QCOALA

Quality Control Of Aluminium Laser-welded Assemblies

Paola De Bono (TWI Ltd)
Wednesday 14 September 2011

- **A collaboration between:**
- **LASAG, Precitec, CIT and SAFEL,**
- **Flisom, SolarPro and VW,**
- **Ruhr-Universität Bochum, Fraunhofer ILT and TWI**

- An idea from Fraunhofer ILT

EU Funded Project
Ref. 260153

QCOALA

Introduction to the project

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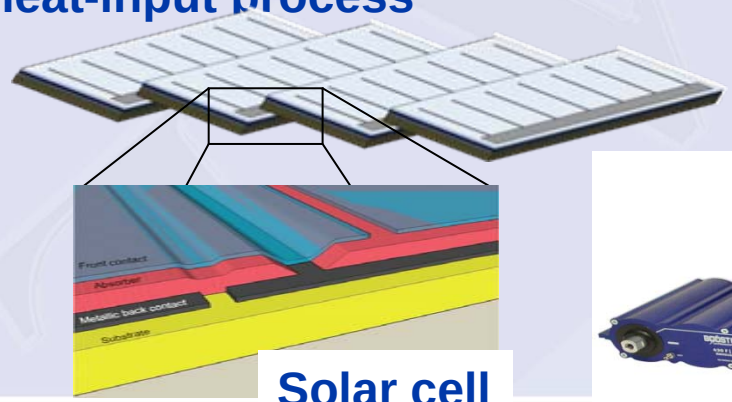
Project Background

- Welding interconnections, aluminium & copper
- EV and HEV markets expanding rapidly
  demand for lithium-ion and super-capacitor batteries
  current manufacturing (RSW, TIG) slow, expensive and inconsistent weld quality
- Flexible thin-film solar cell market growing rapidly
  technical challenges remain, eg shingling
  current manufacturing (US, adhesives) too slow, expensive and sometimes unreliable
  need for accurate, local, low heat-input process



Solar cell

Battery application

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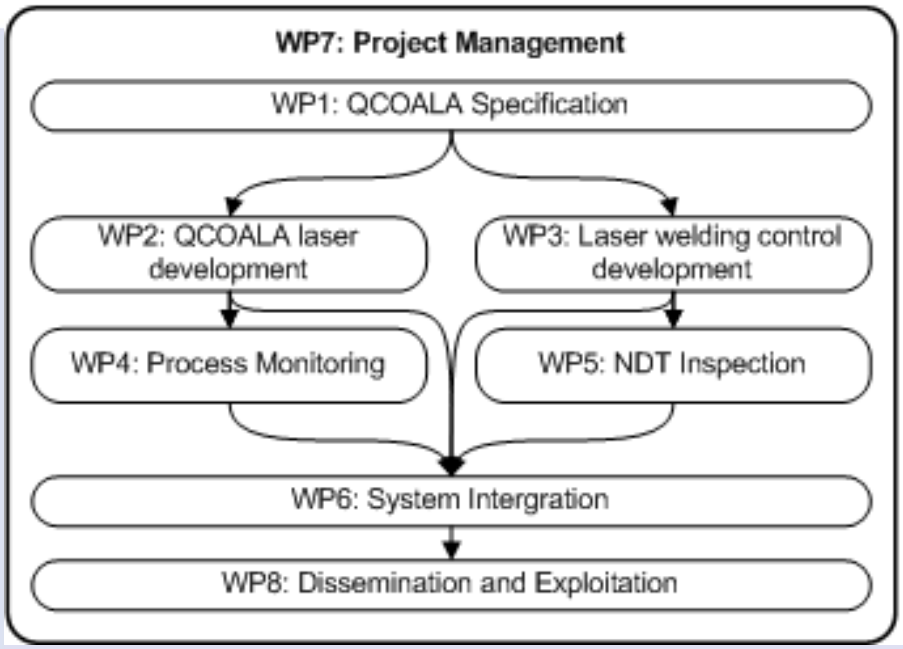
QCOALA Overall Objective

