# Laser welding: the game changer in battery production

## Precision and efficiency for high-performance energy storage

**Wade He**

Laser welding, cutting, and cleaning are crucial processes in battery production for electric vehicles. Precise and efficient manufacturing technologies are required to ensure the performance, safety, and longevity of batteries. Maxphotonics provides exactly these solutions with its laser technologies and beyond that develops specialized solutions to address challenges such as material processing and process security for a Chinese battery manufacturer.


Source all figures: Maxphotonics

Video in the online version


Fig. 1 MFSC 4000W (Rack) Elite Single Module

Batteries are the heart of electric vehicles, serving as energy storage units that supply power for propulsion. Their performance significantly influences the range, efficiency, and longevity of vehicles. High energy density ensures a compact design with maximum storage capacity, while fast charging times and a long lifespan are essential for practical usability.

The production of these high-performance batteries requires pinpoint-accurate and cost-effective manufacturing technologies. Every connection within a battery – whether between cell connectors, electrodes, or casings – and therefore every weld seam must be extremely reliable so that energy losses are minimized, heat generation is controlled, and safety risks such as short circuits or thermal runaway are prevented.

Laser technology has established itself as a key process in battery manufacturing. Before its introduction, traditional methods such as resistance welding and mechanical joining techniques were used, but they have their limitations: resistance welding causes material deformations due to high heat input, while mechanical methods do not provide the same durability and conductivity. Lasers, on the other hand, offer a contactless, high-precision solution with minimal heat input, significantly improving quality, cost-effectiveness, and production speed.

## Maxphotonics: a provider of industrial laser technologies

Maxphotonics was founded in China in 2004 and develops as well as manufactures a wide range of fiber lasers, including cw fiber lasers, pulsed fiber lasers, and laser welding systems. With its research and development department, the company continuously drives innovation and thereby enhances the performance and precision of industrial manufacturing processes. Through close collaboration with partners from various industries, Maxphotonics has established itself as a provider of ultra-modern laser solutions. The company's expertise significantly contributes to the advancement of battery production, particularly in the electromobility sector.

## From laser manufacturer to industry partner

For several years, Maxphotonics has been working with one of China's leading battery manufacturers, which plays a key role in the global electromobility industry. What began with the supply of laser technologies has now evolved into a strategic partnership. The partner company develops and produces innovative battery systems, energy storage solutions, and industrial applications. In addition to battery manufacturing, it is also one of the largest electric vehicle manufacturers worldwide and actively drives the development of new mobility solutions. Through close collaboration with Maxphotonics, which has designed laser technology specifically for battery production, the company has been able to optimize its manufacturing processes and set new standards for quality and productivity.


## Wade He

Wade He is employed at Maxphotonics as overseas product manager. He has many years of experience in laser processing projects. At Maxphotonics, he leads a team to complete different projects such as laser cutting, laser marking, removal, welding, etc.

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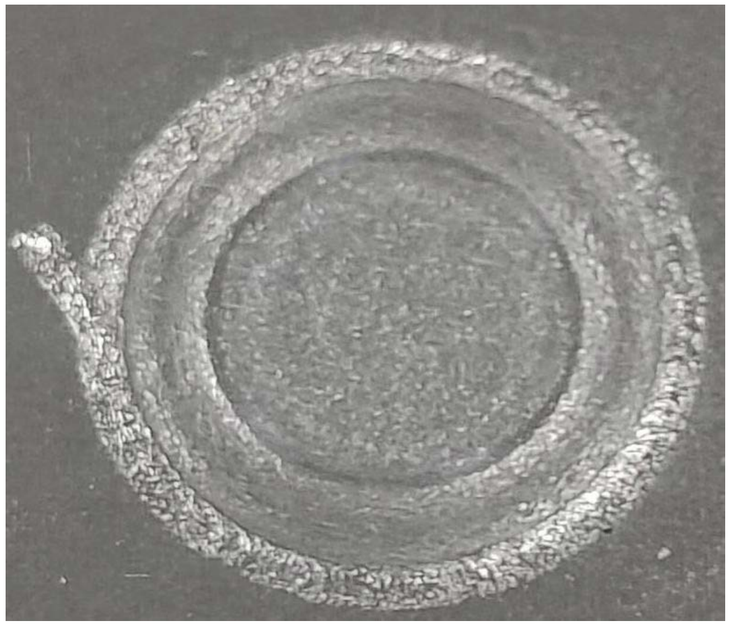

