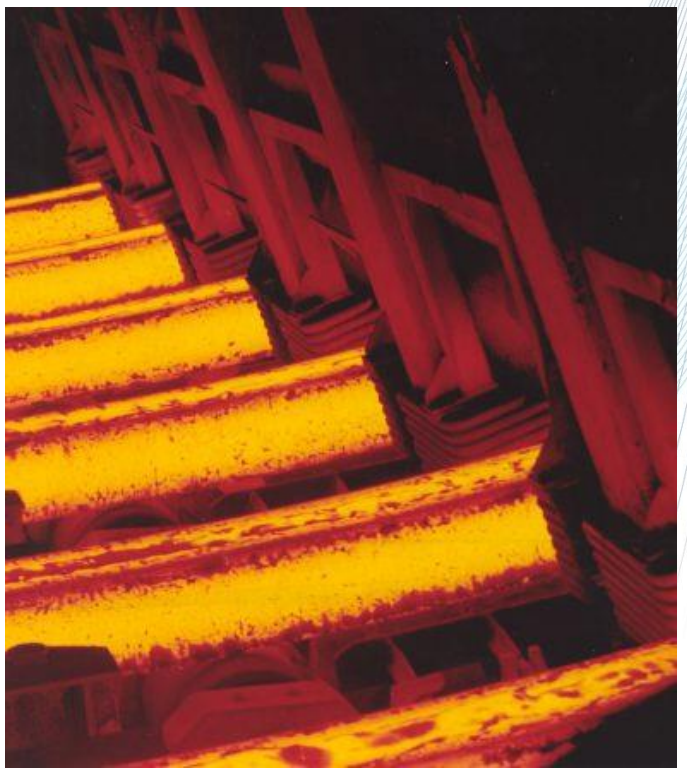
RealTimeCastSupport (RTCS)

Embedded real-time analysis of continuous casting for machine-supported quality optimisation

Webinar on 8th of September 2023

New measurement techniques

Birgit Palm, Marc Köster (BFI)



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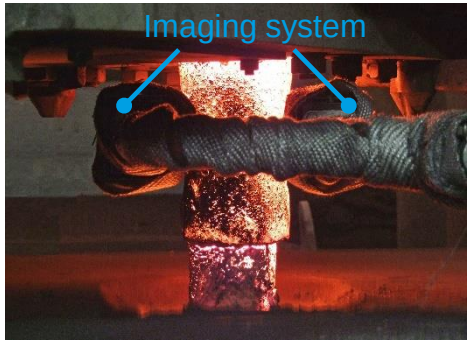
Stahl

Continuous online monitoring of casting powder coverage

A casting powder monitoring system (NIR range using a filter/sensor combination) was first applied at a billet casting machine above the mould [1]



Advantages

- Capable of detecting the casting powder break-up prior than visible inspection
- Continuous, online monitoring and data storage
- Removal of disturbing influences (flames, dust, sparks) by digital image processing
- Warning system is a decision support for the operator
- Quality of casting powder coverage is measurable
- Usable for powder and granulate
- Flexible application at different formats (billet, bloom, slab)

Tasks in RTCS project

- Adapt camera system to IR range to further enhance early detection of break-up
- Adapt and enhance for application at a slab caster (wider surface and larger heat impact)
- Adapt protective housing and cooling to local conditions in the plant to protect the sensor from high tempera-tures, heat radiation and dust

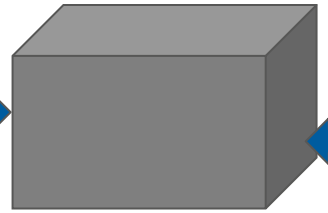
[1] Stephens et al.: "*Effects of transients on quality of continuously cast product (TRANSIENT).*" EUR 26399 EN, 2014

Main components of casting powder monitoring system

Image analysis system

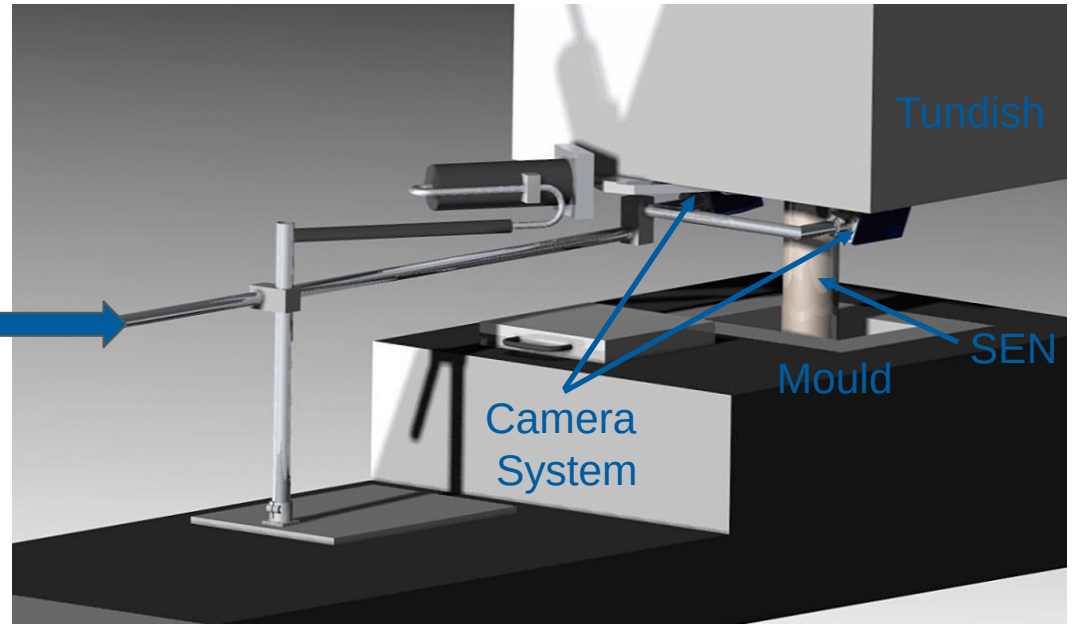
- Image acquisition from camera
- Analysis of images
- Extraction of important information, e.g. starting point, frequency and intensity of mould powder break-up
- Display of results on screen
- Transfer of results to a project data base

