EMPIR Call 2017 – Industry, Fundamental, Normative and Research Potential

Selected Research Topic number: **SRT- f05**
Version: 1.0

Title: Volume Photography: a new approach to the three dimensional measurement of light distributions

Abstract

"Volume photography" involves embedding photosensitive materials inside complex photonic media to generate 3D images of how light distributes inside their structure. This topic could open new pathways for the investigation of photonic materials, enabling the study of fundamental aspects regarding light propagation and confinement and paving the way to the characterisation and design of materials with new photonic functionalities.

Keywords

Volume photography; light distribution; photonic structures; light responsive materials; micro-tomography; x-ray scattering; x-ray spectrometry; microscale.

Background to the Metrological Challenges

"Volume Photography" will enable direct measurements of the optical modes inside photonic materials and provide a new method for studying photonic structures. By creating both solid and virtual 3D representations of the distribution of light inside photonic materials, the fundamental study of light propagation and the practical characterisation of novel materials or new photonic structures will be improved, providing a more conceptual understanding of light-matter interaction inside these devices and feedback to improve their designs.

The optical properties of photonic materials depend on the way that light waves behave inside a bulk structure. In photonic crystals, for instance, light waves are scattered internally from a periodic lattice which leads to the formation of standing waves, and various types of optical modes. A photonic crystal resonator relies on the resonances that are formed internally around a defect. Another example is that of a disordered structure in which the multiple scattering of waves inside the material gives rise to complex interference patterns. These interference patterns determine the optical properties of the materials and constitute, for example, the modes of random lasers. Research on such photonic materials deals on one side with basic questions about light propagation and how clever arrangements of the constituent elements can give rise to new optical effects. On the other hand, very concrete applications are being explored including the efficiency enhancement of solar cells, novel light sources, resonators, and sensors.

The optical characterisation of photonic materials is typically done from the outside by studying the reflection and transmission of waves, either resolved in angle, frequency, or time, or a combination of these. The actual behaviour of the light inside such materials is then inferred from these indirect measurements. This new method would allow for direct measurements of the optical modes inside photonic materials, opening up a new strategy for studying photonic structures.

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 metrological capacity in the three dimensional measurement of light distribution.

The specific objectives are

1. To develop photosensitive materials that will be used in micrometric scale photonic devices (waveguides, resonant cavities etc.), fluorescent markers and/or metallic enriched resists. Quantitative measurement of the mode intensity should be explored by calibrating the exposure time required for each photo-responsive material with rigorous numerical calculations of the full electromagnetic problem.
2. To develop complementary reconstruction techniques (X-ray tomography, holographic or interferometric optical imaging, 3D electron microscopy, SIMS) with different spatial resolution, for the visualisation of the intensity mode distribution inside the photonic devices. Techniques that take advantage of processes with threshold activation or non-linear response should be explored.
3. To investigate plasmonic enhancement processes of complementary spectroscopic techniques (Surface Enhanced InfraRed Absorption, SEIRA and Surface Enhanced Raman Spectroscopy, SERS) by chemically characterising and evaluating the spectral response of model analytes. Traceable x-ray analytical methods should contribute to the understanding and quantification of plasmonic enhancement effects in SERS and SEIRA. Mapping with depth resolution of <5 nm and spatial resolution of 200 nm and the ability to resolve chemical differences requiring a mass resolving power of > 100,000 should also be investigated.
4. To contribute in the wider understanding of the relation between the physical structure of a material and its optical modes by disseminating results through publications/presentations and by creating strong links with the photonics, communications and sensing community.

Proposers shall give priority to work that aims at excellent science exploring new techniques or methods for metrology and novel primary measurement standards, and brings together the best scientists in Europe and beyond, whilst exploiting the unique capabilities of the National Metrology Institutes and Designated Institutes.

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 1.5 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 40 % of the total EU Contribution to the project.

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,

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.