In-line production monitoring of battery welding processes

Workshop Laser eMobility – 2022

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Area Manager MKS Ophir

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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 LEADER

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 micro-machining industry
- Q2 2016 – acquired Newport Corporation
  - Leader in sophisticated laser, light and motion products

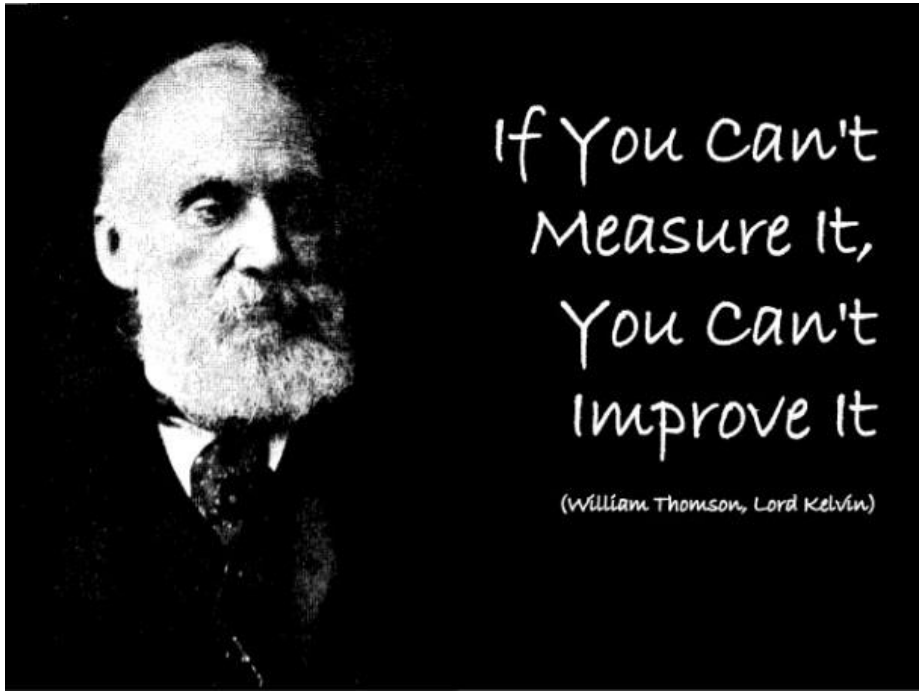
INNOVATIVE SOLUTIONS

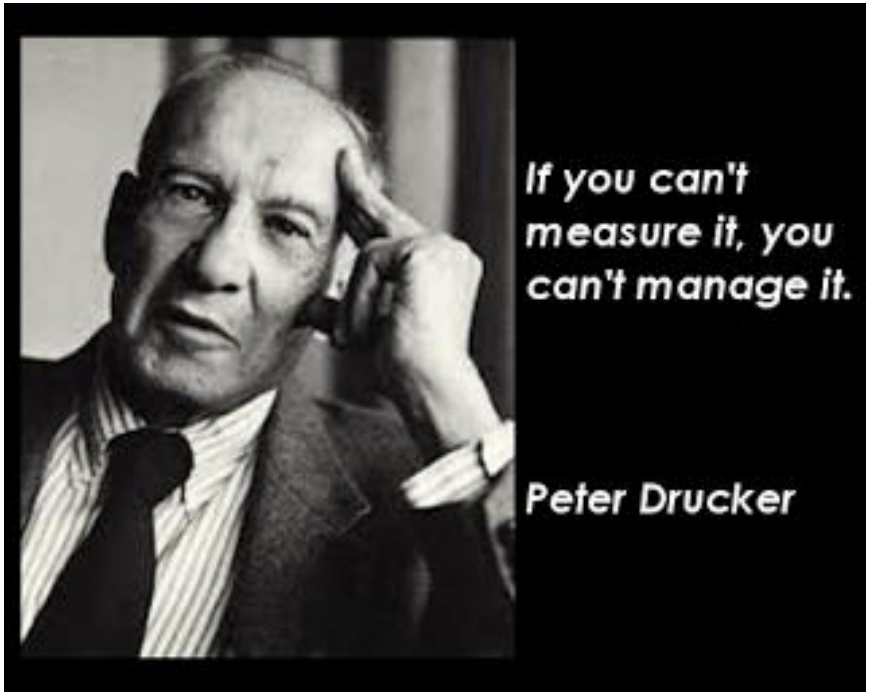
- Vacuum Processing
  - Pressure measurement & control, flow, power, reactive gas analysis, automation
- Laser Solutions
  - Precision laser applications
- Motion, Photonics & Optics
  - Vibration & performance motion control, gratings & optics, laser measurement
- Laser-Based Process Equipment
  - Advanced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