Fig. 2 Laser welding of battery cover plate

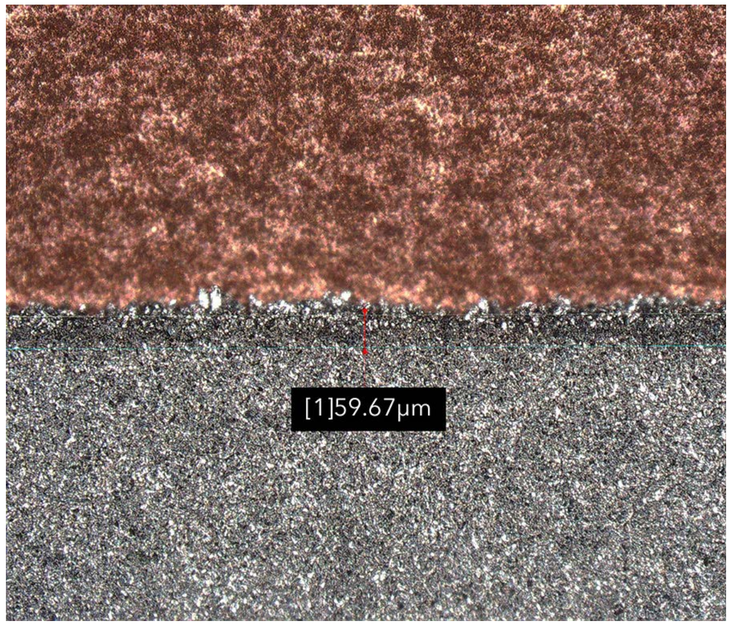


Fig. 3 Heat-affected zone (HAZ)

## Battery production in focus: today's challenges

The production of batteries for electric vehicles is highly complex and presents numerous technical challenges that impact both production quality and the safety and performance of the battery.

One of the biggest difficulties is the precise processing of highly conductive materials such as copper and aluminum. Copper reflects a large portion of laser light, making processing difficult. Aluminum, on the other hand, conducts heat very well, making it challenging to control temperature distribution within the material. Selecting the right laser parameters – such as power, beam shaping, and welding speed – is crucial to achieving reliable connections without material deformation or welding defects. An optimized combination of these ensures stable weld seams with high mechanical strength and minimal heat input.

Additionally, specific process risks can arise during laser welding:

- **Explosion points** – Explosion points can form at the weld seam when contaminants such as dirt or foreign particles are present on the material surface or when laser energy output is unstable. These points can lead to structural weaknesses in the connection.
- **Porosity** – During the welding process, pores, particularly hydrogen-induced gas bubbles, can form. These mainly occur due to the rapid cooling of the weld seam and the collapse of small voids, which can reduce mechanical stability.
- **Hot cracking** – Materials such as aluminum alloys, which are commonly used for battery casings, tend to develop hot cracks during the welding process. These include crystallization cracks or heat-affected zone (HAZ – liquation cracking), which can compromise the structural integrity of the battery.

Besides the stability of weld connections, electrodes and separators also play a critical role. Electrodes store and transfer electrical charge within the cell, while separators act as an insulating layer between the anode and cathode, preventing short circuits. Precise laser welding is essential to connect these sensitive components without thermal damage or unwanted material changes, ensuring the safety and functionality of the battery.

The automotive industry is undergoing a transformation, with increasing demand on production costs and resource conservation playing a major role. In addition to economic factors, more sustainable manufacturing methods are becoming increasingly important to reduce material consumption and harmful gas emissions.

