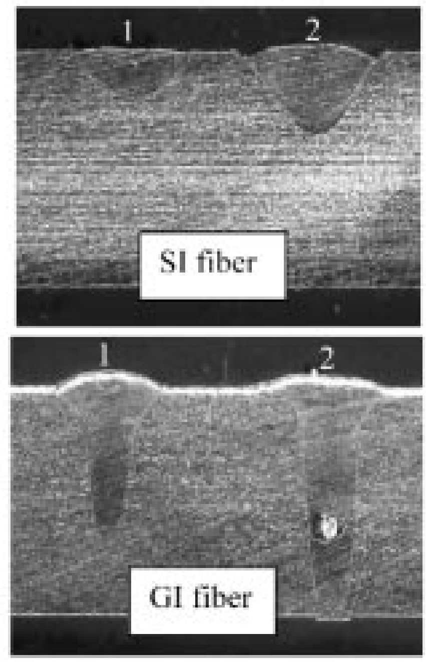

Figure 2 Highlights the difference in weld penetration between SI and GI fibers. These two sets welds were completed at identical focal conditions, and energy levels; (1) 1.4J and (2) 2J.

The question then arises why would an SI fiber ever be used? In some cases a wide shallow weld is required. The low power density of the SI fiber lowers the potential for weld inclusions and porosity, and the broader energy spread across the focus spot can aid tracking tolerances. For high penetration requirements, and welding applications with heat sensitive parts in close proximity GI fibers are ideal. The selection of GI fibers also reduces the overall energy requirements for the weld, and may allow a lower power laser to be used.

Focus Optics

The focus head effectively images the end of the fiber onto the part. The fiber optic delivers the beam to the focus head where the beam is first collimated, and then focused to a spot. The image is either enlarged or reduced according to the ratio of the collimating and focus lens.

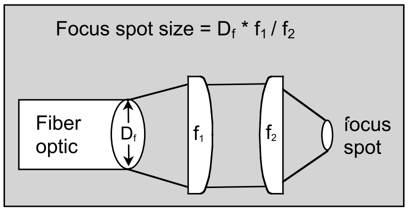

Figure 3 Shows the relationship in terms of final spot size for the diameter of the fiber optic cable, and focus head lenses.

The focus optics can be used to fine tune the spot size for an application, or provide a reduced spot size when a large core diameter fiber must be used for power handling. The selection of final focus lens focal length also determines the standoff distance of the focus head from the part.

Peak Power and Pulse Width

Peak power directly affects the peak power density, that controls weld penetration. The peak power setting is a balance between penetration and the on set of weld defects such as porosity and drilling.

The pulse width controls the heat into the part, therefore increasing the pulse width increases the weld dimensions through increased heat conduction time.

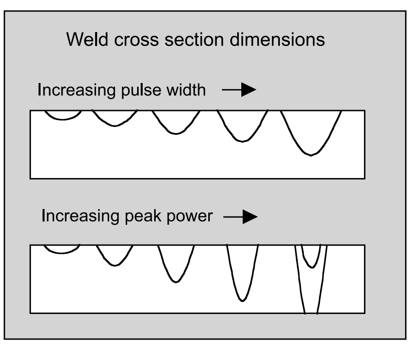

Figure 4 Shows the effect of increasing pulse width and peak power on weld dimensions

Optimum peak power is defined as the peak power that creates the deepest penetration at a given energy without material expulsion. This also minimizes the heat input into the part.

Welds made with high peak powers exhibit narrow deep welds that exert a high thermal cycle on the weld material. To increase weld width, reduce the thermal cycling and minimize depth variation, the pulse width can be increased to introduce a more conduction based welding mechanism.

Seam Welding

The additional parameters for seam welding are the pulse repetition rate and the welding speed. A further descriptive for seam welding is spot overlap percentage, a function of speed, pulse repetition rate and focused spot diameter.

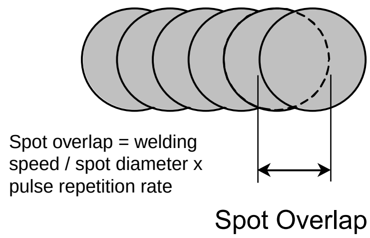

Figure 5 Relationship of spot diameter, welding speed and pulse repetition rate.

When seam welding, a balance is reached between the pulse penetration parameters, the welding speed and pulse repetition rate. In most cases this is worked from initially selecting the pulse penetration parameters, the effective penetration and therefore the spot overlap, and then determining the welding speed – Welding speed = Spot diameter x (1- Spot Overlap/100) x prr (units in/s)

For example, for a spot diameter of 0.005", and an overlap of 50%, with a pulse repetition rate of 10Hz, the welding speed is given by –
Welding speed = 0.005 x (1 – 0.5) x 10 = 0.025 in/s.

The effective weld penetration determines the spot overlap percentage, and welding speed.

The level of overlap determines the effective penetration, this is particularly important for hermetic welding applications, where around 85% overlap is nominally used. As the overlap is increased the welding speed is reduced

Pulse Shaping

Most welding cases use a square welding pulse, however there are a few cases where the use of pulse shaping can enhance welding. There are numerous pulse shapes, however, two basic cases are most commonly used. The first is for overcoming highly reflective material such as copper and aluminum, and the other is to minimize the thermal cycling experienced by the part during welding for materials susceptible to cracking.

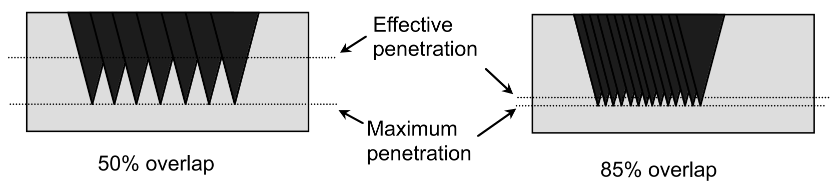

Figure 6 Schematic representation of overlap versus effective penetration depth for various overlaps

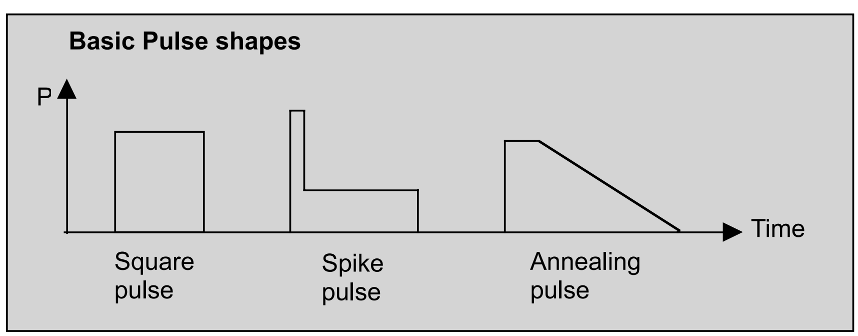

Figure 7 Two basic pulse shapes; Spike pulse used for high reflective materials, and Annealing pulse for materials susceptible to cracking.

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