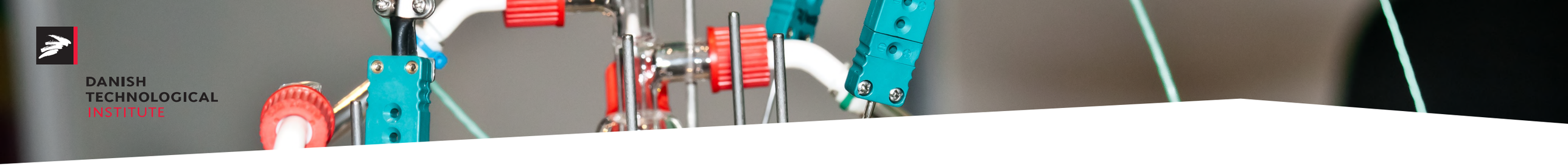
DANISH
TECHNOLOGICAL
INSTITUTE

Sporbar *on-site* måling af overfladetemperatur med fosfortermometri

Temadag hos Teknologisk Institut d. 10. oktober 2019



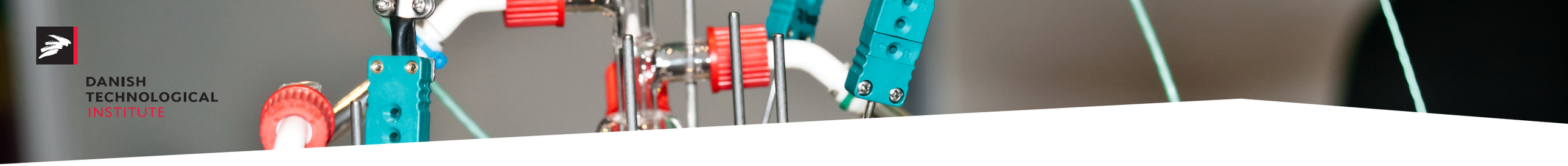
DANISH
TECHNOLOGICAL
INSTITUTE

Ambition

To ensure **real** traceability on measurement of surface temperature in order to ensure reproducibility in industrial processing

How?

- ✓ Thorough analysis of uncertainty components
- ✓ Develop new techniques for better measurements
- ✓ Effective best practices to align calibration and measurement



DANISH TECHNOLOGICAL INSTITUTE

Content

- What is traceability?
- What is a surface temperature?
- Practical conditions when measuring a surface temperature
- How to ensure the traceability?
- New techniques ready for industry – phosphor thermometry
- Measurement and calibration of surface temperature – a EURAMET guideline

Activities supported by:

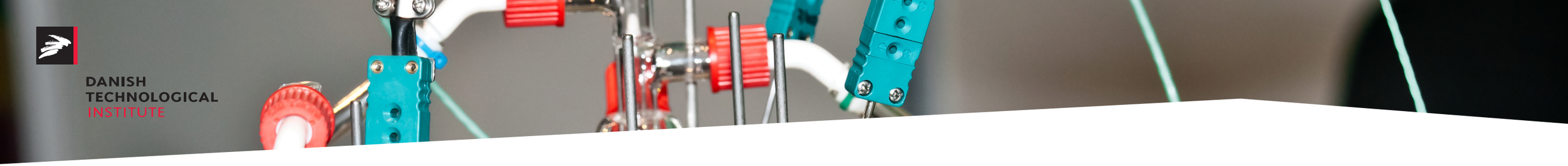
EMPIR EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Uddannelses- og Forskningsministeriet

Conducted in performance contract and projects:

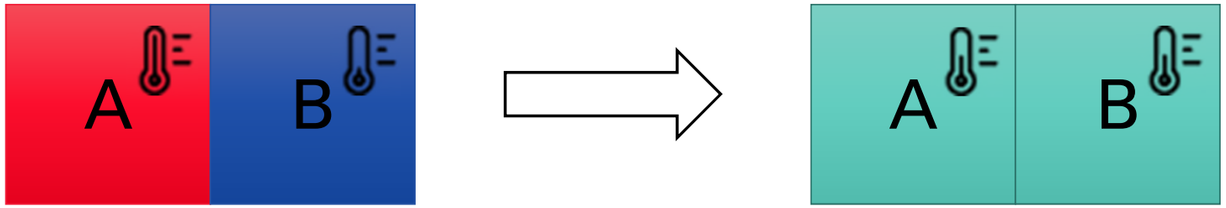
EMPRESS TEMPERATURE METROLOGY FOR PROCESS EFFICIENCY