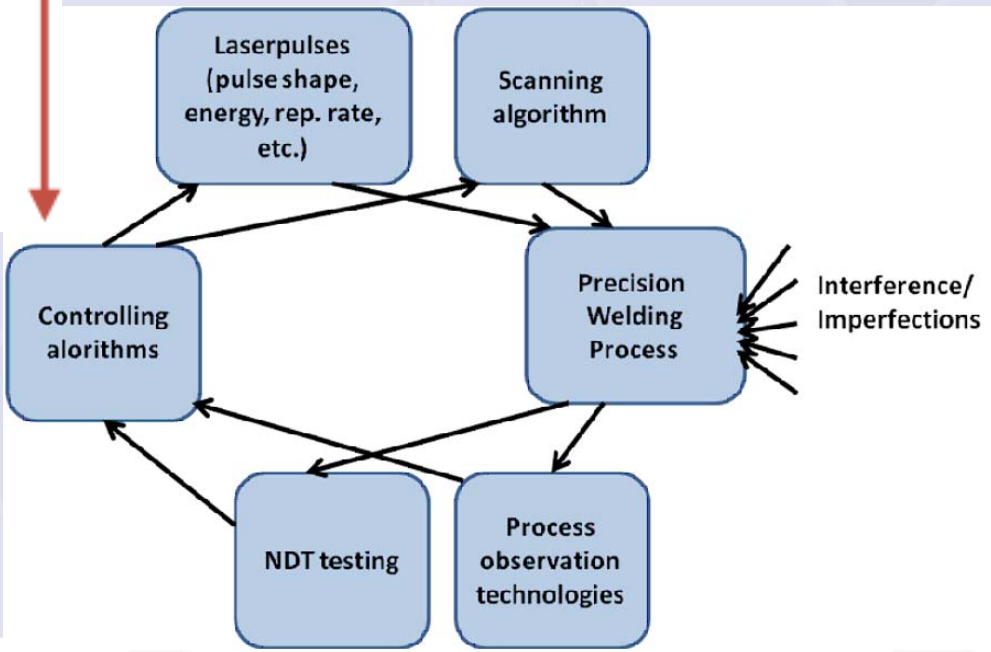
To develop a new laser processing system for the welding of thin-gauge aluminium and copper, 0.1mm to 1.0mm in thickness, with integrated process monitoring and in-line non-destructive inspection, and

to establish its capability to provide a reliable, high-speed, low-cost and high-quality joining solution for electric car battery and thin-film photovoltaic (PV) cell interconnections.

Any additional specific applications can be discussed

QCOALA Technologies





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QCOALA Key Features

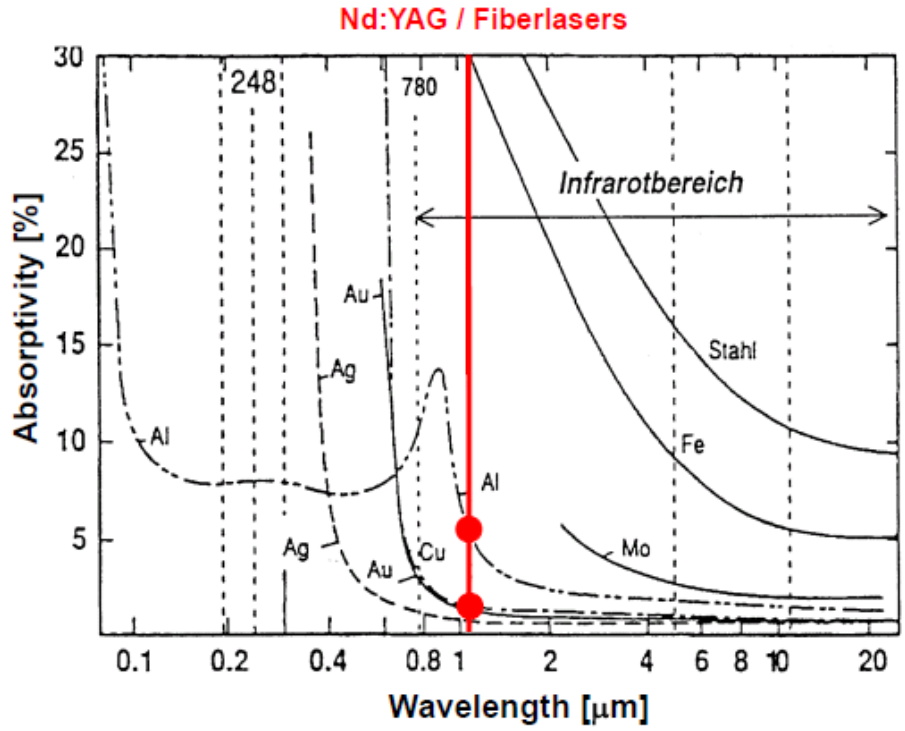
- ***Quality:***
  - **QA through real-time process monitoring and NDT inspection**
  - **Weld *fingerprint*: measure → compare → action**
  - **Integrated ICT and SPC: 100% non-destructive inspection to reduce scrap to <1% and pseudo-errors<1%**
- ***Productivity:***
  - **Tailored energy strategies for aluminium and copper (⇩>20%)**
  - **Optimum weld quality → reliability / durality → productivity (⇧ 50-100%)**
- ***Autonomous operation:***
  - **Integrated ICT and SPC**
  - **100% non-destructive inspection → immediate remedial action**