Supply box



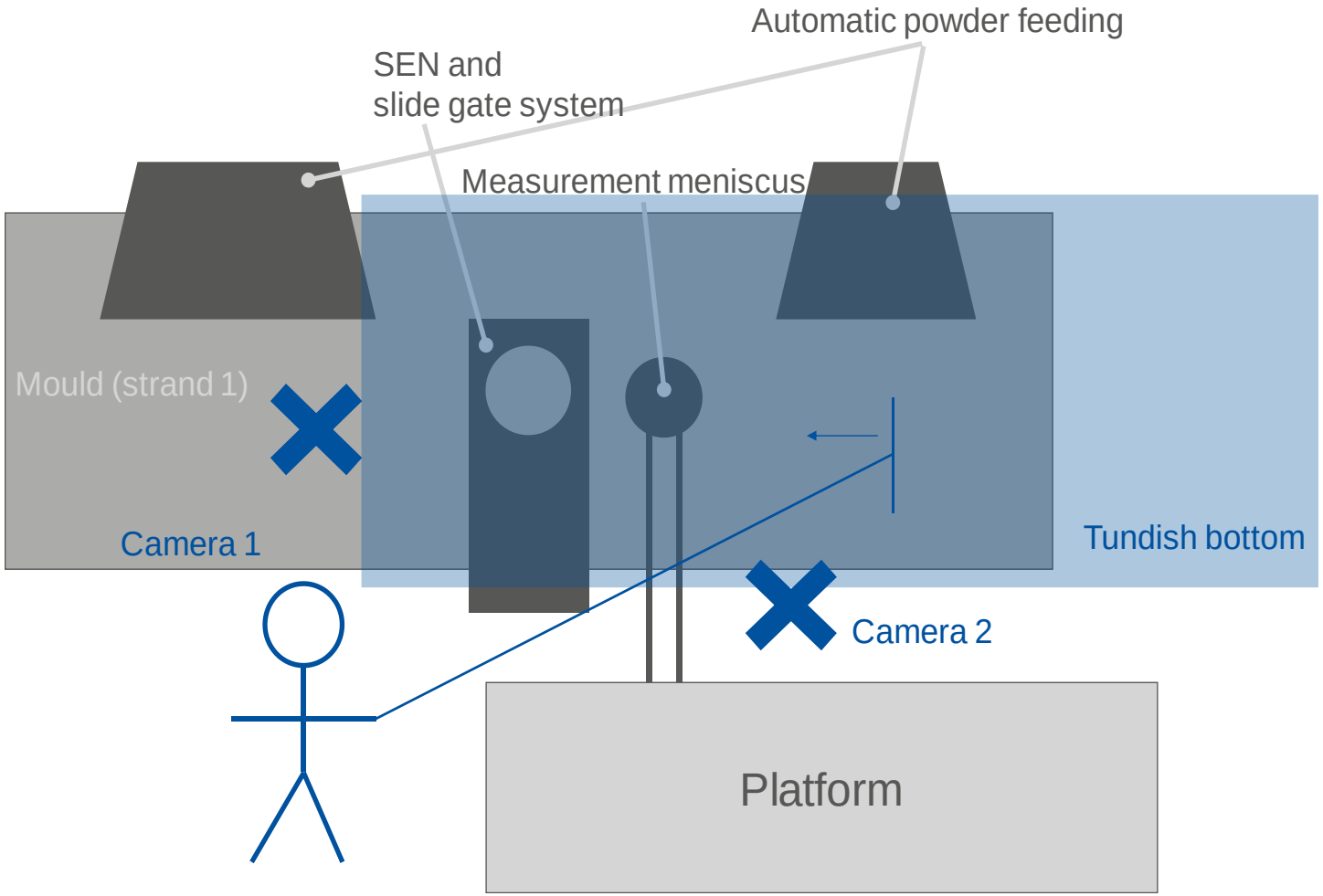
- Supply of:
  - Data transfer
  - Power to cameras
  - Cooling gas

Monitoring system for casting powder cover



- Camera with IR sensor to monitor the thermal radiation of the mould powder surface
- Protective housing to protect camera against harsh environment

Sketch measurement technique casting powder monitoring



Selection of suitable camera and housing for monitoring system

- Comparison of different cameras
- Selection, order and laboratory test of the most suitable camera:
  Optris Xi80
  - IR resolution: 80 x 80 Pixel
  - Image frequency: 50 Hz
  - Spectral range IR: 8-14 µm
  - Object temperature range: -20 °C to +900 °C
  - Accuracy: ±2 °C or ±2% of reading
  - Operating temperature range: 0°C to +50 °C
  - Dimensions (diameter x H): 36 x 90 mm
- Selection, order and laboratory test of suitable protective housing

	Flir AX8	Flir BOSON 320	InfraTec PIR uc 180	irPOD TC160	irPOD TC388	optris Xi80	optris PI200	Teledyne DALSA Calibir
Spectral range [µm]	VIS and 7,5-13	7,5-13	7,5-13	8-14	8-14	8-14	VIS and 7,5-13	8-14
Resolution [Pixel]	640x480 and 80x60	320x256	160x120	160x120	384x288	80x80	640x480 and 160x120	320x240
Frame rate [Hz]	9	9	100	50/60	50	50	32 and 128	30
T measurement range [°C]	-10 to 150	n.s.	-20 to 250	n.s.	n.s.	-20 to 900	-20 to 900	-25 to 125
Minimum working distance [m]/ variable objektives	0,2 / no	n.s. / yes	0,1 or 0,5 * / ja	0,13 or 0,3 etc. * / yes	n.s.	n.s. / yes	n.s. / yes	1 or more * / yes
Field of view [°]	48x37	n.s.	dep. on objective	dep. on objective	n.s.	n.s.	54x40 and dep. on objective	dep. on objective
Dimensions [mm]	54x25x95	21x21x11	51×51×65	48,5x49x50 plus objective	35,5x44,5x44,5	36x90 **	45x45x62	29x51x29
Max. operating temperature [°C]	50	80	50	50	60	50	50	50
Interface	Ethernet	USB 2	USB 2	BNC, LVDS	BNC, LVDS	Ethernet	USB 2	GigE
Price [€]	~1.100	ab ~2.100	n.s.	~ 2.000	~2.100	ab 940	ab 3.300	~10.000
Ranking list	1	2	3	out	out	1	4	out