EMPRESS 2 TEMPERATURE METROLOGY FOR PROCESS EFFICIENCY

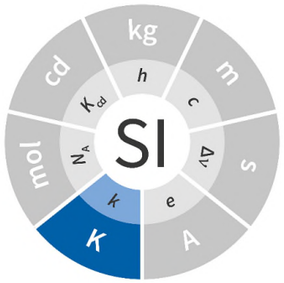


DANISH TECHNOLOGICAL INSTITUTE

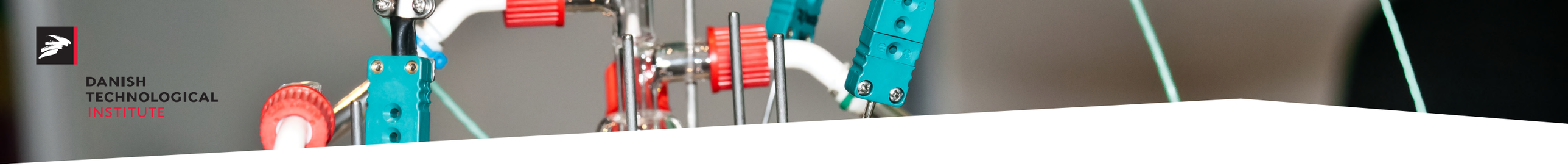
Temperature and traceability



Reproducibility through traceability in industrial measurements

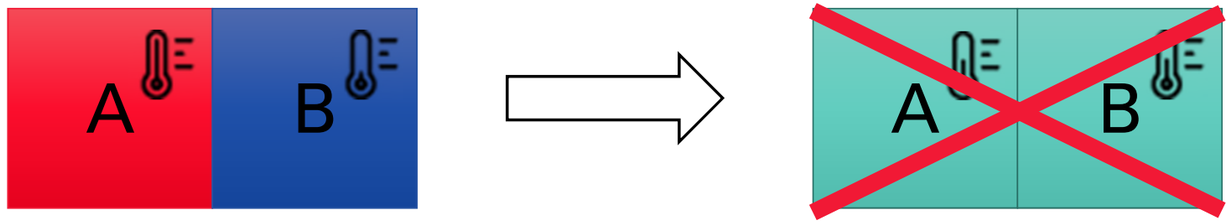


$k = 1{,}380649 \times 10^{-23}\ \mathrm{J\ K^{-1}}$

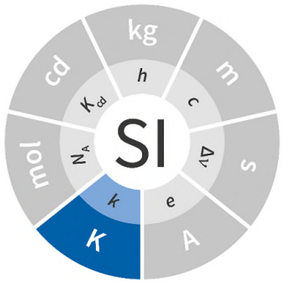


DANISH TECHNOLOGICAL INSTITUTE

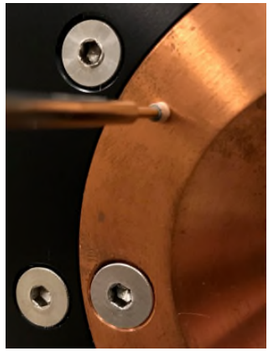
Surface temperature and traceability

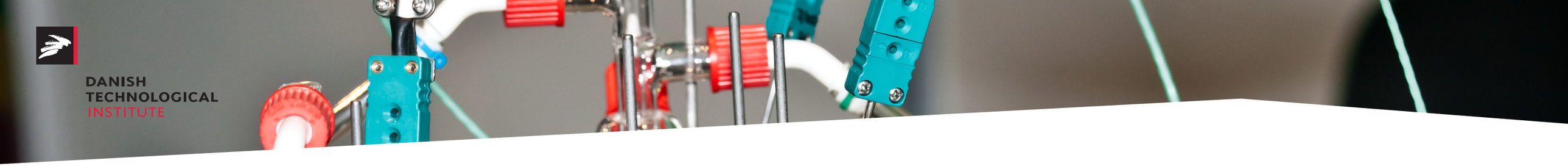


Reproducibility through traceability in industrial measurements



$k = 1{,}380649 \times 10^{-23}\ \mathrm{J\ K^{-1}}$



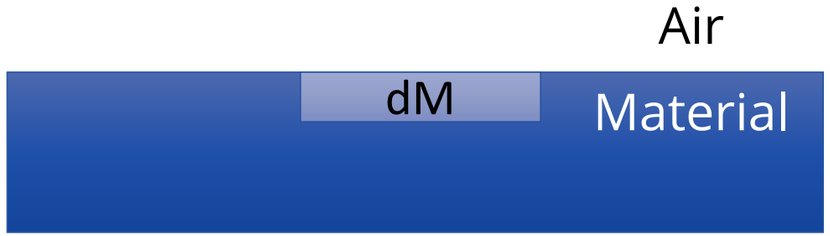


DANISH TECHNOLOGICAL INSTITUTE

What is a surface temperature?

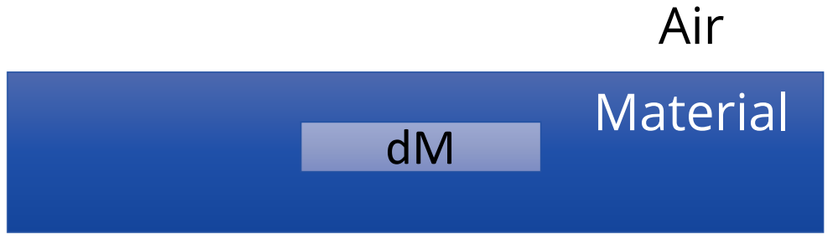
<u>Two different scenarios:</u>

Direct measurement of surface temperature:



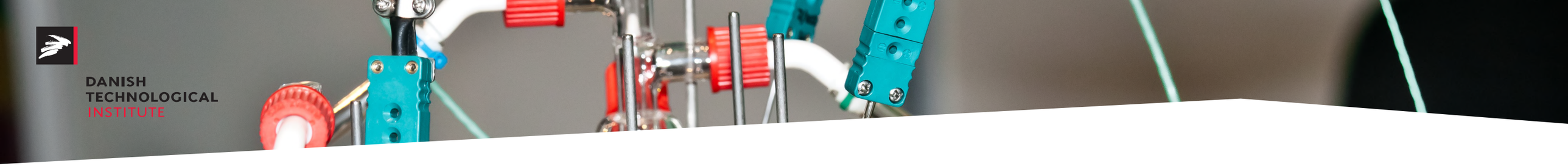
Estimate of the surface temperature in the material/air interface

Indirect measurement of surface temperature:



Estimate of the internal temperature of the material, or a fluid inside a pipe.

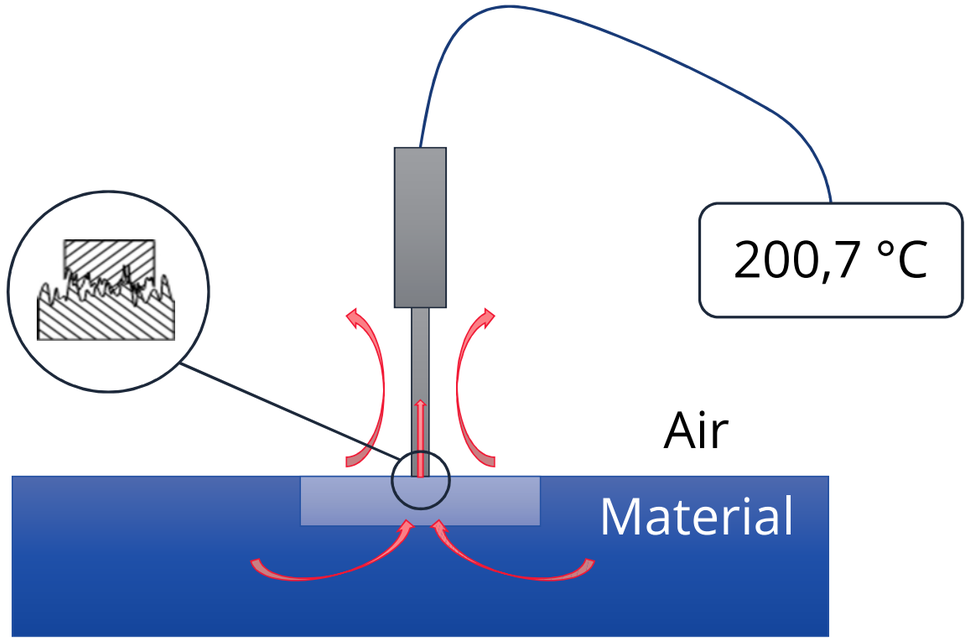
Adopted from French guide on surface temperature measurement written by CETIAT



DANISH TECHNOLOGICAL INSTITUTE

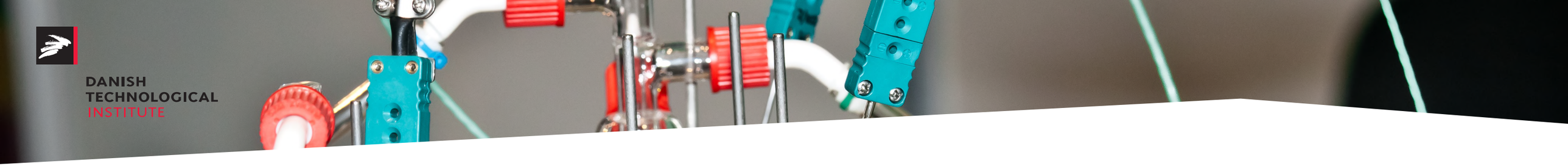
Practical conditions during measurement

Direct measurement of surface temperature:



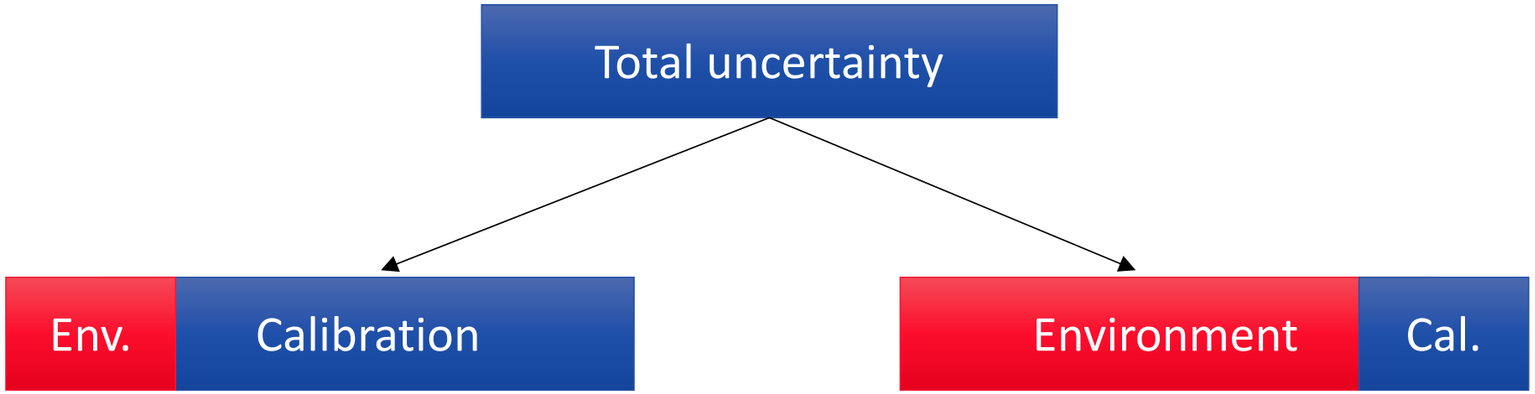
Parasitic effects on the measurement:

- Thermal conduction of heat to the interior of the material
- Contact resistance between the thermometer and the surface
- Radiator effect increases the heat loss



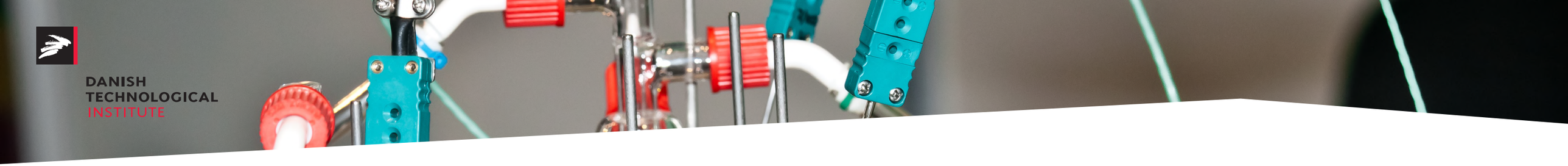
How to ensure the traceability (I)

The uncertainty of the final measurement in the process can be achieved in two different ways:



Imitate environmental conditions in the calibration to estimate the uncertainty contribution.