QCOALA Technologies

- **Laser System Development (WP2)**
  - **Development of a dual-wavelength scanning system, capable of emitting both the 532nm and the 1064nm.**

Wavelength Dependence of Metal Absorptivity

Wavelength dependence of metal absorptivity



Room temperature

Solid state

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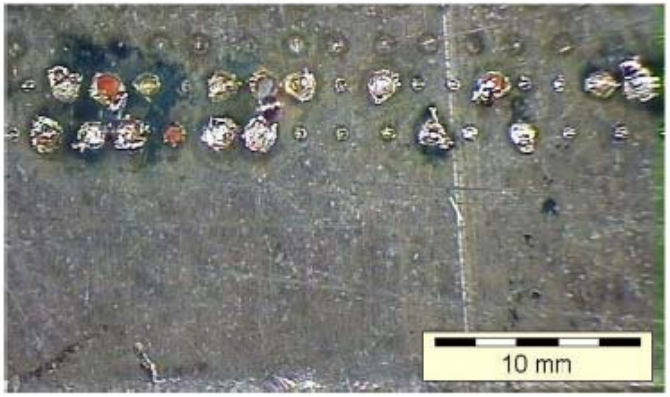
General Problem: Bad Reproducibility

General problem: bad reproducibility



Laser parameters: 4MW/cm², 1064nm

Strongly varying absorptivity:

- Missing weld spots
- Totally unpredictable results
- Very bad reproducibility

How can one achieve reproducible Cu-welds ???

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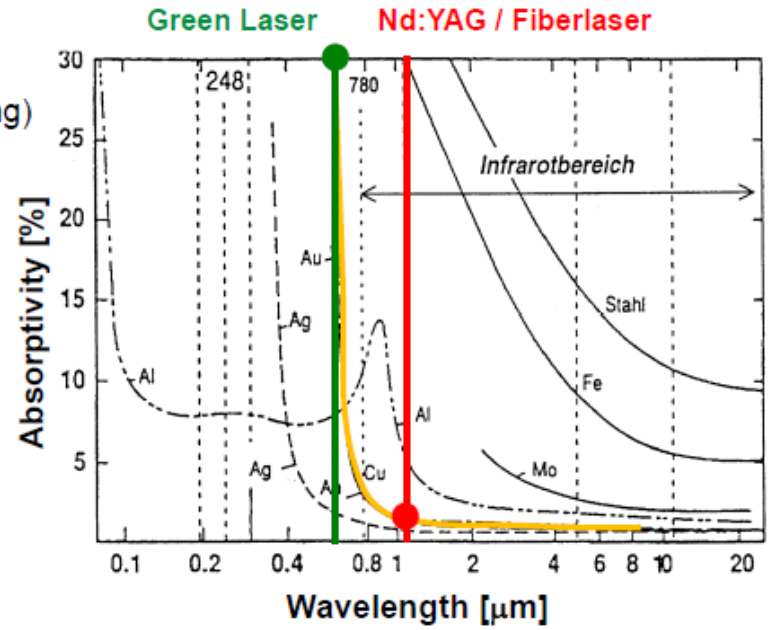
Solutions to Increase Absorption

Solutions to increase absorption

- Surface treatment (e.g. coating)
  → too expensive
  → too laborious
- Green laser
  → low process efficiency
- **IR + Green mixing AND pulse shaping**



