Enhancing process efficiency through improved temperature measurements

EMPRESS Workshop
22 March 2017

Traceable surface temperature measurement with contact sensors (*WP 3)*

*NMI Partners: **INRIM**, NPL, DTI, CMI*
Industrial Partners: BAE, GF

Lucia Rosso

Traceable surface temperature measurement with contact sensors

The aim of this WP is to enhance materials/chemical processing, such as forming, joining and welding, by providing more reliable, traceable surface temperature measurement

Needs

- Accurate measurements of surface temperature are required in a wide range of industrial applications to ensure high process efficiency and good product quality and consistency. **However, surface temperature measurement with contact probes is very problematic…**
- New techniques need to be adapted for use in high-value manufacturing processes to provide traceable surface temperature measurements

EMPRESS WP3: activity

- Development of novel surface temperature measurement techniques with contact thermometers (**INRiM**, CMI, DTI, NPL)

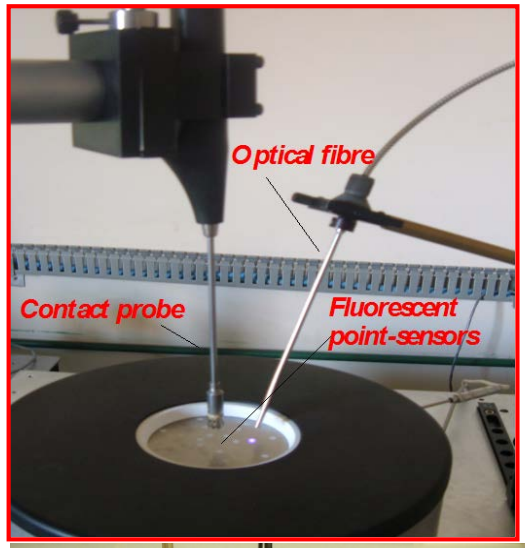
  *The **aim** is to develop and validate traceable surface temperature measurement for temperatures below 500 °C*

- Implementation of novel surface temperature measurement techniques in industry (**INRIM**, NPL, CMI, BAE, GF)

  *The **aim** is to transfer at the industrial level the techniques developed*

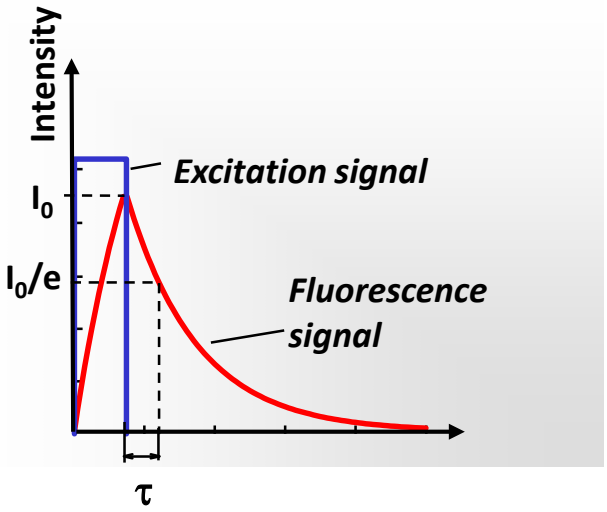
Development of novel surface temperature measurement techniques with contact thermometers

- ✓ *A novel approach, based on **phosphor thermometry**, that is immune from errors associated with conventional thermometry methods, will be exploited*
  - *directly applied to a commercially available apparatus for calibrating conventional surface temperature probes*
  - *to develop a novel remote fibre-optic thermometer able to provide traceable surface temperature measurements in selected industrial processes*
- ✓ *Another novel approach is to apply **dynamic compensation** to surface probes in order to reduce the error due to loading effects in conventional probes*