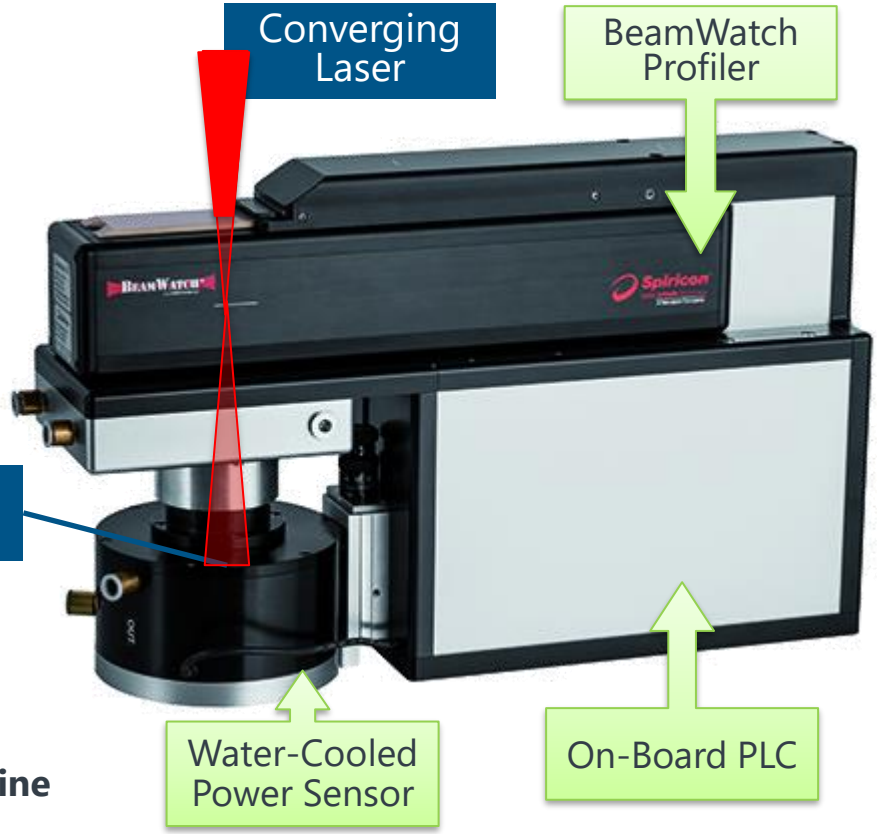
Speaking of
physical science

Speaking of
workplace efficiency

BeamWatch Integrated : Non-Contact device for production

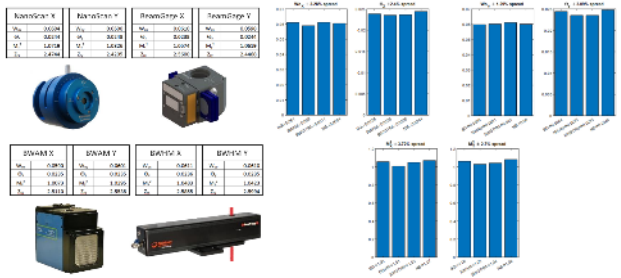
Ophir BeamWatch Integrated

- 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, M^2 and Rayleigh length, the max divergence was of 3.7%.



- For more detail refer to the White Paper

To be found here:

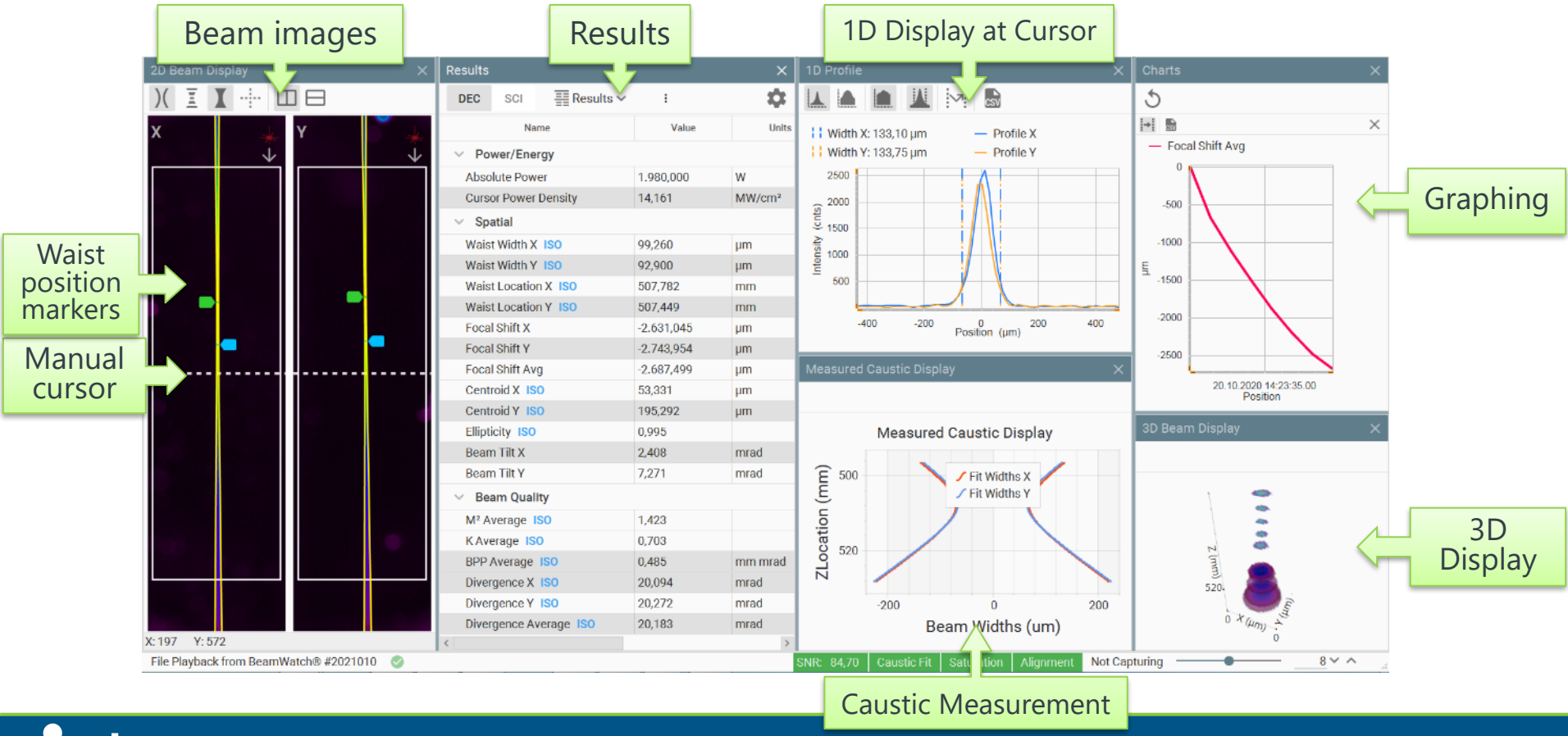
ISO compliance of non-contact, real-time beam analysis