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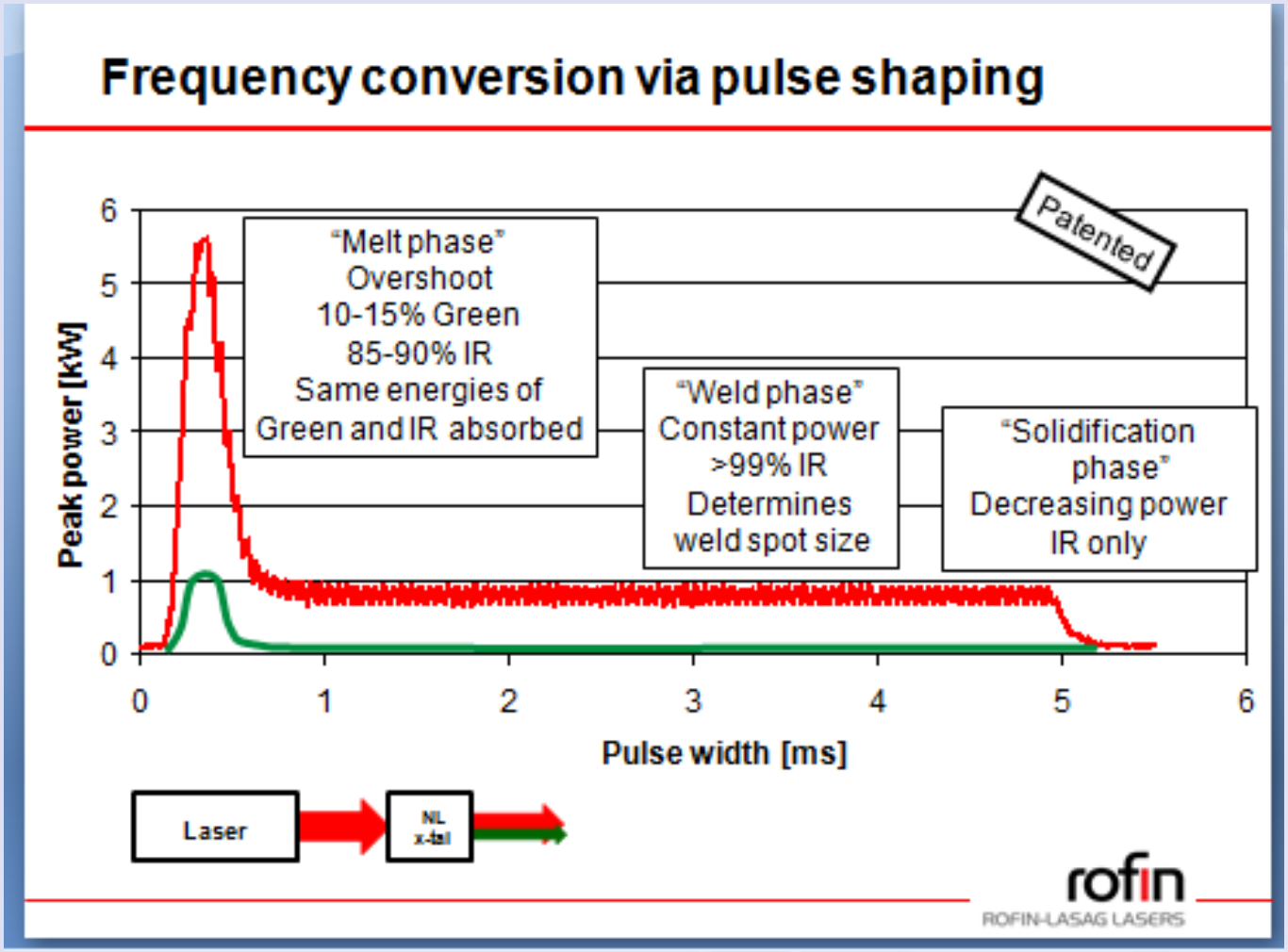
Dual Wavelength System