Phosphor-based thermometry

Principle

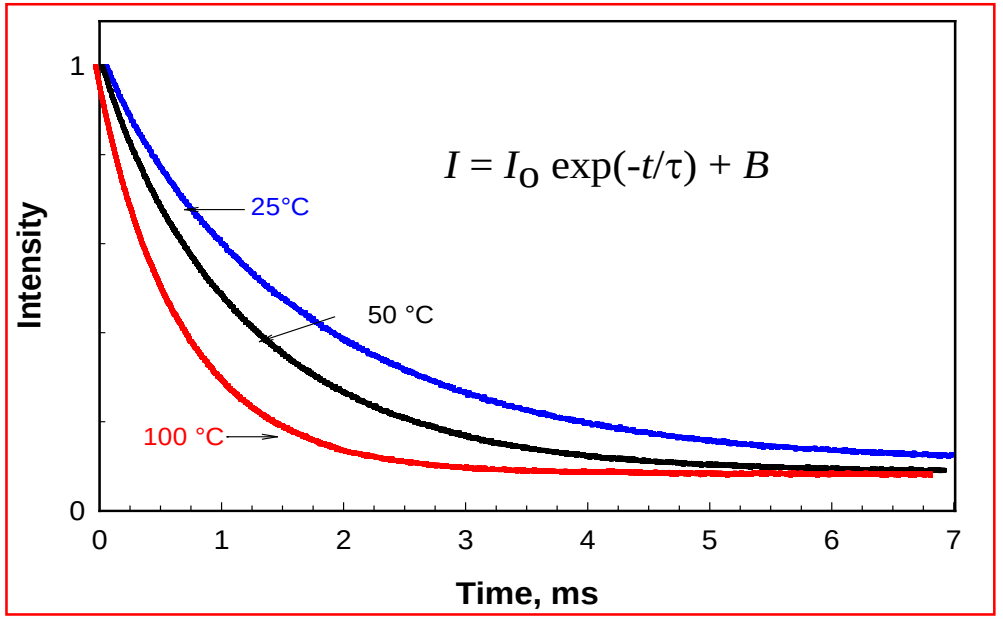


✓ *A phosphor is a temperature sensitive material; in fact, its fluorescence decay time τ depends on temperature T*

$$I = I_0\, e^{-t/\tau} \qquad \text{where} \qquad \tau = f(T) \Rightarrow T \text{ is obtained}$$

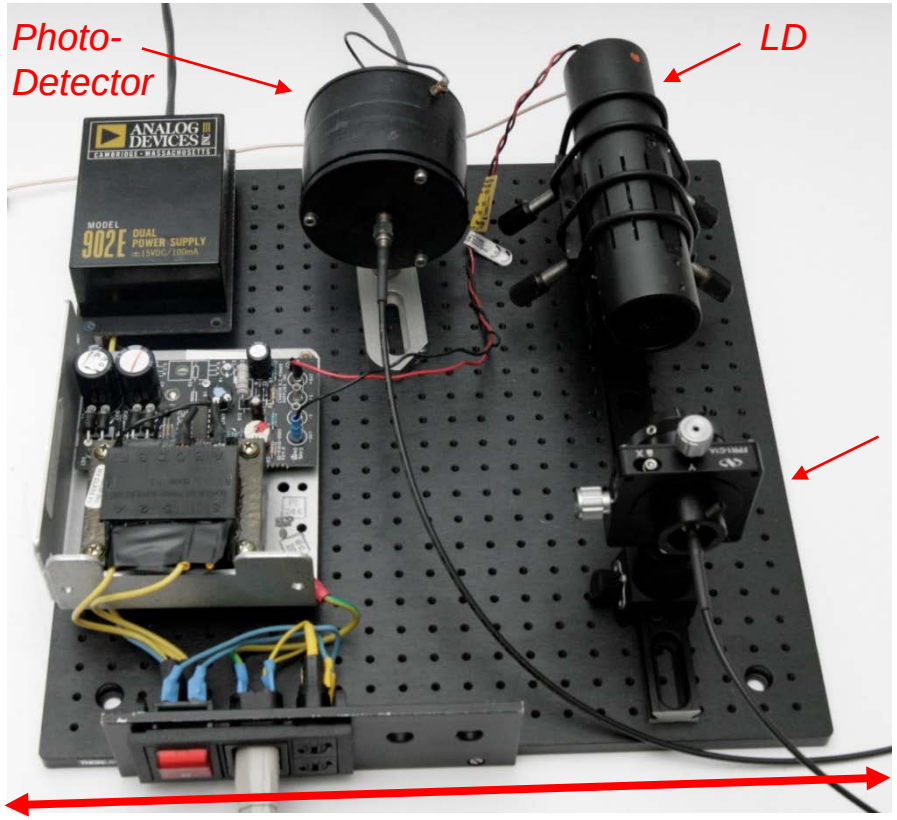
✓ *The surface temperature can be determined by measuring the fluorescence decay time, τ, of a temperature-sensitive phosphor layer coated on the surface under test*