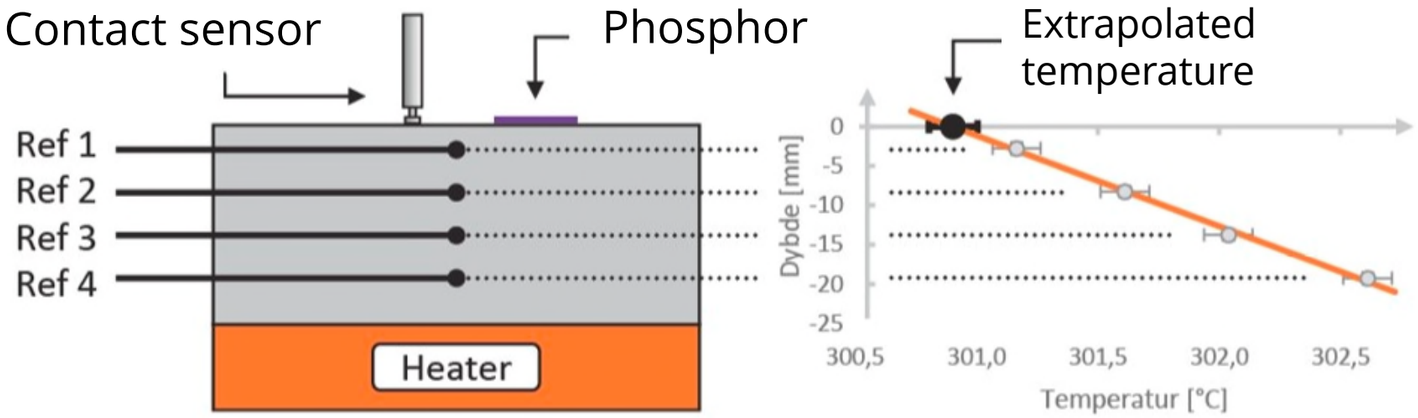
Calibration at the same material



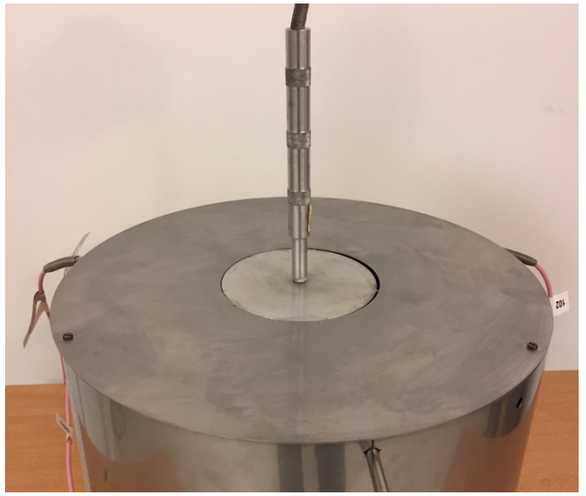
DANISH TECHNOLOGICAL INSTITUTE

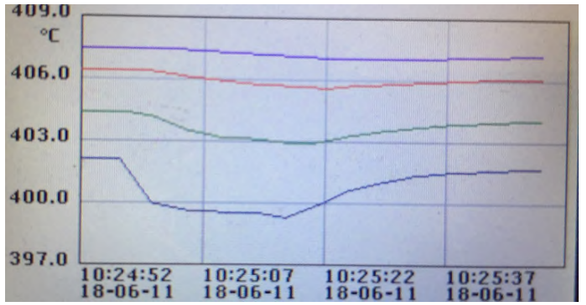
How to ensure the traceability (II)

Surface temperature calibrator at DTI in Aarhus (50 °C to 500 °C):

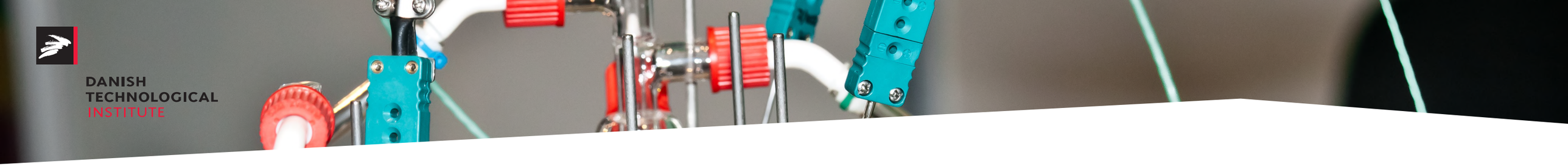


From article in Teknisk Nyt nr. 3-2019





Sensor on surface at 400 °C



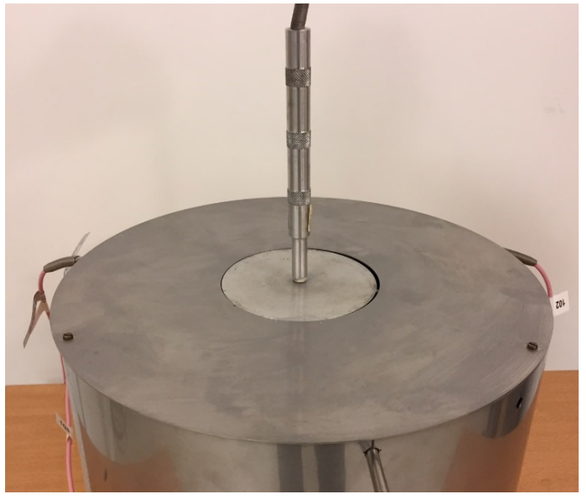
DANISH
TECHNOLOGICAL
INSTITUTE

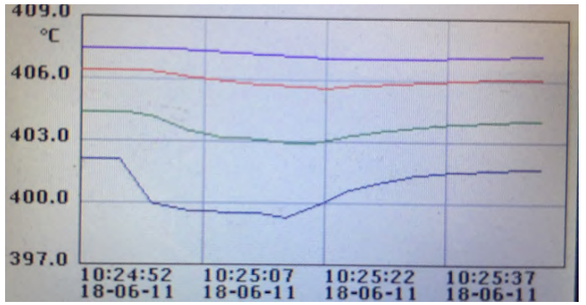
How to ensure the traceability (III)

