Inspection for IBC Process Control

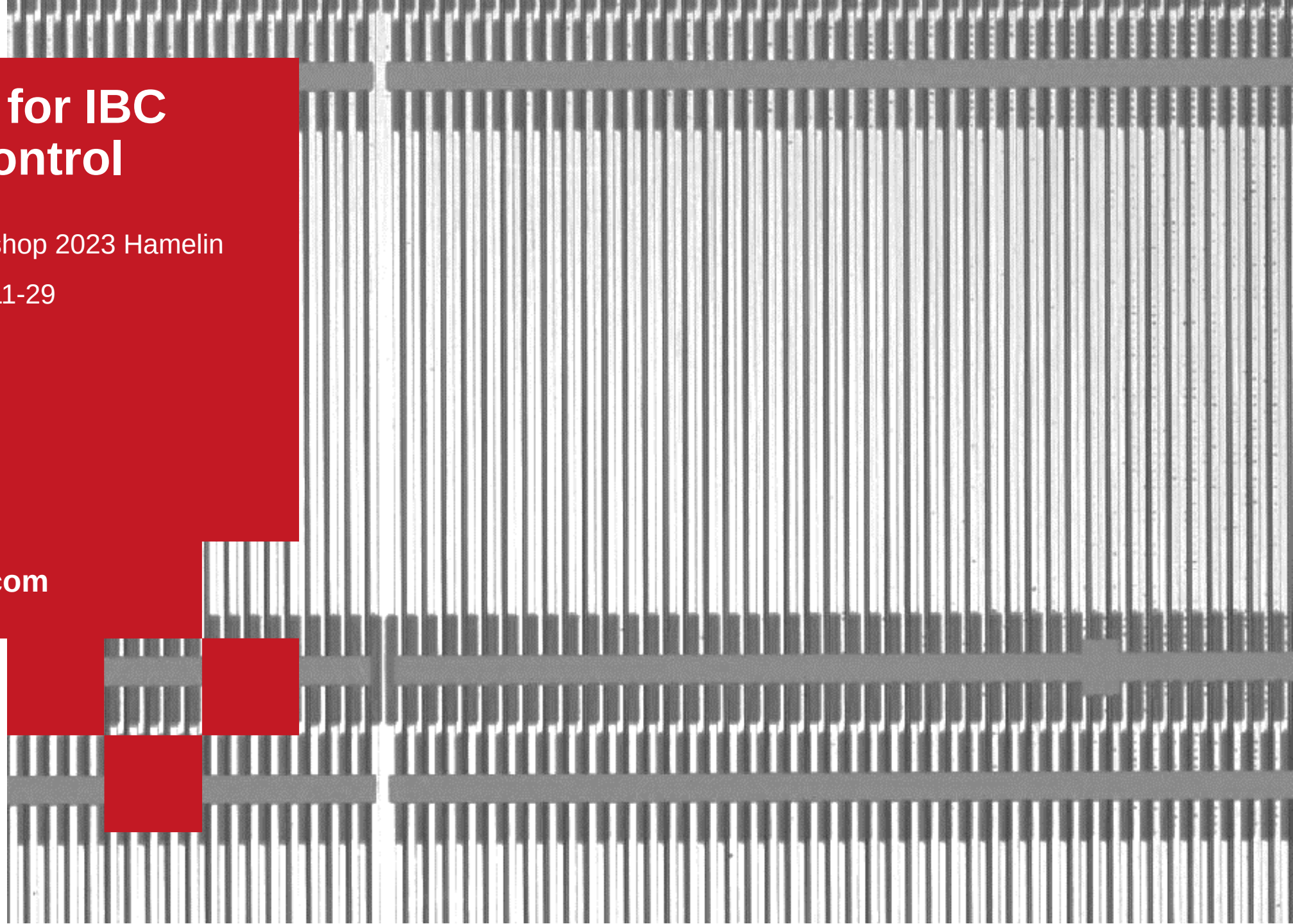
Back Contact Workshop 2023 Hamelin

Christopher | 2023-11-29

www.isravision.com

ISRA VISION

Part of Atlas Copco Group



Agenda

Content

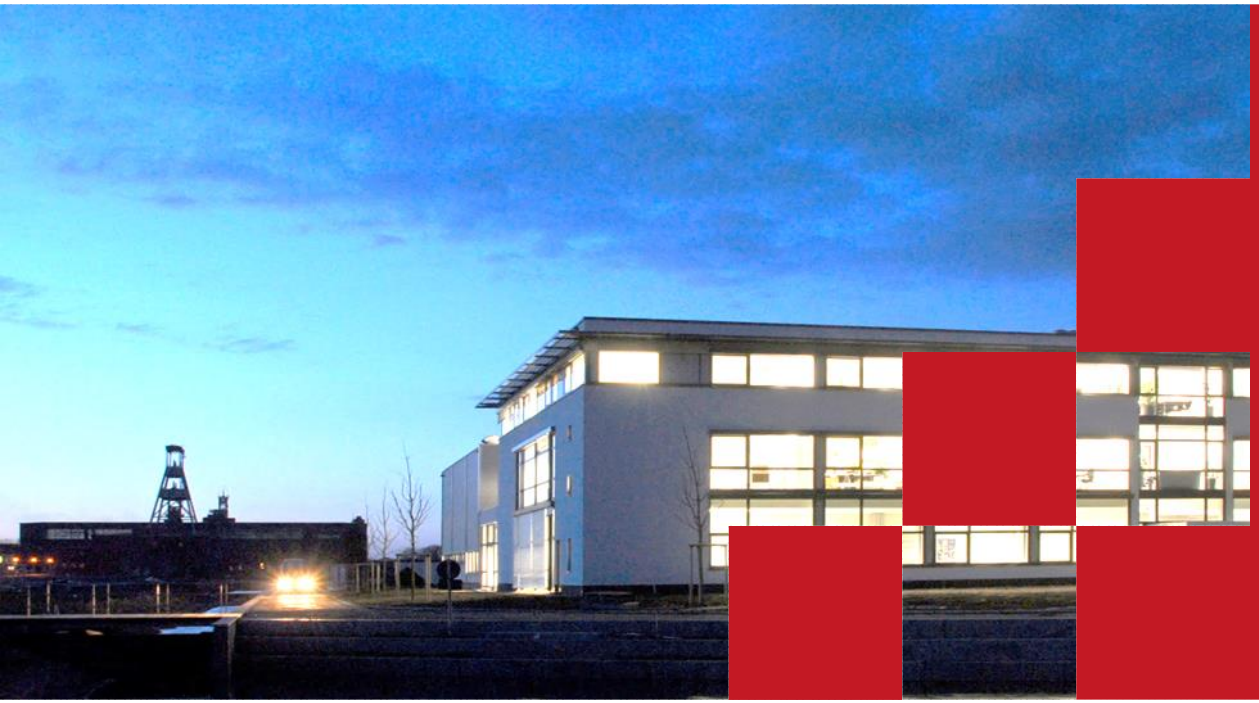
01 Company Introduction

02 Process Control in IBC

03 Color Sorting

04 Summary

ISRA VISION
Part of Atlas Copco Group



1 Company Introduction

ISRA VISION
Part of Atlas Copco Group

ISRA VISION

Solar Inspection – ISRA VISION GP Solar

ISRA VISION established 1985 in Darmstadt

2013 acquisition of GP Solar

