Title: Traceability of sub-nm length measurements

Abstract

Cutting edge metrology projects such as determining the lattice spacing of silicon require 10^{-8} and better relative accuracy over length scales from a fraction of a millimetre to many centimetres. The current state of the art in dimensional measurement can achieve a relative accuracy significantly exceeding 10^{-8}, however several anomalies have been observed, and are not yet been explained.

The proposed JRP should develop practical methods of analysing of real optical interferometer & capacitive sensor performance, whilst supporting this with theoretical models and numerical methods. This will enable traceable length measurements at the picometre scale, at a suitable accuracy to support cutting edge metrology research.

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 13, 38 and 39.

Keywords

Optical interferometry, software for interferometer simulation and design, capacitive sensors, length metrology, sub-nm accuracy, x-ray interferometry

Background to the Metrological Challenges

The gauge of macroscopic bodies and displacements with atomic-scale accuracy is the goal of the most sophisticated and demanding projects in dimensional metrology. These include the determination of the lattice spacing of silicon, velocity measurements in the watt-balance experiments, the tracking of a free-falling body in absolute gravimetry, angle measurements for the absolute nuclear spectroscopy, and the extension of traceability to X-ray and gamma-ray wavelength measurements. All of them aim at a 10^{-8} and better relative accuracy over length scales from a fraction of a millimetre to many centimetres.

The current state of the art (used in the determination of the Planck and Avogadro constants) achieve a relative accuracy significantly exceeding 10^{-8}, however several anomalies were observed, and have not yet been explained. Currently in development is a GAMS6 diffractometer (at Institut Laue-Langevin in France), which will be capable of a 10^{-8} relative uncertainty, for angle measurements.

Methods based on optical interferometry, direct link for traceable measurements, have to be studied to evaluate the relevant corrections as detailed wavefronts in real interferometers to support development and validation of theoretical models.

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 the traceable measurement in the length field based on optical interferometry and capacitive sensors and investigate performance at the sub-nanometre and picometre sensitivity level

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EMRP
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The specific objectives are:

1. To develop and validate methods for the practical analysis of real optical interferometer & capacitive sensor performance. This may include:
    - traceable methods for the assessment of wavefront distortion
    - validation of a dimensional "test-bed" based on x-ray interferometry to provide traceability of length measurements at picometre scale (with proven uncertainties at the sub-nanometre level)
    - study of various environmental conditions

2. To develop theoretical models and numerical methods to support the traceability of length measurements at the picometre scale. The models shall:
    - Be applicable to both optical interferometry and capacitive sensors
    - Be experimentally validated (software in particular)
    - Calculate corrections for length measurements at the picometre scale (with proven uncertainties at the sub-nanometre level)
    - be deliverable in a suitable format for use by stakeholders

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 verify the stakeholder need for extension beyond the current state of the art and explain how their proposed project goes beyond current state of the art, including the currently funded EMRP projects:

- T3 J1.4NANOTRACE: New Traceability Routes for Nanometrology
- IND05 MEPROVISC: Dynamic Mechanical Properties and Long-term Deformation Behaviour of Viscous Materials
- IND17 Scatterometry: Metrology of small structures for the manufacturing of electronic and optical devices

The total eligible cost of any proposal received for this SRT is expected to be significantly below 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 metrology community, including fundamental projects such as projects related to Planck and Avogadro constants, and the dimensional metrology community
- transfer knowledge to semi-conductor manufacturing, optics and precision engineering sectors

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.