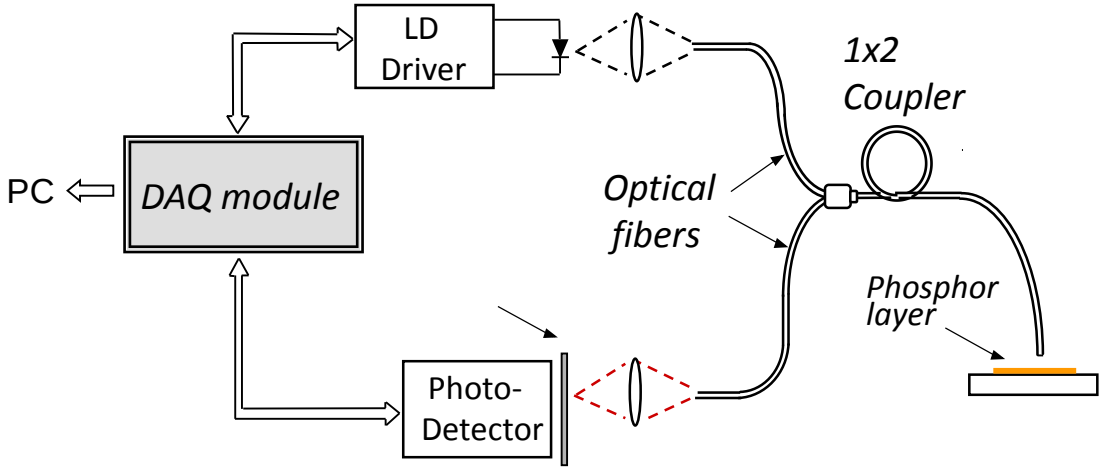
Temperature dependence of lifetime

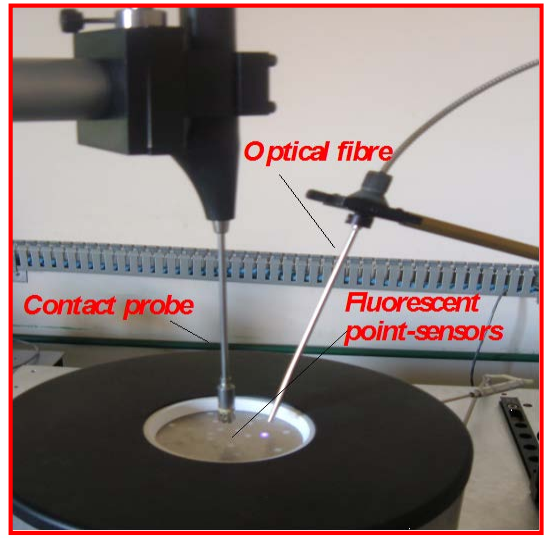


INRiM electro-optical system for phosphor thermometry

Fluorescence excitation/detection portable unit

