**EMPIR Call 2015 – Health, SI, Normative and Research Potential**

Selected Research Topic number: **SRT-s12**
Version: 1.0

# Title: Practical realisation and traceability in the new SI for optical power quantities


## Abstract

This SRT calls for proposals that will combine two independent primary standard detectors: a solid-state predictable quantum efficient detector (PQED) and a thermal detector (Cryogenic ESR) to create a robust link to the new SI by measuring fundamental constant ratio e/h. Packaging of the two standards together could facilitate improved dissemination of optical quantities particularly where a primary standard needs to be used in challenging non-NMI environments. Development of improved spectrally invariant detectors could also enable wider spectral and dynamic range than the PQED alone and is hence applicable to a greater range of customers.



## Keywords

Predictable Quantum Efficient Detector (PQED), cryogenic radiometer (CR), new SI, self-calibration, electrical substitution radiometer (ESR), packaging technology, spectrally invariant detectors, new experimental techniques


## Background to the Metrological Challenges

The development and exploitation of optical techniques is rapidly emerging as a key enabling technology in applications to support developments within other technical areas such as time, flow, electromagnetics, length and temperature and 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). To remove the confidence obstacle that prevents the wider uptake of PQEDs, the radiometry community requests experimental techniques able to measure the internal quantum deficiency of photodiodes, as PQEDs can pick up drift and potential degradation over time. 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 CR [1]. 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 but currently this packaging technology has not been developed. This packaging technology will also enable the development of a “self-calibration” procedure of commercially available single photodiodes and establish a measurement standard that operates for higher power levels than 1 mW. Measurements in the field need self-calibrating procedures in order to provide the necessary accuracy for remote unattended and non-transportable instrumentation. The photonics industry needs simplified traceability, by developing new technologies and new experimental methods, for a wide dynamic range to meet the needs of emerging markets. The PQED as a predictable standard is currently limited to the visible spectral range with the important infrared spectral range providing challenges. Spectrally invariant detectors are generally used to transfer traceability to this challenging spectral region but they need to be improved in terms of signal to noise ratio and spectral flatness / blackness.

## 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


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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 quantities that enable users improved and simplified traceability to the proposed new SI over a wide spectral and dynamic range.

The specific objectives are

1. To develop a link to the new SI through the comparison of two independent primary standards of optical power, i.e., a PQED photodiode working either in photocurrent or electrical substitution mode at an optimum temperature in the 20 K – 300 K range. The target is to measure e/h ratio to an agreement with CODATA values within 1 ppm.
2. To develop self-calibrating photodiodes operating at room temperature to be used (with metrology grade packaging and improved signal processing) in both photocurrent and electrical-substitution modes so that somewhere in the 100 µW – 1 mW range the photocurrent mode can be calibrated by the electrical substitution mode to within a relative uncertainty of 0.1 %.
3. To extend the dynamic range of photodiodes from the single photon regime to power levels exceeding existing solid state standards by operating photodiodes in the photocurrent mode and in the electrical substitution mode.
4. To develop spectrally invariant detectors operating at room temperature and capable of transferring traceability over a 250 nm - 2500 nm range with a relative uncertainty better than 0.05 %.
5. To facilitate the take up of the technology and measurement infrastructure developed by the project by the measurement supply chain (accredited laboratories, instrumentation manufacturers) and end users (photonics industry).

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 outside Europe 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.

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 and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 21 % of the total EU Contribution to the project. Any deviation from this must be justified.

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 radiometry and metrology community.

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.

## Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] M. White, J. Gran, N. Thomlin, J. Lehman, “A detector combining quantum and thermal radiometric standards in the same artefact”, Metrologia 51 (2014) S245-S251.