Author:

By Jed Simmons Ph.D. & Kevin Kirkham

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

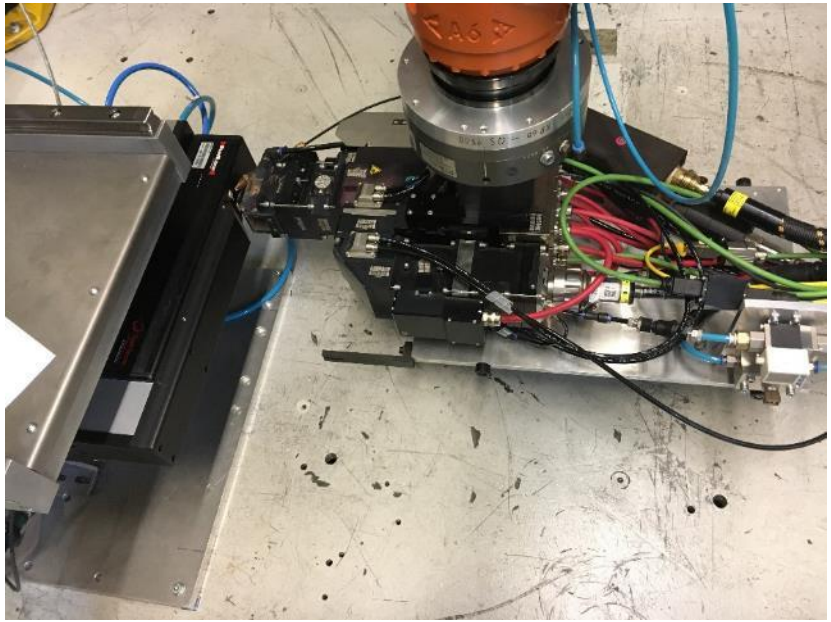
BeamWatch Software: Beam Profiling Non-Contact



Ophir BeamWatch Integrated Mounting Examples

Vertical

Horizontal



Case 1:
Production Monitoring – Battery Welding

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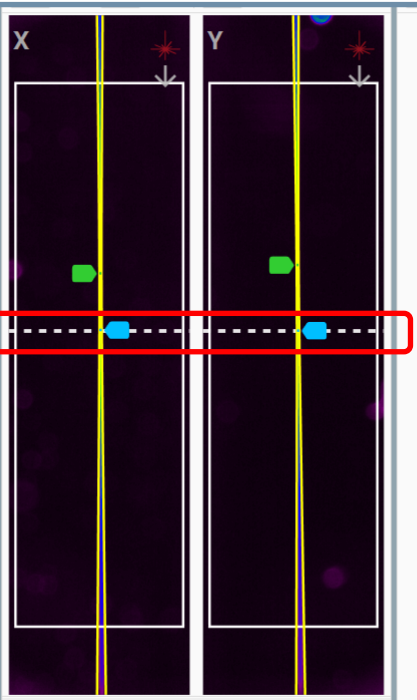
Case 1: Production monitoring – Battery Welding

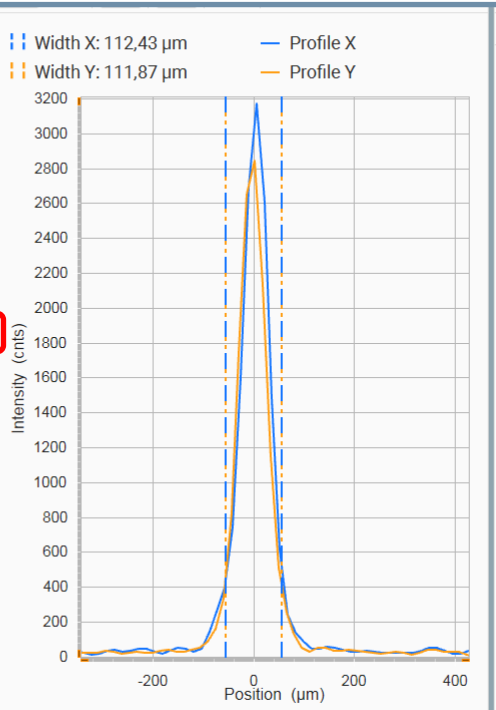
- Laser System:
  - 2 kW single-mode laser
  - 3-Axis gantry
  - Welding head:
    - 500 mm working distance
    - ~100µm spot size
- Application:
  - Laser welding of battery packs
- Aim of the measurement:
  - Process optimization through compensation for thermal drift during the laser on time
  - Predictive maintenance: Trending information for changes in beam caustic in an industrial environment
- Measurement Equipment:
  - Ophir **BeamWatch Integrated** non-contact beam analyzer

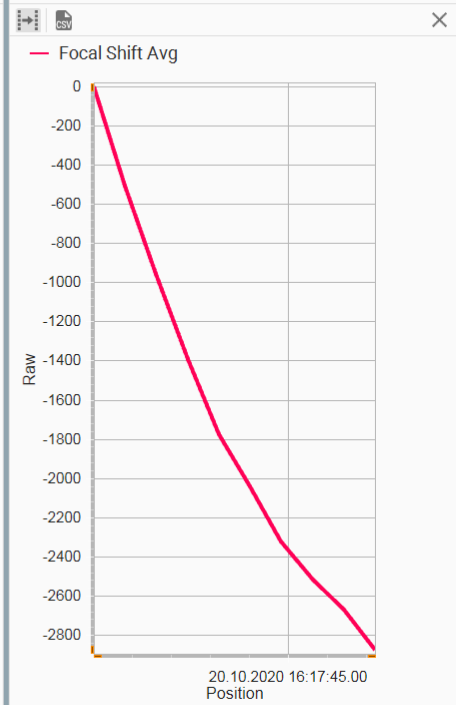
Case 1: Production monitoring – Battery Welding