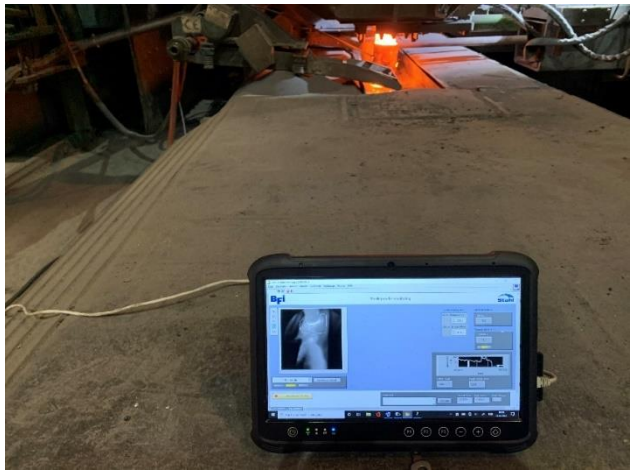
Ranking:

* depending on objective
** cylindric

important for selection:
Distance to casting powder surface

First industrial trial with one camera at caster of AGDH

- Setup of BFI casting powder monitoring system at tundish on SGA 5 (holder DH with magnets, Optris IR camera on blowing device, connection with compressed air in Marsotec hose, connection with industrial tablet and power bank BFI in 2nd Marsotec hose)
- Evaluation and recording of data from BFI software and Optris software
- Test of different settings
- Dismantling BFI casting powder measuring system after approx. 2.5 h



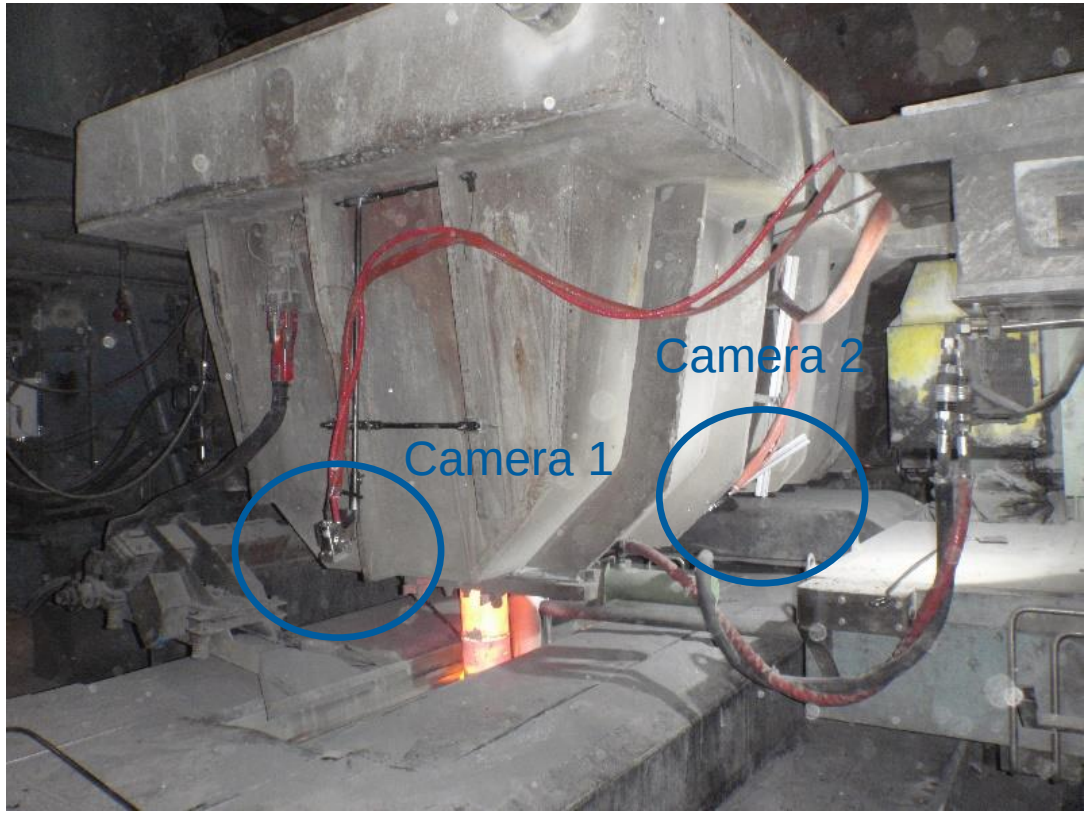
- System worked well over the whole time, dismantling not because of any problems, but because of collecting enough data
- Camera seems to be suitable for monitoring of casting powder cover despite low resolution
- One minor improvement of software regarding saving/re-loading of ROI should be implemented

