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

Selected Research Topic number: **SRT-f12**
Version: 1.0

Title: Self-calibrating photodiodes for the radiometric linkage to fundamental constants

Abstract

This topic concerns the novel combination of two independent primary standard detectors: a solid-state predictable quantum efficient detector (PQED) and a cryogenic electrical substitution radiometer (ESR) to create a robust link to the new SI by measuring fundamental constant ratio e/h. The novel packaging of the two standards could also facilitate improved dissemination of optical quantities particularly where a primary standard needs to be used in challenging non-NMI environments, generating for the first time an “NMI-on-a-chip” for optical power measurements. Material research and improved 3D charge-transfer simulation models would also be required to ensure optimum performance in quantum mode at cryogenic temperatures, as well as to predict the response from 400 to 850 nm over a wide dynamic range.

Keywords

Predictable Quantum Efficient Detector (PQED), 3D simulation models, improved passivation, new SI, self-calibration, electrical substitution radiometer (ESR), packaging technology, NMI-on-a-chip.

Background to the Metrological Challenges

The development and exploitation of optical techniques is rapidly emerging as a key enabling technology in applications to support industry, innovation and science. There is a pressing need for simplified traceability for optical quantities over a wide spectral and dynamic range.

Previous EMRP projects qu-Candela and SIB57 NEWSTAR developed a predictable quantum efficient detector (PQED). The PQED was approved in the *mise-en-pratique* for the definition of the candela as an alternative primary standard to the well-established cryogenic ESR. It is likely that the SI system will be changed in 2018 based on the definition of 7 fundamental constants. Recently, a new method has been demonstrated that enables the measurement of fundamental constants to be done on one artefact by running the photodiodes in two different modes; both as a PQED and cryogenic ESR. A comparison of these two primary standards, which enables the derivation of the e/h ratio, can contribute to strengthen the coherence of the new SI system.

The SI link requires that a sensitive temperature sensor is properly attached to the PQED photodiodes so that the device can be easily handled while used in either mode of operation and with a geometry and choice of materials ensuring equivalence in optical and electrical heating. Improvements in this packaging technology that ensures equivalence between optical and electrical heating has recently been demonstrated. The same packaging technology will enable the development of a “self-calibration” procedure of commercially available single photodiodes and establish a measurement standard detector that also operates for higher power levels than 1 mW (the current limit of linearity). This requires that both modes are sufficiently accurate and linear in parts of the same power levels. In the Photometry/Radiometry Roadmaps for climate and basic science “self-calibrating instruments making climate quality measurements in the field” and “low-cost, high accuracy transfer standards” are requested as a need in order to provide the necessary accuracy for remote unattended and non-transportable instrumentation. The device will therefore be a self-calibrating detector, working as an “NMI-on-a-chip” in potentially remote operation.

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 new experimental techniques for optical power measurements over a wide spectral and dynamic range by the production of an “NMI-on-a-chip” – developed as a self-calibrating silicon photodiode.

The specific objectives are:

1. To develop improved 3D charge-transfer models and to validate the models by measuring the response of suitable, presently available photodiodes.
2. To use the improved 3D models for evaluation of passivation layer materials, passivation strategy and charge increasing techniques. To manufacture a batch of optimised PQED photodiodes for cryogenic operation and to acquire commercially available bare-chip photodiodes for room temperature operation.
3. To develop instrumentation and packaging for self-calibrating photodiodes. The photodiodes should be operated in both photocurrent and electrical substitution mode with sufficient sensitivity and equivalence between optical and electrical heating over a temperature range from 20 K to 300 K.
4. To provide traceability of the self-calibrating photodiodes to the proposed new SI by measuring the fundamental constant ratio e/h to 1 ppm uncertainty at cryogenic temperatures and further to 0.05 % uncertainty at room temperature for wavelengths 400 – 850 nm over a wide dynamic range.
5. To facilitate the take up of the technology and measurement infrastructure developed by the project by engaging standardisation bodies and international organisations (CCPR, CIE, EURAMET and other RMO TC-PR), the measurement supply chain (accredited laboratories, instrumentation manufacturers) and end users (photonics industry).

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. In particular, proposers should outline the achievements of the iMERA plus project qu-Candela and EMRP project SIB57 NEWSTAR 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 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.