Reference sensors: **4 Type N** thermocouples of diameter 1.5 mm

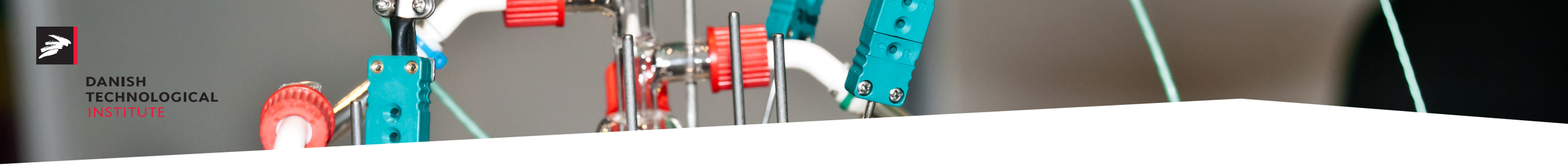
⇩

Calibrated by immersion to provide traceability to the ITS-90



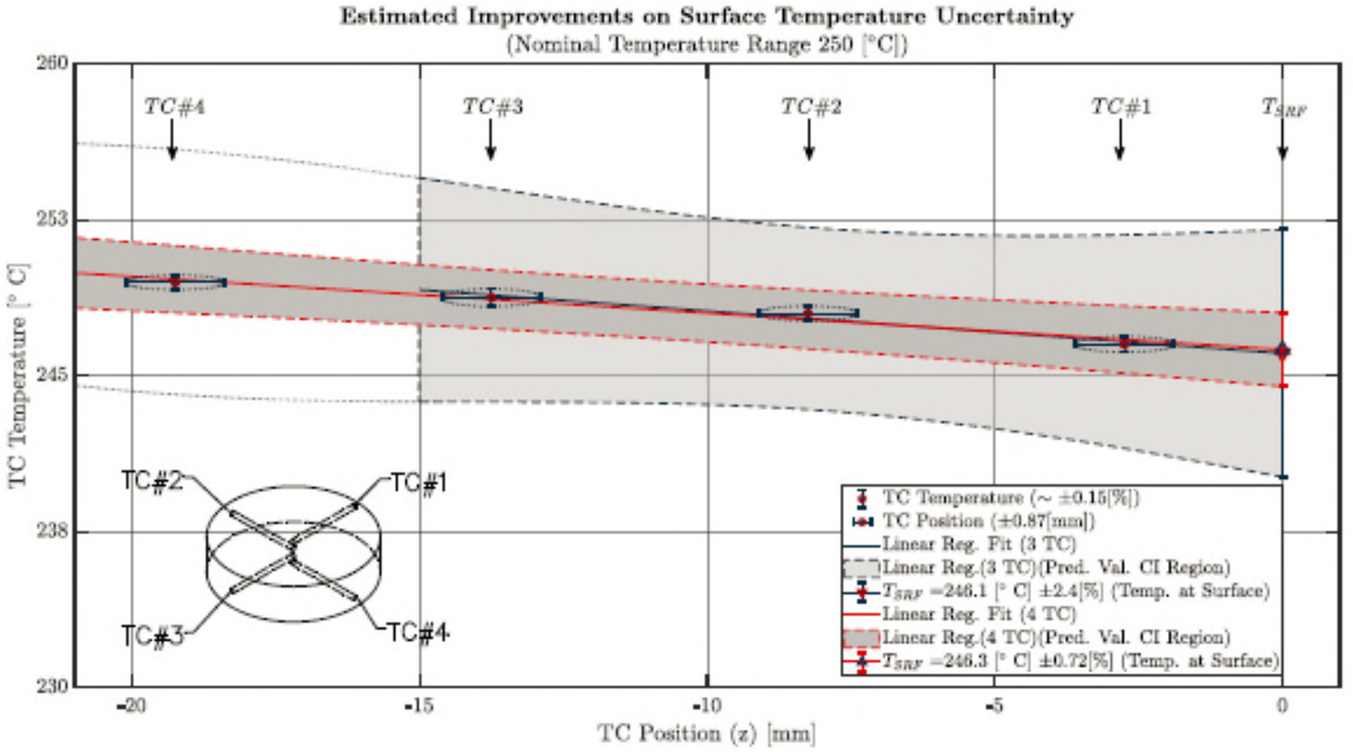


Sensor on surface at 400 °C

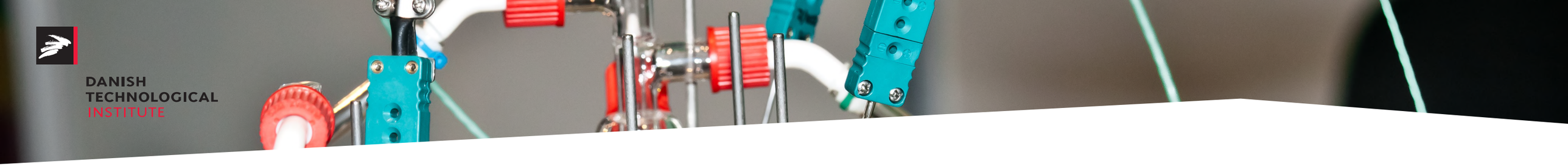


DANISH TECHNOLOGICAL INSTITUTE

The number of thermocouples matters



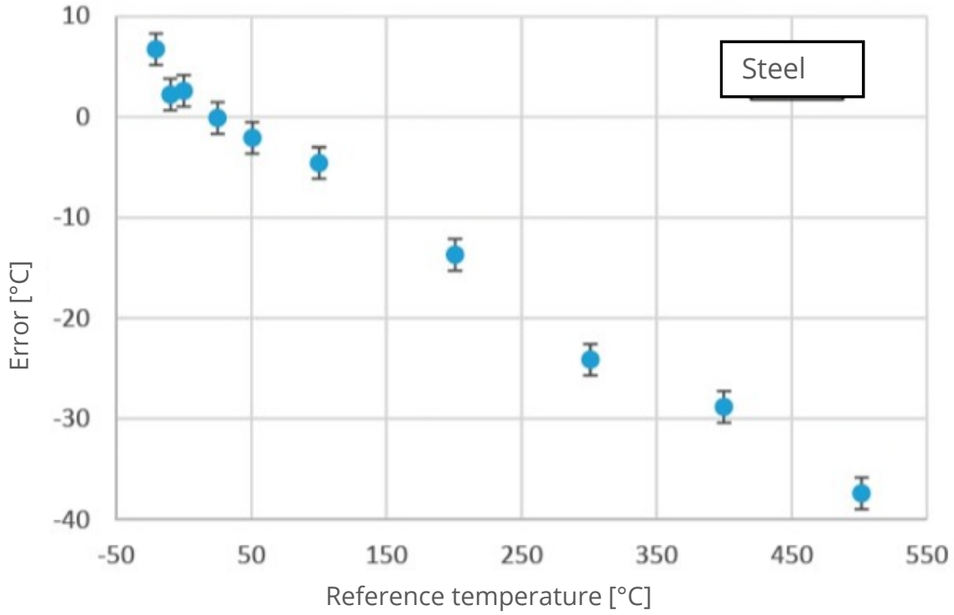
From: ”Javier I. Camacho, Phosphor Thermometry – Preliminary development of a phosphor thermometry system, Master Thesis, 2018”



