EURAMET
European Association of National Metrology Institutes

Title: Wavefont metrology for the characterisation of optical systems in industry

Abstract

High-quality optical systems play a dominant role in current industrial process control and production. Their quality is normally assessed by characterising each optical component separately but an in-situ characterisation of the whole system is strongly preferred since it is closer to the desired functionality. This can be done by measuring the wavefront of an optical field transmitted by the system. Current wavefront sensors cannot measure this wavefront with enough accuracy and spatial resolution. Special methods that reconstruct the phase from measured field intensities at focal regions could meet these needs. Such techniques should be developed and new high precision wavefront standards designed and disseminated.

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 38 and 39.

Keywords

Wavefront metrology, wavefront measurements, aberrations in optical systems, through-focus phase retrieval, lithographic systems, optical microscopy, freeform optics, wavefront standards, wavefront sensors.

Background to the Metrological Challenges

The role that optical systems and components play in current society cannot be overestimated. In fact, optical technology and science is everywhere around us, hidden inside almost any device, from computers and smart phones to space and defence technology, from telecommunications to medical systems. Optics impacts the growth of electronics by improving the quality and spatial resolution of lithographic systems and through optical inspection methods for silicon wafers.

The 2011 edition of the International Technology Roadmap for Semiconductors says 'Microscopy is used in most of the core technology processes where two-dimensional distributions, that is digital images of the shape and appearance of integrated circuit features, reveal important information. Usually, imaging is the first, but many times the only step in the "being able to see it, measure it, and control it" chain'. Also 'For all types of microscopy and for the metrology based on them it is becoming increasingly important to develop and provide reliable and easy-to-use methods that monitor the performance of the instruments'.

Especially in high speed production machines, in situ measurement techniques are of great interest since aberrations of the optical systems in these machines can change due to temperature effects and mounting operations.

In recent years, a great deal of research has focused on measuring and controlling optical field wavefronts. The problem of measuring and controlling the phase of a wavefield, in the visible range, is not an easy task. In fact, electromagnetic field oscillations are too fast to be directly measured by any currently available detector and generally only the amplitude can be measured with any phase information being lost.

In order underpin the development of more and more reliable metrology tools for Industry, there is a strong need for wavefront metrology methodologies which overcome these limitations with an increased spatial resolution reaching the theoretical diffraction limit. Additionally, these methods have to be easy-to-use, not

technical and space demanding and they should allow an easy integration into pre-existing industrial processes or devices.

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 of phase in coherent optical fields to improve the characterisation of optical systems in industry.

The specific objectives are

1. To develop traceable phase-retrieval techniques, suitable for implementation in industrial environments, with spatial resolutions at the diffraction limit in the focal region and uncertainties of a few nanometres. Approaches to be considered could include:
    a. The extended Nijboer-Zernike expansion method
    b. Iterative propagation methods
    c. adaptive optics methods
    d. vectorial phase retrieval techniques
2. The development of high precision spherical and planar wavefront standards in the UV wavelength range.
3. The development of an adjustable and programmable wavefront standard based on spatial light modulator technology.

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this, and the current developments in the EMRP JRP SIB08 “Traceability of sub-nm length measurements”.

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 optical, space and semiconductor sectors.

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.