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

Selected Research Topic number: **SRT-s10**
Version: 1.0

Title: Angle metrology

Abstract

Angle metrology is key for many high value scientific and industrial applications, including the measurement of beam-shaping optical surfaces in synchrotron beamlines and Free Electron Lasers (FEL) and high accuracy angle measurements in precision engineering. Currently, synchrotron and linear accelerator centres performing sub-nanometre topography measurements, require the ability to calibrate autocollimators with an uncertainty of less than 0.01” (50 nrad), particularly in the measurement range ±3600” (17 mrad). In order to achieve the uncertainties required specially designed, state of the art angular measurement devices are needed. In addition, low cost, portable and precise small angle generators for regular checking of autocollimators are required by synchrotron and linear accelerator centres.

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 13, 39 and 40.

Keywords

Autocollimators, angle calibration, radian, deflectometry, synchrotron beamlines, traceability, angular encoders, small angle generators, precision engineering

Background to the Metrological Challenges

Most robots and machine tools used in industry and the majority of measurement equipment used in geodesy, long distance measurement, and large volume metrology (e.g. laser trackers and theodolites) are fitted with angle measuring equipment such as angular encoders and the accuracy of such devices depends on the precision of these angular encoders. Therefore, the development of improved angle encoder calibration with lower measurement uncertainties would benefit many industrial sectors.

One area requiring lower measurement uncertainties is synchrotron centres, where the form measurement of highly curved optical surfaces is particularly important, Form measurement currently limits the fabrication of optical surfaces and the next generation of synchrotrons and FEL X-ray light sources will need a further improvement of the angle metrology of autocollimators. The target uncertainty required for calibration is less than 0.01” (50 nrad), particularly in the measurement range ±3600” (17 mrad) with an additional target for FEL optics of 0.01 arcsec rms / 0.05 µrad rms slope deviation, corresponding to 0.5 nm rms form deviation. By investigating the factors affecting the angular response of autocollimators this should provide a more accurate calibration of autocollimators and help to meet these targets.

Regular checks on the performance of autocollimators are very important when using them in high precision applications such as deflectometry. Shocks to the autocollimator, particularly during transportation can affect previous calibration values e.g. in a recent comparison where the front lens of a circulated test autocollimator was loosened during transportation. This compromise to the autocollimator would have affected angle measurements and normally would only have been realised when the next calibration of autocollimator was performed. Therefore, portable and precise small angle generators for regular checking of autocollimators need to be developed.

EURAMET, EMRP-MSU
National Physical Laboratory
Hampton Road, Teddington,
Middlesex, TW11 0LW, UK

Phone: +44 20 8943 6666
emrpA169@npl.co.uk
www.euramet.org

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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 metrology for angle measurements, as required for precision engineering and the form measurement of beam-shaping optical surfaces.

The specific objectives are

1. To improve the accuracy of angle measurements by:
    a. improving autocollimator performance at small apertures,
    b. producing guidelines for the calibration of autocollimators,
    c. developing two-axis (2D) calibration of autocollimators,
    d. developing ray-tracing models of autocollimators to link experimental data to opto-mechanical causes
2. To characterise the relationship between the distance between the autocollimator and the optical surface on its angular response and the behaviour of autocollimators when used with small apertures at various distances to the target.
3. To produce high precision profilometers and alternative non-autocollimator based, non-contact optical measurement methods.
4. To produce portable and cost effective small angle generations with an uncertainty of less than 0.01” (50 nrad) in the range of about 3600” (17 mrad).
5. To develop hybrid angle calibrators and accurate facilities for the calibration of angular encoders.

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.

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 (e.g. 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 industrial sector, including robotics, geodesy, long distance measurement and large volume metrology.

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.