Title: Metrology for the photonics industry, optical component manufacturing and optical interconnects within data centres

Abstract

The recent rapid developments in modern photonics are currently insufficiently supported by metrology. Reliable characterisation of complex optical fibres, waveguides and functional optical components is challenging, and often impossible with commercially available tools. Measurement standards are also insufficiently defined and there is a lack of validated and traceable measurement and calibration techniques. Competitiveness of the European photonics industry relies on high added value and requires continuous innovation, therefore new traceable and validated measurement techniques, instruments and infrastructures need to be developed in order to sustain Europe's strong position in the global photonics and optical component markets.

Keywords

Photonics components, waveguides, complex optical fibres, process and quality control, optical metrology, measurement instruments, optical printed circuit boards, refractive index profiling

Background to the Metrological Challenges

Photonics is regarded as one of the main driving forces for innovation, development and growth, and is recognised by international research initiatives such as Horizon 2020 in Europe, the American Institute for Manufacturing Integrated Photonics (AIM Photonics) in the USA and Photonics Electronics Technology Research Association (PETRA) in Japan. Photonics has also been identified as a key enabling technology by the European Commission. Photonic components are expected to play a key role in emerging quantum technologies and secure communication links in next-generation optical systems. Europe in particular is at the forefront of research and innovation, with the European industrial sector having approximately 20 % of the total share of the photonics market, approximately €60 billion, with an estimated compound annual growth rate of 8-10 %.

Integrated photonics is an emerging technology that has only recently been incorporated into commercial optical communication products. Thus there is currently a lack of validated and traceable measurement and calibration techniques. Existing calibration techniques are predominantly adapted to standard telecommunication fibres and components, and are consequently limited to a restricted set of wavelengths and properties that are not always suitable for the characterisation and calibration of new types of optical fibres and components.

Polymer waveguides can be cost effectively integrated into Printed Circuit Boards (PCBs), and are able to accommodate the very high bandwidth densities necessary for the exponentially growing demand for data transfer rates. Optimisation of waveguide performance is linked to material properties and waveguide geometry and while the former is usually known, calculating the contribution to waveguide performance due to geometry is a challenge. Thus to optimise performance and to ensure a reliable quality of service by the photonics industry, validated methods are needed for the characterisation of waveguides within photonics devices, as well as an understanding of their functional performance, refractive index profiling and advanced optical modulation formats.

Fibre lasers continue to grow in importance in industry and biomedical photonics, increasingly replacing crystal- and gas-based lasers in material processing and medical applications. However, the interaction of co-dopants required within the core components of current high power fibre systems is not well understood. In addition there are outstanding metrological issues associated with the use of fibre intrinsic and extrinsic sensors, and optical fibres with special polarisation properties for sensor applications. To address these issues, advanced fibre optic components and devices will be key elements, which need to be accurately characterised, however the necessary metrology is not currently available. Therefore novel and traceable instrumentation and calibration techniques are needed for both complex fibres, sensor applications and fibre-based instruments.

Further to this, surface functionalisation is a way of adding value through improved performance of optical elements. However, the nanometre scale structuring of such optical elements poses challenges for the quality control of manufacturing. Therefore, the scalability of this technology requires the development of new techniques for the online measurement of functional and geometrical properties of optical elements.

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 traceable measurement and characterisation of optical components for the photonics industry, optical component manufacturing and optical interconnects within data centres.

The specific objectives are

1. To develop validated methods for the characterisation of waveguides within photonic devices. This should include (i) new techniques for refractive index profiling, the measurement of encircled angular flux and chromatic dispersion, (ii) characterisation methods for the launch condition and transmission of waveguides, and refractive index engineering, (ii) waveguiding methods for infrared devices, and (iii) new methods to characterise the dispersion of short optical interconnects and properties of wideband photodiodes for multilevel modulation formats, in order to increase data capacity in data centres.
2. To develop traceable measurement techniques for refractive index profiling, core positioning and numerical aperture measurement in complex fibres used for telecoms and sensor applications. This should include (i) the development of measurement techniques for transversely resolved fluorescence in advanced infrared fibres, (ii) traceable calibration procedures for the linear and non-linear properties of complex fibres, including spectral attenuation, crosstalk, non-linear coefficients and Brillouin frequency shifts, and (iii) reliable and validated methods for estimating optimum modal distributions and limit values of complex multimode fibre systems.
3. To develop novel and validated optical measurement techniques for use in inline characterisation of geometrical and functional properties of moulded optical components and optical elements with nanometre scale structures. The developed techniques should be suitable for replicative optical element manufacturing process monitoring and control.
4. To develop novel and validated instruments for traceable characterisation of fibre-based instruments. This should include developing (i) a traceable refracted near-field measuring instrument for performing simultaneous measurements of the index profile and of the core positioning of multicore and complex fibres, (ii) distributed optical fibre sensors for temperature, strain and vibration, (iii) traceable calibration artefacts for optical vector analysers, and (iv) instruments for traceable measurement of low-intensity and single photon components.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, instrument manufacturers), standards developing organisations (e.g. IEC TC 86 and SC 86B) and end users (the telecoms and sensor industry).

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMPIR project 14IND13 and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded 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,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the telecoms sector.

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 EMPIR 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.