Since 2020 part of ATLAS COPCO

Global Technology Leader for Automatic Optical Inspection (AOI)

Local Infrastructure with presence in more than 60 countries

Since 1998 supporting solar success with wafer, cell and module inspection

More than 5000 solar cell inspection systems worldwide

Inspection solutions for PERC, Bifi-PERC, TopCon, IBC, HJT, and upcoming technologies

Solar glass, thin film, and embedding foil inspection

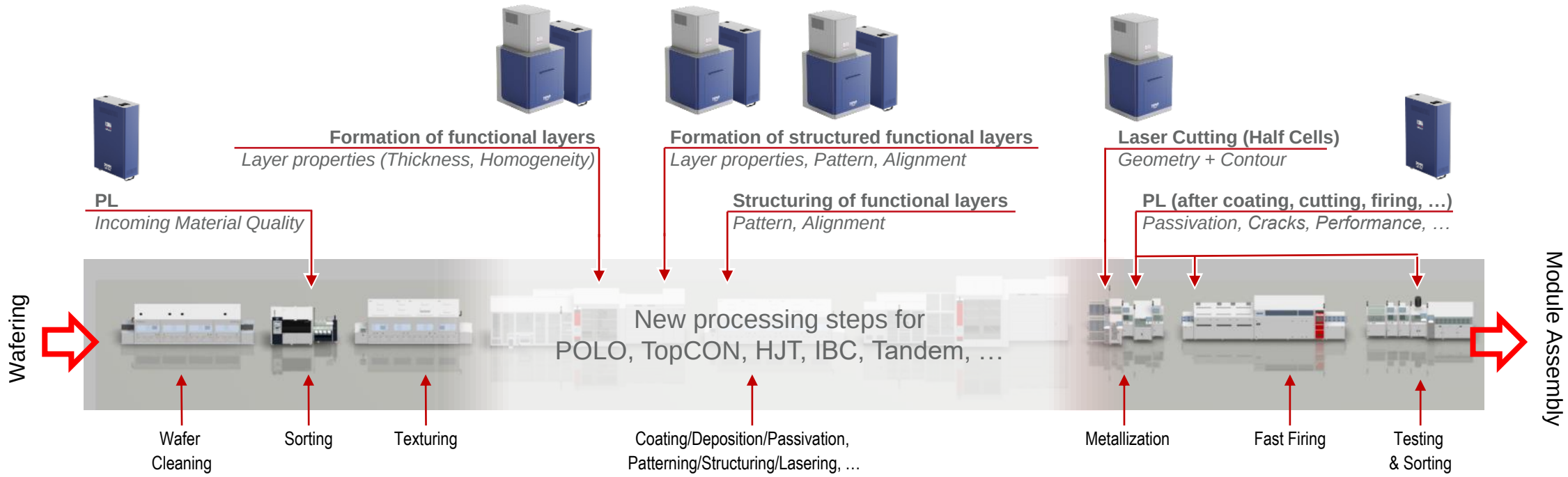
Focus on advanced production concepts (Industry 4.0 / IOT) and multi-GW productions