Second industrial trial with two cameras at caster of AGDH

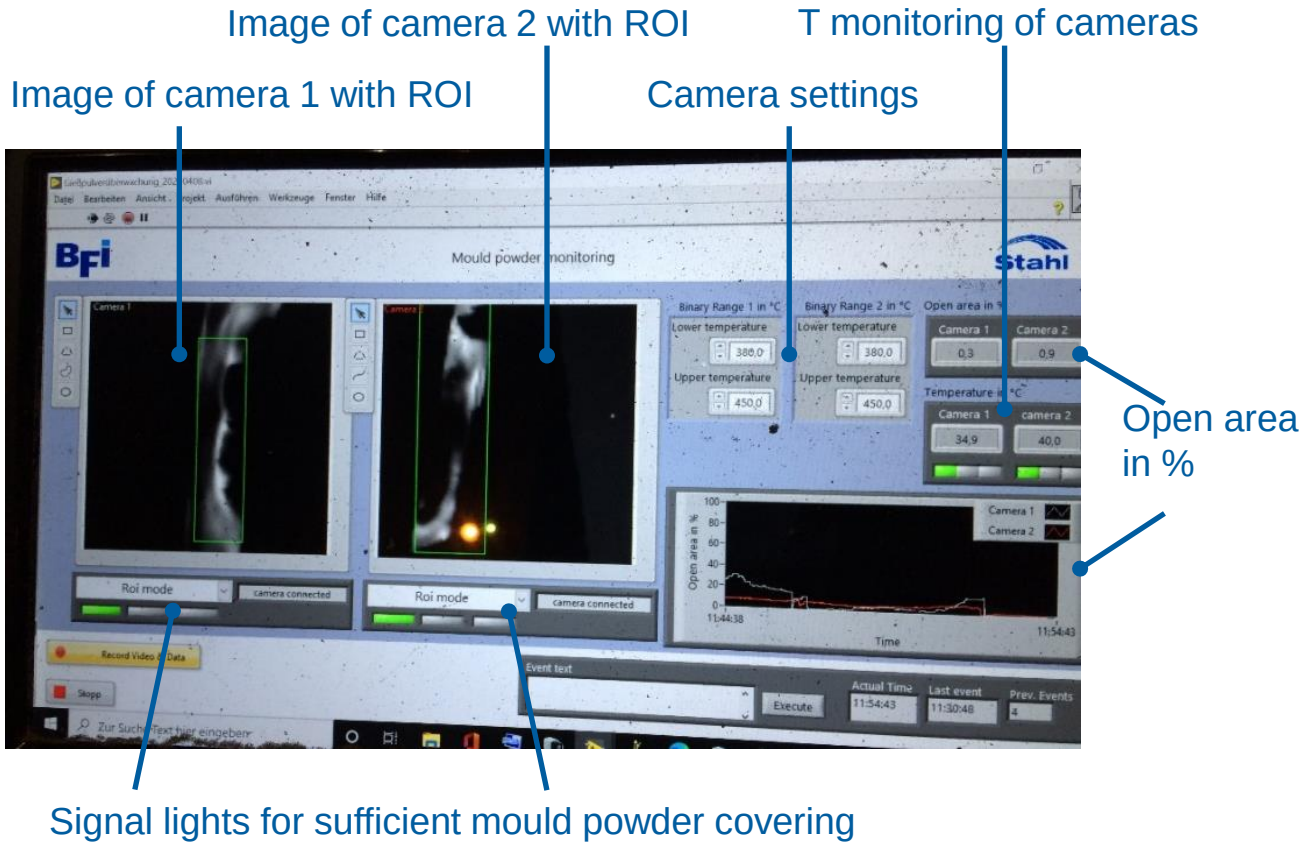
- Setup of BFI casting powder monitoring system at tundish on SGA 5 (one holder DH for fixed installation for camera 1, one holder DH with magnets for camera 2, Optris IR cameras on blowing device, connections with compressed air in Marsotec hose, connections with industrial tablet via PoE switch BFI in 2nd Marsotec hose)
- Evaluation and recording of data from BFI software
- Test of different positions for camera 2
- Dismantling BFI casting powder measuring system after approx. 3.5 h

- System worked well over the whole time without any problems
- Optimal camera positions found
- Camera 2 closer to mould surface due to limited field of view → Temperature at camera higher than at camera 1 → Compressed air had to be increased in the course of the test → Protective glass broken, probably due to thermal shock when increasing the pressure of the compressed air too quickly

