EMRP Call 2012 – Open Excellence, Industry and SI Broader Scope

Selected Research Topic number: **SRT-s19**
Version: 1.0

Title: New primary standards and traceability for radiometry

Abstract

Progress in optical technologies requires improved metrological methods and standards. This SRT seeks new and advanced means of realising the unit of optical power and other derived SI units, especially in the visible range, and a simplified traceability to the end-user through more practical and cost efficient techniques. This can be achieved by an optimised realisation of the primary standard for radiometry in the visible with a 1 ppm uncertainty and by developing new techniques for providing traceability with an uncertainty below 100 ppm by accurately characterised filter radiometers for photometry and radiation temperature. The main goal of the SRT should be a primary standard for radiometry having approximately the same cost and functionality as transfer standard detectors enabling the primary standard to be built into different applications taking full advantage of its properties.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Industry & Fundamental Metrology on pages 33 and 34.

Keywords

Radiometry, spectral radiometry, filter radiometry, silicon detectors, predictable quantum efficient detectors, photometry

Background to the Metrological Challenges

Optical Radiometry is the measurement of radiation in the frequency range from $3x10^{11}$ to $3x10^{16}$ Hz, including the frequency regions commonly called ultraviolet, visible and infrared.

The definition of the candela allows primary laboratories to base their photometric measurements on optical detector technology in the visible region. In many, the candela is based on the spectral responsivity of detectors calibrated by means of a high accuracy cryogenic radiometer, as the primary standard for the measurement of optical power. The operation of these detectors at temperatures below 20 K enables the current state of the art measurement uncertainty to be around 50 ppm.

The iMERA+ qu-candela project demonstrated the feasibility of a new radiometric standard based on silicon photodiodes, called the Predictable Quantum Efficiency Detector (PQED). They are almost as easy to use and can be operated in the same way as any conventional photodiode. The elaborated novel PQED as a candidate for primary standard of optical power can be applied in the measurements with a relative uncertainty of 100 ppm within the range of visible wavelengths even at room temperature. This is approximately the same that is ordinarily achieved with liquid-helium cooled cryogenic radiometer. When the PQED is cooled to liquid nitrogen temperature the same quantum efficiency as at room temperature was reached. The advantage of low temperature operation is that the quantum efficiency can be predicted theoretically with less than 10 ppm uncertainty. The challenge of further research is to validate the latter uncertainty.

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 traceable measurement of optical power and spectral responsivity. The main goal is the development of a primary standard for radiometry having approximately the same cost and functionality as transfer standard detectors but enabling the primary standard to be built into different applications. The objectives stem from the results achieved in the iMERA+ Project qu-candela, where the feasibility has been demonstrated of a new radiometric standard based on silicon photodiodes, called the Predictable Quantum Efficiency Detector (PQED).

The specific objectives are

1. Development of primary standards for absolute radiometry at 1 ppm uncertainty in the visible wavelength range by optimisation of PQED operating at low temperatures, by demonstration of the wide dynamic range and by improved modelling of charge-carrier losses
2. Validation of the claimed ultra-low uncertainty by best possible measurements with cryogenic radiometers based on the electrical substitution principle
3. Implementation of room temperature primary standards (PQED) in applications of filter radiometry and photometry at 100 ppm uncertainty
4. To check the robustness of the standards and their stability with time to determine if they are suitable for use as travelling artefacts for comparisons

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, and the current development in the following EMRP JRPs:

- T1 J2.3 qu-Candela “Candela: Towards quantum-based photon standards”

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. The available budget for integral Research Excellence Grants is 42 months of effort.

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 how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the radiometry sector.

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

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 and includes 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 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.