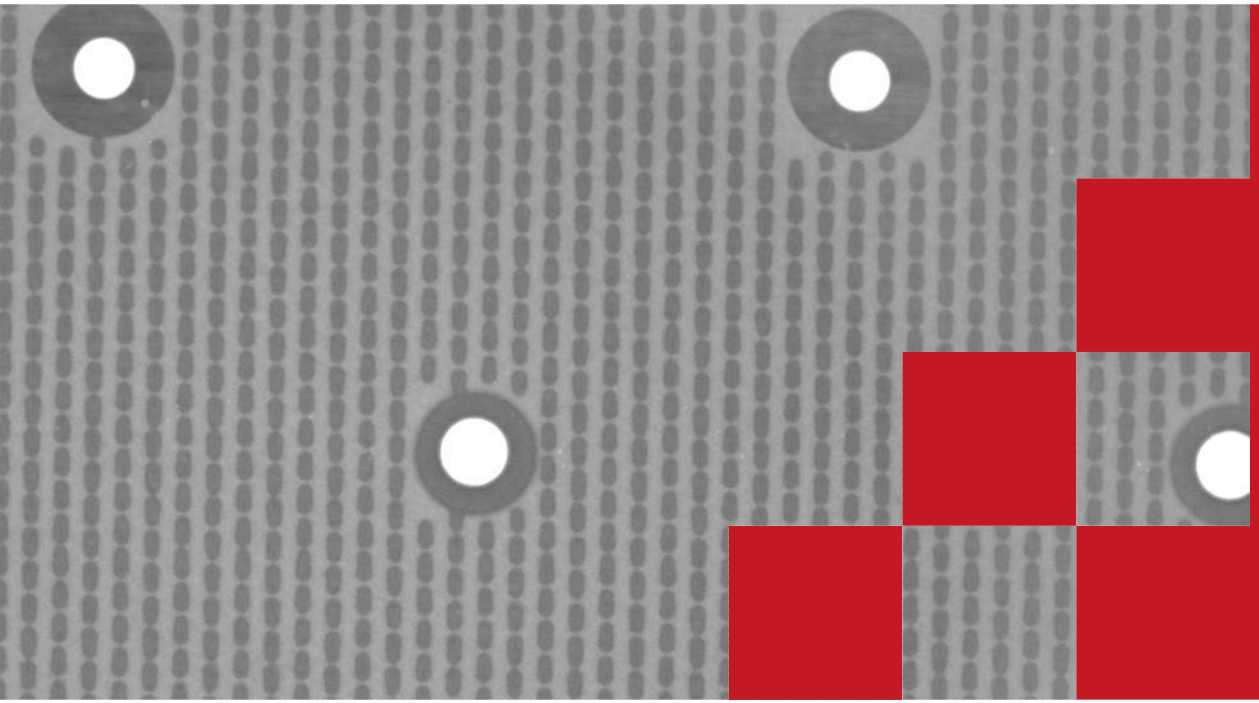
Common Optical Inspection Tasks (PERC, PERC+)

Inspection Systems for Solar Cell Production

Additional Inspection Tasks for New Technologies

Inspection Systems for Solar Cell Production



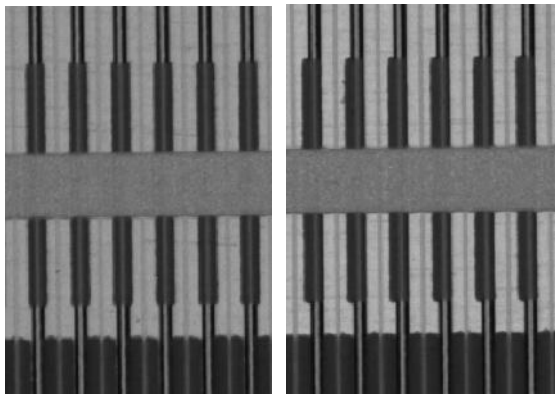


2 Process Control in IBC

Main differences between „normal“ and IBC Cells

- Cosmetic inspection becomes functional inspection – paste stains can be more than an optical flaw!
- Critical Defects **optically visible** at an early stage:
  - **Printed shorts (bridging)**: fingers of different polarity connected due to print defects (finger nodes, paste stains or smearings)
  - **Misalignment shorts**: shifted print making contact to opposite polarity region
  - **Pinhole shorts:** pinholes in masking/insulation layers potentially leading to shorts when busbars are connected

- **Simultaneous inspection** of (minimum) two layers is required:
  - Inspect top layer for defects
  - Inspect alignment of top layer with underlying patterned layers
- Alignment must fit ***everywhere*** on the cell, not only at the fiducial marks



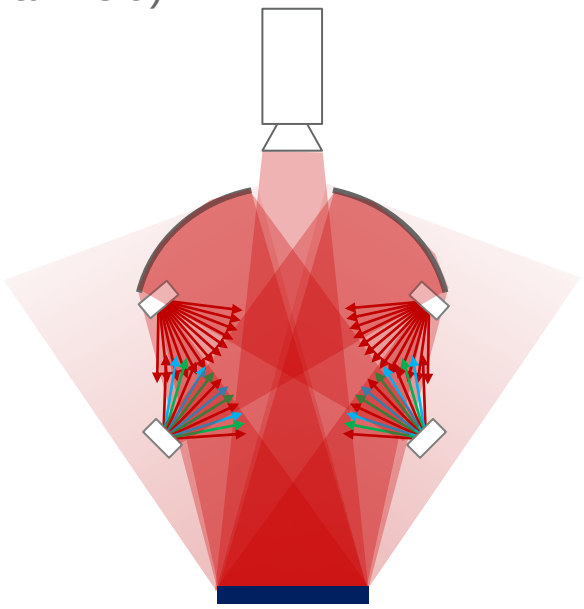
ISC ZEBRA CELL, same cell, different positions: Insulation layer shifted in some positions