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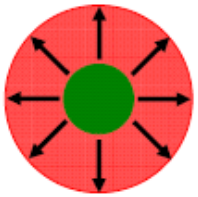
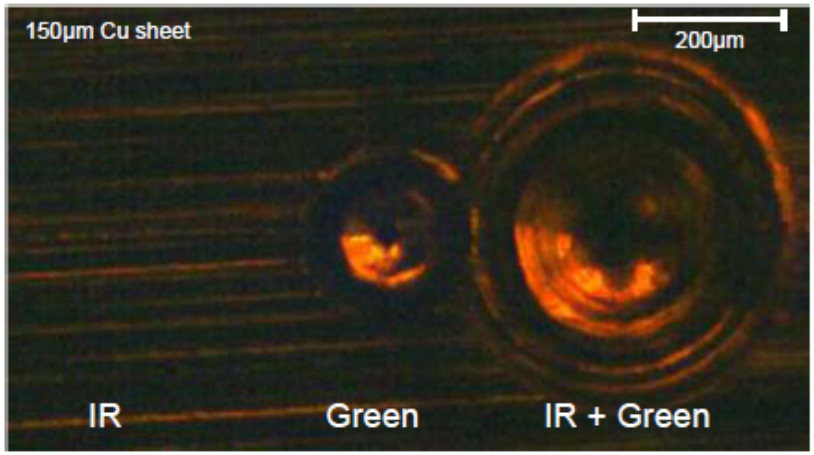
IR+Green Mixing: the LASAG Approach

IR+Green mixing: the LASAG approach

Superimposed
IR and Green pulse



Heating / melting
from center



Laser parameters: IR: 2.5MW/cm², Green: 1.1MW/cm²

Heat diffusion: $Lp = (\alpha t_p)^{1/2}$

Example (Cu): α = 1.14 cm²/s, t_p=1ms Lp = 0.34mm

→ Mixing of IR and green clearly enhances melt pool formation

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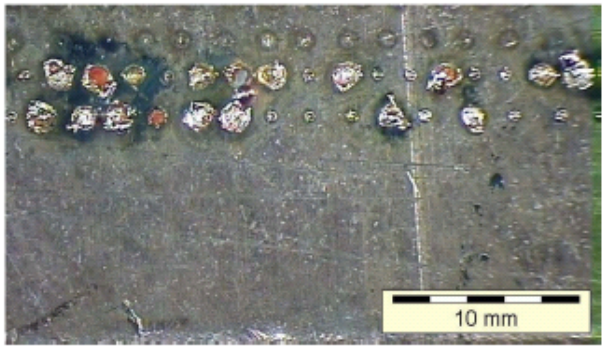
Enhanced Reproducibility

Enhanced reproducibility

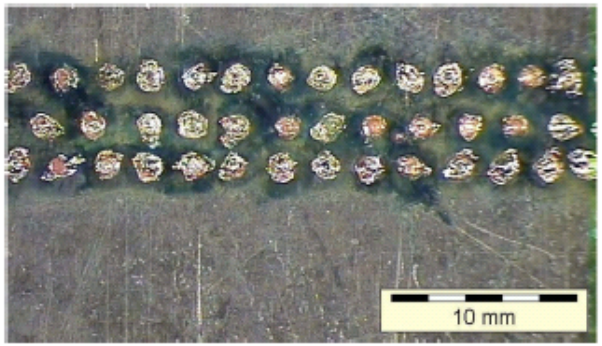


Constant laser parameters

100% IR

Missing weld spots

Very bad reproducibility



IR + Green mixing, pulse shaping

88% IR, 12% Green

No missing spots

Good reproducibility

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QCOALA Technologies

- **Intelligent Laser Welding (WP3)**
  - **Empirical evaluation of the effect of spot size, beam quality, pulse length, average and peak power, and repetition rate, on welding performance* of 0.1-1.0mm Al and Cu for 1064nm λ.**
  - **Empirical evaluation of the effect of the 532nm λ on welding performance***
  - **Develop tailored energy strategies to control HI and keyhole/weld pools stability**

