In-line production monitoring of battery welding processes

Workshop Laser eMobility – 2022 Dr. Luca Porcelluzzi

Area Manager MKS Ophir

omks

Summary

- There are many variables inherent to laser processes.
- Understanding how your laser is performing, through the measurement of key performance indicators, is the first step to managing laser system variables.
- Laser measurement products help quickly restore a laser system to its designed performance.
- But understanding how your laser performs over time will ultimately help you maintain a consistent, high-quality, ever-improving laser process.
- The appropriate laser measurement product should help to detect performance drift at an early stage and prevent production of bad parts.



MKS helps the most innovative companies in the world **SOLVE COMPLEX PROBLEMS**

MARKET

- MKS is a leading global provider of process control solutions for
- Semiconductor
- Industrial Technologies
- Life & Health Sciences
- Research & Defense

STRATEGIC GROWTH

Q1 2019 – acquired Electro Scientific Industries (ESI)

- Leader in laser-based manufacturing for the micromachining industry
- Q2 2016 acquired Newport Corporation
 - Leader in sophisticated laser, light and motion products

INNOVATIVE SOLUTIONS

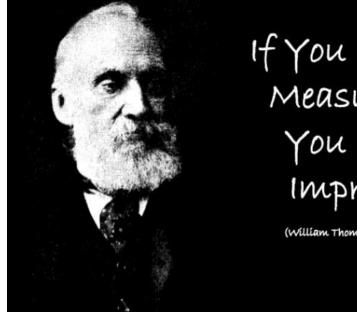
Vacuum Processing

- Pressure measurement & control, flow, power, reactive gas analysis, automation
- Laser Solutions
 - Precision laser applications
- Motion, Photonics & Optics
 - Vibration & performance motion control, gratings & optics, laser measurement
- Laser-Based Process
 Equipment
 - Advanced PCB, Semi & component manufacturing

KEY FACTS

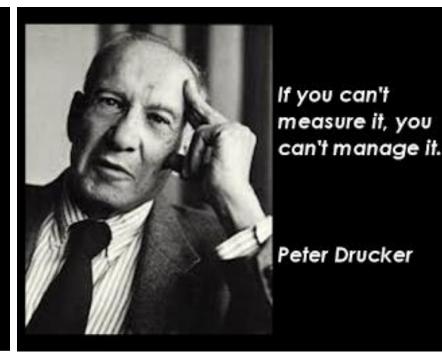
- Founded: 1961
- HQ: Andover MA
- IPO: 1999 (NASDAQ MKSI)
- Selling in ~100 countries
- In 2020
 - Sales: \$2.3B
 - Employees: 5,800⁺
 Engineers & Scientists: 1,000⁺
 - R&D Investment: ~\$173M
 - Worldwide Patents: 2,100⁺

Food For Thought



If You Can't Measure It, You Can't Improve It

(William Thomson, Lord Kelvin)



Speaking of physical science

Speaking of workplace efficiency

MKS CONFIDENTIAL

BeamWatch Integrated : Non-Contact device for production

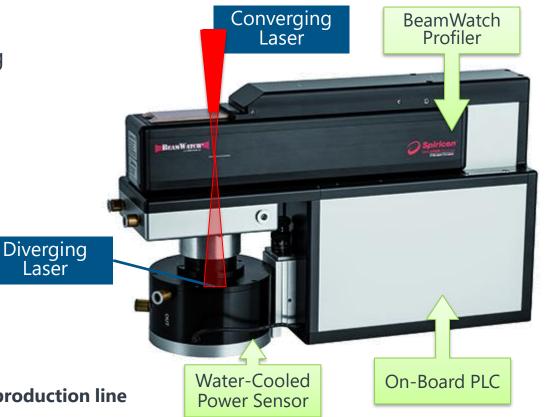
Ophir BeamWatch Integrated

- All-In-One Power & Beam Profiling
 - BeamWatch Beam Profiler
 - Power Head sensor up to 30KW
 - ProfiNet, Ethernet/IP, CC-Link, GigE

KPI

- Laser Power
- Laser Spot Size
- Laser Power Density
- Focal Shift
- M2 / BPP / K / Beam Divergence
- Good for:

- Short/Long- time measurements
- System Feedback
- Full automated in order to operate in production line



Non-Contact Beam Profiling and ISO 11146

- It's too new to be directly mentioned in the ISO ...
- Comparing cameras, scanning slits and non-contact technologies to measure beam waist, divergence, M² and Rayleigh length, the max divergence was of 3.7%.
- For more detail refer to the White Paper

To be found here:



ISO compliance of non-contact, real-time beam analysis

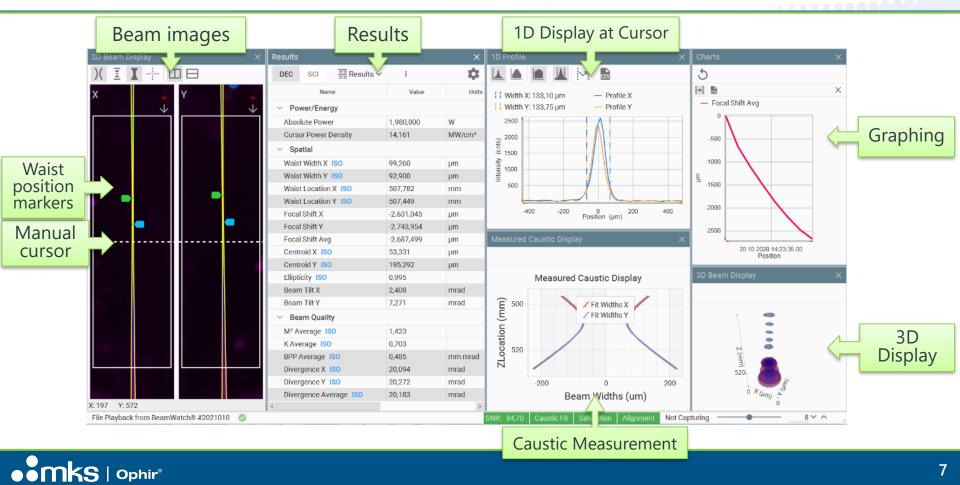
Author:

By Jed Simmons Ph.D. & Kevin Kirkham

https://www.ophiropt.com/laser--measurement/knowledge-center/article/13236



BeamWatch Software: Beam Profiling Non-Contact

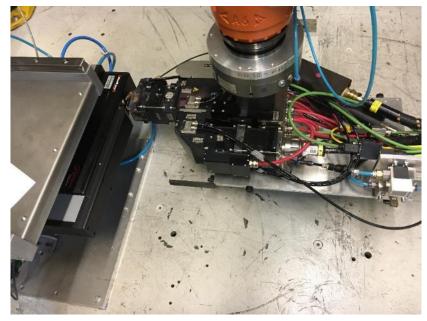


Ophir BeamWatch Integrated Mounting Examples

Vertical



Horizontal







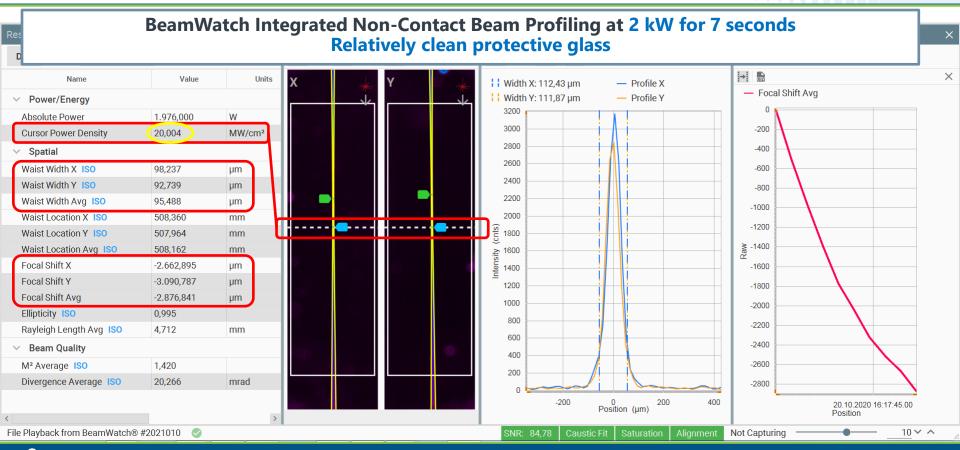
- Laser System:
 2 kW single-mode laser

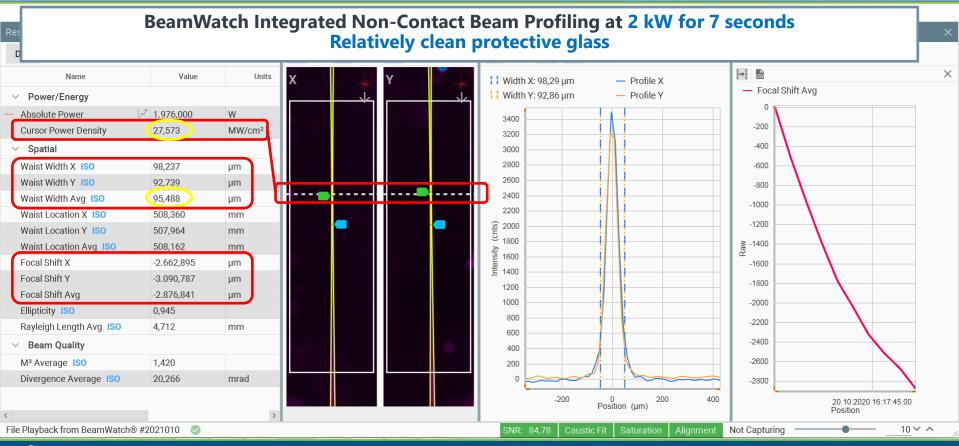
 - 3-Axis gantry
 Welding head:
 - 500 mm working distance
 - ~100µm spot size
- Application:

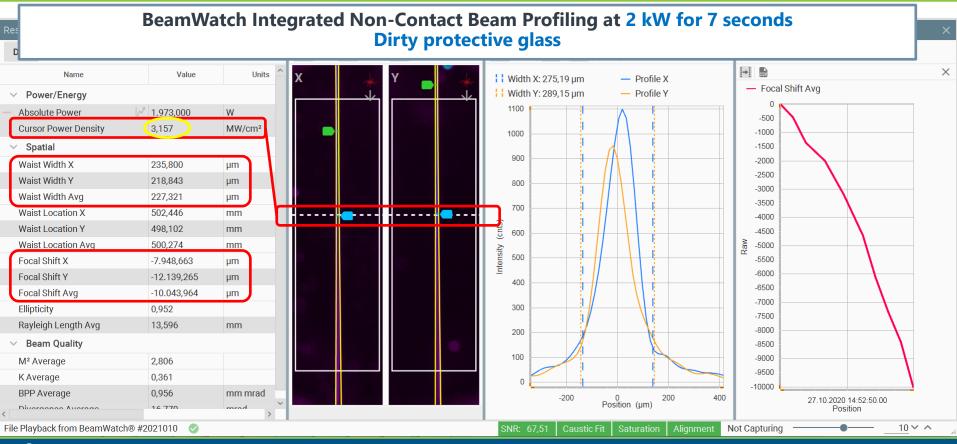
- Laser welding of battery packs
- Aim of the measurement:
 - Process optimization through compensation for thermal drift during the laser on time
 Predictive maintenance: Trending information for changes in beam caustic in an industrial
 - environment
- Measurement Equipment:

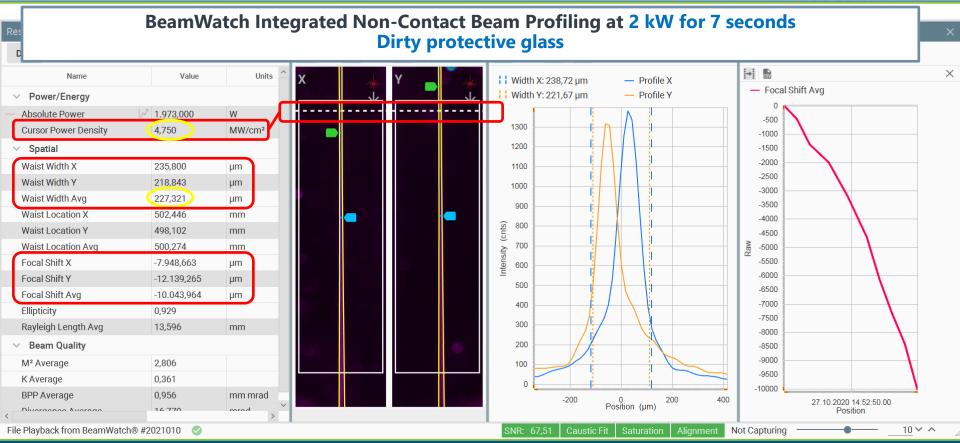
 Ophir BeamWatch Integrated non-contact beam analyzer











Results:

MKS | Ophir®

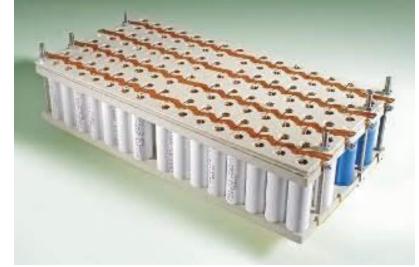
- A dirty protective glass drastically increases focus shift.
- Processes using single mode laser beams should be more tolerant to focus shift...
- But a dirty cover glass also increases the beam diameter independently of the focus shift.
- **BeamWatch Integrated** measures the laser for every few parts produced.
- The trending capability is used to determine as when to clean or replace the protective window before producing bad parts.







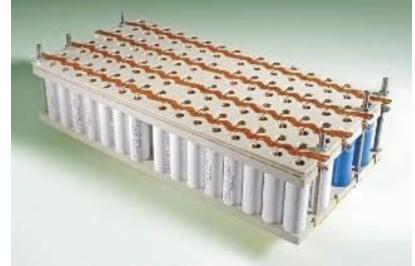
- Laser System:
 - Single-mode fiber laser
 - 2 kW rated power
 - 3-Axis gantry
 - Welding head:
 - 625 mm working distance
 - ~50 µm spot size (expected)
- Application:
 - Battery bus bar welding (Cu/Al)
 - <u>Problem:</u> Loss of penetration at end of weld cycle, weld test failures, suspected focus shift
- Measurement Equipment:
 - Integrated water-cooled sensor to HMI.
 - Ophir BeamWatch non-contact beam analyzer



Source: eenewspower

Before Maintenance:

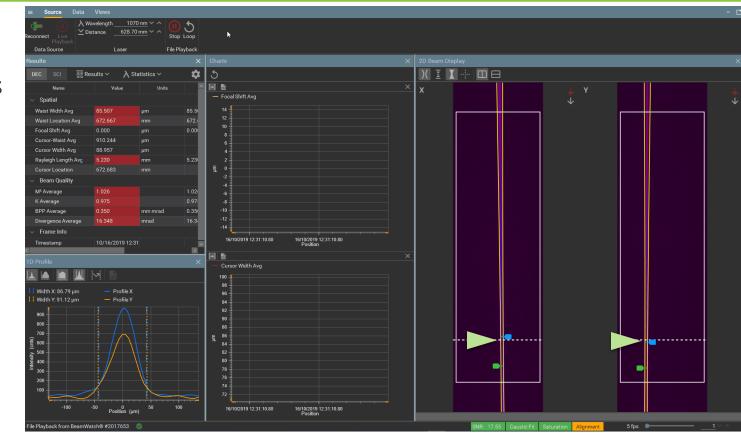
- Problems:
 - Lack of weld penetration from beginning of weld cycle to end.
 - Parts being scrapped because of failures in weld testing (conductivity and pull tests).
 - Having to put pause between welds to compensate for overheating.
 - Loss of production time
- Theories:
 - Focus shift due to overheating of some component
 - Improper maintenance of system
 - Faulty design or integration



Source: eenewspower

Before Maintenance:

- Measurements of interest:
 - Focus Shift
 - Focused Spot Location

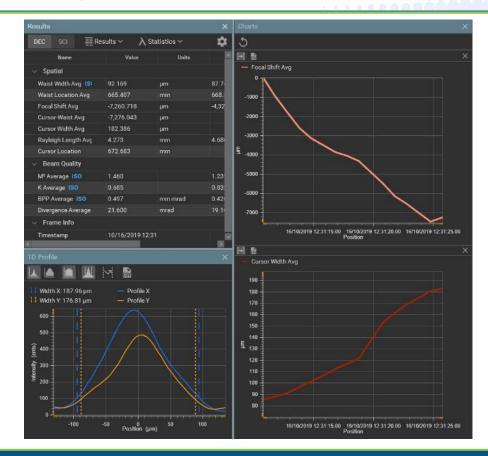




Before Maintenance:

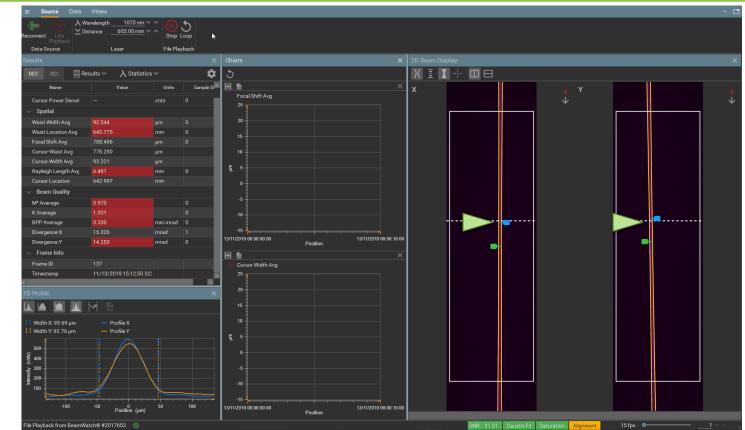
• At 500 W:

- Focus Shift: 2.5 mm
- Beam Waist at Process: +47%
- At just < 1500 W:
 - Focus Shift: 7.2 mm
 - Beam Waist at Process: +94%
- Focused Spot Location:
 - ~16mm off from expected



After Maintenance:

- Changed several components in laser system
- Measurements of interest:
 - Focus Shift
 - Focused Spot Location



After Maintenance:

• At 500 W:

- Focus Shift: **1.2 mm**
- Beam Waist at Process: +24%
- At just < 1500 W:
 - Focus Shift: 4.5 mm
 - Beam Waist at Process: +33%
- Focused Spot Location:
 - Able to locate the beam waist and compensate with less focus shift

Name Value Units Sample % Cursor Power Densit - onts 0 Spatial - onts 0 Spatial mm 24 Watet Location Avg 638 441 mm 24 Focal Shift Avg -4,555.205 µm 24 Cursor Weith Avg -4,555.432 µm - Cursor Weith Avg 123.334 µm - Cursor Weith Avg 4.857 mm 24 Rayleigh Length Aug 4.857 mm 24 K Average 0.411 mm mrad 24 Divergence X 18.166 mrad 24 Divergence X 18.166 mrad 24 Divergence X 18.166 mrad 24 V Farme Info Cursor Weith Avg 13/11/2019 15.13.01.52 Frame Info 160 Cursor Weith Avg 13/11/2019 15.13.01.52 Width X: 116.23 µm - Profile X 10 10 Mage	Cursor Power Densit Spatial Waist Width Avg 89 Waist Location Avg 638 Focal Shift Avg 4,5 Cursor Waist Avg 4,5 Cursor Width Avg 123 Rayleigh Length Avg 48 Cursor Location 642 Beam Quality M ⁴ Average 12 K Average 0,8 BPP Average 0,4 Divergence X 18. Divergence Y 18. V Frame Info 160	362 441 45 226 55 432 57 2.997 07 33 11 615 156	ents µm mm µm ym mm mm mm mm mm mm mrad	0 24 24 24 24 24 24 24 24 24		Deal Shift Avg				151300 00
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Thanks, questions are welcome...

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