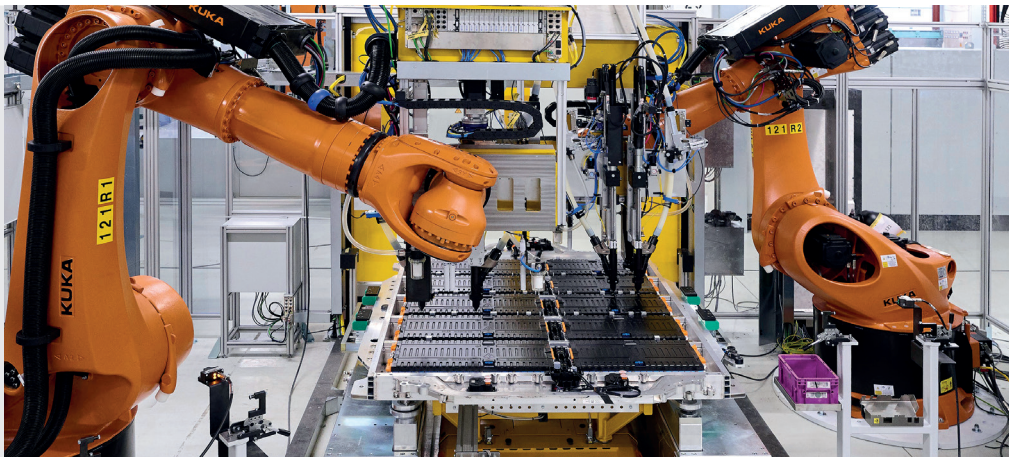


# SAFE LASER WELDING IN THE PRODUCTION OF BATTERIES

Automobile manufacturer counts on 100% inspection with Ophir BeamWatch Integrated systems



Battery modules are the beating heart of every electric car. They ensure mobility and security, and their reliability determines whether a vehicle is accepted or not. The BMW Group launched the i3, the first fully electric production vehicle, back in 2013 – so the company is well aware of the pitfalls of battery production, which grow in complexity with every uptick in capacity. Up to 144 laser welds are required for contacting a 5th-generation battery module. Thanks to Ophir BeamWatch Integrated systems, the automaker can check the laser beam before manufacturing each new module, independent of cycle times and with success. Before, in order to confirm ideal weld-in depths, spot checks by means of micrographs were carried out on a weekly basis.

## Cycle-time-neutral testing of the laser beam

Laser welding in the production of battery cells requires absolute precision. Regularly checking the key parameters of the laser beam before welding contributes significantly to the quality of the finished battery pack. From the very first discussion with the experts from the BMW Group, the focus was on how to do this as completely – and with as little impact on cycle time – as possible. Within the ongoing process, the key metrics to be captured were:

- Focus diameter
- Focus position
- Laser power
- Focus shift

The latter two are particularly crucial for single-mode lasers, but measuring them quickly proved difficult. The only method capable of this is non-contact measurement of the laser beam based on the principle of Rayleigh scattering – a technology developed by MKS and employed in the Ophir BeamWatch product family. The company designed the Ophir BeamWatch Integrated System specifically for automated manufacturing. This combined beam profiler and power gauge has various interfaces that permit direct implementation in industrial networks. For the experts in technology development at the BMW Group, this instrument came at exactly the right time.

### Product:

- Ophir® BeamWatch® Integrated

### Field of application:

- Contact welding in battery production

### Uses:

- Automated measurement of laser parameters

### Benefits:

- Cycle time neutral measurement
- Detects focal shift
- OK/NOK check assures weld quality
- Scrap is avoided

### **Non-contact detection of focus shift**

The first Ophir BeamWatch Integrated System was put into operation in 2019 as part of the prototyping and basic definition for the battery production line. An intensive test phase in technology development followed. It soon became clear that the device could ascertain all the required parameters. Moreover, the results quickly revealed that the thermal focus shift in the process had been underestimated: Measurements with BeamWatch Integrated showed a thermal focus shift in the mm range that the engineers had not expected; however, once the magnitude of this shift was known, adjustments could be made in the manufacturing process. For the automaker, this was an important step towards attaining a consistent weld depth for all contact welds. In the development phase, micrographs of the contact welds were used to determine the relationship between the focus shift and the weld depth. Based on this, and working in close cooperation with the Ophir experts, the team determined the limit values for the focus shift.

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### **Diminished weld penetration depth due to weld spatter**

Another finding that emerged from the investigations was about the optics of the single-mode fiber lasers used for contact welding: They are affected by spatters on the protective glass. The spatters made their mark not only in terms of focus shift but even more directly on the focus diameter. The effects of laser beam defocusing, for example due to a smudged protective glass, could also be analyzed through the measurements taken with the BeamWatch Integrated. Because of these deviations in the laser beam parameters, the team also checked the weld penetration depth of the respective weld seams. Although the seam looked completely flawless, the weld depth was clearly too shallow. It was concluded that measurement technology had to be integrated into the series production process – as only then can the quality of the contact welds be guaranteed over the long term.

