Medical device welding with a cw fiber laser

TRUMPF

Whitepaper compact

The performance advantages of fiber lasers over conventional technologies in terms of beam quality, depth of focus and parametric dynamic performance have been well recognised. Coupled with the benefits in wall plug efficiency, process versatility, reliability and cost have led to an increasing level of deployment in medical device manufacturing in both fine cutting and micro welding applications.

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Introduction

In welding applications, medium power fiber lasers in the range 100 W to 1.000 W offer new degrees of operational freedom and process control. The ability to operate with pulse lengths continuously tuneable from a few microseconds to full CW operation and with pulse repetition rates up to tens of kilohertz offers the applications engineer the ability to optimize the process conditions over a wide range of applications. By appropriate choice of process conditions fiber fasers can weld across conduction, quasi keyhole and keyhole regimes.
Due to their monolithic single mode fiber construction fiber lasers do not suffer from changes in focus position due to thermal lensing as the average power is changed, and don’t require periodic adjustment or tuning of the laser cavity or component maintenance to ensure output stability.

Key advantages of laser welding - an established technology in medical device manufacturing

01 Process control

The high beam quality and a resulting spot size control together with the continuously tuneable average power of a fiber laser ensure that the weld energy is delivered only where it is needed and with exceptional control. This enables laser welds to be placed very close to polymer seals, glass-to-metal seals, soldered components, and thermally sensitive electronic circuits.

02 Process repeatability

Laser welding is a non-contact process which eliminates potential problems caused by wearing parts, contact deformation or contamination.

03 Hermeticity

Unlike soldering or brazing, laser welding can provide high quality hermetic welds with high yield, both of which are fundamental requirements in the manufacturing of high value implantable medical devices.

04 Surface finish

In addition to the aesthetic quality, the smooth and pore-free surface finish achievable enables reliable autoclave sterilisation.

TruFiber P compact fiber laser features

Our TruFiber P compact range of fiber lasers have been designed to enable maximum process control and flexibility for precision micro welding applications using the following unique performance features.

Figure 1: Welding examples demonstrating process control and hermetic weld quality.

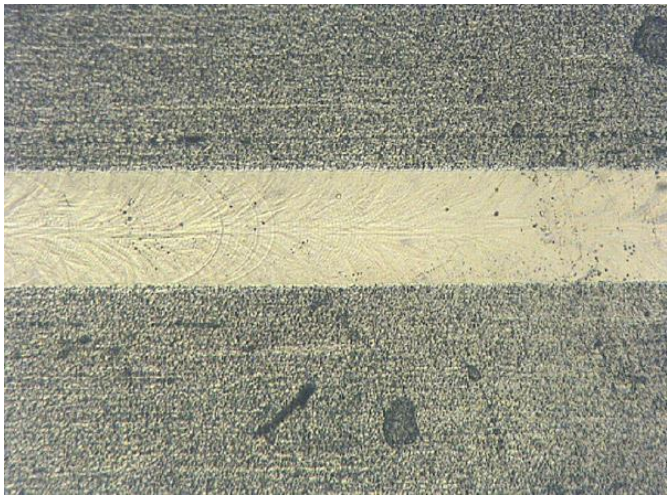

Figure 2: Surface quality of stainless steel weld 0.15 mm thickness

Power control

The careful design of the laser drive and cooling platforms for the TruFiber P compact products allows them to provide exceptional output power stability, under CW or modulated operation.

Output power stability of typically < 1% are achievable over time. For device manufacturing metrology, this process power output of these lasers can be continuously recorded using and internal parameter data logging. Functionality of the proprietary FiberView control software.

Choice of beam profiles

Depending on the type of welding application either the gaussian mode profile of standard single model or the larger spot size of a multi-mode beam, with a more even energy spatial distribution, can provide the better weld profile.

The TruFiber P compact laser range offers the process engineer a choice of high power density and large depth of field from the single-mode beam delivery options, or multi-mode beams from either a 50 µm or 100 µm core diameter delivery fiber. The 100 µm fiber is ideal for producing conduction limited weld profiles with a high width to depth ratio. The higher beam quality from the 50 µm fibers (with an intermediate beam quality of M2 = 6.5), allows for fine welding applications with smooth top bead, but still requiring a reasonable penetration depth.

Extended performance range with low power mode

The standard operating range for TruFiber P compact lasers is from 10 - 100% of rated power. The low power mode feature on TruFiber lasers over 500 W, enables the laser to be switched to operate at very low CW powers in the range from 30 W up to 300 W. This unique capability enables the user to access a wide range of process parameters.
For example, using this feature the same laser can be used from the very low powers required for fine wire bonding to the high peak power required for the hermetic seam welding of device enclosures.
In addition, the laser is able to operate with modulated waveforms, allowing an added layer of control on the average laser power.

Pulse shape equalization with simmer mode

Under normal operation, when the laser is pulsed following an idle period, a proportion of pump laser power is absorbed in raising the laser inversion to the threshold level for lasing action to begin. This results in an increased turn-on delay time for the first pulse and results in a loss of proportionality between the pump input power and the laser power output.
The simmer mode function on TruFiber P compact lasers allows the user to set a level of pump bias which is sufficient to hold the laser just below threshold. This ensures the first pulse turn-on delay is minimised and the energy in the first pulse is equalised with subsequent pulses in the train.

Inherent pulse shaping with FiberView parameter sets

In many micro welding applications, precise control over the temporal pulse shape is a critical requirement. In a fiber laser the optical output response is highly linear with the electrical drive signal.
Integral to the TruFiber P compact laser range is a high speed pulse generator, which coupled to the FiberView GUI and its graphical pulse editor, allows almost infinite control over the temporal pulse shape of the laser.
The parameter sets feature of the laser allows these pulse parameters to be stored within the laser for either software or real time hardware selection controls.
With an digital control bandwidth of 50 kHz, together with the simmer mode feature described above, the TruFiber P compact lasers have a unique capability for pulse shape optimisation.

Conclusion

When considering a technology for medical device welding applications, our TruFiber P compact fiber lasers offer compelling advantages over conventional alternatives. For many applications a TruFiber laser is the ideal solution, bringing proven technology to enable reliability and high quality in high value manufacturing applications.

For more information visit:
https://www.trumpf.com/s/trufiber-p-compact

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