BeamWatch Integrated Non-Contact Beam Profiling at 2 kW for 7 seconds
Relatively clean protective glass

Name	Value	Units
Power/Energy		
Absolute Power	1.976,000	W
Cursor Power Density	20,004	MW/cm²
Spatial		
Waist Width X ISO	98,237	µm
Waist Width Y ISO	92,739	µm
Waist Width Avg ISO	95,488	µm
Waist Location X ISO	508,360	mm
Waist Location Y ISO	507,964	mm
Waist Location Avg ISO	508,162	mm
Focal Shift X	-2.662,895	µm
Focal Shift Y	-3.090,787	µm
Focal Shift Avg	-2.876,841	µm
Ellipticity ISO	0,995	
Rayleigh Length Avg ISO	4,712	mm
Beam Quality		
M² Average ISO	1,420	
Divergence Average ISO	20,266	mrad





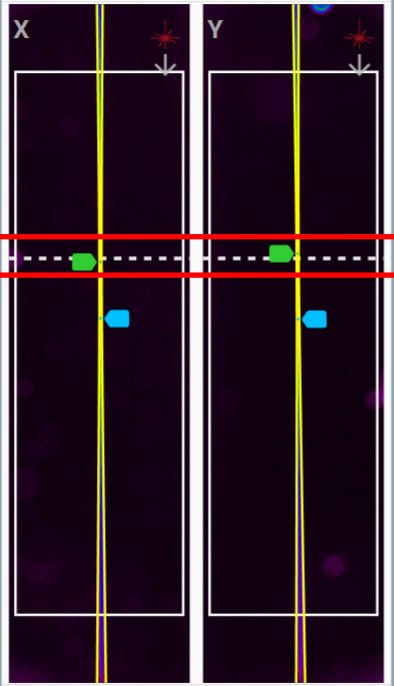


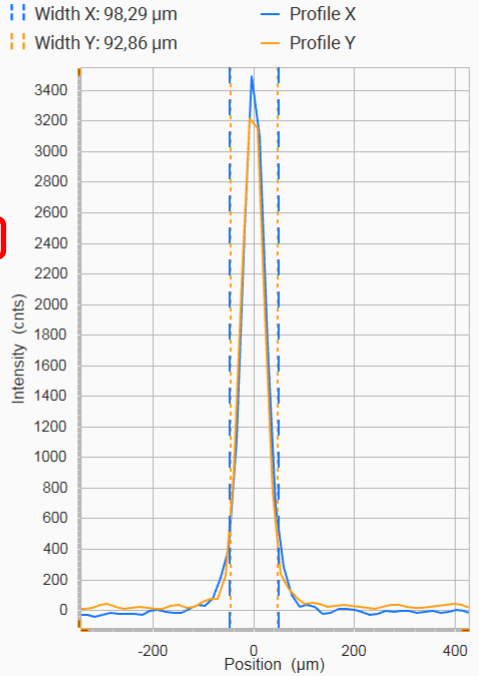
File Playback from BeamWatch® #2021010 | SNR: 84,78 | Caustic Fit | Saturation | Alignment | Not Capturing | 10

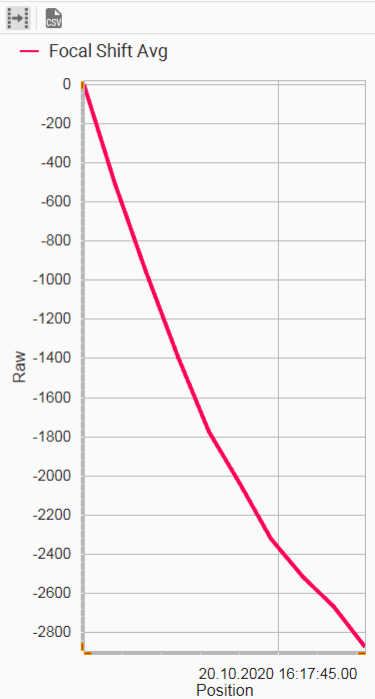
Case 1: Production monitoring – Battery Welding

BeamWatch Integrated Non-Contact Beam Profiling at 2 kW for 7 seconds
Relatively clean protective glass

Name	Value	Units
Power/Energy		
Absolute Power	1.976,000	W
Cursor Power Density	27,573	MW/cm²
Spatial		
Waist Width X ISO	98,237	µm
Waist Width Y ISO	92,739	µm
Waist Width Avg ISO	95,488	µm
Waist Location X ISO	508,360	mm
Waist Location Y ISO	507,964	mm
Waist Location Avg ISO	508,162	mm
Focal Shift X	-2.662,895	µm
Focal Shift Y	-3.090,787	µm
Focal Shift Avg	-2.876,841	µm
Ellipticity ISO	0,945	
Rayleigh Length Avg ISO	4,712	mm
Beam Quality		
M² Average ISO	1,420	
Divergence Average ISO	20,266	mrad







