EMRP Call 2011 - Health, SI Broader Scope & New Technologies

Selected Research Topic number: **SRT-s02**
Version: 1.0

Title: Quantum Ampere: Realisation of the new SI ampere

Abstract

The development of practical means for the realisation and dissemination of the future SI ampere is necessary, following the requirements arising from the *Mise en pratique* for the realisation of the impending new ampere definition. In particular, the development of advanced quantum-based sources and meters have become necessary for the generation, scaling, and measurement of electric currents of 100 pA or higher, with a relative uncertainty <= 0.1 ppm.

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 10, 11 and 32.

Keywords

SI base units, ampere definition, ampere realisation, primary current standard, amperemeter, quantum electrical standards.

Background to the Metrological Challenges

The ampere will soon be defined using an agreed value of the electron charge [1], and realised in the laboratory using current sources based on the fast controlled transfer of single electrons [2]. This will provide a short, direct chain of traceability from the definition to the practical realisation in accordance with the Mise en pratique. Research is needed to make the new definition of the ampere a practical reality.

Generally, SET current standards are considered the most natural candidates for the realisation of the future ampere definition because they provide a direct frequency-to-current conversion. To date, however, prototype single-electron current sources have demonstrated relatively small currents of up to around 100 pA. For this reason, they have made an impact only in specialised areas. To extend the practical usefulness of single-electron current sources across the whole range of electrical metrology requires two main ingredients: greater confidence in the accuracy of the sources themselves at the 0.1 part per million level, and technology to scale the current up to much to the µA level for their comparison and measurement. Further practical important properties to be improved are device robustness in operation and handling.

A previous EMRP project “REUNIAM”, has pioneered two types of single parameter (SP) single-electron current source devices. These are simpler to operate and can achieve higher currents than earlier types of pump based on metallic tunnel barriers. They are SP tuneable-barrier pump (semiconductor) devices and SP hybrid turnstile (metallic) devices. Both types of devices have the required low theoretically predicted accuracy for use as primary current standards. Verifying their accuracy and testing how simple they are to fabricate needs further work.

The idea that single-electron pumping errors can be detected and accounted for was investigated theoretically as part of the “REUNIAM” project. The first test of error accounting in combination with a tunable-barrier pump device has recently been demonstrated, but the technology is still in its infancy.

The development of quantum-based current standard source devices and setups requires a complementary development of advanced amperemeters. Available state-of-the-art amperemeters for current measurements in the pA range, based on electronic current amplifier stages and calibrated with the best available methods, show an accuracy of not better than about one part in 10^5, therefore further developments are required to reach ultimate accuracy.

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EMRP
European Metrology Research Programme
Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

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 overall objective of the SRT is to provide practical means for realizing and disseminating the re-defined ampere. Quantum-based current sources and amperemeters of highest performance shall be developed.

The specific objectives are

1. Realisation of quantum based current sources with an output current of 100 pA or higher and a relative uncertainty <= 0.1 ppm;
2. Verification and implementation of advanced concepts for single-electron error accounting in single-electron generating circuits by on-chip detection methods;
3. Realisation of "self-referenced" quantum current standards by integrating quantum current sources and error accounting technologies;
4. Realisation of quantum base amperemeters for the calibration of practical electrical current sources at ultimate accuracy.

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.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. Reference should be made to the iMERA-Plus project T1 J1.3 REUNIAM.

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 instrumentation sector;
- the European electrical measurement community.

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.

Additional information

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

[1] Draft Chapter 2 for SI Brochure, following redefinitions of the base units, p. 4 and pp. 8, (2010)

[2] Mise en pratique for the ampere and other electric units in the International System of Units (SI), CCEM/09-05, Note to the reader and Point 4, (2009).