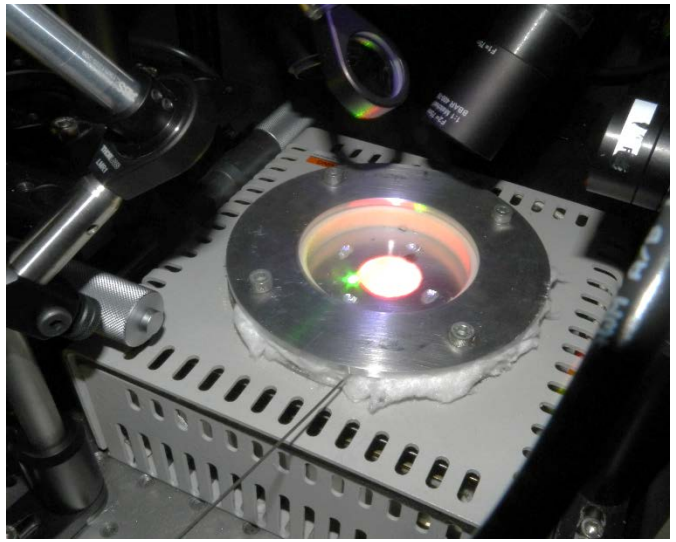




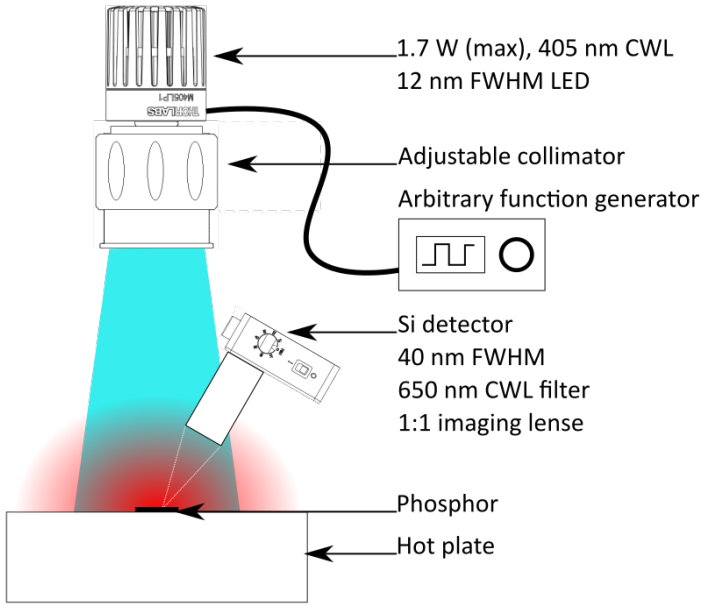


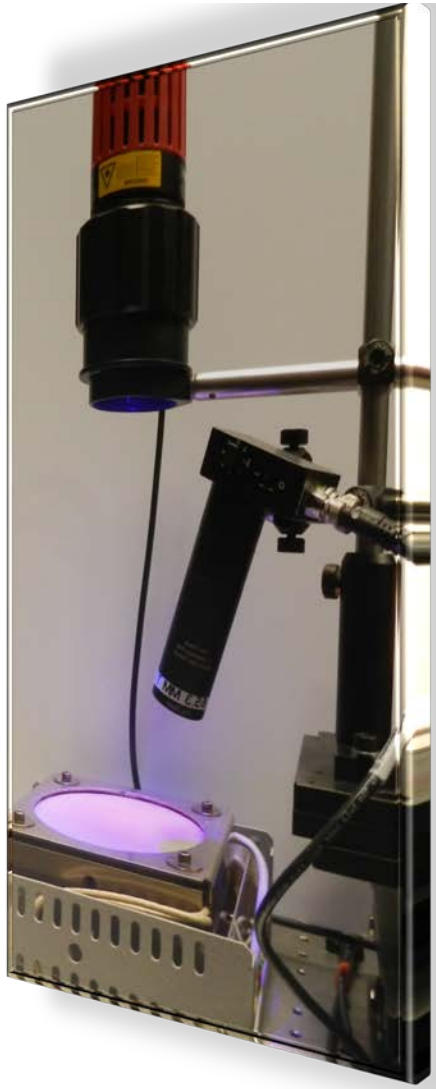
NPL phosphor thermometer

Laboratory based phosphor thermometry system based on decay lifetime of Mg_4FGeO_6:Mn developed