- **Many structures** (e.g. 2x fingers) → fast algorithms
- Large structures, but small tolerances for alignment, especially at edges of polarity regions → high resolution needed
- **Many different patterns** → flexible definition of the desired patterns required!
- Plus higher requirements for the front side color appearance!
  - No contrast from print to background – sensitive to small color variations!
  - VIPV/BIPV: Viewing angle? Angular color variation into focus!

IBC Inspection series Product – SBD Dome

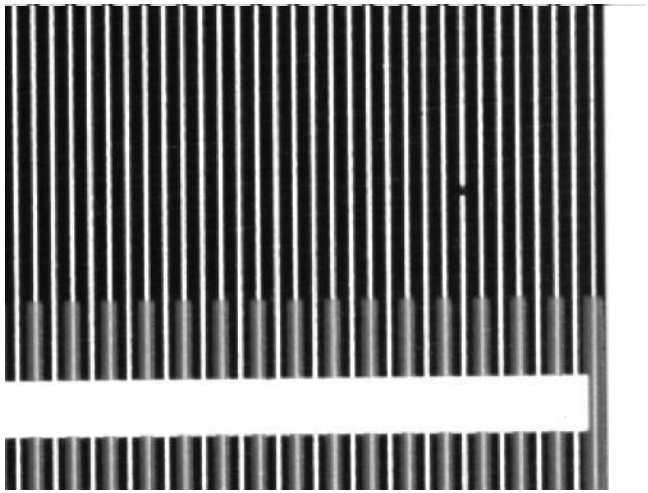
- Matrix Camera System
- 6i (M10 / 185 mm / 200 mm FOV)
  9i (G12 / 230 mm / 250 mm FOV)
- up to 65M camera (25…35 µm/px depending on FOV)

- SBD Illumination:
  Brightfield-RGB and separate Darkfield)