To remain competitive, manufacturers must increasingly rely on technologies that enhance productivity, reduce error rates, and promote environmentally friendly production. Overcoming these challenges is crucial to making the next generation of electric vehicles both economically and technologically future-proof.

## Precision meets efficiency – laser technology as the solution

To overcome the obstacles in battery manufacturing, Maxphotonics relies on advanced laser technology that optimizes key production steps such as welding, cutting, and cleaning. Both continuous-wave (cw) fiber lasers and pulsed MOPA lasers are used to enable precise and material-friendly processing.

## Laser welding: reliable connections for high-performance batteries

One of the most decisive applications of laser technology is welding, which is used in battery manufacturing for various components. Maxphotonics lasers are utilized for welding pole terminals, explosion-proof valves, covers, and cell connectors.

Battery modules and casings are welded to mechanically protect and thermally insulate the battery cells. These components require robust and deeply penetrating weld seams to guarantee mechanical stability and resistance to thermal stress. Maxphotonics' cw fiber lasers 4000W and 6000W are particularly well-suited for this application, as they enable uniform material penetration, creating durable connections. At the same time, contactless processing helps to reduce material fatigue and production defects.

The use of Maxphotonics' fiber lasers with high beam quality and precise parameter control lead to reliable welds. For example, when welding pole connectors, the DBW-2000/2000 laser is used with an F150 field lens, achieving a welding speed of up to 130 mm/s with a reject rate of less than 1 %. High-performance laser systems are also employed in battery cover welding: A round spot laser with a welding head, F100 collimation, and F200 focusing achieves a welding speed of 100 mm/s with an actual reject rate of less than 5 %.

## Laser cutting – efficient, precise, and material-friendly

In addition to welding, laser cutting of electrode tabs is a key aspect of battery production. These thin metal connectors conduct electricity from the electrodes to the cell connectors and are essential for the electrical performance of the battery. The Chinese battery manufacturer utilizes MOPA-250W lasers, which secure a heat-affected zone of less than 100 µm and minimal burrs under 10 µm after cutting. A small heat-affected zone protects the sensitive electrode material from thermal damage, while minimal burr formation creates a precise contact surface, eliminating the need for additional post-processing steps. This technology allows for enhanced and material-friendly processing, boosts battery cell quality, and reduces production waste.

## Optimized processes with laser cleaning

Laser cleaning is an essential process in modern battery manufacturing and maintenance. It facilitates the precise removal of unwanted material layers and significantly contributes to the quality and efficiency of various production and repair processes. In the collaboration between Maxphotonics and the Chinese battery manufacturer, laser cleaning with a Mopa-500W or 1000W with square spot is applied in several key areas. For example, the surface of battery casings is intentionally roughened to improve the adhesion of coatings or adhesives.

Another important application is the removal of PET films during battery repair. Since these films have high viscosity, manual removal has traditionally been time-consuming and labor-intensive. However, with laser technology, the film can be completely removed in just ten seconds. Purge is also highly effective for cleaning battery terminals. High-frequency and high-energy laser pulses reliably remove contaminants and oxidation without damaging the material, thereby optimizing electrical conductivity. Compared to conventional methods, laser cleaning offers superior quality, environmental friendliness, and efficiency. The processing time for terminal cleaning is just 160 $mm^2$/s surface, ensuring a fast and cost-effective process.

## Innovative solutions from Maxphotonics

Next to providing cw fiber lasers and pulsed MOPA lasers, Maxphotonics has developed specialized solutions in close collaboration with the Chinese battery manufacturer, a process that took about one year.

## Annular beam solution – more control, less error

To minimize welding defects such as spatter formation and microdefects, as well as explosion points, pore formation, and hot cracking, Maxphotonics developed the annular beam solution in 2024, based on its cw laser technology, in collaboration with its Chinese partner in battery manufacturing. Specifically designed for battery pole welding, this technology enables independent control of the inner and outer laser beams. The outer beam preheats the material and ensures uniform temperature changes during the welding process, effectively preventing explosion points, pore formation, and cracks. The controlled energy input enhances the stability of the weld seam. As a result, not only is scrap reduced, but also material losses and damage to adjacent battery components are significantly minimized. The inner beam, on the other hand, performs the actual welding, ensuring a precise and stable connection.