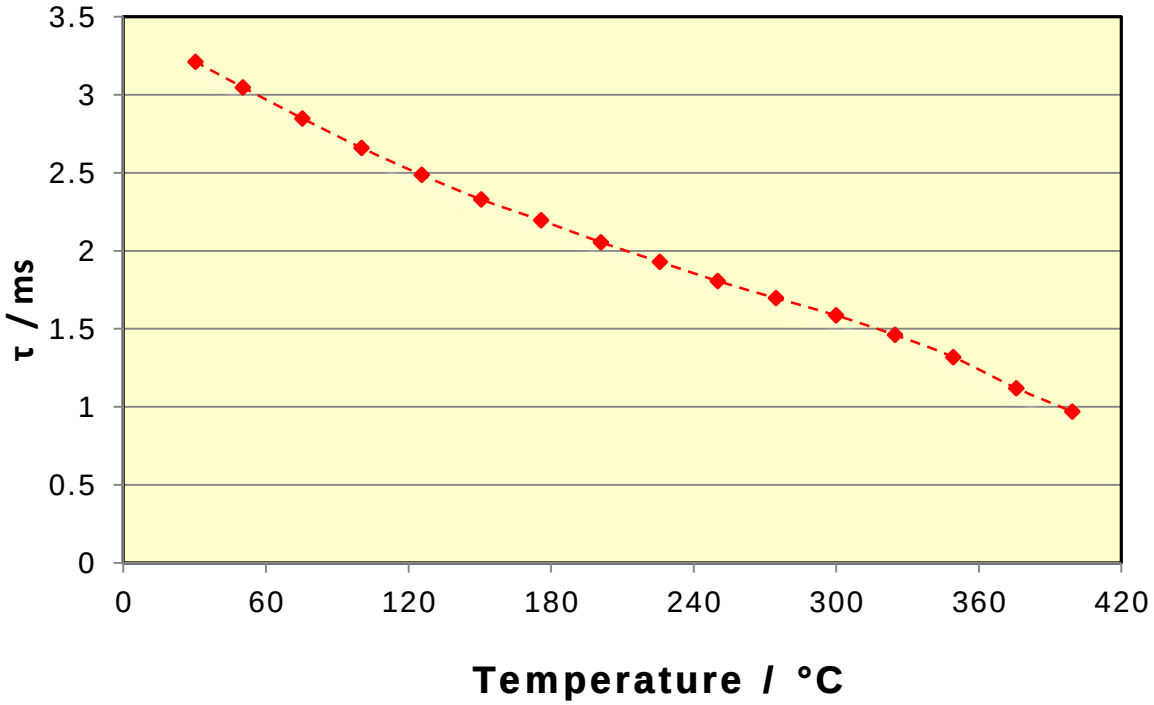
- **Hot plate currently capable of temperatures up to 360 °C**
- **Calibration surface can be interchanged for other materials**