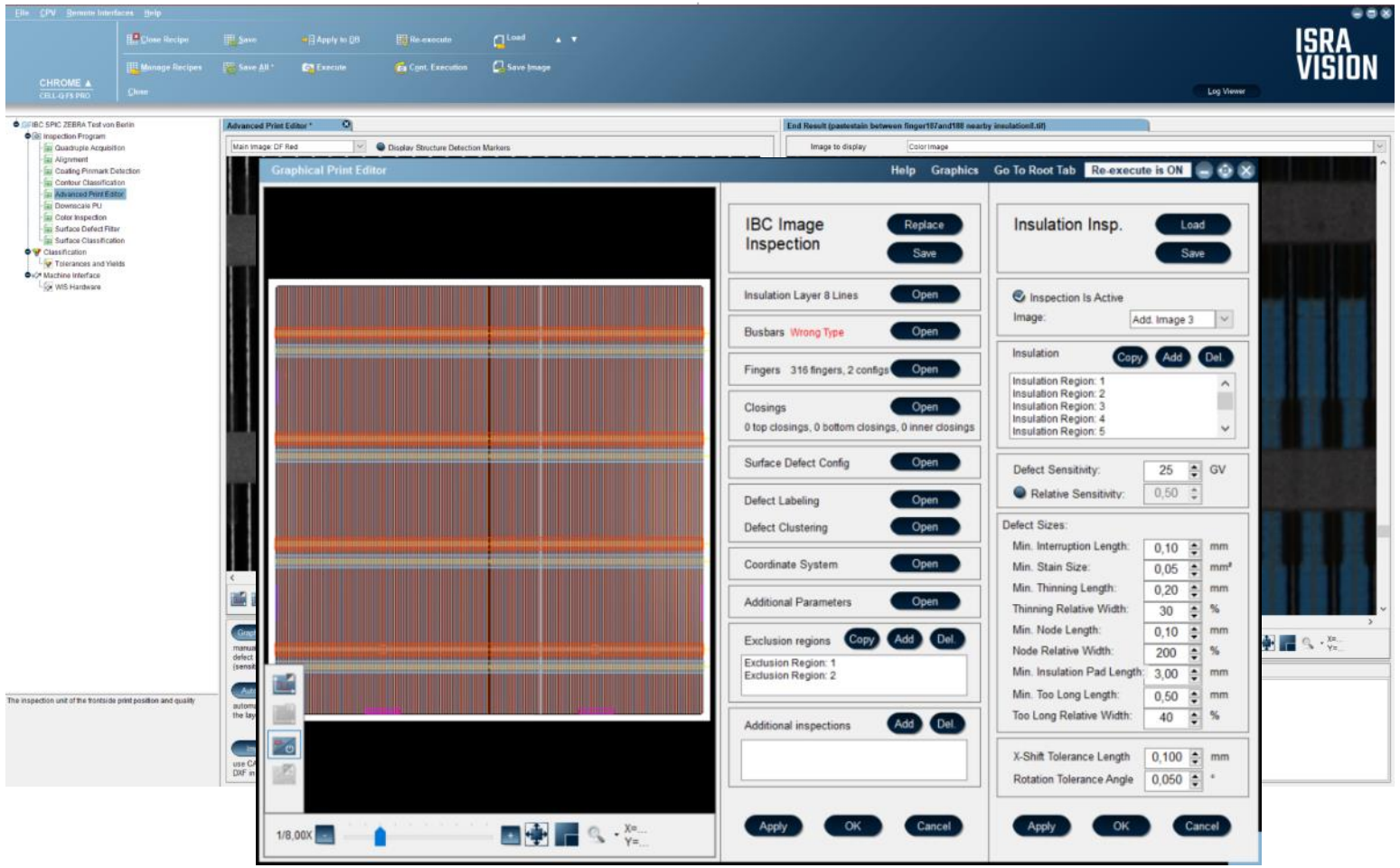


- Freedom in system design for LED wavelengths, coaxial illumination, polarization…

- Bright Field in RGB
  for Surface/Color Inspection
- Dark Field
  to visualize „scattering structures“
- Perfect Platform for structure and alignment control