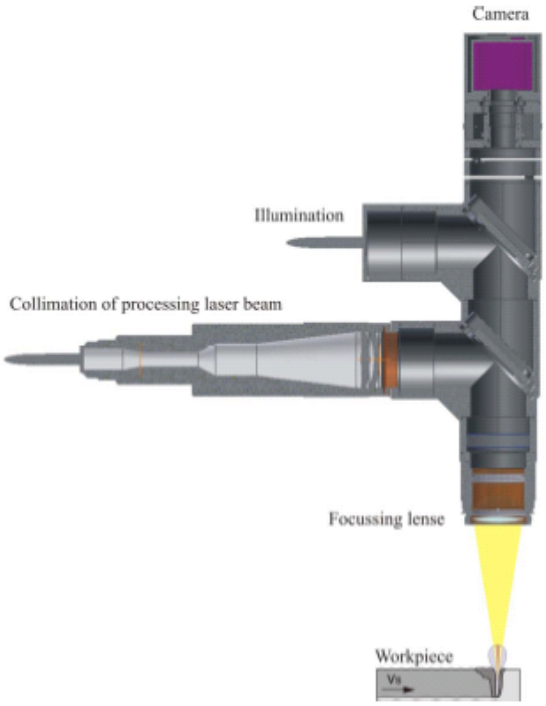
*** Welding performance = absorption, welding speed and weld quality**

QCOALA Technologies

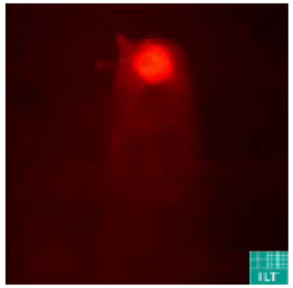
- **Integrated Process Monitoring (WP4)**
  - **Development of a CMOS camera-based WMS that can handle both 532nm and 1064nm, capable of assessing weld pool stability and identifying likelihood of imperfections occurring, through fast-rate image acquisition (>1000fps). The imperfection-recognition software will comprise image processing algorithms.**
  - **Development of an interactive WMS graphical user-interface**
  - **Integration of the WMS into the QCOALA laser demonstration platform**

Process Monitoring

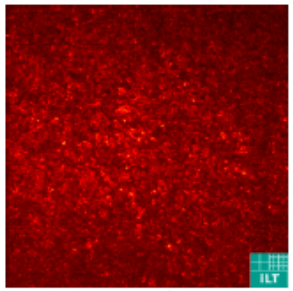
Coaxial process monitoring - Setup



Welding process



monitoring of the process radiation (no illumination)



monitoring with external illumination

1.4301, 2 KW Nd:YAG, 2m/min

Page 3

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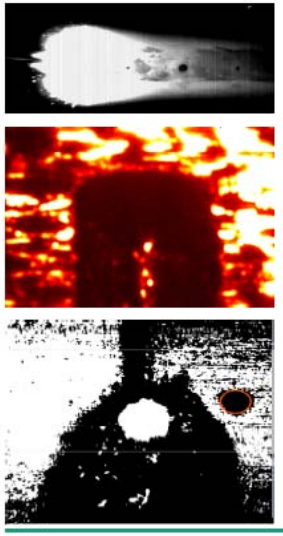
Process Monitoring

Monitoring Quality Parameters



Quality Parameters suitable for in-process monitoring

- Geometry of seam at surface
- Width of kerf
- Cladded geometry
- Pores at surface
- Splatter

Page 4

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Monitoring Process Parameters

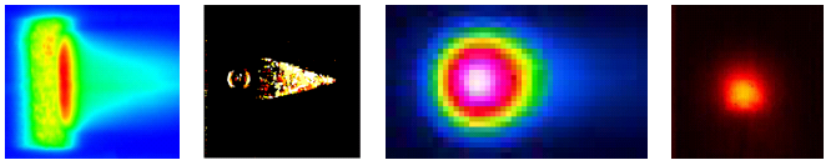
Process parameters

- Geometry of melt pool
- Temperature radiation
- Plasma radiation

Correlation

Quality Parameters unsuitable for in-process monitoring

- Microstructure
- Lack of fusion
- Adhesion of dross
- Ripples at cutting
- Strength behaviour



