High-power fiber optic cable with integrated active sensors for live process monitoring

Mats Blomqvist, Optoskand AB;

High Power Laser Optics and Fibers

www.optoskand.se
Outline

- Introduction
- Fundamental design
- Integrated active sensors
- Integrated active sensors for system safety
- Experimental setup
- Results
- Discussion and Conclusions
Optoskand at a glance

- Located in Gothenburg, Sweden.
- About 45 employees. Turnover in FY 2011 was approx. €10M.
- More than 20 years of know-how with-in fiber optical beam delivery systems.
- Developing, manufacturing and marketing fiber optical systems for industrial high power lasers.
- >120 customers worldwide last 12 months.
- Main customers are laser manufacturers.
- All-embracing product line for fiber optic beam delivery.
Introduction

It will be presented how standard integrated sensors can give very good feedback from a process in action.

Integrated sensors can effectively be used to switch of the laser system in case of an abnormal situation.

Activated by intergrated sensor-board

Optical fiber interlock circuit
Fundamental design (Optoskand patents)

Sensitive areas when transmitting power through an optical fiber.

The mode-striper is a layer or a part of the fiber. The mode-striper removes any cladding light.

A quartz block gives a larger entrance/exit surface, which makes it less sensitive. It is also possible to use AR-coating.
Fundamental design (*Optoskand patents*)

QBH – Water behind the Quartz block

Measure $\Delta T$ of the cooling water

$1000 \text{ W and } 1 \text{ l/min}$

$\Rightarrow$

$\Delta T = 14 \text{ C}$

$dT = T_{\text{out}} - T_{\text{in}}$
Integrated active sensors

Light sensors

Light guide

Glas cylinder with or without AR-coating

Beam in forward direction

Mode stripper

Back reflected light (process-light)

ΔT sensor

\( T_{\text{out}} - T_{\text{in}} \)

Temperature sensor

Humidity sensor

FiSC 2012, Dresden
Integrated active sensors for system safety

- Integrated sensor board can be used to switch off the optical interlock in case of unexpected sensor values
- The system is protected from major damages
Experimental

- Can the integrated sensors be used for process monitoring?
- Tests were made in an application lab with access to:
  - A 6 kW IPG fiber laser
  - An ABB robot
  - A process head from PERMANOVA
  - An Optoskand QD fiber with integrated active sensors
- Two experiment were executed
  - Welding two metal sheets together in a straight line. Disturbances were introduced in process and detected by the process monitoring system.
  - Welding two metal sheets together using a ”sophisticated pattern”. Also here, some disturbances were introduced during the process.
Results – welding metal sheets

Good penetration through the plates

Photo diode level about 0.13

No penetration, no bonding between plates

Photo diode level about 0.15

Input side remains at ~0.12

UC-bor-plate, 2x1.3 mm, 2000W, 2m/min, Focus = 0mm

UC-bor-plate, 2x1.3 mm, 2000W, 2m/min, Focus = +6mm

FiSC 2012, Dresden
Results – welding metal sheets

Galvanized steel sheet 2x1.25mm with a buckle, 2000W, 2 m/min, Focus +3mm

Defect, cut through first plate
No bonding between plates.
Results – welding metal sheets with pattern

Penetration only in the corners

Penetration all the way through the process

Acceleration and deceleration detectable via the diode signal

FiSC 2012, Dresden
Result – What defects are possible to see?

- Two Cu-wires are placed on a steel plate.
- The robot speed is set to 6 m/min and 8 m/min.
- 16-bit A/D converter with sample speed 2 ms.
Result – What defects are possible to see?

16-bit A/D converter with sample speed 2 ms.

2kW in focus on black steel plate
6m/min

Thread thickness 0.5mm

Thread thickness 0.15mm

Signal during 10 samples (mean value filters 50 points).
Result – What defects are possible to see?

2kW in focus on black steel plate
8m/min

Signal during 10 samples (mean value filters 50 points).

Thread thickness 0.5mm
Thread thickness 0.15mm
Result – Pen stripes on a steel plate

2kW in focus on black steel plate
6m/min

Photo diode signal

Time (ms)
Discussion and Conclusions

Optoskand has implemented a number of sensors as a standard in our QD fiber connector (European Automotive Industry standard). The sensors are:

- Photo sensors to monitor optical light inside the fiber connector
- $\Delta T$ sensor to measure the temperature difference in the cooling water
- Absolute temperature
- Humidity sensor

**System safety**

- The sensors can be used to switch off the system in case of an unexpected behavior.
- This function can save components in the system from breakage and expensive repairs.

**Process monitoring**

- The sensors can be used for process monitoring and application qualification.
- Experimentally a 0.15 mm thick Cu-wire has been resolved at 8 m/min welding speed.
- Information from the sensors can be built into a closed loop regulation system.
Acknowledgements

- PERMANOVA Lasersystem AB
  For helping out during tests with process knowledge!

- Volvo Cars Corporation
  Guidance and encouraging partner!