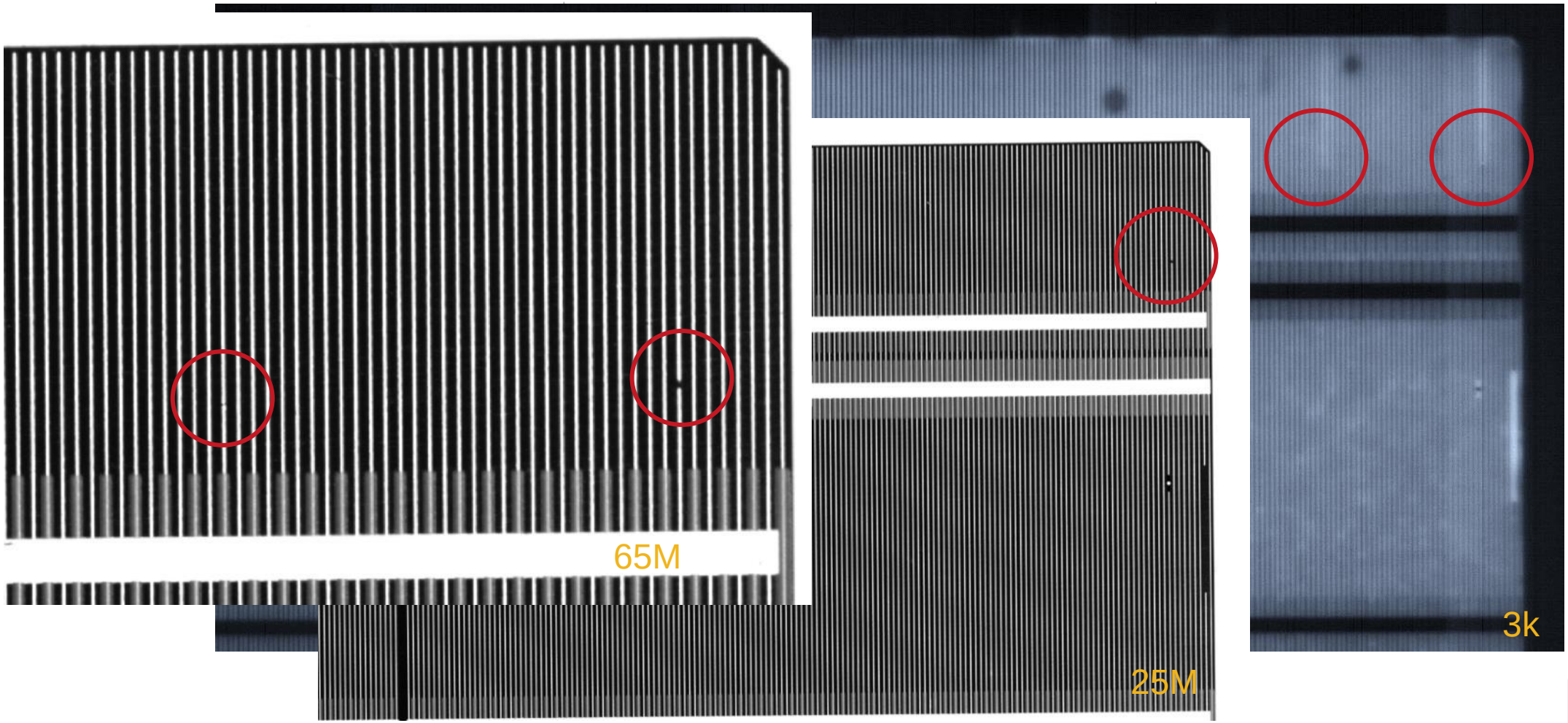
IBC Inspection - ZEBRA

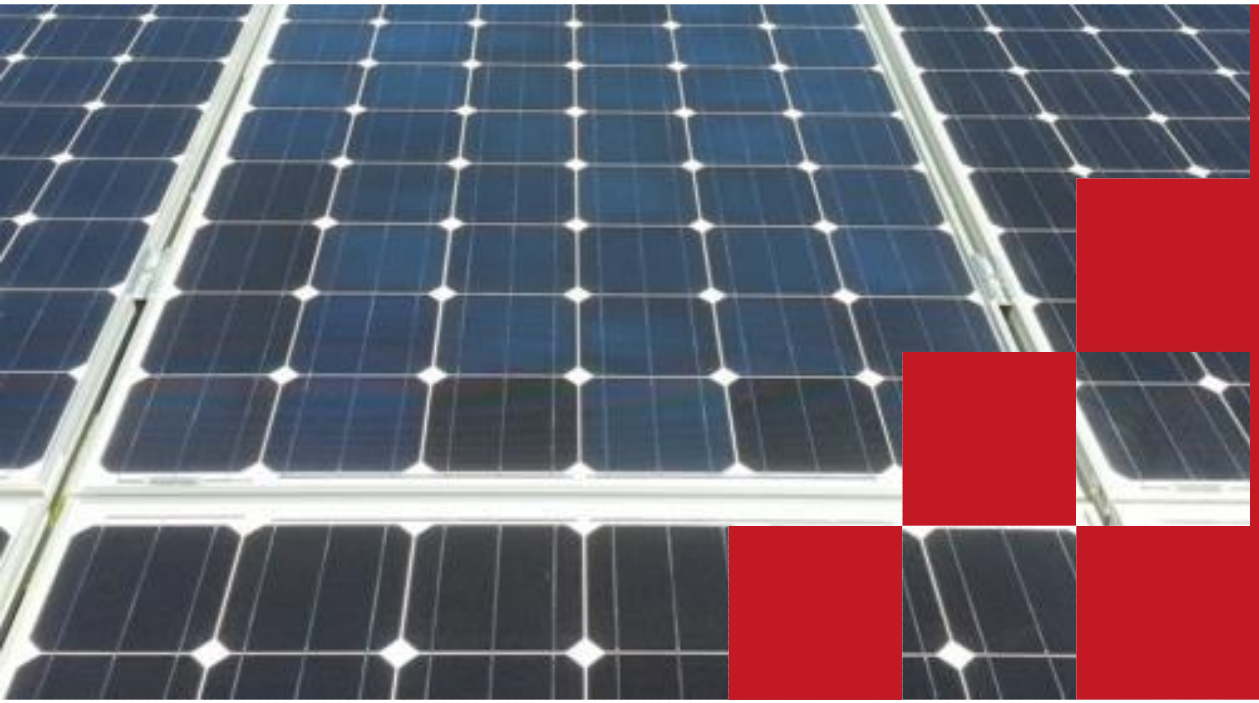


- Full support for ZEBRA
  - fingers, insulation, busbars
- polyZEBRA
  - p/n region formation & isolation control (under construction)
- Challenges:
  - ZEBRA design evolves and changes
  - large variety if "xBC" with *very* different designs
- Deep Learning is not a good idea:
  - Detection of defects – good and versatile (after good training)
  - Measurement of features and defects (contrast, size, …) – poor!

PL Imaging of IBC cells

Cosmetic defects are more than cosmetic defects…





3 Color Sorting

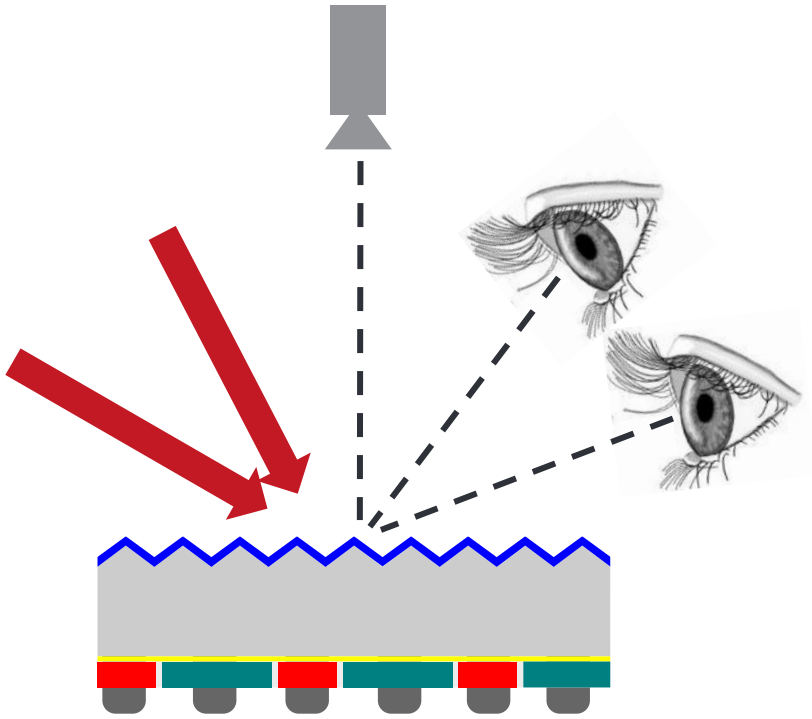
ISRA VISION
Part of Atlas Copco Group

What is the color of a solar cell?

A solar cell has no color.