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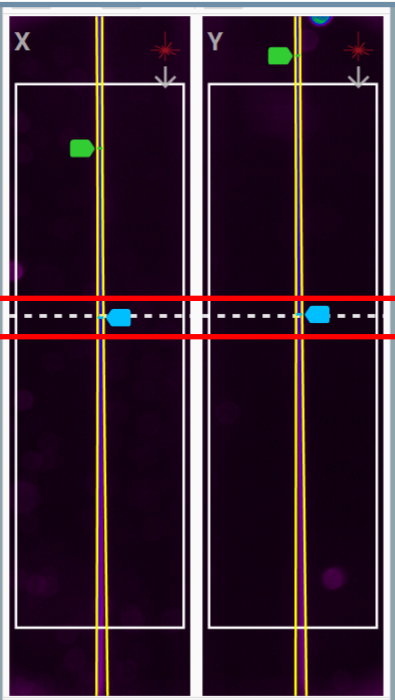
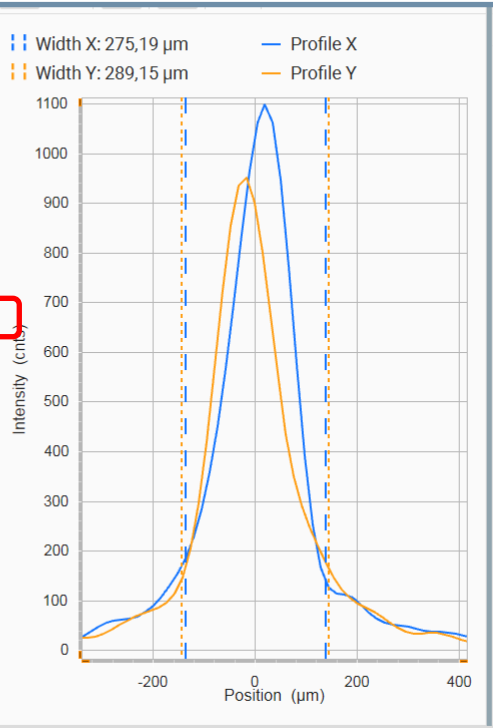
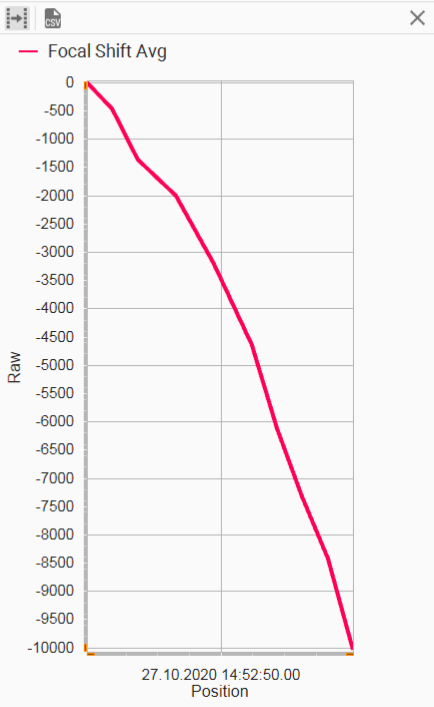
Case 1: Production monitoring – Battery Welding

BeamWatch Integrated Non-Contact Beam Profiling at 2 kW for 7 seconds
Dirty protective glass

Name	Value	Units
Power/Energy		
Absolute Power	1.973,000	W
Cursor Power Density	3,157	MW/cm²
Spatial		
Waist Width X	235,800	µm
Waist Width Y	218,843	µm
Waist Width Avg	227,321	µm
Waist Location X	502,446	mm
Waist Location Y	498,102	mm
Waist Location Avg	500,274	mm
Focal Shift X	-7.948,663	µm
Focal Shift Y	-12.139,265	µm
Focal Shift Avg	-10.043,964	µm
Ellipticity	0,952	
Rayleigh Length Avg	13,596	mm
Beam Quality		
M² Average	2,806	
K Average	0,361	
BPP Average	0,956	mm mrad







File Playback from BeamWatch® #2021010 | SNR: 67,51 | Caustic Fit | Saturation | Alignment | Not Capturing

Case 1: Production monitoring – Battery Welding

BeamWatch Integrated Non-Contact Beam Profiling at 2 kW for 7 seconds
Dirty protective glass

Name	Value	Units
Power/Energy		
Absolute Power	1.973,000	W
Cursor Power Density	4,750	MW/cm²
Spatial		
Waist Width X	235,800	µm
Waist Width Y	218,843	µm
Waist Width Avg	227,321	µm
Waist Location X	502,446	mm
Waist Location Y	498,102	mm
Waist Location Avg	500,274	mm
Focal Shift X	-7.948,663	µm
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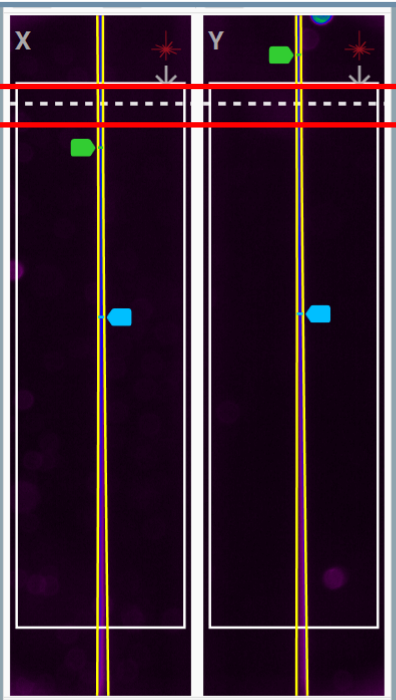