### **Reproducible quality of the contact welds**

Today, the Ophir BeamWatch Integrated System is built into all the automated production lines where BMW 5th-generation battery modules are made worldwide. During the loading and unloading process, the laser is briefly operated at full power to determine focus shift. Only after confirmation (IO signal) that the parameters of the laser beam correspond to specs does the welding begin.

While production was still in the start-up phase, measurements were taken after each module. For series production at full capacity, however, the decision was made to measure the laser beam after every tenth module produced. Should the BeamWatch Integrated detect a deviation in one of the previously defined parameters, it displays a warning message. The operator responsible for the line then checks the protective glass of the laser and cleans or exchanges it, as necessary. Potential errors due to deviations of the laser beam's caustic can thus be avoided from the outset. In addition to this proactive testing, all modules are subjected to an electrical function test after the welding process.

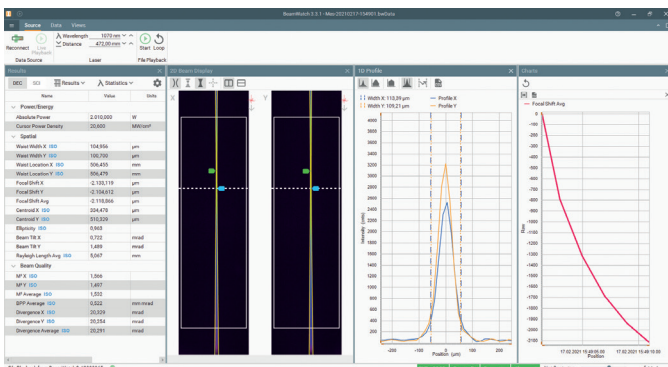


Fig. 1+2: Ophir BeamWatch Integrated 500 was especially developed to measure single mode fiber lasers with focal lengths of more than 500mm.

MKS measurement technology has contributed to the optimization of both the development of the BMW Group's laser welding process as a whole and the quality of the manufactured modules.

### Essential tool for monitoring

The production of a battery module is a very complex process overall. The individual battery cells are stacked, pressed and placed into a frame. Then, all positive and negative poles must be welded in the cell contacting system – upwards of 15,000 spot welds per hour are performed in each system!

The engineers of the technology team are certain that the quality of the manufactured modules depends in large part on the consistently high quality of the laser beam parameters: Ophir BeamWatch Integrated is an essential tool for monitoring the laser beam in the production of the battery modules. And the equipment operators in the production lines are convinced of this too. Overall, MKS measurement technology has contributed to the optimization of both the development of the BMW Group's laser welding process as a whole and the quality of the manufactured modules.

### The BMW Group

The BMW Group is the world's leading premium manufacturer of automobiles and motorcycles and also provides premium financial and mobility services. The BMW Group production network comprises over 30 production sites worldwide; the company has a global sales network in more than 140 countries. As of December 31, 2021, the BMW Group had a workforce of 118,909 employees.



## WHY MKS?

CRITICAL TECHNOLOGIES	PROVEN PARTNER	OPERATIONAL EXCELLENCE	COMPREHENSIVE PORTFOLIO
World-class technology and development capabilities for leading-edge processes	Recognized leader delivering innovative, reliable solutions for our customers' most complex problems	Consistent execution across all aspects of our business	Extensive offering of products and services for the Semiconductor, Advanced Electronics and Specialty Industrial markets.

### MKS Photonics Solutions

MKS Instruments helps businesses solve their hardest technology challenges. A trusted partner of the world's largest electronics and industrial companies, we leverage leading-edge science and engineering capabilities to offer solutions that improve process performance and productivity for our customers. Spectra-Physics, Ophir, Newport and ESI are brands within the MKS Instruments Photonics Solutions division. Spectra-Physics combines groundbreaking laser technologies with deep application expertise to deliver industry leading lasers for precision industrial and scientific research applications. Ophir specializes in laser and LED measurement products, including laser power and energy meters and laser beam profilers. Ophir also provides high-performance IR thermal imaging lenses and optical elements as well as optics for CO<sub>2</sub> and high-power fiber laser material processing. Newport provides a full range of solutions including precision motion control, optical tables and vibration isolation systems, photonic instruments, temperature sensing, optical and opto-mechanical components. ESI systems deliver market-leading solutions for Flexible PCB laser processing, high-speed MLCC testing, and CO<sub>2</sub>-laser-based systems HDI PCB and IC substrate manufacturing. MKS Photonics Solutions enhance our customers' capabilities and productivity in the semiconductor, advanced electronics and specialty industrial markets.