Second industrial trial with two cameras at caster of AGDH



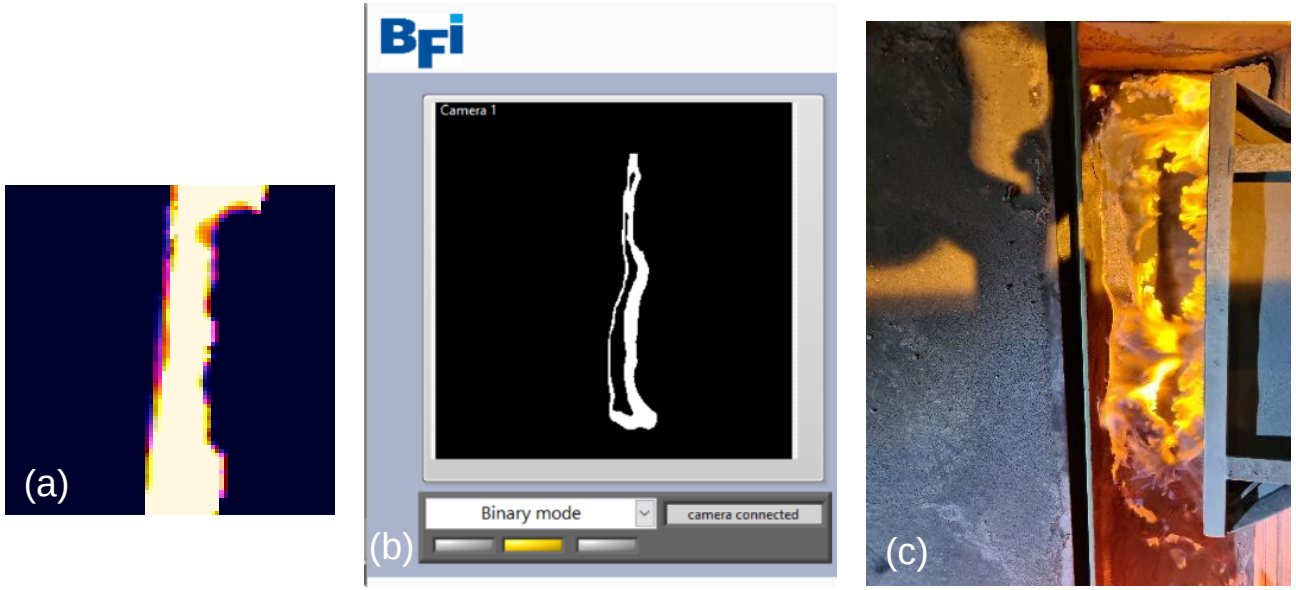
Two cameras at tundish above mould



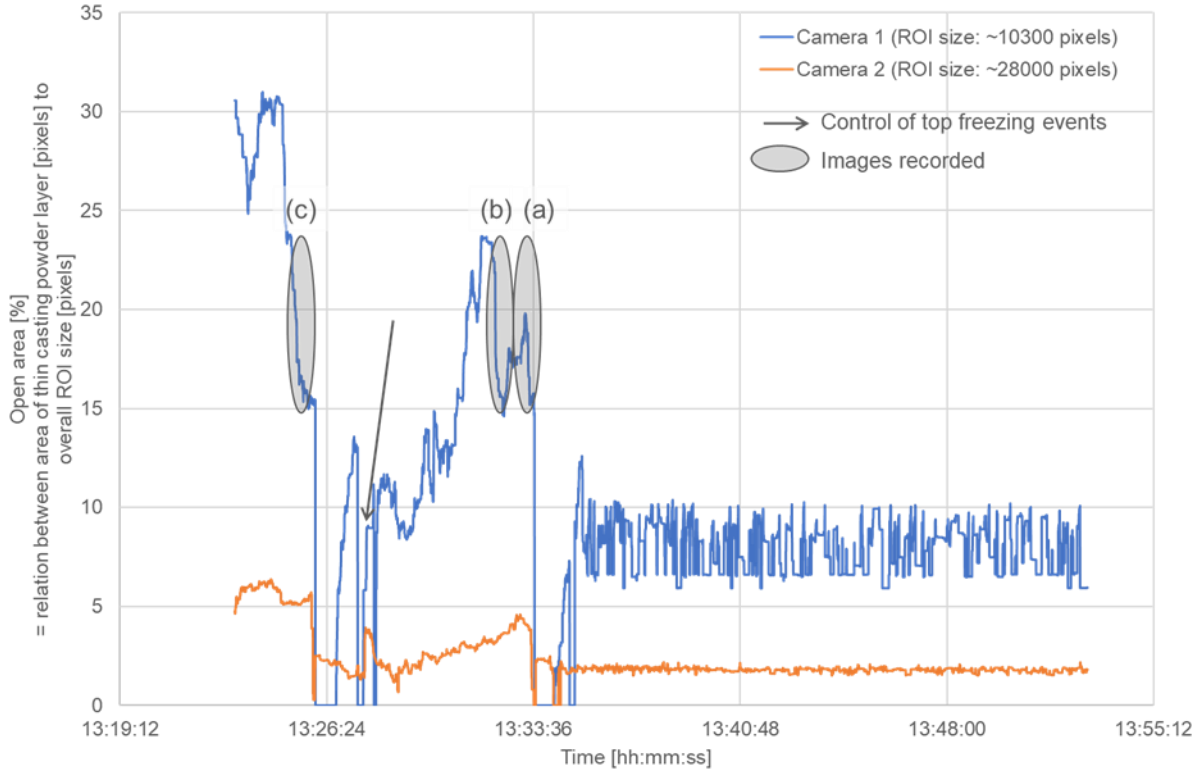
Actual status of Graphical User Interface (GUI) as in trial

Exemplary results of industrial trial

- Images recorded with BFI software and supplier software
- Open area calculated online as the relation between the area of thin casting powder layer to the overall ROI size
- Data (open area & manually entered events) collected in a local database
  → data for further analysis & optimization provided



Comparison of camera image in Optris (a, left) (13:33), binary image in BFI software (b, middle) (13:32), and photo (c, right) (13:25)



Exemplary results of the casting powder monitoring system: Open area plotted over time for both cameras

FOTS measurements in mould

Features of Fibre-Optical-Temperature-Sensors (FOTS)

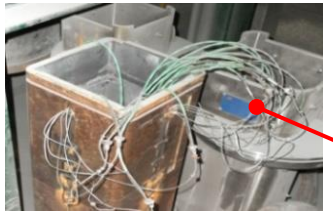
FOTS

- No influences by electro-magnetic fields
- Less influence of water flow
- Less access points per mould plate
- Geometrically free positioning up to 20 temperature sensors in one fibre
- Multiple usage also possible

Mould instrumentation

Possible use

- Early detection of disturbances in strand shell formation
- Evaluating of the homogeneity of heat transfer
- Avoidance of breakthroughs
- Control of the meniscus level



Cable bundle
15 thermocouple

FOTS application with
40 measuring points.

