INDUSTRIAL Laser Solutions FOR MANUFACTURING

application report

A golden opportunity

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DIODE LASER IS THE KEY LINK IN CHAIN WELDING

Welding with pulsed Nd:YAG lasers is the technique of choice for applications that require high precision, reduced heat affected zone, material purity (welding without the addition of alloying or brazing materials) and high surface quality. This application field includes medical/surgical devices, dental appliances and prosthesis and jewelry fabrication. Here we focus on the use of Nd:YAG laser welding techniques for the volume production of gold jewelry chains. Pulsed Nd:YAG laser welding is the only technique that allows direct welding automatic machines that join 24-carat gold links (without alloying material) to form fully assembled chain product.

Recently, users of spot welding systems have shown a strong demand for increasing precision, stability and repeatability of solid-state lasers. For example, watch manufacturers have set new standards in stability and beam quality requirements for laser spot welders because the typical joint width is some tens of microns. Also, jewelry manufacturers require precise laser welding for the fabrication of small gauge gold chains whose links are made from micro-gold wire.

These high-precision welding applications barely tolerate the limits of traditional flashlamp-pumped Nd:YAG laser welders. Repeatable laser spot sizes of 0.1 mm or less present a problem to laser manufacturers, because typical beam quality of these lasers is only fair, as is their pointing stability. This results in a randomly fluctuating welding spot shape and position on the scale of tens of microns. If fiber beam delivery is used, traditional lamp-pumped sources are typically coupled in fiber cores larger than 0.2 mm in diameter, leading to aberrations in the laser spot when focused at less than 0.1 mm focal spot diameter. Precision welding of fine mechanical parts can also require a strict control of the laser peak power and/or the control of the laser pulse shape in order to obtain constant quality of optimized micro-welding spots. Flashlamp-pumped lasers may show peak power fluctuations due to lamp flash statistics and lamp deterioration. Furthermore, only a few lamp supplies allow the control of a complex power profile of the laser pulse, with the restriction that only slowly varying pulse shapes can be fully controlled.

Pumping lamps exhibit a typical lifetime of a few million to a few tens of million shots, with some variation from lamp to lamp. Therefore, in continuously working laser spot welders (as is often the case in the high-volume production of gold chain), lamps are replaced more or less each month, giving rise to problems such as downtime for maintenance, laser resonator contamination and deterioration with time.

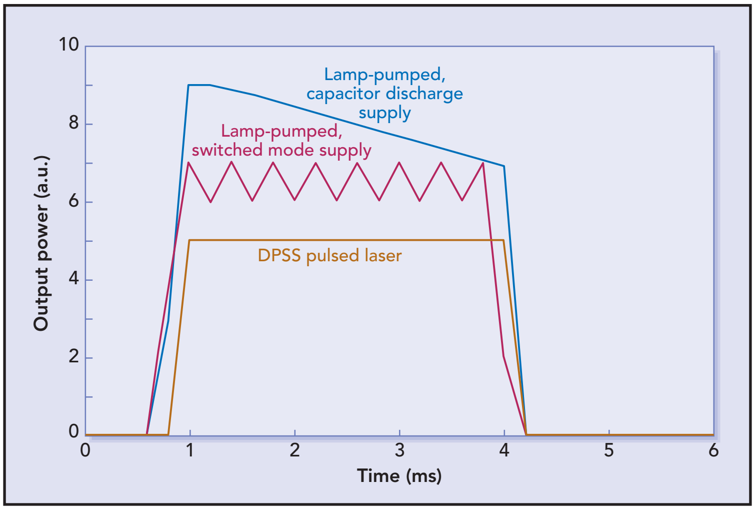

FIGURE 1. Typical output power pulse profiles corresponding to a square pulse input for a lamp-pumped Nd:YAG spot welder, respectively, with a capacitor discharging power supply, with a switch mode power supply and for a DPSS pulsed laser welder. Peak power control in the DPSS laser welder is at least 10 times more accurate than in the case of lamp-pumped spot welders.

Additionally spot welding techniques based on pulsed lamp-pumped lasers suffer from very low energy conversion efficiency, which usually results in the necessity of noisy and cumbersome water cooling systems, which draw considerable energy to run and increase cost of ownership even further.

These issues associated with traditional lamp-pumped Nd:YAG laser welders have stimulated laser manufacturers to invent and produce, with varying success, more sophisticated (and costly) flashlamp-pumped lasers and laser delivery architectures that are meant to improve the typical properties of the common Nd:YAG spot welder.

Recently Bright Solutions (Cura Carpignano, Italy) in collaboration with Laservall (Donnas, Italy) has introduced a novel laser spot welding technique (patent pending) based on pulsed diode-pumped solid-state (DPSS) lasers, designed to solve the problems related with precision welding using traditional lamp-pumped laser techniques. The use of a diode-pumped high brightness laser allows the laser output to be easily launched into 100-micron core fibers, thus giving sharp, repeatable laser spots smaller than 100 microns in diameter. Diode lifetime is on the order of one billion shots, so maintenance is a rare event on such a laser spot welder. Due to small, aberration-free laser spots the energy required per welded spot is substantially lower than that required from a corresponding lamp-pumped spot welder. For the same reason, the heat-affected zone is greatly reduced.