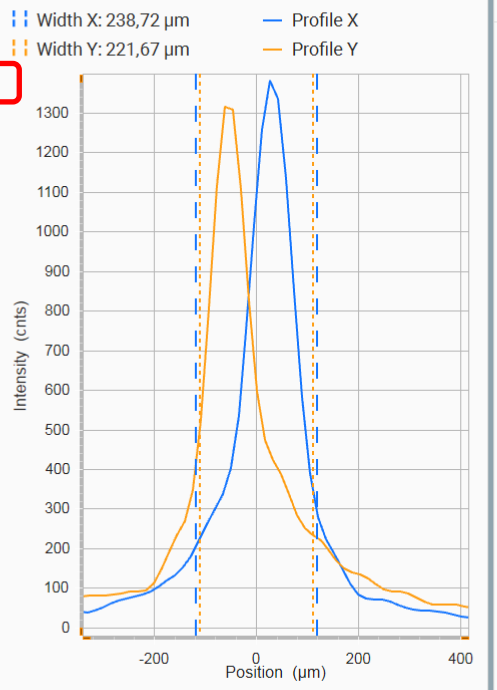

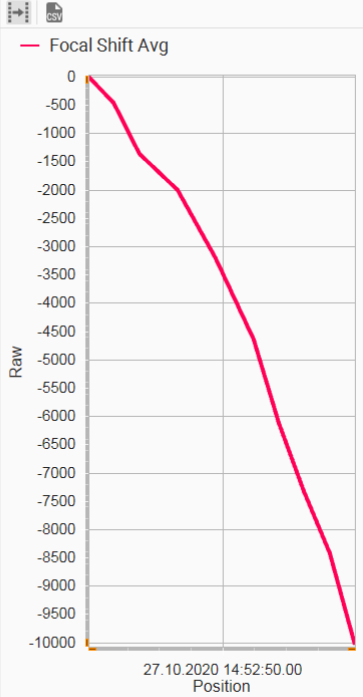

File Playback from BeamWatch® #2021010

SNR: 67,51 | Caustic Fit | Saturation | Alignment | Not Capturing

Case 1: Production monitoring – Battery Welding

Results:

- 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.

Case 2: Production Troubleshooting - Battery Welding

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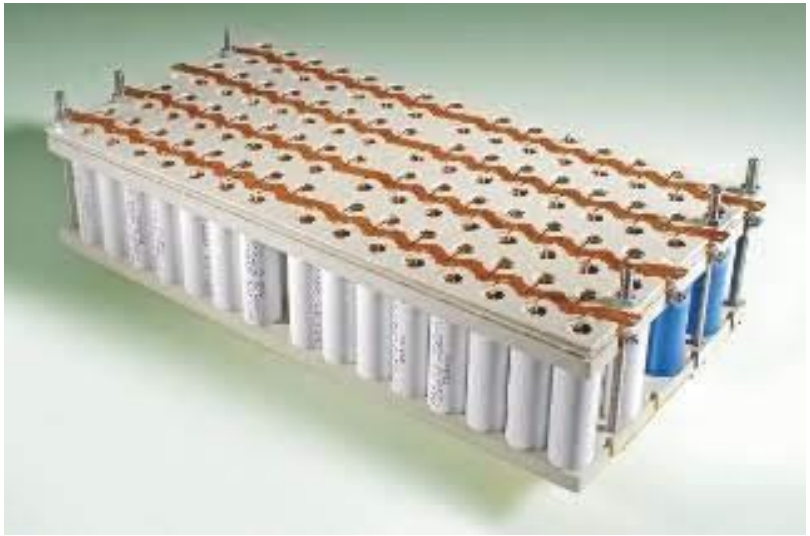
Case 2: Production Troubleshooting - Battery Welding

- 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)
  - Problem: 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