The color is only the result of the interaction between

- illumination
- surface texture
- surface coating
- observer



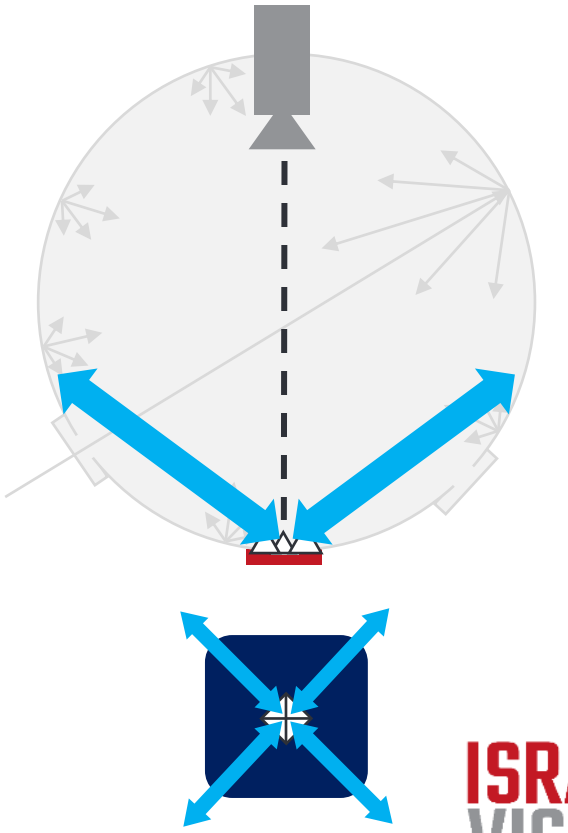
Measuring "the" reflection spectrum

…note that there are many different reflectance spectra!

- Integrating Sphere setup:
  - light from any port to any port only via the sphere surface

- "indirect" illumination into the sphere
- Lambertian scattering at inner sphere surface
- specimen receives same amount of light from all spherical angles
- reflection from specimenback to the sphere surface
- the reflected light changes the brightness for each wavelength inside the sphere
- sensor to measure wavelength-resolved brightness level inside the sphere
- Calibration of the setup using a "white standard"

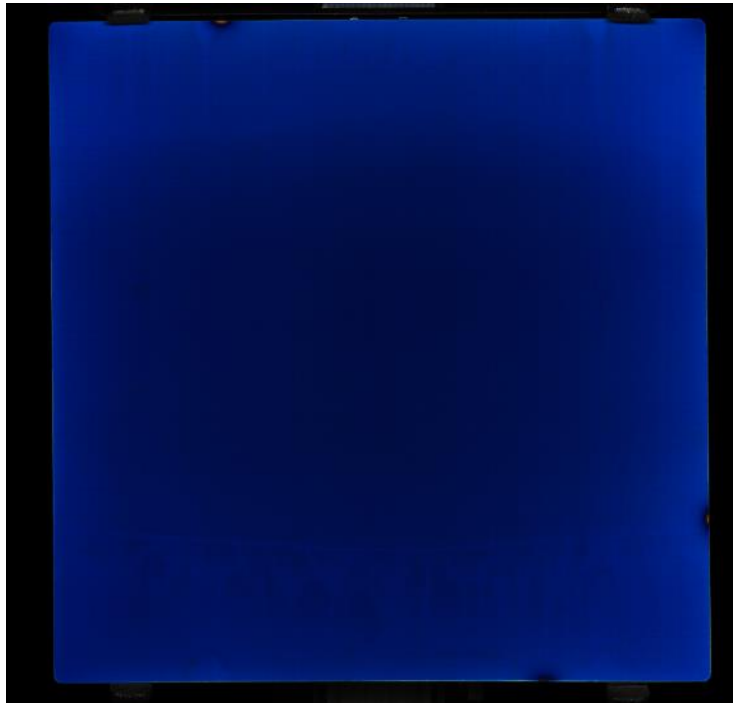
- The strongest contribution comes from the direct reflection of the tilted pyramid surfaces!



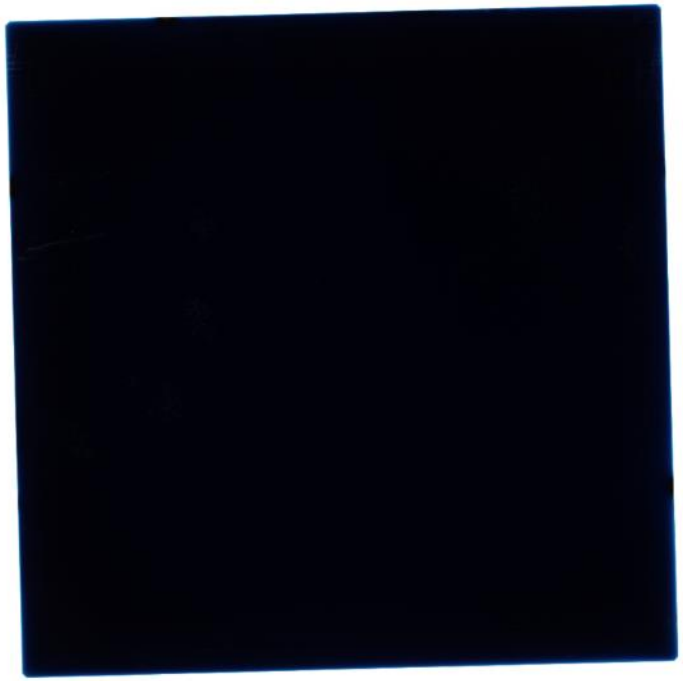
COL-Q SCAN using direct reflection

- Linescan camera setup
- direct reflection from pyramid surfaces – stronger signal
- Higher signal
- Directional dependance: only "one side" of the pyramids inspected
- Consequences:
  - only small variations for color
  - larger directional dependence for defects that impact only one surface of the pyramid!
  - still under observation