Page 5

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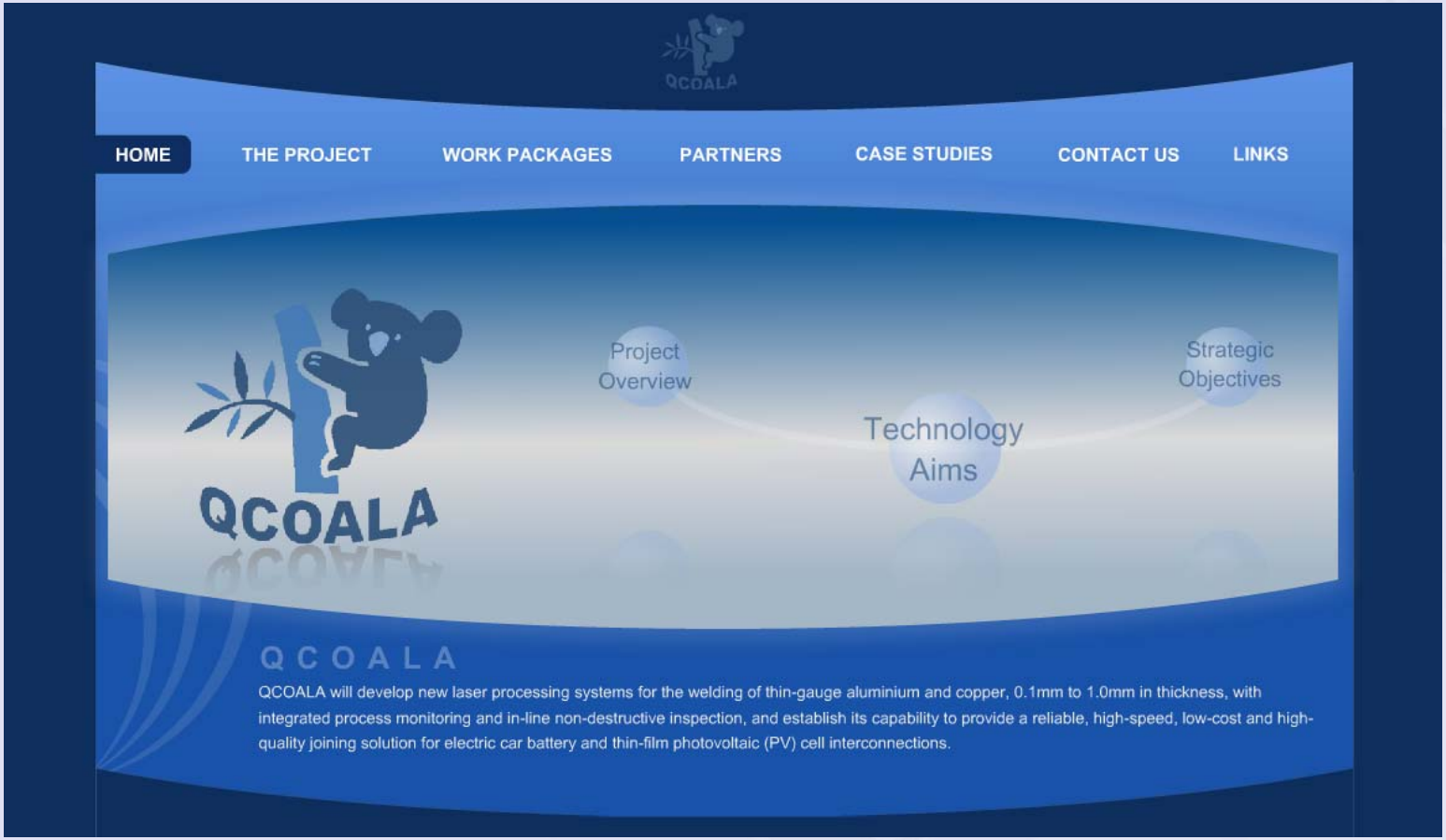
QCOALA technologies

- **In-line Weld Inspection (WP5)**
  - **Development of Eddy Current (EC) weld inspection probes with very small sensing area (estimated <0.5mm) and frequencies suitable for the investigated applications , with suitable instrumentation. Modelling and experimental validation**
  - **Development of digital radiography (DR) weld inspection system with contrast sensitivity <2% and spatial resolution better than 10µm will be developed, with incorporated Automatic Defect Recognition (ADR)**

QCOALA Website

- **http://www.qcoala.eu**



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Thank You

- **For more information please contact:**
- **Paola De Bono** (QCOALA Project Coordinator): paola.debono@twi.co.uk
- Or any of the QCOALA's Partners

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