Title: Metrology for integrated photonic devices and new photonic materials

Abstract

Optical communication and sensing are growing markets with economic and social benefits. Enhanced communications rely on the development and integration of novel photonic materials and devices with superior performance and flexibility. The development of optimised novel devices requires measurements with improved sensitivity and accuracy (particularly to understand non-linear effects) and improved spatial resolution and dimensional measurement, suitable for the nanoscale devices under development.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on "Grand Challenges" related to Health, New Technologies & Fundamental Metrology on pages 9 and 14.

Keywords

Integrated photonic devices, micro-structured fibre, photonic crystal fibres, photonic meta-materials, non-linear optical properties, integrated opto-mechanical systems, nano-optics, optical metrology

Background to the Metrological Challenges

Although optical fibre communications and measurements are well established, the development of microstructure fibres (such as gas-filled hollow core fibres and photonic crystal fibres) has brought with it a number of measurement challenges. Microstructure fibres are drawn from non-standard materials to enable applications like supercontinuum generation, high peak power pulse delivery, low-crosstalk data transfer, spectroscopy, gas sensing and optical frequency standards. The relevant spectral range extends from VIS to mid-IR (10 µm). In order to optimise the structures and match them to the relevant applications, better uncertainties are required in the measurement of chromatic dispersion, polarisation mode dispersion and effective non-linearity. Current methods for nonlinear index measurements are z-scan and non-degenerate four-wave mixing which rely on transversal effects and are therefore not usable in waveguide geometries. Instead, nearly degenerate four wave mixing (NDFWM) can be applied to standard optical fibres. However, this method is not sufficiently sensitive to be applicable to fibres with low nonlinearity or short (sub-cm) samples such as integrated photonic circuits

The communication sector has also seen the development of optical metamaterials; these are nanostructured materials with optical properties not found in natural materials, the most prominent example being a negative index of refraction. Although large-scale industrial applications are some way off, metrology to support development, and verify performance, are key to European success in this field. Measurement of transmittance, reflectance and ellipsometric measurements of these materials are key to verifying device performance, whilst scatterometry and measurement of the Mueller matrix are key to building a stronger theoretical understanding of these nanostructured materials, and linking the nanoscale performance to the macroscale.

A final step towards intergrated photonics circuitry is the requirement to undertake practical insitu measurements at various points on the waveguide's path. The continual reduction of device sizes leads to a need for increased measurement resolution which is now required below 20 µm$^{2.}$ Recent developments in combining NDFWM with heterodyne detection has demonstrated improved sensitivity and the capability to measure both real and imaginary part of the nonlinear susceptibility and this has the potential to be applied to short samples (<10 µm). Modification of this method could enable nonlinear characterisation spatially confined to a well-defined position along the waveguide and may offer potential for straightforward traceability.

Scientific and Technological 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 JRP-Protocol.

The JRP shall focus on the traceable measurement and characterisation of improved metrological tools for the assessment of photonic devices and materials operating across a wide spectral range from 0.5 µm to 10 µm.

The specific objectives are:

1. Develop measurement methods for linear and non-linear optical parameters such as chromatic dispersion, polarisation mode dispersion or effective nonlinearity. Measurements are required from 0.5 µm to 10 µm for optical fibres (including micro-structured fibres) and optical metamaterials with measurement areas of down to 100 $µm^2$.
2. Develop and validate measurement methods for optical characterisation of waveguide paths at various positions within integrated photonic circuits (in the telecom window near 1.5 µm). Spatial measurement resolution of 20 µm is required.
3. Develop traceable dimensional and optical characterisation of nanostructured optical devices, including refractive index at the nanoscale (this may include scatterometry and Mueller polarimetry). Link the nanoscale properties of the nanostructured optical devices to their macroscopic optical functionality by rigorous solution of Maxwell's equations.

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, the involvement of the appropriate user community such as industry, and standardisation and regulatory bodies, is strongly recommended.

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

The total eligible cost of any proposal received for this SRT is expected to be around the 2.7 M€ guideline for proposals in this call.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the "end user" community (eg letters of support) is encouraged.

You should detail other impacts of your proposed JRP as detailed in the document "Guide 4: Writing a Joint Research Project"

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the photonics and communications sectors.

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology. 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 Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.