## Maxphotonics

**Company:** Maxphotonics GmbH
**Office:** Gilching, Germany
**Parent Company:** Maxphotonics Co., Ltd.
**Founding year:** 2004
**Head office:** Shenzhen, China
**Employees:** Over 5,000
**Global presence:**
Customers in over 80 countries
**Product portfolio:** cw fiber lasers, pulsed MOPA fiber lasers, laser cleaning equipment, laser cutting systems
**Industry:** Fiber laser technology and manufacturing
**Key applications:** Automotive and aerospace, precision engineering and medical devices, electronics and semiconductor processing
**Patents:** 550+ (domestic and international)
**Specials:** own R&D department

**https://en.maxphotonics.com**


Fig. 4 Battery case welding

The power of the inner core and outer ring can be flexibly adjusted to meet various welding requirements, providing high versatility for different projects. The maximum total power of the system is currently 8 kW.

Another technical advantage lies in the high beam quality of the laser, which guarantees stable process control. An example of this is an annular beam laser with the following parameters:

- Inner core diameter: 34 µm
- Outer diameter: 100 µm
- Total power: 6 kW
- Beam parameter product (BPP): 1.2 mm·mrad (inner core) / 4 mm·mrad (outer ring)

The long-term operational stability of ≤2% prevents fluctuations in laser power, thereby avoiding welding defects associated with inconsistent energy delivery. To date, more than one hundred of these lasers have been sold to the Chinese battery manufacturer, with a welding process reject rate of less than 1 %.

With the annular beam solution, Maxphotonics fulfills the increasing demand for smaller heat-affected zones and higher surface quality in battery production. The combination of high beam quality and stable power output enables more precise processing and reduced spatter formation. An example of this is an 8-kW laser with a 50-µm core (5 kW) and a 150-µm outer ring (3 kW), achieving a beam parameter product (BPP) of 2 mm·mrad (core) and 7 mm·mrad (outer ring), effectively minimizing the heat-affected zone. Temperature control of the outer ring avoids strong thermal fluctuations, ensuring a uniform, high-quality weld seam.

## Film laser cleaning equipment – goodbye adhesive residues

Another innovation is the film laser cleaning equipment, developed for removing adhesive films from battery casings. These films serve as insulation and protection during battery use. However, during the battery repair process, they must be completely removed for subsequent processing steps.

Previously, this process was performed manually, making it time-consuming and prone to errors. The use of the specialized MOPA-1000W laser significantly refines this process: Precisely controlled laser radiation selectively alters the adhesive properties of the film, allowing it to be easily and completely removed without damaging the battery casing. By specifically adjusting viscosity, the film can be removed in just ten seconds. This automation leads to significant time and cost savings in battery production: Manual removal takes about one to two minutes, whereas after laser cleaning, the efficiency is improved by over 90 %. Additionally, the laser-based cleaning system reduces material waste and enhances sustainability in manufacturing, as it eliminates the need for chemical solvents.

## No way around it

The collaboration between Maxphotonics and the leading Chinese battery manufacturer demonstrates how specialized laser solutions can revolutionize battery production. By combining proven cw laser technology, MOPA lasers, and innovative developments such as the annular beam solution and film laser cleaning equipment, efficiency, quality, and cost-effectiveness have been significantly improved. In addition to these advancements, Maxphotonics is working on AI-supported process monitoring and real-time corrections during the welding process. By integrating optical coherence tomography and artificial intelligence, welding parameters will be automatically adjusted, further optimizing process quality. These ongoing developments will help establish laser technology as the industry standard in battery production. ■

## Information

Parameters of the most relevant laser used:
Laser power: MOPA-1000W
Wavelength: 1,060 – 1,070 nm
Pulse duration: 30 – 120 ns (FWHM)
Modes: Pulse & Continuous
Beam quality: BPP <25 (100 mJ)
Applications: Laser cleaning