- Color Image in COL-Q SCAN DR

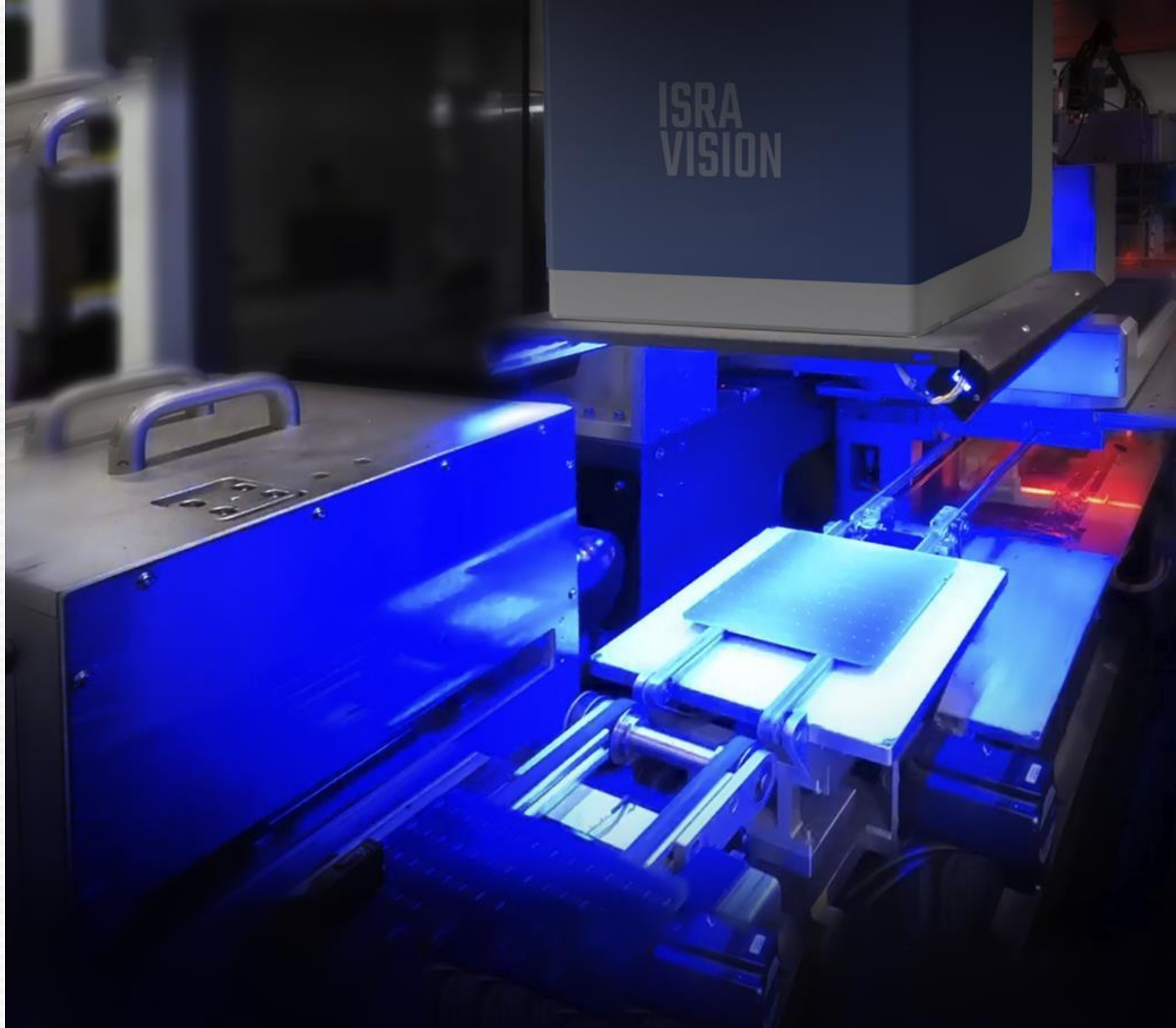


- Color Image in SBD Dome (vertical camera view)



Summary

- Examples for camera-based process control, challenges and products that enable early detection of crucial defects in IBC processing
- Full support for all print and color inspection in ZEBRA process and a few other xBC
- Generalized inspection and new setups for polyZEBRA under development
- Short dive into solar cell color
- COL-Q SCAN with direct reflection - potential game-changer for color sorting



ISRA VISION GmbH

Industriestr. 14
64297 Darmstadt
Germany

+49 6151 948-0
info@isravision.com
www.isravision.com

Thank You

Funded by
the European Union

Part of this work is funded by the European Union under grant number 101084046 (PILATUS). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

ISRA VISION
Part of Atlas Copco Group