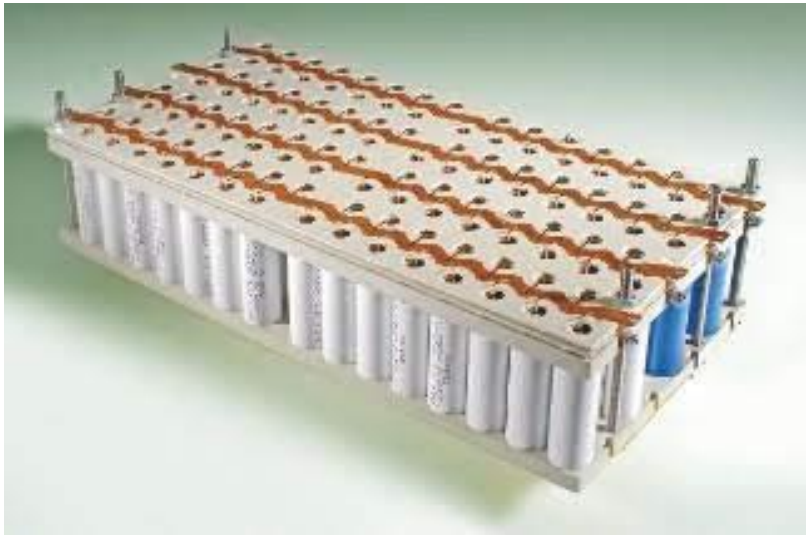


Source: eenewspower

Case 2: Production Troubleshooting - Battery Welding

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

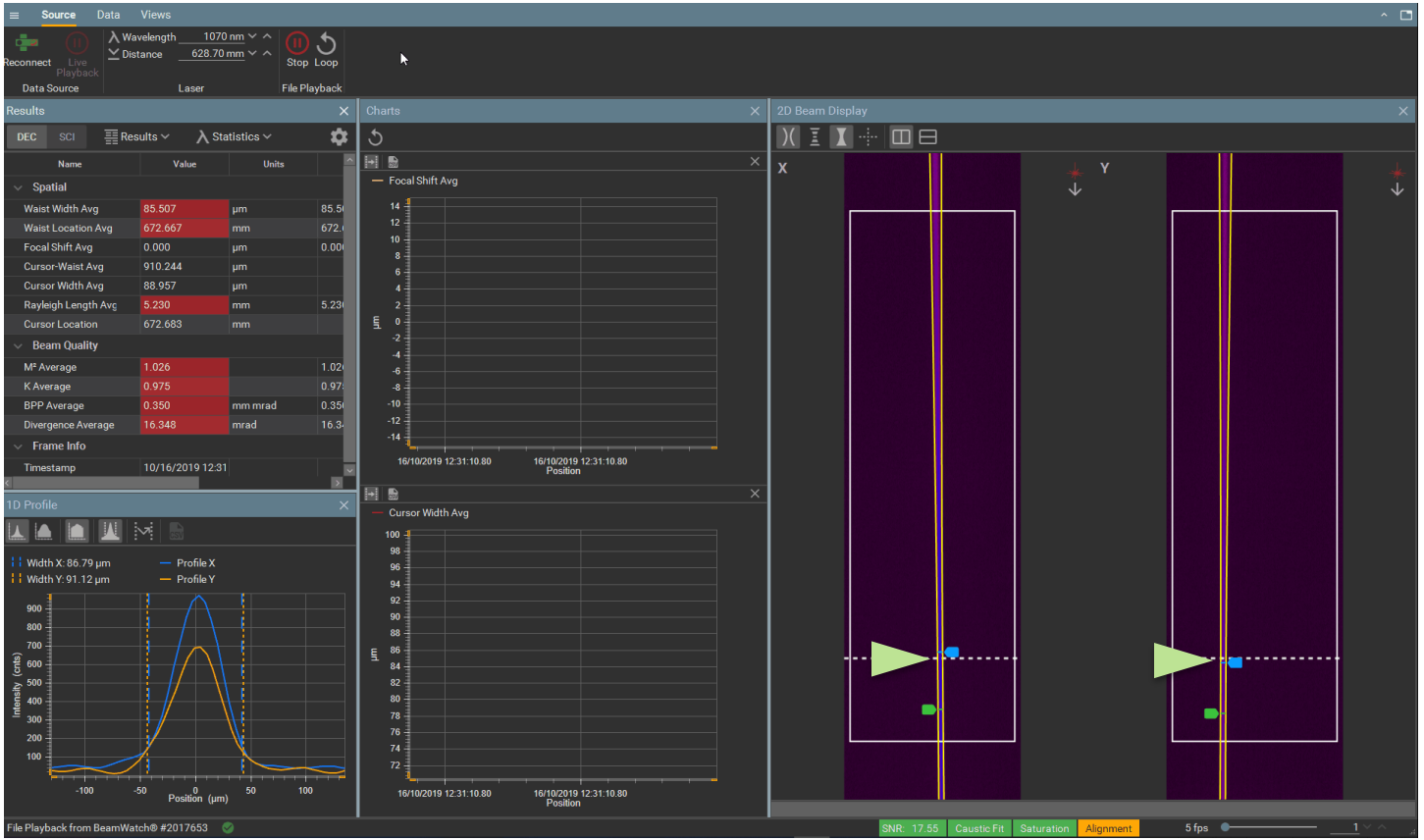


Source: eenewspower

Case 2: Production Troubleshooting - Battery Welding

Before Maintenance:

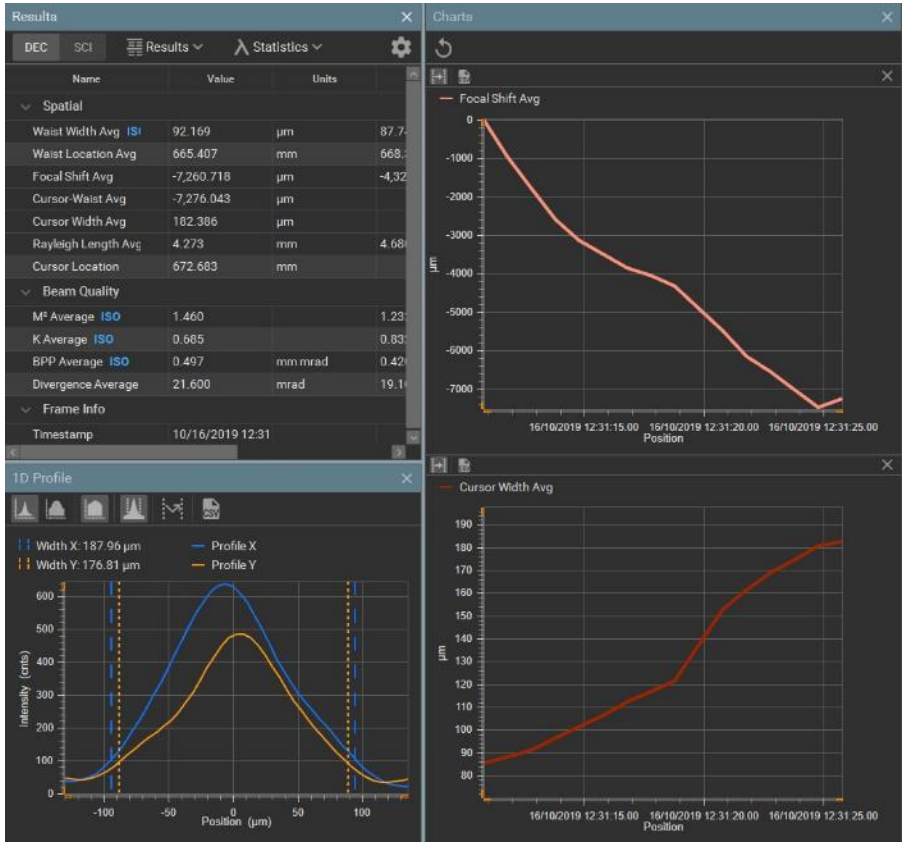
- Measurements of interest:
  - Focus Shift
  - Focused Spot Location



Case 2: Production Troubleshooting - Battery Welding

Before Maintenance:

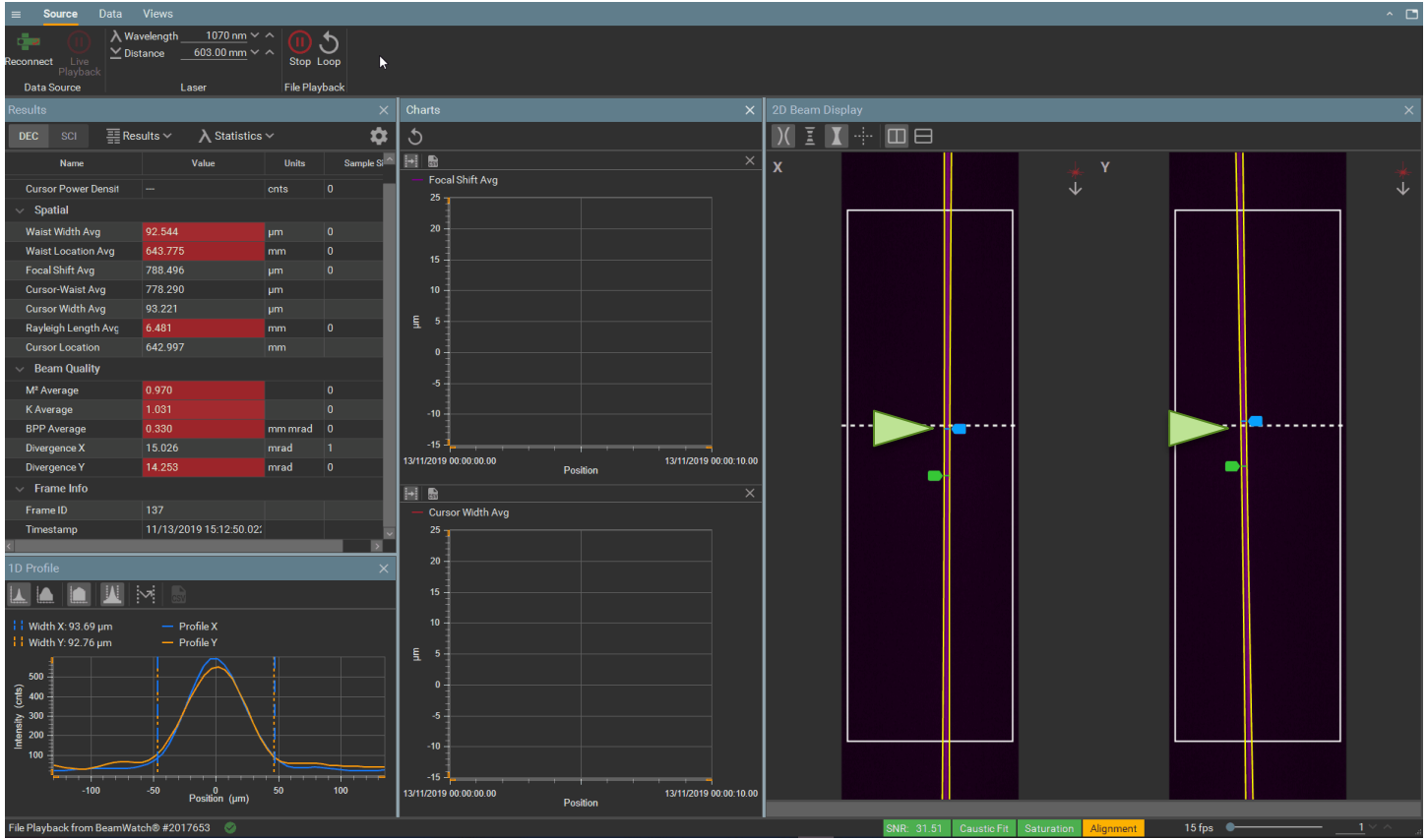
- At 500 W:
  - Focus Shift: **2.5 mm**
  - Beam Waist at Process: +47%
- At just < 1500 W:
  - Focus Shift: **7.2 mm**
  - Beam Waist at Process: +94%
- Focused Spot Location:
  - ~16mm off from expected



Case 2: Production Troubleshooting - Battery Welding

After Maintenance:

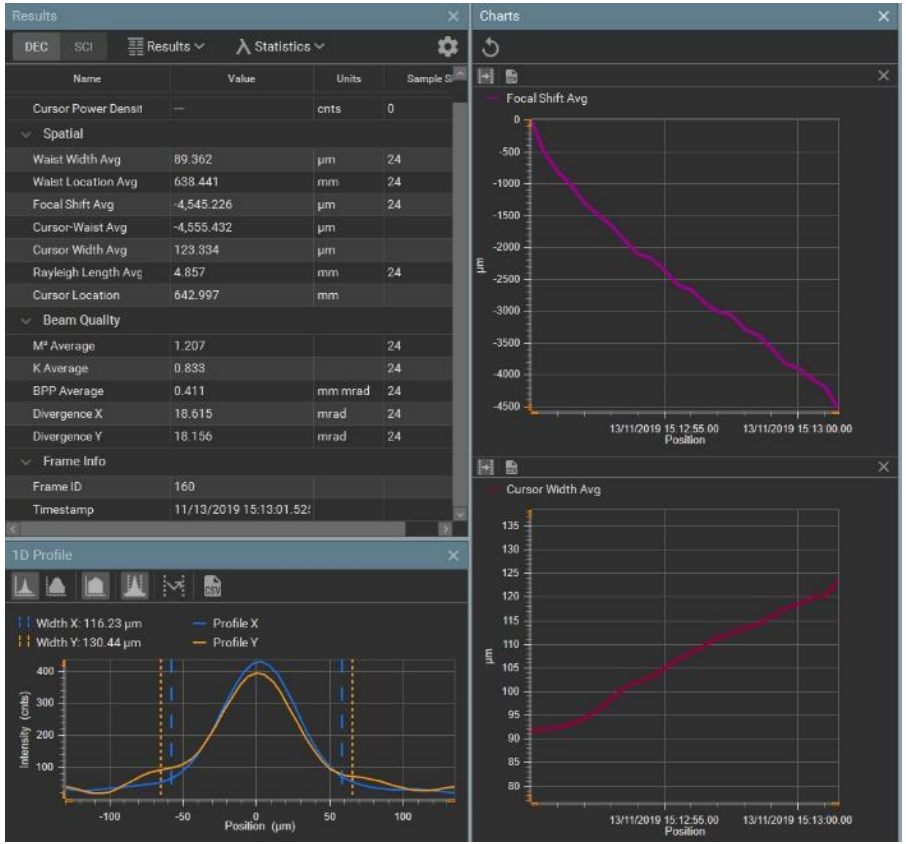
- Changed several components in laser system
- Measurements of interest:
  - Focus Shift
  - Focused Spot Location



Case 2: Production Troubleshooting - Battery Welding

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



Thanks, questions are welcome…

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