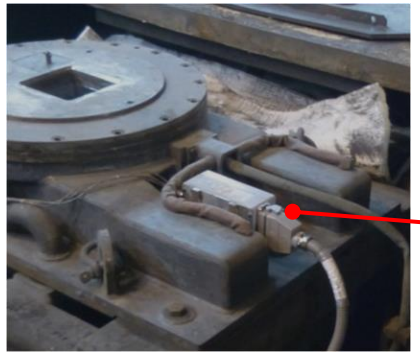
FOTS measurements in mould

Example: Fixed installation at the billet mould

Mould tube, grooves at all four faces

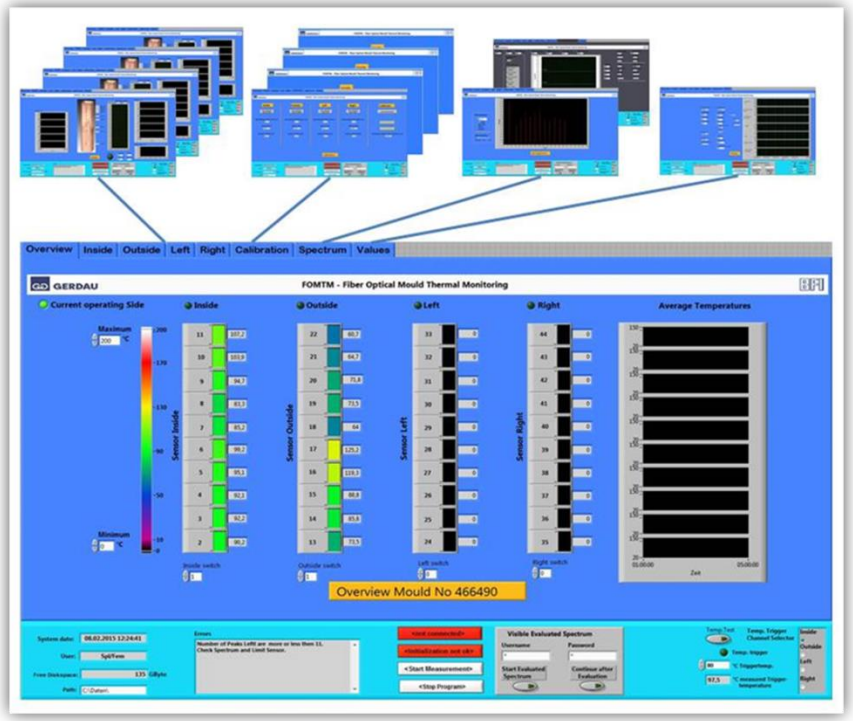
Sealed FOTS in the meniscus region

4-channel feed through, pressure-proof



Instrumented mould ready for casting

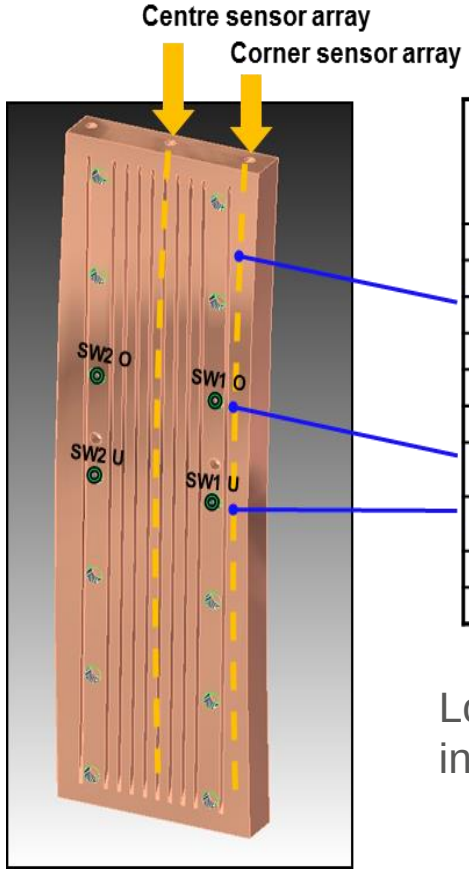
Industrial plug, 4-channel, each 10 FOTS



Graphic user interface

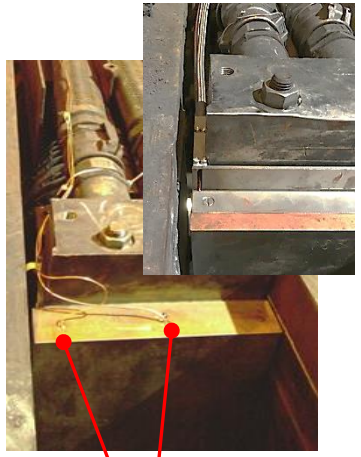
FOTS measurements in mould

Example: Removable installation at the slab caster using a guiding rod



No	Distance from Upper Edge of Copper Plate in mm	Relative Distance to Meniscus in mm	Remark
1	40	-50	
2	65	-25	
3	90	0	meniscus
4	115	25	
5	140	50	
6	190	100	
7	240	150	S*1 O, S*2 O upper thermocouple
8	490	400	S*1 U, S*2 U lower thermocouple
9	565	475	
10	790	700	

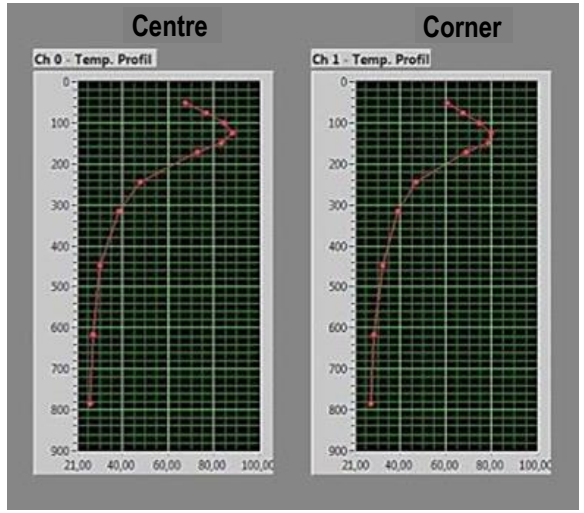
Location of multi point FOTS installed at the narrow face



Instrumented narrow face ready for casting

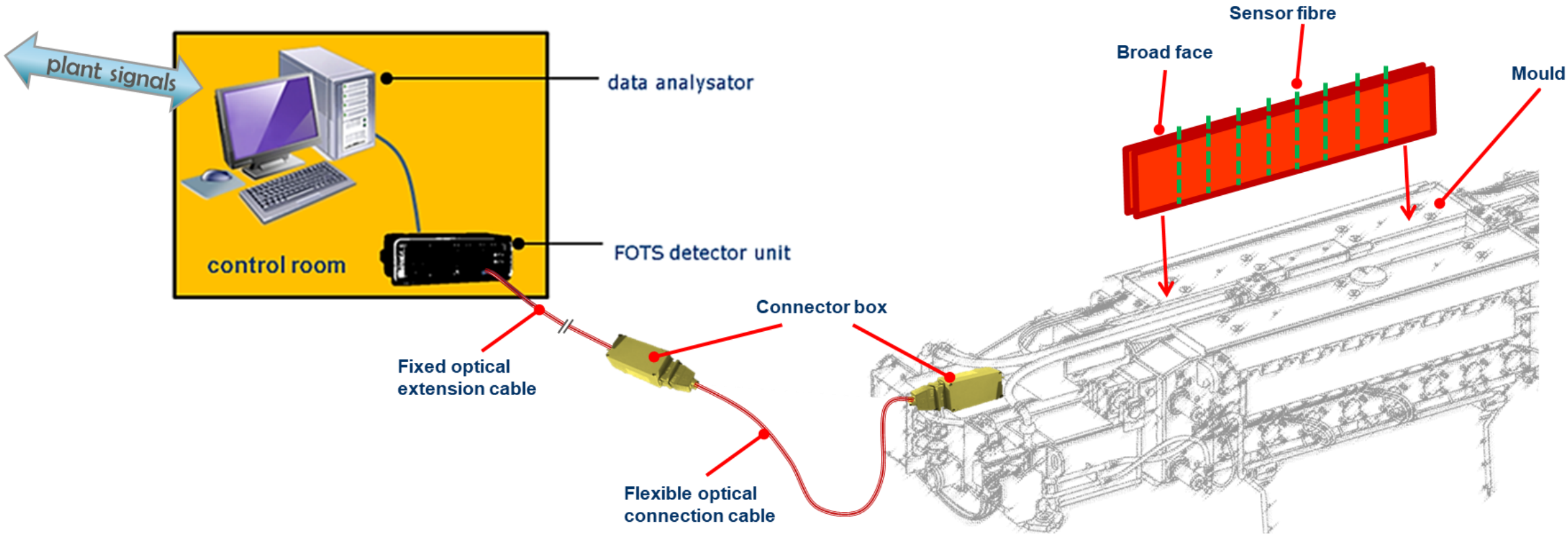
Mobile unit: detector and analysis system