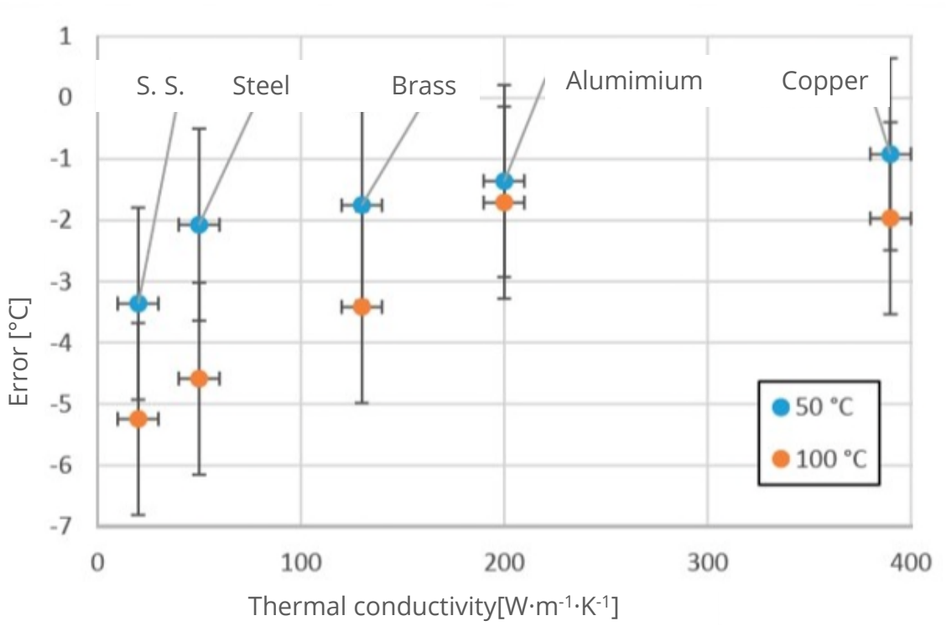
DANISH TECHNOLOGICAL INSTITUTE

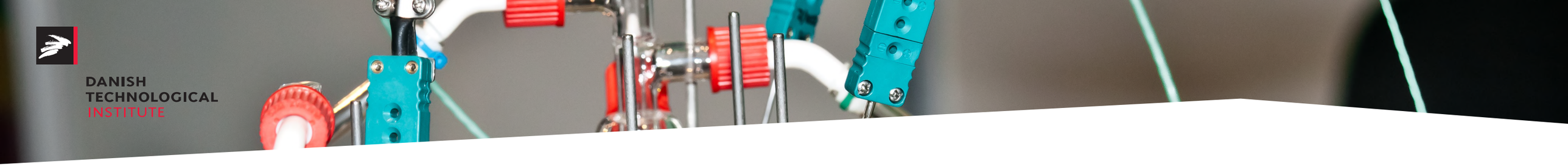
Results of a surface temperature calibration

Results from the calibration of a surface sensor at steel:



Results from calibration of surface sensor at five different materials:





DANISH TECHNOLOGICAL INSTITUTE

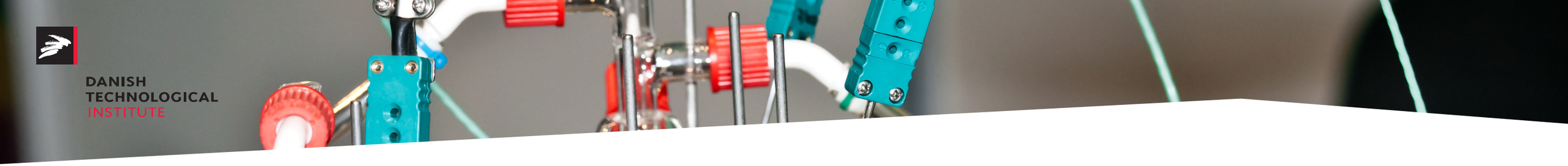
Recommendations

<u>5 points to ensure traceability:</u>

- Calibrate the sensor under conditions that imitate the environment
- Optimize the thermal contact between the sensor and the surface
- Reduce the contactpoint between the sensor and the surface.
- Use a sensor that reduces the radiator effect
- The sensing element should be close to the surface

Education and guidelines

- Guideline in calibration and measurement of surface temperature
- Education and dissimination
- Implementation of guidelines at the accredited laboratories



DANISH TECHNOLOGICAL INSTITUTE

New techniques for industry

EMPIR EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

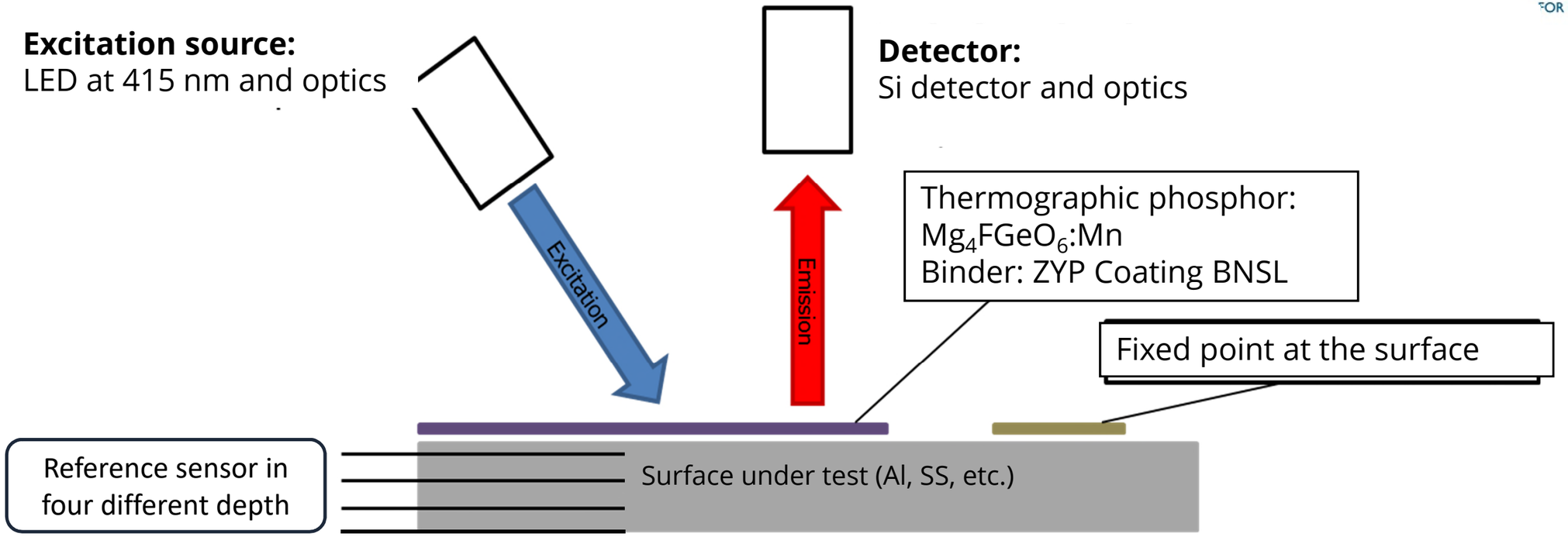
EMPRESS
TEMPERATURE METROLOGY FOR PROCESS EFFICIENCY

EMPRESS 2
TEMPERATURE METROLOGY FOR PROCESS EFFICIENCY

Phosphor thermometry:

Excitation source:
LED at 415 nm and optics

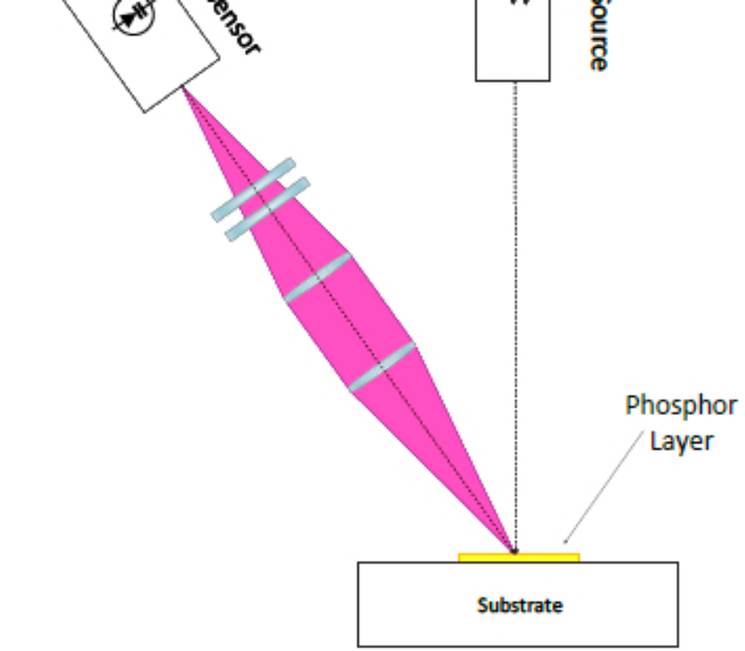
Detector:
Si detector and optics

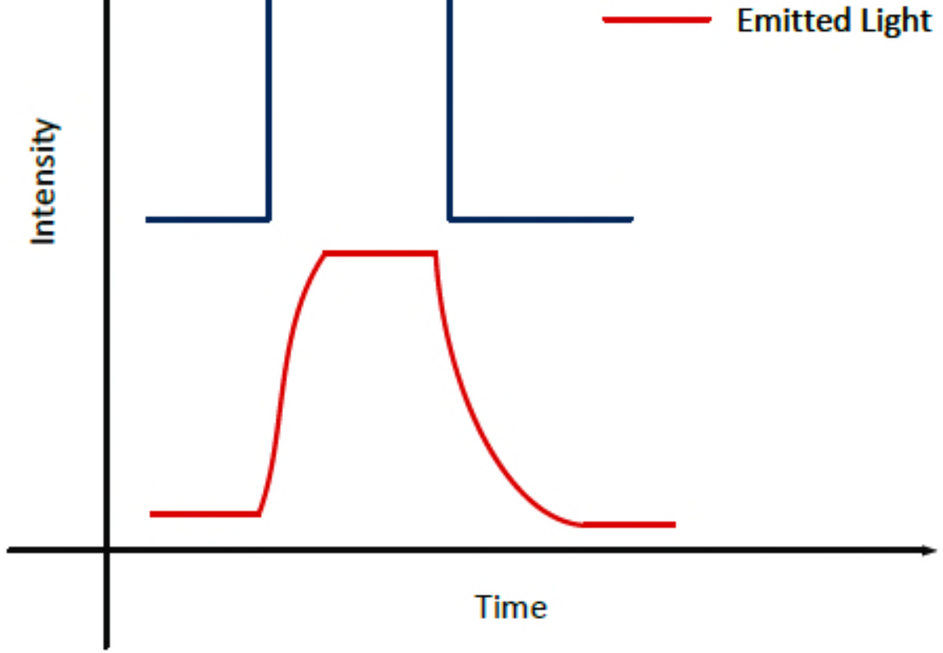


DANIS
TECHN
INSTIT

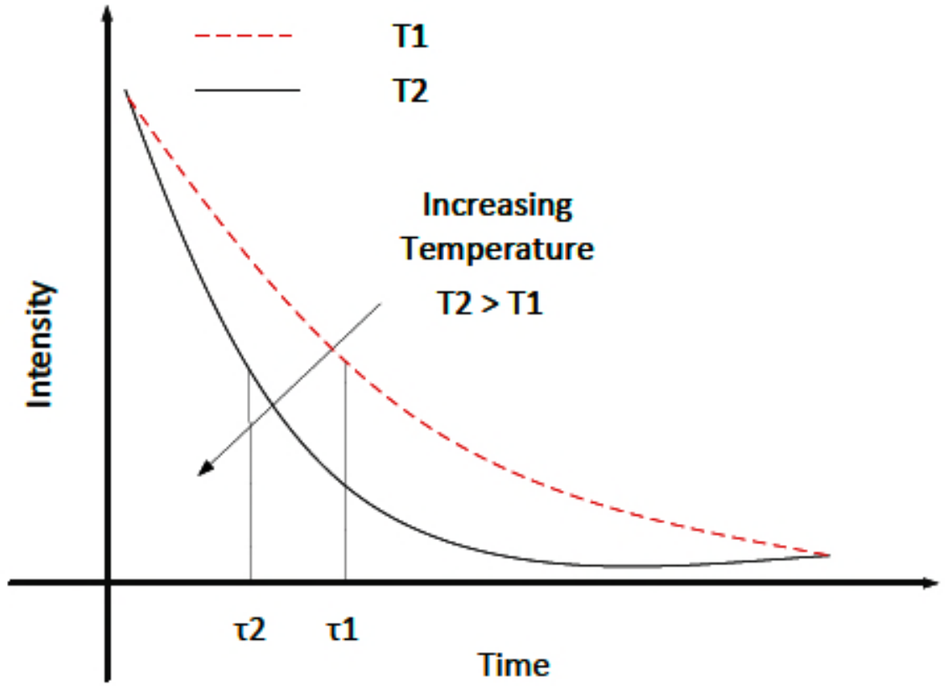
Pl

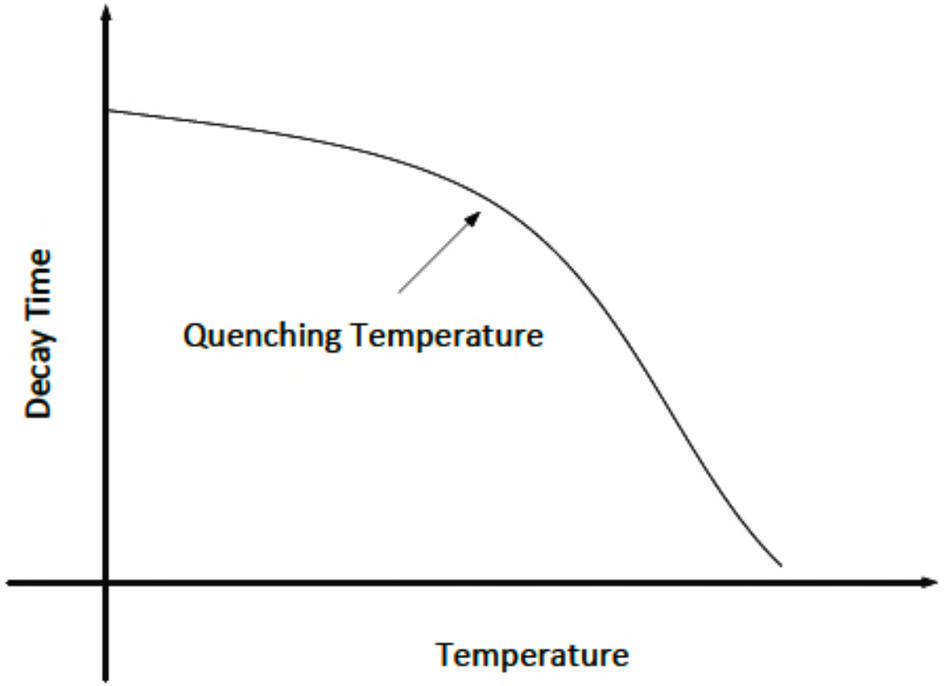
The

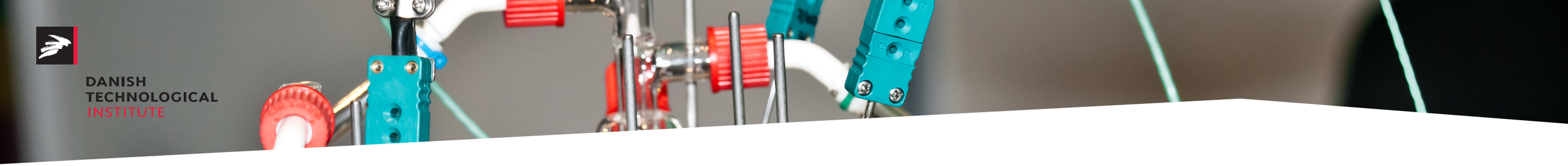




From
The
of a
Mas



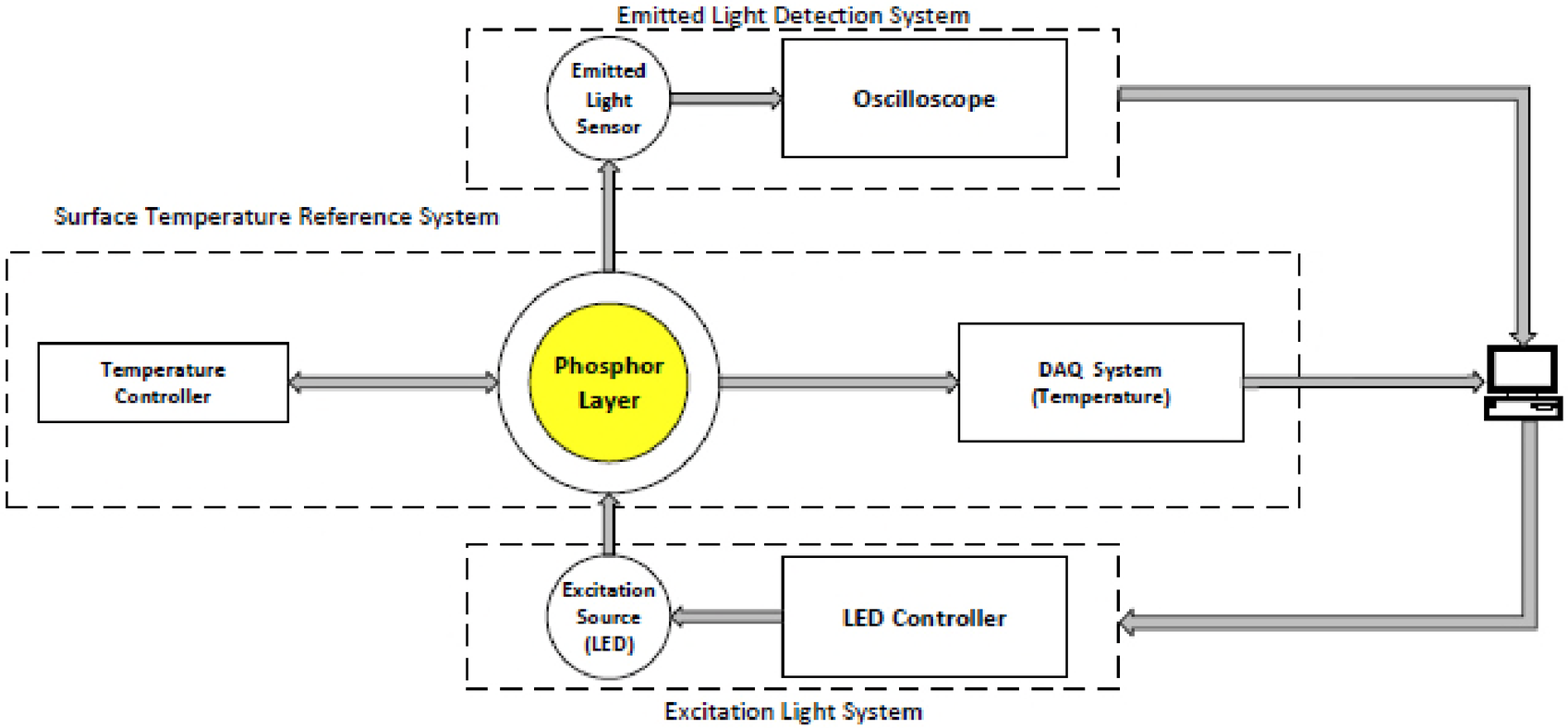