Current control of diode lasers through high-precision power supplies requires lower currents at much lower voltages as compared to flashlamps. Thus, the precision of output power pulse profiles is superior, even in very fast transients. A photodiode monitor can be used to close a control loop allowing operation in 'power mode' instead of 'current mode;' so users can program the effective output power profile that will be performed by the laser, spot after spot, independent of diode age or other component degradation. In this case the laser power repeatability is better than one percent for the whole device lifetime. Due to a wall plug efficiency close to 20 percent and to lower energy levels required, the typical DPSS spot welding laser system has an overall volume smaller than 10 liters and does not need water-cooling.

Recent tests conducted with this laser welding system by Fasti Industriale (Montalto Dora, Italy), one of the world's leading manufacturers of high-speed precious metal chain manufacturing equipment, showed its reliability and repeatability. Fasti tested DPSS laser spot welding on automatic gold chain fabricating machines, to weld links of gold wire with a diameter of 0.2 mm. Most gold chain fabricating machines cut gold wire and bend it to produce interconnected links; a spot weld closes each link. Production rate is typically about five links per second. In the case of Fasti, a first attempt with laser welding had been made using a standard lamp-pumped laser spot welder with a 300-micron core fiber delivery. This led to some good results in welding links with 2 J pulse energy, but still showed a heat-affected zone much larger than desired, with some loss in brilliance of the welded chain. Furthermore, welding with the lamp-pumped laser spot welder was not consistent because aberrations in the focal spot caused part of the laser power to be reflected, hitting very delicate positioning tools and causing mechanical degradation with time.

With the diode-pumped laser welder, full-depth welded links were produced with 0.7 J pulse energy (one-third of the energy required from the lamp-pumped laser welder). There was no laser-induced damage on the surrounding positioning equipment.

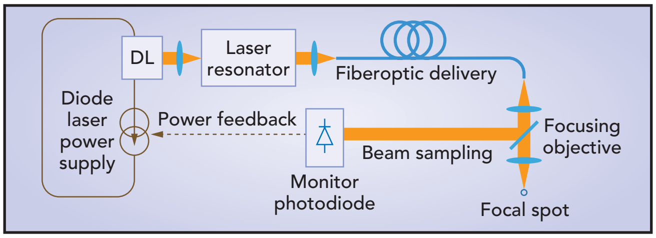

FIGURE 2. Power mode operation of a DPSS pulsed laser welder. Peak power can be accurately programmed and controlled via a feedback loop on a microsecond time scale. The monitor photodiode placed as close as possible to working area guarantees a true power-on-the-workpiece measurement. Instant power incident on the welding spot can exhibit better than one percent repeatability independently on any system-aging factor or environmental variations.

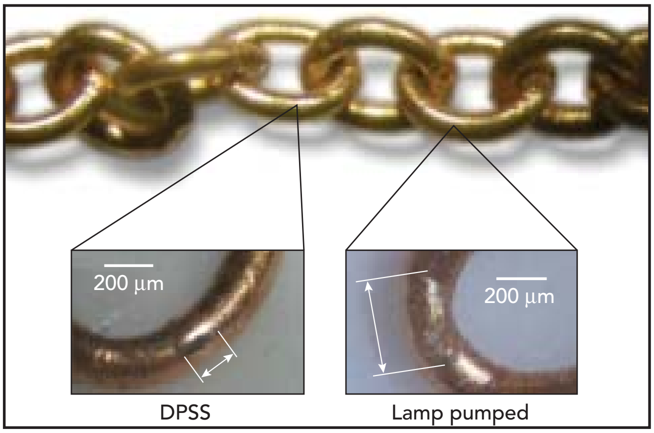

FIGURE 3. For this gold chain laser welding application, the gold wire diameter is 0.2 mm. Lamp-pumped (at 2 J output energy) and DPSS (at 0.7 J output energy) results are shown. Heat-affected zone is indicated in both cases.

During tests, waste heat for the two systems was evaluated at 5 Hz repetition rate. The lamp-pumped spot welder transferred around 600 W to the surrounding environment through its closed-loop liquid-to-air exchanger. The diode-pumped laser welder showed a total dissipated heat (through a small-finned heat sink) of 30 W. This performance shouldn't be underestimated: in the typical production area comprising 10 to 20 laser welding stations the first case would show a dissipation of 6000 to 12,000 watts with obvious problems for the ambient temperature control, while in the diode laser case the total power dissipation would be only 300 to 600 watts.

Laservall has introduced a new solid-state spot welder design philosophy whose goal is not a generic reduction of the cost per unit laser energy, but an optimized approach, with a reduced cost per welded piece, designed to solve modern problems of precision welding especially in the fields of fine mechanics (such as watch making), bio-medical device fabrication, photonics packaging and precious metal chain manufacturing.

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