Industrial plug, 4-channel



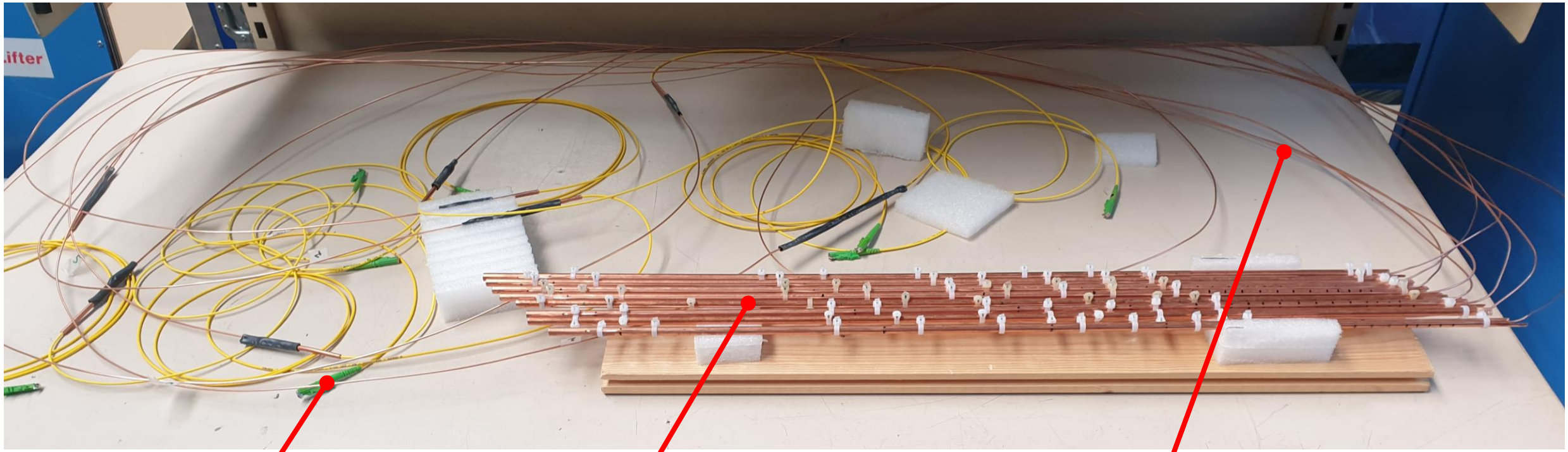
Temperature profile

Main components of measurement system



Manufacturing and software development for FOTS measurements in mould copper

› Manufacturing of 8 guide rods with FOTS fibre capillaries at BFI laboratory (18 temperature sensors per fibre)