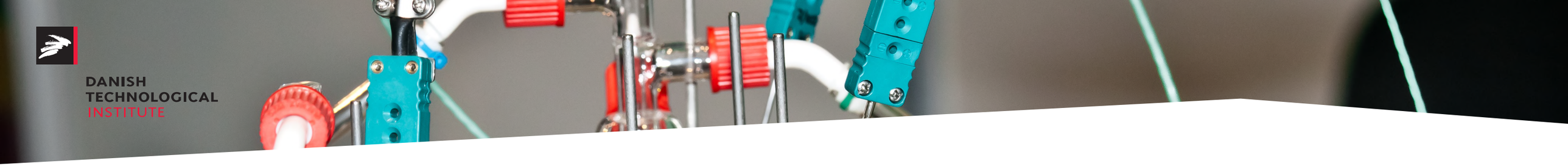


DANISH
TECHNOLOGICAL
INSTITUTE

Phosphor thermometry (II)

Experimental setup and DAQ system:

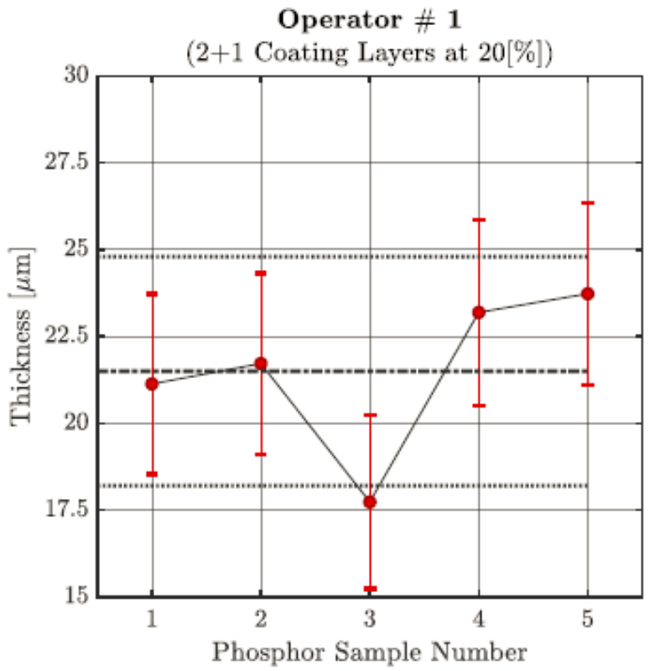


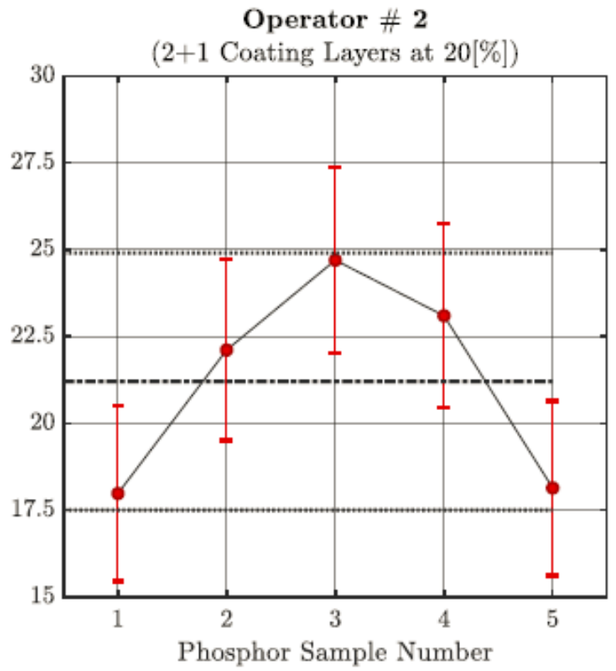


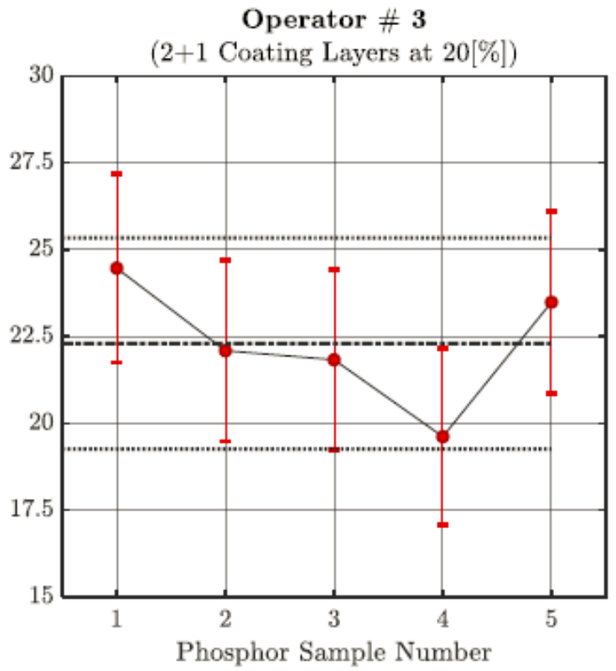
DANISH
TECHNOLOGICAL
INSTITUTE

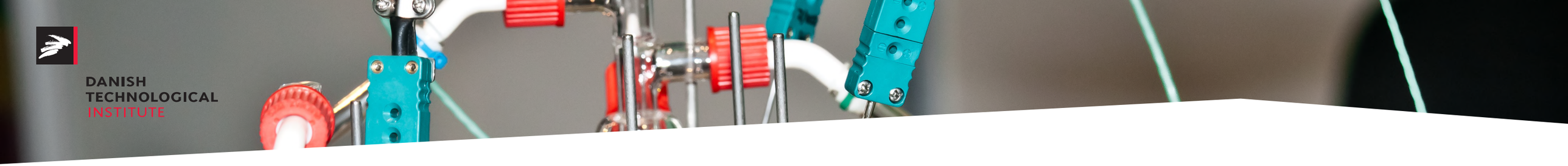
Phosphor thermometry (III)