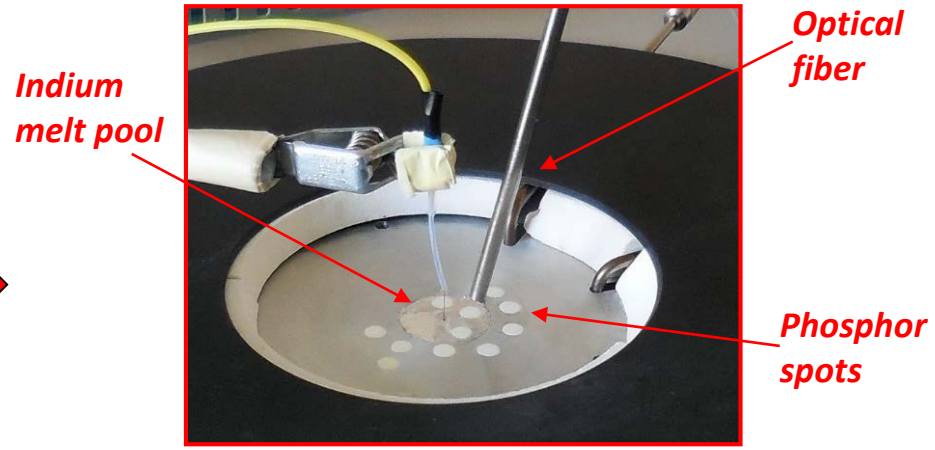
Mean of ~85 k decays

Results: phosphor calibration

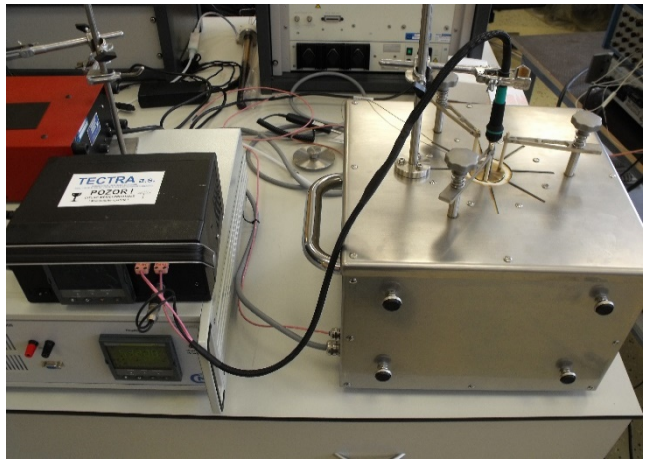


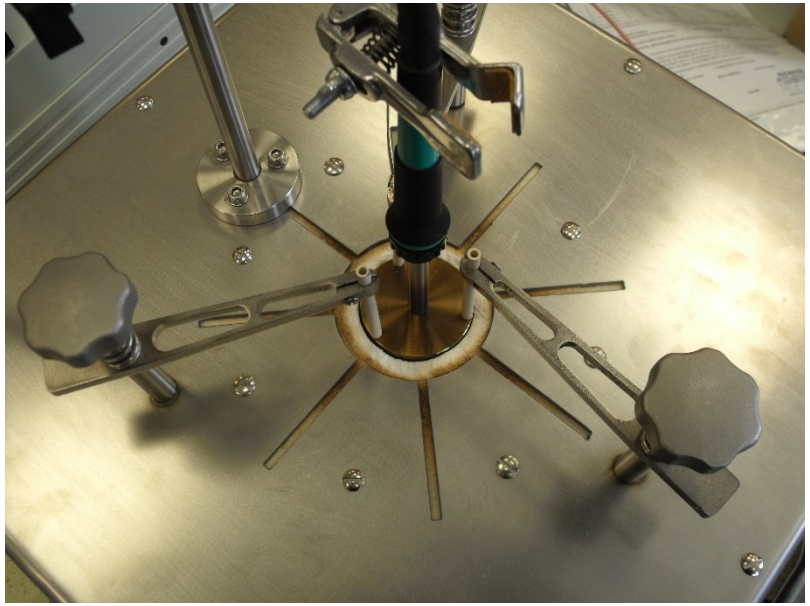
*The phosphor **Mg_4FGeO_6:Mn** was calibrated by contact on the hot plate surface in the temperature range from 30 °C to 400 °C*

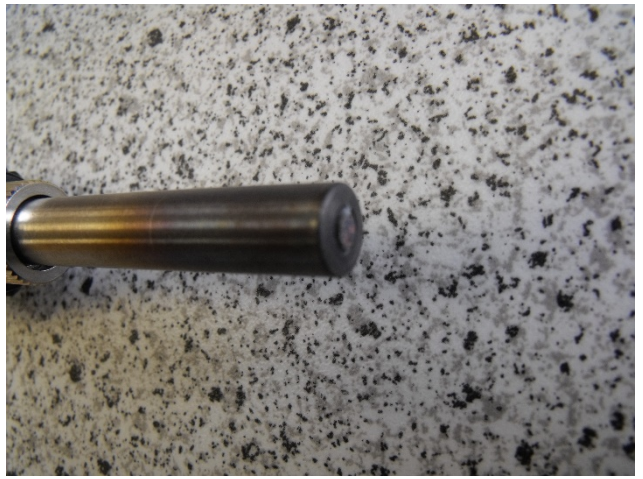
*The phosphor was also calibrated by contact by coating a metal (**Indium**) with known phase-change temperature and measuring phosphorescence during melting*



CMI dynamically compensated surface probe







- ✓ *An overall calibration uncertainty better than 0.8 °C with a repeatability of 0.5 °C*

Implementation of novel surface temperature measurement techniques in industry

*The **aim** is to transfer at the industrial level the techniques developed*

To meet this aim

- ✓ The new phosphor-based method will be applied in industrial manufacturing processes (heat treatment for welding at BAE and hot-forming of aluminium alloy billets at Gamma).
- ✓ The new dynamically compensated surface probe will be tested in comparison with standard surface probes by seeking access to steel industry applications. The effectiveness of the new probe will be demonstrated by *in situ* calibration

Industrial Challenges

1. *In **aerospace** and **automotive** manufacturing forging of aluminium alloy billets necessitates precise temperature control in pre-heating (± 5 °C)*

2. *In **marine construction** (ships, submarines, oil, gas, and renewable energy platforms) post-weld heat treatment temperature is an essential variable*

Surface contact sensors are used but poorly characterized and also prone to subjectivity.
Infra-red thermometry is beset with emissivity problems

Industrial application: hot-forging of aluminium alloy billets