Plugs of measurement fibres

8 guide rods

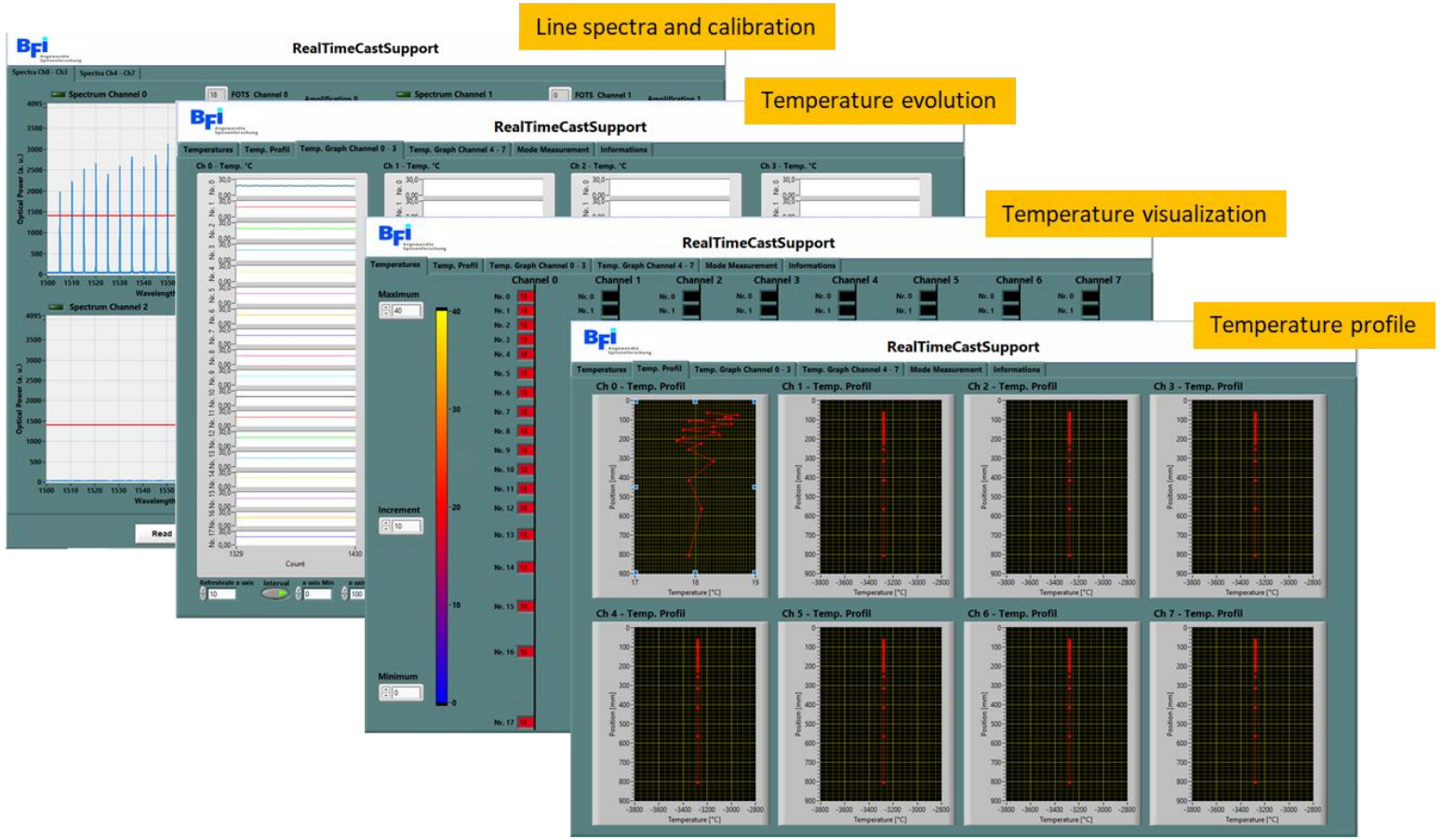
Fibre capillaries

Flexible optical connection cable

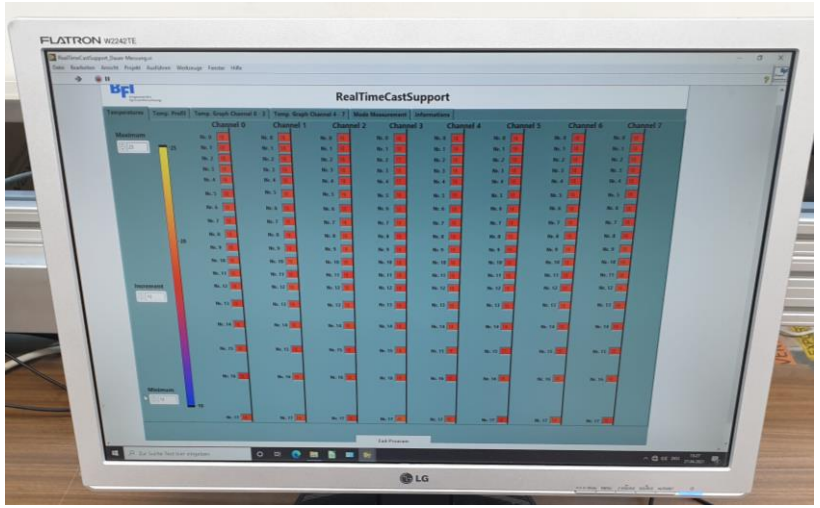
Optical lens connector and connector boxes for high industrial reliability

Software development for FOTS measurements in mould copper

› Adaption of FOTS software



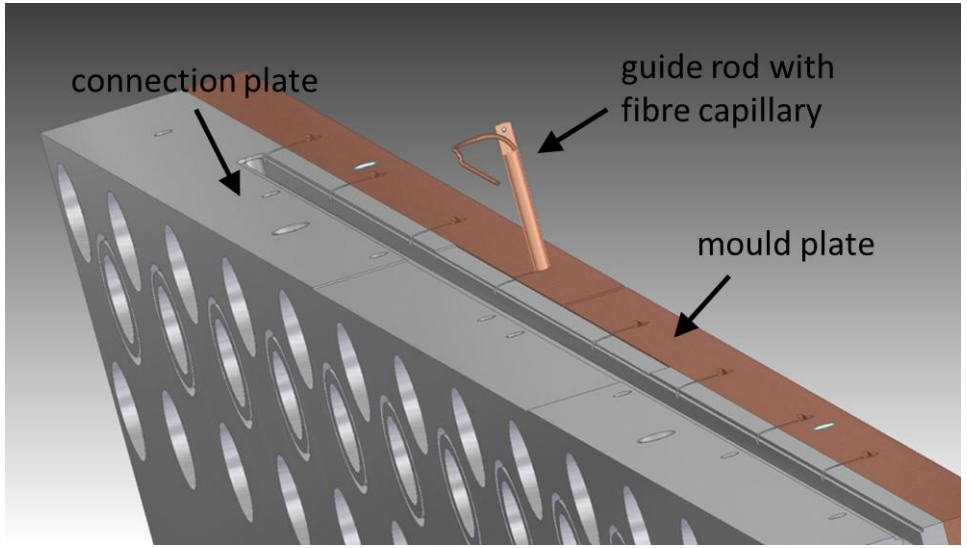
Long term test measurement at BFI laboratory



Commissioning of FOTS measurement systems in the steel plant

› Commissioning of FOTS-system at VASL

Illustration of sensor installation at VASL mould



Mould instrumented with FOTS-system at VASL caster

Commissioning of FOTS measurement systems in the steel plant

› First visualisation of mould temperature profile with FOTS software at start of casting

Dynamic 2d temperature profile of mould with in total 144 FOTS sensors and ~ 50 Hz measurement frequency

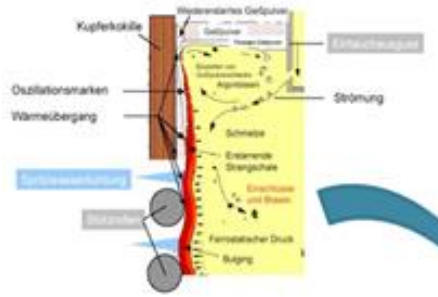
Meniscus level

Low temperatures at edges since narrow faces of mould were retracted

Application at voestalpine

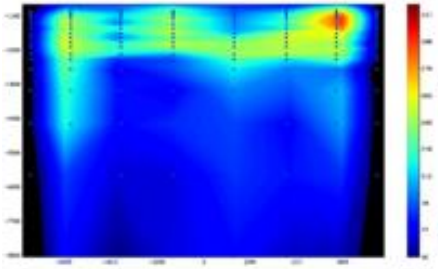
- Correlation between measured thermal inhomogeneities and sliver occurrence detected

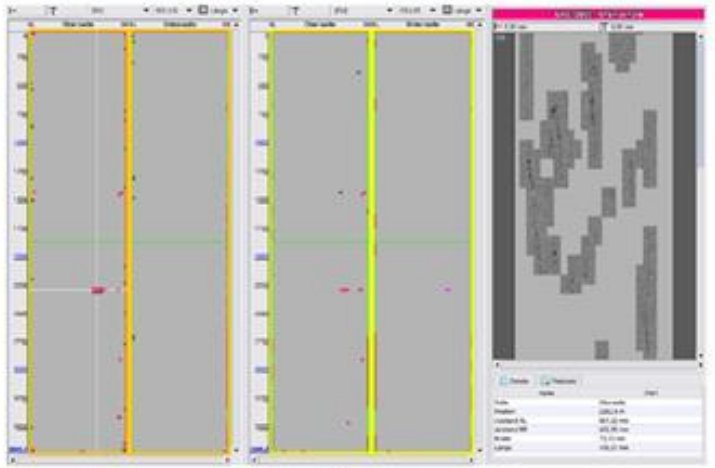
- Improved process control to increase casting quality, avoid defects and waste of low quality products



APROL system

Feature extraction





Sliver on cold rolled strip

Thank you for your attention!