Title: Integrated European research, calibration and testing infrastructure for fibre-optic thermometry

Abstract

The measurement and control of temperature plays a key role in achieving the goals of the European Green Deal for a low-carbon energy system. Fibre-optic thermometry is a developing technology offering advantages, such as distributed sensing and immunity to electromagnetic fields, in many applications. However, since fibre-optic thermometers exhibit cross-sensitivities to other quantities, these must be investigated, minimised, and quantified to obtain traceable and reliable results. The proposed project aims to overcome limitations that prevent their widespread use by creating a dedicated European metrological infrastructure addressing research, testing, calibration, and training.

Keywords

Fibre optic thermometry, distributed temperature sensing, European Green Deal, high temperature process control, temperature, sensor manufacturers

Background to the Metrological Challenges

Temperature is one of the most frequently measured physical quantities in science and industry. The measurement and control of temperature plays a key role in supporting ambitions of the European Green Deal for a low-carbon energy system and improved measurements are needed in several applications. Energy intensive high-temperature processes such as cement production and heat treatment of metals require accurate and drift-free thermometers. Currently thermocouples are used but these exhibit significant instability due to harsh process conditions. Increased use of renewable energy sources demands a close-meshed, reliable, and disturbance-free temperature monitoring of the electricity infrastructure. State-of-the-art temperature sensors such as thermocouples exhibit high sensitivities to electromagnetic interferences. Nuclear energy has an important role in the ongoing transition to net-zero emissions. The safe operation of existing and future nuclear power plants requires radiation resistant thermometers. Although some progress has been made to reduce the influence of hazardous environments when using conventional contact thermometers there is still a need for greater robustness. The development and deployment of thermal energy storage technologies is a central element of the European Green Deal. This can provide much-needed flexibility across timescales from hours to several days, which is essential for the transition to a system dominated by variable energy supply through renewables. More advanced thermal storage solutions need to be developed to span a variety of temperature ranges from below 0 °C to above 500 °C.

Fibre optic thermometry offers many advantages over more traditional temperature measurement such as thermocouples. Over the past few decades optical fibres have been optimised and widely deployed in long-distance telecommunications and other technical areas. In parallel, technologies were developed to use these optical fibres for spatial resolved measurements of temperature and further physical or chemical quantities. Fibre optic thermometry uses distributed temperature sensing (DTS) techniques (based on very different measurement principles such as Rayleigh, Raman or Brillouin scattering, fibre Bragg gratings or photoluminescence) to measure temperature distribution over the length of an optical fibre cable using the fibre itself as the sensing element. Fibre optic thermometry has demonstrated significant improvements. It is less sensitive to various environmental effects and offers high immunity to electromagnetic interference, but metrological characterisation, improved reliability and validation is required. The number of sensor manufacturers in the field of fibre optic thermometry is steadily growing, and numerous applications have already been investigated that would benefit from the unique advantages of these techniques. However, many of these applications require a quality management system based on certification or accreditation to facilitate widespread use. A rigorous metrological characterisation of existing fibre optic thermometers is needed. There is a variety of fibre optic thermometers commercially available. These are often developed and optimized for specific technical applications such as geothermal energy use, leak detection on pipelines or fire detection on cables. Their proper operation requires experts with specific knowledge of method dependent advantages and disadvantages and of cross-sensitivities by other physical or chemical quantities. Greater understanding of the various applications is needed to ensure take up of the techniques.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the development of an integrated European research, calibration and testing infrastructure for traceable fibre-optic thermometry measurements.

The specific objectives are

1. To develop accurate methods for quantifying the sources of measurement uncertainty and cross-sensitivities of existing fibre optic thermometers. This should include (i) disturbance effects such as thermal expansion, strain, vibrations, humidity of surrounding air or pressure, (ii) aging effects and (iii) the influence of sensor mounting.
2. To develop accurate and validated distributed temperature sensing (DTS) techniques for large scale applications, based on principles such as Rayleigh, Raman or Brillouin scattering or multiplexed fibre Bragg Gratings (FBG). Measurement uncertainty and spatial resolution should be determined for the DTS methods, with an expanded target uncertainty ($k=2$) of 3 °C up to 500 °C.
3. To develop validated fibre-based thermometry (e.g., FBG sensors) for harsh environments. These should include high temperature process control with an expanded target uncertainty of 3 °C up to 1600 °C and precise temperature monitoring at elevated temperatures (expanded target uncertainty 1 °C up to 700 °C).
4. Using the techniques developed in Objectives 1, 2 and 3 to perform industrial case studies in at least 4 key applications for fibre optic thermometry such as the monitoring of (i) electrical power cables or transformers, (ii) energy-intensive high-temperature processes, (iii) the loading state of heat storage tanks and (iv) nuclear power plants. To provide validated information on suitable fibre optic thermometry techniques for specific applications, specific temperature ranges, spatial temperature resolution and achievable measurement uncertainties.
5. To establish an integrated European metrology infrastructure including testing and calibration guides and certified European training centres for fibre optic thermometry. In addition, to facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, certification and accreditation bodies), standards developing organisations (ISO, CEN, IEA) and end users (sensor manufacturers, industry and energy sectors).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources both within and outside Europe, plus engagement with existing European research infrastructures and European Partnerships is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry and end users.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.9 M€ and has defined an upper limit of 2.6 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 25 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the ‘end user’ community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the ‘end user’ community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Develop an integrated self-sustaining European metrology infrastructure,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the manufacturing, nuclear and energy sectors.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of the Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Time-scale

The project should be of up to 3 years duration.