Layer preparation:



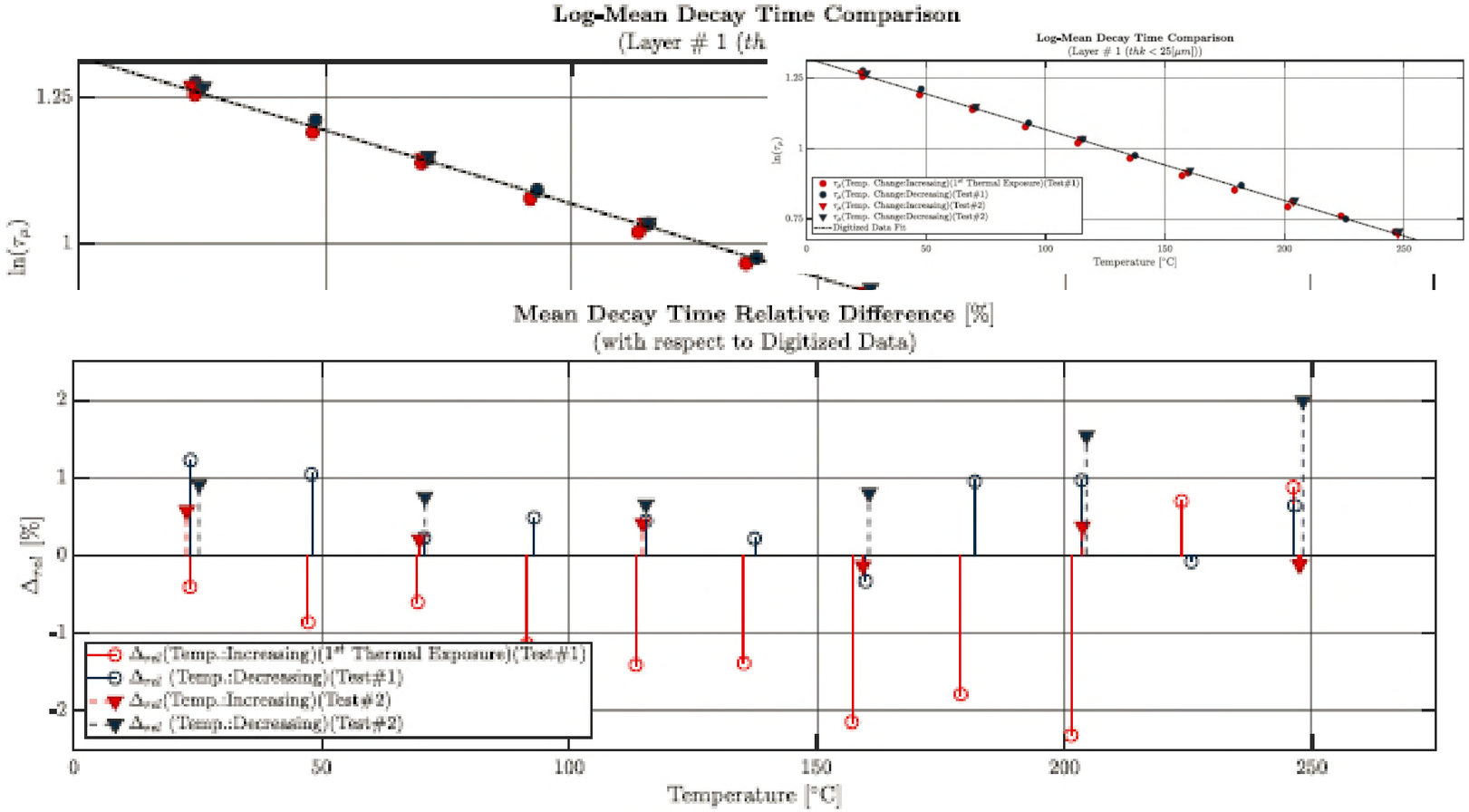


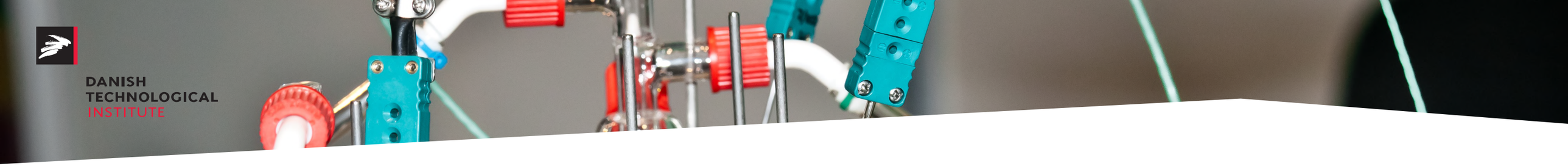




DANISH
TECHNOLOGICAL
INSTITUTE

Phosphor thermometry (IV) - Results





DANISH
TECHNOLOGICAL
INSTITUTE

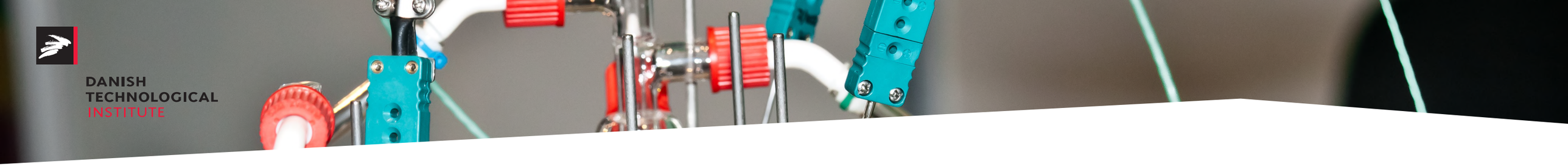
Phosphor thermometry (V) – What's next?

- Optimised setup with faster oscilloscope - done
- System automation - done
- Full characterisation – in progress
- Fibre optic surface probe – in progress
- Fibre optic immersion sensor – in progress

Javier

Mikkel

Masters Student



Conclusion

- ✓ Surface temperature was defined – agree to the definition and stict to it
- ✓ Development of a surface temperature reference system at DTI (50 °C to 500 °C) – the number of sensors matters
- ✓ Development of a phosphor thermometry system for surfaces
- ✓ Work continues in EMPRESS 2 with extented temperature range – requires fast signal processing
- ✓ EURAMET guideline on contact surface thermometry to include phosphor thermometry in EMPRESS 2

Acknowledgements

Activities have been supported by:

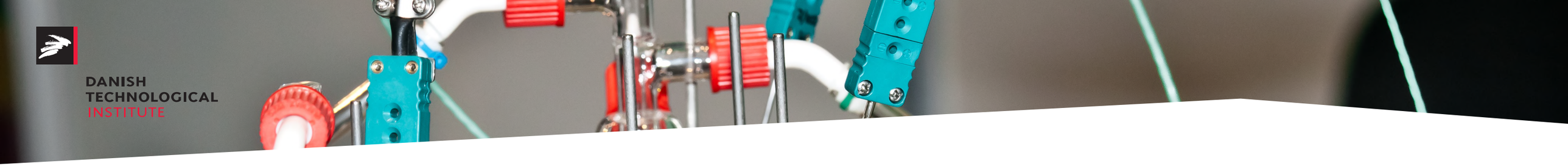
EMPIR EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Uddannelses- og Forskningsministeriet

Work conducted as part of the EMPIR projects:

EMPRESS TEMPERATURE METROLOGY FOR PROCESS EFFICIENCY

EMPRESS 2 TEMPERATURE METROLOGY FOR PROCESS EFFICIENCY



DANISH
TECHNOLOGICAL
INSTITUTE

Questions?